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# 1 Background

See chapter 1. Background" in MISRA C++:2008, which is applicable for this document as well.

This document specifies coding guidelines for the usage of the C++14 language as defined by ISO/IEC 14882:2014 [3], in the safety-related and critical systems. The main application sector is automotive, but it can be used in other embedded application sectors.

This document is defined as an update of MISRA C++:2008 [7]. The rules that are adopted from MISRA C++ without modifications, are only referred in this document by ID and rule text, without repeating their complete contents. Therefore, MISRA C++:2008 is required prerequisite for the readers of this document. MISRA C++:2008 can be purchased over MISRA web store. The reference to the adopted MISRA C++:2008 rules is not considered as a reproduction of a part of MISRA C++:2008.

Most of the rules are automatically enforceable by static analysis. Some are partially enforceable or even non-enforceable and they need to be enforced by a manual code review.

Most of the rules are typical coding guidelines i.e. how to write code. However, for the sake of completeness and due to the fact that some rules are relaxed with respect to MISRA C++:2008 (e.g. exceptions and dynamic memory is allowed), there are also some rules related to compiler toolchain and process-related rules concerning e.g. analysis or testing.

This document is not about the style of code in a sense of naming conventions, layout or indentation. But as there are several C++ code examples, they need some form of style guide convention. Therefore, the code examples are written in a similar way like the MISRA C++:2008 code examples.

## 2 The vision

### 2.1 Rationale for the production of AUTOSAR C++14

Currently, no appropriate coding standards for C++14 or C++11 exist for the use in critical and safety-related software. Existing standards are incomplete, covering old C++ versions or not applicable for critical/safety-related. In particular, MISRA C++:2008 does not cover C++11/14. Therefore this document is to cover this gap.

MISRA C++:2008 is covering the C++03 language, which is 13 years old at the time of writing this document. In the meantime, the market evolved, by:

1. substantial evolution/improvement of C++ language
2. more widespread use of object-oriented languages in safety-related and critical environments
3. availability of better compilers
4. availability of better testing, verification and analysis tools appropriate for C++
5. availability of better development methodologies (e.g. continuous integration) that allow to detect/handle errors earlier
6. higher acceptance of object-oriented languages by safety engineers and
7. strong needs of development teams for a powerful C++ language features
8. creation of ISO 26262 safety standard, which HIC++, JSF++, CERT C++, C++ Core Guidelines

As a result, MISRA C++:2008 requires an update. This document is therefore an add-on on MISRA and it specifies:

1. which MISRA rules are obsolete and do not need to be followed
2. a number of updated MISRA rules (for rules that only needed some improvements)
3. several additional rules.

Moreover, at the time of writing, MISRA C++:2008 was already not complete / fully appropriate. For example, it completely disallows dynamic memory, standard libraries are not fully covered, security is not covered.

### 2.2 Objectives of AUTOSAR C++14

This document specifies coding guidelines for the usage of the C++14 language, in the safety-related and critical environments, as an update of MISRA C++:2008, based on other leading coding standards and the research/analysis done by AUTOSAR. The

main application sector is automotive, but it can be used in other embedded application sectors.

The AUTOSAR C++14 Coding Guidelines addresses high-end embedded micro-controllers that provide efficient and full C++14 language support, on 32 and 64 bit micro-controllers, using POSIX or similar operating systems.

For the ISO 26262 clauses allocated to software architecture, unit design and implementation, the document provides an interpretation of how these clauses apply specifically to C++.

## 3 Scope

This specification is obsolete and will be removed from the standard in an upcoming release. The work has been handed over to MISRA and will no longer be maintained by AUTOSAR.

See also chapter "3. Scope" in MISRA C++:2008, which is applicable for this document as well.

This document specifies coding guidelines for the usage of the C++14 language as defined by ISO/IEC 14882:2014 [3], in the safety-related and critical environments, as an update of MISRA C++:2008. The main application sector is automotive, but it can be used in other embedded application sectors.

The document is built using the MISRA C++:2008 document structure, document logic and convention and formatting. Each rule is specified using the MISRA C++:2008 pattern and style.

Several rules from MISRA C++:2008 were adopted without modifications. See [B.1](#) for the comparison. The adopted MISRA rules are only referenced by ID and title, without providing the full contents. The inclusion of ID and of the rule title for the adopted rules is considered not be a "reproduction".

Several other coding standards and resources are referenced in this document or used as a basis of the rules in this document:

1. Joint Strike Fighter Air Vehicle C++ Coding Standards [8]
2. High Integrity C++ Coding Standard Version 4.0 [9]
3. CERT C++ Coding Standard [10]
4. C++ Core Guidelines [11]
5. Google C++ Style Guide [12]

### 3.1 Allowed features of C++ language

This document allows most of C++ language features, but with detailed restrictions, as expressed by the rules. This has an important impact on the compiler toolchains, as well as other software development tools, as these tools need to provide a full support of the C++ features (as long as these features are used in accordance to the coding guidelines).

The document allows in particular the usage of dynamic memory, exceptions, templates, inheritance and virtual functions. On the other side, the compiler toolchain needs to provide them correctly. In most cases, this requires a tool qualification.

The explanatory summary table [3.1](#) lists features introduced in C++11 and C++14 and it also summarizes pre-C++11 features, together with their support by the coding standard.





Category:	Feature:	Since:	May be used:	Shall not be used:
6.0 Language independent issues				
	Dynamic memory management	-	X	
	Floating-point arithmetic	-	X	
6.1 General				
	Operators new and delete	-	X	
	malloc and free functions	-		X
	Sized deallocation	C++11	X	
6.2 Lexical conventions				
	Namespaces	-	X	
6.3 Basic Concepts				
	Fixed width integer types	C++11	X	
6.4 Standard Conversions				
	Nullptr pointer literal	C++11	X	
6.5 Expressions				
	C-style casts	-		X
	const_cast conversion	-		X
	dynamic_cast conversion	-		X
	reinterpret_cast conversion	-		X
	static_cast conversion	-	X	
	Lambda expressions	C++11	X	
	Binary literals	C++14	X	
6.6 Statements				
	Range-based for loops	C++11	X	
	goto statement	-		X
6.7 Declaration				
	constexpr specifier	C++11	X	
	auto specifier	C++11	X	
	decltype specifier	C++11	X	
	Generic lambda expressions	C++14	X	
	Trailing return type syntax	C++11	X	
	Return type deduction	C++14		X
	typedef specifier	-		X
	using specifier	C++11	X	
	Scoped enumerations	C++11	X	
	std::initializer_list	C++11	X	
	asm declaration	-		X
6.8 Declarators				
	Default arguments	-	X	
	Variadic arguments	-		X



2. The rule set for security (as long as it is not common to critical software or safety-related software) is not provided
3. The rule set for C++ standard libraries is partial (incomplete)
4. All remaining non-analyzed rules from CERT and HIC++ are concurrency/security related
5. The traceability to C++ Core Guidelines contains some non-analyzed rules

The limitations will be addressed in future versions of this document.

If the user of this document uses parallel computing, C++ standard libraries or develops security-related software, then they are responsible to apply their own guidelines for these topics.

Further analysis of the following rules will be made for a future release: [A2-10-1](#), [A5-1-8](#), [A7-1-3](#), [A7-1-5](#), [A12-1-1](#), [A12-1-2](#), [A12-1-3](#), [A12-4-1](#), [A12-4-2](#), [A13-5-3](#), [A14-7-1](#), [A16-0-1](#), [A16-2-2](#), [A16-7-1](#), [A17-1-1](#), [A18-9-2](#), [A27-0-2](#), [A27-0-4](#).

## 4 Using AUTOSAR C++14

See chapter "4. Using MISRA C++" in MISRA C++:2008, which is applicable for this document as well.

## 5 Introduction to the rules

### 5.1 Rule classification

#### 5.1.1 Rule classification according to compatibility with MISRA

The rules in this document are defined as a “delta” to MISRA C++:2008. Therefore, the rules are of two types from this perspective:

#### 5.1.2 Rule classification according to obligation level

The rules are classified according to obligation level:

**required:** These are mandatory requirements placed on the code. C++ code that is claimed to conform to AUTOSAR C++14 shall comply with every “Required” rule. Formal deviations must be raised where this is not the case.

**advisory:** These are requirements placed on the code that should normally be followed. However they do not have the mandatory status of “Required” rules. Note that the status of “Advisory” does not mean that these items can be ignored, but that they should be followed as far as is reasonably practical. Formal deviations are not necessary for “Advisory” rules, but may be raised if it is considered appropriate.

#### 5.1.3 Rule classification according to enforcement by static analysis

The rules are classified according to enforcement by static code analysis tools:

**automated:** These are rules that are automatically enforceable by means of static analysis.

**partially automated:** These are the rules that can be supported by static code analysis, e.g. by heuristic or by covering some error scenarios, as a support for a manual code review.

**non-automated:** These are the rules where the static analysis cannot provide any reasonable support by a static code analysis and they require other means, e.g. manual code review or other tools.

Most of the rules are automatically enforceable by a static analysis. A static code analysis tool that claims a full compliance to this standard shall fully check all “enforceable static analysis” rules and it shall check the rules that are “partially enforceable by static analysis” to the extent that is possible/reasonable.

The compliance to all rules that are not “enforceable by static analysis” shall be ensured by means of manual activities like review, analyses.

#### 5.1.4 Rule classification according to allocated target

Finally, the rules are classified according to the target:

implementation: These are the rules that apply to the implementation of the project (code and to software design and architecture).

verification: These are the rules that apply to the verification activities (e.g. code review, analysis, testing).

toolchain: These are the rules that apply to the toolchain (preprocessor, compiler, linker, compiler libraries).

infrastructure: These are the rules that apply to the operating system and the hardware.

## 5.2 Organization of rules

The rules are organized in chapter 6, similar to the structure of ISO/IEC 14882:2014 document. In addition, rules that do not fit to this structure are defined in chapter 6.0.

## 5.3 Exceptions to the rules

Some rules contain an Exception section that lists one or more exceptional conditions under which the rule need not be followed. These exceptions effectively modify the headline rule.

## 5.4 Redundancy in the rules

There are a few cases within this document where rules are partially overlapping (redundant). This is intentional.

Firstly, this approach brings often more clarity and completeness. Secondly, it is because several redundant rules are reused from MISRA C++:2008. Third, it may be that the developer chooses to raise a deviation against one of the partially overlapping rules, but not against others.

For example, goto statement is prohibited by rule [A6-6-1](#) and the usage of goto is restricted by rules [M6-6-1](#) and [M6-6-2](#) that are overlapping to [A6-6-1](#). So if the developer decides to deviate from [A6-6-1](#), they can still comply to [M6-6-1](#) and [M6-6-2](#).

## 5.5 Presentation of rules

The individual rules are presented in the format similar to the format of MISRA C++:2008.

## 5.6 Understanding the issue references

In this document release, references to C++ Language Standard are not provided.

## 5.7 Scope of rules

While the majority of rules can be applied within a single translation unit, all rules shall be applied with the widest possible interpretation.

In general, the intent is that all the rules shall be applied to templates. However, some rules are only meaningful for instantiated templates.

Unless otherwise specified, all rules shall apply to implicitly-declared or implicitly-defined special member functions (e.g. default constructor, copy constructor, copy assignment operator and destructor).



## 6 AUTOSAR C++14 coding rules

This chapter contains the specification of AUTOSAR C++14 coding rules.

### 6.0 Language independent issues

#### 6.0.1 Unnecessary constructs

**Rule M0-1-1 (required, implementation, automated)**  
**A project shall not contain unreachable code.**

See MISRA C++ 2008 [7]

**Rule M0-1-2 (required, implementation, automated)**  
**A project shall not contain infeasible paths.**

See MISRA C++ 2008 [7]

Note: A path can also be infeasible because of a call to `constexpr` function which returned value, known statically, will never fulfill the condition of a condition statement.

**Rule M0-1-3 (required, implementation, automated)**  
**A project shall not contain unused variables.**

See MISRA C++ 2008 [7]

**Rule M0-1-4 (required, implementation, automated)**  
**A project shall not contain non-volatile POD variables having only one use.**

See MISRA C++ 2008 [7]

**Rule A0-1-1 (required, implementation, automated)**  
**A project shall not contain instances of non-volatile variables being given values that are not subsequently used.**

#### Rationale

Known as a DU dataflow anomaly, this is a process whereby there is a data flow in which a variable is given a value that is not subsequently used. At best this is inefficient,

but may indicate a genuine problem. Often the presence of these constructs is due to the wrong choice of statement aggregates such as loops.

See: [DU-Anomaly](#).

## Exception

Loop control variables (see Section 6.6.5) are exempt from this rule.

## Example

```

1  /// $Id: A0-1-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2  #include <array>
3  #include <cstdint>
4  std::uint8_t Fn1(std::uint8_t param) noexcept
5  {
6      std::int32_t x{
7          0}; // Non-compliant - DU data flow anomaly; Variable defined,
8          // but not used
9      if (param > 0)
10     {
11         return 1;
12     }
13     else
14     {
15         return 0;
16     }
17 }
18 std::int32_t Fn2() noexcept
19 {
20     std::int8_t x{10U}; // Compliant - variable defined and will be used
21     std::int8_t y{20U}; // Compliant - variable defined and will be used
22     std::int16_t result = x + y; // x and y variables used
23
24     x = 0; // Non-compliant - DU data flow anomaly; Variable defined, but x is
25         // not subsequently used and goes out of scope
26     y = 0; // Non-compliant - DU data flow anomaly; Variable defined, but y is
27         // not subsequently used and goes out of scope
28     return result;
29 }
30 std::int32_t Fn3(std::int32_t param) noexcept
31 {
32     std::int32_t x{param +
33         1}; // Compliant - variable defined, and will be used in
34         // one of the branches
35         // However, scope of x variable could be reduced
36     if (param > 20)
37     {
38         return x;
39     }
40     return 0;
41 }
42 std::int32_t Fn4(std::int32_t param) noexcept

```

```

43 {
44     std::int32_t x{param +
45         1}; // Compliant - variable defined, and will be used in
46             // some of the branches
47     if (param > 20)
48     {
49         return x + 1;
50     }
51     else if (param > 10)
52     {
53         return x;
54     }
55     else
56     {
57         return 0;
58     }
59 }
60 void Fn5() noexcept
61 {
62     std::array<std::int32_t, 100> arr{};
63     arr.fill(1);
64
65     constexpr std::uint8_t limit{100U};
66     std::int8_t x{0};
67     for (std::uint8_t i{0U}; i < limit; ++i) // Compliant by exception - on the
68         // final loop, value of i defined will
69         // not be used
70     {
71         arr[i] = arr[x];
72         ++x; // Non-compliant - DU data flow anomaly on the final loop, value
73             // defined and not used
74     }
75 }

```

## See also

MISRA C++2008: 0-1-6 A project shall not contain instances of non-volatile variables being given values that are never subsequently used.

### Rule A0-1-2 (required, implementation, automated)

**The value returned by a function having a non-void return type that is not an overloaded operator shall be used.**

## Rationale

A called function may provide essential information about its process status and result through return statement. Calling a function without using the return value should be a warning that incorrect assumptions about the process were made.

Overloaded operators are excluded, as they should behave in the same way as built-in operators.

## Exception

The return value of a function call may be discarded by use of a `static_cast<void>` cast, so intentions of a programmer are explicitly stated.

## Example

```
1 // $Id: A0-1-2.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <algorithm>
3 #include <cstdint>
4 #include <vector>
5 std::uint8_t Fn1() noexcept
6 {
7     return 0U;
8 }
9 void Fn2() noexcept
10 {
11     std::uint8_t x = Fn1();           // Compliant
12     Fn1();                           // Non-compliant
13     static_cast<void>(Fn1()); // Compliant by exception
14 }
15 void Fn3()
16 {
17     std::vector<std::int8_t> v{0, 0, 1, 1, 2, 2, 3, 3, 4, 4, 5, 5};
18     std::unique(v.begin(), v.end()); // Non-compliant
19     v.erase(std::unique(v.begin(), v.end()), v.end()); // Compliant
20 }
```

## See also

MISRA C++ 2008 [7]: Rule 0-1-7 The value returned by a function having a non-void return type that is not an overloaded operator shall always be used.

HIC++ v4.0 [9]: 17.5.1 Do not ignore the result of `std::remove`, `std::remove_if` or `std::unique`.

**Rule M0-1-8 (required, implementation, automated)**  
**All functions with void return type shall have external side effect(s).**

See MISRA C++ 2008 [7]

**Rule M0-1-9 (required, implementation, automated)**  
**There shall be no dead code.**

See MISRA C++ 2008 [7]

## See also

JSF December 2005 [8]: AV Rule 181: Redundant explicit casts will not be used.

**Rule M0-1-10 (advisory, implementation, automated)**  
**Every defined function should be called at least once.**

See MISRA C++ 2008 [7]

Note: This rule enforces developers to statically and explicitly use every function in the source code. A function does not necessarily need to be called at run-time. Rule [M0-1-1](#) detects all unreachable code occurrences.

**Rule A0-1-3 (required, implementation, automated)**  
**Every function defined in an anonymous namespace, or static function with internal linkage, or private member function shall be used.**

## Rationale

Functions which are not callable from outside the compilation unit in which they are defined, or from outside the class implementation to which they pertain, and which are not used may be symptomatic of serious problems, such as poor software design or missing paths in flow control.

This rule enforces developers to statically and explicitly use every such function in the source code. A function does not necessarily need to be called at run-time. Rule [M0-1-1](#) detects all unreachable code occurrences.

Note that this rule applies equally to static and non-static private member functions.

## Example

```
1  //% $Id: A0-1-3.cpp 291350 2017-10-17 14:31:34Z jan.babst $
2  #include <cstdlib>
3  static void F1() // Compliant
4  {
5  }
6
7  namespace
8  {
9      void F2() // Non-compliant, defined function never used
10     {
11     }
12 }
13
14 class C
15 {
16     public:
17         C() : x(0) {}
18         void M1(std::int32_t i) // Compliant, member function is used
19         {
20             x = i;
21 }
```

```
22     void M2(std::int32_t i,  
23           std::int32_t j) // Compliant, never used but declared  
24                           // as public  
25     {  
26         x = (i > j) ? i : j;  
27     }  
28  
29     protected:  
30     void M1ProtectedImpl(std::int32_t j) // Compliant, never used but declared  
31                                           // as protected  
32     {  
33         x = j;  
34     }  
35  
36     private:  
37     std::int32_t x;  
38     void M1PrivateImpl(  
39         std::int32_t j) // Non-compliant, private member function never used  
40     {  
41         x = j;  
42     }  
43 };  
44 int main(int, char**)  
45 {  
46     F1();  
47     C c;  
48     c.M1(1);  
49     return 0;  
50 }
```

## See also

MISRA C++ 2008 [7]: Rule 0-1-10 Every defined function shall be called at least once.

HIC++ v4.0 [9]: 1.2.2 Ensure that no expression or sub-expression is redundant.

**Rule A0-1-4 (required, implementation, automated)**  
**There shall be no unused named parameters in non-virtual functions.**

## Rationale

Unused named parameters are often a result of a design changes and can lead to mismatched parameter lists.

Note: This rule does not apply to unnamed parameters, as they are widely used in SFINAE and concept compliance.

## Example

```
1  //%% $Id: A0-1-4.cpp 305588 2018-01-29 11:07:35Z michal.szczepankiewicz $
2
3  #include <type_traits>
4  #include <string>
5
6  //Logger.hpp
7  class Logger
8  {
9  public:
10     struct console_t {};
11     struct file_t {};
12
13     constexpr static console_t console = console_t();
14     constexpr static file_t file = file_t();
15
16     void init(console_t);
17     void init(file_t, const std::string& prefix);
18 };
19
20 //Logger.cpp
21 void Logger::init(console_t)
22 {
23 //initialization for a console logger
24 }
25 void Logger::init(file_t, const std::string& prefix)
26 {
27 //initialization for a file logger for a given prefix path
28 }
29
30 //Message.h
31 struct MessagePolicy {};
32 struct WriteMessagePolicy final : public MessagePolicy {};
33
34 template <typename T> struct is_mutable : std::false_type {};
35 template <> struct is_mutable<WriteMessagePolicy> : std::true_type {};
36
37 template <typename T, typename Policy = MessagePolicy>
38 class Message
39 {
40 public:
41     static_assert(std::is_base_of<MessagePolicy, Policy>::value == true, "Given parameter is not
42     derived from MessagePolicy");
43     using value_type = T;
44
45     template<typename U = void>
46     void set(T&& u, typename std::enable_if<is_mutable<Policy>::value, U>::type*
47     = 0)
48     {
49         v = u;
50     }
51 }
```

```
50 private:
51     value_type v;
52 };
53
54 int main(int, char**)
55 {
56     Logger log;
57     log.init(Logger::console);
58     log.init(Logger::file, std::string("/tmp/"));
59
60     Message<uint8_t> read;
61     Message<uint8_t, WriteMessagePolicy> write;
62
63     //read.set(uint8_t(12)); Compilation error
64     write.set(uint8_t(12));
65
66     return 0;
67 }
```

## See also

C++ Core Guidelines [11]: F.9: Unused parameters should be unnamed

**Rule A0-1-5 (required, implementation, automated)**  
**There shall be no unused named parameters in the set of parameters for a virtual function and all the functions that override it.**

## Rationale

Unused named parameters are often a result of a design changes and can lead to mismatched parameter lists.

Note: This rule does not apply to unnamed parameters, as overridden methods for some subclasses may need additional parameters.

## Example

```
1  //% $Id: A0-1-5.cpp 305588 2018-01-29 11:07:35Z michal.szczepankiewicz $
2
3  #include <cstdint>
4  #include <vector>
5
6  //Compressor.h
7  class Compressor
8  {
9  public:
10     using raw_memory_type = std::vector<uint8_t>;
11
12     raw_memory_type Compress(const raw_memory_type& in, uint8_t ratio);
13
14 private:
```



```
15     virtual raw_memory_type __Compress(const raw_memory_type& in, uint8_t ratio)
16     = 0;
17 };
18 //Compressor.cpp
19 Compressor::raw_memory_type Compressor::Compress(const raw_memory_type& in, uint8_t
20     ratio)
21 {
22     return __Compress(in, ratio);
23 }
24 //JPEGCompressor.h
25 class JPEGCompressor : public Compressor
26 {
27 private:
28     raw_memory_type __Compress(const raw_memory_type& in, uint8_t ratio) override
29     ;
30 };
31 //JPEGCompressor.cpp
32 JPEGCompressor::raw_memory_type JPEGCompressor::__Compress(const raw_memory_type& in,
33     uint8_t ratio)
34 {
35     raw_memory_type ret;
36     //jpeg compression, ratio used
37     return ret;
38 }
39 //HuffmanCompressor.h
40 class HuffmanCompressor : public Compressor
41 {
42 private:
43     raw_memory_type __Compress(const raw_memory_type& in, uint8_t) override;
44 };
45 //JPEGCompressor.cpp
46 HuffmanCompressor::raw_memory_type HuffmanCompressor::__Compress(const
47     raw_memory_type& in, uint8_t)
48 {
49     raw_memory_type ret;
50     //Huffman compression, no ratio parameter available in the algorithm
51     return ret;
52 }
```

## See also

C++ Core Guidelines [11]: F.9: Unused parameters should be unnamed

**Rule A0-1-6 (advisory, implementation, automated)**  
**There should be no unused type declarations.**

### Rationale

Unused type declarations make code unnecessary more complex and complicate review process. Unused types can be redundant or be unused by mistake.

Note: Libraries development require introduction new types not used internally.

### Example

```
1 // $Id: A0-1-6.cpp$
2 #include <cstdint>
3
4 std::uint32_t Fn() noexcept
5 {
6     using LocalUIntPtr = std::uint32_t*;
7     return 0U;
8 }
```

### See also

MISRA C++ 2008 [7]: Rule 0-1-5 reclassified from required to advisory.

## 6.0.2 Storage

**Rule M0-2-1 (required, implementation, automated)**  
**An object shall not be assigned to an overlapping object.**

See MISRA C++ 2008 [7]

## 6.0.3 Runtime failures

**Rule M0-3-1 (required, implementation / verification, non-automated)**  
**Minimization of run-time failures shall be ensured by the use of at least one of: (a) static analysis tools/techniques; (b) dynamic analysis tools/techniques; (c) explicit coding of checks to handle run-time faults.**

See MISRA C++ 2008 [7]

**Rule M0-3-2 (required, implementation, non-automated)****If a function generates error information, then that error information shall be tested.**

See MISRA C++ 2008 [7]

Note: This rule does not cover exceptions due to different behavior. Exception handling is described in chapter [6.15](#).

## 6.0.4 Arithmetic

**Rule M0-4-1 (required, implementation, non-automated)****Use of scaled-integer or fixed-point arithmetic shall be documented.**

See MISRA C++ 2008 [7]

**Rule M0-4-2 (required, implementation, non-automated)****Use of floating-point arithmetic shall be documented.**

See MISRA C++ 2008 [7]

**Rule A0-4-1 (required, infrastructure / toolchain, non-automated)****Floating-point implementation shall comply with IEEE 754 standard.**

### Rationale

Floating-point arithmetic has a range of problems associated with it. Some of these can be overcome by using an implementation that conforms to IEEE 754 (IEEE Standard for Floating-Point Arithmetic).

Note that the rule implies that toolchain, hardware, C++ Standard Library and C++ built-in types (i.e. float, double) will provide full compliance to IEEE 754 standard in order to use floating-points in the project.

Also, see: [A0-4-2](#).

### Example

```
1 //% $Id: A0-4-1.cpp 271389 2017-03-21 14:41:05Z piotr.tanski $
2 #include <limits>
3 static_assert(
4     std::numeric_limits<float>::is_iec559,
5     "Type float does not comply with IEEE 754 single precision format");
6 static_assert(
```

```
7     std::numeric_limits<float>::digits == 24,  
8     "Type float does not comply with IEEE 754 single precision format");  
9  
10    static_assert(  
11        std::numeric_limits<double>::is_iec559,  
12        "type double does not comply with IEEE 754 double precision format");  
13    static_assert(  
14        std::numeric_limits<double>::digits == 53,  
15        "Type double does not comply with IEEE 754 double precision format");
```

## See also

MISRA C++ 2008 [7]: Rule 0-4-3 Floating-point implementations shall comply with a defined floating-point standard.

JSF December 2005 [8]: AV Rule 146 Floating point implementations shall comply with a defined floating point standard.

**Rule A0-4-2 (required, implementation, automated)**  
**Type long double shall not be used.**

## Rationale

The width of long double type, and therefore width of the significand, is implementation-defined.

The width of long double type can be either:

64 bits, as the C++14 Language Standard allows long double to provide at least as much precision as type double does, or

80 bits, as the IEEE 754 standard allows extended precision formats (see: [Extended-Precision-Format](#)), or

128 bits, as the IEEE 754 standard defines quadruple precision format

## Example

```
1  //% $Id: A0-4-2.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $  
2  void Fn() noexcept  
3  {  
4      float f1{0.1F};           // Compliant  
5      double f2{0.1};          // Compliant  
6      long double f3{0.1L};    // Non-compliant  
7  }
```

## See also

none

**Rule A0-4-3 (required, toolchain, automated)****The implementations in the chosen compiler shall strictly comply with the C++14 Language Standard.****Rationale**

It is important to determine whether implementations provided by the chosen compiler strictly follow the ISO/IEC 14882:2014 C++ Language Standard.

**Example**

Since the ISO/IEC 14882:2014 C++ Language Standard, the integer division and modulo operator results are no longer implementation-defined. The sentence “if both operands are nonnegative then the remainder is nonnegative; if not, the sign of the remainder is implementation-defined” from ISO/IEC 14882:2003 is no longer present in the standard since ISO/IEC 14882:2011. Note that this rule also covers the modulo operator as it is defined in terms of integer division.

Deducing the type of an auto variable initialized using `auto x{<value>}` is implemented differently depending on the language standard. In C++11 and C++14, `x` will be a `std::initializer_list`, whereas in C++17, `x` will be a type deduced from the specified `<value>`. Furthermore, some compilers may already implement the C++17 behavior even when operated in C++14 mode.

Note: Rule [A8-5-3](#) forbids initializing an auto variable with the curly braces (`{}`) syntax.

Other features provided by the chosen compiler also should follow the ISO/IEC 14882:2014 C++ Language Standard.

**See also**

MISRA C++ 2008 [7]: Rule 1-0-3 The implementation of integer division in the chosen compiler shall be determined and documented.

C++ Core Guidelines [11]: F.46: `int` is the return type for `main()`.

**Rule A0-4-4 (required, implementation, partially automated)****Range, domain and pole errors shall be checked when using math functions.****Rationale**

The C Standard defines the following types of error related to math functions specifically:

domain error – input arguments are outside a domain of a mathematical function definition

pole error – for finite input arguments a function gives an exact infinite result

range error – a result of a mathematical function cannot be represented by the return type limitations

Domain and pole errors require that bounds are checked for input parameters before calling a mathematical function. Range errors in most cases cannot be prevented, as their occurrence mostly depend on the implementation of floating-point numbers (see [A0-4-1](#)).

Checking for range errors for multi-threaded applications require that floating-point exception state is in a per-thread basis.

### Example

```
1  /// $Id: A0-4-4.cpp 305588 2018-01-29 11:07:35Z michal.szczepankiewicz $
2
3  #include <cmath>
4  #include <cfenv>
5
6  float Foo(float val)
7  {
8      //non-compliant, domain error for negative values
9      return std::sqrt(val);
10 }
11
12 float Bar(float val)
13 {
14     //non-compliant
15     //domain error for val < 0
16     //pole error for val==0
17     return std::log(val);
18 }
19
20 //\return true, if a range error occurred
21 bool DetectRangeErr()
22 {
23     return ((math_errhandling & MATH_ERREXCEPT) &&
24             (fetestexcept(FE_INEXACT | FE_OVERFLOW | FE_UNDERFLOW) != 0));
25 }
```

### See also

SEI CERT C++ Coding Standard [10]: FLP32-C: Prevent or detect domain and range errors in math functions

## 6.1 General

### 6.1.1 Scope

**Rule A1-1-1 (required, implementation, automated)**  
**All code shall conform to ISO/IEC 14882:2014 - Programming Language C++ and shall not use deprecated features.**

## Rationale

The current version of the C++ language is as defined by the ISO International Standard ISO/IEC 14822:2014(E) "Information technology - Programming languages - C++".

The C++14 is the improved version of the C++11. It is also “the state of the art” of C++ development that is required by ISO 26262 standard [6].

Any reference in this document to “C++ Language Standard” refers to the ISO/IEC 14822:2014 standard.

Note that all of the deprecated features of C++ Language Standard are defined in ISO/IEC 14882:2014 - Programming Language C++ Annexes C “Compatibility” and D “Compatibility features”.

## Example

```
1  ///  
2  #include <cstdlib>  
3  #include <stdexcept>  
4  void F(std::int32_t i)  
5  {  
6      std::int32_t* a = nullptr;  
7  
8      ///  
9      try // Compliant - try keyword is a part of C++ Language Standard  
10     {  
11         a = new std::int32_t[i];  
12         // ...  
13     }  
14  
15     ///  
16     // extension  
17     catch (  
18         std::exception&) // Compliant - C++ Language Standard does not define  
19         // finally block, only try and catch blocks  
20     {  
21         delete[] a;  
22         a = nullptr;  
23     }  
24 }
```

## See also

MISRA C++ 2008 [7]: 1-0-1 All code shall conform to ISO/IEC 14882:2003 “The C++ Standard Incorporating Technical Corrigendum 1”

JSF December 2005 [8]: 4.4.1 All code shall conform to ISO/IEC 14882:2002(E) standard C++.

HIC++ v4.0 [9]: 1.1.1 Ensure that code complies with the 2011 ISO C++ Language Standard.

HIC++ v4.0 [9]: 1.3.4 Do not use deprecated STL library features.

**Rule M1-0-2 (required, toolchain, non-automated)**  
**Multiple compilers shall only be used if they have a common, defined interface.**

See MISRA C++ 2008 [7]

**Rule A1-1-2 (required, implementation / toolchain, non-automated)**  
**A warning level of the compilation process shall be set in compliance with project policies.**

### Rationale

If compiler enables the high warning level, then it is able to generate useful warning messages that point out potential run-time problems during compilation time. The information can be used to resolve certain errors before they occur at run-time.

Note that it is common practice to turn warnings into errors.

Also, note that enabling the highest compiler warning level may produce numerous useless messages during compile time. It is important that the valid warning level for the specific compiler is established in the project.

### See also

JSF December 2005 [8]: AV Rule 218 Compiler warning levels will be set in compliance with project policies.

**Rule A1-1-3 (required, toolchain, non-automated)**  
**An optimization option that disregards strict standard compliance shall not be turned on in the chosen compiler.**

### Rationale

Enabling optimizations that disregard compliance with the C++ Language Standard may create an output program that should strictly comply to the standard no longer valid.

### See also

none



## 6.1.2 Normative references

**Rule A1-2-1 (required, toolchain, non-automated)**

**When using a compiler toolchain (including preprocessor, compiler itself, linker, C++ standard libraries) in safety-related software, the tool confidence level (TCL) shall be determined. In case of TCL2 or TCL3, the compiler shall undergo a “Qualification of a software tool”, as per ISO 26262-8.11.4.6 [6].**

### Rationale

Vulnerabilities and errors in the compiler toolchain impact the binary that is built.

### Example

The following mechanisms could help to increase the Tool error Detection (TD) and thus allowing to reduce the Tool Confidence Level:

1. Achievement of MC/DC code coverage on generated project assembly code
2. Diverse implementation of safety requirements at software or even at system level (e.g. two micro-controllers)
3. Usage of diverse compilers or compilation options
4. Diversity at the level of operating system
5. Extensive testing (e.g. equivalence class testing, boundary value testing), testing at several levels (e.g. unit testing, integration testing)

Note that in most automotive applications, the compiler is evaluated TCL3 or TCL2. In case of TCL2 or TCL3, the following are typically performed (by compiler vendor or by a project), see table 4 in ISO 26262-8:

1. Evaluation of the tool development process
2. Validation of the software tool, by performing automatic compiler tests that are derived from the C++ language specification

### See also

ISO 26262-8 [6]: 11 Confidence in the use of software tools.

## 6.1.4 Implementation compliance

**Rule A1-4-1 (required, implementation / verification, non-automated)**

**Code metrics and their valid boundaries shall be defined and code shall comply with defined boundaries of code metrics.**

## Rationale

Code metrics that concern i.e. project's structure, function's complexity and size of a source code shall be defined at the project level. It is also important to determine valid boundaries for each metric to define objectives of the measurement.

Source code metrics needs to be measured for the project and comply with defined boundaries. This gives valuable information whether the source code is complex, maintainable and efficient.

## See also

HIC++ v4.0 [9]: 8.3.1 Do not write functions with an excessive McCabe Cyclomatic Complexity.

HIC++ v4.0 [9]: 8.3.2 Do not write functions with a high static program path count.

HIC++ v4.0 [9]: 8.2.2 Do not declare functions with an excessive number of parameters.

**Rule A1-4-3 (advisory, implementation, automated)**  
**All code should compile free of compiler warnings.**

## Rationale

Compiler warnings provide the earliest tool-supported indication of potential problems in source code. Developers should not ignore compiler warnings.

Note: Compiler warnings should be turned on to a level matching (as far as possible) the rules in this document, in particular [A1-1-1](#). A possible enforcement of this rule is to turn compiler warnings into errors.

## See also

[A1-1-1](#) in section [6.1.1](#)

## 6.2 Lexical conventions

### 6.2.3 Character sets

**Rule A2-3-1 (required, architecture / design / implementation, automated)**  
**Only those characters specified in the C++ Language Standard basic source character set shall be used in the source code.**

## Rationale

“The basic source character set consists of 96 characters: the space character, the control characters representing horizontal tab, vertical tab, form feed, and new-line,

plus the following 91 graphical characters: a b c d e f g h i j k l m n o p q r s t u v w x y z  
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z 0 1 2 3 4 5 6 7 8 9 \_ { } [ ] # ( ) < > % : ; . ? \* + - / ^ & | ~ ! = , \ " ' ”

” [C++ Language Standard [3]]

### Exception

It is permitted to use other characters inside the text of a wide string and a UTF-8 encoded string literal.

It is also permitted to use a character @ inside comments. See rule [A2-7-3](#).

### Example

```

1 // $Id: A2-3-1.cpp 307578 2018-02-14 14:46:20Z michal.szczepankiewicz $
2 #include <cstdlib>
3
4 void Fn() noexcept
5 {
6     std::int32_t sum = 0; // Compliant
7     // std::int32_t Â£_value = 10; // Non-compliant
8     // sum += Â£_value; // Non-compliant
9     // Variable sum stores Â£ pounds // Non-compliant
10 }
```

### See also

JSF December 2005 [8]: AV Rule 9: Only those characters specified in the C++ basic source character set will be used.

## 6.2.5 Alternative tokens

**Rule A2-5-1 (required, implementation, automated)**  
**Trigraphs shall not be used.**

### Rationale

Trigraphs are denoted to be a sequence of 2 question marks followed by a specified third character (e.g. ??' represents a ~character. They can cause accidental confusion with other uses of two question marks.

The Trigraphs are: ??=, ??/, ??', ??(, ??), ??!, ??<, ??>, ??-.

### Example

```

1 // % $Id: A2-5-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <iostream>
3 void Fn1()
4 {
```

```
5     std::cout << "Enter date ??/??/??"; // Non-compliant, ??/??/?? becomes \\??
6                                         // after trigraph translation
7 }
8 void Fn2()
9 {
10    std::cout << "Enter date dd/mm/yy"; // Compliant
11 }
```

## See also

MISRA C++2008: Rule 2-3-1 (Required) Trigraphs shall not be used.

JSF December 2005 [8]: AV Rule 11 Trigraphs will not be used.

HIC++ v4.0 [9]: 2.2.1 Do not use digraphs or trigraphs.

**Rule A2-5-2 (required, implementation, automated)**  
**Digraphs shall not be used.**

## Rationale

The digraphs are: <%, %>, <:, :>, %:, %:%:.

The use of digraphs may not meet developer expectations.

## Example

```
1  //% $Id: A2-5-2.cpp 305382 2018-01-26 06:32:15Z michal.szczepankiewicz $
2  class A
3  {
4      public:
5          void F2() {}
6  };
7  // void fn1(A* a<:10:>) // Non-compliant
8  // <%
9  //     a<:0:>->f2();
10 // %>
11 void Fn2(A* a[10]) // Compliant, equivalent to the above
12 {
13     a[0]->F2();
14 }
```

## See also

MISRA C++ 2008 [7]: advisory 2-5-1 Digraphs should not be used.

JSF December 2005 [8]: 4.4.1 AV Rule 12 The following digraphs will not be used.

HIC++ v4.0 [9]: 2.2.1 Do not use digraphs or trigraphs.

## 6.2.7 Comments

**Rule M2-7-1 (required, implementation, automated)**  
The character sequence `/*` shall not be used within a C-style comment.

See MISRA C++ 2008 [7]

**Rule A2-7-1 (required, implementation, automated)**  
The character `\` shall not occur as a last character of a C++ comment.

### Rationale

If the last character in a single-line C++ comment is `\`, then the comment will continue in the next line. This may lead to sections of code that are unexpectedly commented out.

### Example

```
1 // $Id: A2-7-1.cpp 305382 2018-01-26 06:32:15Z michal.szczepankiewicz $
2 #include <cstdint>
3 void Fn() noexcept
4 {
5     std::int8_t idx = 0;
6     // Incrementing idx before the loop starts // Requirement X.X.X \
7     ++idx; // Non-compliant - ++idx was unexpectedly commented-out because of \
8           // character occurrence in the end of C++ comment
9
10    constexpr std::int8_t limit = 10;
11    for (; idx <= limit; ++idx)
12    {
13        // ...
14    }
```

### See also

none

**Rule A2-7-2 (required, implementation, non-automated)**  
Sections of code shall not be “commented out”.

### Rationale

Comments, using both C-style and C++ comments, should only be used to explain aspect of the source code. Code that is commented-out may become out of date, which may lead to confusion while maintaining the code.

Additionally, C-style comment markers do not support nesting, and for this purpose commenting out code is dangerous, see: [M2-7-1](#).

Note that the code that is a part of a comment (e.g. for clarification of the usage of the function, for specifying function behavior) does not violate this rule. As it is not possible to determine if a commented block is a textual comment, a code example or a commented-out piece of code, this rule is not enforceable by static analysis tools.

### Example

```
1 // $Id: A2-7-2.cpp 305382 2018-01-26 06:32:15Z michal.szczepankiewicz $
2 #include <cstdint>
3 void Fn1() noexcept
4 {
5     std::int32_t i = 0;
6     // /*
7     // * ++i; /* incrementing the variable i */
8     // */ // Non-compliant - C-style comments nesting is not supported,
9     // compilation error
10    for (; i < 10; ++i)
11    {
12        // ...
13    }
14 }
15 void Fn2() noexcept
16 {
17     std::int32_t i = 0;
18     // ++i; // Incrementing the variable i // Non-compliant - code should not
19     // be commented-out
20     for (; i < 10; ++i)
21     {
22         // ...
23     }
24 }
25 void Fn3() noexcept
26 {
27     std::int32_t i = 0;
28     ++i; // Incrementing the variable i using ++i syntax // Compliant - code
29         // is not commented-out, but ++i occurs in a
30         // comment too
31     for (; i < 10; ++i)
32     {
33         // ...
34     }
35 }
```

### See also

MISRA C++ 2008 [7]: Rule 2-7-2 Sections of code shall not be “commented out” using C-style comments.

MISRA C++ 2008 [7]: Rule 2-7-3 Sections of code should not be “commented out” using C++ comments.

**Rule A2-7-3 (required, implementation, automated)**  
**All declarations of “user-defined” types, static and non-static data members, functions and methods shall be preceded by documentation.**

## Rationale

Every declaration needs to provide a proper documentation.

This is compatible with the C++ standard library documentation. This forces a programmer to provide a clarification for defined types and its data members responsibilities, methods and functions usage, their inputs and outputs specification (e.g. memory management, ownership, valid boundaries), and exceptions that could be thrown.

## Example

```

1  //% $Id: A2-7-3.hpp 305382 2018-01-26 06:32:15Z michal.szczepankiewicz $
2  #include <cstdint>
3
4  void F1(std::int32_t) noexcept; // Non-compliant documentation
5
6  std::int32_t F2(std::int16_t input1,
7                std::int32_t input2); // Non-compliant documentation
8
9  /// @brief Function description
10 ///
11 /// @param input1 input1 parameter description
12 /// @param input2 input2 parameter description
13 /// @throw std::runtime_error conditions to runtime_error occur
14 ///
15 /// @return return value description
16 std::int32_t F3(
17     std::int16_t input1,
18     std::int16_t input2) noexcept(false); // Compliant documentation
19
20 /// @brief Class responsibility
21 class C // Compliant documentation
22 {
23     public:
24         /// @brief Constructor description
25         ///
26         /// @param input1 input1 parameter description
27         /// @param input2 input2 parameter description
28         C(std::int32_t input1, float input2) : x{input1}, y{input2} {}
29
30         /// @brief Method description
31         ///

```

```
32     /// @return return value description
33     std::int32_t const* GetX() const noexcept { return &x; }
34
35 private:
36     /// @brief Data member description
37     std::int32_t x;
38     /// @brief Data member description
39     float y;
40 };
```

## See also

JSF December 2005 [8]: AV Rule 129: Comments in header files should describe the externally visible behavior of the functions or classes being documented.

none

**Rule A2-7-5 (required, implementation, non-automated)**  
**Comments shall not document any actions or sources (e.g. tables, figures, paragraphs, etc.) that are outside of the file.**

## Rationale

Commenting only actions and sources that are inside a particular file reduce dependencies among files. Comments in a file will require changes only when content of the file reworked.

Note: This rule does not affect valid assumptions or preconditions for entities within the file.

## See also

JSF December 2005 [8]: AV Rule 128: Comments that document actions or sources (e.g. tables, figures, paragraphs, etc.) outside of the file being documented will not be allowed.

### 6.2.8 Header names

**Rule A2-8-1 (required, architecture / design / implementation, non-automated)**  
**A header file name should reflect the logical entity for which it provides declarations.**

## Rationale

Naming a header file with a name of a declared type or accordingly to a collection of free functions or forwarded headers makes include-directives and a project structure more clear and readable.



## See also

JSF December 2005 [8]: AV Rule 55: The name of a header file should reflect the logical entity for which it provides declarations.

**Rule A2-8-2 (advisory, architecture / design / implementation, non-automated)**  
**An implementation file name should reflect the logical entity for which it provides definitions.**

## Rationale

Naming an implementation file with a name of a declared type or accordingly to a collection of free functions makes a project structure more clear and readable.

## See also

JSF December 2005 [8]: AV Rule 56: The name of an implementation file should reflect the logical entity for which it provides definitions and have a “.cpp” extension (this name will normally be identical to the header file that provides the corresponding declarations.).

### 6.2.10 Identifiers

**Rule M2-10-1 (required, architecture / design / implementation, automated)** Different identifiers shall be typographically unambiguous.

See MISRA C++ 2008 [7]

**Rule A2-10-1 (required, architecture / design / implementation, automated)**  
**An identifier declared in an inner scope shall not hide an identifier declared in an outer scope.**

## Rationale

If an identifier is declared in an inner scope and it uses the same name as an identifier that already exists in an outer scope, then the innermost declaration will “hide” the outer one. This may lead to developer confusion. The terms outer and inner scope are defined as follows:

Identifiers that have file scope can be considered as having the outermost scope. Identifiers that have block scope have a more inner scope.

Successive, nested blocks, introduce more inner scopes.

Note that declaring identifiers in different named namespaces, classes, structs or enum classes will not hide other identifiers from outer scope, because they can be accessed using fully-qualified id.

## Exception

An identifier declared within a namespace using the same name as an identifier of the containing namespace does not violate the rule.

An identifier declared locally inside a lambda expression and not referring to a name of a captured variable does not violate the rule.

## Example

```
1  //% $Id: A2-10-1.cpp 313834 2018-03-27 11:35:19Z michal.szczepankiewicz $
2  #include <cstdint>
3  std::int32_t sum = 0;
4  namespace
5  {
6  std::int32_t sum; // Non-compliant, hides sum in outer scope
7  }
8  class C1
9  {
10     std::int32_t sum; // Compliant, does not hide sum in outer scope
11 };
12 namespace n1
13 {
14     std::int32_t sum; // Compliant, does not hide sum in outer scope
15     namespace n2
16     {
17         std::int32_t sum; // Compliant, does not hide sum in outer scope
18     }
19 }
20
21 std::int32_t idx;
22 void F1(std::int32_t idx)
23 {
24     //Non-compliant, hides idx in outer scope
25 }
26
27 void F2()
28 {
29     std::int32_t max = 5;
30
31     for (std::int32_t idx = 0; idx < max;
32         ++idx) // Non-compliant, hides idx in outer scope
33     {
34         for (std::int32_t idx = 0; idx < max;
35             ++idx) // Non-compliant, hides idx in outer scope
36             {
37             }
38     }
```

```
39 }
40 void F3()
41 {
42     std::int32_t i = 0;
43     std::int32_t j = 0;
44     auto lambda = [i]() {
45         std::int32_t j =
46             10; // Compliant - j was not captured, so it does not hide
47                // j in outer scope
48         return i + j;
49     };
50 }
```

## See also

MISRA C++ 2008 [7]: required 2-10-2 Identifiers declared in an inner scope shall not hide an identifier declared in an outer scope.

JSF December 2005 [8]: 4.15 AV Rule 135 Identifiers in an inner scope shall not use the same name as an identifier in an outer scope, and therefore hide that identifier.

HIC++ v4.0 [9]: 3.1.1 Do not hide declarations.

**Rule A2-10-6 (required, implementation, automated)**  
**A class or enumeration name shall not be hidden by a variable, function or enumerator declaration in the same scope.**

## Rationale

C++ Language Standard [3] defines that a class or enumeration name can be hidden by an explicit declaration (of the same name) of a variable, data member, function, or enumerator in the same scope, regardless of the declaration order. Such declarations can be misleading for a developer and can lead to compilation errors.

## Example

```
1  /// $Id: A2-10-6.cpp 313821 2018-03-27 11:16:14Z michal.szczepankiewicz $
2  #include <cstdlib>
3
4  namespace NS1 {
5  class G {};
6  void G() {} //non-compliant, hides class G
7  }
8
9  namespace NS2 {
10 enum class H { VALUE=0, };
11 std::uint8_t H = 17; //non-compliant, hides
12                      //scoped enum H
13 }
```

```
14
15 namespace NS3 {
16 class J {};
17 enum H //does not hide NS2::H, but non-compliant to A7-2-3
18 {
19     J=0, //non-compliant, hides class J
20 };
21 }
22
23 int main(void)
24 {
25     NS1::G();
26     //NS1::G a; //compilation error, NS1::G is a function
27                 //after a name lookup procedure
28     class NS1::G a{}; //accessing hidden class type name
29
30     enum NS2::H b ; //accessing scoped enum NS2::H
31     NS2::H = 7;
32
33     class NS3::J c{}; //accessing hidden class type name
34     std::uint8_t z = NS3::J;
35 }
```

## See also

ISO/IEC 14882:2014 [3]: 3.3.10.2: [basic.scope.hiding]

MISRA C++ 2008 [7]: 2-10-6: If an identifier refers to a type, it shall not also refer to an object or a function in the same scope.

HIC++ v4.0 [9]: 3.1.1: Do not hide declarations.

**Rule A2-10-4 (required, implementation, automated)**  
**The identifier name of a non-member object with static storage duration or static function shall not be reused within a namespace.**

## Rationale

No identifier with static storage duration should be re-used in the same namespace across any source files in the project.

This may lead to the developer or development tool confusing the identifier with another one.

## Example

```
1 //% $Id: A2-10-4.cpp 305382 2018-01-26 06:32:15Z michal.szczepankiewicz $
2 #include <cstdlib>
3 // f1.cpp
4 namespace ns1
5 {
```

```
6 static std::int32_t globalvariable = 0;
7 }
8
9 // f2.cpp
10 namespace ns1
11 {
12 // static std::int32_t globalvariable = 0; // Non-compliant - identifier reused
13 // in ns1 namespace in f1.cpp
14 }
15 namespace ns2
16 {
17 static std::int32_t globalvariable =
18     0; // Compliant - identifier reused, but in another namespace
19 }
20
21 // f3.cpp
22 static std::int32_t globalvariable =
23     0; // Compliant - identifier reused, but in another namespace
```

## See also

MISRA C++ 2008 [7]: advisory 2-10-5 The identifier name of a non-member object or function with static storage duration should not be reused.

**Rule A2-10-5 (advisory, design / implementation, automated) An identifier name of a function with static storage duration or a non-member object with external or internal linkage should not be reused.**

## Rationale

Regardless of scope, no identifier with static storage duration should be re-used across any source files in the project. This includes objects or functions with external linkage and any objects or functions with static storage class specifier. While the compiler can understand this, the possibility exists for the developer or development tool to incorrectly associate unrelated variables with the same name.

Note: This rule does not apply to objects without linkage, e.g. function local static objects.

## Example

```
1 // % $Id: A2-10-5.cpp 305382 2018-01-26 06:32:15Z michal.szczepankiewicz $
2 #include <cstdlib>
3 // f1.cpp
4 namespace n_s1
5 {
6 static std::int32_t globalvariable = 0;
7 }
8 static std::int32_t filevariable = 5; // Compliant - identifier not reused
9 static void Globalfunction();
```

```
10
11 // f2.cpp
12 namespace n_s1
13 {
14 // static std::int32_t globalvariable = 0; // Non-compliant - identifier reused
15 static std::int16_t modulevariable = 10; // Compliant - identifier not reused
16 }
17 namespace n_s2
18 {
19 static std::int16_t modulevariable2 = 20;
20 }
21 static void Globalfunction(); // Non-compliant - identifier reused
22 static std::int16_t modulevariable2 = 15; // Non-compliant - identifier reused
```

### See also

MISRA C++ 2008 [7]: advisory 2-10-5 The identifier name of a non-member object or function with static storage duration should not be reused.

### 6.2.11 Keywords

**Rule A2-11-1 (required, design / implementation, automated)**  
**Volatile keyword shall not be used.**

#### Rationale

The volatile keyword disables compiler optimizations for a particular variable or object's value in case those values may change in ways not specified by the language (e.g. object representing a hardware register). It is error prone and often misused by developers, as they expect this is equal to variable or object's value being atomic.

Note: The main intention of this rule is to eliminate incorrect usages of volatile keyword and force developers to precisely document each usage of volatile keyword.

#### See also

JSF December 2005 [8]: AV Rule 205: The volatile keyword shall not be used unless directly interfacing with hardware.

HIC++ v4.0 [9]: 18.2.3: Do not share volatile data between threads.

C++ Core Guidelines [11]: CP.8: Don't try to use volatile for synchronization.

C++ Core Guidelines [11]: CP.200: Use volatile only to talk to non-C++ memory.

### 6.2.13 Literals

**Rule A2-13-1 (required, architecture / design / implementation, automated) Only those escape sequences that are defined in ISO/IEC 14882:2014 shall be used.**

### Rationale

The use of an undefined escape sequence leads to undefined behavior. The defined escape sequences (ISO/IEC 14882:2014) are: `\'`, `\"`, `\?`, `\\`, `\a`, `\b`, `\f`, `\n`, `\r`, `\t`, `\v`, `\<Octal Number>`, `\x<Hexadecimal Number>`.

Note: Universal-character-names (`\u` hex-quad and `\U` hex-quad hex-quad) are also allowed in character and string literals (although they look similar to escape sequences, they are handled in a different way by the C++ language, see [A2-13-6](#)).

### Example

```
1 //% $Id: A2-13-1.cpp 305629 2018-01-29 13:29:25Z piotr.serwa $
2 #include <string>
3 void F()
4 {
5     const std::string a = "\k";           // Non-compliant
6     const std::string b = "\n";         // Compliant
7     const std::string c = "\U0001f34c"; // Compliant
8 }
```

### See also

MISRA C++ 2008 [7]: required 2-13-1 Only those escape sequences that are defined in ISO/IEC14882:2003 shall be used.

**Rule A2-13-6 (required, architecture / design / implementation, automated) Universal character names shall be used only inside character or string literals.**

### Rationale

Using universal-character-names to define a language identifier can be confusing for a developer and may be troublesome to use this identifier in the source code.

### Example

```
1 //% $Id: A2-13-6.cpp 307578 2018-02-14 14:46:20Z michal.szczepankiewicz $
2 #include <string>
3 void F()
4 {
5     const std::string c = "\U0001f34c"; // Compliant
6 }
7
8 //non-compliant
9 void \U0001f615()
```

```
10 {  
11 //  
12 }
```

**Rule A2-13-5 (advisory, implementation, automated)**  
**Hexadecimal constants should be upper case.**

### Rationale

Using upper case literals for hexadecimal constants makes the source code consistent in this matter and removes a potential developer confusion.

### Example

```
1 //% $Id: A2-13-5.cpp 305629 2018-01-29 13:29:25Z piotr.serwa $  
2  
3 #include <cstdint>  
4  
5 int main(void)  
6 {  
7     std::int16_t a = 0x0f0f; //non-compliant  
8     std::int16_t b = 0x0f0F; //non-compliant  
9     std::int16_t c = 0x0F0F; //compliant  
10  
11     return 0;  
12 }
```

### See also

JSF December 2005 [8]: AV Rule 150: Hexadecimal constants will be represented using all uppercase letters.

**Rule M2-13-2 (required, architecture / design / implementation, automated)** Octal constants (other than zero) and octal escape sequences (other than “\0” ) shall not be used.

See MISRA C++ 2008 [7]

**Rule M2-13-3 (required, architecture / design / implementation, automated)** A “U” suffix shall be applied to all octal or hexadecimal integer literals of unsigned type.

See MISRA C++ 2008 [7]



**Rule M2-13-4 (required, architecture / design / implementation, automated) Literal suffixes shall be upper case.**

See MISRA C++ 2008 [7]

**Rule A2-13-2 (required, implementation, automated)  
String literals with different encoding prefixes shall not be concatenated.**

## Rationale

Concatenation of wide and narrow string literals leads to undefined behavior.

“In translation phase 6 (2.2), adjacent string-literals are concatenated. If both string-literals have the same encoding-prefix, the resulting concatenated string literal has that encoding-prefix. If one string-literal has no encoding-prefix, it is treated as a string-literal of the same encoding-prefix as the other operand. If a UTF-8 string literal token is adjacent to a wide string literal token, the program is ill-formed. Any other concatenations are conditionally-supported with implementation-defined behavior. [ Note: This concatenation is an interpretation, not a conversion. Because the interpretation happens in translation phase 6 (after each character from a literal has been translated into a value from the appropriate character set), a string-literal’s initial rawness has no effect on the interpretation or well-formedness of the concatenation. -end note ]” [C++14 Language Standard] [3]

## Example

```
1  // % $Id: A2-13-2.cpp 305629 2018-01-29 13:29:25Z piotr.serwa $
2
3  char16_t nArray[] =
4      u"Hello"
5      u"World"; // Compliant, "u" stands for char16_t type
6
7  char32_t nArray2[] =
8      U"Hello"
9      U"World"; // Compliant, "U" stands for char32_t type
10
11 wchar_t wArray[] =
12     L"Hello"
13     L"World"; // Compliant, "L" stands for wchar_t type - violates A2-13-3
14                // rule.
15
16 wchar_t mixed1[] =
17     "Hello"
18     L"World"; // Compliant
19
20 char32_t mixed2[] =
21     "Hello"
22     U"World"; // Compliant
```

```
23
24 char16_t mixed3[] =
25     "Hello"
26     u"World"; // Compliant
27
28 // wchar_t mixed1[] = u"Hello" L"World"; // Non-compliant - compilation error
29
30 // char32_t mixed2[] = u"Hello" U"World"; // Non-compliant - compilation error
```

## See also

MISRA C++ 2008 [7]: required 2-13-5 Narrow and wide string literals shall not be concatenated.

HIC++ v4.0 [9]: 2.5.1 Do not concatenate strings with different encoding prefixes

**Rule A2-13-3 (required, architecture / design / implementation, automated) Type wchar\_t shall not be used.**

## Rationale

Width of wchar\_t type is implementation-defined.

Types char16\_t and char32\_t should be used instead.

## Example

```
1 // % $Id: A2-13-3.cpp 305629 2018-01-29 13:29:25Z piotr.serwa $
2 char16_t string1[] = u"ABC"; // Compliant
3 char32_t string2[] = U"DEF"; // Compliant
4 wchar_t string3[] = L"GHI"; // Non-compliant
```

## See also

none

**Rule A2-13-4 (required, architecture / design / implementation, automated) String literals shall not be assigned to non-constant pointers.**

## Rationale

Since C++0x, there was a change in subclause 2.13.5 for string literals. To prevent from calling an inappropriate function that might modify its argument, the type of a string literal was changed from “array of char” to “array of const char”.

Such a usage is deprecated by the Standard and reported by a compiler as a warning. This rule is deliberately redundant, in case rules [A1-1-1](#) and [A1-4-3](#) are disabled in a project.

## Example

```
1  //% $Id: A2-13-4.cpp 307578 2018-02-14 14:46:20Z michal.szczepankiewicz $
2
3  int main(void)
4  {
5      char* nc1 = "AUTOSAR";           //non-compliant
6      char nc2[] = "AUTOSAR"; //compliant with A2-13-4, non-compliant with A18 -1-1
7
8      char nc3[8] = "AUTOSAR"; //compliant with A2-13-4, non-compliant with A18 -1-1
9
10     nc1[3] = 'a'; // undefined behaviour
11     const char* c1 = "AUTOSAR";           //compliant
12     const char c2[] = "AUTOSAR"; //compliant with A2-13-4, non-compliant with A18-1-1
13
14     const char c3[8] = "AUTOSAR"; //compliant with A2-13-4, non-compliant with A18-1-1
15
16     //c1[3] = 'a'; //compilation error
17
18     return 0;
19 }
```

## See also

JSF December 2005 [8]: AV Rule 151.1: A string literal shall not be modified.

## 6.3 Basic concepts

### 6.3.1 Declarations and definitions

**Rule A3-1-1 (required, architecture / design / implementation, automated) It shall be possible to include any header file in multiple translation units without violating the One Definition Rule.**

#### Rationale

A header file is a file that holds declarations used in more than one translation unit and acts as an interface between separately compiled parts of a program. A header file often contains classes, object declarations, enums, functions, inline functions, templates, typedefs, type aliases and macros.

In particular, a header file is not supposed to contain or produce definitions of global objects or functions that occupy storage, especially objects that are not declared “extern” or definitions of functions that are not declared “inline”.

#### Example

```
1  //% $Id: A3-1-1.hpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2  #include <cstdint>
3  void F1();           // Compliant
```



```

4 extern void F2(); // Compliant
5 void F3()
6 {
7 } // Non-compliant
8 static inline void F4()
9 {
10 } // Compliant
11 template <typename T>
12 void F5(T)
13 {
14 } // Compliant
15 std::int32_t a; // Non-compliant
16 extern std::int32_t b; // Compliant
17 constexpr static std::int32_t c = 10; // Compliant
18 namespace ns
19 {
20 constexpr static std::int32_t d = 100; // Compliant
21 const static std::int32_t e = 50; // Compliant
22 static std::int32_t f; // Non-compliant
23 static void F6() noexcept; // Non-compliant
24 }

```

## See also

MISRA C++ 2008 [7]: Rule 3-1-1 It shall be possible to include any header file in multiple translation units without violating the One Definition Rule.

**Rule A3-1-2 (required, architecture / design / implementation, automated) Header files, that are defined locally in the project, shall have a file name extension of one of: ".h", ".hpp" or ".hxx".**

## Rationale

This is consistent with developer expectations to provide header files with one of the standard file name extensions.

## Example

```

1 // % $Id: A3-1-2.cpp 266557 2017-02-07 13:08:19Z piotr.tanski $
2 ##include <h3.h> // Compliant
3 ##include <h1.hpp> // Compliant
4 ##include <h2.hxx> // Compliant
5 ##include <h4.cpp> // Non-compliant
6 ##include <h5.c> // Non-compliant
7 ##include <h6.hdr> // Non-compliant
8 ##include <h7.inc> // Non-compliant

```

## See also

JSF December 2005 [8]: 4.9.2 AV Rule 53 Header files will always have a file name extension of ".h".

**Rule A3-1-3 (advisory, architecture / design / implementation, automated) Implementation files, that are defined locally in the project, should have a file name extension of ".cpp".**

### Rationale

This is consistent with developer expectations to provide C++ implementation files with the standard file name extension.

Note that compilers support various file name extensions for C++ implementation files.

### See also

JSF December 2005 [8]: 4.9.2 AV Rule 54 Implementation files will always have a file name extension of ".cpp".

**Rule M3-1-2 (required, implementation, automated)  
Functions shall not be declared at block scope.**

See MISRA C++ 2008 [7]

**Rule A3-1-4 (required, design / implementation, automated)  
When an array with external linkage is declared, its size shall be stated explicitly.**

### Rationale

Although it is possible to declare an array of incomplete type and access its elements, it is safer to do so when the size of the array can be explicitly determined.

### Example

```
1 // % $Id: A3-1-4.hpp 271687 2017-03-23 08:57:35Z piotr.tanski $
2 #include <cstdint>
3 extern std::int32_t array1[]; // Non-compliant
4 extern std::int32_t array2[42]; // Compliant
```

### See also

MISRA C++ 2008 [7]: Rule 3-1-3 When an array is declared, its size shall either be stated explicitly or defined implicitly by initialization.

**Rule A3-1-5 (required, design, partially-automated)  
A function definition shall only be placed in a class definition if (1) the function is intended to be inlined (2) it is a member function template (3) it is a member function of a class template.**

## Rationale

Merging the implementation into the declaration instructs a compiler to inline the method which may save both time and space for short functions. For templates, it allows to reduce repetitions of template syntax elements (e.g. parameter list), which makes code less difficult to read and maintain.

## Example

```
1  /// $Id: A3-1-5.cpp 305629 2018-01-29 13:29:25Z piotr.serwa $
2  #include <cstdlib>
3  #include <iostream>
4
5  class A
6  {
7  public:
8      ///compliant with (2)
9      template <typename T>
10     void Foo(T&& t)
11     {
12         std::cout << __PRETTY_FUNCTION__ << " defined inside with param: " << t
13         << std::endl;
14     }
15
16     ///non-compliant with (2)
17     template <typename T>
18     void Bar(T&& t);
19
20     ///compliant with (1)
21     std::uint32_t GetVal() const noexcept
22     {
23         return val;
24     }
25
26     ///non-compliant with (1)
27     std::uint32_t GetVal2() const noexcept;
28 private:
29     std::uint32_t val = 5;
30 };
31
32
33 template <typename T>
34 void A::Bar(T&& t)
35 {
36     std::cout << __PRETTY_FUNCTION__ << " defined outside with param: " << t << std::endl;
37 }
38
39 std::uint32_t A::GetVal2() const noexcept
40 {
```

```
41     return val;
42 }
43
44 template <typename T>
45 class B
46 {
47 public:
48     B(const T& x) : t(x) {}
49
50     //compliant with (3)
51     void display() const noexcept
52     {
53         std::cout << t << std::endl;
54     }
55
56     //non-compliant with (3)
57     void display2() const noexcept;
58
59 private:
60     T t;
61 };
62
63 template <typename T>
64 void B<T>::display2() const noexcept
65 {
66     std::cout << t << std::endl;
67 }
68
69 int main(void)
70 {
71     std::uint32_t tmp = 5;
72     A a;
73     a.Foo(3.14f);
74     a.Bar(5);
75
76     std::cout << a.GetVal() << std::endl;
77
78     B<std::int32_t> b(7);
79     b.display();
80
81     return 0;
82 }
```

## See also

JSF December 2005 [8]: AV Rule 109: A function definition should not be placed in a class specification unless the function is intended to be inlined.



**Rule A3-1-6 (advisory, design, automated)**  
**Trivial accessor and mutator functions should be inlined.**

### Rationale

Inlining trivial accessors and mutators saves time and space, as it reduces multiple syntax elements that has to be repeated.

### Example

```

1  //% $Id: A3-1-6.cpp 305629 2018-01-29 13:29:25Z piotr.serwa $
2  #include <cstdint>
3
4  class A
5  {
6  public:
7      A(std::int32_t l) noexcept : limit{l} {}
8      //compliant
9      std::int32_t Limit() const noexcept { return limit; }
10     //compliant
11     void SetLimit(std::int32_t l) { limit = l; }
12
13     //non-compliant
14     //std::int32_t Limit() const noexcept
15     //{
16         //open file, read data, close file
17         //return value
18     //}
19     //non-compliant
20     //void SetLimit(std::int32_t l)
21     //{
22         //open file, write data, close file
23     //}
24
25 private:
26     std::int32_t limit;
27 };

```

### See also

JSF December 2005 [8]: AV Rule 122: Trivial accessor and mutator functions should be inlined.

## 6.3.2 One Definition Rule

**Rule M3-2-1 (required, implementation, automated)**  
**All declarations of an object or function shall have compatible types.**

See MISRA C++ 2008 [7]

**Rule M3-2-2 (required, implementation, automated)**  
**The One Definition Rule shall not be violated.**

See MISRA C++ 2008 [7]

**Rule M3-2-3 (required, implementation, automated)**  
**A type, object or function that is used in multiple translation units shall be declared in one and only one file.**

See MISRA C++ 2008 [7]

**Rule M3-2-4 (required, implementation, automated)**  
**An identifier with external linkage shall have exactly one definition.**

See MISRA C++ 2008 [7]

### 6.3.3 Scope

**Rule A3-3-1 (required, implementation, automated)**  
**Objects or functions with external linkage (including members of named namespaces) shall be declared in a header file.**

#### Rationale

Placing the declarations of objects and functions with external linkage in a header file means that they are intended to be accessible from other translation units.

If external linkage is not needed, then the object or function is supposed to be either declared in an unnamed namespace or declared static in the implementation file. This reduces the visibility of objects and functions, which allows to reach a higher encapsulation and isolation.

Note that members of named namespace are by default external linkage objects.

#### Exception

This rule does not apply to main, or to members of unnamed namespaces.

#### Example

```
1 //% $Id: A3-3-1.hpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdint>
3 extern std::int32_t a1;
4 extern void F4();
```

```

5 namespace n
6 {
7 void F2();
8 std::int32_t a5; // Compliant, external linkage
9 }

1 //% $Id: A3-3-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include "A3-3-1.hpp"
3 std::int32_t a1 = 0; // Compliant, external linkage
4 std::int32_t a2 = 0; // Non-compliant, static keyword not used
5 static std::int32_t a3 = 0; // Compliant, internal linkage
6 namespace
7 {
8 std::int32_t a4 = 0; // Compliant by exception
9 void F1() // Compliant by exception
10 {
11 }
12 }
13 namespace n
14 {
15 void F2() // Compliant, external linkage
16 {
17 }
18 std::int32_t a6 = 0; // Non-compliant, external linkage
19 }
20 extern std::int32_t a7; // Non-compliant, extern object declared in .cpp file
21 static void F3() // Compliant, static keyword used
22 {
23 }
24 void F4() // Compliant, external linkage
25 {
26 a1 = 1;
27 a2 = 1;
28 a3 = 1;
29 a4 = 1;
30 n::a5 = 1;
31 n::a6 = 1;
32 a7 = 1;
33 }
34 void F5() // Non-compliant, static keyword not used
35 {
36 a1 = 2;
37 a2 = 2;
38 a3 = 2;
39 a4 = 2;
40 n::a5 = 2;
41 n::a6 = 2;
42 a7 = 2;
43 }
44 int main(int, char**) // Compliant by exception
45 {
46 F1();

```

```
47     n::F2();
48     F3();
49     F4();
50     F5();
51 }
```

## See also

MISRA C++ 2008 [7]: Rule 3-3-1 Objects or functions with external linkage shall be declared in a header file.

**Rule A3-3-2 (required, implementation, automated)**  
**Static and thread-local objects shall be constant-initialized.**

## Rationale

In general, using non-const global and static variables obscures the true dependencies of an API, since they can be accessed from any place of the source code. It therefore makes the code more difficult to maintain, less readable, and significantly less testable.

A particular problem is that the order in which constructors and initializers for static variables are called is only partially specified by the C++ Language Standard and can even change from build to build. This can cause issues that are difficult to find or debug.

The compiler performs constant-initialization, if

- the object is initialized by a `constexpr` constructor with only constant expression as arguments; or

- the object is not initialized by a constructor call, but is value-initialized (`T object{};`); or

- the object is not initialized by a constructor call, but is initialized by an initializer consisting only of constant expressions.

Constant initialization is guaranteed to occur before any other initialization of static or thread-local objects and may happen at compile time. Thus it is guaranteed that problematic dependencies between the initializers of constant-initialized static or thread-local objects cannot occur.

Note that declaring a static variable as `constexpr` (static is implied in this case, but may be added to the declaration), enforces constant initialization by the compiler.

Note that the rule applies to:

- global variables (i.e. `extern`) static variables
- static class member variables
- static function-scope variables

## Example

```

1 // $Id: A3-3-2.cpp 305690 2018-01-29 14:35:00Z jan.babst $
2 #include <cstdint>
3 #include <limits>
4 #include <string>
5 class A
6 {
7     public:
8         static std::uint8_t instanceId;
9         static float const pi;
10        static std::string const separator;
11
12        A() {}
13        // Implementation...
14 };
15 std::uint8_t A::instanceId = 0; // Compliant - constant initialization
16 float const A::pi = 3.14159265359; // Compliant - constant initialization
17 std::string const A::separator =
18     "===== "; // Non-compliant - string c'tor is not constexpr
19
20 class C
21 {
22     public:
23         constexpr C() = default;
24 };
25
26 namespace
27 {
28     constexpr std::int32_t maxInt32 =
29         std::numeric_limits<std::int32_t>::max(); // Compliant - constexpr variable
30
31     A instance{}; // Compliant - constant (value) initialization
32     constexpr C c{}; // Compliant - constexpr c'tor call
33 } // namespace
34
35 void Fn() noexcept
36 {
37     static A a{}; // Non-compliant - A's default c'tor is not constexpr
38     static std::int32_t counter{0}; // Compliant
39     static std::string border(5, '*'); // Non-compliant - not a constexpr c'tor
40 }
41
42 class D
43 {
44     public:
45         D() = default;
46         D(D const&) = default;
47         D(D&&) = default;
48         D& operator=(D const&) = default;
49         D& operator=(D&&) = default;
50         ~D() = default;

```

```
51  
52 private:  
53     static D* instance;  
54 };  
55 D* D::instance = nullptr; // Compliant - initialization by constant expression
```

### See also

cppreference.com [16]: Constant initialization.

HIC++ v4.0 [9]: 3.3.1: Do not use variables with static storage duration.

JSF December 2005 [8]: AV Rule 214: Assuming that non-local static objects, in separate translation units, are initialized in a special order shall not be done.

SEI CERT C++ Coding Standard [10]: DCL56-CPP: Avoid cycles during initialization of static objects.

C++ Core Guidelines [11]: I.22: Avoid complex initialization of global objects.

Google C++ Style Guide [12]: Static and Global Variables.

#### **Rule M3-3-2 (required, implementation, automated)**

**If a function has internal linkage then all re-declarations shall include the static storage class specifier.**

See MISRA C++ 2008 [7]

Note: Static storage duration class specifier is redundant and does not need to be specified if a function is placed in an unnamed namespace.

### 6.3.4 Name lookup

#### **Rule M3-4-1 (required, implementation, automated)**

**An identifier declared to be an object or type shall be defined in a block that minimizes its visibility.**

See MISRA C++ 2008 [7]

### See also

C++ Core Guidelines [11]: ES.21: Don't introduce a variable (or constant) before you need to use it.

### 6.3.8 Object lifetime

**Rule A3-8-1 (required, implementation, not automated)**  
**An object shall not be accessed outside of its lifetime.****Rationale**

Accessing an object outside of its lifetime, i.e. before its initialization or constructor has completed, or after its non-trivial destructor has finished, is well defined only for a very restricted number of cases, as laid out by the language standard. Outside of these cases it leads to undefined behavior.

Note: The AUTOSAR C++14 guidelines contain several other rules which are special cases of this rule (see references below). This rule was added to provide generic coverage for all cases not contained in these specialized rules. This also makes it easier to provide tracing from other standards with a similar generic rule.

Note: The examples given below are not intended to represent a complete list of situations where violations of this rule can occur.

**Example**

```
1  %% $Id: A3-8-1.cpp 305786 2018-01-30 08:58:33Z michal.szczepankiewicz $
2
3  //
4  // 1. Pointer to virtual base is passed as function argument after lifetime of
5  // object has ended.
6  //
7
8  class B
9  {
10 };
11
12 class C1 : public virtual B // violates M10-1-1
13 {
14 };
15
16 class C2 : public virtual B // violates M10-1-1
17 {
18 };
19
20 class D : public C1, public C2
21 {
22 };
23
24 void f(B const* b){};
25
26 void example1()
27 {
28     D* d = new D(); // lifetime of d starts (violates A18-5-2)
29     // Use d
30     delete d; // lifetime of d ends (violates A18-5-2)
31
```

```
32     f(d); // Non-compliant - Undefined behavior, even if argument is not used
33         // by f().
34 }
35
36 //
37 // 2. Accessing an initializer_list after lifetime of initializing array has
38 // ended.
39 //
40 class E
41 {
42     std::initializer_list<int> lst;
43
44     public:
45     // Conceptually, this works as if a temporary array {1, 2, 3} was created
46     // and a reference to this array was passed to the initializer_list. The
47     // lifetime of the temporary array ends when the constructor finishes.
48     E() : lst{1, 2, 3} {}
49
50     int first() const { return *lst.begin(); }
51 };
52
53 void example2()
54 {
55     E e;
56     std::out << e.first() << "\n"; // Non-compliant
57 }
58
59 //
60 // 3. Exiting main while running tasks depend on static objects
61 //
62 void initialize_task()
63 {
64     // start some task (separate thread) which depends on some static object.
65     // ...
66 }
67
68 int main()
69 {
70     // static constructors are called
71
72     initialize_task();
73 } // main ends, static destructors are called
74
75 // Non-compliant
76 // Task begins to run and accesses destroyed static object.
77
78 //
79 // 4. Storage reuse without explicit destructor call
80 //
81 void example4()
82 {
```



```
83     std::string str;
84     new (&a) std::vector<int>{}; // Non-compliant: storage of str reused without
85                               // calling its non-trivial destructor.
86 } // Non-compliant: Destructor of str is implicitly called at scope exit, but
87   // storage contains object of different type.
```

## See also

ISO/IEC 14882:2014 [3]: 3.8: [basic.life]

JSF December 2005 [8]: AV Rule 70.1: An object shall not be improperly used before its lifetime begins or after its lifetime ends.

SEI CERT C++ Coding Standard [10]: EXP54-CPP: Do not access an object outside of its lifetime.

[A5-1-4](#) in section [6.5.1](#)

[M7-5-1](#) in section [6.7.5](#)

[M7-5-2](#) in section [6.7.5](#)

[A7-5-1](#) in section [6.7.5](#)

[M12-1-1](#) in section [6.12.1](#)

### 6.3.9 Types

#### **Rule M3-9-1 (required, implementation, automated)**

The types used for an object, a function return type, or a function parameter shall be token-for-token identical in all declarations and re-declarations.

See MISRA C++ 2008 [7]

#### **Rule A3-9-1 (required, implementation, automated)**

Fixed width integer types from `<cstdint>`, indicating the size and signedness, shall be used in place of the basic numerical types.

## Rationale

The basic numerical types of `char`, `int`, `short`, `long` are not supposed to be used, specific-length types from `<cstdint>` header need be used instead.

Fixed width integer types are:

`std::int8_t`

`std::int16_t`

```
std::int32_t
std::int64_t
std::uint8_t
std::uint16_t
std::uint32_t
std::uint64_t
```

### Exception

The `wchar_t` does not need a typedef as it always maps to a type that supports wide characters.

### Example

```
1  //% $Id: A3-9-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2  #include <cstdint>
3  void F()
4  {
5      std::int32_t    i1 = 5;           // Compliant
6      int i2 = 10;           // Non-compliant
7      std::int64_t i3 = 250; // Compliant
8      long int i4    = 50;       // Non-compliant
9      std::int8_t    i5 = 16;     // Compliant
10     char          i6 = 23;     // Non-compliant
11 }
```

### See also

MISRA C++ 2008 [7]: Rule 3-9-2 typedefs that indicate size and signedness should be used in place of the basic numerical types.

**Rule M3-9-3 (required, implementation, automated)**  
The underlying bit representations of floating-point values shall not be used.

See MISRA C++ 2008 [7]

## 6.4 Standard conversions

### 6.4.5 Integral promotions

**Rule M4-5-1 (required, implementation, automated)**  
Expressions with type `bool` shall not be used as operands to built-in operators other than the assignment operator `=`, the logical operators

**&&, ||, !, the equality operators == and !=, the unary & operator, and the conditional operator.**

See MISRA C++ 2008 [7]

**Rule A4-5-1 (required, implementation, automated)**  
**Expressions with type enum or enum class shall not be used as operands to built-in and overloaded operators other than the subscript operator [ ], the assignment operator =, the equality operators == and !=, the unary & operator, and the relational operators <, <=, >, >=.**

## Rationale

Enumerations, i.e. enums or enum classes, have implementation-defined representations and they are not supposed to be used in arithmetic contexts.

Note that only enums can be implicitly used as operands to other built-in operators, like operators +, -, \*, etc. Enum class needs to provide definitions of mentioned operators in order to be used as operand.

## Exception

It is allowed to use the enumeration as operand to all built-in and overloaded operators if the enumeration satisfies the “BitmaskType” concept [16].

## Example

```
1 // $Id: A4-5-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <stdint>
3 enum Colour : std::uint8_t
4 {
5     Red,
6     Green,
7     Blue,
8     ColoursCount
9 };
10 void F1() noexcept(false)
11 {
12     Colour colour = Red;
13     if (colour == Green) // Compliant
14     {
15     }
16
17     if (colour == (Red + Blue)) // Non-compliant
18     {
19     }
20
21     if (colour < ColoursCount) // Compliant
22     {
23     }
```

```

24 }
25 enum class Car : std::uint8_t
26 {
27     Model1,
28     Model2,
29     Model3,
30     ModelsCount
31 };
32 void F2() noexcept(false)
33 {
34     Car car = Car::Model1;
35     if (car != Car::Model2) // Compliant
36     {
37     }
38
39     if (car == Car::Model3) // Compliant
40     {
41     }
42
43     // if (car == (Car::Model1 + Car::Model2)) // Non-compliant -
44     // operator+ not provided for Car enum class, compilation error
45     //{
46     //}
47     if (car < Car::ModelsCount) // Compliant
48     {
49     }
50 }
51 Car operator+(Car lhs, Car rhs)
52 {
53     return Car::Model3;
54 }
55 void F3() noexcept(false)
56 {
57     Car car = Car::Model3;
58     if (car == (Car::Model1 + Car::Model2)) // Non-compliant - overloaded
59                                         // operator+ provided, no
60                                         // compilation error
61     {
62     }
63 }
64 enum Team : std::uint8_t
65 {
66     TeamMember1 = 0,
67     TeamMember2 = 1,
68     TeamMember3 = 2,
69     TeamMember4 = 3,
70     TeamMembersStart = TeamMember1,
71     TeamMembersEnd = TeamMember2,
72     TeamMembersCount = 4
73 };
74 void F4(const char* teamMember)

```

```
75 {  
76     // Implementation  
77 }  
78 void F5()  
79 {  
80     const char* team[TeamMembersCount]; // Compliant  
81     // ...  
82     F4(team[TeamMember2]); // Compliant  
83 }
```

## See also

MISRA C++ 2008 [7]: Rule 4-5-2 Expressions with type enum shall not be used as operands to built-in operators other than the subscript operator [ ], the assignment operator =, the equality operators == and !=, the unary & operator, and the relational operators <, <=, >, >=.

**Rule M4-5-3 (required, implementation, automated)**  
**Expressions with type (plain) char and wchar\_t shall not be used as operands to built-in operators other than the assignment operator =, the equality operators == and !=, and the unary & operator.**

See MISRA C++ 2008 [7]

## 6.4.7 Integral conversion

**Rule A4-7-1 (required, implementation, automated)**  
**An integer expression shall not lead to data loss.**

### Rationale

Implicit conversions, casts and arithmetic expressions may lead to data loss, e.g. overflows, underflows or wrap-around.

Integral expressions need to be performed on proper integral types that ensure that the data loss will not occur or appropriate guards should be used to statically detect or counteract such a data loss.

### Example

```
1 // $Id: A4-7-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $  
2 #include <cstdint>  
3 #include <stdexcept>  
4 std::int8_t Fn1(std::int8_t x, std::int8_t y) noexcept  
5 {  
6     return (x + y); // Non-compliant - may lead to overflow
```

```

7 }
8 std::int8_t Fn2(std::int8_t x, std::int8_t y)
9 {
10     if (x > 100 || y > 100) // Range check
11     {
12         throw std::logic_error("Preconditions check error");
13     }
14     return (x + y); // Compliant - ranges of x and y checked before the
15                   // arithmetic operation
16 }
17 std::int16_t Fn3(std::int8_t x, std::int8_t y) noexcept
18 {
19     return (static_cast<std::int16_t>(x) + y); // Compliant - std::int16_t type
20                                               // is enough for this arithmetic
21                                               // operation
22 }
23 std::uint8_t Fn4(std::uint8_t x, std::uint8_t y) noexcept
24 {
25     return (x * y); // Non-compliant - may lead to wrap-around
26 }
27 std::int8_t Fn5(std::int16_t x)
28 {
29     return static_cast<std::int8_t>(x); // Non-compliant - data loss
30 }
31 std::int8_t Fn6(std::int16_t x)
32 {
33     return x; // Non-compliant - data loss by implicit conversion
34 }
35 void F()
36 {
37     std::int8_t x1 =
38         Fn1(5, 10); // Compliant - overflow will not occur for these values
39     std::int8_t x2 = Fn1(250, 250); // Non-compliant - Overflow occurs
40     try
41     {
42         std::int8_t x3 =
43             Fn2(250, 250); // Compliant - No overflow, range checks
44                           // inside fn2() function
45     }
46     catch (std::logic_error&)
47     {
48         // Handle an error
49     }
50     std::int16_t x4 = Fn3(250, 250); // Compliant - No overflow, arithmetic
51                                     // operation underlying type is wider than
52                                     // std::int8_t
53     std::uint8_t x5 = Fn4(50, 10); // Non-compliant - Wrap-around occurs
54     std::int8_t x6 = Fn5(100); // Compliant - data loss will not occur
55     std::int8_t x7 = Fn5(300); // Non-compliant - Data loss occurs
56     std::int8_t x8 = Fn6(300); // Non-compliant - Data loss occurs
57

```

```
58     std::int8_t x9 = 150;
59     std::int16_t x10 = static_cast<std::int16_t>(x9 + x9); // Non-compliant
60     x10 = x9 + x9; // Non-compliant
61     x10 = static_cast<std::int16_t>(x9) + x9; // Compliant
62
63     std::int8_t x11 = x9 << 5; // Non-compliant
64
65     std::int8_t x12 = 127;
66     ++x12; // Non-compliant
67
68     std::uint8_t x13 = 255;
69     ++x13; // Non-compliant
70 }
```

## See also

MISRA C++ 2008 [7]: Rule 5-0-6 An implicit integral or floating-point conversion shall not reduce the size of the underlying type.

MISRA C++ 2008 [7]: Rule 5-0-8 An explicit integral or floating-point conversion shall not increase the size of the underlying type of a cvalue expression.

HIC++ v4.0 [9]: 4.2.2 Ensure that data loss does not demonstrably occur in an integral expression.

JSF December 2005 [8]: AV Rule 212: Underflow or overflow functioning shall not be depended on in any special way.

C++ Core Guidelines [11]: ES.46: Avoid lossy (narrowing, truncating) arithmetic conversions.

### 6.4.10 Pointer conversions

**Rule M4-10-1 (required, implementation, automated)**  
**NULL shall not be used as an integer value.**

See MISRA C++ 2008 [7]

**Rule A4-10-1 (required, architecture / design / implementation, automated)**  
**Only nullptr literal shall be used as the null-pointer-constant.**

## Rationale

In C++, the literal NULL is both the null-pointer-constant and an integer type. To meet developer expectations, only nullptr pointer literal shall be used as the null-pointer-constant.

Note that, nullptr pointer literal allows parameters forwarding via a template function.

### Example

```
1  //% $Id: A4-10-1.cpp 298086 2017-11-24 11:13:27Z michal.szczepankiewicz $
2  #include <cstdint>
3  #include <stdint>
4
5  void F1(std::int32_t);
6  void F2(std::int32_t*);
7  void F3()
8  {
9      F1(0); // Compliant
10     F1(NULL); // Non-compliant - NULL used as an integer,
11     // compilable
12     // f1(nullptr); // Non-compliant - nullptr used as an integer
13     // compilation error
14     F2(0); // Non-compliant - 0 used as the null pointer constant
15     F2(NULL); // Non-compliant - NULL used as the null pointer constant
16     F2(nullptr); // Compliant
17 }
18 void F4(std::int32_t*);
19 template <class F, class A>
20 void F5(F f, A a)
21 {
22     F4(a);
23 }
24 void F6()
25 {
26     // f5(f4, NULL); // Non-compliant - function f4(std::int32_t) not declared
27     F5(F4, nullptr); // Compliant
28 }
```

### See also

HIC++ v4.0 [9]: 2.5.3 Use nullptr for the null pointer constant

**Rule M4-10-2 (required, implementation, automated)**  
**Literal zero (0) shall not be used as the null-pointer-constant.**

See MISRA C++ 2008 [7]

## 6.5 Expressions

### 6.5.0 General



**Rule A5-0-1 (required, implementation, automated)**  
**The value of an expression shall be the same under any order of evaluation that the standard permits.**

## Rationale

Apart from a few operators (notably `&&`, `||`, `?:` and `,`) the order in which sub-expressions are evaluated is unspecified and can vary. This means that no reliance can be placed on the order of evaluation of sub-expressions and, in particular, no reliance can be placed on the order in which side effects occur. Those points in the evaluation of an expression at which all previous side effects can be guaranteed to have taken place are called “sequencing”. Sequencing and side effects are described in Section 1.9(7) of ISO/IEC 14882:2014 [3].

Note that the “order of evaluation” problem is not solved by the use of parentheses, as this is not a precedence issue.

## Example

```
1 // $Id: A5-0-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdint>
3 #include <stack>
4 // The following notes give some guidance on how dependence on order of
5 // evaluation may occur, and therefore may assist in adopting the rule.
6
7 // 1) Increment or decrement operators
8 // As an example of what can go wrong, consider
9 void F1(std::uint8_t (&arr)[10], std::uint8_t idx) noexcept(false)
10 {
11     std::uint16_t x = arr[idx] + idx++;
12 }
13 // This will give different results depending on whether arr[idx] is evaluated
14 // before idx++ or vice versa. The problem could be avoided by putting the
15 // increment operation in a separate statement. For example:
16 void F2(std::uint8_t (&arr)[10], std::uint8_t idx) noexcept(false)
17 {
18     std::uint8_t x = arr[idx] + idx;
19     idx++;
20 }
21
22 // 2) Function arguments
23 // The order of evaluation of function arguments is unspecified.
24 extern std::uint8_t Func(std::uint8_t x, std::uint8_t y);
25 void F3() noexcept(false)
26 {
27     std::uint8_t i = 0;
28     std::uint8_t x = Func(++i, i);
29 }
30 // This will give different results depending on which of the functions two
31 // parameters is evaluated first.
32
```

```
33 // 3) Function pointers
34 // If a function is called via a function pointer there shall be no
35 // dependence
36 // on the order in which function-designator and function arguments are
37 // evaluated.
38 struct S
39 {
40     void TaskStartFn(S* obj) noexcept(false);
41 };
42 void F4(S* p) noexcept(false)
43 {
44     p->TaskStartFn(p++);
45 }
46
47 // 4) Function calls
48 // Functions may have additional effects when they are called (e.g. modifying
49 // some global data). Dependence on order of evaluation could be avoided by
50 // invoking the function prior to the expression that uses it, making use of a
51 // temporary variable for the value. For example:
52 extern std::uint16_t G(std::uint8_t) noexcept(false);
53 extern std::uint16_t Z(std::uint8_t) noexcept(false);
54 void F5(std::uint8_t a) noexcept(false)
55 {
56     std::uint16_t x = G(a) + Z(a);
57 }
58 // could be written as
59 void F6(std::uint8_t a) noexcept(false)
60 {
61     std::uint16_t x = G(a);
62     x += Z(a);
63 }
64 // As an example of what can go wrong, consider an expression to take two values
65 // off a stack, subtract the second from the first, and push the result back on
66 // the stack:
67 std::int32_t Pop(std::stack<std::int32_t>& s)
68 {
69     std::int32_t ret = s.top();
70     s.pop();
71     return ret;
72 }
73 void F7(std::stack<std::int32_t>& s)
74 {
75     s.push(Pop(s) - Pop(s));
76 }
77 // This will give different results depending on which of the pop() function
78 // calls is evaluated first (because pop() has side effects).
79
80 // 5) Nested assignment statements
81 // Assignments nested within expressions cause additional side effects. The best
82 // way to avoid any possibility of this leading to a dependence on order of
83 // evaluation is not to embed assignments within expressions. For example, the
```

```
84 // following is not recommended:
85 void F8(std::int32_t& x) noexcept(false)
86 {
87     std::int32_t y = 4;
88     x = y = y++; // It is undefined whether the final value of y is 4 or 5
89 }
90 // 6) Accessing a volatile
91 // The volatile type qualifier is provided in C++ to denote objects whose value
92 // can change independently of the execution of the program (for example an
93 // input register). If an object of volatile qualified type is accessed this may
94 // change its value. C++ compilers will not optimize out reads of a volatile. In
95 // addition, as far as a C++ program is concerned, a read of a volatile has a
96 // side effect (changing the value of the volatile). It will usually be
97 // necessary to access volatile data as part of an expression, which then means
98 // there may be dependence on order of evaluation. Where possible, though, it is
99 // recommended that volatiles only be accessed in simple assignment statements,
100 // such as the following:
101 void F9(std::uint16_t& x) noexcept(false)
102 {
103     volatile std::uint16_t v;
104     // ...
105     x = v;
106 }
107
108 // The rule addresses the order of evaluation problem with side effects. Note
109 // that there may also be an issue with the number of times a sub-expression is
110 // evaluated, which is not covered by this rule. This can be a problem with
111 // function invocations where the function is implemented as a macro. For
112 // example, consider the following function-like macro and its invocation:
113 #define MAX(a, b) (((a) > (b)) ? (a) : (b))
114 // ...
115 void F10(std::uint32_t& i, std::uint32_t j)
116 {
117     std::uint32_t z = MAX(i++, j);
118 }
119 // The definition evaluates the first parameter twice if a > b but only once if
120 // a = b. The macro invocation may thus increment i either once or twice,
121 // depending on the values of i and j.
122 // It should be noted that magnitude-dependent effects, such as those due to
123 // floating-point rounding, are also not addressed by this rule. Although
124 // the
125 // order in which side effects occur is undefined, the result of an operation is
126 // otherwise well-defined and is controlled by the structure of the expression.
127 // In the following example, f1 and f2 are floating-point variables; F3, F4
128 // and
129 // F5 denote expressions with floating-point types.
130
131 // f1 = F3 + ( F4 + F5 );
132 // f2 = ( F3 + F4 ) + F5;
133
134 // The addition operations are, or at least appear to be, performed in the order
```

```
135 // determined by the position of the parentheses, i.e. firstly F4 is added to F5
136 // then secondly F3 is added to give the value of f1. Provided that F3, F4 and
137 // F5 contain no side effects, their values are independent of the order in
138 // which they are evaluated. However, the values assigned to f1 and f2 are not
139 // guaranteed to be the same because floating-point rounding following the
140 // addition operations are dependent on the values being added.
```

## See also

MISRA C++ 2008 [7]: Rule 5-0-1 The value of an expression shall be the same under any order of evaluation that the standard permits

HIC++ v4.0 [9]: 5.1.2: Do not rely on the sequence of evaluation within an expression.

C++ Core Guidelines [11]: ES.40: Avoid complicated expressions

C++ Core Guidelines [11]: ES.43: Avoid expressions with undefined order of evaluation.

C++ Core Guidelines [11]: ES.44: Don't depend on order of evaluation of function arguments.

C++ Core Guidelines [11]: R.13: Perform at most one explicit resource allocation in a single expression statement.

**Rule M5-0-2 (advisory, implementation, partially automated)**  
**Limited dependence should be placed on C++ operator precedence rules in expressions.**

See MISRA C++ 2008 [7]

## See also

C++ Core Guidelines [11]: ES.41: If in doubt about operator precedence, parenthesize

**Rule M5-0-3 (required, implementation, automated)**  
**A cvalue expression shall not be implicitly converted to a different underlying type.**

See MISRA C++ 2008 [7]

**Rule M5-0-4 (required, implementation, automated)**  
**An implicit integral conversion shall not change the signedness of the underlying type.**

See MISRA C++ 2008 [7]

**Rule M5-0-5 (required, implementation, automated) There shall be no implicit floating-integral conversions.**

See MISRA C++ 2008 [7]

**Rule M5-0-6 (required, implementation, automated)  
An implicit integral or floating-point conversion shall not reduce the size of the underlying type.**

See MISRA C++ 2008 [7]

**Rule M5-0-7 (required, implementation, automated)  
There shall be no explicit floating-integral conversions of a cvalue expression.**

See MISRA C++ 2008 [7]

Note: Standard library functions, i.e. `std::floor` and `std::ceil`, return a floating-point data type:

```
1 #include <cmath>
2 #include <cstdint>
3
4 void Fn() noexcept
5 {
6     float f = -4.5;
7     std::int8_t x1 = static_cast<std::int8_t>(f); // Compliant, x1 = -4
8     std::int8_t x2 =
9         static_cast<std::int8_t>(std::floor(f)); // Compliant, x2 = -5
10    std::int8_t x3 =
11        static_cast<std::int8_t>(std::ceil(f)); // Compliant, x3 = -4
12 }
```

**Rule M5-0-8 (required, implementation, automated)  
An explicit integral or floating-point conversion shall not increase the size of the underlying type of a cvalue expression.**

See MISRA C++ 2008 [7]

**Rule M5-0-9 (required, implementation, automated)  
An explicit integral conversion shall not change the signedness of the underlying type of a cvalue expression.**

See MISRA C++ 2008 [7]

**Rule M5-0-10 (required, implementation, automated)**

If the bitwise operators `~` and `<<` are applied to an operand with an underlying type of unsigned char or unsigned short, the result shall be immediately cast to the underlying type of the operand.

See MISRA C++ 2008 [7]

**Rule M5-0-11 (required, implementation, automated)**

The plain char type shall only be used for the storage and use of character values.

See MISRA C++ 2008 [7]

**Rule M5-0-12 (required, implementation, automated)**

Signed char and unsigned char type shall only be used for the storage and use of numeric values.

See MISRA C++ 2008 [7]

**Rule A5-0-2 (required, implementation, automated)**

The condition of an if-statement and the condition of an iteration statement shall have type bool.

## Rationale

If an expression with type other than bool is used in the condition of an if-statement or iteration-statement, then its result will be implicitly converted to bool. The condition expression shall contain an explicit test (yielding a result of type bool) in order to clarify the intentions of the developer.

Note that if a type defines an explicit conversion to type bool, then it is said to be “contextually converted to bool” (Section 4.0(4) of ISO/IEC 14882:2014 [3]) and can be used as a condition of an if-statement or iteration statement.

## Exception

A condition of the form type-specifier-seq declarator is not required to have type bool. This exception is introduced because alternative mechanisms for achieving the same effect are cumbersome and error-prone.

## Example

```
1 // $Id: A5-0-2.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <stdint>
3 #include <memory>
```

```

4  extern std::int32_t* Fn();
5  extern std::int32_t Fn2();
6  extern bool Fn3();
7  void F() noexcept(false)
8  {
9      std::int32_t* ptr = nullptr;
10
11     while ((ptr = Fn()) != nullptr) // Compliant
12     {
13         // Code
14     }
15
16     // The following is a cumbersome but compliant example
17     do
18     {
19         std::int32_t* ptr = Fn();
20
21         if (nullptr == ptr)
22         {
23             break;
24         }
25
26         // Code
27     } while (true); // Compliant
28
29     std::unique_ptr<std::int32_t> uptr;
30     if (!uptr) // Compliant - std::unique_ptr defines an explicit conversion to
31               // type bool.
32     {
33         // Code
34     }
35
36     while (std::int32_t length = Fn2()) // Compliant by exception
37     {
38         // Code
39     }
40
41     while (bool flag = Fn3()) // Compliant
42     {
43         // Code
44     }
45
46     if (std::int32_t* ptr = Fn())
47         ; // Compliant by exception
48
49     if (std::int32_t length = Fn2())
50         ; // Compliant by exception
51
52     if (bool flag = Fn3())
53         ; // Compliant
54

```

```
55     std::uint8_t u = 8;
56
57     if (u)
58         ; // Non-compliant
59
60     bool boolean1 = false;
61     bool boolean2 = true;
62
63     if (u && (boolean1 <= boolean2))
64         ; // Non-compliant
65
66     for (std::int32_t x = 10; x; --x)
67         ; // Non-compliant
68 }
```

### See also

MISRA C++ 2008 [7]: 5-0-13 The condition of an if-statement and the condition of an iteration statement shall have type bool.

**Rule M5-0-14 (required, implementation, automated)**  
**The first operand of a conditional-operator shall have type bool.**

See MISRA C++ 2008 [7]

**Rule M5-0-15 (required, implementation, automated) Array indexing shall be the only form of pointer arithmetic.**

See MISRA C++ 2008 [7]

**Rule M5-0-16 (required, implementation, automated)**  
**A pointer operand and any pointer resulting from pointer arithmetic using that operand shall both address elements of the same array.**

See MISRA C++ 2008 [7]

Note: The next element beyond the end of an array indicates the end of the array.

**Rule M5-0-17 (required, implementation, automated)**  
**Subtraction between pointers shall only be applied to pointers that address elements of the same array.**

See MISRA C++ 2008 [7]



**Rule A5-0-4 (required, implementation, automated)**  
**Pointer arithmetic shall not be used with pointers to non-final classes.****Rationale**

Pointer arithmetic is only well defined if the pointed-to type of the pointer equals the element type of the array it points into, otherwise the behavior is undefined. This property can only be guaranteed if the pointer operand is a pointer to non-class type or a pointer to final class type.

Note: This also applies to the subscripting operator as  $E1[E2]$  is defined in terms of pointer arithmetic as  $*((E1)+(E2))$ .

**Example**

```
1 // $Id: A5-0-4.cpp 309849 2018-03-02 09:36:31Z christof.meerwald $
2 #include <algorithm>
3 #include <array>
4 #include <cstdint>
5 #include <cstdlib>
6 #include <memory>
7 #include <vector>
8
9 class Base
10 {
11     public:
12         virtual ~Base() noexcept = 0;
13         virtual void Do() = 0;
14 };
15
16 class Derived1 final : public Base
17 {
18     public:
19         void Do() final
20         {
21             // ...
22         }
23
24     private:
25         std::int32_t m_value { 0 };
26 };
27
28 class Derived2 final : public Base
29 {
30     public:
31         void Do() final
32         {
33             // ...
34         }
35
36     private:
```

```

37     std::string m_value { };
38 };
39
40 void Foo(Base *start, size_t len)
41 {
42     // Non-Compliant: pointer arithmetic on non-final pointer type
43     for (Base *iter = start; iter != start + len; ++iter)
44     {
45         iter->Do();
46     }
47 }
48
49 void Foo(const std::vector<std::unique_ptr<Base>> &v)
50 {
51     // Compliant: uses std::unique_ptr for polymorphic objects
52     std::for_each(v.begin(), v.end(),
53         [] (const std::unique_ptr<Base> &ptr) {
54             ptr->Do();
55         });
56 }
57
58 void DoOpt(Base *obj)
59 {
60     if (obj != nullptr)
61     {
62         obj->Do();
63     }
64 }
65
66 void Bar()
67 {
68     std::array<Derived1, 2> arr1;
69     Base *base1 { arr1.data() };
70     Foo(base1, arr1.size());
71
72     DoOpt(&arr1[1]);           // Compliant: pointer arithmetic on final class
73     DoOpt(&base1[1]);         // Non-Compliant: pointer arithmetic on base class
74
75
76     std::array<Derived2, 2> arr2;
77     Base *base2 { arr2.data() };
78     Foo(base2, arr2.size());
79
80     DoOpt(arr2.data() + 1); // Compliant: pointer arithmetic on final class
81     DoOpt(base2 + 1); // Non-Compliant: pointer arithmetic on base class
82
83
84     std::vector<std::unique_ptr<Base>> v;
85     v.push_back(std::make_unique<Derived1>());
86     v.push_back(std::make_unique<Derived2>());
87

```

```

88     Foo(v);
89 }

```

## See also

SEI CERT C++ Coding Standard [10]: CTR56-CPP: Do not use pointer arithmetic on polymorphic objects.

JSF December 2005 [8]: AV Rule 96: Arrays shall not be treated polymorphically.

C++ Core Guidelines [11]: T.82: Do not mix hierarchies and arrays.

### Rule M5-0-18 (required, implementation, automated)

**>, >=, <, <= shall not be applied to objects of pointer type, except where they point to the same array.**

See MISRA C++ 2008 [7]

### Rule A5-0-3 (required, implementation, automated)

**The declaration of objects shall contain no more than two levels of pointer indirection.**

## Rationale

Use of more than two levels of indirection can seriously impair the ability to understand the behavior of the code, and therefore should be avoided.

## Example

```

1 // $Id: A5-0-3.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdlib>
3 using IntPtr = std::int8_t*;
4 struct S
5 {
6     std::int8_t* s1;           // Compliant
7     std::int8_t** s2;        // Compliant
8     std::int8_t*** s3;       // Non-compliant
9 };
10 S* ps1;                      // Compliant
11 S** ps2;                     // Compliant
12 S*** ps3; // Non-compliant
13
14 std::int8_t** (*pfunc1)();    // Compliant
15 std::int8_t** (**pfunc2)();  // Compliant
16 std::int8_t** (**pfunc3)();  // Non-compliant
17 std::int8_t*** (**pfunc4)(); // Non-compliant
18
19 void Fn(std::int8_t* par1,    // Compliant
20         std::int8_t** par2,  // Compliant

```

```

21     std::int8_t*** par3,           // Non-compliant
22     IntPtr* par4,                // Compliant
23     IntPtr* const* const par5,   // Non-compliant
24     std::int8_t* par6[],         // Compliant
25     std::int8_t** par7[]])      // Non-compliant
26 {
27     std::int8_t* ptr1;           // Compliant
28     std::int8_t** ptr2;         // Compliant
29     std::int8_t*** ptr3;        // Non-compliant
30     IntPtr* ptr4;               // Compliant
31     IntPtr* const* const ptr5 = nullptr; // Non-compliant
32     std::int8_t* ptr6[10];      // Compliant
33     std::int8_t** ptr7[10];     // Compliant
34 }
35 // Explanation of types
36 // 1) par1 and ptr1 are of type pointer to std::int8_t.
37 // 2) par2 and ptr2 are of type pointer to pointer to std::int8_t.
38 // 3) par3 and ptr3 are of type pointer to a pointer to a pointer
39 // to std::int8_t.
40 // This is three levels and is non-compliant.
41 // 4) par4 and ptr4 are expanded to a type of pointer to a pointer to
42 // std::int8_t.
43 // 5) par5 and ptr5 are expanded to a type of const pointer to a const
44 // pointer
45 // to a pointer to std::int8_t. This is three levels and is non-compliant.
46 // 6) par6 is of type pointer to pointer to std::int8_t because arrays
47 // are converted
48 // to a pointer to the initial element of the array.
49 // 7) ptr6 is of type pointer to array of std::int8_t.
50 // 8) par7 is of type pointer to pointer to pointer to
51 // std::int8_t because arrays are
52 // converted to a pointer to the initial element of the array. This is
53 // three
54 // levels and is non-compliant.
55 // 9) ptr7 is of type array of pointer to pointer to std::int8_t. This
56 // is compliant.

```

## See also

MISRA C++ 2008 [7]: 5-0-19 The declaration of objects shall contain no more than two levels of pointer indirection.

**Rule M5-0-20 (required, implementation, automated) Non-constant operands to a binary bitwise operator shall have the same underlying type.**

See MISRA C++ 2008 [7]

**Rule M5-0-21 (required, implementation, automated)**  
**Bitwise operators shall only be applied to operands of unsigned underlying type.**

See MISRA C++ 2008 [7]

### 6.5.1 Primary expression

**Rule A5-1-1 (required, implementation, partially automated)**  
**Literal values shall not be used apart from type initialization, otherwise symbolic names shall be used instead.**

#### Rationale

Avoid use of “magic” numbers and strings in expressions in preference to constant variables with meaningful names. Literal values are supposed to be used only in type initialization constructs, e.g. assignments and constructors.

The use of named constants improves both the readability and maintainability of the code.

#### Exception

It is allowed to use literal values in combination with logging mechanism.

#### Example

```

1 // $Id: A5-1-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <array>
3 #include <cstdint>
4 #include <iostream>
5 #include <stdexcept>
6 namespace
7 {
8     const std::int32_t maxIterations = 10; // Compliant - assignment
9     const char* const loopIterStr = "iter "; // Compliant - assignment
10    const char separator = ':'; // Compliant - assignment
11 }
12 void F1() noexcept
13 {
14     for (std::int32_t i = 0; i < 10; ++i) // Non-compliant
15     {
16         std::cout << "iter " << i << ':' << '\n'; // Compliant by exception
17     }
18
19     for (std::int32_t i = 0; i < maxIterations; ++i) // Compliant
20     {
21         std::cout << loopIterStr << i << separator << '\n'; // Compliant

```

```
22     }
23
24     for (std::int32_t i = 0; i < maxIterations; ++i) // Compliant
25     {
26         std::cout << "iter " << i << " " << '\n'; // Compliant by exception
27     }
28 }
29 void F2()
30 {
31     // ...
32     throw std::logic_error("Logic Error"); // Compliant
33     // initialization of exception object
34 }
35 class C
36 {
37 public:
38     C() : x(0), y(nullptr) // Compliant - initialization
39     {
40     }
41     C(std::int8_t num, std::int32_t* ptr) : x(num), y(ptr) {}
42
43 private:
44     std::int8_t x;
45     std::int32_t* y;
46 };
47 static std::int32_t* globalPointer = nullptr; // Compliant - assignment
48 void F3() noexcept
49 {
50     C c1;
51     // ...
52     C c2(0, globalPointer); // Compliant - initialization of C object
53 }
54 std::int32_t F4(std::int32_t x, std::int32_t y) noexcept
55 {
56     return x + y;
57 }
58 void F5() noexcept
59 {
60     std::int32_t ret = F4(2, 5); // Non-compliant
61     // ...
62     std::int32_t x = 2;
63     std::int32_t y = 5;
64     ret = F4(x, y); // Compliant
65
66     std::array<std::int8_t, 5> arr{{1, 2, 3, 4, 5}}; // Compliant
67 }
```

## See also

HIC++ v4.0 [9]: 5.1.1 Use symbolic names instead of literal values in code.

**Rule A5-1-2 (required, implementation, automated)**  
**Variables shall not be implicitly captured in a lambda expression.**

## Rationale

Capturing variables explicitly helps document the intention of the author. It also allows for different variables to be explicitly captured by copy or by reference within the lambda definition.

## Exception

It is allowed to implicitly capture variables with non-automatic storage duration.

## Example

```
1 // $Id: A5-1-2.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <algorithm>
3 #include <cstdlib>
4 #include <vector>
5 void Fn1(const std::vector<std::int32_t>& v)
6 {
7     std::uint64_t sum = 0;
8     std::for_each(v.begin(), v.end(), [&](std::int32_t lhs) {
9         sum += lhs;
10    }); // Non-compliant
11
12    sum = 0;
13    std::for_each(v.begin(), v.end(), [&sum](std::int32_t lhs) {
14        sum += lhs;
15    }); // Compliant
16 }
17 void Fn2()
18 {
19     constexpr std::uint8_t n = 10;
20     static std::int32_t j = 0;
21     [n]() {
22         std::int32_t array[n]; // Compliant
23         j += 1; // Compliant by exception
24     };
25 }
```

## See also

HIC++ v4.0 [9]: 5.1.4 Do not capture variables implicitly in a lambda.

C++ Core Guidelines [11]: F.54: If you capture this, capture all variables explicitly (no default capture).

**Rule A5-1-3 (required, implementation, automated)**  
**Parameter list (possibly empty) shall be included in every lambda expression.**

### Rationale

The lambda-declarator is optional in a lambda expression and results in a closure that can be called without any parameters.

To avoid any visual ambiguity with other C++ constructs, it is recommended to explicitly include (), even though it is not strictly required.

### Example

```
1 // $Id: A5-1-3.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdlib>
3 void Fn()
4 {
5     std::int32_t i = 0;
6     std::int32_t j = 0;
7     auto lambda1 = [&i, &j] { ++i, ++j; }; // Non-compliant
8     auto lambda2 = [&i, &j]() {
9         ++i;
10        ++j;
11    }; // Compliant
12 }
```

### See also

HIC++ v4.0 [9]: 5.1.5 Include a (possibly empty) parameter list in every lambda expression

**Rule A5-1-4 (required, implementation, automated)**  
**A lambda expression object shall not outlive any of its reference-captured objects.**

### Rationale

When an object is captured by reference in a lambda, lifetime of the object is not tied to the lifetime of the lambda.

If a lambda object leaves the scope of one of its reference-captured object, the execution of the lambda expression results in an undefined behavior once the reference-captured object is accessed.

### Example

```
1 // $Id: A5-1-4.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdlib>
```



```
3 #include <functional>
4 std::function<std::int32_t()> F()
5 {
6     std::int32_t i = 12;
7     return ([&i]() -> std::int32_t {
8         i = 100;
9         return i;
10    }); // Non-compliant
11 }
12 std::function<std::int32_t()> G()
13 {
14     std::int32_t i = 12;
15     return ([i]() mutable -> std::int32_t { return ++i; }); // Compliant
16 }
17 void Fn()
18 {
19     auto lambda1 = F();
20     std::int32_t i = lambda1(); // Undefined behavior
21     auto lambda2 = G();
22     i = lambda2(); // lambda2() returns 13
23 }
```

## See also

SEI CERT C++ [10]: EXP61-CPP. A lambda object must not outlive any of its reference captured objects.

C++ Core Guidelines [11]: F.53: Avoid capturing by reference in lambdas that will be used nonlocally, including returned, stored on the heap, or passed to another thread.

**Rule A5-1-6 (advisory, implementation, automated)**  
**Return type of a non-void return type lambda expression should be explicitly specified.**

## Rationale

If a non-void return type lambda expression does not specify its return type, then it may be confusing which type it returns. It leads to developers confusion.

Note that, while the return type is specified, implicit conversion between type of returned value and return type specified in the lambda expression may occur. This problem should not be ignored.

## Example

```
1 // $Id: A5-1-6.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdint>
3 void Fn() noexcept
4 {
```

```

5     auto lambda1 = []() -> std::uint8_t {
6         std::uint8_t ret = 0U;
7         // ...
8         return ret;
9     }; // Compliant
10    auto lambda2 = []() {
11        // ...
12        return 0U;
13    }; // Non-compliant - returned type is not specified
14    auto x = lambda1(); // Type of x is std::uint8_t
15    auto y = lambda2(); // What is the type of y?
16 }

```

## See also

none

**Rule A5-1-7 (required, implementation, automated)**  
**A lambda shall not be an operand to decltype or typeid.**

## Rationale

“The type of the lambda-expression (which is also the type of the closure object) is a unique, unnamed non-union class type [...]” [C++14 Language Standard] [3]

Each lambda expression has a different unique underlying type, and therefore the type is not to be used as a decltype or typeid argument. It is allowed to use it as a template parameter and a function argument.

## Example

```

1 // $Id: A5-1-7.cpp 289815 2017-10-06 11:19:11Z michal.szczepankiewicz $
2 #include <cstdlib>
3 #include <functional>
4 #include <vector>
5 void Fn()
6 {
7     auto lambda1 = []() -> std::int8_t { return 1; };
8     auto lambda2 = []() -> std::int8_t { return 1; };
9
10    if (typeid(lambda1) == typeid(lambda2)) // Non-compliant - types of lambda1
11                                           // and lambda2 are different
12    {
13        // ...
14    }
15
16    std::vector<decltype(lambda1)> v; // Non-compliant
17    // v.push_back([]() { return 1; }); // Compilation error, type of pushed
18    // lambda is different than decltype(lambda1)
19    // using mylambda_t = decltype([](){ return 1; }); // Non-compliant -
20    // compilation error

```

```
21 auto lambda3 = []() { return 2; };
22 using lambda3_t = decltype(lambda3); // Non-compliant - lambda3_t type can
23                                     // not be used for lambda expression
24                                     // declarations
25 // lambda3_t lambda4 = []() { return 2; }; // Conversion error at
26 // compile-time
27 std::function<std::int32_t()> f1 = []() { return 3; };
28 std::function<std::int32_t()> f2 = []() { return 3; };
29
30 if (typeid(f1) == typeid(f2)) // Compliant - types are equal
31 {
32     // ...
33 }
34 }
35
36 template <typename T>
37 void Foo(T t);
38
39 void Bar()
40 {
41     Foo([]() {}); // Compliant
42 }
```

## See also

none

**Rule A5-1-8 (advisory, implementation, automated)**  
**Lambda expressions should not be defined inside another lambda expression.**

## Rationale

Defining lambda expressions inside other lambda expressions reduces readability of the code.

## Example

```
1 // $Id: A5-1-8.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdlib>
3 void Fn1()
4 {
5     std::int16_t x = 0;
6     auto f1 = [&x]() {
7
8         auto f2 = []() {}; // Non-compliant
9         f2();
10
11         auto f4 = []() {}; // Non-compliant
12         f4();
13     };
14 }
```

```
13
14     }; // Non-compliant
15
16     f1();
17 }
18 void Fn2()
19 {
20     auto f5 = []() {
21         // Implementation
22     }; // Compliant
23     f5();
24 }
```

## See also

none

**Rule A5-1-9 (advisory, implementation, automated)**  
**Identical unnamed lambda expressions shall be replaced with a named function or a named lambda expression.**

## Rationale

Code duplication reduces readability and maintainability as it might not be obvious that the lambda expressions are identical and any changes need to be applied in more than one place.

## Example

```
1 // $Id: A5-1-9.cpp 307019 2018-02-09 15:16:47Z christof.meerwald $
2 #include <algorithm>
3 #include <cstdint>
4 #include <vector>
5
6 void Fn1(const std::vector<int16_t> &v)
7 {
8     // Non-compliant: identical unnamed lambda expression
9     if (std::none_of(v.begin(), v.end(),
10                    [] (int16_t i) { return i < 0; }))
11     {
12         // ...
13     }
14     else if (std::all_of(v.begin(), v.end(),
15                        [] (int16_t i) { return i < 0; }))
16     {
17         // ...
18     }
19 }
20
21 void Fn2(const std::vector<int16_t> &v)
```

```
22 {  
23     // Compliant: re-using lambda expression  
24     auto is_negative = [] (int16_t i) { return i < 0; };  
25  
26     if (std::none_of(v.begin(), v.end(), is_negative))  
27     {  
28         // ...  
29     }  
30     else if (std::all_of(v.begin(), v.end(), is_negative))  
31     {  
32         // ...  
33     }  
34 }
```

### See also

C++ Core Guidelines [11]: T.141: Use an unnamed lambda if you need a simple function object in one place only.

## 6.5.2 Postfix expressions

### Rule M5-2-2 (required, implementation, automated)

**A pointer to a virtual base class shall only be cast to a pointer to a derived class by means of `dynamic_cast`.**

See MISRA C++ 2008 [7]

### See also

JSF December 2005 [8]: AV Rule 178: Down casting (casting from base to derived class) shall only be allowed through one of the following mechanism: Virtual functions that act like dynamic casts (most likely useful in relatively simple cases); Use of the visitor (or similar) pattern (most likely useful in complicated cases).

### Rule M5-2-3 (advisory, implementation, automated)

**Casts from a base class to a derived class should not be performed on polymorphic types.**

See MISRA C++ 2008 [7]

Note: Type is polymorphic if it declares or inherits at least one virtual function.

**Rule A5-2-1 (advisory, implementation, automated)**  
**dynamic\_cast should not be used.**

### Rationale

Implementations of dynamic\_cast mechanism are unsuitable for use with real-time systems where low memory usage and determined performance are essential.

If dynamic casting is essential for your program, usage of its custom implementation should be considered. Also, usage of the dynamic\_cast can be replaced with polymorphism, i.e. virtual functions.

### Example

```
1 // $Id: A5-2-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 class A
3 {
4     public:
5         virtual void F() noexcept;
6 };
7 class B : public A
8 {
9     public:
10        void F() noexcept override {}
11 };
12 void Fn(A* aptr) noexcept
13 {
14     // ...
15     B* bptr = dynamic_cast<B*>(aptr); // Non-compliant
16
17     if (bptr != nullptr)
18     {
19         // Use B class interface
20     }
21     else
22     {
23         // Use A class interface
24     }
25 }
```

### See also

JSF December 2005 [8]: AV Rule 178: Down casting (casting from base to derived class) shall only be allowed through one of the following mechanism: Virtual functions that act like dynamic casts (most likely useful in relatively simple cases); Use of the visitor (or similar) pattern (most likely useful in complicated cases).

C++ Core Guidelines [11]: C.146: Use dynamic\_cast where class hierarchy navigation is unavoidable.

Journal of Computing Science and Engineering, Damian Dechev, Rabi Mahapatra, Bjarne Stroustrup: Practical and Verifiable C++ Dynamic Cast for Hard Real-Time Systems.

Software-Practice and Experience, Michael Gibbs and Bjarne Stroustrup: Fast dynamic casting.

**Rule A5-2-2 (required, implementation, automated)**  
**Traditional C-style casts shall not be used.**

### Rationale

C-style casts are more dangerous than the C++ named conversion operators. The C-style casts are difficult to locate in large programs and the intent of the conversion is not explicit.

Traditional C-style casts raise several concerns:

C-style casts enable most any type to be converted to most any other type without any indication of the reason for the conversion

C-style cast syntax is difficult to identify for both reviewers and tools. Consequently, both the location of conversion expressions as well as the subsequent analysis of the conversion rationale proves difficult for C-style casts

Thus, C++ introduces casts (`const_cast`, `dynamic_cast`, `reinterpret_cast`, and `static_cast`) that address these problems. These casts are not only easy to identify, but they also explicitly communicate the developer's intent for applying a cast.

### Example

```
1 // $Id: A5-2-2.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdint>
3 class C
4 {
5     public:
6         explicit C(std::int32_t) {}
7         virtual void Fn() noexcept {}
8 };
9 class D : public C
10 {
11     public:
12         void Fn() noexcept override {}
13 };
14 class E
15 {
16 };
17 std::int32_t G() noexcept
18 {
19     return 7;
20 }
```

```

21 void F() noexcept(false)
22 {
23     C a1 = C{10};           // Compliant
24     C* a2 = (C*)&a1; // Non-compliant
25     const C a3(5);
26     C* a4 = const_cast<C*>(&a3);           // Compliant - violates another rule
27     E* d1 = reinterpret_cast<E*>(a4); // Compliant - violates another rule
28     D* d2 = dynamic_cast<D*>(a2);         // Compliant - violates another rule
29     std::int16_t x1 = 20;
30     std::int32_t x2 = static_cast<std::int32_t>(x1); // Compliant
31     std::int32_t x3 = (std::int32_t)x1;           // Non-compliant
32     std::int32_t x4 = 10;
33     float f1 = static_cast<float>(x4);           // Compliant
34     float f2 = (float)x4;                       // Non-compliant
35     std::int32_t x5 = static_cast<std::int32_t>(f1); // Compliant
36     std::int32_t x6 = (std::int32_t)f1;         // Non-compliant
37     (void)G();                                 // Non-compliant
38     static_cast<void>(G());                   // Compliant
39 }

```

## See also

MISRA C++ 2008 [7]: 5-2-4 C-style casts (other than void casts) and functional notation casts (other than explicit constructor calls) shall not be used.

JSF December 2005 [8]: AV Rule 185 C++ style casts (const\_cast, reinterpret\_cast, and static\_cast) shall be used instead of the traditional C-style casts.

### Rule A5-2-3 (required, implementation, automated)

**A cast shall not remove any const or volatile qualification from the type of a pointer or reference.**

## Rationale

Removal of the const or volatile qualification may not meet developer expectations as it may lead to undefined behavior.

Note that either const\_cast and traditional C-style casts that remove const or volatile qualification shall not be used.

## Example

```

1 // $Id: A5-2-3.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdlib>
3 void F1(const char* str) noexcept(false)
4 {
5     *(const_cast<char*>(str)) =
6         '\0'; // Non-compliant - const qualification removed
7 }

```





```

8 class C
9 {
10 public:
11     explicit C(std::int32_t) {}
12 };
13 void F2() noexcept(false)
14 {
15     C const a1 = C(10);
16     C* a2 = const_cast<C*>(&a1); // Non-compliant - const qualification removed
17     C* a3 = (C*)&a1; // Non-compliant - const qualification removed
18 }
19 extern volatile std::int32_t* F3() noexcept;
20 void F4() noexcept
21 {
22     volatile std::int32_t* ptr1 = F3();
23     // ...
24     std::int32_t* ptr2 = const_cast<std::int32_t*>(
25         ptr1); // Non-compliant - volatile qualification removed
26     // ...
27     std::int32_t* ptr3 =
28         (std::int32_t*)ptr1; // Non-compliant - volatile qualification removed
29 }

```

## See also

MISRA C++ 2008 [7]: 5-2-5 A cast shall not remove any const or volatile qualification from the type of a pointer or reference.

**Rule M5-2-6 (required, implementation, automated)**  
**A cast shall not convert a pointer to a function to any other pointer type, including a pointer to function type.**

See MISRA C++ 2008 [7]

**Rule A5-2-4 (required, implementation, automated)**  
**reinterpret\_cast shall not be used.**

## Rationale

Use of reinterpret\_cast may violate type safety and cause the program to access a variable as if it were of another, unrelated type.

## Example

```

1 // $Id: A5-2-4.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdlib>
3 #include <string>
4 void F1() noexcept

```

```

5 {
6     std::string str = "Hello";
7     std::int32_t* ptr = reinterpret_cast<std::int32_t*>(&str); // Non-compliant
8 }
9 struct A
10 {
11     std::int32_t x;
12     std::int32_t y;
13 };
14 class B
15 {
16     public:
17     virtual ~B() {}
18
19     private:
20     std::int32_t x;
21 };
22 class C : public B
23 {
24 };
25 class D : public B
26 {
27 };
28 void F2(A* ptr) noexcept
29 {
30     B* b1 = reinterpret_cast<B*>(ptr); // Non-compliant
31     std::int32_t num = 0;
32     A* a1 = reinterpret_cast<A*>(num); // Non-compliant
33     A* a2 = (A*)
34         num; // Compliant with this rule, but non-compliant with Rule A5-2-2.
35     B* b2 = reinterpret_cast<B*>(num); // Non-compliant
36     D d;
37     C* c1 = reinterpret_cast<C*>(&d); // Non-compliant - cross cast
38     C* c2 = (C*)&d; // Compliant with this rule, but non-compliant with Rule
39                 // A5-2-2. Cross-cast.
40     B* b3 = &d; // Compliant - class D is a subclass of class B
41 }

```

## See also

MISRA C++ 2008 [7]: Rule 5-2-7 An object with pointer type shall not be converted to an unrelated pointer type, either directly or indirectly.

C++ Core Guidelines [11]: Type.1: Don't use `reinterpret_cast`.

**Rule A5-2-6 (required, implementation, automated)**  
**The operands of a logical `&&` or `\|` shall be parenthesized if the operands contain binary operators.**

## Rationale

Parentheses are required to add clarity in logical expressions making code easier to review versus code based only C++ operator precedence rules.

## Example

```
1 // $Id: A5-2-6.cpp$
2
3 #include <cstdint>
4
5 void Fn(std::int32_t value) noexcept
6 {
7     if (value > 0 && value < 3) // Non-compliant
8     {
9         // do some work
10    }
11    else if ((value > 1) && (value < 2)) // Compliant
12    {
13        // do some work
14    }
15    else
16    {
17        // do some work
18    }
19
20    return;
21 }
```

## See also

MISRA C++ 2008 [7]: M5-2-1: Each operand of a logical && or || shall be a postfix expression.

JSF December 2005 [8]: AV Rule 158: The operands of a logical && or \& shall be parenthesized if the operands contain binary operators.

C++ Core Guidelines [11]: ES.41: If in doubt about operator precedence, parenthesize

### Rule M5-2-8 (required, implementation, automated)

**An object with integer type or pointer to void type shall not be converted to an object with pointer type.**

See MISRA C++ 2008 [7]

### Rule M5-2-9 (required, implementation, automated)

**A cast shall not convert a pointer type to an integral type.**

See MISRA C++ 2008 [7]

Note: Obligation level changed.

**Rule M5-2-10 (required, implementation, automated)**  
**The increment (++) and decrement ( ) operators shall not be mixed with other operators in an expression.**

See MISRA C++ 2008 [7]

Note: Obligation level changed.

**Rule M5-2-11 (required, implementation, automated)**  
**The comma operator, && operator and the || operator shall not be overloaded.**

See MISRA C++ 2008 [7]

**Rule A5-2-5 (required, implementation, automated)**  
**An array or container shall not be accessed beyond its range.**

## Rationale

To avoid undefined behavior, range checks should be coded to ensure that container access via iterator arithmetic or subscript operator is within defined bounds. This could also be achieved by accessing an array via a subscript operator with constant indices only.

When copying data via standard library algorithms (such as `std::copy` or `std::transform`), the target destination must be guaranteed to be large enough to hold the data.

Note: This rule applies to C-style arrays and all other containers (including `std::basic_string`) that access their elements via iterators or via an index. The term iterator includes pointers.

Note: Calculating an iterator one past the last element of the array is well defined, but dereferencing such an iterator is not.

## Example

```
1 // $Id: A5-2-5.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <array>
3 #include <cstdint>
4 #include <iostream>
5 void Fn1() noexcept
6 {
```

```

7     constexpr std::int32_t arraySize = 16;
8     std::int32_t array[arraySize]{0};
9
10    std::int32_t elem1 =
11        array[0]; // Compliant - access with constant literal that
12                // is less than ArraySize
13    std::int32_t elem2 =
14        array[12]; // Compliant - access with constant literal that
15                 // is less than ArraySize
16    for (std::int32_t idx = 0; idx < 20; ++idx)
17    {
18        std::int32_t elem3 =
19            array[idx]; // Non-compliant - access beyond ArraySize
20                    // bounds, which has 16 elements
21    }
22
23    std::int32_t shift = 25;
24    std::int32_t elem4 =
25        *(array + shift); // Non-compliant - access beyond ArraySize bounds
26
27    std::int32_t index = 0;
28    std::cin >> index;
29    std::int32_t elem5 =
30        array[index]; // Non-compliant - index may exceed the ArraySize bounds
31    if (index < arraySize)
32    {
33        std::int32_t elem6 = array[index]; // Compliant - range check coded
34    }
35 }
36 void Fn2() noexcept
37 {
38     constexpr std::int32_t arraySize = 32;
39     std::array<std::int32_t, arraySize> array;
40     array.fill(0);
41
42     std::int32_t elem1 =
43         array[10]; // Compliant - access with constant literal that
44                 // is less than ArraySize
45     std::int32_t index = 40;
46     std::int32_t elem2 =
47         array[index]; // Non-compliant - access beyond ArraySize bounds
48     try
49     {
50         std::int32_t elem3 =
51             array.at(50); // Compliant - at() method provides a
52                         // range check, throwing an exception if
53                         // input exceeds the bounds
54     }
55     catch (std::out_of_range&)
56     {
57         // Handle an error

```

```
58     }
59
60     for (auto&& e : array) // The std::array provides a possibility to iterate
61                           // over its elements with range-based loop
62     {
63         // Iterate over all elements
64     }
65 }
```

### See also

HIC++ v4.0 [9]: 5.2.1: Ensure that pointer or array access is demonstrably within bounds of a valid object.

#### **Rule M5-2-12 (required, implementation, automated)**

**An identifier with array type passed as a function argument shall not decay to a pointer.**

See MISRA C++ 2008 [7]

### See also

C++ Core Guidelines [11]: C.152: Never assign a pointer to an array of derived class objects to a pointer to its base.

C++ Core Guidelines [11]: R.2: In interfaces, use raw pointers to denote individual objects (only).

C++ Core Guidelines [11]: I.13: Do not pass an array as a single pointer.

### 6.5.3 Unary expressions

#### **Rule M5-3-1 (required, implementation, automated)**

**Each operand of the ! operator, the logical && or the logical || operators shall have type bool.**

See MISRA C++ 2008 [7]

#### **Rule M5-3-2 (required, implementation, automated)**

**The unary minus operator shall not be applied to an expression whose underlying type is unsigned.**

See MISRA C++ 2008 [7]

**Rule M5-3-3 (required, implementation, automated)**  
The unary & operator shall not be overloaded.

See MISRA C++ 2008 [7]

**Rule M5-3-4 (required, implementation, automated)**  
Evaluation of the operand to the sizeof operator shall not contain side effects.

See MISRA C++ 2008 [7]

**Rule A5-3-1 (required, implementation, non-automated)**  
Evaluation of the operand to the typeid operator shall not contain side effects.

## Rationale

The operand of typeid operator is evaluated only if it is a function call which returns a reference to a polymorphic type.

Providing side effects to typeid operator, which takes place only under special circumstances, makes the code more difficult to maintain.

## Example

```
1 // $Id: A5-3-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <typeinfo>
3 bool SideEffects() noexcept
4 {
5     // Implementation
6     return true;
7 }
8 class A
9 {
10 public:
11     static A& F1() noexcept { return a; }
12     virtual ~A() {}
13
14 private:
15     static A a;
16 };
17 A A::a;
18 void F2() noexcept(false)
19 {
20     typeid(SideEffects()); // Non-compliant - sideEffects() function not called
21     typeid(A::F1()); // Non-compliant - A::f1() functions called to determine
22                     // the polymorphic type
23 }
```



## See also

HIC++ v4.0 [9]: 5.1.6 Do not code side effects into the right-hand operands of: &&, ||, sizeof, typeid or a function passed to condition\_variable::wait.

### Rule A5-3-2 (required, implementation, partially automated) Null pointers shall not be dereferenced.

## Rationale

Dereferencing a NULL pointer leads to undefined behavior.

Note: It is required requires that a pointer is checked for non-NULL status before dereferencing occurs.

## Example

```
1 // $Id: A5-3-2.cpp 305629 2018-01-29 13:29:25Z piotr.serwa $
2 #include <iostream>
3 #include <memory>
4 #include <cstdint>
5
6 class A
7 {
8 public:
9     A(std::uint32_t a) : a(a) {}
10    std::uint32_t GetA() const noexcept { return a; }
11
12 private:
13    std::uint32_t a;
14 };
15
16 bool Sum(const A* lhs, const A* rhs)
17 {
18     //non-compliant, not checking if pointer is invalid
19     return lhs->GetA() + rhs->GetA();
20 }
21
22
23 int main(void)
24 {
25     auto l = std::make_shared<A>(3);
26     decltype(l) r;
27
28     auto sum = Sum(l.get(), r.get());
29
30     std::cout << sum << std::endl;
31     return 0;
32 }
```

## See also

JSF December 2005 [8]: AV Rule 174: The null pointer shall not be dereferenced.

SEI CERT C++ Coding Standard [10]: EXP34-C: Do not dereference null pointers.

C++ Core Guidelines [11]: ES.65: Don't dereference an invalid pointer.

**Rule A5-3-3 (required, implementation, automated)**  
**Pointers to incomplete class types shall not be deleted.**

## Rationale

Incomplete class types are forward declared class types, for which the compiler has not yet seen a definition. It is undefined behavior if a pointer to an incomplete class type is deleted, and the class has a non-trivial destructor or a deallocation function. This rule prohibits deletion of such a pointer even in the harmless case of a trivially destructible class type without a deallocation function, since a non-trivial destructor or a deallocation function may be added later as the code evolves.

## Example

```
1 // $Id: A5-3-3.cpp 309184 2018-02-26 20:38:28Z jan.babst $
2
3 // Non-compliant: At the point of deletion, pimpl points
4 // to an incomplete class type.
5 class Bad
6 {
7     class Impl;
8     Impl* pimpl;
9
10    public:
11        // ...
12        ~Bad() { delete pimpl; } // violates A18-5-2
13 };
14
15 // Compliant: At the point of deletion, pimpl points to
16 // a complete class type.
17
18 // In a header file ...
19 class Good
20 {
21     class Impl;
22     Impl* pimpl;
23
24    public:
25        // ...
26        ~Good();
27 };
28
```

```
29 // In an implementation file ...
30 class Good::Impl
31 {
32     // ...
33 };
34 // Good::Impl is a complete type now
35
36 Good::~Good()
37 {
38     delete pimpl; // violates A18-5-2
39 }
40
41 // Compliant: Contemporary solution using std::unique_ptr
42 // and conforming to A18-5-2.
43 // Note that std::unique_ptr<Impl> requires Impl to be a complete type
44 // at the point where pimpl is deleted and thus automatically enforces
45 // A5-3-3. This is the reason why the destructor of Better must be defined in an
46 // implementation file when Better::Impl is a complete type, even if the
47 // definition is just the default one.
48
49 // In a header file ...
50 #include <memory>
51 class Better
52 {
53     class Impl;
54     std::unique_ptr<Impl> pimpl;
55
56 public:
57     // ...
58     ~Better();
59 };
60
61 // In an implementation file ...
62 class Better::Impl
63 {
64     // ...
65 };
66 // Better::Impl is a complete type now
67
68 Better::~Better() = default;
```

### See also

ISO/IEC 14882:2014 [3]: 5.3.5: [expr.delete]

SEI CERT C++ Coding Standard [10]: EXP57-CPP: Do not cast or delete pointers to incomplete classes.

### 6.5.5 Pointer-to-member

**Rule A5-5-1 (required, implementation, automated)**  
**A pointer to member shall not access non-existent class members.**

## Rationale

Usage of a pointer-to-member expression leads to undefined behavior in the following cases:

The pointer to member is a null pointer.

The dynamic type of the object does not contain the member to which the called pointer to member refers.

## Example

```
1 // $Id: A5-5-1.cpp 302200 2017-12-20 17:17:08Z michal.szczepankiewicz $
2
3 class A
4 {
5 public:
6     virtual ~A() = default;
7 };
8
9 class AA : public A
10 {
11 public:
12     virtual ~AA() = default;
13     virtual void foo() { }
14
15     using ptr = void (AA::*);
16 };
17
18 class B
19 {
20 public:
21     static AA::ptr foo_ptr2;
22 };
23
24 AA::ptr B::foo_ptr2;
25
26 int main(void)
27 {
28     A* a = new A();
29     void (A::*foo_ptr1)() = static_cast<void(A::*)>(&AA::foo);
30     (a->*foo_ptr1)(); // non-compliant
31     delete a;
32
33     AA* aa = new AA();
34     (aa->*B::foo_ptr2)(); // non-compliant, not explicitly initialized
35     delete aa;
36
37     return 0;
```

38 }

## See also

SEI CERT C++ Coding Standard [10]: OOP55-CPP: Do not use pointer-to-member operators to access nonexistent members

## 6.5.6 Multiplicative operators

**Rule A5-6-1 (required, implementation, automated)**  
**The right hand operand of the integer division or remainder operators shall not be equal to zero.**

### Rationale

The result is undefined if the right hand operand of the integer division or the remainder operator is zero.

### Example

```

1 // $Id: A5-6-1.cpp 305629 2018-01-29 13:29:25Z piotr.serwa $
2 #include <cstdint>
3 #include <stdexcept>
4 std::int32_t Division1(std::int32_t a, std::int32_t b) noexcept
5 {
6     return (a / b); // Non-compliant - value of b could be zero
7 }
8 std::int32_t Division2(std::int32_t a, std::int32_t b)
9 {
10    if (b == 0)
11    {
12        throw std::runtime_error("Division by zero error");
13    }
14    return (a / b); // Compliant - value of b checked before division
15 }
16 double Fn()
17 {
18    std::int32_t x = 20 / 0; // Non-compliant - undefined behavior
19    x = Division1(20, 0); // Undefined behavior
20    x = Division2(20,
21                0); // Preconditions check will throw a runtime_error from
22                // division2() function
23    std::int32_t remainder = 20 % 0; // Non-compliant - undefined behavior
24 }

```

## See also

HIC++ v4.0 [9]: 5.5.1 Ensure that the right hand operand of the division or remainder operators is demonstrably non-zero.

C++ Core Guidelines [11]: ES.105: Don't divide by zero.

## 6.5.8 Shift operators

### Rule M5-8-1 (required, implementation, partially automated)

The right hand operand of a shift operator shall lie between zero and one less than the width in bits of the underlying type of the left hand operand.

See MISRA C++ 2008 [7]

## 6.5.10 Equality operators

### Rule A5-10-1 (required, implementation, automated)

A pointer to member virtual function shall only be tested for equality with null-pointer-constant.

### Rationale

The result of equality comparison between pointer to member virtual function and anything other than null-pointer-constant (i.e. nullptr, see: [A4-10-1](#)) is unspecified.

### Example

```
1 // $Id: A5-10-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 class A
3 {
4     public:
5         virtual ~A() = default;
6         void F1() noexcept {}
7         void F2() noexcept {}
8         virtual void F3() noexcept {}
9 };
10
11 void Fn()
12 {
13     bool b1 = (&A::F1 == &A::F2);           // Compliant
14     bool b2 = (&A::F1 == nullptr);         // Compliant
15     bool b3 = (&A::F3 == nullptr);         // Compliant
16     bool b4 = (&A::F3 != nullptr);         // Compliant
17     bool b5 = (&A::F3 == &A::F1);         // Non-compliant
18 }
```

### See also

HIC++ v4.0 [9]: 5.7.2 Ensure that a pointer to member that is a virtual function is only compared (==) with nullptr.

JSF December 2005 [8]: AV Rule 97.1 Neither operand of an equality operator (== or !=) shall be a pointer to a virtual member function.

### 6.5.14 Logical AND operator

**Rule M5-14-1 (required, implementation, automated)**  
The right hand operand of a logical &&, || operators shall not contain side effects.

See MISRA C++ 2008 [7]

### 6.5.16 Conditional operator

**Rule A5-16-1 (required, implementation, automated)**  
The ternary conditional operator shall not be used as a sub-expression.

#### Rationale

Using the result of the ternary conditional operator as an operand or nesting conditional operators makes the code less readable and more difficult to maintain.

#### Example

```

1 // $Id: A5-16-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdlib>
3 constexpr bool Fn1(std::int32_t x)
4 {
5     return (x > 0); // Compliant
6 }
7 std::int32_t Fn2(std::int32_t x)
8 {
9     std::int32_t i = (x >= 0 ? x : 0); // Compliant
10
11     std::int32_t j =
12         x + (i == 0 ? (x >= 0 ? x : -x) : i); // Non-compliant - nested
13                                     // conditional operator
14                                     // and used as a
15                                     // sub-expression
16     return (
17         i > 0
18         ? (j > 0 ? i + j : i)
19         : (j > 0 ? j : 0)); // Non-compliant - nested conditional operator
20 }

```

#### See also

HIC++ v4.0 [9]: 5.8.1 Do not use the conditional operator (?:) as a sub-expression.

### 6.5.18 Assignment and compound assignment operation

**Rule M5-17-1 (required, implementation, non-automated)**  
**The semantic equivalence between a binary operator and its assignment operator form shall be preserved.**

See MISRA C++ 2008 [7]

### 6.5.19 Comma operator

**Rule M5-18-1 (required, implementation, automated)**  
**The comma operator shall not be used.**

See MISRA C++ 2008 [7]

### 6.5.20 Constant expression

**Rule M5-19-1 (required, implementation, automated)**  
**Evaluation of constant unsigned integer expressions shall not lead to wrap-around.**

See MISRA C++ 2008 [7]

Note: Obligation level changed

Note: This rule applies to bit-fields, too.

## 6.6 Statements

### 6.6.2 Expression statement

**Rule M6-2-1 (required, implementation, automated)**  
**Assignment operators shall not be used in sub-expressions.**

See MISRA C++ 2008 [7]



## Exception

It is allowed that a condition of the form `type-specifier-seq declarator` uses an assignment operator. This exception is introduced because alternative mechanisms for achieving the same effect are cumbersome and error-prone.

**Rule A6-2-1 (required, implementation, automated)**  
**Move and copy assignment operators shall either move or respectively copy base classes and data members of a class, without any side effects.**

## Rationale

It is expected behavior that the move/copy assigned operator are only used to move/copy the object of the class type and possibly set moved-from object to a valid state. Those operators are not supposed to provide any performance overhead or side effects that could affect moving or copying the object.

Note: Class members that are not essential for a class invariant may not need to be moved/copied (e.g. caches, debug information).

## Example

```
1 // $Id: A6-2-1.cpp 305786 2018-01-30 08:58:33Z michal.szczepankiewicz $
2
3 #include <cstdlib>
4 #include <utility>
5 class A
6 {
7 public:
8     A& operator=(const A& oth) // Compliant
9     {
10         if(&oth == this)
11         {
12             return *this;
13         }
14         x = oth.x;
15         return *this;
16     }
17
18 private:
19     std::int32_t x;
20 };
21 class B
22 {
23 public:
24     ~B() { delete ptr; }
25
26     //compliant
27     B& operator=(B&& oth)
28     {
```

```

29         if(&oth == this)
30         {
31             return *this;
32         }
33         ptr = std::move(oth.ptr);
34         // Compliant - this is not a side-effect, in this
35         // case it is essential to leave moved-from object
36         // in a valid state, otherwise double deletion will
37         // occur.
38         return *this;
39     }
40
41 private:
42     std::int32_t* ptr;
43 };
44
45 class C
46 {
47 public:
48     C& operator=(const C& oth)
49     {
50         if(&oth == this)
51         {
52             return *this;
53         }
54         x = oth.x % 2; // Non-compliant - unrelated side-effect
55         return *this;
56     }
57
58 private:
59     std::int32_t x;
60 };
61
62 class D
63 {
64 public:
65     explicit D(std::uint32_t a) : a(a), noOfModifications(0) {}
66
67     D& operator=(const D& oth)
68     {
69         if(&oth == this)
70         {
71             return *this;
72         }
73         a = oth.a;
74         //compliant, not copying the debug information about number of modifications
75
76         return *this;
77     }
78     void SetA(std::uint32_t aa)

```

```
79     {
80         ++noOfModifications;
81         a = aa;
82     }
83     std::uint32_t GetA() const noexcept
84     {
85         return a;
86     }
87
88 private:
89     std::uint32_t a;
90     std::uint64_t noOfModifications;
91 };
```

## See also

JSF December 2005 [8]: AV Rule 83: An assignment operator shall assign all data members and bases that affect the class invariant (a data element representing a cache, for example, would not need to be copied).

**Rule A6-2-2 (required, implementation, automated)**  
**Expression statements shall not be explicit calls to constructors of temporary objects only.**

## Rationale

The developer's intention might have been to define an unnamed local variable that would live until the end of the scope to implement the RAI pattern (Resource Acquisition Is Initialization). But as there are no unnamed variables in C++, it is in fact only creating a temporary object that gets destroyed again at the end of the full expression.

## Example

```
1 // $Id: A6-2-2.cpp 326655 2018-07-20 14:58:55Z christof.meerwald $
2
3 #include <cstdint>
4 #include <fstream>
5 #include <mutex>
6
7 class A
8 {
9 public:
10     void SetValue1(std::int32_t value)
11     {
12         std::lock_guard<std::mutex> {m_mtx}; // Non-compliant: temporary object
13         // Assignment to m_value is not protected by lock
14         m_value = value;
15     }
16
```

```
17     void SetValue2(std::int32_t value)
18     {
19         std::lock_guard<std::mutex> guard{m_mtx}; // Compliant: local variable m_value = value;
20
21     }
22
23 private:
24     mutable std::mutex m_mtx;
25     std::int32_t m_value;
26 };
27
28 void Print(std::string const & fname, std::string const & s)
29 {
30     // Compliant: Not only constructing a temporary object
31     std::ofstream{fname}.write(s.c_str(), s.length());
32 }
```

### See also

C++ Core Guidelines [11]: ES.84: Don't (try to) declare a local variable with no name

C++ Core Guidelines [11]: CP.44: Remember to name your lock\_guards and unique\_locks

**Rule M6-2-2 (required, implementation, partially automated) Floating-point expressions shall not be directly or indirectly tested for equality or inequality.**

See MISRA C++ 2008 [7]

**Rule M6-2-3 (required, implementation, automated)**  
**Before preprocessing, a null statement shall only occur on a line by itself; it may be followed by a comment, provided that the first character following the null statement is a white-space character.**

See MISRA C++ 2008 [7]

### 6.6.3 Compound statement or block

**Rule M6-3-1 (required, implementation, automated)**  
**The statement forming the body of a switch, while, do ... while or for statement shall be a compound statement.**

See MISRA C++ 2008 [7]

#### 6.6.4 Selection statements

**Rule M6-4-1 (required, implementation, automated)**

An `if ( condition )` construct shall be followed by a compound statement. The `else` keyword shall be followed by either a compound statement, or another `if` statement.

See MISRA C++ 2008 [7]

**Rule M6-4-2 (required, implementation, automated)**

All `if ... else if` constructs shall be terminated with an `else` clause.

See MISRA C++ 2008 [7]

**Rule M6-4-3 (required, implementation, automated)**

A `switch` statement shall be a well-formed `switch` statement.

See MISRA C++ 2008 [7]

**Rule M6-4-4 (required, implementation, automated)**

A `switch-label` shall only be used when the most closely-enclosing compound statement is the body of a `switch` statement.

See MISRA C++ 2008 [7]

**Rule M6-4-5 (required, implementation, automated)**

An unconditional `throw` or `break` statement shall terminate every non-empty `switch-clause`.

See MISRA C++ 2008 [7]

**Rule M6-4-6 (required, implementation, automated)**

The final clause of a `switch` statement shall be the `default-clause`.

See MISRA C++ 2008 [7]

**Rule M6-4-7 (required, implementation, automated)**  
**The condition of a switch statement shall not have bool type.**

See MISRA C++ 2008 [7]

Note: "The condition shall be of integral type, enumeration type, or class type. If of class type, the condition is contextually implicitly converted (Clause 4) to an integral or enumeration type." [C++14 Language Standard, 6.4.2 The switch statement]

**Rule A6-4-1 (required, implementation, automated)**  
**A switch statement shall have at least two case-clauses, distinct from the default label.**

## Rationale

A switch statement constructed with less than two case-clauses can be expressed as an if statement more naturally.

Note that a switch statement with no case-clauses is redundant.

## Example

```
1 // $Id: A6-4-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdint>
3 void F1(std::uint8_t choice) noexcept
4 {
5     switch (choice)
6     {
7         default:
8             break;
9     } // Non-compliant, the switch statement is redundant
10 }
11 void F2(std::uint8_t choice) noexcept
12 {
13     switch (choice)
14     {
15         case 0:
16             // ...
17             break;
18
19         default:
20             // ...
21             break;
22     } // Non-compliant, only 1 case-clause
23
24     if (choice == 0) // Compliant, an equivalent if statement
25     {
26         // ...
27     }
28     else
```

```
29     {
30         // ...
31     }
32
33     // ...
34     switch (choice)
35     {
36         case 0:
37             // ...
38             break;
39
40         case 1:
41             // ...
42             break;
43
44         default:
45             // ...
46             break;
47     } // Compliant
48 }
```

## See also

MISRA C++ 2008 [7]: Rule 6-4-8 Every switch statement shall have at least one case-clause.

HIC++ v4.0 [9]: 6.1.4 Ensure that a switch statement has at least two case labels, distinct from the default label.

## 6.6.5 Iteration statements

**Rule A6-5-1 (required, implementation, automated)**  
**A for-loop that loops through all elements of the container and does not use its loop-counter shall not be used.**

### Rationale

A for-loop that simply loops through all elements of the container and does not use its loop-counter is equivalent to a range-based for statement that reduces the amount of code to maintain correct loop semantics.

### Example

```
1 // $Id: A6-5-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdlib>
3 #include <iterator>
4 void Fn() noexcept
5 {
6     constexpr std::int8_t arraySize = 7;
```

```
7     std::uint32_t array[arraySize] = {0, 1, 2, 3, 4, 5, 6};
8
9     for (std::int8_t idx = 0; idx < arraySize; ++idx) // Compliant
10    {
11        array[idx] = idx;
12    }
13
14    for (std::int8_t idx = 0; idx < arraySize / 2;
15         ++idx) // Compliant - for does not loop though all elements
16    {
17        // ...
18    }
19
20    for (std::uint32_t* iter = std::begin(array); iter != std::end(array);
21         ++iter) // Non-compliant
22    {
23        // ...
24    }
25
26    for (std::int8_t idx = 0; idx < arraySize; ++idx) // Non-compliant
27    {
28        // ...
29    }
30
31    for (std::uint32_t value :
32         array) // Compliant - equivalent to non-compliant loops above
33    {
34        // ...
35    }
36
37    for (std::int8_t idx = 0; idx < arraySize; ++idx) // Compliant
38    {
39        if ((idx % 2) == 0)
40        {
41            // ...
42        }
43    }
44 }
```

## See also

HIC++ v4.0 [9]: 6.2.1 Implement a loop that only uses element values as a range-based loop.

C++ Core Guidelines [11]: ES.55: Avoid the need for range checking.

C++ Core Guidelines [11]: ES.71: Prefer a range-for-statement to a for-statement when there is a choice.



**Rule A6-5-2 (required, implementation, automated)**  
**A for loop shall contain a single loop-counter which shall not have floating-point type.**

## Rationale

A for loop without a loop-counter is simply a while loop. If this is the desired behavior, then a while loop is more appropriate.

Floating types, as they should not be tested for equality/inequality, are not to be used as loop-counters.

## Example

```
1 // $Id: A6-5-2.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdint>
3 namespace
4 {
5     constexpr std::int32_t xlimit = 20;
6     constexpr std::int32_t ylimit = 15;
7     constexpr float zlimit = 2.5F;
8     constexpr std::int32_t ilimit = 100;
9 }
10 void Fn() noexcept
11 {
12     std::int32_t y = 0;
13
14     for (std::int32_t x = 0; x < xlimit && y < ylimit;
15         x++, y++) // Non-compliant, two loop-counters
16     {
17         // ...
18     }
19
20     for (float z = 0.0F; z != zlimit;
21         z += 0.1F) // Non-compliant, float with !=
22     {
23         // ...
24     }
25
26     for (float z = 0.0F; z < zlimit; z += 0.1F) // Non-compliant, float with <
27     {
28         // ...
29     }
30
31     for (std::int32_t i = 0; i < ilimit; ++i) // Compliant
32     {
33         // ...
34     }
35 }
```

## See also

MISRA C++ 2008 [7]: Rule 6-5-1 A for loop shall contain a single loop-counter which shall not have floating type.

C++ Core Guidelines [11]: ES.72: Prefer a for-statement to a while-statement when there is an obvious loop variable.

**Rule M6-5-2 (required, implementation, automated)**  
**If loop-counter is not modified by or ++, then, within condition, the loop-counter shall only be used as an operand to <=, <, > or >=.**

See MISRA C++ 2008 [7]

**Rule M6-5-3 (required, implementation, automated)**  
**The loop-counter shall not be modified within condition or statement.**

See MISRA C++ 2008 [7]

**Rule M6-5-4 (required, implementation, automated)**  
**The loop-counter shall be modified by one of: , ++, = n, or + = n; where n remains constant for the duration of the loop.**

See MISRA C++ 2008 [7]

Note: “n remains constant for the duration of the loop” means that “n” can be either a literal, a constant or constexpr value.

**Rule M6-5-5 (required, implementation, automated)**  
**A loop-control-variable other than the loop-counter shall not be modified within condition or expression.**

See MISRA C++ 2008 [7]

**Rule M6-5-6 (required, implementation, automated)**  
**A loop-control-variable other than the loop-counter which is modified in statement shall have type bool.**

See MISRA C++ 2008 [7]

**Rule A6-5-3 (advisory, implementation, automated)**  
**Do statements should not be used.****Rationale**

Do-statements are bug-prone, as the termination condition is checked at the end and can be overlooked.

**Exception**

A do-statement may be used in a function-like macro to ensure that its invocation behaves like an expression statement consisting of a function call (see <http://c-faq.com/cpp/multistmt.html>).

Note: Rule [A16-0-1](#) forbids function-like macros. This exception is kept in case rule [A16-0-1](#) is disabled in a project.

**Example**

```
1 // $Id: A6-5-3.cpp 291350 2017-10-17 14:31:34Z jan.babst $
2
3 #include <cstdlib>
4
5 // Compliant by exception
6 #define SWAP(a, b) \
7     do \
8     { \
9         decltype(a) tmp = (a); \
10        (a) = (b); \
11        (b) = tmp; \
12    } while (0)
13
14 // Non-compliant
15 #define SWAP2(a, b) \
16     decltype(a) tmp = (a); \
17     (a) = (b); \
18     (b) = tmp;
19
20 int main(void)
21 {
22     uint8_t a = 24;
23     uint8_t b = 12;
24
25     if (a > 12)
26         SWAP(a, b);
27
28     // if (a > 12)
29     //SWAP2(a, b);
30     // Does not compile, because only the first line is used in the body of the
31     // if-statement. In other cases this may even cause a run-time error.
32     // The expansion contain two semicolons in a row, which may be flagged by
33     // compiler warnings.
```

```
34 // Expands to:
35 // if (a > 12)
36 //decltype(a) tmp = (a);
37 // (a) = (b);
38 // (b) = tmp;;
39
40 return 0;
41 }
```

## See also

C++ Core Guidelines [11]: ES.75: Avoid do-statements.

**Rule A6-5-4 (advisory, implementation, automated) For-init-statement and expression should not perform actions other than loop-counter initialization and modification.**

## Rationale

If only a loop-counter is used in the for-init-statement and expression, it increases readability and it is easier to understand and maintain code.

## Example

```
1 // $Id: A6-5-4.cpp 305629 2018-01-29 13:29:25Z piotr.serwa $
2 #include <cstdlib>
3
4 void Fn() noexcept
5 {
6     for (std::int32_t x = 0, MAX=10; x < MAX; x++) // compliant with A6-5-2, but
7         // non-compliant with advisory A6-5-4
8         {
9             // ...
10        }
```

## See also

JSF December 2005 [8]: AV Rule 198: The initialization expression in a for loop will perform no actions other than to initialize the value of a single for loop parameter.

JSF December 2005 [8]: AV Rule 199: The increment expression in a for loop will perform no action other than to change a single loop parameter to the next value for the loop.

## 6.6.6 Jump statements

**Rule A6-6-1 (required, implementation, automated)**  
**The goto statement shall not be used.****Rationale**

Using goto statement significantly complicates the logic, makes the code difficult to read and maintain, and may lead to incorrect resources releases or memory leaks.

**Example**

```
1 // $Id: A6-6-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdlib>
3 namespace
4 {
5 constexpr std::int32_t loopLimit = 100;
6 }
7 void F1(std::int32_t n) noexcept
8 {
9     if (n < 0)
10    {
11        // goto exit; // Non-compliant - jumping to exit from here crosses ptr
12        // pointer initialization, compilation
13        // error
14    }
15
16    std::int32_t* ptr = new std::int32_t(n);
17 // ...
18 exit:
19    delete ptr;
20 }
21 void F2() noexcept
22 {
23     // ...
24     goto error; // Non-compliant
25 // ...
26 error; // Error handling and cleanup
27 }
28 void F3() noexcept
29 {
30     for (std::int32_t i = 0; i < loopLimit; ++i)
31     {
32         for (std::int32_t j = 0; j < loopLimit; ++j)
33         {
34             for (std::int32_t k = 0; k < loopLimit; ++k)
35             {
36                 if ((i == j) && (j == k))
37                 {
38                     // ...
39                     goto loop_break; // Non-compliant
40                 }
41             }
42         }
43     }
44 }
```

```
42     }  
43 }  
44  
45 loop_break::    // ...  
46 }
```

## See also

JSF December 2005 [8]: AV Rule 189 The goto statement shall not be used.

C++ Core Guidelines [11]: ES.76: Avoid goto.

C++ Core Guidelines [11]: NR.6: Don't: Place all cleanup actions at the end of a function and goto exit.

**Rule M6-6-1 (required, implementation, automated)**  
Any label referenced by a goto statement shall be declared in the same block, or in a block enclosing the goto statement.

See MISRA C++ 2008 [7]

**Rule M6-6-2 (required, implementation, automated)**  
The goto statement shall jump to a label declared later in the same function body.

See MISRA C++ 2008 [7]

**Rule M6-6-3 (required, implementation, automated)**  
The continue statement shall only be used within a well-formed for loop.

See MISRA C++ 2008 [7]

## 6.7 Declaration

### 6.7.1 Specifiers

**Rule A7-1-1 (required, implementation, automated)**  
Constexpr or const specifiers shall be used for immutable data declaration.

## Rationale

If data is declared to be const or constexpr then its value can not be changed by mistake. Also, such declaration can offer the compiler optimization opportunities.

Note that the `constexpr` specifier in an object declaration implies `const` as well.

### Example

```
1  //% $Id: A7-1-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2  #include <cstdint>
3  #include <limits>
4  void Fn()
5  {
6      const std::int16_t x1 = 5;           // Compliant
7      constexpr std::int16_t x2 = 5;    // Compliant
8      std::int16_t x3 =
9          5; // Non-compliant - x3 is not modified but not declared as
10             // constant (const or constexpr)
11 }
```

### See also

C++ Core Guidelines [11]: ES.25: Declare objects `const` or `constexpr` unless you want to modify its value later on.

C++ Core Guidelines [11]: Con.1: By default, make objects immutable.

C++ Core Guidelines [11]: Con.4: Use `const` to define objects with values that do not change after construction.

**Rule A7-1-2 (required, implementation, automated)**  
**The `constexpr` specifier shall be used for values that can be determined at compile time.**

### Rationale

The `constexpr` specifier declares that it is possible to evaluate the value of the function or variable at compile time, e.g. integral type overflow/underflow, configuration options or some physical constants. The compile-time evaluation can have no side effects so it is more reliable than `const` expressions.

Note that the `constexpr` specifier in an object declaration implies `const`, and when used in a function declaration it implies `inline`.

Note also that since 2014 C++ Language Standard `constexpr` specifier in member function declaration no longer implicitly implies that the member function is `const`.

### Example

```
1  //% $Id: A7-1-2.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2  #include <cstdint>
3  std::int32_t Pow1(std::int32_t number)
4  {
5      return (number * number);
6  }
```

```

7  constexpr std::int32_t Pow2(
8      std::int32_t number) // Possible compile-time computing
9                          // because of constexpr specifier
10 {
11     return (number * number);
12 }
13 void Fn()
14 {
15     constexpr std::int16_t i1 = 20; // Compliant, evaluated at compile-time
16     const std::int16_t i2 = 20; // Non-compliant, possible run-time evaluation
17     std::int32_t twoSquare =
18         Pow1(2); // Non-compliant, possible run-time evaluation
19     const std::int32_t threeSquare =
20         Pow1(3); // Non-compliant, possible run-time evaluation
21     // static_assert(threeSquare == 9, "pow1(3) did not succeed."); // Value
22     // can not be static_assert-ed
23     constexpr std::int32_t fiveSquare =
24         Pow2(5); // Compliant, evaluated at compile time
25     static_assert(fiveSquare == 25,
26                 "pow2(5) did not succeed."); // Compliant, constexpr
27                                             // evaluated at compile    time
28     // constexpr std::int32_t int32Max =
29     // std::numeric_limits<std::int32_t>::max() + 1; //
30     // Compliant - compilation error due to
31     // compile-time evaluation (integer overflow)
32 }
33 class A
34 {
35     public:
36     static constexpr double pi = 3.14159265; // Compliant - value of PI can be
37                                             // determined in compile time
38
39     // constexpr double e = 2.71828182; // Non-compliant - constexprs need
40     // to be static members, compilation error
41
42     constexpr A() = default; // Compliant
43 };

```

## See also

C++ Core Guidelines [11]: Con.5: Use constexpr for values that can be computed at compile time.

### Rule M7-1-2 (required, implementation, automated)

A pointer or reference parameter in a function shall be declared as pointer to const or reference to const if the corresponding object is not modified.

See MISRA C++ 2008 [7]

## See also



C++ Core Guidelines [11]: Con.3: By default, pass pointers and references to consts.

**Rule A7-1-3 (required, implementation, automated) CV-qualifiers shall be placed on the right hand side of the type that is a typedef or a using name.**

## Rationale

If the type is a typedef or a using name, placing const or volatile qualifier on the left hand side may result in confusion over what part of the type the qualification applies to.

## Example

```

1 // $Id: A7-1-3.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdint>
3 using IntPtr = std::int32_t*;
4 using IntConstPtr = std::int32_t* const;
5 using ConstIntPtr = const std::int32_t*;
6 void Fn(const std::uint8_t& input) // Compliant
7 {
8     std::int32_t value1 = 10;
9     std::int32_t value2 = 20;
10
11     const IntPtr ptr1 =
12         &value1; // Non-compliant - deduced type is std::int32_t*
13                 // const, not const std::int32_t*
14
15     // ptr1 = &value2; // Compilation error, ptr1 is read-only variable
16
17     IntPtr const ptr2 =
18         &value1; // Compliant - deduced type is std::int32_t* const
19
20     // ptr2 = &value2; // Compilation error, ptr2 is read-only variable
21
22     IntConstPtr ptr3 = &value1; // Compliant - type is std::int32_t* const, no
23                                 // additional qualifiers needed
24
25     // ptr3 = &value2; // Compilation error, ptr3 is read-only variable
26
27     ConstIntPtr ptr4 = &value1; // Compliant - type is const std::int32_t*
28
29     const ConstIntPtr ptr5 = &value1; // Non-compliant, type is const
30                                       // std::int32_t*          const, not const const
31                                       // std::int32_t*
32     ConstIntPtr const ptr6 =
33         &value1; // Compliant - type is const std::int32_t* const
34 }

```

## See also

HIC++ v4.0 [9]: 7.1.4 Place CV-qualifiers on the right hand side of the type they apply to

**Rule A7-1-4 (required, implementation, automated)**  
**The register keyword shall not be used.**

### Rationale

This feature was deprecated in the 2011 C++ Language Standard [2] and may be withdrawn in a later version.

Moreover, most compilers ignore register specifier and perform their own register assignments.

### Example

```
1 // $Id: A7-1-4.cpp 289448 2017-10-04 11:11:03Z michal.szczepankiewicz $
2 #include <stdint>
3 std::int32_t F1(register std::int16_t number) noexcept // Non-compliant
4 {
5     return ((number * number) + number);
6 }
7 void F2(std::int16_t number) noexcept // Compliant
8 {
9     register std::int8_t x = 10; // Non-compliant
10    std::int32_t result = F1(number); // Compliant
11    // ...
12 }
```

### See also

JSF December 2005 [8]: AV Rule 140 The register storage class specifier shall not be used.

HIC++ v4.0 [9]: 1.3.2 Do not use the register keyword

**Rule A7-1-5 (required, implementation, automated)**  
**The auto specifier shall not be used apart from following cases: (1) to declare that a variable has the same type as return type of a function call, (2) to declare that a variable has the same type as initializer of non-fundamental type, (3) to declare parameters of a generic lambda expression, (4) to declare a function template using trailing return type syntax.**

### Rationale

Using the auto specifier may lead to unexpected type deduction results, and therefore to developers confusion. In most cases using the auto specifier makes the code less readable.

Note that it is allowed to use the auto specifier in following cases:

1. When declaring a variable that is initialized with a function call or initializer of non-fundamental type. Using the auto specifier for implicit type deduction in such cases will ensure that no unexpected implicit conversions will occur. In such case, explicit type declaration would not aid readability of the code.
2. When declaring a generic lambda expression with auto parameters
3. When declaring a function template using trailing return type syntax

## Example

```
1 // $Id: A7-1-5.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdint>
3 #include <vector>
4
5 class A
6 {
7 };
8 void F1() noexcept
9 {
10     auto x1 = 5; // Non-compliant - initializer is of fundamental type
11     auto x2 = 0.3F; // Non-compliant - initializer is of fundamental type
12     auto x3 = {8}; // Non-compliant - initializer is of fundamental type
13
14     std::vector<std::int32_t> v;
15     auto x4 = v.size(); // Compliant with case (1) - x4 is of size_t type that
16                       // is returned from v.size() method
17
18     auto a = A{}; // Compliant with case (2)
19
20     auto lambda1 = []() -> std::uint16_t {
21         return 5U;
22     }; // Compliant with case (2) - lambda1 is of non-fundamental lambda
23       // expression type
24     auto x5 = lambda1(); // Compliant with case (1) - x5 is of
25                       // std::uint16_t type
26 }
27 void F2() noexcept
28 {
29     auto lambda1 = [](auto x, auto y) -> decltype(x + y) {
30         return (x + y);
31     }; // Compliant with cases (2) and (3)
32     auto y1 = lambda1(5.0, 10); // Compliant with case (1)
33 }
34 template <typename T, typename U>
35 auto F3(T t, U u) noexcept -> decltype(t + u) // Compliant with case (4)
36 {
37     return (t + u);
38 }
39 template <typename T>
40 class B
41 {
```

```
42     public:
43         T Fn(T t);
44     };
45     template <typename T>
46     auto B<T>::Fn(T t) -> T // Compliant with case (4)
47     {
48         // ...
49         return t;
50     }
```

## See also

HIC++ v4.0 [9]: 7.1.8 Use auto id = expr when declaring a variable to have the same type as its initializer function call.

C++ Core Guidelines [11]: Use auto.

Google C++ Style Guide [12]: Use auto to avoid type names that are noisy, obvious, or unimportant.

**Rule A7-1-6 (required, implementation, automated)**  
**The typedef specifier shall not be used.**

## Rationale

The typedef specifier can not be easily used for defining alias templates. Also, the typedef syntax makes the code less readable.

For defining aliases, as well as template aliases, it is recommended to use the using syntax instead of the typedef.

Note that active issues related to the using syntax are listed below, in the “See also” section.

## Example

```
1 // $Id: A7-1-6.cpp 271687 2017-03-23 08:57:35Z piotr.tanski $
2 #include <cstdint>
3 #include <type_traits>
4
5 typedef std::int32_t (*fPointer1)(std::int32_t); // Non-compliant
6
7 using fPointer2 = std::int32_t (*)(std::int32_t); // Compliant
8
9 // template<typename T>
10 // typedef std::int32_t (*fPointer3)(T); // Non-compliant - compilation error
11
12 template <typename T>
13 using fPointer3 = std::int32_t (*)(T); // Compliant
```

## See also

C++ Core Guidelines [11]: T.43: Prefer using over typedef for defining aliases

C++ Standard Core Language Active Issues, Revision 96 [18]: 1554. Access and alias templates.

C++ Standard Core Language Defect Reports and Accepted Issues, Revision 96 [18]: 1558. Unused arguments in alias template specializations.

**Rule A7-1-7 (required, implementation, automated)**  
**Each expression statement and identifier declaration shall be placed on a separate line.**

## Rationale

Declaring an identifier on a separate line makes the identifier declaration easier to find and the source code more readable. Also, combining objects, references and pointers declarations with assignments and function calls on the same line may become confusing.

## Exception

It is permitted to declare identifiers in initialization statement of a for loop.

## Example

```
1 // $Id: A7-1-7.cpp 292454 2017-10-23 13:14:23Z michal.szczepankiewicz $
2 #include <cstdlib>
3 #include <vector>
4
5 typedef std::int32_t* ptr; // Compliant
6 typedef std::int32_t *pointer, value; // Non-compliant
7
8 void Fn1() noexcept
9 {
10     std::int32_t x = 0; // Compliant
11     std::int32_t y = 7, *p1 = nullptr; // Non-compliant
12     std::int32_t const *p2, z = 1; // Non-compliant
13 }
14
15 void Fn2()
16 {
17     std::vector<std::int32_t> v{1, 2, 3, 4, 5};
18     for (auto iter{v.begin()}, end{v.end()}; iter != end;
19         ++iter) // Compliant by exception
20     {
21         // ...
22     }
23 }
24
25 void Fn3() noexcept
26 {
```

```
27     std::int32_t x{5};
28     std::int32_t y{15}; // Non-compliant
29     x++;
30     ++y; // Non-compliant
31     for (std::int32_t i{0}; i < 100; ++i)
32     {
33         Fn2(); // Compliant
34     }
35 }
```

## See also

HIC++ v4.0 [9]: 7.1.1 Declare each identifier on a separate line in a separate declaration.

JSF December 2005 [8]: AV Rule 42 Each expression-statement will be on a separate line.

JSF December 2005 [8]: AV Rule 152: Multiple variable declarations shall not be allowed on the same line.

C++ Core Guidelines [11]: NL.20: Don't place two statements on the same line.

**Rule A7-1-8 (required, implementation, automated)**  
**A non-type specifier shall be placed before a type specifier in a declaration.**

## Rationale

Placing a non-type specifier, i.e. typedef, friend, constexpr, register, static, extern, thread\_local, mutable, inline, virtual, explicit, before type specifiers makes the source code more readable.

## Example

```
1 // $Id: A7-1-8.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdint>
3
4 typedef std::int32_t int1; // Compliant
5 std::int32_t typedef int2; // Non-compliant
6
7 class C
8 {
9     public:
10         virtual inline void F1(); // Compliant
11         inline virtual void F2(); // Compliant
12         void virtual inline F3(); // Non-compliant
13     private:
14         std::int32_t mutable x; // Non-compliant
15         mutable std::int32_t y; // Compliant
16 };
```

## See also

HIC++ v4.0 [9]: 7.1.3 Do not place type specifiers before non-type specifiers in a declaration.

**Rule A7-1-9 (required, implementation, automated)**  
**A class, structure, or enumeration shall not be declared in the definition of its type.**

## Rationale

Combining a type definition with a declaration of another entity can lead to readability problems and can be confusing for a developer.

## Example

```
1 // $Id: A7-1-9.cpp 305629 2018-01-29 13:29:25Z piotr.serwa $
2 #include <cstdint>
3
4 enum class DIRECTION
5 {
6     UP,
7     DOWN
8 } dir; //non-compliant
9
10 class Foo
11 {
12 public:
13     enum class ONE {AA, BB}; //compliant
14
15     static constexpr enum class TWO {CC, DD} sVar = TWO::CC; // non-compliant
16     static constexpr ONE sVar2 = ONE::AA; //compliant
17 };
18
19
20 struct Bar
21 {
22     std::uint32_t a;
23 } barObj; //non-compliant
24
25 struct Bar2
26 {
27     std::uint32_t a;
28 } bar2Obj, *bar2Ptr; //non-compliant, also with A7-1-7
29
30 struct Foo2
31 {
32     std::uint32_t f;
33 };
34
35 Foo2 foo2Obj; //compliant
```

## See also

JSF December 2005 [8]: AV Rule 141: A class, structure, or enumeration will not be declared in the definition of its type.

C++ Core Guidelines [11]: C.7: Don't define a class or enum and declare a variable of its type in the same statement.

## 6.7.2 Enumeration declaration

**Rule A7-2-1 (required, implementation, automated)**  
**An expression with enum underlying type shall only have values corresponding to the enumerators of the enumeration.**

### Rationale

It is unspecified behavior if the evaluation of an expression with enum underlying type yields a value which does not correspond to one of the enumerators of the enumeration.

Additionally, other rules in this standard assume that objects of enum type only contain values corresponding to the enumerators. This rule ensures the validity of these assumptions.

One way of ensuring compliance when converting to an enumeration is to use a switch statement.

### Example

```
1 // $Id: A7-2-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdint>
3 enum class E : std::uint8_t
4 {
5     Ok = 0,
6     Repeat,
7     Error
8 };
9 E Convert1(std::uint8_t number) noexcept
10 {
11     E result = E::Ok; // Compliant
12     switch (number)
13     {
14         case 0:
15             {
16                 result = E::Ok; // Compliant
17                 break;
18             }
19         case 1:
20             {
21                 result = E::Repeat; // Compliant
```



```

22         break;
23     }
24     case 2:
25     {
26         result = E::Error; // Compliant
27         break;
28     }
29     case 3:
30     {
31         constexpr std::int8_t val = 3;
32         result = static_cast<E>(val); // Non-compliant - value 3 does not
33                                     // correspond to any of E's
34                                     // enumerators
35         break;
36     }
37     default:
38     {
39         result =
40             static_cast<E>(0); // Compliant - value 0 corresponds to E::Ok
41         break;
42     }
43 }
44 return result;
45 }
46 E Convert2(std::uint8_t userInput) noexcept
47 {
48     E result = static_cast<E>(userInput); // Non-compliant - the range of
49                                           // userInput may not correspond to
50                                           // any of E's enumerators
51     return result;
52 }
53 E Convert3(std::uint8_t userInput) noexcept
54 {
55     E result = E::Error;
56     if (userInput < 3)
57     {
58         result = static_cast<E>(userInput); // Compliant - the range of
59                                             // userInput checked before casting
60                                             // it to E enumerator
61     }
62     return result;
63 }

```

## See also

MISRA C++ 2008 [7]: Rule 7-2-1 An expression with enum underlying type shall only have values corresponding to the enumerators of the enumeration.

**Rule A7-2-2 (required, implementation, automated)**  
**Enumeration underlying base type shall be explicitly defined.**

### Rationale

The enumeration underlying type is implementation-defined, with the only restriction that the type must be able to represent the enumeration values. Although scoped enum will implicitly define an underlying type of int, the underlying base type of enumeration should always be explicitly defined with a type that will be large enough to store all enumerators.

### Example

```
1 // $Id: A7-2-2.cpp 271715 2017-03-23 10:13:51Z piotr.tanski $
2 #include <cstdint>
3 enum class E1 // Non-compliant
4 {
5     E10,
6     E11,
7     E12
8 };
9 enum class E2 : std::uint8_t // Compliant
10 {
11     E20,
12     E21,
13     E22
14 };
15 enum E3 // Non-compliant
16 {
17     E30,
18     E31,
19     E32
20 };
21 enum E4 : std::uint8_t // Compliant - violating another rule
22 {
23     E40,
24     E41,
25     E42
26 };
27 enum class E5 : std::uint8_t // Non-compliant - will not compile
28 {
29     E50 = 255,
30     // E5_1, // E5_1 = 256 which is outside of range of underlying type
31     // std::uint8_t
32     // - compilation error
33     // E5_2 // E5_2 = 257 which is outside of range of underlying type
34     // std::uint8_t
35     // - compilation error
36 };
```

### See also

HIC++ v4.0 [9]: 7.2.1 Use an explicit enumeration base and ensure that it is large enough to store all enumerators

**Rule A7-2-3 (required, implementation, automated)**  
**Enumerations shall be declared as scoped enum classes.**

### Rationale

If unscoped enumeration enum is declared in a global scope, then its values can redeclare constants declared with the same identifier in the global scope. This may lead to developer's confusion.

Using enum-class as enumeration encloses its enumerators in its inner scope and prevent redeclaring identifiers from outer scope.

Note that enum class enumerators disallow implicit conversion to numeric values.

### Example

```
1 // $Id: A7-2-3.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdint>
3
4 enum E1 : std::int32_t // Non-compliant
5 {
6     E10,
7     E11,
8     E12
9 };
10
11 enum class E2 : std::int32_t // Compliant
12 {
13     E20,
14     E21,
15     E22
16 };
17
18 // static std::int32_t E1_0 = 5; // E1_0 symbol redeclaration, compilation
19 // error
20
21 static std::int32_t e20 = 5; // No redeclarations, no compilation error
22
23 extern void F1(std::int32_t number)
24 {
25 }
26
27 void F2()
28 {
29     F1(0);
30
31     F1(E11); // Implicit conversion from enum to std::int32_t type
32
```

```
33     // f1(E2::E2_1); // Implicit conversion not possible, compilation error
34
35     F1(static_cast<std::int32_t>(
36         E2::E21)); // Only explicit conversion allows to
37                 // pass E2_1 value to f1() function
38 }
```

## See also

C++ Core Guidelines [11]: Enum.3: Prefer class enums over "plain" enums.

**Rule A7-2-4 (required, implementation, automated)**  
**In an enumeration, either (1) none, (2) the first or (3) all enumerators shall be initialized.**

## Rationale

Explicit initialization of only some enumerators in an enumeration, and relying on compiler to initialize the remaining ones, may lead to developer's confusion.

## Example

```
1  // % $Id: A7-2-4.cpp 271715 2017-03-23 10:13:51Z piotr.tanski $
2  #include <cstdint>
3  enum class Enum1 : std::uint32_t
4  {
5      One,
6      Two = 2, // Non-compliant
7      Three
8  };
9  enum class Enum2 : std::uint32_t // Compliant (none)
10 {
11     One,
12     Two,
13     Three
14 };
15 enum class Enum3 : std::uint32_t // Compliant (the first)
16 {
17     One = 1,
18     Two,
19     Three
20 };
21 enum class Enum4 : std::uint32_t // Compliant (all)
22 {
23     One = 1,
24     Two = 2,
25     Three = 3
26 };
```

## See also

MISRA C++ 2008 [7]: Rule 8-5-3 In an enumerator list, the = construct shall not be used to explicitly initialize members other than the first, unless all items are explicitly initialized.

HIC++ v4.0 [9]: 7.2.2 Initialize none, the first only or all enumerators in an enumeration.

**Rule A7-2-5 (advisory, design, non-automated)**  
**Enumerations should be used to represent sets of related named constants.**

### Rationale

Explicit declaration of constants as an enumeration clearly shows that they are related, which enhances readability and maintenance.

Note: Using switch statement on an enumeration is a common case and such an approach helps to detect errors, see [M6-4-6](#).

### Example

```
1 //% $Id: A7-2-5.cpp 305629 2018-01-29 13:29:25Z piotr.serwa $
2 #include <cstdint>
3 //compliant
4 enum class WebpageColors: std::uint32_t
5 {
6     Red,
7     Blue,
8     Green
9 };
10 //non-compliant
11 enum class Misc: std::uint32_t
12 {
13     Yellow,
14     Monday,
15     Holiday
16 };
```

### See also

JSF December 2005 [8]: AV Rule 148: Enumeration types shall be used instead of integer types (and constants) to select from a limited series of choices.

C++ Core Guidelines [11]: Enum.2: Use enumerations to represent sets of related named constants.

## 6.7.3 Namespaces

**Rule M7-3-1 (required, implementation, automated)**  
The global namespace shall only contain main, namespace declarations and extern "C" declarations.

See MISRA C++ 2008 [7]

**Rule M7-3-2 (required, implementation, automated)**  
The identifier main shall not be used for a function other than the global function main.

See MISRA C++ 2008 [7]

**Rule M7-3-3 (required, implementation, automated)** There shall be no unnamed namespaces in header files.

See MISRA C++ 2008 [7]

**Rule M7-3-4 (required, implementation, automated)**  
Using-directives shall not be used.

See MISRA C++ 2008 [7]

See: Using-directive [16] concerns an inclusion of specific namespace with all its types, e.g. using namespace std.

**Rule A7-3-1 (required, implementation, automated)**  
All overloads of a function shall be visible from where it is called.

## Rationale

Additional identifiers introduced by a using declaration makes only prior declarations of this identifier visible. Any potential subsequent declarations will not be added to the current scope, which may lead to unexpected results and developers confusion.

Overriding or overloading a member function in a derived class causes other member functions with the same name to be hidden. Thus, a potential function call may result in a different function being called depending on if the call was made using the derived or base class reference/pointer. Introducing hidden names into the derived class by a using declaration helps to avoid such misleading situations.

## Example

```
1 // $Id: A7-3-1.cpp 312801 2018-03-21 16:17:05Z michal.szczepankiewicz $
2 #include <cstdint>
3
4 class Base
5 {
6 public:
7     void P(uint32_t);
8
9     virtual void V(uint32_t);
10    virtual void V(double);
11 };
12
13 class NonCompliant : public Base
14 {
15 public:
16     //hides P(uint32_t) when calling from the
17     //derived class
18     void P(double);
19     //hides V(uint32_t) when calling from the
20     //derived class
21     void V(double) override;
22 };
23
24 class Compliant : public Base
25 {
26 public:
27     //both P(uint32_t) and P(double) available
28     //from the derived class
29     using Base::P;
30     void P(double);
31
32     //both P(uint32_t) and P(double)
33     using Base::V;
34     void V(double) override;
35 };
36
37 void F1()
38 {
39     NonCompliant d{};
40     d.P(0U); // D::P (double) called
41     Base& b{d};
42     b.P(0U); // NonCompliant::P (uint32_t) called
43
44     d.V(0U); // D::V (double) called
45     b.V(0U); // NonCompliant::V (uint32_t) called
46 }
47
48 void F2()
49 {
50     Compliant d{};
51     d.P(0U); // Compliant::P (uint32_t) called
```

```
52     Base& b{d};
53     b.P(0U); // Compliant::P (uint32_t) called
54
55     d.V(0U); // Compliant::V (uint32_t) called
56     b.V(0U); // Compliant::V (uint32_t) called
57 }
58
59 namespace NS
60 {
61     void F(uint16_t);
62 }
63
64 //includes only preceding declarations into
65 //the current scope
66 using NS::F;
67
68 namespace NS
69 {
70     void F(uint32_t);
71 }
72
73 void B(uint32_t b)
74 {
75     //non-compliant, only F(uint16_t) is available
76     //in this scope
77     F(b);
78 }
```

### See also

MISRA C++ 2008 [7]: 7-3-5: Multiple declarations for an identifier in the same namespace shall not straddle a using-declaration for that identifier.

HIC++ v4.0 [9]: 13.1.1: Ensure that all overloads of a function are visible from where it is called.

**Rule M7-3-6 (required, implementation, automated) Using-directives and using-declarations (excluding class scope or function scope using-declarations) shall not be used in header files.**

See MISRA C++ 2008 [7]

See: Using-declaration [16] concerns an inclusion of specific type, e.g. using std::string.

### 6.7.4 The asm declaration



**Rule A7-4-1 (required, implementation, automated)**  
**The asm declaration shall not be used.**

### Rationale

Inline assembly code restricts the portability of the code.

### Example

```
1 // $Id: A7-4-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdint>
3 std::int32_t Fn1(std::int32_t b) noexcept
4 {
5     std::int32_t ret = 0;
6     // ...
7     asm("pushq %%rax \n"
8         "movl %0, %%eax \n"
9         "addl %1, %%eax \n"
10        "movl %%eax, %0 \n"
11        "popq %%rax"
12        : "=r"(ret)
13        : "r"(b)); // Non-compliant
14     return ret;
15 }
16 std::int32_t Fn2(std::int32_t b) noexcept
17 {
18     std::int32_t ret = 0;
19     // ...
20     ret += b; // Compliant - equivalent to asm(...) above
21     return ret;
22 }
```

### See also

HIC++ v4.0 [9]: 7.5.1 Do not use the asm declaration.

**Rule M7-4-1 (required, implementation, non-automated)**  
**All usage of assembler shall be documented.**

See MISRA C++ 2008 [7]

**Rule M7-4-2 (required, implementation, automated)**  
**Assembler instructions shall only be introduced using the asm declaration.**

See MISRA C++ 2008 [7]

**Rule M7-4-3 (required, implementation, automated)**  
**Assembly language shall be encapsulated and isolated.**

See MISRA C++ 2008 [7]

### 6.7.5 Linkage specification

**Rule M7-5-1 (required, implementation, non-automated)**  
**A function shall not return a reference or a pointer to an automatic variable (including parameters), defined within the function.**

See MISRA C++ 2008 [7]

**Rule M7-5-2 (required, implementation, non-automated)**  
**The address of an object with automatic storage shall not be assigned to another object that may persist after the first object has ceased to exist.**

See MISRA C++ 2008 [7]

Note: C++ specifies that binding a temporary object (e.g. automatic variable returned from a function) to a reference to const prolongs the lifetime of the temporary to the lifetime of the reference.

Note: Rule 7-5-2 concerns C++11 smart pointers, i.e. `std::unique_ptr`, `std::shared_ptr` and `std::weak_ptr`, too.

#### See also

C++ Core Guidelines [11]: F.45: Don't return a T&&.

**Rule A7-5-1 (required, implementation, automated)**  
**A function shall not return a reference or a pointer to a parameter that is passed by reference to const.**

#### Rationale

“[...] Where a parameter is of const reference type a temporary object is introduced if needed (7.1.6, 2.13, 2.13.5, 8.3.4, 12.2).” [C++14 Language Standard [3]]

Any attempt to dereferencing an object which outlived its scope will lead to undefined behavior.

References to const bind to both lvalues and rvalues, so functions that accept parameters passed by reference to const should expect temporary objects too.

Returning a pointer or a reference to such an object leads to undefined behavior on accessing it.

### Example

```

1 // $Id: A7-5-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdint>
3 class A
4 {
5     public:
6         explicit A(std::uint8_t n) : number(n) {}
7         ~A() { number = 0U; }
8         // Implementation
9
10        private:
11            std::uint8_t number;
12 };
13 const A& Fn1(const A& ref) noexcept // Non-compliant - the function returns a
14                                     // reference to      const reference parameter
15                                     // which may      bind to temporary      objects.
16                                     // According    to C++14 Language  Standard, it
17 // is undefined whether a temporary object is introduced for const
18 // reference
19 // parameter
20 {
21     // ...
22     return ref;
23 }
24 const A& Fn2(A& ref) noexcept // Compliant - non-const reference parameter does
25                               // not bind      to temporary objects, it is allowed
26                               // that the     function returns a reference to such
27                               // a parameter
28 {
29     // ...
30     return ref;
31 }
32 const A* Fn3(const A& ref) noexcept // Non-compliant - the function returns a
33 // pointer to const reference parameter
34 // which may bind to temporary objects.
35 // According to C++14 Language Standard, it
36 // is undefined whether a temporary object is introduced for const
37 // reference
38 // parameter
39 {
40     // ...
41     return &ref;
42 }
43 template <typename T>
44 T& Fn4(T& v) // Compliant - the function will not bind to temporary objects
45 {
46     // ...
47     return v;

```

```

48 }
49 void F() noexcept
50 {
51     A a{5};
52     const A& ref1 = Fn1(a); // fn1 called with an lvalue parameter from an
53                           // outer scope, ref1 refers to valid object
54     const A& ref2 = Fn2(a); // fn2 called with an lvalue parameter from an
55                           // outer scope, ref2 refers to valid object
56     const A* ptr1 = Fn3(a); // fn3 called with an lvalue parameter from an
57                           // outer scope, ptr1 refers to valid object
58     const A& ref3 = Fn4(a); // fn4 called with T = A, an lvalue parameter from
59                           // an outer scope, ref3 refers to valid object
60
61     const A& ref4 = Fn1(A{10}); // fn1 called with an rvalue parameter
62                               // (temporary), ref3 refers to destroyed object
63                               // A const& ref5 = fn2(A{10}); // Compilation
64                               // error - invalid initialization of non-const
65                               // reference
66     const A* ptr2 = Fn3(A{15}); // fn3 called with an rvalue parameter
67                               // (temporary), ptr2 refers to destroyed
68                               // object
69     // const A& ref6 = fn4(A{20}); // Compilation error - invalid
70     // initialization of non-const reference
71 }

```

## See also

MISRA C++ 2008 [7]: A function shall not return a reference or a pointer to a parameter that is passed by reference or const reference.

**Rule A7-5-2 (required, implementation, automated)**  
**Functions shall not call themselves, either directly or indirectly.**

## Rationale

As the stack space is limited resource, use of recursion may lead to stack overflow at run-time. It also may limit the scalability and portability of the program.

Recursion can be replaced with loops, iterative algorithms or worklists.

## Exception

Recursion in variadic template functions used to process template arguments does not violate this rule, as variadic template arguments are evaluated at compile time and the call depth is known.

Recursion of a constexpr function does not violate this rule, as it is evaluated at compile time.

## Example

```
1 // $Id: A7-5-2.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdint>
3 static std::int32_t Fn1(std::int32_t number);
4 static std::int32_t Fn2(std::int32_t number);
5 static std::int32_t Fn3(std::int32_t number);
6 static std::int32_t Fn4(std::int32_t number);
7 std::int32_t Fn1(std::int32_t number)
8 {
9     if (number > 1)
10    {
11        number = number * Fn1(number - 1); // Non-compliant
12    }
13
14    return number;
15 }
16 std::int32_t Fn2(std::int32_t number)
17 {
18    for (std::int32_t n = number; n > 1; --n) // Compliant
19    {
20        number = number * (n - 1);
21    }
22
23    return number;
24 }
25 std::int32_t Fn3(std::int32_t number)
26 {
27    if (number > 1)
28    {
29        number = number * Fn3(number - 1); // Non-compliant
30    }
31
32    return number;
33 }
34 std::int32_t Fn4(std::int32_t number)
35 {
36    if (number == 1)
37    {
38        number = number * Fn3(number - 1); // Non-compliant
39    }
40
41    return number;
42 }
43 template <typename T>
44 T Fn5(T value)
45 {
46    return value;
47 }
48 template <typename T, typename... Args>
49 T Fn5(T first, Args... args)
50 {
51    return first + Fn5(args...); // Compliant by exception - all of the
```

```
52                                     // arguments are known during compile time
53 }
54 std::int32_t Fn6() noexcept
55 {
56     std::int32_t sum = Fn5<std::int32_t, std::uint8_t, float, double>(
57         10, 5, 2.5, 3.5); // An example call to variadic template function
58     // ...
59     return sum;
60 }
61 constexpr std::int32_t Fn7(std::int32_t x, std::int8_t n)
62 {
63     if (n >= 0)
64     {
65         x += x;
66         return Fn5(x, --n); // Compliant by exception - recursion evaluated at
67                             // compile time
68     }
69     return x;
70 }
```

## See also

MISRA C++ 2008 [7]: Rule 7-5-4 Functions should not call themselves, either directly or indirectly.

JSF December 2005 [8]: AV Rule 119 Functions shall not call themselves, either directly or indirectly (i.e. recursion shall not be allowed).

HIC++ v4.0 [9]: 5.2.2 Ensure that functions do not call themselves, either directly or indirectly.

## 6.7.6 Attributes

**Rule A7-6-1 (required, implementation, automated)**  
**Functions declared with the `[[noreturn]]` attribute shall not return.**

### Rationale

The C++ standard specifies that functions with the `[[noreturn]]` attribute shall not return. Returning from such a function can be prohibited in the following way: throwing an exception, entering an infinite loop, or calling another function with the `[[noreturn]]` attribute. Returning from such a function leads to undefined behavior.

```
1 // $Id: A7-6-1.cpp 305629 2018-01-29 13:29:25Z piotr.serwa $
2 #include <cstdlib>
3 #include <exception>
4
5 class PositiveInputException : public std::exception {};
6
```

```
7 [[noreturn]] void f(int i) //non-compliant
8 {
9     if (i > 0)
10    {
11        throw PositiveInputException();
12    }
13    //undefined behaviour for non-positive i
14 }
15
16 [[noreturn]] void g(int i) //compliant
17 {
18     if (i > 0)
19     {
20         throw "Received positive input";
21     }
22
23     while(1)
24     {
25         //do processing
26     }
27 }
```

### See also

SEI CERT C++ Coding Standard [10]: MSC53-CPP: Do not return from a function declared `[[noreturn]]`.

## 6.8 Declarators

### 6.8.0 General

**Rule M8-0-1 (required, implementation, automated)**  
An `init-declarator-list` or a `member-declarator-list` shall consist of a single `init-declarator` or `member-declarator` respectively.

See MISRA C++ 2008 [7]

### 6.8.2 Ambiguity resolution

**Rule A8-2-1 (required, implementation, automated)**  
When declaring function templates, the trailing return type syntax shall be used if the return type depends on the type of parameters.

## Rationale

Use of trailing return type syntax avoids a fully qualified return type of a function along with the `typename` keyword.

## Example

```
1 // $Id: A8-2-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdint>
3 template <typename T>
4 class A
5 {
6     public:
7         using Type = std::int32_t;
8
9         Type F(T const&) noexcept;
10        Type G(T const&) noexcept;
11 };
12 template <typename T>
13 typename A<T>::Type A<T>::F(T const&) noexcept // Non-compliant
14 {
15     // Implementation
16 }
17 template <typename T>
18 auto A<T>::G(T const&) noexcept -> Type // Compliant
19 {
20     // Implementation
21 }
```

## See also

HIC++ v4.0 [9]: 7.1.7 Use a trailing return type in preference to type disambiguation using `typename`.

### 6.8.3 Meaning of declarators

**Rule M8-3-1 (required, implementation, automated)**  
Parameters in an overriding virtual function shall either use the same default arguments as the function they override, or else shall not specify any default arguments.

See MISRA C++ 2008 [7]

Note: Overriding non-virtual functions in a subclass is called function “hiding” or “redefining”. It is prohibited by [A10-2-1](#).

### 6.8.4 Function definitions



**Rule A8-4-1 (required, implementation, automated)**  
**Functions shall not be defined using the ellipsis notation.**

### Rationale

Passing arguments via an ellipsis bypasses the type checking performed by the compiler. Additionally, passing an argument with non-POD class type leads to undefined behavior.

Variadic templates offer a type-safe alternative for ellipsis notation. If use of a variadic template is not possible, function overloading or function call chaining can be considered.

### Example

```
1 // $Id: A8-4-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2
3 void Print1(char* format, ...) // Non-compliant - variadic arguments are used
4 {
5     // ...
6 }
7
8 template <typename First, typename... Rest>
9 void Print2(const First& first, const Rest&... args) // Compliant
10 {
11     // ...
12 }
```

### See also

MISRA C++ 2008 [7]: Rule 8-4-1 Functions shall not be defined using the ellipsis notation.

HIC++ v4.0 [9]: 14.1.1 Use variadic templates rather than an ellipsis.

C++ Core Guidelines [11]: Type.8: Avoid reading from varargs or passing vararg arguments. Prefer variadic template parameters instead.

C++ Core Guidelines [11]: F.55: Don't use va\_arg arguments.

**Rule M8-4-2 (required, implementation, automated)**  
**The identifiers used for the parameters in a re-declaration of a function shall be identical to those in the declaration.**

See MISRA C++ 2008 [7]

**Rule A8-4-2 (required, implementation, automated)****All exit paths from a function with non-void return type shall have an explicit return statement with an expression.****Rationale**

In a function with non-void return type, return expression gives the value that the function returns. The absence of a return with an expression leads to undefined behavior (and the compiler may not give an error).

**Exception**

A function may additionally exit due to exception handling (i.e. a throw statement).

**Example**

```
1 // $Id: A8-4-2.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdlib>
3 #include <stdexcept>
4 std::int32_t F1() noexcept // Non-compliant
5 {
6 }
7 std::int32_t F2(std::int32_t x) noexcept(false)
8 {
9     if (x > 100)
10    {
11        throw std::logic_error("Logic Error"); // Compliant by exception
12    }
13
14    return x; // Compliant
15 }
16 std::int32_t F3(std::int32_t x, std::int32_t y)
17 {
18     if (x > 100 || y > 100)
19     {
20         throw std::logic_error("Logic Error"); // Compliant by exception
21     }
22     if (y > x)
23     {
24         return (y - x); // Compliant
25     }
26     return (x - y); // Compliant
27 }
```

**See also**

MISRA C++ 2008 [7]: Rule 8-4-3 All exit paths from a function with non-void return type shall have an explicit return statement with an expression.

SEI CERT C++ [10]: MSC52-CPP. Value-returning functions must return a value from all exit paths.

**Rule M8-4-4 (required, implementation, automated)**  
A function identifier shall either be used to call the function or it shall be preceded by &.

See MISRA C++ 2008 [7]

**Rule A8-4-3 (advisory, design, non-automated) Common ways of passing parameters should be used.**

### Rationale

Using common and well-understood parameter passing patterns as summarised in the following table helps meeting developer expectations.

	cheap to copy or move only	cheap to move	expensive to move
<b>in</b>	f(X)	f(const X &)	
<b>in/out</b>	f(X &)		
<b>out</b>	X f()		f(X &)
<b>consume</b>	f(X &&)		
<b>forward</b>	template<typename T> f(T &&)		

### Parameter passing

### Example

```

1 // $Id: A8-4-3.cpp 308906 2018-02-23 15:34:15Z christof.meerwald $
2
3 #include <algorithm>
4 #include <array>
5 #include <cstdint>
6 #include <numeric>
7 #include <string>
8 #include <vector>
9
10 // Compliant: passing cheap-to-copy parameter by value
11 int32_t Increment(int32_t i)
12 {
13     return i + 1;
14 }
15
16 // Compliant: passing expensive to copy parameter by reference to const
17 int32_t Sum(const std::vector<int32_t> &v)
18 {
19     return std::accumulate(v.begin(), v.end(), 0);
20 }
21
22 // Compliant: passing in-out parameter by reference
23 void Decrement(int32_t &i)
24 {

```

```
25     --i;
26 }
27
28 // Compliant: returning out parameter by value
29 std::string GetGreeting()
30 {
31     return "Hello";
32 }
33
34 struct A
35 {
36     std::string text;
37     std::array<std::string, 1000> arr;
38 };
39
40 // Expensive to move "out" parameter passed by reference. If
41 // intentional, violation of A8-4-8 needs to be explained
42 void InitArray(std::array<std::string, 1000> &arr,
43              const std::string &text)
44 {
45     std::for_each(arr.begin(), arr.end(), [&text] (std::string &s) {
46         s = text;
47     });
48 }
49
50 // Compliant: passing in-out parameter by reference
51 void PopulateA(A &a)
52 {
53     InitArray(a.arr, a.text);
54 }
```

## See also

C++ Core Guidelines [11]: F.16: Prefer simple and conventional ways of passing information

**Rule A8-4-4 (advisory, design, automated)**  
**Multiple output values from a function should be returned as a struct or tuple.**

## Rationale

Returning multiple values from a function using a struct or tuple clearly states output parameters and allows to avoid confusion of passing them as a reference in a function call. Returning a struct or tuple will not have an additional overhead for compilers that support return-value-optimization.

In C++14, a returned tuple can be conveniently processed using `std::tie` at the call site, which will put the tuple elements directly into existing local variables. In C++17,

structured bindings allow to initialize local variables directly from members or elements of a returned struct or tuple.

Note: For return types representing an abstraction, a struct should be preferred over a generic tuple.

Note: This rule applies equally to `std::pair`, which is a special kind of tuple for exactly two elements.

### Example

```
1 // $Id: A8-4-4.cpp 289816 2017-10-06 11:19:42Z michal.szczepankiewicz $
2
3 #include <tuple>
4
5 // Non-compliant, remainder returned as the output parameter
6 int Divide1(int dividend, int divisor, int& remainder)
7 {
8     remainder = dividend % divisor;
9     return dividend / divisor;
10 }
11
12 // Compliant, both quotient and remainder returned as a tuple
13 std::tuple<int, int> Divide2(int dividend, int divisor)
14 {
15     return std::make_tuple(dividend / divisor, dividend % divisor);
16 }
17
18 // Compliant since C++17, return tuple using list-initialization
19 // std::tuple<int, int> Divide3(int dividend, int divisor)
20 //{
21 //return { dividend / divisor, dividend % divisor };
22 //}
23
24 int main()
25 {
26     int quotient, remainder;
27     std::tie(quotient, remainder) = Divide2(26, 5); // store in local variables
28     // auto [quotient, remainder] = Divide3(26, 5); // since C++17, by
29     // structured bindings
30     return 0;
31 }
```

### See also

C++ Core Guidelines [11]: F.21: To return multiple "out" values, prefer returning a tuple or struct.

**Rule A8-4-5 (required, design, automated)**  
**"consume" parameters declared as X && shall always be moved from.**

## Rationale

A "consume" parameter is declared with a type of rvalue reference to non-const non-template type (X &&). This documents that the value will be consumed in the function (i.e. left in a moved-from state) and requires an explicit 'std::move' at the call site if an lvalue is passed to the function (an rvalue reference can implicitly bind only to an rvalue).

Note: Other operations may be performed on the "consume" parameter before being moved.

## Example

```
1 // $Id: A8-4-5.cpp 305588 2018-01-29 11:07:35Z michal.szczepankiewicz $
2
3 #include <string>
4 #include <vector>
5
6 class A
7 {
8     public:
9         explicit A(std::vector<std::string> &&v)
10             : m_v{std::move(v)} // Compliant, move from consume parameter
11         {
12         }
13
14     private:
15         std::vector<std::string> m_v;
16 };
17
18 class B
19 {
20     public:
21         explicit B(std::vector<std::string> &&v)
22             : m_v{v} // Non-Compliant, consume parameter not moved from
23         {
24         }
25
26         std::vector<std::string> m_v;
27 };
```

## See also

C++ Core Guidelines [11]: F.18: For "consume" parameters, pass by X&& and std::move the parameter

**Rule A8-4-6 (required, design, automated)**  
**"forward" parameters declared as T && shall always be forwarded.**

## Rationale

A "forward" parameter is declared with a type of forwarding reference (i.e. an rvalue reference to non-const template type (T &&)). As a forwarding reference can bind to both lvalues and rvalues, preserving lvalue-ness and cv qualifications, it is useful when forwarding a value to another function using "std::forward".

However, as the parameter can bind to anything, it should only be used for forwarding without performing any other operations on the parameter.

Note: A forwarding parameter can also be declared via "auto &&" in a generic lambda

## Example

```
1 // $Id: A8-4-6.cpp 305588 2018-01-29 11:07:35Z michal.szczepankiewicz $
2
3 #include <string>
4 #include <vector>
5
6 class A
7 {
8     public:
9     explicit A(std::vector<std::string> &&v);
10 };
11
12 class B
13 {
14     public:
15     explicit B(const std::vector<std::string> &v);
16 };
17
18
19 template<typename T, typename ... Args>
20 T make(Args && ... args)
21 {
22     return T{std::forward<Args>(args) ...}; // Compliant, forwarding args
23 }
24
25 int main()
26 {
27     make<A>(std::vector<std::string>{ });
28
29     std::vector<std::string> v;
30     make<B>(v);
31 }
```

## See also

C++ Core Guidelines [11]: F.19: For "forward" parameters, pass by TP&& and only std::forward the parameter

[A18-9-2](#) in section [6.18.9](#)

**Rule A8-4-7 (required, design, automated)**  
"in" parameters for "cheap to copy" types shall be passed by value.

## Rationale

Passing an argument by value documents that the argument won't be modified. Copying the value (instead of passing by reference to const) also ensures that no indirection is needed in the function body to access the value.

For the purpose of this rule, "cheap to copy" is defined as a trivially copyable type that is no longer than two words (i.e. pointers).

## Example

```
1 // $Id: A8-4-7.cpp 305588 2018-01-29 11:07:35Z michal.szczepankiewicz $
2
3 #include <cstdint>
4 #include <iostream>
5 #include <string>
6
7 // Compliant, pass by value
8 void output(std::uint32_t i)
9 {
10     std::cout << i << '\n';
11 }
12
13 // Non-Compliant, std::string is not trivially copyable
14 void output(std::string s)
15 {
16     std::cout << s << '\n';
17 }
18
19 struct A
20 {
21     std::uint32_t v1;
22     std::uint32_t v2;
23 };
24
25 // Non-Compliant, A is trivially copyable and no longer than two words
26 void output(const A &a)
27 {
28     std::cout << a.v1 << ", " << a.v2 << '\n';
29 }
```

## See also

C++ Core Guidelines [11]: F.16: For "in" parameters, pass cheaply-copied types by value and others by reference to const

JSF December 2005 [8]: AV Rule 116: Small, concrete-type arguments (two or three words in size) should be passed by value if changes made to formal parameters should not be reflected in the calling function.



JSF December 2005 [8]: AV Rule 117.1: An object should be passed as const T& if the function should not change the value of the object.

[A18-9-2](#) in section [6.18.9](#)

**Rule A8-4-8 (required, design, automated)**  
**Output parameters shall not be used.**

## Rationale

Output parameters are passed to a function as non-const references or pointers that can denote either in-out or out-only parameter. Using return value prevents from possible misuse of such a parameter.

Note: Prefer returning non-value types (i.e. types in a inheritance hierarchy) as `std::shared_ptr` or `std::unique_ptr`.

## Example

```
1 // $Id: A8-4-8.cpp 306164 2018-02-01 15:04:53Z christof.meerwald $
2
3 #include <iostream>
4 #include <vector>
5 // Compliant, return value
6 std::vector<int> SortOutOfPlace(const std::vector<int>& inVec);
7
8 // Non-compliant: return value as an out-parameter
9 void FindAll(const std::vector<int>& inVec, std::vector<int>& outVec);
10
11 struct B
12 {
13 };
14
15 struct BB
16 {
17     B GetB() const& { return obj; }
18     B&& GetB() && { return std::move(obj); }
19
20     B obj;
21 };
22
23 // Non-compliant: returns a dangling reference
24 BB&& MakeBb1()
25 {
26     return std::move(BB());
27 }
28
29 // Compliant: uses compiler copy-ellipsis
30 BB MakeBb2()
31 {
32     return BB();
```

```
33 }
34
35 int main()
36 {
37     BB x = MakeBb2();
38
39     auto cpd = x.GetB();           // copied value
40     auto mvd = MakeBb2().GetB(); // moved value
41
42     return 0;
43 }
```

### See also

C++ Core Guidelines [11]: F.20: For "out" output values, prefer return values to output parameters.

**Rule A8-4-9 (required, design, automated) "in-out" parameters declared as T & shall be modified.**

### Rationale

An "in-out" parameter is declared with a type of reference to non-const. This means that a fully constructed object is passed into the function that can be read as well as modified.

Note: Completely replacing the passed in object without reading any data from it would make it an "out" parameter instead and is not considered compliant with this rule, also see rule: [A8-4-8](#)

### Example

```
1 // $Id: A8-4-9.cpp 306178 2018-02-01 15:52:25Z christof.meerwald $
2
3 #include <cstdint>
4 #include <numeric>
5 #include <string>
6 #include <vector>
7
8 // Non-Compliant: does not modify the "in-out" parameter
9 int32_t Sum(std::vector<int32_t> &v)
10 {
11     return std::accumulate(v.begin(), v.end(), 0);
12 }
13
14 // Compliant: Modifying "in-out" parameter
15 void AppendNewline(std::string &s)
16 {
17     s += '\n';
18 }
```

```
19
20 // Non-Compliant: Replacing parameter value
21 void GetFileExtension(std::string &ext)
22 {
23     ext = ".cpp";
24 }
```

## See also

C++ Core Guidelines [11]: F.17: For "in-out" parameters, pass by reference to non-const

JSF December 2005 [8]: AV Rule 117.2: An object should be passed as T& if the function may change the value of the object.

**Rule A8-4-10 (required, design, automated)**  
**A parameter shall be passed by reference if it can't be NULL**

## Rationale

Passing a parameter by pointer suggests that it can be NULL. If it can't be NULL (i.e. it's not optional) it should therefore be passed by reference instead. Only parameters that can be NULL shall be passed by pointer.

Note: The C++ Library Fundamentals TS v2 defines `std::observer_ptr` as a near drop-in replacement for raw pointers that makes it explicit that the object is not owned by the pointer.

Note: `boost::optional` supports reference types, and in C++17 `std::optional` can be used in conjunction with `std::reference_wrapper` (using `std::optional` with a value type would create an undesirable copy of the object)

## Example

```
1 // $Id: A8-4-10.cpp 307966 2018-02-16 16:03:46Z christof.meerwald $
2
3 #include <cstdint>
4 #include <numeric>
5 #include <vector>
6
7 // Non-Compliant: non-optional parameter passed by pointer
8 int32_t Sum(const std::vector<int32_t> *v)
9 {
10     return std::accumulate(v->begin(), v->end(), 0);
11 }
12
13 // Compliant: non-optional parameter passed by reference
14 int32_t Sum(const std::vector<int32_t> &v)
15 {
16     return std::accumulate(v.begin(), v.end(), 0);
17 }
```

## See also

C++ Core Guidelines [11]: F.60: Prefer T\* over T& when "no argument" is a valid option

JSF December 2005 [8]: AV Rule 118: Arguments should be passed via pointers if NULL values are possible.

JSF December 2005 [8]: AV Rule 118.1: An object should be passed as const T\* if its value should not be modified.

JSF December 2005 [8]: AV Rule 118.2: An object should be passed as T\* if its value may be modified.

**Rule A8-4-11 (required, design, automated)**  
**A smart pointer shall only be used as a parameter type if it expresses lifetime semantics**

## Rationale

If the object passed into the function is merely used without affecting the lifetime, it is preferable to pass it by reference or raw pointer instead.

Keeping a copy of a `std::shared_ptr` or moving a `std::unique_ptr` would be examples that affect the lifetime.

Note: When an object whose lifetime is managed by a non-local smart pointer is passed by reference or raw pointer, care needs to be taken that the lifetime of the object doesn't end during the duration of the called function. In the case of a `std::shared_ptr` this can be achieved by keeping a local copy of the `shared_ptr`.

## Exception

A non-owning smart pointer, like `std::observer_ptr` from the C++ Library Fundamentals TS v2, that documents the non-owning property of the parameter does not violate this rule.

## Example

```
1 // $Id: A8-4-11.cpp 307966 2018-02-16 16:03:46Z christof.meerwald $
2
3 #include <cstdint>
4 #include <memory>
5 #include <numeric>
6 #include <vector>
7
8 class A
9 {
10     public:
11         void do_stuff();
12 };
```

```
13
14 // Non-Compliant: passing object as smart pointer
15 void foo(std::shared_ptr<A> a)
16 {
17     if (a)
18     {
19         a->do_stuff();
20     }
21     else
22     {
23         // ...
24     }
25 }
26
27 // Compliant: passing as raw pointer instead
28 void bar(A *a)
29 {
30     if (a != nullptr)
31     {
32         a->do_stuff();
33     }
34     else
35     {
36         // ...
37     }
38 }
39
40
41 class B
42 {
43     public:
44     void add_a(std::shared_ptr<A> a)
45     {
46         m_v.push_back(a);
47     }
48
49     private:
50     std::vector<std::shared_ptr<A>> m_v;
51 };
52
53 // Compliant: storing the shared pointer (affecting lifetime)
54 void bar(B &b, std::shared_ptr<A> a)
55 {
56     b.add_a(a);
57 }
```

## See also

C++ Core Guidelines [11]: R.30: Take smart pointers as parameters only to explicitly express lifetime semantics.

C++ Core Guidelines [11]: R.37: Do not pass a pointer or reference obtained from an aliased smart pointer.

C++ Core Guidelines [11]: F.7: For general use, take T\* or T& arguments rather than smart pointers.

[A18-5-2](#) in section [6.18.5](#)

#### Rule A8-4-12 (required, design, automated)

**A `std::unique_ptr` shall be passed to a function as: (1) a copy to express the function assumes ownership (2) an lvalue reference to express that the function replaces the managed object.**

#### Rationale

Transferring ownership in the (1) case is unconditional. A temporary `std::unique_ptr` is constructed implicitly and move-initialized from the caller's `std::unique_ptr` and then passed to the function. This guarantees that the caller's `std::unique_ptr` object is empty.

Passing an lvalue reference is suggested to be used if a called function is supposed to replace the object managed by the passed `std::unique_ptr`, e.g. call assignment operator or `reset` method. Otherwise, it is recommended to pass an lvalue reference to the underlying object instead, see [A8-4-11](#), [A8-4-10](#).

Note: Passing a const lvalue reference to `std::unique_ptr` does not take ownership and does not allow to replace the managed object. Also, the const qualifier does not apply to the underlying object, but to the smart pointer itself. It is suggested to pass a const lvalue reference to the underlying object instead, see [A8-4-11](#), [A8-4-10](#).

#### Exception

It is allowed to transfer ownership by passing a `std::unique_ptr` by an rvalue reference in case this reference is moved into a `std::unique_ptr` object inside the called function.

#### Example

```
1 // $Id: A8-4-12.cpp 308795 2018-02-23 09:27:03Z michal.szczepankiewicz $
2
3 #include <memory>
4 #include <iostream>
5
6 //compliant, transfers an ownership
7 void Value(std::unique_ptr<int> v) {}
8
9 //compliant, replaces the managed object
10 void Lv1(std::unique_ptr<int>& v)
11 {
12     v.reset();
13 }
14
```

```
15 //non-compliant, does not replace the managed object
16 void Lv2(std::unique_ptr<int>& v) {}
17
18
19 //compliant by exception
20 void Rv1(std::unique_ptr<int>&& r)
21 {
22     std::unique_ptr<int> v(std::move(r));
23 }
24
25 //non-compliant
26 void Rv2(std::unique_ptr<int>&& r) {}
27
28 int main(void)
29 {
30     auto sp = std::make_unique<int>(7);
31     Value(std::move(sp));
32     //sp is empty
33
34     auto sp2 = std::make_unique<int>(9);
35     Rv1(std::move(sp2));
36     //sp2 is empty, because it was moved from in Rv1 function
37
38     auto sp3 = std::make_unique<int>(9);
39     Rv2(std::move(sp3));
40     //sp3 is not empty, because it was not moved from in Rv1 function
41
42     return 0;
43 }
```

## See also

HIC++ v4.0 [9]: 8.2.4: Do not pass `std::unique_ptr` by const reference.

C++ Core Guidelines [11]: R.32: Take a `unique_ptr<widget>` parameter to express that a function assumes ownership of a widget.

C++ Core Guidelines [11]: R.33: Take a `unique_ptr<widget>&` parameter to express that a function reseats the widget.

C++ Core Guidelines [11]: I.11: Never transfer ownership by a raw pointer (T\*) or reference (T&).

### Rule A8-4-13 (required, design, automated)

A `std::shared_ptr` shall be passed to a function as: (1) a copy to express the function shares ownership (2) an lvalue reference to express that the function replaces the managed object (3) a const lvalue reference to express that the function retains a reference count.

## Rationale

Passing a `std::shared_ptr` by value (1) is clear and makes ownership sharing explicit.

Passing an lvalue reference (2) to `std::shared_ptr` is suggested to be used if a called function replaces the managed object on at least one code path, e.g. call assignment operator or `reset` method. Otherwise, it is recommended to pass an lvalue reference to the underlying object instead, see [A8-4-11](#), [A8-4-10](#).

Functions that take a const lvalue reference (3) to `std::shared_ptr` as a parameter are supposed to copy it to another `std::shared_ptr` on at least one code path, otherwise the parameter should be passed by a const lvalue reference to the underlying object instead, see [A8-4-11](#), [A8-4-10](#).

## Example

```
1 // $Id: A8-4-13.cpp 308795 2018-02-23 09:27:03Z michal.szczepankiewicz $
2
3 #include <memory>
4 #include <iostream>
5
6 //compliant, explicit ownership sharing
7 void Value(std::shared_ptr<int> v) {}
8
9 //compliant, replaces the managed object
10 void Lv1(std::shared_ptr<int>& v)
11 {
12     v.reset();
13 }
14
15 //non-compliant, does not replace the managed object
16 //shall be passed by int& so that API that does not
17 //extend lifetime of an object is not polluted
18 //with smart pointers
19 void Lv2(std::shared_ptr<int>& v)
20 {
21     ++(*v);
22 }
23
24 //compliant, shared_ptr copied in the called function
25 void Clv1(const std::shared_ptr<int>& v)
26 {
27     Value(v);
28 }
29
30 //non-compliant, const lvalue reference not copied
31 //to a shared_ptr object on any code path
32 //shall be passed by const int&
33 void Clv2(const std::shared_ptr<int>& v)
34 {
35     std::cout << *v << std::endl;
36 }
```



```
37
38 //non-compliant
39 void Rv1(std::shared_ptr<int>&& r) {}
```

## See also

C++ Core Guidelines [11]: R.34: Take a `shared_ptr<widget>` parameter to express that a function is part owner.

C++ Core Guidelines [11]: R.35: Take a `shared_ptr<widget>&` parameter to express that a function might reseat the shared pointer.

C++ Core Guidelines [11]: R.36: Take a `const shared_ptr<widget>&` parameter to express that it might retain a reference count to the object.

**Rule A8-4-14 (required, design, non-automated)**  
**Interfaces shall be precisely and strongly typed.**

## Rationale

Using precise and strong types in interfaces helps using them correctly.

A large number of parameters of fundamental type (particularly of arithmetic type) can be an indication of bad interface design as it does not make it obvious what the units are, and there is no way for the compiler to warn when parameters are passed in the wrong order (as the types are the same or implicitly convertible).

When several parameters are related, combining the parameters into a separate user-defined type should be considered.

Similarly, a type of pointer to `void` does not provide any type safety and alternatives like a pointer to a common base class or using a (potentially constrained) template parameter should be considered.

## Example

```
1 // $Id: A8-4-14.cpp 326058 2018-07-16 07:52:31Z christof.meerwald $
2
3 #include <cstdint>
4 #include <chrono>
5
6 // Non-compliant: unit of duration not obvious
7 void Sleep(std::uint32_t duration);
8
9 // Compliant: strongly typed
10 void Sleep(std::chrono::seconds duration);
11
12
13 // Non-compliant: list of related parameters with same type
14 void SetAlarm(std::uint32_t year, std::uint32_t month, std::uint32_t day,
15              std::uint32_t hour, std::uint32_t minute, std::uint32_t second);
```

```
16
17 // Compliant: strongly typed
18 void SetAlarm(std::chrono::system_clock::time_point const & when);
```

## See also

C++ Core Guidelines [11]: I.4: Make interfaces precisely and strongly typed

## 6.8.5 Initializers

**Rule A8-5-0 (required, implementation, automated)**  
**All memory shall be initialized before it is read.**

### Rationale

Objects with automatic or dynamic storage duration are default-initialized if no initializer is specified. Default initialization produces indeterminate values for objects of neither class nor array types. Default initialization of array types leads to default initialization of each array element. Reading from indeterminate values may produce undefined behavior.

Thus, all local variables, member variables, or objects allocated dynamically must be explicitly initialized before their values are read, unless they are of class type or array of non-fundamental type. It is recommended practice to initialize all such objects immediately when they are defined.

Note: Zero-initialization will happen before any other initialization for any objects with static or thread-local storage duration. Thus, such objects need not be explicitly initialized.

### Example

```
1 // $Id: A8-5-0.cpp 307536 2018-02-14 12:35:11Z jan.babst $
2 #include <stdint>
3 #include <string>
4
5 static std::int32_t zero; // Compliant - Variable with static storage duration
6                          // is zero-initialized.
7
8 void local()
9 {
10     std::int32_t a;          // No initialization
11     std::int32_t b{};      // Compliant - zero initialization
12
13     b = a;                 // Non-compliant - uninitialized memory read
14     a = zero;             // Compliant - a is zero now
15     b = a;                 // Compliant - read from initialized memory
16
```

```
17     std::string s; // Compliant - default constructor is a called
18     // read from s
19 }
20
21 void dynamic()
22 {
23     // Note: These examples violate A18-5-2
24
25     auto const a = new std::int32_t;           // No initialization
26     auto const b = new std::int32_t{}; // Compliant - zero initialization
27
28     *b = *a; // Non-compliant - uninitialized memory read
29     *a = zero; // Compliant - a is zero now
30     *b = *a; // Compliant - read from initialized memory
31
32     delete b;
33     delete a;
34
35     auto const s =
36         new std::string; // Compliant - default constructor is a called
37     // read from *s
38     delete s;
39 }
40
41 // Members of Bad are default-initialized by the (implicitly generated) default
42 // constructor. Note that this violates A12-1-1.
43 struct Bad
44 {
45     std::int32_t a;
46     std::int32_t b;
47 };
48
49 // Compliant - Members of Good are explicitly initialized.
50 // This also complies to A12-1-1.
51 struct Good
52 {
53     std::int32_t a{0};
54     std::int32_t b{0};
55 };
56
57 void members()
58 {
59     Bad bad; // Default constructor is called, but members a not initialized
60
61     bad.b = bad.a; // Non-compliant - uninitialized memory read
62     bad.a = zero; // Compliant - bad.a is zero now
63     bad.b = bad.a; // Compliant - read from initialized memory
64
65     Good good; // Default constructor is called and initializes members
66
67     std::int32_t x = good.a; // Compliant
```

```
68     std::int32_t y = good.b; // Compliant
69 }
```

## See also

MISRA C++ 2008 [7]: 8-5-1: All variables shall have a defined value before they are used.

HIC++ v4.0 [9]: 8.4.1: Do not access an invalid object or an object with indeterminate value

JSF December 2005 [8]: AV Rule 142: All variables shall be initialized before use.

SEI CERT C++ Coding Standard [10]: EXP53-CPP: Do not read uninitialized memory

C++ Core Guidelines [11]: ES.20: Always initialize an object

ISO/IEC 14882:2014 [3]: 8.5: [dcl.init]

### Rule A8-5-1 (required, implementation, automated)

**In an initialization list, the order of initialization shall be following: (1) virtual base classes in depth and left to right order of the inheritance graph, (2) direct base classes in left to right order of inheritance list, (3) non-static data members in the order they were declared in the class definition.**

## Rationale

To avoid confusion and possible use of uninitialized data members, it is recommended that the initialization list matches the actual initialization order.

Regardless of the order of member initializers in a initialization list, the order of initialization is always:

Virtual base classes in depth and left to right order of the inheritance graph.

Direct non-virtual base classes in left to right order of inheritance list.

Non-static member data in order of declaration in the class definition.

Note that “The order of derivation is relevant only to determine the order of default initialization by constructors and cleanup by destructors.” [C++14 Language Standard [3]]

## Example

```
1 // $Id: A8-5-1.cpp 271696 2017-03-23 09:23:09Z piotr.tanski $
2 #include <cstdint>
3 #include <string>
4 class A
5 {
```

```
6 };
7 class B
8 {
9 };
10 class C : public virtual B, public A
11 {
12     public:
13         C() : B(), A(), s() {} // Compliant
14
15         // C() : A(), B() {} // Non-compliant - incorrect order of initialization
16
17     private:
18         std::string s;
19 };
20 class D
21 {
22 };
23 class E
24 {
25 };
26 class F : public virtual A, public B, public virtual D, public E
27 {
28     public:
29         F() : A(), D(), B(), E(), number1(0), number2(0U) {} // Compliant
30         F(F const& oth)
31             : B(), E(), A(), D(), number1(oth.number1), number2(oth.number2)
32         {
33             } // Non-compliant - incorrect
34             // order of initialization
35
36     private:
37         std::int32_t number1;
38         std::uint8_t number2;
39 };
```

## See also

HIC++ v4.0 [9]:12.4.4 Write members in an initialization list in the order in which they are declared

**Rule M8-5-2 (required, implementation, automated)**  
**Braces shall be used to indicate and match the structure in the non-zero initialization of arrays and structures.**

See MISRA C++ 2008 [7]

**Rule A8-5-2 (required, implementation, automated) Braced-initialization {}, without equals sign, shall be used for variable initialization.**

## Rationale

Braced-initialization using {} braces is simpler and less ambiguous than other forms of initialization. It is also safer, because it does not allow narrowing conversions for numeric values, and it is immune to C++'s most vexing parse.

The use of an equals sign for initialization misleads into thinking that an assignment is taking place, even though it is not. For built-in types like int, the difference is academic, but for user-defined types, it is important to explicitly distinguish initialization from assignment, because different function calls are involved.

Note that most vexing parse is a form of syntactic ambiguity resolution in C++, e.g. "Class c()" could be interpreted either as a variable definition of class "Class" or a function declaration which returns an object of type "Class".

Note that in order to avoid grammar ambiguities, it is highly recommended to use only braced-initialization {} within templates.

## Exception

If a class declares both a constructor taking std::initializer\_list argument and a constructor which invocation will be ignored in favor of std::initializer\_list constructor, this rule is not violated by calling a constructor using () parentheses, see [A8-5-4](#).

## Example

```
1 // $Id: A8-5-2.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdint>
3 #include <initializer_list>
4 void F1() noexcept
5 {
6     std::int32_t x1 =
7         7.9; // Non-compliant - x1 becomes 7 without compilation error
8     // std::int32_t y {7.9}; // Compliant - compilation error, narrowing
9     std::int8_t x2{50}; // Compliant
10    std::int8_t x3 = {50}; // Non-compliant - std::int8_t x3 {50} is equivalent
11                          // and more readable
12    std::int8_t x4 =
13        1.0; // Non-compliant - implicit conversion from double to std::int8_t
14    std::int8_t x5 = 300; // Non-compliant - narrowing occurs implicitly
15    std::int8_t x6(x5); // Non-compliant
16 }
17 class A
18 {
19     public:
20     A(std::int32_t first, std::int32_t second) : x{first}, y{second} {}
21
```

```

22     private:
23         std::int32_t x;
24         std::int32_t y;
25     };
26     struct B
27     {
28         std::int16_t x;
29         std::int16_t y;
30     };
31     class C
32     {
33     public:
34         C(std::int32_t first, std::int32_t second) : x{first}, y{second} {}
35         C(std::initializer_list<std::int32_t> list) : x{0}, y{0} {}
36
37     private:
38         std::int32_t x;
39         std::int32_t y;
40     };
41     void F2() noexcept
42     {
43         A a1{1, 5};           // Compliant - calls constructor of class A
44         A a2 = {1, 5}; // Non-compliant - calls a default constructor of class A
45                          // and not copy constructor or assignment operator.
46         A a3(1, 5);         // Non-compliant
47         B b1{5, 0};        // Compliant - struct members initialization
48         C c1{2, 2};        // Compliant - C(std::initializer_list<std::int32_t>)
49                          // constructor is
50                          // called
51         C c2(2, 2); // Compliant by exception - this is the only way to call
52                   // C(std::int32_t, std::int32_t) constructor
53         C c3{{} }; // Compliant - C(std::initializer_list<std::int32_t>) constructor
54                   // is
55                   // called with an empty initializer_list
56         C c4({2, 2}); // Compliant by exception -
57                   // C(std::initializer_list<std::int32_t>)
58                   // constructor is called
59     };
60     template <typename T, typename U>
61     void F1(T t, U u) noexcept(false)
62     {
63         std::int32_t x = 0;
64         T v1(x); // Non-compliant
65         T v2{x}; // Compliant - v2 is a variable
66         // auto y = T(u); // Non-compliant - is it construction or cast?
67         // Compilation error
68     };
69     void F3() noexcept
70     {
71         F1(0, "abcd"); // Compile-time error, cast from const char* to int
72     }

```

## See also

C++ Core Guidelines [11]: ES.23 Prefer the {} initializer syntax.

C++ Core Guidelines [11]: T.68: Use {} rather than () within templates to avoid ambiguities.

C++ Core Guidelines [11]: ES.64: Use the T{e} notation for construction.

Effective Modern C++ [13]: Item 7. Distinguish between () and {} when creating objects.

**Rule A8-5-3 (required, implementation, automated)**  
**A variable of type auto shall not be initialized using {} or ={} braced-initialization.**

## Rationale

If an initializer of a variable of type auto is enclosed in braces, then the result of type deduction may lead to developer confusion, as the variable initialized using {} or ={} will always be of std::initializer\_list type.

Note that some compilers, e.g. GCC or Clang, can implement this differently - initializing a variable of type auto using {} will deduce an integer type, and initializing using ={} will deduce a std::initializer\_list type. This is desirable type deduction which will be introduced into the C++ Language Standard with C++17.

## Example

```
1 // $Id: A8-5-3.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdlib>
3 #include <initializer_list>
4 void Fn() noexcept
5 {
6     auto x1(10); // Compliant - the auto-declared variable is of type int, but
7                 // not compliant with A8-5-2.
8     auto x2{10}; // Non-compliant - according to C++14 standard the
9                 // auto-declared variable is of type std::initializer_list.
10                // However, it can behave differently on different compilers.
11     auto x3 = 10; // Compliant - the auto-declared variable is of type int, but
12                 // non-compliant with A8-5-2.
13     auto x4 = {10}; // Non-compliant - the auto-declared variable is of type
14                   // std::initializer_list, non-compliant with A8-5-2.
15     std::int8_t x5{10}; // Compliant
16 }
```

## See also

Effective Modern C++ [13]: Item 2. Understand auto type deduction.

Effective Modern C++ [13]: Item 7. Distinguish between () and {} when creating objects.



**Rule A8-5-4 (advisory, implementation, automated)**

If a class has a user-declared constructor that takes a parameter of type `std::initializer_list`, then it shall be the only constructor apart from special member function constructors.

**Rationale**

If an object is initialized using `{}` braced-initialization, the compiler strongly prefers constructor taking parameter of type `std::initializer_list` to other constructors. Thus, if it is defined in the class, it is initially a sole member of the candidate set of the two-phase overload resolution. Only if no viable `std::initializer_list` is found, the rest of constructors are considered in the second overload resolution.

Such a case can be non-intuitive for developers and can lead to reviewers' confusion on which constructor was intended to be called.

If other constructors (besides the `std::initializer_list` one and special member functions) are declared in a class, then it is suggested to use, e.g. the `std::vector<int>({1,1})` syntax instead of `std::vector<int>v{1, 1}`, which makes the intent clear.

**Example**

```
1 // $Id: A8-5-4.cpp 319328 2018-05-15 10:30:25Z michal.szczepankiewicz $
2 #include <cstdlib>
3 #include <initializer_list>
4 #include <vector>
5
6 #include <iostream>
7
8 //non-compliant, there are other constructors
9 //apart from initializer_list one defined
10 class A
11 {
12 public:
13     A() = default;
14     A(std::size_t num1, std::size_t num2) : x{num1}, y{num2} {}
15     A(std::initializer_list<std::size_t> list) : x{list.size()}, y{list.size()} {
16     }
17 private:
18     std::size_t x;
19     std::size_t y;
20 };
21 class B
22 {
23 public:
24     B() = default;
25     B(std::initializer_list<std::size_t> list) : collection{list} {}
26
27 private:
28     std::vector<std::size_t> collection;
```

```
29 };
30
31 void F1() noexcept
32 {
33     A a1{};           // Calls A::A()
34     A a2{};           // Calls A::A(std::initializer_list<std::size_t>)
35     A a3{0, 1};       // Calls A::A(std::initializer_list<std::size_t>), not
                       recommended
36     A a4{{0, 1}};     // Calls A::A(std::initializer_list<std::size_t>), recommended
37     A a5{0, 1}; //    // Calls A::A(std::size_t, std::size_t), compliant with A8-5-2
                       by exception
38 }
39 void F2() noexcept
40 {
41     B b1{};           // Calls B::B()
42     B b2{};           // Calls B::B(std::initializer_list<std::size_t>)
43     B b3{1, 2};       // Calls B::B(std::initializer_list<std::size_t>), not
                       recommended
44     B b4{{1, 2}};     // Calls B::B(std::initializer_list<std::size_t>),
                       recommended
45 }
```

## See also

Effective Modern C++ [13]: Item 7. Distinguish between () and {} when creating objects.

ISO/IEC 14882:2014 [3]: 13.3.1.7: [over.match.list]

## 6.9 Classes

### 6.9.3 Member function

**Rule M9-3-1 (required, implementation, automated)**  
**Const member functions shall not return non-const pointers or references to class-data.**

See MISRA C++ 2008 [7]

Note: This rule applies to smart pointers, too.

Note: “The class-data for a class is all non-static member data and any resources acquired in the constructor or released in the destructor.” [MISRA C++ 2008 [7]]

**Rule A9-3-1 (required, implementation, partially automated)**  
**Member functions shall not return non-const “raw” pointers or references to private or protected data owned by the class.**

## Rationale

By implementing class interfaces with member functions the implementation retains more control over how the object state can be modified and helps to allow a class to be maintained without affecting clients. Returning a handle to data that is owned by the class allows for clients to modify the state of the object without using an interface.

Note that this rule applies to data that are owned by the class (i.e. are class-data). Non-const handles to objects that are shared between different classes may be returned.

See: [Ownership](#).

## Exception

Classes that mimic smart pointers and containers do not violate this rule.

## Example

```
1 // $Id: A9-3-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdint>
3 #include <memory>
4 #include <utility>
5 class A
6 {
7     public:
8         explicit A(std::int32_t number) : x(number) {}
9         // Implementation
10        std::int32_t&
11        GetX() noexcept // Non-compliant - x is a resource owned by the A class
12        {
13            return x;
14        }
15
16    private:
17        std::int32_t x;
18 };
19 void Fn1() noexcept
20 {
21     A a{10};
22     std::int32_t& number = a.GetX();
23     number = 15; // External modification of private class data
24 }
25 class B
26 {
27     public:
28         explicit B(std::shared_ptr<std::int32_t> ptr) : sharedptr(std::move(ptr)) {}
29         // Implementation
30         std::shared_ptr<std::int32_t> GetSharedPtr() const
```

```
31         noexcept // Compliant - sharedptr is a variable being shared between
32                 // instances
33     {
34         return sharedptr;
35     }
36
37 private:
38     std::shared_ptr<std::int32_t> sharedptr;
39 };
40 void Fn2() noexcept
41 {
42     std::shared_ptr<std::int32_t> ptr = std::make_shared<std::int32_t>(10);
43     B b1{ptr};
44     B b2{ptr};
45     *ptr = 50; // External modification of ptr which shared between b1 and b2
46              // instances
47     auto shared = b1.GetSharedPtr();
48     *shared = 100; // External modification of ptr which shared between b1 and
49                  // b2 instances
50 }
51 class C
52 {
53 public:
54     explicit C(std::int32_t number)
55         : ownedptr{std::make_unique<std::int32_t>(number)}
56     {
57     }
58     // Implementation
59     const std::unique_ptr<std::int32_t>& GetOwnedPtr() const
60         noexcept // Non-compliant - only unique_ptr is const, the object that
61                 // it is pointing to is modifiable
62     {
63         return ownedptr;
64     }
65     const std::int32_t& GetData() const noexcept // Compliant
66     {
67         return *ownedptr;
68     }
69
70 private:
71     std::unique_ptr<std::int32_t> ownedptr;
72 };
73 void Fn3() noexcept
74 {
75     C c{10};
76     const std::int32_t& data = c.GetData();
77     // data = 20; // Can not modify data, it is a const reference
78     const std::unique_ptr<std::int32_t>& ptr = c.GetOwnedPtr();
79     *ptr = 20; // Internal data of class C modified
80 }
```

## See also

MISRA C++ 2008 [7]: Rule 9-3-2 Member functions shall not return non-const handles to class-data.

JSF December 2005 [8]: AV Rule 112: Function return values should not obscure resource ownership.

**Rule M9-3-3 (required, implementation, automated)**  
**If a member function can be made static then it shall be made static, otherwise if it can be made const then it shall be made const.**

See MISRA C++ 2008 [7]

Note: Static methods can only modify static members of a class, they are not able to access data of a class instance.

Note: Const methods can only modify static members of a class or mutable-declared members of a class instance.

## See also

C++ Core Guidelines [11]: Con.2: By default, make member functions const.

## 6.9.5 Unions

**Rule A9-5-1 (required, implementation, automated)**  
**Unions shall not be used.**

### Rationale

Unions are not type safe and their usage can be misleading and easily misinterpreted by developers.

### Exception

It is allowed to use tagged unions until `std::variant` is available in the C++ Standard Library (C++17)

### Example

```
1 // $Id: A9-5-1.cpp 305588 2018-01-29 11:07:35Z michal.szczepankiewicz $
2
3 #include <cstdint>
4 // Compliant
5 struct Tagged
6 {
7     enum class TYPE
```

```
8     {
9         UINT,
10        FLOAT
11    };
12    union {
13        uint32_t u;
14        float f;
15    };
16    TYPE which;
17 };
18
19 int main(void)
20 {
21     Tagged un;
22
23     un.u = 12;
24     un.which = Tagged::TYPE::UINT;
25
26     un.u = 3.14f;
27     un.which = Tagged::TYPE::FLOAT;
28
29     return 0;
30 }
```

## See also

MISRA C++ 2008 [7]: M9-5-1: Unions shall not be used

JSF December 2005 [8]: AV Rule 153: Bit-fields shall have explicitly unsigned integral or enumeration types only

C++ Core Guidelines [11]: C.181: Avoid “naked” unions

C++ Core Guidelines [11]: C.182: Use anonymous unions to implement tagged unions

C++ Core Guidelines [11]: Type.7: Avoid naked union: Use variant instead.

## 6.9.6 Bit-fields

**Rule M9-6-1 (required, implementation, non-automated)**  
When the absolute positioning of bits representing a bit-field is required, then the behavior and packing of bit-fields shall be documented.

See MISRA C++ 2008 [7]

**Rule A9-6-1 (required, design, partially automated)**  
**Data types used for interfacing with hardware or conforming to communication protocols shall be trivial, standard-layout and only contain members of types with defined sizes.**

## Rationale

When the layout of data types is important, only those types that have a defined size shall be used (see [A3-9-1](#), this excludes `bool`, `wchar_t`, pointers, and pointers to members). Enumeration types may be used if they have been explicitly declared with an underlying type that has a defined size.

Note: As the use of bit-fields is only allowed for interfacing with hardware or conforming to communication protocols, this restriction on types also applies to bit-fields, see [A9-6-2](#).

Note: The signed exact-width integer types like `std::int16_t` are guaranteed to have a two's complement representation.

## Example

```
1 // $Id: A9-6-1.cpp 319312 2018-05-15 08:29:17Z christof.meerwald $
2 #include <cstdint>
3
4 enum class E1 : std::uint8_t
5 {
6     E11,
7     E12,
8     E13
9 };
10 enum class E2 : std::int16_t
11 {
12     E21,
13     E22,
14     E23
15 };
16 enum class E3
17 {
18     E31,
19     E32,
20     E33
21 };
22 enum E4
23 {
24     E41,
25     E42,
26     E43
27 };
28
29 class C
30 {
```

```
31 public:
32     std::int32_t a : 2;           // Compliant
33     std::uint8_t b : 2U;        // Compliant
34
35     bool c : 1;                 // Non-compliant - the size of bool is implementation defined
36
37     char d : 2;                 // Non-compliant
38     wchar_t e : 2; // Non-compliant - the size of wchar_t is implementation defined
39
40     E1 f1 : 2;                  // Compliant
41     E2 f2 : 2;                  // Compliant
42     E3 f3 : 2; // Non-compliant - E3 enum class does not explicitly define
43                 // underlying type
44     E4 f4 : 2; // Non-compliant - E4 enum does not explicitly define underlying
45                 // type
46 };
47
48 struct D
49 {
50     std::int8_t a;              // Compliant
51
52     bool b;                     // Non-compliant - the size of bool is
53                                 // implementation defined
54
55     std::uint16_t c1 : 8;       // Compliant
56     std::uint16_t c2 : 8;       // Compliant
57 };
58
59 void Fn() noexcept
60 {
61     C c;
62     c.f1 = E1::E11;
63 }
```

## See also

MISRA C++ 2008 [7]: A9-6-2: Bit-fields shall be either bool type or an explicitly unsigned or signed integral type

JSF December 2005 [8]: AV Rule 154: Bit-fields shall have explicitly unsigned integral or enumeration types only

HIC++ v4.0 [9]: 9.2.1: Declare bit-fields with an explicitly unsigned integral or enumeration type

**Rule A9-6-2 (required, design, non-automated) Bit-fields shall be used only when interfacing to hardware or conforming to communication protocols.**



## Rationale

Usage of bit-fields increases code complexity and certain aspects of bit-field manipulation can be error prone and implementation-defined. Hence a bit-field usage is reserved only when interfacing to hardware or conformance to communication protocols

Note: [A9-6-1](#) restricts the types allowed to be used in these contexts.

## See also

JSF December 2005 [8]: AV Rule 155: Bit-fields will not be used to pack data into a word for the sole purpose of saving space.

**Rule M9-6-4 (required, implementation, automated)**  
**Named bit-fields with signed integer type shall have a length of more than one bit.**

See MISRA C++ 2008 [7]

Note: The signed exact-width integer types like `std::int16_t` are guaranteed to have a two's complement representation (see also [A9-6-1](#)). In this case, a single bit signed bit-field contains only a sign bit, thus it can represent values either (-1) or (0). Therefore, to avoid developers' confusion, it is recommended to use unsigned types for single bit bit-fields.

## 6.10 Derived Classes

### 6.10.0 General

**Rule A10-0-1 (required, design, non-automated)**  
**Public inheritance shall be used to implement “is-a” relationship.**

## Rationale

Public and non-public inheritance have a very different application and it shall be used accordingly.

See: [Is-a-relationship](#), [Has-a-relationship](#)

## See also

JSF December 2005 [8]: AV Rule 91: Public inheritance will be used to implement “is-a” relationships.

**Rule A10-0-2 (required, design, non-automated)**  
**Membership or non-public inheritance shall be used to implement “has-a” relationship.**

### Rationale

Public and non-public inheritance have a very different application and it shall be used accordingly.

See: [Is-a-relationship](#), [Has-a-relationship](#)

### See also

JSF December 2005 [8]: AV Rule 93: “has-a” or “is-implemented-in-terms-of” relationships will be modeled through membership or non-public inheritance.

## 6.10.1 Multiple base Classes

**Rule A10-1-1 (required, implementation, automated)**  
**Class shall not be derived from more than one base class which is not an interface class.**

### Rationale

Multiple inheritance exposes derived class to multiple implementations. This makes the code more difficult to maintain.

See: [Diamond-Problem](#), [Interface-Class](#)

### Example

```
1 // $Id: A10-1-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdint>
3 class A
4 {
5     public:
6         void F1() noexcept(false) {}
7
8     private:
9         std::int32_t x{0};
10        std::int32_t y{0};
11 };
12 class B
13 {
14     public:
15         void F2() noexcept(false) {}
16
17     private:
```

```
18     std::int32_t x{0};
19 };
20 class C : public A,
21         public B // Non-compliant - A and B are both not interface classes
22 {
23 };
24 class D
25 {
26     public:
27     virtual ~D() = 0;
28     virtual void F3() noexcept = 0;
29     virtual void F4() noexcept = 0;
30 };
31 class E
32 {
33     public:
34     static constexpr std::int32_t value{10};
35
36     virtual ~E() = 0;
37     virtual void F5() noexcept = 0;
38 };
39 class F : public A,
40         public B,
41         public D,
42         public E // Non-compliant - A and B are both not interface classes
43 {
44 };
45 class G : public A,
46         public D,
47         public E // Compliant - D and E are interface classes
48 {
49 };
```

## See also

JSF December 2005 [8]: AV Rule 88 Multiple inheritance shall only be allowed in the following restricted form: n interfaces plus m private implementations, plus at most one protected implementation.

HIC++ v4.0 [9]: 10.3.1 Ensure that a derived class has at most one base class which is not an interface class.

C++ Core Guidelines [11]: C.135: Use multiple inheritance to represent multiple distinct interfaces.

**Rule M10-1-1 (advisory, implementation, automated)**  
**Classes should not be derived from virtual bases.**

See MISRA C++ 2008 [7]

**Rule M10-1-2 (required, implementation, automated)**  
**A base class shall only be declared virtual if it is used in a diamond hierarchy.**

See MISRA C++ 2008 [7]

**Rule M10-1-3 (required, implementation, automated)**  
**An accessible base class shall not be both virtual and non-virtual in the same hierarchy.**

See MISRA C++ 2008 [7]

### 6.10.2 Member name lookup

**Rule M10-2-1 (advisory, implementation, automated)**  
**All accessible entity names within a multiple inheritance hierarchy should be unique.**

See MISRA C++ 2008 [7]

**Rule A10-2-1 (required, implementation, automated) Non-virtual public or protected member functions shall not be redefined in derived classes.**

#### Rationale

A non-virtual member function specifies an invariant over the hierarchy. It cannot be overridden in derived classes, but it can be hidden by a derived class member (data or function) with the same identifier. The effect of this hiding is to defeat polymorphism by causing an object to behave differently depending on which interface is used to manipulate it, resulting in unnecessary complexity and error.

Note that a maintenance change to a private implementation detail could impact clients of the base class, and often it will be the case that those clients may not be in a position to fix the problem. Therefore, redefinitions of functions which are private in the base class are not affected by this rule.

#### Exception

Redefinition of functions from private inheritance do not violate this rule.

#### Example

```
1 // $Id: A10-2-1.cpp 317123 2018-04-23 08:48:11Z ilya.burylov $
2 class A
3 {
4     public:
5         virtual ~A() = default;
6         void F() noexcept {}
7         virtual void G() noexcept {}
8     private:
9         void H() noexcept {}
10 };
11 class B : public A
12 {
13     public:
14         void
15         F() noexcept {} // Non-compliant - F() function from A class hidden by B class
16
17         void G() noexcept override {} // Compliant - G() function from A class
18                                     // overridden by B class
19     private:
20         void H() noexcept {} // Compliant - H() function is private in A class
21 };
22 class C : private A
23 {
24     public:
25         F() noexcept {} // Compliant by exception - private inheritance
26 };
27 void Fn1(A& object) noexcept
28 {
29     object.F(); // Calls F() function from A
30     object.G(); // Calls G() function from B
31 }
32 void Fn2() noexcept
33 {
34     B b;
35     Fn1(b);
36 }
```

### See also

JSF December 2005 [8]: AV Rule 94 An inherited nonvirtual function shall not be redefined in a derived class.

C++ Core Guidelines [11]: ES.12: Do not reuse names in nested scopes.

### 6.10.3 Virtual functions

**Rule A10-3-1 (required, implementation, automated)**  
**Virtual function declaration shall contain exactly one of the three specifiers:**  
**(1) virtual, (2) override, (3) final.**

## Rationale

Specifying more than one of these three specifiers along with virtual function declaration is redundant and a potential source of errors.

It is recommended to use the virtual specifier only for new virtual function declaration, the override specifier for overrider declaration, and the final specifier for final overrider declaration.

Note that this applies to virtual destructors and virtual operators, too.

## Example

```

1 // $Id: A10-3-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 class A
3 {
4     public:
5         virtual ~A() {} // Compliant
6         virtual void F() noexcept = 0; // Compliant
7         virtual void G() noexcept final = 0; // Non-compliant - virtual final pure
8                                             // function is redundant
9         virtual void
10        H() noexcept final // Non-compliant - function is virtual and final
11        {
12        }
13        virtual void K() noexcept // Compliant
14        {
15        }
16        virtual void J() noexcept {}
17        virtual void M() noexcept // Compliant
18        {
19        }
20        virtual void Z() noexcept // Compliant
21        {
22        }
23        virtual A& operator+=(A const& rhs) noexcept // Compliant
24        {
25            // ...
26            return *this;
27        }
28 };
29 class B : public A
30 {
31     public:
32         ~B() override {} // Compliant
33         virtual void F() noexcept override // Non-compliant - function is specified
34                                             // with virtual and override

```

```

35     {
36     }
37     void K() noexcept override
38         final // Non-compliant - function is specified with override and final
39     {
40     }
41     virtual void M() noexcept // Compliant - violates A10-3-2
42     {
43     }
44     void Z() noexcept override // Compliant
45     {
46     }
47     void J() noexcept // Non-compliant - virtual function but not marked as
48                       // overrider
49     {
50     }
51     A& operator+=(A const& rhs) noexcept override // Compliant - to override
52                                                    // the operator correctly,
53                                                    // its signature needs to be
54                                                    // the same as in the base
55                                                    // class
56     {
57         // ...
58         return *this;
59     }
60 };

```

## See also

C++ Core Guidelines [11]: C.128: Virtual functions should specify exactly one of virtual, override, or final.

### Rule A10-3-2 (required, implementation, automated)

**Each overriding virtual function shall be declared with the override or final specifier.**

## Rationale

Explicit use of the override or final specifier enables the compiler to catch mismatch of types and names between base and derived classes virtual functions.

Note that this rule applies to virtual destructor overriders, too.

Also, note that this rule applies to a pure virtual function which overrides another pure virtual function.

## Example

```

1 // $Id: A10-3-2.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 class A
3 {

```

```
4 public:
5     virtual ~A() {}
6     virtual void F() noexcept = 0;
7     virtual void G() noexcept {}
8     virtual void Z() noexcept {}
9     virtual A& operator+=(A const& oth) = 0;
10 };
11 class B : public A
12 {
13     public:
14     ~B() override {} // Compliant
15     void F() noexcept // Non-compliant
16     {
17     }
18     virtual void G() noexcept // Non-compliant
19     {
20     }
21     void Z() noexcept override // Compliant
22     {
23     }
24     B& operator+=(A const& oth) override // Compliant
25     {
26         return *this;
27     }
28 };
29 class C : public A
30 {
31     public:
32     ~C() {} // Non-compliant
33     void F() noexcept override // Compliant
34     {
35     }
36     void G() noexcept override // Compliant
37     {
38     }
39     void Z() noexcept override // Compliant
40     {
41     }
42     C& operator+=(A const& oth) // Non-compliant
43     {
44         return *this;
45     }
46 };
```

## See also

HIC++ v4.0 [9]: 10.2.1 Use the override special identifier when overriding a virtual function

C++ Core Guidelines [11]: C.128: Virtual functions should specify exactly one of virtual, override, or final.



**Rule A10-3-3 (required, implementation, automated)**  
**Virtual functions shall not be introduced in a final class.**

### Rationale

Declaring a class as final explicitly specifies that the class cannot be inherited. Declaring a virtual function inside a class specifies that the function can be overridden in the inherited class, which is inconsistent.

### Example

```
1 // $Id: A10-3-3.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 class A
3 {
4     public:
5         virtual ~A() = default;
6         virtual void F() noexcept = 0;
7         virtual void G() noexcept {}
8 };
9 class B final : public A
10 {
11     public:
12         void F() noexcept final // Compliant
13         {
14         }
15         void G() noexcept override // Non-compliant
16         {
17         }
18         virtual void H() noexcept = 0; // Non-compliant
19         virtual void Z() noexcept // Non-compliant
20         {
21         }
22 };
```

### See also

HIC++ v4.0 [9]: 9.1.5 Do not introduce virtual functions in a final class.

**Rule A10-3-5 (required, implementation, automated)**  
**A user-defined assignment operator shall not be virtual.**

### Rationale

If an overloaded operator is declared virtual in a base class A, then in its subclasses B and C identical arguments list needs to be provided for the overrides. This allows to call an assignment operator of class B that takes an argument of type C which may lead to undefined behavior.

Note that this rule applies to all assignment operators, as well to copy and move assignment operators.

## Example

```
1 // $Id: A10-3-4.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 class A
3 {
4     public:
5         virtual A& operator=(A const& oth) = 0; // Non-compliant
6         virtual A& operator+=(A const& rhs) = 0; // Non-compliant
7 };
8 class B : public A
9 {
10     public:
11         B& operator=(A const& oth) override // It needs to take an argument of type
12                                             // A& in order to override
13     {
14         return *this;
15     }
16         B& operator+=(A const& oth) override // It needs to take an argument of
17                                             // type A& in order to override
18     {
19         return *this;
20     }
21         B& operator-=(B const& oth) // Compliant
22     {
23         return *this;
24     }
25 };
26 class C : public A
27 {
28     public:
29         C& operator=(A const& oth) override // It needs to take an argument of type
30                                             // A& in order to override
31     {
32         return *this;
33     }
34         C& operator+=(A const& oth) override // It needs to take an argument of
35                                             // type A& in order to override
36     {
37         return *this;
38     }
39         C& operator-=(C const& oth) // Compliant
40     {
41         return *this;
42     }
43 };
44 // class D : public A
45 // {
46 //     public:
47 //     //D& operator=(D const& oth) override // Compile time error - this method
48 //     //does not override because of different
49 //     // signature
50 //     {
```

```
51 //           return *this;
52 //       }
53 //D& operator+=(D const& oth) override // Compile time error - this method
54 //does not override because of different
55 // signature
56 // {
57 //           return *this;
58 //       }
59 //};
60 void Fn() noexcept
61 {
62     B b;
63     C c;
64     b = c; // Calls B::operator= and accepts an argument of type C
65     b += c; // Calls B::operator+= and accepts an argument of type C
66     c = b; // Calls C::operator= and accepts an argument of type B
67     c += b; // Calls C::operator+= and accepts an argument of type B
68     // b -= c; // Compilation error, because of types mismatch. Expected
69     // behavior
70     // c -= b; // Compilation error, because of types mismatch. Expected
71     // behavior
72
73     B b2;
74     C c2;
75     b -= b2;
76     c -= c2;
77 }
```

## See also

none

### Rule M10-3-3 (required, implementation, automated)

**A virtual function shall only be overridden by a pure virtual function if it is itself declared as pure virtual.**

See MISRA C++ 2008 [7]

See: [A10-3-2](#) for pure virtual function overriders declaration.

## 6.10.4 Abstract Classes

### Rule A10-4-1 (advisory, design, non-automated)

**Hierarchies should be based on interface classes.**

## Rationale

Software design that provides common and standardized interfaces without committing to a particular implementation:

eliminates of potential redundancy.

increases software reusability.

hides implementation details.

can be easily extended.

facilitates different objects iteration.

Well-defined interfaces are less prone to require further reworking and maintenance.

See: [Interface-Class](#)

### See also

JSF December 2005 [8]: AV Rule 87: Hierarchies should be based on abstract classes.

C++ Core Guidelines [11]: I.25: Prefer abstract classes as interfaces to class hierarchies.

C++ Core Guidelines [11]: C.122: Use abstract classes as interfaces when complete separation of interface and implementation is needed.

## 6.11 Member access control

### 6.11.0 General

**Rule M11-0-1 (required, implementation, automated)**  
**Member data in non-POD class types shall be private.**

See MISRA C++ 2008 [7]

See: [POD-type](#), [Standard-Layout-Class](#), [Trivially-Copyable](#)

**Rule A11-0-1 (advisory, implementation, automated)**  
**A non-POD type should be defined as class.**

### Rationale

Types that are not POD types are supposed to be defined as class objects, as a class specifier forces the type to provide private access control for all its members by default. This is consistent with developer expectations, because it is expected that a class has its invariant, interface and could provide custom-defined constructors.

### Example

```
1 // $Id: A11-0-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdint>
3 #include <limits>
4 class A // Compliant - A provides user-defined constructors, invariant and
5         // interface
6 {
7     std::int32_t x; // Data member is private by default
8
9     public:
10    static constexpr std::int32_t maxValue =
11        std::numeric_limits<std::int32_t>::max();
12    A() : x(maxValue) {}
13    explicit A(std::int32_t number) : x(number) {}
14    A(A const&) = default;
15    A(A&&) = default;
16    A& operator=(A const&) = default;
17    A& operator=(A&&) = default;
18
19    std::int32_t GetX() const noexcept { return x; }
20    void SetX(std::int32_t number) noexcept { x = number; }
21 };
22 struct B // Non-compliant - non-POD type defined as struct
23 {
24     public:
25     static constexpr std::int32_t maxValue =
26         std::numeric_limits<std::int32_t>::max();
27     B() : x(maxValue) {}
28     explicit B(std::int32_t number) : x(number) {}
29     B(B const&) = default;
30     B(B&&) = default;
31     B& operator=(B const&) = default;
32     B& operator=(B&&) = default;
33
34     std::int32_t GetX() const noexcept { return x; }
35     void SetX(std::int32_t number) noexcept { x = number; }
36
37     private:
38     std::int32_t x; // Need to provide private access specifier for x member
39 };
40 struct C // Compliant - POD type defined as struct
41 {
42     std::int32_t x;
43     std::int32_t y;
44 };
45 class D // Compliant - POD type defined as class, but not compliant with
46         // M11-0-1
47 {
48     public:
49     std::int32_t x;
50     std::int32_t y;
51 };
```

## See also

C++ Core Guidelines [11]: C.2: Use class if the class has an invariant; use struct if the data members can vary independently.

stackoverflow.com [17]: When should you use a class vs a struct in C++?

### Rule A11-0-2 (required, implementation, automated)

**A type defined as struct shall: (1) provide only public data members, (2) not provide any special member functions or methods, (3) not be a base of another struct or class, (4) not inherit from another struct or class.**

## Rationale

This is consistent with developer expectations that a class provides its invariant, interface and encapsulation guarantee, while a struct is only an aggregate without any class-like features.

An example of a struct type is POD type.

See: [POD-type](#).

## Example

```
1 // $Id: A11-0-2.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdint>
3 struct A // Compliant
4 {
5     std::int32_t x;
6     double y;
7 };
8 struct B // Compliant
9 {
10    std::uint8_t x;
11    A a;
12 };
13 struct C // Compliant
14 {
15    float x = 0.0f;
16    std::int32_t y = 0;
17    std::uint8_t z = 0U;
18 };
19 struct D // Non-compliant
20 {
21    public:
22    std::int32_t x;
23
24    protected:
25    std::int32_t y;
26
27    private:
```

```
28     std::int32_t z;
29 };
30 struct E // Non-compliant
31 {
32     public:
33         std::int32_t x;
34         void Fn() noexcept {}
35
36     private:
37         void F1() noexcept(false) {}
38 };
39 struct F : public D // Non-compliant
40 {
41 };
```

## See also

[stackoverflow.com \[17\]: When should you use a class vs a struct in C++?](https://stackoverflow.com/questions/1714487/when-should-you-use-a-class-vs-a-struct-in-c)

### 6.11.3 Friends

**Rule A11-3-1 (required, implementation, automated)**  
Friend declarations shall not be used.

#### Rationale

Friend declarations reduce encapsulation and result in code that is more difficult to maintain.

#### Exception

It is allowed to declare comparison operators as friend functions, see [A13-5-5](#).

#### Example

```
1 // $Id: A11-3-1.cpp 325916 2018-07-13 12:26:22Z christof.meerwald $
2 class A
3 {
4     public:
5         A& operator+=(A const& oth);
6         friend A const operator+(A const& lhs, A const& rhs); // Non-compliant
7 };
8 class B
9 {
10     public:
11         B& operator+=(B const& oth);
12         friend bool operator==(B const& lhs, B const& rhs) // Compliant by exception
13 }
```

```
14         // Implementation
15     }
16 };
17
18 B const operator+(B const& lhs, B const& rhs) // Compliant
19 {
20     // Implementation
21 }
```

## See also

JSF December 2005 [8]: AV Rule 70 A class will have friends only when a function or object requires access to the private elements of the class, but is unable to be a member of the class for logical or efficiency reasons.

HIC++ v4.0 [9]: 11.2.1 Do not use friend declarations.

## 6.12 Special member functions

### 6.12.0 General

#### **Rule A12-0-1 (required, implementation, automated)**

**If a class declares a copy or move operation, or a destructor, either via “=default”, “=delete”, or via a user-provided declaration, then all others of these five special member functions shall be declared as well.**

### Rationale

The semantics of five of the special member functions,

- the copy constructor,
- the move constructor,
- the copy assignment operator,
- the move assignment operator, and the destructor,

are closely related to each other. If, for example, there is need to provide a non-default destructor to release a resource, special handling usually also needs to be added in the copy and move operations to properly handle this resource.

Language rules exist to generate the special member functions under certain conditions. For historical reasons, these language rules are not entirely consistent. For example, the presence of a destructor does not prevent the compiler from generating copy operations. However, it prevents the move operations from being generated. Thus



it is required, in order to maintain consistency and document the programmer's intent, that either none or all of the five functions are declared.

This rule is also known as “the rule of zero”, or “the rule of five” respectively. It is highly recommended to design classes in a way that the rule of zero can be followed.

Note that the default constructor (which is also a special member function) is not part of this rule. The presence of any user-declared constructor inhibits the generation of the default constructor. Therefore, if a user-declared constructor is present, it may be necessary (depending on requirements) to also declare the default constructor. However, the presence of a user-declared default constructor does not inhibit the generation of the other five special member functions. This rule therefore allows to follow the rule of zero when the class only has a user-declared default constructor (and possibly one or more constructors which are not special member functions).

### Example

```
1 // $Id: A12-0-1.cpp 309769 2018-03-01 17:40:29Z jan.babst $
2 #include <string>
3
4 namespace v1
5 {
6 // Class is copyable and moveable via the compiler generated funtions.
7 // Compliant - rule of zero.
8 class A
9 {
10 private:
11 // Member data ...
12 };
13 } // namespace v1
14
15 namespace v2
16 {
17 // New requirement: Destructor needs to be added.
18 // Now the class is no longer moveable, but still copyable. The program
19 // still compiles, but may perform worse.
20 // Non-compliant - Unclear if this was the developers intent.
21 class A
22 {
23 public:
24 ~A()
25 {
26 // ...
27 }
28
29 private:
30 // Member data ...
31 };
32 } // namespace v2
33
34 namespace v3
35 {
```

```
36 // Move operations are brought back by defaulting them.
37 // Copy operations are defaulted since they are no longer generated
38 // (complies to A12-0-1 but will also be a compiler error if they are needed).
39 // Default constructor is defaulted since it is no longer generated
40 // (not required by A12-0-1 but will be a compiler error if it is needed).
41 // Compliant - rule of five. Programmer's intent is clear, class behaves the
42 // same as v1::A.
43 class A
44 {
45     public:
46         A() = default;
47         A(A const&) = default;
48         A(A&&) = default;
49         ~A()
50         {
51             // ...
52         }
53         A& operator=(A const&) = default;
54         A& operator=(A&&) = default;
55
56     private:
57         // Member data ...
58 };
59 } // namespace v3
60
61 // A class with regular (value) semantics.
62 // Compliant - rule of zero.
63 class Simple
64 {
65     public:
66         // User defined constructor, also acts as default constructor.
67         explicit Simple(double d = 0.0, std::string s = "Hello")
68             : d_(d), s_(std::move(s))
69         {
70         }
71
72         // Compiler generated copy c'tor, move c'tor, d'tor, copy assignment, move
73         // assignment.
74
75     private:
76         double d_;
77         std::string s_;
78 };
79
80 // A base class.
81 // Compliant - rule of five.
82 class Base
83 {
84     public:
85         Base(Base const&) = delete; // see also A12-8-6
86         Base(Base&&) = delete; // see also A12-8-6
```

```
87     virtual ~Base() = default; // see also A12-4-1
88     Base& operator=(Base const&) = delete; // see also A12-8-6
89     Base& operator=(Base&&) = delete; // see also A12-8-6
90
91     // Declarations of pure virtual functions ...
92
93     protected:
94         Base() = default; // in order to allow construction of derived objects
95 };
96
97 // A move-only class.
98 // Compliant - rule of five.
99 class MoveOnly
100 {
101     public:
102         MoveOnly();
103         MoveOnly(MoveOnly const&) = delete;
104         MoveOnly(MoveOnly&&) noexcept;
105         ~MoveOnly();
106         MoveOnly& operator=(MoveOnly const&) = delete;
107         MoveOnly& operator=(MoveOnly&&) noexcept;
108
109     private:
110         // ...
111 };
```

## See also

C++ Core Guidelines [11]: C.21: If you define or =delete any default operation, define or =delete them all.

C++ Core Guidelines [11]: C.81: Use =delete when you want to disable default behavior (without wanting an alternative).

**Rule A12-0-2 (required, implementation, partially automated)**  
**Bitwise operations and operations that assume data representation  
in memory shall not be performed on objects.**

## Rationale

Object representations may consist of more than only the declared fields (unless the objects are standard-layout or trivially copyable). Performing bitwise operations on objects may access bits that are not part of the value representation, which may lead to undefined behavior. Operations on objects (e.g. initialization, copying, comparing, setting, accessing) shall be done by dedicated constructors, overloaded operators, accessors or mutators.

## Example

```
1 // $Id: A12-0-2.cpp 305629 2018-01-29 13:29:25Z piotr.serwa $
```

```
2 //
3 #include <cstdint>
4 #include <cstring>
5
6 class A
7 {
8 public:
9     A() = default;
10    A(uint8_t c, uint32_t i, int8_t d, int32_t h) : c(c), i(i), d(d), h(h) {}
11
12    bool operator==(const A& rhs) const noexcept
13    {
14        return c==rhs.c && i==rhs.i && d==rhs.d && h==rhs.h;
15    }
16
17 private:
18     uint8_t c;
19     uint32_t i;
20     int8_t d;
21     int32_t h;
22 };
23
24
25 int main(void)
26 {
27     A noninit;
28
29     //setting field c
30     std::memset(&noninit, 3, 1); //non-compliant
31     //setting field i
32     std::memset(((uint8_t*)&noninit)+sizeof(uint8_t)+3, 5, 1); //non-compliant
33
34     A init(3, 5, 7, 9); //compliant
35
36     if (noninit == init) //compliant
37     {
38
39     }
40
41     if (0 == std::memcmp(&noninit, &init, sizeof(init)))
42     { //non-compliant, includes padding bytes
43
44     }
45
46     return 0;
47 }
```

## See also

JSF December 2005 [8]: AV Rule 156: All the members of a structure (or class) shall be named and shall only be accessed via their names.

JSF December 2005 [8]: AV Rule 210: Algorithms shall not make assumptions concerning how data is represented in memory (e.g. big endian vs. little endian, base class subobject ordering in derived classes, nonstatic data member ordering across access specifiers, etc.)

JSF December 2005 [8]: AV Rule 210.1: Algorithms shall not make assumptions concerning the order of allocation of nonstatic data members separated by an access specifier.

JSF December 2005 [8]: AV Rule 211: Algorithms shall not assume that shorts, ints, longs, floats, doubles or long doubles begin at particular addresses.

SEI CERT C++ Coding Standard [10]: EXP42-C: Do not compare padding data

SEI CERT C++ Coding Standard [10]: EXP62-C: Do not access the bits of an object representation that are not part of the object's value representation

SEI CERT C++ Coding Standard [10]: OOP57-CPP: Prefer special member functions and overloaded operators to C Standard Library functions

## 6.12.1 Constructors

**Rule A12-1-1 (required, implementation, automated)**  
**Constructors shall explicitly initialize all virtual base classes, all direct non-virtual base classes and all non-static data members.**

### Rationale

A constructor of a class is supposed to completely initialize its object. Explicit initialization of all virtual base classes, direct non-virtual base classes and non-static data members reduces the risk of an invalid state after successful construction.

### Example

```
1 // $Id: A12-1-1.cpp 271696 2017-03-23 09:23:09Z piotr.tanski $
2 #include <cstdint>
3 class Base
4 {
5     // Implementation
6 };
7 class VirtualBase
8 {
9 };
10 class A : public virtual VirtualBase, public Base
11 {
12     public:
13     A() : VirtualBase{}, Base{}, i{0}, j{0} // Compliant
14     {
15     }
```

```
16     A(A const& oth)
17         : Base(), j{0}           // Non-compliant - VirtualBase base class and member
18                                   // i not initialized
19     {
20     }
21
22     private:
23         std::int32_t i;
24         std::int32_t j;
25         static std::int32_t k;
26 };
27 std::int32_t A::k{0};
```

## See also

MISRA C++ 2008 [7]: Rule 12-1-2 All constructors of a class should explicitly call a constructor for all of its immediate base classes and all virtual base classes.

HIC++ v4.0 [9]:12.4.2 Ensure that a constructor initializes explicitly all base classes and non-static data members.

JSF December 2005 [8]: AV Rule 71: Calls to an externally visible operation of an object, other than its constructors, shall not be allowed until the object has been fully initialized.

**Rule M12-1-1 (required, implementation, automated)**  
**An object's dynamic type shall not be used from the body of its constructor or destructor.**

See MISRA C++ 2008 [7]

Note: This rule prohibits both direct and indirect usage of object's dynamic type from its constructor or destructor.

## See also

C++ Core Guidelines [11]: C.50: Use a factory function if you need “virtual behavior” during initialization.

**Rule A12-1-2 (required, implementation, automated)**  
**Both NSDMI and a non-static member initializer in a constructor shall not be used in the same type.**

## Rationale

Since 2011 C++ Language Standard it is allowed to initialize a non-static member along with the declaration of the member in the class body using NSDMI (“non-static data member initializer”). To avoid possible confusion which values are actually used,

if any member is initialized by NSDMI or with a constructor, then all others should be initialized the same way.

### Exception

The move and copy constructors are exempt from this rule, because these constructors copy the existing values from other objects.

### Example

```
1 // $Id: A12-1-2.cpp 271696 2017-03-23 09:23:09Z piotr.tanski $
2 #include <cstdint>
3 #include <utility>
4 class A
5 {
6     public:
7         A() : i1{0}, i2{0} // Compliant - i1 and i2 are initialized by the
8                         // constructor only. Not compliant with A12-1-3
9         {
10        }
11        // Implementation
12
13     private:
14         std::int32_t i1;
15         std::int32_t i2;
16 };
17 class B
18 {
19     public:
20        // Implementation
21
22     private:
23         std::int32_t i1{0};
24         std::int32_t i2{
25             0}; // Compliant - both i1 and i2 are initialized by NSDMI only
26 };
27 class C
28 {
29     public:
30         C() : i2{0} // Non-compliant - i1 is initialized by NSDMI, i2 is in
31                 // member in member initializer list
32         {
33        }
34         C(C const& oth) : i1{oth.i1}, i2{oth.i2} // Compliant by exception
35         {
36        }
37         C(C&& oth)
38             : i1{std::move(oth.i1)},
39             i2{std::move(oth.i2)} // Compliant by exception
40         {
41        }
42        // Implementation
```

```
43
44 private:
45     std::int32_t i1{0};
46     std::int32_t i2;
47 };
```

## See also

HIC++ v4.0 [9]:12.4.3 Do not specify both an NSDMI and a member initializer in a constructor for the same non static member

**Rule A12-1-3 (required, implementation, automated)**  
**If all user-defined constructors of a class initialize data members with constant values that are the same across all constructors, then data members shall be initialized using NSDMI instead.**

## Rationale

Using NSDMI lets the compiler to generate the function that can be more efficient than a user-defined constructor that initializes data member variables with pre-defined constant values.

## Example

```
1 // $Id: A12-1-3.cpp 291949 2017-10-19 21:26:22Z michal.szczepankiewicz $
2 #include <cstdint>
3 #include <string>
4 class A
5 {
6     public:
7         A() : x(0), y(0.0F), str() // Non-compliant
8         {
9         }
10        // ...
11
12    private:
13        std::int32_t x;
14        float y;
15        std::string str;
16 };
17 class B
18 {
19     public:
20        // ...
21
22    private:
23        std::int32_t x = 0; // Compliant
24        float y = 0.0F; // Compliant
25        std::string str = ""; // Compliant
26};
```



```

27 class C
28 {
29     public:
30         C() : C(0, 0.0F, decltype(str)()) // Compliant
31         {
32         }
33         C(std::int32_t i, float f, std::string s) : x(i), y(f), str(s) // Compliant
34         {
35         }
36         // ...
37
38     private:
39         std::int32_t x =
40             0; // Non-compliant - there's a constructor that initializes C
41                // class with user input
42         float y = 0.0F; // Non-compliant - there's a constructor that initializes C
43                // class with user input
44         std::string str = ""; // Non-compliant - there's a constructor that
45                // initializes C class with user input
46 };

```

## See also

C++ Core Guidelines [11]: C.45: Don't define a default constructor that only initializes data members; use in-class member initializers instead.

**Rule A12-1-4 (required, implementation, automated)**  
**All constructors that are callable with a single argument of fundamental type shall be declared explicit.**

## Rationale

The explicit keyword prevents the constructor from being used to implicitly convert a fundamental type to the class type.

See: [Fundamental-Types](#).

## Example

```

1 // $Id: A12-1-4.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdint>
3 class A
4 {
5     public:
6         explicit A(std::int32_t number) : x(number) {} // Compliant
7         A(A const&) = default;
8         A(A&&) = default;
9         A& operator=(A const&) = default;
10        A& operator=(A&&) = default;
11

```

```
12 private:
13     std::int32_t x;
14 };
15 class B
16 {
17     public:
18     B(std::int32_t number) : x(number) {} // Non-compliant
19     B(B const&) = default;
20     B(B&&) = default;
21     B& operator=(B const&) = default;
22     B& operator=(B&&) = default;
23
24     private:
25     std::int32_t x;
26 };
27 void F1(A a) noexcept
28 {
29 }
30 void F2(B b) noexcept
31 {
32 }
33 void F3() noexcept
34 {
35     F1(A(10));
36     // f1(10); // Compilation error - because of explicit constructor it is not
37     // possible to implicitly convert integer
38     // to type of class A
39     F2(B(20));
40     F2(20); // No compilation error - implicit conversion occurs
41 }
```

## See also

MISRA C++ 2008 [7]: Rule 12-1-3 (Required) All constructors that are callable with a single argument of fundamental type shall be declared explicit.

**Rule A12-1-5 (required, implementation, partially automated)**  
**Common class initialization for non-constant members shall be done by a delegating constructor.**

## Rationale

Common initialization of non-constant members in a delegating constructor prevents from code repetition, accidental differences and maintenance problems.

## Example

```
1 // $Id: A12-1-5.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2
3 #include <cstdint>
```

```
4
5 class A
6 {
7     public:
8         // Compliant
9         A(std::int32_t x, std::int32_t y) : x(x + 8), y(y) {}
10        explicit A(std::int32_t x) : A(x, 0) {}
11
12    private:
13        std::int32_t x;
14        std::int32_t y;
15 };
16
17 class B
18 {
19     public:
20         // Non-compliant
21         B(std::int32_t x, std::int32_t y) : x(x + 8), y(y) {}
22        explicit B(std::int32_t x) : x(x + 8), y(0) {}
23
24    private:
25        std::int32_t x;
26        std::int32_t y;
27 };
```

## See also

HIC++ v4.0 [9]: 12.4.5: Use delegating constructors to reduce code duplication.

C++ Core Guidelines [11]: C.51: Use delegating constructors to represent common actions for all constructors of a class.

**Rule A12-1-6 (required, implementation, automated)**  
**Derived classes that do not need further explicit initialization and require all the constructors from the base class shall use inheriting constructors.**

## Rationale

Reimplementing constructors that do not need further initialization is error-prone and may lead to using wrong base class constructor accidentally.

## Example

```
1 // $Id: A12-1-6.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2
3 #include <cstdlibint>
4
5 class A
6 {
7     public:
8         A(std::int32_t x, std::int32_t y) : x(x + 8), y(y) {}
```

```
9     explicit A(std::int32_t x) : A(x, 0) {}
10
11     private:
12         std::int32_t x;
13         std::int32_t y;
14 };
15
16 // Non-compliant
17 class B : public A
18 {
19     public:
20         B(std::int32_t x, std::int32_t y) : A(x, y) {}
21         explicit B(std::int32_t x) : A(x) {}
22 };
23
24 // Compliant
25 class C : public A
26 {
27     public:
28         using A::A;
29 };
```

## See also

C++ Core Guidelines [11]: C.52: Use inheriting constructors to import constructors into a derived class that does not need further explicit initialization.

### 6.12.4 Destructors

**Rule A12-4-1 (required, implementation, automated)**  
**Destructor of a base class shall be public virtual, public override or protected non-virtual.**

#### Rationale

If an object is supposed to be destroyed through a pointer or reference to its base class, the destructor in the base class needs to be virtual. Otherwise, destructors for derived types will not be invoked.

Note that if it is prohibited to destroy an object through a pointer or reference to its base class, the destructor in the base class is supposed to be protected.

#### Example

```
1 // $Id: A12-4-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 class A
3 {
4     public:
5         ~A() // Non-compliant
```

```
6     {
7     }
8 };
9 class B : public A
10 {
11 };
12 class C
13 {
14     public:
15     virtual ~C() // Compliant
16     {
17     }
18 };
19 class D : public C
20 {
21 };
22 class E
23 {
24     protected:
25     ~E(); // Compliant
26 };
27 class F : public E
28 {
29 };
30 void F1(A* obj1, C* obj2)
31 {
32     // ...
33     delete obj1; // Only destructor of class A will be invoked
34     delete obj2; // Both destructors of D and C will be invoked
35 }
36 void F2()
37 {
38     A* a = new B;
39     C* c = new D;
40     F1(a, c);
41 }
```

## See also

JSF December 2005 [8]: AV Rule 78 All base classes with a virtual function shall define a virtual destructor.

HIC++ v4.0 [9]: 12.2.1 Declare virtual, private or protected the destructor of a type used as a base class.

SEI CERT C++ Coding Standard [10]: OOP52-CPP: Do not delete a polymorphic object without a virtual destructor.

C++ Core Guidelines [11]: C.35: A base class destructor should be either public and virtual, or protected and nonvirtual.

C++ Core Guidelines [11]: Discussion: Make base class destructors public and virtual, or protected and nonvirtual.

**Rule A12-4-2 (advisory, implementation, automated)**  
**If a public destructor of a class is non-virtual, then the class should be declared final.**

## Rationale

If a public destructor of a class is non-virtual (i.e. no virtual, override or final keyword), then the class is not supposed to be used as a base class in inheritance hierarchy.

Note that a destructor needs to be virtual in a base class in order to correctly destroy an instance of a derived class through a pointer to the base class.

## Example

```
1 // $Id: A12-4-2.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 class A // Non-compliant - class A should not be used as a base class because
3         // its destructor is not virtual, but it is
4         // not declared final
5 {
6     public:
7         A() = default;
8         A(A const&) = default;
9         A(A&&) = default;
10        A& operator=(A const&) = default;
11        A& operator=(A&&) = default;
12        ~A() = default; // Public non-virtual destructor
13 };
14 class B final // Compliant - class B can not be used as a base class, because
15              // it is declared final, and           it should not be derived
16              // because its destructor is           not virtual
17 {
18     public:
19         B() = default;
20         B(B const&) = default;
21         B(B&&) = default;
22         B& operator=(B const&) = default;
23         B& operator=(B&&) = default;
24         ~B() = default; // Public non-virtual destructor
25 };
26 class C // Compliant - class C is not final, and its destructor is virtual. It
27         // can be used as a base class
28 {
29     public:
30         C() = default;
31         C(C const&) = default;
32         C(C&&) = default;
33         C& operator=(C const&) = default;
34         C& operator=(C&&) = default;
```

```
35     virtual ~C() = default; // Public virtual destructor
36 };
37 class AA : public A
38 {
39 };
40 // class BA : public B // Compilation error - can not derive from final base
41 // class B
42 //{
43 //};
44 class CA : public C
45 {
46 };
47 void Fn() noexcept
48 {
49     AA obj1;
50     CA obj2;
51     A& ref1 = obj1;
52     C& ref2 = obj2;
53
54     ref1.~A(); // Calls A::~~A() only
55     ref2.~C(); // Calls both CA::~~CA() and C::~~C()
56 }
```

## See also

SEI CERT C++ Coding Standard [10]: OOP52-CPP: Do not delete a polymorphic object without a virtual destructor.

## 6.12.6 Initialization

**Rule A12-6-1 (required, implementation, automated)**  
**All class data members that are initialized by the constructor shall be initialized using member initializers.**

### Rationale

Using the constructor's member initializers is more efficient than assigning a copy of passed values to data members in the constructor's body. Also, it supports the programmer to prevent "data usage before initialization" errors.

Note that if a data member is already initialized using member initializer, then changing its value in the constructor's body does not violate this rule.

### Example

```
1 // $Id: A12-6-1.cpp 271696 2017-03-23 09:23:09Z piotr.tanski $
2 #include <cstdlib>
3 #include <string>
4 class A
```

```
5 {
6 public:
7     A(std::int32_t n, std::string s) : number{n}, str{s} // Compliant
8     {
9     }
10    // Implementation
11
12 private:
13     std::int32_t number;
14     std::string str;
15 };
16 class B
17 {
18 public:
19     B(std::int32_t n, std::string s) // Non-compliant - no member initializers
20     {
21         number = n;
22         str = s;
23     }
24    // Implementation
25
26 private:
27     std::int32_t number;
28     std::string str;
29 };
30 class C
31 {
32 public:
33     C(std::int32_t n, std::string s) : number{n}, str{s} // Compliant
34     {
35         n += 1; // This does not violate the rule
36         str.erase(str.begin(),
37                 str.begin() + 1); // This does not violate the rule
38     }
39    // Implementation
40
41 private:
42     std::int32_t number;
43     std::string str;
44 };
```

## See also

C++ Core Guidelines [11]: C.49: Prefer initialization to assignment in constructors.

## 6.12.7 Construction and destructions



**Rule A12-7-1 (required, implementation, automated)**

**If the behavior of a user-defined special member function is identical to implicitly defined special member function, then it shall be defined “=default” or be left undefined.**

**Rationale**

If a user-defined version of a special member function is the same as would be provided by the compiler, it will be less error prone and more maintainable to replace it with “=default” definition or leave it undefined to let the compiler define it implicitly.

Note that this rule applies to all special member functions of a class.

See: [Implicitly-Defined-Default-Constructor](#), [Implicitly-Defined-Copy-Constructor](#), [Implicitly-Defined-Move-Constructor](#), [Implicitly-Defined-Copy-Assignment-Operator](#), [Implicitly-Defined-Move-Assignment-Operator](#), [Implicitly-Defined-Destructor](#)

**Example**

```

1 // $Id: A12-7-1.cpp 271715 2017-03-23 10:13:51Z piotr.tanski $
2 #include <stdint>
3 #include <utility>
4 class A
5 {
6     public:
7         A() : x(0), y(0) {} // Compliant
8         A(std::int32_t first, std::int32_t second) : x(first), y(second) {} // Compliant
9
10
11 // anyway, such
12 // a constructor
13 // cannot be
14 // defaulted.
15 A(const A& oth)
16     : x(oth.x),
17       y(oth.y) // Non-compliant - equivalent to the implicitly
18               // defined copy constructor
19 {
20 }
21 A(A&& oth)
22     : x(std::move(oth.x)),
23       y(std::move(
24         oth.y)) // Non-compliant - equivalent to the implicitly
25               // defined move constructor
26 {
27 }
28 ~A() // Non-compliant - equivalent to the implicitly defined destructor
29 {
30 }

```

```

31 private:
32     std::int32_t x;
33     std::int32_t y;
34 };
35 class B
36 {
37 public:
38     B() {} // Non-compliant - x and y are not initialized
39           // should be replaced with: B() : x{0}, y{0} {}
40     B(std::int32_t first, std::int32_t second) : x(first), y(second) {} // Compliant
41
42     B(const B&) =
43         default; // Compliant - equivalent to the copy constructor of class A
44     B(B&&) =
45         default; // Compliant - equivalent to the move constructor of class A
46     ~B() = default; // Compliant - equivalent to the destructor of class A
47
48 private:
49     std::int32_t x;
50     std::int32_t y;
51 };
52 class C
53 {
54 public:
55     C() = default; // Compliant
56     C(const C&) = default; // Compliant
57     C(C&&) = default; // Compliant
58 };
59 class D
60 {
61 public:
62     D() : ptr(nullptr) {} // Compliant - this is not equivalent to what the
63                           // implicitly defined default constructor would do
64     D(C* p) : ptr(p) {} // Compliant
65     D(const D&) = default; // Shallow copy will be performed, user-defined copy
66                           // constructor is needed to perform deep copy on ptr variable
67     D(D&&) = default; // ptr variable will be moved, so ptr will still point to
68                       // the same object
69     ~D() = default; // ptr will not be deleted, the user-defined destructor is
70                     // needed to delete allocated memory
71
72 private:
73     C* ptr;
74 };
75 class E // Compliant - special member functions definitions are not needed as
76         // class E uses only implicit definitions
77 {
78 };

```

## See also

HIC++ v4.0 [9]: 12.5.2 Define special members =default if the behavior is equivalent.

C++ Core Guidelines [11]: C.80: Use =default if you have to be explicit about using the default semantics.

## 6.12.8 Copying and moving class objects

**Rule A12-8-1 (required, implementation, automated)**  
**Move and copy constructors shall move and respectively copy base classes and data members of a class, without any side effects.**

### Rationale

It is expected behavior that the move/copy constructors are only used to move/copy the object of the class type and possibly set moved-from object to a valid state.

Move and copy constructors of an object are frequently called by STL algorithms and containers, so they are not supposed to provide any performance overhead or side effects that could affect moving or copying the object.

Note: Class members that are not essential for a class invariant may not need to be copied (e.g. caches, debug information).

### Example

```

1 // $Id: A12-8-1.cpp 303582 2018-01-11 13:42:56Z michal.szczepankiewicz $
2 #include <cstdint>
3 #include <utility>
4 class A
5 {
6     public:
7         // Implementation
8         A(A const& oth) : x(oth.x) // Compliant
9         {
10            }
11
12     private:
13         std::int32_t x;
14 };
15 class B
16 {
17     public:
18         // Implementation
19         B(B&& oth) : ptr(std::move(oth.ptr)) // Compliant
20         {
21             oth.ptr = nullptr; // Compliant - this is not a side-effect, in this
22                               // case it is essential to leave moved-from object
23                               // in a valid state, otherwise double deletion will

```

```
24                                     // occur.
25     }
26     ~B() { delete ptr; }
27
28     private:
29         std::int32_t* ptr;
30 };
31 class C
32 {
33     public:
34         // Implementation
35         C(C const& oth) : x(oth.x)
36         {
37             // ...
38             x = x % 2; // Non-compliant - unrelated side-effect
39         }
40
41     private:
42         std::int32_t x;
43 };
44
45 class D
46 {
47     public:
48         explicit D(std::uint32_t a) : a(a), noOfModifications(0) {}
49         D(const D& d) : D(d.a) {} //compliant, not copying the debug information about number of
50         // modifications
51         void SetA(std::uint32_t aa)
52         {
53             ++noOfModifications;
54             a = aa;
55         }
56         std::uint32_t GetA() const noexcept
57         {
58             return a;
59         }
60     private:
61         std::uint32_t a;
62         std::uint64_t noOfModifications;
63 };
```

## See also

MISRA C++ 2008 [7]: Rule 12-8-1 A copy constructor shall only initialize its base classes and the nonstatic members of the class of which it is a member.

HIC++ v4.0 [9]: 12.5.3 Ensure that a user defined move/copy constructor only moves/copies base and member objects.

JSF December 2005 [8]: AV Rule 77: A copy constructor shall copy all data members and bases that affect the class invariant (a data element representing a cache, for example, would not need to be copied).

**Rule A12-8-2 (advisory, implementation, automated) User-defined copy and move assignment operators should use user-defined no-throw swap function.**

## Rationale

Using a non-throwing swap operation in the copy and move assignment operators helps to achieve Strong Exception Safety. Each assignment operator is also simplified because it does not require check for assignment to itself.

## Example

```
1 // $Id: A12-8-2.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <stdint>
3 #include <utility>
4 class A
5 {
6     public:
7     A(const A& oth)
8     {
9         // ...
10    }
11    A(A&& oth) noexcept
12    {
13        // ...
14    }
15    A& operator=(const A& oth) & // Compliant
16    {
17        A tmp(oth);
18        Swap(*this, tmp);
19        return *this;
20    }
21    A& operator=(A&& oth) & noexcept // Compliant
22    {
23        A tmp(std::move(oth));
24        Swap(*this, tmp);
25        return *this;
26    }
27    static void Swap(A& lhs, A& rhs) noexcept
28    {
29        std::swap(lhs.ptr1, rhs.ptr1);
30        std::swap(lhs.ptr2, rhs.ptr2);
31    }
32
33    private:
34    std::int32_t* ptr1;
```

```
35     std::int32_t* ptr2;
36 };
37 class B
38 {
39     public:
40     B& operator=(const B& oth) & // Non-compliant
41     {
42         if (this != &oth)
43         {
44             ptr1 = new std::int32_t(*oth.ptr1);
45             ptr2 = new std::int32_t(
46                 *oth.ptr2); // Exception thrown here results in
47                             // a memory leak of ptr1
48         }
49
50         return *this;
51     }
52     B& operator=(B&& oth) & noexcept // Non-compliant
53     {
54         if (this != &oth)
55         {
56             ptr1 = std::move(oth.ptr1);
57             ptr2 = std::move(oth.ptr2);
58             oth.ptr1 = nullptr;
59             oth.ptr2 = nullptr;
60         }
61
62         return *this;
63     }
64
65     private:
66     std::int32_t* ptr1;
67     std::int32_t* ptr2;
68 };
```

## See also

HIC++ v4.0 [9]: 12.5.6 Use an atomic, non-throwing swap operation to implement the copy and move assignment operators

**Rule A12-8-3 (required, implementation, partially automated)**  
**Moved-from object shall not be read-accessed.**

## Rationale

Except in rare circumstances, an object will be left in an unspecified state after its values has been moved into another object. Accessing data members of such object may result in abnormal behavior and portability concerns.

## Exception

It is permitted to access internals of a moved-from object if it is guaranteed to be left in a well-specified state.

The following Standard Template Library functions are guaranteed to leave the moved-from object in a well-specified state:

move construction, move assignment, “converting” move construction and “converting” move assignment of `std::unique_ptr` type

move construction, move assignment, “converting” move construction, “converting” move assignment of `std::shared_ptr` type

move construction and move assignment from a `std::unique_ptr` of `std::shared_ptr` type

move construction, move assignment, “converting” move construction and “converting” move assignment of `std::weak_ptr` type

`std::move()` of `std::basic_ios` type

move constructor and move assignment of `std::basic_filebuf`

type move constructor and move assignment of `std::thread` type

move constructor and move assignment of `std::unique_lock` type

move constructor and move assignment of `std::shared_lock` type

move constructor and move assignment of `std::promise` type

move constructor and move assignment of `std::future` type

move construction, move assignment, “converting” move construction and “converting” move assignment of `std::shared_future` type

move constructor and move assignment of `std::packaged_task` type

## Example

```
1 // $Id: A12-8-3.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdlib>
3 #include <iostream>
4 #include <memory>
5 #include <string>
6 void F1()
7 {
8     std::string s1{"string"};
9     std::string s2{std::move(s1)};
10    // ...
11    std::cout << s1 << "\n"; // Non-compliant - s1 does not contain "string"
12                           // value after move operation
13 }
14 void F2()
```

```

15 {
16     std::unique_ptr<std::int32_t> ptr1 = std::make_unique<std::int32_t>(0);
17     std::unique_ptr<std::int32_t> ptr2{std::move(ptr1)};
18     std::cout << ptr1.get() << std::endl; // Compliant by exception - move
19                                         // construction of std::unique_ptr
20                                         // leaves moved-from object in a
21                                         // well-specified state
22 }

```

## See also

SEI CERT C++ [10]: EXP63-CPP Do not rely on the value of a moved-from object.

**Rule A12-8-4 (required, implementation, automated)**  
**Move constructor shall not initialize its class members and base classes using copy semantics.**

## Rationale

Data members or base classes initialization in move constructor needs to be done with move semantics. Move construction is an optimization strategy and the copy-initialization for data members and base classes will have negative impact on the program's performance, as well as it does not meet developer expectations.

## Exception

In move constructor, copy initialization for data members of scalar types does not violate this rule.

See: [Scalar-Types](#).

## Example

```

1 // $Id: A12-8-4.cpp 271696 2017-03-23 09:23:09Z piotr.tanski $
2 #include <cstdint>
3 #include <string>
4 class A
5 {
6     public:
7         // ...
8         A(A&& oth)
9             : x(std::move(oth.x)),           // Compliant
10              s(std::move(oth.s))           // Compliant
11     {
12     }
13
14     private:
15         std::int32_t x;
16         std::string s;
17 };

```



```
18 class B
19 {
20     public:
21         // ...
22         B(B&& oth)
23             : x(oth.x),           // Compliant by exception, std::int32_t is of scalar
24                                   // type
25             s(oth.s)           // Non-compliant
26     {
27     }
28
29     private:
30         std::int32_t x;
31         std::string s;
32 };
33 class C
34 {
35     public:
36         // ...
37         C(C&& oth)
38             : x(oth.x),           // Compliant by exception
39             s(std::move(oth.s))  // Compliant
40     {
41     }
42
43     private:
44         std::int32_t x = 0;
45         std::string s = "Default string";
46 };
```

## See also

SEI CERT C++ [10]: OOP11-CPP Do not copy-initialize members or base classes from a move constructor.

**Rule A12-8-5 (required, implementation, automated)**  
**A copy assignment and a move assignment operators shall handle self-assignment.**

## Rationale

User-defined copy assignment operator and move assignment operator need to prevent self-assignment, so the operation will not leave the object in an indeterminate state. If the given parameter is the same object as the local object, destroying object-local resources will invalidate them. It violates the copy/move assignment postconditions.

Note that STL containers assume that self-assignment of an object is correctly handled. Otherwise it may lead to unexpected behavior of an STL container.

Self-assignment problem can also be solved using swap operators. See rule: [A12-8-2](#).

### Example

```

1 // $Id: A12-8-5.cpp 271773 2017-03-23 13:16:53Z piotr.tanski $
2 #include <cstdint>
3 #include <stdexcept>
4 struct A
5 {
6     std::int32_t number;
7     std::int32_t* ptr;
8     // Implementation
9 };
10 class B
11 {
12     public:
13     // ...
14     B& operator=(B const& oth) // Non-compliant
15     {
16         i = oth.i;
17         delete aPtr;
18
19         try
20         {
21             aPtr = new A(*oth.aPtr); // If this is the self-copy case, then
22                                     // the oth.a_ptr is already deleted
23         }
24         catch (std::bad_alloc&)
25         {
26             aPtr = nullptr;
27         }
28
29         return *this;
30     }
31
32     private:
33     std::int16_t i = 0;
34     A* aPtr = nullptr;
35 };
36 class C
37 {
38     public:
39     C& operator=(C const& oth) // Compliant
40     {
41         if (this != &oth)
42         {
43             A* tmpPtr = new A(*oth.aPtr);
44
45             i = oth.i;
46             delete aPtr;
47             aPtr = tmpPtr;
48         }

```

```

49     return *this;
50 }
51 C&& operator=(C&& oth) // Compliant
52 {
53     if (this != &oth)
54     {
55         A* tmpPtr = new A{std::move(*oth.aPtr)};
56
57         i = oth.i;
58         delete aPtr;
59         aPtr = tmpPtr;
60     }
61     return *this;
62 }
63
64 private:
65     std::int16_t i = 0;
66     A* aPtr = nullptr;
67 };

```

## See also

SEI CERT C++ [10]: OOP54-CPP Gracefully handle self-assignment.

C++ Core Guidelines [11]: C.62: Make copy assignment safe for self-assignment.

**Rule A12-8-6 (required, implementation, automated)**  
**Copy and move constructors and copy assignment and move assignment operators shall be declared protected or defined “=delete” in base class.**

## Rationale

Invoking copy or move constructor or copy assignment or move assignment operator from the top of a class hierarchy bypasses the underlying implementations. This results in “slicing” where only the base sub-objects being copied or moved.

## Example

```

1 // $Id: A12-8-6.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <memory>
3 #include <utility>
4 #include <vector>
5 class A // Abstract base class
6 {
7     public:
8         A() = default;
9         A(A const&) = default; // Non-compliant
10        A(A&&) = default; // Non-compliant
11        virtual ~A() = 0;
12        A&& operator=(A const&) = default; // Non-compliant

```

```

13     A& operator=(A&&) = default;           // Non-compliant
14 };
15 class B : public A
16 {
17 };
18 class C // Abstract base class
19 {
20     public:
21         C() = default;
22         virtual ~C() = 0;
23
24     protected:
25         C(C const&) = default;           // Compliant
26         C(C&&) = default;               // Compliant
27         C& operator=(C const&) = default; // Compliant
28         C& operator=(C&&) = default;     // Compliant
29 };
30 class D : public C
31 {
32 };
33 class E // Abstract base class
34 {
35     public:
36         E() = default;
37         virtual ~E() = 0;
38         E(E const&) = delete;           // Compliant
39         E(E&&) = delete;                // Compliant
40         E& operator=(E const&) = delete; // Compliant
41         E& operator=(E&&) = delete;     // Compliant
42 };
43 class F : public E
44 {
45 };
46 class G // Non-abstract base class
47 {
48     public:
49         G() = default;
50         virtual ~G() = default;
51         G(G const&) = default;         // Non-compliant
52         G(G&&) = default;              // Non-compliant
53         G& operator=(G const&) = default; // Non-compliant
54         G& operator=(G&&) = default;     // Non-compliant
55 };
56 class H : public G
57 {
58 };
59 void Fn1() noexcept
60 {
61     B obj1;
62     B obj2;
63     A* ptr1 = &obj1;

```

```

64     A* ptr2 = &obj2;
65     *ptr1 = *ptr2; // Partial assignment only
66     *ptr1 = std::move(*ptr2); // Partial move only
67     D obj3;
68     D obj4;
69     C* ptr3 = &obj3;
70     C* ptr4 = &obj4;
71     // *ptr3 = *ptr4; // Compilation error - copy assignment operator of class C
72     // is protected
73     // *ptr3 = std::move(*ptr4); // Compilation error - move assignment operator
74     // of class C is protected
75     F obj5;
76     F obj6;
77     E* ptr5 = &obj5;
78     E* ptr6 = &obj6;
79     // *ptr5 = *ptr6; // Compilation error - use of deleted copy assignment
80     // operator
81     // *ptr5 = std::move(*ptr6); // Compilation error - use of deleted move
82     // assignment operator
83     H obj7;
84     H obj8;
85     G* ptr7 = &obj7;
86     G* ptr8 = &obj8;
87     *ptr7 = *ptr8; // Partial assignment only
88     *ptr7 = std::move(*ptr8); // Partial move only
89 }
90 class I // Non-abstract base class
91 {
92     public:
93         I() = default;
94         ~I() = default;
95
96     protected:
97         I(I const&) = default; // Compliant
98         I(I&&) = default; // Compliant
99         I& operator=(I const&) = default; // Compliant
100        I& operator=(I&&) = default; // Compliant
101 };
102 class J : public I
103 {
104     public:
105         J() = default;
106         ~J() = default;
107         J(J const&) = default;
108         J(J&&) = default;
109         J& operator=(J const&) = default;
110         J& operator=(J&&) = default;
111 };
112 void Fn2() noexcept
113 {
114     std::vector<I> v1;

```



```

115 // v1.push_back(J{}); // Compilation-error on calling a deleted move
116 // constructor of I class, slicing does not occur
117 // v1.push_back(I{}); // Compilation-error on calling a deleted move
118 // constructor of I class
119
120 std::vector<J> v2;
121 v2.push_back(J{}); // No compilation error
122
123 std::vector<std::unique_ptr<I>> v3;
124 v3.push_back(std::unique_ptr<I>{}); // No compilation error
125 v3.push_back(std::make_unique<I>()); // No compilation error
126 v3.push_back(std::make_unique<J>()); // No compilation error
127 v3.emplace_back(); // No compilation error
128 }

```

## See also

MISRA C++ 2008 [7]: Rule 12-8-2 The copy assignment operator shall be declared protected or private in an abstract class.

HIC++ v4.0 [9]: 12.5.8 Make the copy assignment operator of an abstract class protected or define it =delete.

C++ Core Guidelines [11]: C.67: A base class should suppress copying, and provide a virtual clone instead if "copying" is desired.

C++ Core Guidelines [11]: C.81: Use =delete when you want to disable default behavior (without wanting an alternative).

**Rule A12-8-7 (advisory, implementation, automated)**  
**Assignment operators should be declared with the ref-qualifier &.**

## Rationale

User declared assignment operators differ from built-in operators in a way that they accept rvalues as parameters, which is confusing. Adding & to the function declaration prohibits rvalue parameters and ensures that all of the calls can only be made on lvalue objects, which results with the same behavior as for built-in types.

Note that this rule applies to all assignment operators, e.g. operator=(), operator\*=(), operator+=.

## Example

```

1 // $Id: A12-8-7.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <cstdint>
3 class A
4 {
5     public:
6     A() = default;
7     A& operator*=(std::int32_t i) // Non-compliant

```

```
8     {
9         // ...
10        return *this;
11    }
12 };
13 A F1() noexcept
14 {
15     return A{};
16 }
17 class B
18 {
19     public:
20     B() = default;
21     B& operator*=(std::int32_t) & // Compliant
22     {
23         // ...
24         return *this;
25     }
26 };
27 B F2() noexcept
28 {
29     return B{};
30 }
31 std::int32_t F3() noexcept
32 {
33     return 1;
34 }
35 int main(int, char**)
36 {
37     F1() *= 10; // Temporary result of f1() multiplied by 10. No compile-time
38                // error.
39     ;
40     // f2() *= 10; // Compile-time error due to ref-qualifier
41     ;
42     // f3() *= 10; // Compile-time error on built-in type
43 }
```

## See also

HIC++ v4.0 [9]: 12.5.7 Declare assignment operators with the ref-qualifier &.  
cppreference.com [16]: Assignment operators.

## 6.13 Overloading

### 6.13.1 Overloadable declarations



**Rule A13-1-2 (required, implementation, automated)**  
**User defined suffixes of the user defined literal operators shall start with underscore followed by one or more letters.**

### Rationale

Suffixes that do not begin with the underscore character are reserved for operators provided by the standard library.

### Example

```
1 // $Id: A13-1-2.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 constexpr long double operator"" _m(long double meters) // Compliant
3 {
4     // Implementation
5     return meters;
6 }
7 constexpr long double operator"" _kg(long double kilograms) // Compliant
8 {
9     // Implementation
10    return kilograms;
11 }
12 constexpr long double operator"" m(long double meters) // Non-compliant
13 {
14     // Implementation
15     return meters;
16 }
17 constexpr long double operator"" kilograms(
18     long double kilograms) // Non-compliant
19 {
20     // Implementation
21     return kilograms;
22 }
23 void Fn()
24 {
25     long double weight = 20.0_kg;
26     long double distance = 204.8_m;
27 }
```

### See also

none

**Rule A13-1-3 (required, implementation, automated)**  
**User defined literals operators shall only perform conversion of passed parameters.**

## Rationale

It is expected behavior that the user-defined literals operators are only used to convert passed parameters to the type of declared return value. User-defined literals are not supposed to provide any other side-effects.

## Example

```
// $Id: A13-1-3.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <cstdlib>
#include <iostream>
struct Cube
{
    unsigned long long int volume;
    constexpr explicit Cube(unsigned long long int v) : volume(v) {}
};
constexpr Cube operator"" _m3(unsigned long long int volume)
{
    return Cube(volume); // Compliant
}
struct Temperature
{
    unsigned long long int kelvins;
    constexpr explicit Temperature(unsigned long long int k) : kelvins(k) {}
};
constexpr Temperature operator"" _K(unsigned long long int kelvins)
{
    return Temperature(kelvins); // Compliant
}
static void SumDistances(std::int32_t distance)
{
    static std::int32_t overallDistance = 0;
    overallDistance += distance;
}
struct Distance
{
    long double kilometers;
    explicit Distance(long double kms) : kilometers(kms) {}
};
Distance operator"" _m(long double meters)
{
    SumDistances(meters); // Non-compliant - function has a side-effect
    return Distance(meters / 1000);
}
void operator"" _print(const char* str)
{
    std::cout << str << '\n'; // Non-compliant - user-defined literal operator
                                // does not perform conversion and has a
                                // side-effect
}
40
41
}
```

## See also

none

### 6.13.2 Declaration matching

**Rule A13-2-1 (required, implementation, automated)**  
**An assignment operator shall return a reference to “this”.**

#### Rationale

Returning a type “T&” from an assignment operator is consistent with the C++ Standard Library.

#### Example

```
// $Id: A13-2-1.cpp 271687 2017-03-23 08:57:35Z piotr.tanski $
class A
{
public:
// ...
A& operator=(const A&) & // Compliant
{
// ...
return *this;
}
};
12
class B
{
public:
// ...
const B& operator=(const B&) & // Non-compliant - violating consistency
// with standard types
{
// ...
return *this;
}
};
24
class C
{
public:
// ...
C operator=(const C&) & // Non-compliant
{
// ...
return *this;
}
};
35
```

```
class D
{
public:
// ...
D* operator=(const D&) & // Non-compliant
{
// ...
return this;
}
};
```

### See also

HIC++ v4.0 [9]: 13.2.2 Ensure that the return type of an overloaded binary operator matches the built-in counterparts.

C++ Core Guidelines [11]: F.47: Return T& from assignment operators.

**Rule A13-2-2 (required, implementation, automated)**  
**A binary arithmetic operator and a bitwise operator shall return a “prvalue”.**

### Rationale

Returning a type “T” from binary arithmetic and bitwise operators is consistent with the C++ Standard Library.

See: [prvalue](#).

### Example

```
// $Id: A13-2-2.cpp 271687 2017-03-23 08:57:35Z piotr.tanski $
#include <cstdlib>
3
class A
{
};
7
A operator+(A const&, A const&) noexcept // Compliant
{
return A{};
}
std::int32_t operator/(A const&, A const&) noexcept // Compliant
{
return 0;
}
A operator&(A const&, A const&)noexcept // Compliant
{
return A{};
}
const A operator-(A const&, std::int32_t) noexcept // Non-compliant
{
```

```
return A{};
}
A* operator|(A const&, A const&) noexcept // Non-compliant
{
return new A{};
}
```

## See also

HIC++ v4.0 [9]: 13.2.2 Ensure that the return type of an overloaded binary operator matches the built-in counterparts.

**Rule A13-2-3 (required, implementation, automated)**  
**A relational operator shall return a boolean value.**

## Rationale

Returning a type “bool” from a relational operator is consistent with the C++ Standard Library.

## Example

```
// $Id: A13-2-3.cpp 271687 2017-03-23 08:57:35Z piotr.tanski $
#include <cstdint>
3
class A
{
};
7
bool operator==(A const&, A const&) noexcept // Compliant
{
return true;
}
bool operator<(A const&, A const&) noexcept // Compliant
{
return false;
}
bool operator!=(A const& lhs, A const& rhs) noexcept // Compliant
{
return !(operator==(lhs, rhs));
}
std::int32_t operator>(A const&, A const&) noexcept // Non-compliant
{
return -1;
}
A operator>=(A const&, A const&) noexcept // Non-compliant
{
return A{};
}
const A& operator<=(A const& lhs, A const& rhs) noexcept // Non-compliant
```

```
{  
return lhs;  
}
```

### See also

HIC++ v4.0 [9]: 13.2.2 Ensure that the return type of an overloaded binary operator matches the built-in counterparts.

### 6.13.3 Overload resolution

**Rule A13-3-1 (required, implementation, automated)**  
**A function that contains “forwarding reference” as its argument shall not be overloaded.**

#### Rationale

A template parameter that is declared “T&&” (Scott Meters called it a “universal reference”, while C++ Language Standard calls it a “forwarding reference”) will deduce for any type. Overloading functions with “forwarding reference” argument may lead to developer’s confusion on which function will be called.

#### Exception

Declaring an overloading function that takes a “forwarding reference” parameter to be “=delete” does not violate this rule.

Declaring a “forwarding constructor” that is constrained (via SFINAE) to not match any other overloads also does not violate this rule, see [A14-5-1](#).

#### Example

```
// $Id: A13-3-1.cpp 309903 2018-03-02 12:54:18Z christof.meerwald $  
#include <cstdlib>  
template <typename T>  
void F1(T&& t) noexcept(false)  
{  
}  
void F1(  
std::int32_t&& t) noexcept // Non-compliant - overloading a function with  
                          // forwarding reference  
{  
}  
template <typename T>  
void F2(T&& t) noexcept(false)  
{  
}  
void F2(std::int32_t&) = delete; // Compliant by exception
```

17

```

class A
{
public:
// Compliant by exception, constrained to not match copy/move ctors
template<typename T,
23         std::enable_if_t<! std::is_same<std::remove_cv_t<std::
        remove_reference_t<T>>, A>::value> * = nullptr>
A(T &&value);
};
26
int main(int, char**)
{
std::int32_t x = 0;
30     F1(x); // Calls f1(T&&) with T = int&
F1(+x); // Calls f1(std::int32_t&&)
F1(0); // Calls f1(std::int32_t&&)
F1(0U); // Calls f1(T&&) with T = unsigned int
F2(0); // Calls f2(T&&) with T = int
// f2(x); // Compilation error, the overloading function is deleted
}

```

## See also

HIC++ v4.0 [9]: 13.1.2 If a member of a set of callable functions includes a universal reference parameter, ensure that one appears in the same position for all other members.

Effective Modern C++ [13]: Item 26. Avoid overloading on universal references.

## 6.13.5 Overloaded operators

**Rule A13-5-1 (required, implementation, automated)**  
**If “operator[]” is to be overloaded with a non-const version, const version shall also be implemented.**

### Rationale

A non-const overload of the subscript operator allows an object to be modified, by returning a reference to member data, but it does not allow reading from const objects. The const version of “operator[]” needs to be implemented to ensure that the operator can be invoked on a const object.

Note that one can provide a const version of operator[] (to support read-only access to elements), but without a non-const version.

### Example

```

// $Id: A13-5-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <cstdint>

```

```

class Container1
{
public:
std::int32_t& operator[](
std::int32_t index) // Compliant - non-const version
{
return container[index];
}
std::int32_t operator[](
std::int32_t index) const // Compliant - const version
{
return container[index];
}
16
private:
static constexpr std::int32_t maxSize = 10;
std::int32_t container[maxSize];
};
void Fn() noexcept
{
Container1 c1;
std::int32_t e = c1[0]; // Non-const version called
25     c1[0] = 20; // Non-const version called
Container1 const c2{};
e = c2[0]; // Const version called
// c2[0] = 20; // Compilation error
}
class Container2 // Non-compliant - only non-const version of operator[]
31     // implemented
{
public:
std::int32_t& operator[](std::int32_t index) { return container[index]; }
35
private:
static constexpr std::int32_t maxSize = 10;
std::int32_t container[maxSize];
};

```

## See also

HIC++ v4.0 [9]: 13.2.4 When overloading the subscript operator (operator[]) implement both const and non-const versions.

**Rule A13-5-2 (required, implementation, automated)**  
**All user-defined conversion operators shall be defined explicit.**

## Rationale

Without explicit keyword, a single user defined conversion can be invoked in a standard conversion sequence, which can lead to accidental errors.



## Example

```
// $Id: A13-5-2.cpp 303121 2018-01-09 09:03:52Z michal.szczepankiewicz $
class A
{
public:
explicit A(double d) : d(d) {}
explicit operator double() const { return d; } // Compliant
private:
double d;
};
10
int main(void)
{
A a{3.1415926535897932384626433832795028841971693993751058209749445923078};
14
double tmp1{a};
// float tmp2{a}; //compilation error instead of warning, prevents from data
// precision loss
18
return 0;
}
```

## See also

HIC++ v4.0 [9]: 12.1.1: Do not declare implicit user defined conversions.

**Rule A13-5-3 (advisory, implementation, automated)**  
**User-defined conversion operators should not be used.**

## Rationale

Explicitly named conversions using dedicated member function eliminate any potential errors that can arise if the type conversion operators have to be used.

If using conversion operators is fundamental in an application domain, see [A13-5-2](#).

## Example

```
// $Id: A13-5-3.cpp 305629 2018-01-29 13:29:25Z piotr.serwa $
#include <iostream>
3
class Complex
{
public:
Complex (double r, double i = 0.0) : re(r), im(i) {}
explicit operator double() const noexcept { return re; }
double AsDouble() const noexcept { return re; }
private:
double re;
double im;
```

```
};  
14  
int main(void)  
{  
  Complex c(2.0f);  
18  
19      std::cout << (double) c << std::endl; //compliant with A13-5-2, non-compliant with A13-5-3  
  
  std::cout << c.AsDouble() << std::endl; //compliant  
21  
  return 0;  
}
```

## See also

JSF December 2005 [8]: AV Rule 177: User-defined conversion functions should be avoided.

C++ Core Guidelines [11]: C.164: Avoid conversion operators.

**Rule A13-5-4 (required, implementation, automated)**  
**If two opposite operators are defined, one shall be defined in terms of the other.**

## Rationale

Defining one operator in terms of the other simplifies maintenance and prevents from accidental errors during code development.

Note: Completeness of relational operators can be achieved by implementing just `operator==` and `operator<` and using namespace `rel_ops`.

## Example

```
// $Id: A13-5-4.cpp 328319 2018-08-03 14:08:42Z christof.meerwald $  
#include <cstdint>  
3  
// non-compliant  
class A  
{  
  public:  
8      explicit A(std::uint32_t d) : d(d) {}  
9  
10     friend bool operator==(A const & lhs, A const & rhs) noexcept  
11     {  
12         return lhs.d == rhs.d;  
13     }  
14     friend bool operator!=(A const & lhs, A const & rhs) noexcept  
15     {  
16         return lhs.d != rhs.d;  
17     }  
}
```

```
18
private:
std::uint32_t d;
};
22
// compliant
class B
{
public:
explicit B(std::uint32_t d) : d(d) {}
28
    friend bool operator==(B const & lhs, B const & rhs) noexcept
30    {
31        return lhs.d == rhs.d;
32    }
33
    friend bool operator!=(B const & lhs, B const & rhs) noexcept
34    {
35        return !(lhs == rhs);
36    }
private:
std::uint32_t d;
};
```

### See also

JSF December 2005 [8]: AV Rule 85: When two operators are opposites (such as == and !=), both will be defined and one will be defined in terms of the other.

**Rule A13-5-5 (required, implementation, automated)**  
**Comparison operators shall be non-member functions with identical parameter types and noexcept.**

### Rationale

Any asymmetric behavior for comparison functions can be confusing. In order to achieve fully symmetric treatment, comparison functions need to be defined as non-member functions, as the implicit object parameter of a member function does not allow user-defined conversions to be applied (but the right hand side would).

Since comparison is a fundamental operation, it should never throw an exception.

Note: This rule applies to ==, !=, <, <=, >, and >=

Note: Declaring a comparison operator as a friend allows it to access internal data similar to a member function and is allowed by exception in rule [A11-3-1](#).

### Example

```
// $Id: A13-5-5.cpp 325916 2018-07-13 12:26:22Z christof.meerwald $
#include <cstdint>
```

```
3
class A
{
public:
explicit A(std::uint32_t d)
: m_d(d)
{}
10
11     bool operator==(A const & rhs) const // Non-compliant: member, not noexcept
12     {
13         return m_d == rhs.m_d;
14     }
15
private:
std::uint32_t m_d;
};
19
class C
{
public:
operator A() const;
};
25
void Foo(A const & a, C const & c)
{
a == c; // asymmetric as "a == c" compiles, but "c == a" doesn't compile
}
30
31
class B
{
public:
explicit B(std::uint32_t d)
: m_d(d)
{}
38
39     Compliant: non-member, identical parameter types, noexcept friend bool operator
40     ==(B const & lhs, B const & rhs) noexcept
41     {
42         return lhs.m_d == rhs.m_d;
43     }
44
private:
std::uint32_t m_d;
};
48
class D
{
public:
operator B() const;
};
```

54

```
void Bar(B const & b, D const & d)
{
  b == d;
  d == b;
}
```

## See also

C++ Core Guidelines [11]: C.86: Make == symmetric with respect to operand types and noexcept

### 6.13.6 Build-in operators

**Rule A13-6-1 (required, implementation, automated)**  
**Digit sequences separators ' shall only be used as follows: (1) for decimal, every 3 digits, (2) for hexadecimal, every 2 digits, (3) for binary, every 4 digits.**

#### Rationale

Since C++14 Language Standard it is allowed (optionally) to separate any two digits in digit sequences with separator '. However, to meet developer expectations, usage of separator in integer and floating-point digit sequences should be unified:

for decimal values, separator can be placed every 3 digits, e.g. 3'000'000,  
3.141'592'653

for hexadecimal values, separator can be placed every 2 digits, e.g.  
0xFF'FF'FF'FF

for binary values, separator can be placed every 4 digits, e.g. 0b1001'1101'0010

#### Example

```
// $Id: A13-6-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <cstdint>
void Fn() noexcept
{
  5     std::uint32_t decimal1      = 3'000'000;      // Compliant
  6     std::uint32_t decimal2      = 4'500;          // Compliant
  7     std::uint32_t decimal3      = 54'00'30;       // Non-compliant
  8     float decimal4 = 3.141'592'653;               // Compliant
  9     float decimal5 = 3.1'4159'265'3;             // Non-compliant
 10     std::uint32_t hex1 = 0xFF'FF'FF'FF;           // Compliant
 11     std::uint32_t hex2 = 0xFAB'1'FFFFFF;         // Non-compliant
 12     std::uint8_t binary1 =      0b1001'0011;     // Compliant
std::uint8_t binary2 = 0b10'00'10'01; // Non-compliant
}
```

## See also

ISO 26262-6 [5]: 8.4.4 e) readability and comprehensibility

## 6.14 Templates

### 6.14.0 General

#### 6.14.1 Template parameters

**Rule A14-1-1 (advisory, implementation, non-automated)**  
**A template should check if a specific template argument is suitable for this template.**

### Rationale

If a template class or function requires specific characteristics from a template type (e.g. if it is move constructible, copyable, etc.), then it needs to check whether the type matches the requirements to detect possible faults. The goal of this rule is to ensure that a template defines all of the preconditions that a template argument needs to fulfill without having any information about the specific class.

This can be achieved in compile time using `static_assert` assertion.

### Example

```
// $Id: A14-1-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <utility>
class A
{
public:
A() = default;
~A() = default;
A(A const&) = delete;
A& operator=(A const&) = delete;
A(A&&) = delete;
A& operator=(A&&) = delete;
};
class B
{
public:
B() = default;
B(B const&) = default;
B& operator=(B const&) = default;
B(B&&) = default;
B& operator=(B&&) = default;
};
template <typename T>
```

```

void F1(T const& obj) noexcept(false)
{
    static_assert(
        std::is_copy_constructible<T>(),
        "Given template type is not copy constructible."); // Compliant
}
template <typename T>
class C
{
    // Compliant
    static_assert(std::is_trivially_copy_constructible<T>(),
        34         "Given template type is not trivially copy constructible.");
    35
    // Compliant
    static_assert(std::is_trivially_move_constructible<T>(),
        38         "Given template type is not trivially move constructible.");
    39
    // Compliant
    static_assert(std::is_trivially_copy_assignable<T>(),
        42         "Given template type is not trivially copy assignable.");
    43
    // Compliant
    static_assert(std::is_trivially_move_assignable<T>(),
        46         "Given template type is not trivially move assignable.");
    47
public:
    C() = default;
    C(C const&) = default;
    C& operator=(C const&) = default;
    C(C&&) = default;
    C& operator=(C&&) = default;
54
private:
    T c;
};
template <typename T>
class D
{
public:
    D() = default;
    63     D(D const&) = default; // Non-compliant - T may not be copyable
    D& operator=(D const&) = default; // Non-compliant - T may not be copyable
    65     D(D&&) = default; // Non-compliant - T may not be movable
    D& operator=(D&&) = default; // Non-compliant - T may not be movable
67
private:
    T d;
};
void F2() noexcept
{
    A a;

```

```
B b;  
// f1<A>(a); // Class A is not copy constructible, compile-time error  
// occurs  
F1<B>(b); // Class B is copy constructible  
// C<A> c1; // Class A can not be used for template class C, compile-time  
// error occurs  
C<B> c2; // Class B can be used for template class C  
D<A> d1;  
// D<A> d2 = d1; // Class D can not be copied, because class A is not  
// copyable, compile-time error occurs  
// D<A> d3 = std::move(d1); // Class D can not be moved, because class A is  
// not movable, compile-time error occurs  
D<B> d4;  
D<B> d5 = d4;  
D<B> d6 = std::move(d4);  
}
```

### See also

JSF December 2005 [8]: AV Rule 103: Constraint checks should be applied to template arguments.

C++ Core Guidelines [11]: T.150: Check that a class matches a concept using `static_assert`.

## 6.14.5 Template declarations

**Rule A14-5-1 (required, implementation, automated)**  
**A template constructor shall not participate in overload resolution for a single argument of the enclosing class type.**

### Rationale

A template constructor is never a copy or move constructor and therefore doesn't prevent the implicit definition of a copy or move constructor even if the template constructor looks similar and might easily be confused.

At the same time, copy or move operations do not necessarily only use a copy or move constructor, but go through the normal overload resolution process to find the best matching function to use.

This can cause confusion in the following cases:

- a template constructor that looks like a copy/move constructor is not selected for a copy/move operation because the compiler has generated an implicit copy/move constructor as well

- a template constructor is selected in preference over a copy/move constructor because the template constructor is a better match



To avoid these confusing situations, template constructors shall not participate in overload resolution for a single argument of the enclosing class type to avoid a template constructor being selected for a copy/move operation. It also makes it clear that the constructor is not a copy/move constructor and that it does not prevent the implicit generation of copy/move constructors.

### Example

```
// $Id: A14-5-1.cpp 309903 2018-03-02 12:54:18Z christof.meerwald $
#include <cstdint>
#include <type_traits>
4
class A
{
public:
// Compliant: template constructor does not participate in overload
9 // resolution for copy/move operations
template<typename T,
11     std::enable_if_t<! std::is_same<std::remove_cv_t<T>, A>::value> * = nullptr>
A(const T &value)
: m_value { value }
{ }
15
private:
std::int32_t m_value;
};
19
void Foo(A const &a)
{
A myA { a }; // will use the implicit copy ctor, not the template converting
           ctor
23
A a2 { 2 }; // will use the template converting ctor
}
26
class B
{
public:
B(const B &) = default;
B(B &&) = default;
32
// Compliant: forwarding constructor does not participate in overload
34 // resolution for copy/move operations
template<typename T,
36     std::enable_if_t<! std::is_same<std::remove_cv_t<std::
remove_reference_t<T>>, B>::value> * = nullptr>
B(T &&value);
};
39
void Bar(B b)
{
```

```
B myB { b }; // will use the copy ctor, not the forwarding ctor
}
44
class C
{
public:
C(const C &) = default;
C(C &&) = default;
50
// Non-Compliant: unconstrained template constructor
template<typename T>
C(T &);
};
55
void Bar(C c)
{
C myC { c }; // will use template ctor instead of copy ctor
}
```

## See also

MISRA C++ 2008 [7]: M14-5-2: A copy constructor shall be declared when there is a template constructor with a single parameter that is a generic parameter.

**Rule A14-5-2 (advisory, design, partially-automated)**  
**Class members that are not dependent on template class parameters should be defined in a separate base class.**

## Rationale

Having non-dependent members in a class template can lead to unnecessary template instantiations and potential code bloat. It is therefore preferred to move those members to a non-dependent base class so they can be used without any template instantiation.

## Example

```
// $Id: A14-5-2.cpp 323444 2018-06-22 14:38:18Z christof.meerwald $
#include <cstdlib>
3
template<typename T>
class A
{
public:
enum State // Non-Compliant: member doesn't depend on template parameter
{
State1,
State2
};
13
State GetState();
```

```
};  
16  
class B_Base  
{  
public:  
enum State // Compliant: not a member of a class template  
{  
State1,  
State2  
};  
};  
26  
template<typename T>  
class B : B_Base  
{  
public:  
State GetState();  
};
```

### See also

C++ Core Guidelines [11]: T.62: Place non-dependent class template members in a non-templated base class

#### Rule A14-5-3 (advisory, design, automated)

**A non-member generic operator shall only be declared in a namespace that does not contain class (struct) type, enum type or union type declarations.**

### Rationale

Argument-dependent lookup (ADL) adds additional associated namespaces to the set of scopes searched when lookup is performed for the names of called functions. A generic operator found in one of these additional namespaces would be added to the overload set and chosen by overload resolution. ADL is complicated by several possible use forms for operators (via function calls and via expression, operators can be declared as members and as non-members) and lookup in those cases is different, which is likely to be inconsistent with developer expectation.

Generic operator is a non-member operator template that can be called without explicit template arguments and has at least one generic parameter. A template type parameter *T* is a generic parameter if, in the function declaration, it has the (possibly cv-qualified) form of *T*, or *T* & or *T* &&.

### Example

```
// $Id: A14-5-3.cpp $  
#include <cstdint>  
3  
template<typename T>
```

```
class B
{
public:
bool operator+( long rhs );
9
void f()
{
*this + 10;
}
};
15
namespace NS1
{
class A {};
19
template<typename T>
bool operator+( T, std::int32_t ); // Non-Compliant: a member of namespace
22                                     // with other declarations
}
24
namespace NS2
{
void g();
28
template<typename T>
bool operator+( T, std::int32_t ); // Compliant: a member of namespace
31                                     // with declarations of functions only
}
33
template class B<NS1::A>; // NS1::operator+ will be used in function B::f()
35                                     // instead of B::operator+
```

## See also

MISRA C++ 2008 [7]: M14-5-1: A non-member generic function shall only be declared in a namespace that contains only operator declarations.

**Rule M14-5-3 (required, implementation, automated)**  
A copy assignment operator shall be declared when there is a template assignment operator with a parameter that is a generic parameter.

See MISRA C++ 2008 [7]

### 6.14.6 Name resolution

**Rule M14-6-1 (required, implementation, automated)**

In a class template with a dependent base, any name that may be found in that dependent base shall be referred to using a qualified-id or this->.

See MISRA C++ 2008 [7]

### 6.14.7 Template instantiation and specialization

**Rule A14-7-1 (required, implementation, automated)**

A type used as a template argument shall provide all members that are used by the template.

#### Rationale

If a type used as a template argument does not provide all the members used by the template, the instantiation of the template will result in an ill-formed program. It is not clear for developer whether the template should be used with the type.

#### Example

```
// $Id: A14-7-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <cstdint>
class A
{
public:
void SetProperty(std::int32_t x) noexcept { property = x; }
void DoSomething() noexcept {}
8
private:
std::int32_t property;
};
struct B
{
};
class C
{
public:
void DoSomething() noexcept {}
};
template <typename T>
class D
{
public:
void F1() {}
void F2()
{
T t;
```

```
t.SetProperty(0);
}
void F3()
{
  T t;
  t.DoSomething();
}
};
36
void Fn() noexcept
{
  D<A> d1; // Compliant - struct A provides all needed members
  d1.F1();
  d1.F2();
  d1.F3();
43
  D<B> d2; // Non-compliant - struct B does not provide needed members
  d2.F1();
  // d2.f2(); // Compilation error - no 'property' in struct B
  // d2.f3(); // Compilation error - no member named 'doSomething' in struct
  // B
49
  D<C> d3; // Non-compliant - struct C does not provide property
  d3.F1();
  // d3.F2(); // Compilation error - no property in struct C
  d3.F3();
}
```

## See also

MISRA C++ 2008 [7]: Rule 14-7-2 (Required) For any given template specialization, an explicit instantiation of the template with the template arguments used in the specialization shall not render the program ill-formed.

**Rule A14-7-2 (required, implementation, automated)**  
Template specialization shall be declared in the same file (1) as the primary template (2) as a user-defined type, for which the specialization is declared.

## Rationale

It is undefined behavior, when a compiler sees the (partial or explicit) template specialization after it already has instantiated the primary or less specialized template. Moreover, the case (2) allows compile-time interfaces to be extensible, as developers can safely provide custom specializations e.g. for traits classes or `std::hash`.

## Example

```
// $Id: A14-7-2.cpp 312645 2018-03-21 11:44:35Z michal.szczepankiewicz $
#include <cstdint>
```

3

```

//in A.hpp
5
#include <functional>
7
struct A
{
std::uint8_t x;
};
12
namespace std {
14
//compliant, case (2)
//template specialization for the user-defined type
//in the same file as the type declaration
template <>
struct hash<A>
{
size_t operator()(const A& a) const noexcept
{
return std::hash<decltype(a.x)>()(a.x);
}
};
26
}
28
//traits.hpp
30
#include <type_traits>
#include <cstdint>
33
template <typename T>
struct is_serializable : std::false_type {};
36
//compliant, case (1)
template <>
struct is_serializable<std::uint8_t> : std::true_type {};
40
//func.cpp
42
#include <vector>
44
//non-compliant, not declared
//in the same file as
//is_serializable class
template <>
struct is_serializable<std::uint16_t> : std::true_type {};
50
template <typename T, typename = std::enable_if<is_serializable<T>::value>>
std::vector<std::uint8_t> serialize(const T& t)
{
//only a basic stub

```

```
return std::vector<std::uint8_t>{t};
}
57
#include <string>
int main()
{
serialize(std::uint8_t{3});
}
```

## See also

MISRA C++ 2008 [7]: Rule 14-7-2 (Required) For any given template specialization, an explicit instantiation of the template with the template arguments used in the specialization shall not render the program ill-formed.

## 6.14.8 Function template specializations

**Rule A14-8-2 (required, implementation, automated)**  
**Explicit specializations of function templates shall not be used.**

### Rationale

Specializations of function templates do not participate in overload resolution. They are only considered after their primary template has been selected during overload resolution. This is highly dependent on the declaration order of overloads and specializations and may be inconsistent with developer expectations.

A non-template function is always selected over a function template specialization if they are otherwise an equally good match, which also may be confusing for developers.

Function templates cannot be partially specialized, which may lead to troublesome implementations. If a partial specialization is required, then it is recommended to write a single function template that delegates to a class template (which can be partially specialized).

### Example

```
// $Id: A14-8-2.cpp 312698 2018-03-21 13:17:36Z michal.szczepankiewicz $
#include <cstdlib>
#include <memory>
#include <iostream>
5
template <typename T>
void F1(T t)
{
//compliant, (a)
std::cout << "(a)" << std::endl;
}
```



```
12
template <>
void F1<>(uint16_t* p)
{
//non-compliant
//(x), explicit specialization of
//(a), not (b), due to declaration
//order
std::cout << "(x)" << std::endl;
}
22
template <typename T>
void F1(T* p)
{
//compliant, (b), overloads (a)
std::cout << "(b)" << std::endl;
}
29
template <>
void F1<>(uint8_t* p)
{
//non-compliant
//(c), explicit specialization of (b)
std::cout << "(c)" << std::endl;
}
37
void F1(uint8_t* p)
{
//compliant
//(d), plain function, overloads with (a), (b)
//but not with (c)
std::cout << "(d)" << std::endl;
}
45
int main(void)
{
auto sp8 = std::make_unique<uint8_t>(3);
auto sp16 = std::make_unique<uint16_t>(3);
50
51     F1(sp8.get()); //calls (d), which might be
52                   //confusing, but (c) is non-compliant
53
54     F1(sp16.get()); //calls (b), which might be
55                   //confusing, but (b) is non-compliant
}
```

## See also

MISRA C++ 2008 [7]: 14-8-1: Overloaded function templates shall not be explicitly specialized.

MISRA C++ 2008 [7]: 14-8-2: The viable function set for a function call should either contain no function specializations, or only contain function specializations.

HIC++ v4.0 [9]: 14.2.2: Do not explicitly specialize a function template that is overloaded with other templates.

C++ Core Guidelines [11]: T.144: Don't specialize function templates.

## 6.15 Exception handling

### Advantages of using exceptions

“The exception handling mechanism can provide an effective and clear means of handling error conditions, particularly where a function needs to return both some desired result together with an indication of success or failure. However, because of its ability to transfer control back up the call tree, it can also lead to code that is difficult to understand. Hence it is required that the mechanism is only used to capture behavior that is in some sense undesirable, and which is not expected to be seen in normal program execution.” [MISRA C++ 2008]

“The preferred mechanism for reporting errors in a C++ program is exceptions rather than using error codes. A number of core language facilities, including `dynamic_cast`, operator `new()`, and `typeid`, report failures by throwing exceptions. In addition, the C++ standard library makes heavy use of exceptions to report several different kinds of failures. Few C++ programs manage to avoid using some of these facilities.” [ISO C++ Core Guidelines].

Consequently, C++ programs need to be prepared for exceptions to occur and need to handle each appropriately.

### Challenges of using exceptions

Issue:	Solution:
Correctness of the exception handling	Exception handling mechanism is implemented by the compiler (by its library functions and machine code generator) and defined by the C++ Language Standard. Rule <a href="#">A1-2-1</a> requires that the compiler (including its exception handling routines), when used for safety-related software, meets appropriate safety requirements.
Hidden control flow	ISO 26262-6 (Table *) recommends “no hidden data flow or control flow” for ASIL A software and highly recommends it for ASIL B/C/D. Therefore, the Rule <a href="#">A15-0-1</a> prohibits the usage of exceptions for normal control flow of software - they are allowed only for errors where a function failed to perform its assigned task.

Additional exit point from functions	ISO 26262-6 (Table *) highly recommends “one entry and one exit point in subprograms and functions” for ASIL A software. Therefore, the Rule <a href="#">A15-0-1</a> prohibits the usage of exceptions for normal control flow of software - they are allowed only for errors where a function failed to perform its assigned task.
Code readability	If exceptions are used correctly, in particularly by using checked and unchecked exception types, see Rules: <a href="#">A15-0-4</a> and <a href="#">A15-0-5</a> , the code is easier to read and maintain than if using error codes. It avoids nesting if/else error-checking statements.
Exception safety and program state consistency after exception is thrown	The Rule <a href="#">A15-0-2</a> requires that functions provide at least “basic exception safety” (Note: this C++ term is not related to functional safety)
Impact on runtime performance	If a function does not throw an exception (i.e. error conditions do not occur), then there could be a little overhead due to exception handling mechanism initialization. However, some compilers offer “zero cost exception handling”, which means that there is no performance overhead if the exception is not thrown.
Impact on worst-case execution time	The <a href="#">A15-0-7</a> rule requires that the exception handling mechanism provides real-time implementation. Note that this is not the case for e.g. GCC compiler that allocates dynamic memory on throwing an exception. However, it is possible to fix it simply by avoiding memory allocation.
Maturity of exceptions	Exceptions are a widespread concept in several programming languages, not only in C++, but also in e.g. Ada, Java, Modula-3, ML, OCaml, Python, Ruby, C#, Lisp, Eiffel, and Modula-2.
Tool support	There are several tools that support exceptions well: compilers (e.g. gcc, clang, visual studio), IDEs (e.g. eclipse, clion, visual studio), static analysis tools (e.g. QA C++, Coverity Prevent) and compiler validation suites (e.g. SuperTest).
Appropriate usage of exceptions in implementation	Exceptions need to be used properly in the code, therefore this document specifies almost 40 precise rules defining how to code using exceptions, in particular defining the rules for checked/unchecked exceptions.

**Table 6.1: Challenges of exceptions usage**

## Checked and unchecked exceptions

Like MISRA introduces a concept of "underlying type", AUTOSAR C++14 Guidelines introduces a concept of unchecked and checked exceptions. This is based on the classification used in Java language, having as a goal an efficient, complete and consistent way of specifying the exceptions. There are therefore two exclusive categories of exceptions:

**Checked Exceptions:** Used to represent errors that are expected and reasonable to recover from, so they are supposed to be documented by functions using a dedicated tag (e.g. `@throws`) and have to be either handled or documented (in the same way) by caller functions. Exceptions are marked as Checked using a separate tag (e.g. `@checkedException`) that precedes an exception class declaration.

**Unchecked Exceptions:** Used to represent errors that a program typically can not recover from. However, unchecked exceptions can be documented by functions, i.e in cases when all preconditions of thrown exception are defined and known. It is context dependent where such an exception can be caught (e.g. is it done before main function) and what is the proper handling (e.g. other than program termination). However, it is not forced so that unchecked exceptions are documented by caller functions (even if they are documented by called functions). By default, all exceptions are unchecked (also from third-party libraries used), unless their definition is preceded by the dedicated tag.

“Checked exceptions are a wonderful feature of the Java programming language. Unlike return codes, they force the programmer to deal with exceptional conditions, greatly enhancing reliability.” [Effective Java 2nd Edition [15]]

The following sections specify several specific rules defining the usage of exceptions, in particular concerning the use of unchecked and checked exceptions.

### 6.15.0 General

#### **Rule A15-0-1 (required, architecture / design / implementation, non-automated)**

**A function shall not exit with an exception if it is able to complete its task.**

#### **Rationale**

“The notion of an exception is provided to help get information from the point where an error is detected to a point where it can be handled. A function that cannot cope with a problem throws an exception, hoping that its (direct or indirect) caller can handle the problem. A function that wants to handle a kind of problem indicates that by catching the corresponding exception.” [The C++ Programming Language [14]]

Exceptions are only supposed to be used to capture incorrect, and which is not expected to be seen in normal program, execution. Using exception handling mechanism to transfer control back up the call stack, in error-free situation, leads to

code that is difficult to understand and significantly less efficient than returning from a function.

Note that most of the monitoring or supervision functions are not supposed to throw an exception when an error is detected.

### Example

```

1 // % $Id: A15-0-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <fstream>
3 #include <stdexcept>
4 #include <string>
5 #include <vector>
6 std::uint8_t ComputeCrc(std::string& msg);
7 bool IsMessageCrcCorrect1(std::string& message)
8 {
9     std::uint8_t computedCRC = ComputeCrc(message);
10    std::uint8_t receivedCRC = message.at(0);
11
12    if (computedCRC != receivedCRC)
13    {
14        throw std::logic_error(
15            "Computed CRC is invalid."); // Non-compliant - CheckMessageCRC()
16            // was able to perform
17        // its task, nothing exceptional about its invalid result
18    }
19
20    return true;
21 }
22 bool IsMessageCrcCorrect2(std::string& message)
23 {
24    bool isCorrect = true;
25    std::uint8_t computedCRC = ComputeCrc(message);
26    std::uint8_t receivedCRC = message.at(0);
27
28    if (computedCRC != receivedCRC)
29    {
30        isCorrect =
31            false; // Compliant - if CRC is not correct, then return "false"
32    }
33
34    return isCorrect;
35 }
36 void SendData(std::string message)
37 {
38    if (message.empty())
39    {
40        throw std::logic_error("Preconditions are not met."); // Compliant -
41            // SendData() was
42            // not able to
43            // perform its
44            // task

```

```

}
46
bool sendTimeoutReached = false;
48
// Implementation
if (sendTimeoutReached)
{
throw std::runtime_error(
53             "Timeout on sending a message has been reached."); // Compliant -
54                                     // SendData()
55                                     // did not
56                                     //     perform its
57                                     //     task
}
}
std::int32_t FindIndex(std::vector<std::int32_t>& v, std::int32_t x) noexcept
{
try
{
std::size_t size = v.size();
for (std::size_t i = 0U; i < size; ++i)
{
67         if (v.at(i) == x) // v.at() throws an std::out_of_range exception
68             {
69                 throw i; // Non-compliant - nothing exceptional about finding a
70                         // value in vector
71             }
}
}
74
catch (std::size_t
76         foundIdx) // Non-compliant -     nothing exceptional about finding a
77                 // value in vector
{
return foundIdx;
}
81
catch (std::out_of_range&
83         e) // Compliant - std::out_of_range error shall be handled
{
return -1;
}
87
return -1;
}
bool ReadFile(std::string& filename) noexcept
{
try
{
std::ifstream file(filename, std::ios_base::in);
95

```

```
if (!file.is_open())
{
    98         throw std::runtime_error(
    99             "File cannot be opened"); // Compliant - error on opening a
    100                                     // file is an exceptional case
}
102
char c = file.get();
104
if (!file.good())
{
    107         throw std::runtime_error(
    108             "Cannot read from file"); // Compliant - error on reading from
    109                                     // file is an exceptional case
}
}
112
catch (std::exception& e)
{
    return false;
}
117
return true;
}
void Fn1(
std::uint32_t x) // Non-compliant - inefficient and less readable version
                // than its obvious alternative, e.g. fn2()
122 // function
{
    try
    {
        if (x < 10)
        {
            129             throw 10;
        }
    }
    131 // Action "A"
}
134
catch (std::int32_t y)
{
    // Action "B"
}
}
void Fn2(
std::uint32_t x) // Compliant - the same functionality as fn1() function
{
    if (x < 10)
    {
        // Action "B"
    }
}
```

```
else  
{  
  // Action "A"  
}  
}
```

## See also

MISRA C++ 2008 [7]: 15-0-1 (Document) Exceptions shall only be used for error handling.

C++ Core Guidelines [11]: E.3: Use exceptions for error handling only

Effective Java 2nd Edition [15]: Item 57: Use exceptions only for exceptional conditions

The C++ Programming Language [14], 13.1.1. Exceptions

**Rule A15-0-2 (required, architecture / design / implementation, partially automated)**  
**At least the basic guarantee for exception safety shall be provided for all operations. In addition, each function may offer either the strong guarantee or the nothrow guarantee**

## Rationale

Exceptions introduce additional data flow into a program. It is important to consider all the effects of code taking such paths to always recover from an exception error properly and always preserve object's invariants.

“Well-designed functions are exception safe, meaning they offer at least the basic exception safety guarantee (i.e., the basic guarantee). Such functions assure callers that even if an exception is thrown, program invariants remain intact (i.e., no data structures are corrupted) and no resources are leaked. Functions offering the strong exception safety guarantee (i.e., the strong guarantee) assure callers that if an exception arises, the state of the program remains as it was prior to the call.”  
[effective modern c++]

The C++ standard library always provides one of the following guarantees for its operations, the same needs to be followed by code compliant to the guidelines. “

**Basic guarantee for all operations:** The basic invariants of all objects are maintained, and no resources, such as memory, are leaked. In particular, the basic invariants of every built-in and standard-library type guarantee that you can destroy an object or assign to it after every standard-library operation

**Strong guarantee for key operations:** in addition to providing the basic guarantee, either the operation succeeds, or it has no effect.

**Nothrow guarantee for some operations:** in addition to providing the basic guarantee, some operations are guaranteed not to throw any exception.



” [C++ Programming Reference]

Nothrow means in this context that the function not only does not exit with an exception, but also that internally an exception cannot occur.

### Example

```

//% $Id: A15-0-2.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <cstdlib>
#include <cstring>
class C1
{
public:
C1(const C1& rhs)
{
9         CopyBad(rhs);           // Non-compliant - if an exception is thrown, an object
10                                // will be left in an indeterminate state
CopyGood(rhs); // Compliant - full object will be properly copied or
12                                // none of its properties will be changed
}
~C1() { delete[] e; }
void CopyBad(const C1& rhs)
{
if (this != &rhs)
{
19         delete[] e;
20         e = nullptr;           // e changed before the block where an exception can
21                                // be thrown
22         s = rhs.s;             // s changed before the block where an exception can be
23                                // thrown
24
25         if (s > 0)
26         {
27             e = new std::int32_t[s]; // If an exception will be thrown
28                                     // here, the
29                                     // object will be left in an indeterminate
30                                     // state
31             std::memcpy(e, rhs.e, s * sizeof(std::int32_t));
32         }
}
}
void CopyGood(const C1& rhs)
{
std::int32_t* eTmp = nullptr;
38
if (rhs.s > 0)
{
41         eTmp = new std::int32_t[rhs.s]; // If an exception will be thrown
42                                         // here, the
43                                         // object will be left unchanged
44         std::memcpy(eTmp, rhs.e, rhs.s * sizeof(std::int32_t));
}
}

```

```

46 delete[] e;
   e = eTmp;
   s = rhs.s;
   }
51 private:
   std::int32_t* e;
   std::size_t s;
   };
   class A
   {
   public:
   A() = default;
   };
   class C2
   {
   public:
   C2() : a1(new A), a2(new A) // Non-compliant - if a2 memory allocation
65                                     // fails, a1 will never be deallocated
   {
   }
68 private:
   A* a1;
   A* a2;
   };
   class C3
   {
   public:
   C3() : a1(nullptr), a2(nullptr) // Compliant
   {
   try
   {
80         a1 = new A;
81         a2 = new A; // If memory allocation for a2 fails, catch-block will
82                                     // deallocate a1
   }
84 catch (...)
   {
87         delete a1;
88         a1 = nullptr;
89         delete a2;
90         a2 = nullptr;
91         throw;
   }
   }
94 private:
   A* a1;

```

```
A* a2;  
};
```

## See also

SEI CERT C++ [10]: ERR56-CPP. Guarantee exception safety

**Rule A15-0-3 (required, implementation, non-automated)**  
**Exception safety guarantee of a called function shall be considered.**

## Rationale

Supplying an external function with an object that throws an exception on specific operations (e.g. in special member functions) may lead to function's unexpected behavior.

Note that the result of a function call supplied with an object which throws on specific operations may differ when the function guarantees the basic exception safety and the strong exception safety.

## Example

```
//% $Id: A15-0-3.cpp 271687 2017-03-23 08:57:35Z piotr.tanski $  
#include <cstdlib>  
#include <stdexcept>  
#include <vector>  
class A  
{  
public:  
explicit A(std::int32_t value) noexcept(false) : x(value)  
{  
if (x == 0)  
{  
12         throw std::invalid_argument("Constructor: Invalid Argument");  
}  
}  
15  
private:  
std::int32_t x;  
};  
int main(int, char**)  
{  
constexpr std::int32_t limit = 10;  
std::vector<A> vec1; // Constructor and assignment operator of A class  
23                     // throw exceptions  
24  
try  
{  
for (std::int32_t i = 1; i < limit; ++i)  
{
```

```
29         vec1.push_back(A(i)); // Constructor of A class will not throw for
30                               // value from 1 to 10
31     }
32
33     vec1.emplace(vec1.begin(),
34                0); // Non-compliant - constructor A(0) throws    in an
35                   // emplace() method    of std::vector. This leads to
36                   // unexpected result of emplace()    method. Throwing an
37                   // exception inside    an object constructor in emplace()
38                   //    leads to duplication of one of    vector's    elements.
39 // Vector invariants are valid and the object is destructible.
40 }
41 catch (std::invalid_argument& e)
42 {
43     // Handle an exception
44 }
45
46 std::vector<A> vec2;
47 vec2.reserve(limit);
48 try
49 {
50     for (std::int32_t i = limit - 1; i >= 0; --i)
51     {
52         vec2.push_back(A(i)); // Compliant - constructor of A(0) throws for
53                               // i = 0, but in this case strong exception
54                               // safety is guaranteed. While push_back()
55                               // offers strong exception safety guarantee,
56                               // push_back can only succeed to add a new
57                               // element or fails and does not change the
58                               // container
59     }
60 }
61 catch (std::invalid_argument& e)
62 {
63     // Handle an exception
64 }
65
66 return 0;
67 }
```

## See also

none

**Rule A15-0-4 (required, architecture / design / implementation, non-automated)**  
**Unchecked exceptions shall be used to represent errors from which the caller cannot reasonably be expected to recover.**

## Rationale

Problems that are unpreventable and not expected by the caller are represented with instances of unchecked exceptions category. Such problems include:

Software errors, i.e. preconditions/postconditions violations, arithmetic errors, failed assertions, sanity checks or invalid variable access, that in C++ are typically represented by `logic_error`, `bad_exception`, `bad_cast` and `bad_typeid` exceptions or their subclasses

Internal errors of the executable (like `VirtualMachineError` of Java language), that in C++ are represented by `bad_alloc` and `bad_array_new_length` exceptions

It is not possible to recover from such errors in a meaningful way.

## Example

```
//% $Id: A15-0-4.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <cstdlib>
#include <stdexcept>
#include <vector>
class InvalidArguments : public std::logic_error // Compliant - invalid
6
// arguments error is
// "unchecked" exception
7
{
public:
using std::logic_error::logic_error;
};
class OutOfMemory : public std::bad_alloc // Compliant - insufficient memory
13
error is "unchecked" exception
{
public:
using std::bad_alloc::bad_alloc;
};
class DivisionByZero : public std::logic_error // Compliant - division by zero
19
error is "unchecked"
20
exception
{
public:
using std::logic_error::logic_error;
};
class CommunicationError : public std::logic_error // Non-compliant -
26
// communication error
27
// should be "checked"
// exception but defined to be "unchecked"
{
public:
using std::logic_error::logic_error;
};
double Division(std::int32_t a, std::int32_t b) noexcept(false)
{
// ...
if (b == 0)
```

```

{
throw DivisionByZero(
39     "Division by zero error");           // Unchecked exception thrown correctly
}
41
// ...
}
void Allocate(std::uint32_t bytes) noexcept(false)
{
// ...
throw OutOfMemory(); // Unchecked exception thrown correctly
}
void InitializeSocket() noexcept(false)
{
bool validParameters = true;
52
// ...
if (!validParameters)
{
throw InvalidArguments("Invalid parameters passed"); // Unchecked
57                                     // exception
58                                     // thrown
59                                     // correctly
}
}
void SendData(std::int32_t socket) noexcept(false)
{
// ...
bool isSentSuccessfully = true;
66
// ...
if (!isSentSuccessfully)
{
throw CommunicationError("Could not send data"); // Unchecked exception
71                                     // thrown when checked
72                                     // exception should
73                                     // be.
}
}
void IterateOverContainer(const std::vector<std::int32_t>& container,
77     std::uint64_t length) noexcept(false)
{
for (std::uint64_t idx{0U}; idx < length; ++idx)
{
int32_t value = container.at(idx); // at() throws std::out_of_range
82                                     // exception    when passed integer
83                                     // exceeds the size of    container.
84                                     // Unchecked exception thrown
85                                     // correctly
}
}
}

```

## See also

Effective Java: Item 58: Use checked exceptions for recoverable conditions and runtime exceptions for programming errors, Item 60: Favor the use of standard exceptions

**Rule A15-0-5 (required, architecture / design / implementation, non-automated)**  
**Checked exceptions shall be used to represent errors from which the caller can reasonably be expected to recover.**

## Rationale

All expected by the caller, but also reasonable to recover from, problems are represented with instances of checked exceptions. Such problems include input/output and other application's runtime errors. It is possible to handle such errors in a meaningful way.

“Overuse of checked exceptions can make an API far less pleasant to use. If a method throws one or more checked exceptions, the code that invokes the method must handle the exceptions in one or more catch blocks, or it must declare that it throws the exceptions and let them propagate outward. Either way, it places a nontrivial burden on the programmer.

The burden is justified if the exceptional condition cannot be prevented by proper use of the API and the programmer using the API can take some useful action once confronted with the exception. Unless both of these conditions hold, an unchecked exception is more appropriate.” [Effective Java 2nd Edition [15]]

## Example

```
//% $Id: A15-0-5.cpp 309502 2018-02-28 09:17:39Z michal.szczepankiewicz $
#include <stdint>
#include <stdexcept>
#include <system_error>
5
// @checkedException
class CommunicationError
: public std::exception // Compliant - communication error is "checked"
{
public:
explicit CommunicationError(const char* message) : msg(message) {}
CommunicationError(CommunicationError const&) noexcept = default;
CommunicationError& operator=(CommunicationError const&) noexcept = default;
~CommunicationError() override = default;
15
const char* what() const noexcept override { return msg; }
17
private:
const char* msg;
```

```

};
21
// @checkedException
class BusError
: public CommunicationError // Compliant - bus error is "checked"
{
public:
using CommunicationError::CommunicationError;
};
29
// @checkedException
class Timeout : public std::runtime_error // Compliant - communication timeout
// is "checked"
{
public:
using std::runtime_error::runtime_error;
};
37
// @checkedException
class PreconditionsError : public std::exception // Non-compliant - error on
// preconditions check should
// be "unchecked" but is
// defined to be "checked"
{
// Implementation
};
46
void Fn1(std::uint8_t* buffer, std::uint8_t bufferLength) noexcept(false)
{
bool sentSuccessfully = true;
50
// ...
if (!sentSuccessfully)
{
throw CommunicationError(
55     "Could not send data"); // Checked exception thrown correctly
}
}
void Fn2(std::uint8_t* buffer, std::uint8_t bufferLength) noexcept(false)
{
bool initSuccessfully = true;
61
if (!initSuccessfully)
{
throw PreconditionsError(); // An exception thrown on preconditions
// check failure should be "Unchecked", but
// PreconditionsError is "Checked"
65
66
}
68
// ...
bool sentSuccessfully = true;

```



```

bool isTimeout = false;
72
// ...
if (!sentSuccessfully)
{
throw BusError(
77         "Could not send data");           // Checked exception thrown correctly
}
79
// ...
if (isTimeout)
{
throw Timeout("Timeout reached"); // Checked exception thrown correctly
}
}
void Fn3(std::uint8_t* buffer) noexcept(false)
{
bool isResourceBusy = false;
89
// ...
if (isResourceBusy)
{
throw std::runtime_error(
94         "Resource is busy now");           // Checked exception thrown correctly
}
}
class Thread // Class which mimics the std::thread
{
public:
// Implementation
101
Thread() noexcept(false)
{
bool resourcesAvailable = false;
// ...
if (!resourcesAvailable)
{
108         throw std::system_error(
109             static_cast<int>(std::errc::resource_unavailable_try_again),
110             std::generic_category()); // Compliant - correct usage of
111                                     // checked exception system_error
}
}
};

```

## See also

Effective Java: Item 58 - Use checked exceptions for recoverable conditions and runtime exceptions for programming errors.

**Rule A15-0-6 (required, verification / toolchain, non-automated)**

An analysis shall be performed to analyze the failure modes of exception handling. In particular, the following failure modes shall be analyzed: (a) worst time execution time not existing or cannot be determined, (b) stack not correctly unwound, (c) exception not thrown, other exception thrown, wrong catch activated, (d) memory not available while exception handling.

**Rationale**

Note that the worst-case execution time and behavior of exception handling can be hardware specific. This rule requires only that the exception handling is deterministic in the sense that it has a deterministic behavior.

Note: this analysis can be performed by the compiler supplier or it can be done by the project.

**See also**

none

**Rule A15-0-7 (required, verification / toolchain, partially automated)**

**Exception handling mechanism shall guarantee a deterministic worst-case time execution time.**

**Rationale**

Compilers, i.e. GCC or Clang, uses dynamic memory allocation in order to allocate currently thrown exception in their exception handling mechanism implementations. This causes a non-deterministic execution time and run-time allocation errors. A possible working approach is to modify the memory allocator so that the dynamic memory does not need to be obtained (from OS) when an exception is thrown.

A static code analysis can search for a use of dynamic memory in the implementation of the try/catch mechanism of the compiler, to show if worst-case time cannot be ensured.

GCC compiler uses following gcc library's functions to provide exception handling mechanism routines:

`__cxa_allocate_exception`

`__cxa_throw`

`__cxa_free_exception`

`__cxa_begin_catch`

`__cxa_end_catch`

Specific stack unwinding functions, i.e. `_Unwind_RaiseException`, `_Unwind_Resume`, `_Unwind_DeleteException`, etc.

## Example

```
//% $Id: A15-0-7.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <cstdlib>
#include <cstring>
struct CxaException
{
// Exception's structure implementation
};
extern "C" void FatalError(const char* msg)
{
// Reports an error and terminates the program
}
12
extern "C" void* CxaAllocateExceptionDynamically(size_t thrownSize)
{
size_t size = thrownSize + sizeof(CxaException);
CxaException* buffer = static_cast<CxaException*>(
malloc(size)); // Non-compliant - dynamic memory allocation used
18
if (!buffer)
{
FatalError("Not enough memory to allocate exception!");
}
23
memset(buffer, 0, sizeof(CxaException));
return buffer + 1;
}
extern "C" void* StaticMalloc(size_t size)
{
void* mem = NULL;
// Allocates memory using static memory pool
return mem;
}
extern "C" void* CxaAllocateExceptionStatically(size_t thrownSize)
{
size_t size = thrownSize + sizeof(CxaException);
CxaException* buffer = static_cast<CxaException*>(StaticMalloc(
size)); // Compliant - memory allocation on static memory pool used
38
if (!buffer)
{
FatalError("Not enough memory to allocate exception!");
}
43
memset(buffer, 0, sizeof(CxaException));
return buffer + 1;
}
```

## See also

none

**Rule A15-0-8 (required, verification / toolchain, non-automated)**  
**A worst-case execution time (WCET) analysis shall be performed to determine maximum execution time constraints of the software, covering in particular the exceptions processing.**

### Rationale

Some systems require a guarantee that an action will be performed within predictable time constraints. Such real-time systems are allowed to use exception handling mechanism only if there is a tool support for accurate predicting such maximum time boundaries.

“Before deciding that you cannot afford or don’t like exception-based error handling, have a look at the alternatives; they have their own complexities and problems. Also, as far as possible, measure before making claims about efficiency.” [C++ Core Guidelines]

### See also

MISRA C++ 2008 [7]: 15-0-1 (Document) Exceptions shall only be used for error handling.

open-std.org [18]: ISO/IEC TR 18015:2006(E). Technical Report on C++ Performance

## 6.15.1 Throwing an exception

**Rule A15-1-1 (advisory, implementation, automated)**  
**Only instances of types derived from `std::exception` should be thrown.**

### Rationale

If an object that inherits from `std::exception` is thrown, there’s a guarantee that it serves to document the cause of an exception in a unified way. Also, "it makes your code easier to learn and re-use, because it matches established conventions with which programmers are already familiar.". [Effective Java 2nd Edition [15]]

This means that only standard library exceptions or user-defined exceptions that inherit from `std::exception` base class should be used for exceptions.

Note that direct instances of `std::exception` are not to be thrown as they can not be unique.

### Example

```
//% $Id: A15-1-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $  
#include <memory>  
#include <stdexcept>  
class A
```

```

{
// Implementation
};
class MyException : public std::logic_error
{
public:
using std::logic_error::logic_error;
// Implementation
};
void F1()
{
throw - 1; // Non-compliant - integer literal thrown
}
void F2()
{
throw nullptr; // Non-compliant - null-pointer-constant thrown
}
void F3()
{
throw A();           Non-compliant - user-defined type that does not inherit from
25                   std::exception thrown
}
void F4()
{
throw std::logic_error{
"Logic Error"}; // Compliant - std library exception thrown
}
void F5()
{
throw MyException{"Logic Error"}; // Compliant - user-defined type that
35                                     // inherits from std::exception thrown
}
void F6()
{
throw std::make_shared<std::exception>(
std::logic_error{"Logic Error"}); // Non-compliant - shared_ptr does
41                                     // not inherit from std::exception
}
void F7()
{
try
{
F6();
}
49
catch (std::exception& e) // An exception of
51                                     // std::shared_ptr<std::exception> type will not
52                                     // be caught here
{
// Handle an exception
}
}

```

```
catch (std::shared_ptr<std::exception>& e) // An exception of
// std::shared_ptr<std::exception>
// type will be caught here, but
// unable to access
// std::logic_error information
{
// Handle an exception
}
}
```

## See also

HIC++ v4.0 [9]: 15.1.1 Only use instances of `std::exception` for exceptions

C++ Core Guidelines [11]: E.14: Use purpose-designed user-defined types as exceptions (not built-in types)

Effective Java 2nd Edition [15]: Item 60: Favor the use of standard exceptions

**Rule A15-1-2 (required, implementation, automated)**  
**An exception object shall not be a pointer.**

## Rationale

If an exception object of pointer type is thrown and that pointer refers to a dynamically created object, then it may be unclear which function is responsible for destroying it, and when. This may lead to memory leak.

If an exception object of pointer type is thrown and that pointer refers to an automatic variable, it allows using a variable after its destruction, leading to undefined behavior.

This ambiguity does not exist if a copy of the object is thrown.

## Example

```
/// $Id: A15-1-2.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <cstdint>
class A
{
// Implementation
};
void Fn(std::int16_t i)
{
A a1;
A& a2 = a1;
A* a3 = new A;
12
if (i < 10)
{
throw a1; // Compliant - copyable object thrown
}
}
```

```
17
else if (i < 20)
{
throw A(); // Compliant - copyable object thrown
}
22
else if (i < 30)
{
throw a2; // Compliant - copyable object thrown
}
27
else if (i < 40)
{
throw & a1; // Non-compliant - pointer type thrown
}
32
else if (i < 50)
{
throw a3; // Non-compliant - pointer type thrown
}
37
else if (i < 60)
{
throw(*a3); // Compliant - memory leak occurs, violates other rules
}
42
else
{
throw new A; // Non-compliant - pointer type thrown
}
}
```

## See also

MISRA C++ 2008 [7]: 15-0-2 An exception object should not have pointer type.

C++ Core Guidelines [11]: E.13: Never throw while being the direct owner of an object

**Rule M15-0-3 (required, implementation, automated)**  
**Control shall not be transferred into a try or catch block using a goto or a switch statement.**

See MISRA C++ 2008 [7]

**Rule M15-1-1 (required, implementation, automated)**  
**The assignment-expression of a throw statement shall not itself cause an exception to be thrown.**

See MISRA C++ 2008 [7]

**Rule M15-1-2 (required, implementation, automated)**  
**NULL shall not be thrown explicitly.**

See MISRA C++ 2008 [7]

**Rule M15-1-3 (required, implementation, automated)**  
**An empty throw (throw;) shall only be used in the compound statement of a catch handler.**

See MISRA C++ 2008 [7]

**Rule A15-1-3 (advisory, implementation, automated)**  
**All thrown exceptions should be unique.**

## Rationale

Defining unique exceptions in the project significantly simplifies debug process.

An exception is considered to be unique if at least one of the following conditions is fulfilled:

- The type of the exception does not occur in any other place in the project

- The error message (i.e. message itself, error code, etc.) of the exception does not occur in any other place in the project

## Example

```
///  
#include <iostream>  
#include <sstream>  
#include <stdexcept>  
#include <string>  
static std::string ComposeMessage(const char* file,  
7         const char* func,  
8         std::int32_t line,  
9         const std::string& message) noexcept  
{  
std::stringstream s;  
s << "(" << file << ", " << func << ":" << line << ") " << message;
```



```

return s.str();
}
void F1()
{
// ...
throw std::logic_error("Error");
}
void F2()
{
// ...
throw std::logic_error("Error"); // Non-compliant - both exception type and
24                                     // error message are not unique
}
void F3()
{
// ...
throw std::invalid_argument(
"Error"); // Compliant - exception type is unique
}
void F4() noexcept(false)
{
// ...
throw std::logic_error("f3(): preconditions were not met"); // Compliant -
36                                     // error
37                                     // message is
38                                     // unique
}
void F5() noexcept(false)
{
// ...
throw std::logic_error(ComposeMessage(
__FILE__,
__func__,
__LINE__,
"postconditions were not met")); // Compliant - error message is unique
}
void F6() noexcept
{
try
{
F1();
F2();
F3();
}
57
catch (std::invalid_argument& e)
{
std::cout << e.what() << '\n'; // Only f3() throws this type of
61                                     // exception, it is easy to deduce which
62                                     // function threw
}
}

```

```
64
catch (std::logic_error& e)
{
std::cout << e.what() << '\n'; // f1() and f2() throw exactly the same
68                               // exceptions, unable to deduce which
69                               // function threw
}
71
try
{
F4();
F5();
}
77
catch (std::logic_error& e)
{
std::cout << e.what() << '\n'; // Debugging process simplified, because
81                               // of unique error message it is known
82                               // which function threw
}
}
```

## See also

Effective Java 2nd Edition [15]: Item 63: Include failure-capture information in detail messages

### **Rule A15-1-4 (required, implementation, partially automated)**

**If a function exits with an exception, then before a throw, the function shall place all objects/resources that the function constructed in valid states or it shall delete them.**

## Rationale

If the only handler to dynamically allocated memory or system resource (e.g. file, lock, network connection or thread) goes out of scope due to throwing an exception, memory leak occurs. Memory leaks lead to performance degradation, security violations and software crashes.

Allocated memory or system resource can be released by explicit call to resource deinitialization or memory deallocation function (such as operator delete), before each return/try/break/continue statement. However, this solution is error prone and difficult to maintain.

The recommended way of releasing dynamically allocated objects and resources is to follow RAII ("Resource Acquisition Is Initialization") design pattern, also known as Scope-Bound Resource Management or "Constructor Acquires, Destructor Releases" (CADRe). It allows to bind the life cycle of the resource to the lifetime of a scope-bound object. It guarantees that resources are properly deinitialized and released when data flow reaches the end of the scope.

Examples of RAII design pattern that significantly simplifies releasing objects/resources on throwing an exception are C++ smart pointers: `std::unique_ptr` and `std::shared_ptr`.

### Example

```

//% $Id: A15-1-4.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <stdint>
#include <memory>
#include <stdexcept>
extern std::uint32_t F1();
void FVeryBad() noexcept(false)
{
    std::logic_error* e = new std::logic_error("Logic Error 1");
    // ...
    std::uint32_t i = F1();
11
    if (i < 10)
    {
        throw(*e); // Non-compliant - fVeryBad() is not able to clean-up
15                      // allocated memory
    }
17
    // ...
    delete e;
}
void FBad() noexcept(false)
{
    std::int32_t* x = new std::int32_t(0);
    // ...
    std::uint32_t i = F1();
26
    if (i < 10)
    {
        throw std::logic_error("Logic Error 2"); // Non-compliant - exits from
30                      // fBad() without cleaning-up
31                      // allocated resources and
32                      // causes a memory leak
    }
34
    else if (i < 20)
    {
        throw std::runtime_error("Runtime Error 3"); // Non-compliant - exits
38                      // from fBad() without
39                      // cleaning-up allocated
40                      // resources and causes a
41                      // memory leak
    }
43
    // ...
    delete x; // Deallocates claimed resource only in the end of fBad() scope
}

```

```

void FGood() noexcept(false)
{
std::int32_t* y = new std::int32_t(0);
// ...
std::uint32_t i = F1();
52
if (i < 10)
{
delete y; // Deletes allocated resource before throwing an exception
throw std::logic_error("Logic Error 4"); // Compliant - deleting y
57 // variable before exception
58 // leaves the fGood() scope
}
60
else if (i < 20)
{
delete y; // Deletes allocated resource before throwing an exception
throw std::runtime_error("Runtime Error 5"); // Compliant - deleting y
65 // variable before
66 // exception leaves the
67 // fGood() scope
}
69
else if (i < 30)
{
delete y; // Deletes allocated resource before throwing an exception
73 // again, difficult to maintain
throw std::invalid_argument(
75     "Invalid Argument 1"); // Compliant - deleting
76 // y variable before
77 // exception leaves the
78 // fGood() scope
}
80
// ...
delete y; // Deallocates claimed resource also in the end of fGood() scope
}
void FBest() noexcept(false)
{
std::unique_ptr<std::int32_t> z = std::make_unique<std::int32_t>(0);
// ...
std::uint32_t i = F1();
89
if (i < 10)
{
throw std::logic_error("Logic Error 6"); // Compliant - leaving the
93 // fBest() scope causes
94 // deallocation of all
// automatic variables, unique_ptrs, too
}
97

```

```

else if (i < 20)
{
throw std::runtime_error("Runtime Error 3"); // Compliant - leaving the
101 // fBest() scope causes
102 // deallocation of all
103 // automatic variables,
104 // unique_ptrs, too
}
106
else if (i < 30)
{
throw std::invalid_argument(
110 "Invalid Argument 2"); // Compliant - leaving the fBest() scope
111 // causes deallocation of all automatic
112 // variables, unique_ptrs,
// too
}
115
// ...
// z is deallocated automatically here, too
}
class CRaii // Simple class that follows RAII pattern
{
public:
CRaii(std::int32_t* pointer) noexcept : x(pointer) {}
~CRaii()
{
delete x;
x = nullptr;
}
128
private:
std::int32_t* x;
};
void FBest2() noexcept(false)
{
CRaii a1(new std::int32_t(10));
// ...
std::uint32_t i = F1();
137
if (i < 10)
{
throw std::logic_error("Logic Error 7"); // Compliant - leaving the
141 // fBest2() scope causes a1
142 // variable deallocation
143 // automatically
}
else if (i < 20)
{
throw std::runtime_error("Runtime Error 4"); // Compliant - leaving the
148 // fBest2() scope causes

```

```
149                                     // a1 variable
150                                     // deallocation
151                                     // automatically
}
else if (i < 30)
{
throw std::invalid_argument(
156     "Invalid Argument 3"); // Compliant - leaving the fBest2() scope
157     // causes a1 variable deallocation
158     // automatically
}
160 // ...
// a1 is deallocated automatically here, too
}
```

## See also

SEI CERT C++ [10]: ERR57-CPP. Do not leak resources when handling exceptions

C++ Core Guidelines [11]: E.6: Use RAII to prevent leaks.

### Rule A15-1-5 (required, implementation, non-automated)

**Exceptions shall not be thrown across execution boundaries.**

## Rationale

An execution boundary is the delimitation between code compiled by differing compilers, including different versions of a compiler produced by the same vendor. For instance, a function may be declared in a header file but defined in a library that is loaded at runtime. The execution boundary is between the call site in the executable and the function implementation in the library. Such boundaries are also called ABI (application binary interface) boundaries because they relate to the interoperability of application binaries.

Throwing an exception across an execution boundary requires that both sides of the execution boundary use the same ABI for exception handling, which may be difficult to ensure.

## Exception

If it can be ensured that the execution boundaries use the same ABI for exception handling routines on both sides, then throwing an exception across these execution boundaries is allowed.

## See also

SEI CERT C++ [10]: ERR59-CPP. Do not throw an exception across execution boundaries

## 6.15.2 Constructors and destructors

**Rule A15-2-1 (required, implementation, automated)**  
**Constructors that are not noexcept shall not be invoked before program startup.**

### Rationale

Before the program starts executing the body of main function, it is in a start-up phase, constructing and initializing static objects. There is nowhere an exception handler can be placed to catch exceptions thrown during this phase, so if an exception is thrown it leads to the program being terminated in an implementation-defined manner.

Such errors may be more difficult to find because an error message can not be logged, due to lack of exception handling mechanism during static initialization.

### Example

```
//% $Id: A15-2-1.cpp 271927 2017-03-24 12:01:35Z piotr.tanski $
#include <cstdlib>
#include <stdexcept>
class A
{
public:
A() noexcept : x(0)
{
// ...
}
explicit A(std::int32_t n) : x(n)
{
// ...
throw std::runtime_error("Unexpected error");
}
A(std::int32_t i, std::int32_t j) noexcept : x(i + j)
{
try
{
20         // ...
21         throw std::runtime_error("Error");
22         // ...
}
}
24 catch (std::exception& e)
{
}
}
29 private:
std::int32_t x;
};
```

```
33 static A a1;           // Compliant - default constructor of type A is noexcept
static A a2(5); // Non-compliant - constructor of type A throws, and the
35 // exception will not be caught by the handler in main function
static A a3(5, 10); // Compliant - constructor of type A is noexcept, it
37 // handles exceptions internally
int main(int, char**)
{
try
{
// program code
}
catch (...)
{
// Handle exceptions
}
48
return 0;
}
```

## See also

SEI CERT C++ [10]: ERR51-CPP. Handle all exceptions.

**Rule A15-2-2 (required, implementation, partially automated)**  
**If a constructor is not noexcept and the constructor cannot finish object initialization, then it shall deallocate the object's resources and it shall throw an exception.**

## Rationale

Leaving the constructor with invalid object state leads to undefined behavior.

## Example

```
/// $Id: A15-2-2.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <fstream>
#include <stdexcept>
class A
{
public:
A() = default;
};
class C1
{
public:
C1()
noexcept(false)
14 : a1(new A), a2(new A) // Non-compliant - if a2 memory allocation
15 // fails, a1 will never be deallocated
{
```



```

}
C1(A* pA1, A* pA2)
noexcept : a1(pA1), a2(pA2) // Compliant - memory allocated outside of C1
20                                     // constructor, and no exceptions can be thrown
{
}
23
private:
A* a1;
A* a2;
};
class C2
{
public:
C2() noexcept(false) : a1(nullptr), a2(nullptr)
{
try
{
35         a1 = new A;
36         a2 = new A; // If memory allocation for a2 fails, catch-block will
37         // deallocate a1
}
39
catch (std::exception& e)
{
42         throw; // Non-compliant - whenever a2 allocation throws an
43         // exception, a1 will never be deallocated
}
}
46
private:
A* a1;
A* a2;
};
class C3
{
public:
C3() noexcept(false) : a1(nullptr), a2(nullptr), file("./filename.txt")
{
try
{
58         a1 = new A;
59         a2 = new A;
60
61         if (!file.good())
62         {
63             throw std::runtime_error("Could not open file.");
64         }
}
}
66
catch (std::exception& e)

```

```
{
69         delete a1;
70         a1 = nullptr;
71         delete a2;
72         a2 = nullptr;
73         file.close();
74         throw; // Compliant - all resources are deallocated before the
75                // constructor exits with an exception
}
}
78
private:
A* a1;
A* a2;
std::ofstream file;
};
class C4
{
public:
C4() : x(0), y(0)
{
// Does not need to check preconditions here - x and y initialized with
// correct values
}
C4(std::int32_t first, std::int32_t second)
noexcept(false) : x(first), y(second)
{
CheckPreconditions(x,
96                 y); // Compliant - if constructor failed to create a
97                    // valid object, then throw an exception
}
static void CheckPreconditions(std::int32_t x,
100                             std::int32_t y) noexcept(false)
{
if (x < 0 || x > 1000)
{
104         throw std::invalid_argument(
105             "Preconditions of class C4 were not met");
}
107
else if (y < 0 || y > 1000)
{
110         throw std::invalid_argument(
111             "Preconditions of class C4 were not met");
}
}
}
114
private:
std::int32_t x; // Acceptable range: <0; 1000>
std::int32_t y; // Acceptable range: <0; 1000>
};
```

## See also

C++ Core Guidelines [11]: C.42: If a constructor cannot construct a valid object, throw an exception

### 6.15.3 Handling an exception

**Rule M15-3-1 (required, implementation, automated)**  
**Exceptions shall be raised only after start-up and before termination.**

See MISRA C++ 2008 [7]

**Rule A15-3-2 (required, implementation, non-automated)**  
**If a function throws an exception, it shall be handled when meaningful actions can be taken, otherwise it shall be propagated.**

## Rationale

Provide exception handlers only for functions that actually are able to take recovery or cleanup actions. Implementing meaningless exception handlers that only re-throw caught exception results in an implementation that is inefficient and difficult to maintain.

## Example

```
//% $Id: A15-3-2.cpp 309502 2018-02-28 09:17:39Z michal.szczepankiewicz $
#include <cstdint>
#include <iostream>
#include <stdexcept>
#include <memory>
6
/// @checkedException
class CommunicationError : public std::exception
{
// Implementation
};
12
/// @throw CommunicationError Exceptional communication errors
extern void Send(std::uint8_t* buffer) noexcept(false);
15
void SendData1(std::uint8_t* data) noexcept(false)
{
try
{
Send(data);
}
22
catch (CommunicationError& e)
```

```

{
std::cerr << "Communication error occurred" << std::endl;
throw; // Non-compliant - exception is not handled, just re-thrown
}
}
extern void BusRestart() noexcept;
extern void BufferClean() noexcept;
void SendData2(std::uint8_t* data) noexcept(false)
{
try
{
Send(data);
}
37
catch (CommunicationError& e)
{
std::cerr << "Communication error occurred" << std::endl;
BufferClean();
throw; // Compliant - exception is partially handled and re-thrown
}
}
void F1() noexcept
{
std::uint8_t* buffer = nullptr;
48
// ...
try
{
SendData2(buffer);
}
54
catch (CommunicationError& e)
{
std::cerr << "Communication error occurred" << std::endl;
BusRestart();
// Compliant - including SendData2() exception handler, exception is now
// fully handled
}
}
void SendData3(std::uint8_t* data) noexcept
{
try
{
Send(data);
}
69
catch (CommunicationError& e)
{
std::cerr << "Communication error occurred" << std::endl;
BufferClean();
BusRestart();
}
}

```

```

// Compliant - exception is fully handled
}
}
78
struct A
{
  std::uint32_t x;
};
83
std::unique_ptr<A[]> Func1()
{
  //rather throws std::bad_alloc
  return std::make_unique<A[]>(999999999999999999);
}
89
std::unique_ptr<A[]> Func2()
{
  //does not catch std::bad_alloc
  //because nothing meaningful can be done here
  return Func1();
}
96
std::unique_ptr<A[]> Func3()
{
  //does not catch std::bad_alloc
  //because nothing meaningful can be done here
  return Func2();
}
103
extern void Cleanup() noexcept;
105
int main(void)
{
  try
  {
    Func3();
  }
  catch (const std::exception& ex)
  {
    //catches std::bad_alloc here and
    //terminates the application
    //gracefully
    Cleanup();
  }
119
  return 0;
}

```

## See also

none

**Rule A15-3-3 (required, implementation, partially-automated)**  
**Main function and a task main function shall catch at least: base class exceptions from all third-party libraries used, std::exception and all otherwise unhandled exceptions.**

## Rationale

If a program throws an unhandled exception in main function, as well as in init thread function, the program terminates in an implementation-defined manner. In particular, it is implementation-defined whether the call stack is unwound, before termination, so the destructors of any automatic objects may or may not be executed. By enforcing the provision of a “last-ditch catch-all”, the developer can ensure that the program terminates in a consistent manner.

Exceptions hierarchy from external libraries may be completely separate from C++ Standard Library `std::exception`. Handling such base exception classes separately may provide some additional information about application termination causes.

## Example

```
/// $Id: A15-3-3.cpp 309502 2018-02-28 09:17:39Z michal.szczepankiewicz $
#include <stdexcept>
3
//base exception class from external library that is used
class ExtLibraryBaseException {};
6
int MainGood(int, char**) // Compliant
{
try
{
// program code
}
catch (std::runtime_error& e)
{
// Handle runtime errors
}
catch (std::logic_error& e)
{
// Handle logic errors
}
catch (ExtLibraryBaseException &e)
{
// Handle all expected exceptions
// from an external library
}
catch (std::exception& e)
{
// Handle all expected exceptions
}
catch (...)
{
```

```

// Handle all unexpected exceptions
}
34
return 0;
}
int MainBad(int, char**) // Non-compliant - neither unexpected exceptions
38                               // nor external libraries exceptions are caught
{
try
{
// program code
}
catch (std::runtime_error& e)
{
// Handle runtime errors
}
catch (std::logic_error& e)
{
// Handle logic errors
}
catch (std::exception& e)
{
// Handle all expected exceptions
}
56
return 0;
}
void ThreadMainGood() // Compliant
{
try
{
// thread code
}
catch (ExtLibraryBaseException &e)
{
// Handle all expected exceptions
// from an external library
}
catch (std::exception& e)
{
// Handle all expected exception
}
catch (...)
{
// Handle all unexpected exception
}
79
80 void ThreadMainBad() // Non-compliant - neither unexpected exceptions
81                               // nor external libraries exceptions are caught
{

```

```
try
{
// thread code
}
catch (std::exception& e)
{
// Handle all expected exceptions
}
91
// Uncaught unexpected exception will cause an immediate program termination
}
```

### See also

MISRA C++ 2008 [7]: 15-3-2 There should be at least one exception handler to catch all otherwise unhandled exceptions.

SEI CERT C++ [10]: ERR51-CPP. Handle all exceptions

Effective Java 2nd Edition [15]: Item 65: Don't ignore exceptions

**Rule A15-3-4 (required, implementation, non-automated) Catch-all (ellipsis and `std::exception`) handlers shall be used only in (a) main, (b) task main functions, (c) in functions that are supposed to isolate independent components and (d) when calling third-party code that uses exceptions not according to AUTOSAR C++14 guidelines.**

### Rationale

Catching an exception through catch-all handlers does not provide any detailed information about caught exception. This does not allow to take meaningful actions to recover from an exception other than to re-throw it. This is inefficient and results in code that is difficult to maintain.

### Example

```
11 // % $Id: A15-3-4.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <stdexcept>
#include <thread>
extern std::int32_t Fn(); // Prototype of external third-party library function
void F1() noexcept(false)
{
try
{
std::int32_t ret = Fn();
// ...
}
12
// ...
catch (...) // Compliant
```



```
{
// Handle all unexpected exceptions from fn() function
}
}
void F2() noexcept(false)
{
std::int32_t ret =
Fn(); // Non-compliant - can not be sure whether fn() throws or not
23
if (ret < 10)
{
throw std::underflow_error("Error");
}
28
else if (ret < 20)
{
// ...
}
else if (ret < 30)
{
throw std::overflow_error("Error");
}
37
else
{
throw std::range_error("Error");
}
}
void F3() noexcept(false)
{
try
{
F2();
}
49
catch (std::exception& e) // Non-compliant - caught exception is too
// general, no information which error occurred
51
{
// Nothing to do
throw;
}
}
void F4() noexcept(false)
{
try
{
F3();
}
63
catch (...) // Non-compliant - no information about the exception
{
```

```
// Nothing to do
throw;
}
}
class ExecutionManager
{
public:
ExecutionManager() = default;
void Execute() noexcept(false)
{
try
{
78         F3();
}
80
// ...
catch (std::exception& e) // Compliant
{
84         // Handle all expected exceptions
}
catch (...) // Compliant
{
88         // Handle all unexpected exceptions
}
}
};
void ThreadMain() noexcept
{
try
{
F3();
}
98
// ...
catch (std::exception& e) // Compliant
{
// Handle all expected exceptions
}
catch (...) // Compliant
{
// Handle all unexpected exceptions
}
}
int main(int, char**)
{
try
{
ExecutionManager execManager;
execManager.Execute();
// ...
std::thread t(&ThreadMain);
```

```
// ...  
F4();  
}  
120  
// ...  
catch (std::exception& e) // Compliant  
{  
// Handle all expected exceptions  
}  
catch (...) // Compliant  
{  
// Handle all unexpected exceptions  
}  
130  
return 0;  
}
```

### See also

none

**Rule M15-3-3 (required, implementation, automated)**  
**Handlers of a function-try-block implementation of a class constructor or destructor shall not reference non-static members from this class or its bases.**

See MISRA C++ 2008 [7]

**Rule M15-3-4 (required, implementation, automated)**  
**Each exception explicitly thrown in the code shall have a handler of a compatible type in all call paths that could lead to that point.**

See MISRA C++ 2008 [7]

**Rule A15-3-5 (required, implementation, automated)**  
**A class type exception shall be caught by reference or const reference.**

### Rationale

If a class type exception object is caught by value, slicing occurs. That is, if the exception object is of a derived class and is caught as the base, only the base class's functions (including virtual functions) can be called. Also, any additional member data in the derived class cannot be accessed. If the exception is caught by reference or const reference, slicing does not occur.

### Example

```

//% $Id: A15-3-5.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <iostream>
#include <stdexcept>
class Exception : public std::runtime_error
{
public:
using std::runtime_error::runtime_error;
const char* what() const noexcept(true) override
{
return "Exception error message";
}
};
void Fn()
{
try
{
// ...
throw std::runtime_error("Error");
// ...
throw Exception("Error");
}
22
catch (const std::logic_error& e) // Compliant - caught by const reference
{
// Handle exception
}
catch (std::runtime_error& e) // Compliant - caught by reference
{
std::cout << e.what() << "\n"; // "Error" or "Exception error message"
// will be printed, depending upon the
// actual type of thrown object
throw e; // The exception re-thrown is of its original type
}
34
catch (
std::runtime_error
37         e) // Non-compliant - derived types will be caught as the base type
{
std::cout
40         << e.what()
41         << "\n"; // Will always call what() method from std::runtime_error
throw e; // The exception re-thrown is of the std::runtime_error type,
43         // not the original exception type
}
}
}

```

## See also

MISRA C++ 2008 [7]: 15-3-5 A class type exception shall always be caught by reference.

SEI CERT C++ [10]: ERR61-CPP. Catch exceptions by lvalue reference

C++ Core Guidelines [11]: E.15: Catch exceptions from a hierarchy by reference

**Rule M15-3-6 (required, implementation, automated)**

Where multiple handlers are provided in a single try-catch statement or function-try-block for a derived class and some or all of its bases, the handlers shall be ordered most-derived to base class.

See MISRA C++ 2008 [7]

**Rule M15-3-7 (required, implementation, automated)**

Where multiple handlers are provided in a single try-catch statement or function-try-block, any ellipsis (catch-all) handler shall occur last.

See MISRA C++ 2008 [7]

#### 6.15.4 Exception specifications

**Rule A15-4-1 (required, implementation, automated)**

Dynamic exception-specification shall not be used.

#### Rationale

This feature was deprecated in the 2011 C++ Language Standard (See: Deprecating Exception Specifications).

Main issues with dynamic exception specifications are:

Run-time checking: Exception specifications are checked at runtime, so the program does not guarantee that all exceptions will be handled. The run-time failure mode does not lend itself to recovery.

Run-time overhead: Run-time checking requires the compiler to produce additional code that hampers optimizations.

Unusable in generic code: It is not possible to know what types of exceptions may be thrown from templates arguments operations, so a precise exception specification cannot be written.

In place of dynamic exception-specification, use noexcept specification that allows to declare whether a function throws or does not throw exceptions.

Note: `std::unexpected_handler` shall not be used.

#### Example

```

//% $Id: A15-4-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <stdexcept>
void F1() noexcept; // Compliant - note that noexcept is the same as
                    // noexcept(true)
4 void F2() throw(); // Non-compliant - dynamic exception-specification is
                    // deprecated
6 void F3() noexcept(false); // Compliant
void F4() throw(std::runtime_error); // Non-compliant - dynamic
// exception-specification is deprecated
void F5() throw(
...); // Non-compliant - dynamic exception-specification is deprecated
template <class T>
void F6() noexcept(noexcept(T)); // Compliant

```

## See also

C++ Core Guidelines [11]: E.12: Use noexcept when exiting a function because of a throw is impossible or unacceptable

open-std.org [18]: open std Deprecating Exception Specifications

mill22: A Pragmatic Look at Exception Specifications

**Rule A15-4-2 (required, implementation, automated)**  
**If a function is declared to be noexcept, noexcept(true) or noexcept(<true condition>), then it shall not exit with an exception.**

## Rationale

If a function declared to be noexcept, noexcept(true) or noexcept(true condition) throws an exception, then std::terminate() is called immediately. It is implementation-defined whether the call stack is unwound before std::terminate() is called.

To ensure that the rule is not violated, if function's noexcept specification can not be determined, then always declare it to be noexcept(false).

## Example

```

//% $Id: A15-4-2.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
2 #include <stdexcept>
// library.h
void LibraryFunc();
// project.cpp
void F1() noexcept
{
// ...
throw std::runtime_error("Error");
10
11
}
void F2() noexcept(true)

```

Non-compliant - f1 declared to be noexcept, but exits with exception.  
This leads to std::terminate() call

```
{
try
{
// ...
throw std::runtime_error(
19         "Error");    // Compliant - exception will not leave f2
}
catch (std::runtime_error& e)
{
// Handle runtime error
}
}
void F3() noexcept(false)
{
// ...
throw std::runtime_error("Error"); // Compliant
}
void F4() noexcept(
false) // Compliant - no information whether library_func() throws or not
{
LibraryFunc();
}
```

## See also

MISRA C++ 2008 [7]: 15-5-2: Where a function's declaration includes an exception-specification, the function shall only be capable of throwing exceptions of the indicated type(s).

MISRA C++ 2008 [7]: 15-5-3: The terminate() function shall not be called implicitly.

HIC++ v4.0 [9]: 15.3.2: Ensure that a program does not result in a call to std::terminate

SEI CERT C++ Coding Standard [10]: ERR50-CPP: Do not abruptly terminate the program.

### **Rule A15-4-3 (required, implementation, automated)**

**The noexcept specification of a function shall either be identical across all translation units, or identical or more restrictive between a virtual member function and an overrider.**

## Rationale

Declarations of the same function, even in different translation units, have to specify the same noexcept specification. Overriding functions have to specify the same or a stricter noexcept specification than the base class function which they override.

Note that in many cases, a violation of this rule will lead to a compilation error. This is not guaranteed, however, in particular when function declarations appear in separate translation units.

### Example

```
//% $Id: A15-4-3.cpp 317753 2018-04-27 07:44:02Z jan.babst $
// f1.hpp
void Fn() noexcept;
4
// f1.cpp
// #include <f1.hpp>
void Fn() noexcept // Compliant
{
// Implementation
}
11
// f2.cpp
// #include <f1.hpp>
void Fn() noexcept(false) // Non-compliant - different exception specifier
{
// Implementation
}
18
class A
{
public:
void F() noexcept;
void G() noexcept(false);
virtual void V1() noexcept = 0;
virtual void V2() noexcept(false) = 0;
};
void A::F() noexcept // Compliant
// void A::F() noexcept(false) // Non-compliant - different exception specifier
// than in declaration
{
// Implementation
}
void A::G() noexcept(false) // Compliant
// void A::G() noexcept // Non-compliant - different exception specifier than
// in declaration
{
// Implementation
}
class B : public A
{
public:
void V1() noexcept override // Compliant
// void V1() noexcept(false) override // Non-compliant - less restrictive
// exception specifier in derived method, non-compilable
{
// Implementation
```



```

}
void V2() noexcept override // Compliant - stricter noexcept specification
{
// Implementation
}
};

```

## See also

MISRA C++ 2008 [7]: 15-4-1: If a function is declared with an exception-specification, then all declarations of the same function (in other translation units) shall be declared with the same set of type-ids.

**Rule A15-4-4 (required, implementation, automated)**  
**A declaration of non-throwing function shall contain noexcept specification.**

## Rationale

Noexcept specification is a method for a programmer to inform the compiler whether or not a function should throw exceptions. The compiler can use this information to enable certain optimizations on non-throwing functions as well as enable the noexcept operator, which can check at compile time if a particular expression is declared to throw any exceptions.

Noexcept specification is also a method to inform other programmers that a function does not throw any exceptions.

A non-throwing function needs to declare noexcept specifier. A function that may or may not throw exceptions depending on a template argument, needs to explicitly specify its behavior using noexcept(<condition>) specifier.

Note that it is assumed that a function which does not contain explicit noexcept specification throws exceptions, similarly to functions that declare noexcept(false) specifier.

## Example

```

//% $Id: A15-4-4.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <iostream>
#include <stdexcept>
void F1(); // Compliant - f1, without noexcept specification, declares to throw
5         // exceptions implicitly
6 void F2() noexcept; // Compliant - f2 does not throw exceptions
7 void F3() noexcept(true); // Compliant - f3 does not throw exceptions
void F4() noexcept(false); // Compliant - f4 declares to throw exceptions
9 void F5() noexcept // Compliant - f5 does not throw exceptions
{
try
{

```

```

F1()); // Exception handling needed, f1 has no noexcept specification
}
15
catch (std::exception& e)
{
// Handle exceptions
}
20
F2()); // Exception handling not needed, f2 is noexcept
F3()); // Exception handling not needed, f3 is noexcept(true)
23
try
{
F4()); // Exception handling needed, f4 is noexcept(false)
}
28
catch (std::exception& e)
{
// Handle exceptions
}
}
template <class T>
void F6() noexcept(noexcept(T())); // Compliant - function f6() may be
36                                     // noexcept(true) or noexcept(false)
37                                     // depending on constructor of class T
template <class T>
class A
{
public:
A() noexcept(noexcept(T())) // Compliant - constructor of class A may be
// noexcept(true) or noexcept(false) depending on
// constructor of class T
{
}
};
class C1
{
public:
C1()
noexcept(
true) // Compliant - constructor of class C1 does not throw exceptions
{
}
// ...
};
class C2
{
public:
C2() // Compliant - constructor of class C2 throws exceptions
{
}
}

```

```
64     // ...
65 };
66 void F7() noexcept // Compliant - f7 does not throw exceptions
67 {
68     std::cout << noexcept(A<C1>()) << '\n';           // prints '1' - constructor of
69                                                         // A<C1> class is noexcept(true)
70                                                         // because constructor of C1 class
71                                                         // is declared to be noexcept(true)
72     std::cout << noexcept(A<C2>()) << '\n';           // prints '0' - constructor of
73                                                         // A<C2> class is noexcept(false)
74                                                         // because constructor of C2 class
75                                                         // has no noexcept specifier
76 }
```

## See also

none

**Rule A15-4-5 (required, implementation, automated)**  
**Checked exceptions that could be thrown from a function shall be specified together with the function declaration and they shall be identical in all function declarations and for all its overrides.**

## Rationale

In C++ language, all exceptions are unchecked, because the compiler does not force to either handle the exception or specify it. Because dynamic-exception specification is obsolete and error prone, an alternative mechanism of specifying checked exceptions using C++ comments along with function declarations is used. It is a concept that is based on Java exception handling mechanism.

When analyzing a given function *f*, a static code analysis needs to analyze functions invoked by *f* and analyze if they throw any checked exceptions that are not caught by *f* and not listed by *f* in the function comment.

## Exception

Within generic code, it is not generally possible to know what types of exceptions may be thrown from operations on template arguments, so a precise exception specification cannot be written. Therefore, this rule does not apply for templates.

## Example

```
/// % $Id: A15-4-5.cpp 309502 2018-02-28 09:17:39Z michal.szczepankiewicz $
#include <cstdlib>
#include <stdexcept>
4
/// @checkedException
class CommunicationError : public std::exception
{
```

```

// Implementation
};
/// @checkedException
class BusError : public CommunicationError
{
// Implementation
};
/// @checkedException
class Timeout : public std::runtime_error
{
public:
using std::runtime_error::runtime_error;
// Implementation
};
/// @throw CommunicationError Communication error
/// @throw BusError Bus error
24 /// @throw Timeout On send timeout exception
void Send1(
std::uint8_t* buffer,
std::uint8_t bufferLength) noexcept(false) // Compliant - All and only
28 // those checked exceptions
29 // that can be thrown are
30 // specified
{
// ...
throw CommunicationError();
// ...
throw BusError();
// ...
throw Timeout("Timeout reached");
// ...
}
/// @throw CommunicationError Communication error
void Send2(
std::uint8_t* buffer,
std::uint8_t bufferLength) noexcept(false) // Non-compliant - checked
44 // exceptions that can be
45 // thrown are missing from
46 // specification
{
// ...
throw CommunicationError();
// ...
throw Timeout("Timeout reached");
// ...
}
class MemoryPartitioningError : std::exception
{
// Implementation
};
/// @throw CommunicationError Communication error

```

```
/// @throw BusError Bus error
60 /// @throw Timeout      On send timeout exception
/// @throw MemoryPartitioningError Memory partitioning error prevents message
/// from being sent.
void Send3(
std::uint8_t* buffer,
std::uint8_t bufferLength) noexcept(false) // Non-compliant - additional
66                                     // checked exceptions are
67                                     // specified
{
// ...
throw CommunicationError();
// ...
throw Timeout("Timeout reached");
// ...
}
```

## See also

Effective Java 2nd Edition [15]: Item 62: Document all exceptions thrown by each method

### 6.15.5 Special functions

#### **Rule A15-5-1 (required, implementation, automated)**

**All user-provided class destructors, deallocation functions, move constructors, move assignment operators and swap functions shall not exit with an exception. A noexcept exception specification shall be added to these functions as appropriate.**

#### Rationale

When an exception is thrown, the call stack is unwound up to the point where the exception is to be handled. The destructors for all automatic objects declared between the point where the exception is thrown and where it is to be handled will be invoked. If one of these destructors or delete operators exits with an exception, then the program will terminate in an implementation-defined manner.

Move constructors and move assignment operators are usually expected to be non-throwing. If they throw exceptions, strong exception safety cannot be guaranteed, because the original type values could be already modified or partially modified.

Note that some operations in the standard library statically check the noexcept specification of the move constructors and move assignment operators of parameter types. They may choose less efficient algorithms or provide fewer exception safety guarantees if these are not noexcept.

The standard-library containers and algorithms will not work correctly if swapping of two elements exits with an exception. A non-throwing swap function is also an important basic tool to implement the strong exception safety guarantee in a copy assignment operator (see [A12-8-2](#)).

Note that it is acceptable for a destructor or deallocation function to throw an exception that is handled within this function, for example within a try-catch block.

Note that deallocation functions are declared noexcept by default. A destructor is declared as noexcept by default unless a destructor of any base class or member is potentially-throwing. Using a base class or member with a potentially-throwing destructor is a violation of this rule. The respective base class or member destructor must be fixed in order to comply to this rule. The intention of this rule is that the implementation of a user-provided destructor is ensured to not exit with an exception. Only then, the default noexcept specification added implicitly to the user-provided destructor is correct. It may be explicitly restated as noexcept for documentation purposes.

The compiler also adds a noexcept specification implicitly for any defaulted special member function. This noexcept specification depends on the noexcept specification of the member and base class operations that the defaulted special member function will call implicitly. It is therefore not required to default a special member function only to add the noexcept specification. Reasons to default a special member function exist independently from this rule, for example due to [A12-0-1](#).

## Exception

Generic move constructors, generic move assignment operators, and generic swap functions may have noexcept specifications which depend on type properties of the template parameters.

## Example

```
//% $Id: A15-5-1.cpp 309720 2018-03-01 14:05:17Z jan.babst $
#include <stdexcept>
#include <type_traits>
4
class C1
{
public:
C1() = default;
9
// Compliant - move constructor is non-throwing and declared to be noexcept
C1(C1&& rhs) noexcept {}
12
// Compliant - move assignment operator is non-throwing and declared to be
// noexcept
C1& operator=(C1&& rhs) noexcept { return *this; }
16
// Compliant - destructor is non-throwing and declared to be noexcept by
// default
```

```
~C1() noexcept {}  
};  
21  
void Swap(C1& lhs,  
C1& rhs) noexcept // Compliant - swap function is non-throwing and  
24 // declared to be noexcept  
{  
// Implementation  
}  
28  
class C2  
{  
public:  
C2() = default;  
33  
// Compliant - move constructor is non-throwing and declared to be noexcept  
C2(C2&& rhs) noexcept  
{  
try  
{  
39 // ...  
40 throw std::runtime_error(  
41 "Error"); // Exception will not escape this function  
}  
43  
catch (std::exception& e)  
{  
46 // Handle error  
}  
}  
49  
C2& operator=(C2&& rhs) noexcept  
{  
try  
{  
54 // ...  
55 throw std::runtime_error(  
56 "Error"); // Exception will not escape this function  
}  
58  
catch (std::exception& e)  
{  
61 // Handle error  
}  
return *this;  
}  
65  
// Compliant - destructor is non-throwing and declared to be noexcept by  
// default  
~C2()  
{
```

```
try
{
    72         // ...
    73         throw std::runtime_error(
    74             "Error"); // Exception will not escape this function
}
76
catch (std::exception& e)
{
    79         // Handle error
}
};
83
// Non-compliant - swap function is declared to be noexcept(false)
void Swap(C2& lhs, C2& rhs) noexcept(false)
{
    // ...
    // Non-compliant - Implementation exits with an exception
    throw std::runtime_error("Swap function failed");
}
91
class C3
{
public:
    C3() = default;
    C3(C3&& rhs) // Non-compliant - move constructor throws
    {
        // ...
        throw std::runtime_error("Error");
    }
    C3& operator=(C3&& rhs) // Non-compliant - move assignment operator throws
    {
        // ...
        throw std::runtime_error("Error");
        return *this;
    }
    ~C3() // Non-compliant - destructor exits with an exception
    {
        throw std::runtime_error("Error");
    }
    static void operator delete(void* ptr, std::size_t sz)
    {
        // ...
        throw std::runtime_error("Error"); // Non-compliant - deallocation
    115                                     // function exits with an exception
    }
};
118
void Fn()
{
```



```
C3 c1; // program terminates when c1 is destroyed
C3* c2 = new C3;
// ...
delete c2; // program terminates when c2 is deleted
}
126
template <typename T>
class Optional
{
public:
// ...
132
// Compliant by exception
Optional(Optional&& other) noexcept(
std::is_nothrow_move_constructible<T>::value)
{
// ...
}
139
// Compliant by exception
Optional& operator=(Optional&& other) noexcept(
std::is_nothrow_move_assignable<T>::value&&
143          std::is_nothrow_move_constructible<T>::value)
{
// ...
return *this;
}
148
// ...
};
```

## See also

MISRA C++ 2008 [7]: 15-5-1: A class destructor shall not exit with an exception.

HIC++ v4.0 [9]: 15.2.1: Do not throw an exception from a destructor

C++ Core Guidelines [11]: E.16: Destructors, deallocation, and swap must never fail

C++ Core Guidelines [11]: C.85: Make swap noexcept

ISO/IEC 14882:2014 [3]: 15.4: [except.spec]

ISO/IEC 14882:2014 [3]: 20.2.4, paragraph 9:

[forward] [A12-0-1](#) in section [6.12.0](#)

[A12-8-2](#) in section [6.12.8](#)

**Rule A15-5-2 (required, implementation, partially automated) Program shall not be abruptly terminated. In particular, an implicit or**

**explicit invocation of `std::abort()`, `std::quick_exit()`,  
`std::_Exit()`, `std::terminate()` shall not be done.**

## Rationale

Functions that are used to terminate the program in an immediate fashion, i.e. `std::abort()`, `std::quick_exit()`, `std::_Exit()`, do so without calling exit handlers or calling destructors of automatic, thread or static storage duration objects. It is implementation-defined whether opened streams are flushed and closed, and temporary files are removed.

The `std::terminate()` function calls `std::abort()` implicitly in its terminate handler, and it is implementation-defined whether or not stack unwinding will occur.

Note: `std::terminate_handler` shall not be used.

## Example

```
//% $Id: A15-5-2.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <cstdlib>
#include <exception>
void F1() noexcept(false);
void F2() // Non-compliant
{
    F1(); // A call to throwing f1() may result in an implicit call to
    // std::terminate()
}
void F3() // Compliant
{
    try
    {
        F1(); // Handles all exceptions from f1() and does not re-throw
    }
    catch (...)
    {
        // Handle an exception
    }
}
void F4(const char* log)
{
    // Report a log error
    // ...
    std::exit(0); // Call std::exit() function which safely cleans up resources
}
void F5() // Compliant by exception
{
    try
    {
        F1();
    }
    catch (...)
    {
```

```
F4("f1() function failed");
}
}
int main(int, char**)
{
if (std::atexit(&F2) != 0)
{
// Handle an error
}
44
if (std::atexit(&F3) != 0)
{
// Handle an error
}
49
// ...
return 0;
}
```

## See also

MISRA C++ 2008 [7]: 15-5-3 (Required) The `terminate()` function shall not be called implicitly.

HIC++ v4.0 [9]: 15.3.2 Ensure that a program does not result in a call to `std::terminate`

SEI CERT C++ [10]: ERR50-CPP. Do not abruptly terminate the program

**Rule A15-5-3 (required, implementation, automated)**  
**The `std::terminate()` function shall not be called implicitly.**

## Rationale

It is implementation-defined whether the call stack is unwound before `std::terminate()` is called. There is no guarantee that the destructors of automatic thread or static storage duration objects will be called.

These are following ways to call `std::terminate()` function implicitly, according to (`std::terminate()` in CppReference [16]):

- an exception is thrown and not caught (it is implementation-defined whether any stack unwinding is done in this case)

- an exception is thrown during exception handling (e.g. from a destructor of some local object, or from a function that had to be called during exception handling)

- the constructor or the destructor of a static or thread-local object throws an exception

- a function registered with `std::atexit` or `std::at_quick_exit` throws an exception

a noexcept specification is violated (it is implementation-defined whether any stack unwinding is done in this case)

a dynamic exception specification is violated and the default handler for `std::unexpected` is executed

a non-default handler for `std::unexpected` throws an exception that violates the previously violated dynamic exception specification, if the specification does not include `std::bad_exception`

`std::nested_exception::rethrow_nested` is called for an object that isn't holding a captured exception

an exception is thrown from the initial function of `std::thread`

a joinable `std::thread` is destroyed or assigned to

Note: `std::terminate_handler` shall not be used.

## Example

```
///% $Id: A15-5-3.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <stdexcept>
#include <thread>
extern bool F1();
class A
{
public:
A() noexcept(false)
{
// ...
throw std::runtime_error("Error1");
}
~A()
{
// ...
throw std::runtime_error("Error2"); // Non-compliant - std::terminate()
// called on throwing an exception
// from noexcept(true) destructor
}
};
class B
{
public:
~B() noexcept(false)
{
// ...
throw std::runtime_error("Error3");
}
};
void F2()
{
throw;
```

```

}
void ThreadFunc()
{
A a; // Throws an exception from a's constructor and does not handle it in
// thread_func()
}
void F3()
{
try
{
std::thread t(&ThreadFunc); // Non-compliant - std::terminate() called
44                                     // on throwing an exception from
45                                     // thread_func()
46
if (F1())
{
49         throw std::logic_error("Error4");
}
51
else
{
54         F2(); // Non-compliant - std::terminate() called if there is no
55             // active exception to be re-thrown by f2
}
}
catch (...)
{
B b; // Non-compliant - std::terminate() called on throwing an
61             // exception from b's destructor during exception handling
62
// ...
F2();
}
}
static A a; // Non-compliant - std::terminate() called on throwing an exception
68             // during program's start-up phase
int main(int, char**)
{
F3(); // Non-compliant - std::terminate() called if std::logic_error is
// thrown
return 0;
}

```

## See also

MISRA C++ 2008 [7]: 15-5-3 (Required) The terminate() function shall not be called implicitly.

## 6.16 Preprocessing directives

### 6.16.0 General

**Rule A16-0-1 (required, implementation, automated)**

The pre-processor shall only be used for unconditional and conditional file inclusion and include guards, and using the following directives: (1) `#ifndef`, `#ifdef`, (3) `#if`, (4) `#if defined`, (5) `#elif`, (6) `#else`, (7) `#define`, (8) `#endif`, (9) `#include`.

#### Rationale

C++ provides safer, more readable and easier to maintain ways of achieving what is often done using the pre-processor. The pre-processor does not obey the linkage, lookup and function call semantics. Instead, constant objects, constexprs, inline functions and templates are to be used.

#### Example

```
// $Id: A16-0-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#pragma once // Non-compliant - implementation-defined feature
3
#ifndef HEADER_FILE_NAME // Compliant - include guard
#define HEADER_FILE_NAME // Compliant - include guard
6
#include <stdint> // Compliant - unconditional file inclusion
8
#ifdef WIN32
#include <windows.h> // Compliant - conditional file inclusion
#endif
12
#ifdef WIN32
std::int32_t fn1(
std::int16_t x,
std::int16_t y) noexcept; // Non-compliant - not a file inclusion
#endif
18
#if defined VERSION && VERSION > 2011L // Compliant
20 #include <array> // Compliant - conditional file inclusion
#elif VERSION > 1998L // Compliant
22 #include <vector> // Compliant - conditional file inclusion
23 #endif // Compliant
24
#define MAX_ARRAY_SIZE 1024U // Non-compliant
26 #ifndef MAX_ARRAY_SIZE // Non-compliant
#error "MAX_ARRAY_SIZE has not been defined" // Non-compliant
28 #endif // Non-compliant
#undef MAX_ARRAY_SIZE // Non-compliant
30
#define MIN(a, b) (((a) < (b)) ? (a) : (b)) // Non-compliant
```

```
#define PLUS2(X) ((X) + 2) // Non-compliant - function should be used instead
#define PI 3.14159F // Non-compliant - constexpr should be used instead
#define std ::int32_t long // Non-compliant - 'using' should be used instead
#define STARTIF if( // Non-compliant - language redefinition
#define HEADER "filename.h" // Non-compliant - string literal
37
void Fn2() noexcept
{
#ifdef __linux__ // Non-compliant - ifdef not used for file inclusion
41
// ...
43
#elif WIN32 // Non-compliant - elif not used for file inclusion
45
// ...
47
#elif __APPLE__ // Non-compliant - elif not used for file inclusion
49
// ...
51
#else // Non-compliant - else not used for file inclusion
53
// ...
55
#endif // Non-compliant - endif not used for file inclusion or include guards
}
58
#endif // Compliant - include guard
```

## See also

MISRA C++ 2008 [7]: Rule 16-2-1 The pre-processor shall only be used for file inclusion and include guards.

MISRA C++ 2008 [7]: Rule 16-2-2 C++ macros shall only be used for: include guards, type qualifiers, or storage class specifiers.

JSF December 2005 [8]: AV Rule 26 Only the following pre-processor directives shall be used: 1. #ifndef 2. #define 3. #endif 4. #include.

JSF December 2005 [8]: AV Rule 27 #ifndef, #define and #endif will be used to prevent multiple inclusions of the same header file. Other techniques to prevent the multiple inclusions of header files will not be used.

JSF December 2005 [8]: AV Rule 28 The #ifndef and #endif pre-processor directives will only be used as defined in AV Rule 27 to prevent multiple inclusions of the same header file.

JSF December 2005 [8]: AV Rule 29 The #define pre-processor directive shall not be used to create inline macros. Inline functions shall be used instead.

JSF December 2005 [8]: AV Rule 30 The #define pre-processor directive shall not be used to define constant values. Instead, the const qualifier shall be applied to variable declarations to specify constant values.

JSF December 2005 [8]: AV Rule 31 The #define pre-processor directive will only be used as part of the technique to prevent multiple inclusions of the same header file.

JSF December 2005 [8]: AV Rule 32 The #include pre-processor directive will only be used to include header (\*.h) files.

HIC++ v4.0 [9]: 16.1.1 Use the preprocessor only for implementing include guards, and including header files with include guards.

**Rule M16-0-1 (required, implementation, automated)**  
**#include directives in a file shall only be preceded by other pre-processor directives or comments.**

See MISRA C++ 2008 [7]

**Rule M16-0-2 (required, implementation, automated)**  
**Macros shall only be #define'd or #undef'd in the global namespace.**

See MISRA C++ 2008 [7]

**Rule M16-0-5 (required, implementation, automated)**  
**Arguments to a function-like macro shall not contain tokens that look like pre-processing directives.**

See MISRA C++ 2008 [7]

Note: Function-like macros are anyway not allowed, see [A16-0-1](#). This rule is kept in case [A16-0-1](#) is disabled in a project.

**Rule M16-0-6 (required, implementation, automated)**  
**In the definition of a function-like macro, each instance of a parameter shall be enclosed in parentheses, unless it is used as the operand of # or ##.**

See MISRA C++ 2008 [7]

Note: Function-like macros are anyway not allowed, see [A16-0-1](#). This rule is kept in case [A16-0-1](#) is disabled in a project.



**Rule M16-0-7 (required, implementation, automated)**  
Undefined macro identifiers shall not be used in `#if` or `#elif` pre-processor directives, except as operands to the defined operator.

See MISRA C++ 2008 [7]

Note: “`#if`” and “`#elif`” are anyway only allowed for conditional file inclusion, see [A16-0-1](#). This rule is kept in case [A16-0-1](#) is disabled in a project.

**Rule M16-0-8 (required, implementation, automated)**  
If the `#` token appears as the first token on a line, then it shall be immediately followed by a pre-processing token.

See MISRA C++ 2008 [7]

### 6.16.1 Conditional inclusion

**Rule M16-1-1 (required, implementation, automated)**  
The defined pre-processor operator shall only be used in one of the two standard forms.

See MISRA C++ 2008 [7]

Note: “`#if defined`” is anyway only allowed for conditional file inclusion, see [A16-0-1](#). This rule is kept in case [A16-0-1](#) is disabled in a project.

**Rule M16-1-2 (required, implementation, automated)**  
All `#else`, `#elif` and `#endif` pre-processor directives shall reside in the same file as the `#if` or `#ifdef` directive to which they are related.

See MISRA C++ 2008 [7]

Note: “`#if`”, “`#elif`”, “`#else`” and “`#ifdef`” are anyway only allowed for conditional file inclusion, see [A16-0-1](#). This rule is kept in case [A16-0-1](#) is disabled in a project.

### 6.16.2 Source file inclusion

**Rule M16-2-3 (required, implementation, automated)**  
Include guards shall be provided.

See MISRA C++ 2008 [7]

**Rule A16-2-1 (required, implementation, automated)**

The `'`, `"`, `/*`, `//`, `\` characters shall not occur in a header file name or in `#include` directive.

**Rationale**

It is undefined behavior if the `'`, `"`, `/*`, `//`, `\` characters are used in `#include` directive, between `<` and `>` or `" "` delimiters.

**Example**

```
// $Id: A16-2-1.cpp 271687 2017-03-23 08:57:35Z piotr.tanski $
2
// #include <directory/headerfile.hpp> // Compliant
// #include <headerfile.hpp> // Compliant
// #include "directory/headerfile.hpp" // Compliant
// #include "headerfile.hpp" // Compliant
// #include <directory/*.hpp> // Non-compliant
// #include <header*file.hpp> // Non-compliant
// #include <"headerfile.hpp"> // Non-compliant
// #include <directory\\headerfile.hpp> // Non-compliant
```

**See also**

MISRA C++ 2008 [7]: Rule 16-2-4 The `'`, `"`, `/*` or `//` characters shall not occur in a header file name.

MISRA C++ 2008 [7]: Rule 16-2-5 The `\` character shall not occur in a header file name.

**Rule A16-2-2 (required, implementation, automated)**

There shall be no unused include directives.

**Rationale**

Presence of unused include directives considerably slows down compilation phase, makes the code base larger and introduces unneeded dependencies.

Note: In order to determine what an unused include directive is, only the immediate level of includes, and the specifications of external libraries shall be considered. So, for example, if a source file uses the standard library algorithm `std::copy`, it is required (see also rule [A16-2-3](#)) to include the standard library header `<algorithm>`. It is not a violation of this rule if `<algorithm>`, possibly through inclusion of other headers, contains declarations of symbols not used in the source file.

**Example**

```
// $Id: A16-2-2.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <algorithm> // Non-compliant - nothing from algorithm header file is used
```

```
3 #include <array>           // Non-compliant - nothing from array header file is used
4 #include <cstdint>         // Compliant - std::int32_t, std::uint8_t are used
5 #include <iostream>       // Compliant - cout is used
#include <stdexcept> // Compliant - out_of_range is used
7 #include <vector>         // Compliant - vector is used
void Fn1() noexcept
{
std::int32_t x = 0;
// ...
std::uint8_t y = 0;
// ...
}
void Fn2() noexcept(false)
{
try
{
std::vector<std::int32_t> v;
// ...
std::uint8_t idx = 3;
std::int32_t value = v.at(idx);
}
catch (std::out_of_range& e)
{
std::cout << e.what() << '\n';
}
}
```

## See also

HIC++ v4.0 [9]: 16.1.5 Include directly the minimum number of headers required for compilation.

**Rule A16-2-3 (required, implementation, non-automated)**  
**An include directive shall be added explicitly for every symbol used in a file.**

## Rationale

All header files that define types or functions used in a file should be included explicitly. The actual header to include depends on the specification of the library/component used.

## Exception

Types defined via forward declarations do not violate this rule.

## Example

```
// $Id: A16-2-3.hpp 319944 2018-05-21 09:00:40Z ilya.burylov $
#ifndef HEADER_HPP
```

```
#define HEADER_HPP
4
#include <array>
#include <cstdint>
7
class B; // Compliant - type B can be included using forward declaration
9
class OutOfRangeException
: public std::out_of_range // Non-compliant - <stdexcept> which defines
12                                     // out_of_range included
13                                     // implicitly through <array>
{
public:
using std::out_of_range::out_of_range;
};
18
class A
{
public:
// Interface of class A
23
private:
std::array<std::uint32_t, 10>
mArray; // Compliant - <array> included explicitly
B* mB;
std::int32_t mX; // Compliant - <cstdint> included explicitly
};
30
#endif
```

## See also

none

### 6.16.3 Macro replacement

#### Rule M16-3-1 (required, implementation, automated)

There shall be at most one occurrence of the # or ## operators in a single macro definition.

See MISRA C++ 2008 [7]

Note: Operators # and ## are anyway not allowed, see [M16-3-2](#). This rule is kept in case [M16-3-2](#) is disabled in a project.

**Rule M16-3-2 (advisory, implementation, automated)**  
**The # and ## operators should not be used.**

See MISRA C++ 2008 [7]

### 6.16.6 Error directive

**Rule A16-6-1 (required, implementation, automated)**  
**#error directive shall not be used.**

#### Rationale

Using the pre-processor `#error` directive may lead to code that is complicated and not clear for developers. The `#error` directive can not be applied to templates as it will not be evaluated as a per-instance template deduction.

Static assertion, similarly to `#error` directive, provides a compile-time error checking. However, `static_assert` behaves correctly in all C++ concepts and makes the code more readable and does not rely on pre-processor directives.

Note: “`#error`” is anyway not allowed, see [A16-0-1](#). This rule is kept in case [A16-0-1](#) is disabled in a project.

#### Example

```
// $Id: A16-6-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <stdint>
#include <type_traits>
constexpr std::int32_t value = 0;
#if value > 10
#error "Incorrect value" // Non-compliant
#endif
void F1() noexcept
{
static_assert(value <= 10, "Incorrect value"); // Compliant
// ...
}
template <typename T>
void F2(T& a)
{
static_assert(std::is_copy_constructible<T>::value,
              "f2() function requires copying"); // Compliant
// ...
}
```

#### See also

none

### 6.16.7 Pragma directive

**Rule A16-7-1 (required, implementation, automated)**  
**The #pragma directive shall not be used.**

#### Rationale

The #pragma directive is implementation-defined and causes the implementation to behave in implementation-defined manner.

#### Example

```
// $Id: A16-7-1.hpp 270497 2017-03-14 14:58:50Z piotr.tanski $  
// #pragma once // Non-compliant - implementation-defined manner  
#ifndef A16_7_1_HPP // Compliant - equivalent to #pragma once directive  
#define A16_7_1_HPP  
5  
// ...  
7  
#endif
```

#### See also

MISRA C++ 2008 [7]: Rule 16-6-1 All uses of the #pragma directive shall be documented.

## 6.17 Library introduction - partial

### 6.17.1 General

**Rule A17-0-1 (required, implementation, automated)**  
**Reserved identifiers, macros and functions in the C++ standard library shall not be defined, redefined or undefined.**

#### Rationale

It is generally bad practice to #undef a macro that is defined in the standard library. It is also bad practice to #define a macro name that is a C++ reserved identifier, or C++ keyword or the name of any macro, object or function in the standard library. For example, there are some specific reserved words and function names that are known to give rise to undefined behavior if they are redefined or undefined, including defined, \_\_LINE\_\_, \_\_FILE\_\_, \_\_DATE\_\_, \_\_TIME\_\_, \_\_STDC\_\_, errno and assert.

Refer to C++ Language Standard for a list of the identifiers that are reserved. Generally, all identifiers that begin with the underscore character are reserved.

Note that this rule applies regardless of which header files, if any, are actually included.

### Example

```
// $Id: A17-0-1.cpp 271389 2017-03-21 14:41:05Z piotr.tanski $  
2 #undef __TIME__ // Non-compliant  
#define __LINE__ 20 // Non-compliant
```

### See also

MISRA C++ 2008 [7]: Rule 17-0-1 Reserved identifiers, macros and functions in the standard library shall not be defined, redefined or undefined.

**Rule M17-0-2 (required, implementation, automated)**  
**The names of standard library macros and objects shall not be reused.**

See MISRA C++ 2008 [7]

**Rule M17-0-3 (required, implementation, automated)**  
**The names of standard library functions shall not be overridden.**

See MISRA C++ 2008 [7]

**Rule A17-0-2 (required, implementation, non-automated)**  
**All project's code including used libraries (including standard and user-defined libraries) and any third-party user code shall conform to the AUTOSAR C++14 Coding Guidelines.**

### Rationale

Note that library code can be provided as source code or be provided in a compiled form. The rule applies for any form of libraries.

As for any rule in this standard, a deviation procedure can be performed for this rule and the project needs to argue what are the measures ensuring that non-compliant libraries can be used in a project, addressing:

- interference from the non-compliant code (for example, a library function overwrites the stack or heap of the caller)

- residual errors in non-compliant code resulting with its wrong outputs, which are subsequently used (for example, a library function delivers wrong return value used by the caller).

## Exception

If a function is defined in a library or any third-party user code but it is ensured that the function will not be used (directly or indirectly) in the project, then the function may not conform to the AUTOSAR C++14 Coding Guidelines.

## See also

none

**Rule M17-0-5 (required, implementation, automated)**  
**The `setjmp` macro and the `longjmp` function shall not be used.**

See MISRA C++ 2008 [7]

See: [A6-6-1](#).

## 6.17.2 The C standard library

**Rule A17-1-1 (required, implementation, non-automated)**  
**Use of the C Standard Library shall be encapsulated and isolated.**

## Rationale

The C Standard Library leaves the responsibility for handling errors, data races and security concerns up to developers. Therefore, use of the C Standard Library needs to be separated and wrapped with functions that will be fully responsible for all specific checks and error handling.

## Example

```
// $Id: A17-1-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <cerrno>
#include <cstdio>
#include <cstring>
#include <iostream>
#include <stdexcept>
7
void Fn1(const char* filename) // Compliant - C code is isolated; fn1()
9                             // function is a wrapper.
{
FILE* handle = fopen(filename, "rb");
if (handle == NULL)
{
throw std::system_error(errno, std::system_category());
}
// ...
fclose(handle);
```



```
}
19
void Fn2() noexcept
{
try
{
Fn1("filename.txt"); // Compliant - fn1() allows you to use C code like
25                               // C++ code
26
// ...
}
catch (std::system_error& e)
{
std::cerr << "Error: " << e.code() << " - " << e.what() << '\n';
}
}
34
std::int32_t Fn3(const char* filename) noexcept // Non-compliant - placing C
// functions calls along with C++
// code forces a developer to be
// responsible for C-specific error
// handling, explicit resource
// cleanup, etc.
{
FILE* handle = fopen(filename, "rb");
if (handle == NULL)
{
std::cerr << "An error occured: " << errno << " - " << strerror(errno)
46                               << '\n';
return errno;
}
}
49
try
{
// ...
fclose(handle);
}
catch (std::system_error& e)
{
fclose(handle);
}
catch (std::exception& e)
{
fclose(handle);
}
63
return errno;
}
```

## See also

MISRA C++ 2008 [7]: Rule 19-3-1 The error indicator `errno` shall not be used.

HIC++ v4.0 [9]: 17.2.1 Wrap use of the C Standard Library.

JSF December 2005 [8]: Chapter 4.5.1: Standard Libraries, AV Rule 17 - AV Rule 25.

### 6.17.3 Definitions

The corresponding section in the C++14 standard provides a glossary only.

### 6.17.6 Library-wide requirements

**Rule A17-6-1 (required, implementation, automated) Non-standard entities shall not be added to standard namespaces.**

#### Rationale

Adding declarations or definitions to namespace `std` or its sub-namespaces, or to namespace `posix` or its sub-namespaces leads to undefined behavior.

Declaring an explicit specialization of a member function or member function template of a standard library class or class template leads to undefined behavior.

Declaring an explicit or partial specialization of a member class template of a standard library class or class template leads to undefined behavior.

#### Exception

It is allowed by the language standard to add a specialization to namespace `std` if the declaration depends on a user-defined type, meets the requirements for the original template and is not explicitly forbidden.

It is allowed by the language standard to explicitly instantiate a template defined in the standard library if the declaration depends on a user defined type and meets the requirements for the original template.

#### Example

```
// $Id: A17-6-1.cpp 305588 2018-01-29 11:07:35Z michal.szczepankiewicz $
#include <cstdlib>
#include <limits>
#include <memory>
#include <type_traits>
#include <utility>
7
namespace std
{
10
// Non-compliant - An alias definition is added to namespace std.
```

```
// This is a compile error in C++17, since std::byte is already defined.
using byte = std::uint8_t;
14
// Non-compliant - A function definition added to namespace std.
pair<int, int> operator+(pair<int, int> const& x, pair<int, int> const& y)
{
return pair<int, int>(x.first + y.first, x.second + y.second);
}
20
} // namespace std
22
struct MyType
{
int value;
};
27
namespace std
{
30
// Non-compliant - std::numeric_limits may not be specialized for
// non-arithmetic types [limits.numeric].
template <>
struct numeric_limits<MyType> : numeric_limits<int>
{
};
37
// Non-compliant - Structures in <type_traits>, except for std::common_type,
// may not be specialized [meta.type.synop].
template <>
struct is_arithmetic<MyType> : true_type
{
};
44
// Compliant - std::hash may be specialized for a user type if the
// specialization fulfills the requirements in [unord.hash].
template <>
struct hash<MyType>
{
50     using result_type = size_t; // deprecated in C++17
using argument_type = MyType; // deprecated in C++17
52
size_t operator()(MyType const& x) const noexcept
{
return hash<int>()(x.value);
}
};
58
} // namespace std
```

## See also

SEI CERT C++ Coding Standard [10]: DCL58-CPP: Do not modify the standard namespaces

C++ Core Guidelines [11]: SL.3: Do not add non-standard entities to namespace std

ISO/IEC 14882:2014 [3]: 17.6.4.2: [namespace.constraints]

ISO/IEC 14882:2014 [3]: 18.3.2.1: [limits.numeric]

ISO/IEC 14882:2014 [3]: 20.9.13: [unord.hash]

ISO/IEC 14882:2014 [3]: 20.10.2: [meta.type.synop]

## 6.18 Language support library - partial

The corresponding chapter in the C++ standard defines the fundamental support libraries, including integer types, dynamic memory, start and termination.

### 6.18.0 General

**Rule A18-0-1 (required, implementation, automated)**  
**The C library facilities shall only be accessed through C++ library headers.**

#### Rationale

C libraries (e.g. <stdio.h>) also have corresponding C++ libraries (e.g. <cstdio>). This rule requires that the C++ version is used.

#### See also

MISRA C++ 2008 [7]: Rule 18-0-1 (Required) The C library shall not be used.

HIC++ v4.0 [9]: 1.3.3 Do not use the C Standard Library .h headers.

**Rule A18-0-2 (required, implementation, automated)**  
**The error state of a conversion from string to a numeric value shall be checked.**

#### Rationale

Error conditions of a string-to-number conversion must be detected and properly handled. Such errors can happen when an input string:

does not contain a number;

contains a number, but it is out of range;

contains additional data after a number.

Some functions for string-to-number conversion from the C Standard library have undefined behavior when a string cannot be converted to a number, e.g. `atoi()`. Since the C++11 Language Standard, new numeric conversion functions are available (see: `std::stoi()`, `std::stol()`, `std::stoll()` [16]). These guarantee defined behavior.

Moreover, errors shall be checked also for formatted input stream functions (e.g. `istream::operator>>()`), by using `basic_ios::fail()`.

## Example

```
// $Id: A18-0-2.cpp 312092 2018-03-16 15:47:01Z jan.babst $
#include <cstdlib>
#include <cstdlib>
#include <iostream>
#include <string>
6
std::int32_t F1(const char* str) noexcept
{
    return atoi(str); // Non-compliant - undefined behavior if str can not
10                          // be converted
}
std::int32_t F2(std::string const& str) noexcept(false)
{
    return std::stoi(str); // Compliant - throws a std::invalid_argument
15                          // exception if str can not be converted
}
17
std::uint16_t ReadFromStdin1() // non-compliant
{
    std::uint16_t a;
    std::cin >> a; // no error detection
    return a;
}
24
std::uint16_t ReadFromStdin2() // compliant
{
    std::uint16_t a;
28
    std::cin.clear(); // clear all flags
    std::cin >> a;
    if (std::cin.fail())
    {
        throw std::runtime_error{"unable to read an integer"};
    }
    std::cin.clear(); // clear all flags for subsequent operations
    return a;
}
```

## See also

MISRA C++ 2008 [7]: 18-0-2: The library functions `atof`, `atoi` and `atol` from library `<cstdlib>` shall not be used.

SEI CERT C++ Coding Standard [10]: ERR34-C: Detect errors when converting a string to a number

SEI CERT C++ Coding Standard [10]: ERR62-CPP: Detect errors when converting a string to a number

**Rule M18-0-3 (required, implementation, automated)**  
**The library functions `abort`, `exit`, `getenv` and `system` from library `<cstdlib>` shall not be used.**

See MISRA C++ 2008 [7]

**Rule M18-0-4 (required, implementation, automated)**  
**The time handling functions of library `<ctime>` shall not be used.**

See MISRA C++ 2008 [7]

Note: Facilities from `<chrono>` shall be used instead.

**Rule M18-0-5 (required, implementation, automated)**  
**The unbounded functions of library `<cstring>` shall not be used.**

See MISRA C++ 2008 [7]

Note: The intention of this rule is to prohibit the functions from `<cstring>` which have a `char*` or `char const*` parameter, but no additional `size_t` parameter placing a bound on the underlying loop. Other functions from `<cstring>` taking a `char*` or `char const*` parameter fall under the restrictions of rule [A27-0-4](#). Use of `memchr`, `memcmp`, `memset`, `memcpy`, and `memmove` is still allowed by this rule, but limited by rule [A12-0-2](#).

### See also

Rule [A12-0-2](#) in section [6.12.0](#)

Rule [A27-0-4](#) in section [6.27.1](#)

**Rule A18-0-3 (required, implementation, automated)**  
**The library `<locale>` (`locale.h`) and the `setlocale` function shall not be used.**

### Rationale

A call to the `setlocale` function introduces a data race with other calls to `setlocale` function.

It may also introduce a data race with calls to functions that are affected by the current locale settings: `fprintf`, `isprint`, `iswdigit`, `localeconv`, `tolower`, `fscanf`, `ispunct`, `iswgraph`, `mblen`, `toupper`, `isalnum`, `isspace`, `iswlower`, `mbstowcs`, `towlower`, `isalpha`, `isupper`, `iswprint`, `mbtowc`, `toupper`, `isblank`, `iswalnum`, `iswpunct`, `setlocale`, `wscoll`, `isctrl`, `iswalpha`, `iswspace`, `strcoll`, `wctod`, `isdigit`, `iswblank`, `iswupper`, `strerror`, `wctombs`, `isgraph`, `iswcntrl`, `iswxdigit`, `strtod`, `wcsxfrm`, `islower`, `iswctype`, `isxdigit`, `strxfrm`, `wctomb`.

## See also

JSF December 2005 [8]: AV Rule 19 <locale.h> and the `setlocale` function shall not be used.

## 6.18.1 Types

**Rule A18-1-1 (required, implementation, automated)**  
**C-style arrays shall not be used.**

### Rationale

A C-style array is implicitly convertible to a raw pointer and easily loses information about its size. This construct is unsafe, unmaintainable, and a source of potential errors.

For fixed-size, stack-allocated arrays, `std::array` is supposed to be used instead. This type is designed to work with standard library algorithms.

### Exception

It is allowed to declare a static `constexpr` data member of a C-style array type.

### Example

```
// $Id: A18-1-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <algorithm>
#include <array>
#include <cstdint>
void Fn() noexcept
{
    const std::uint8_t size = 10;
    8     std::int32_t a1[size]; // Non-compliant
    std::array<std::int32_t, size> a2; // Compliant
    // ...
    std::sort(a1, a1 + size);
    std::sort(a2.begin(), a2.end()); // More readable and maintainable way of
    13                                // working with STL algorithms
}
class A
{
public:
```

```
static constexpr std::uint8_t array[]{0, 1, 2}; // Compliant by exception
};
```

## See also

C++ Core Guidelines [11]: ES.27: Use `std::array` or `stack_array` for arrays on the stack.

C++ Core Guidelines [11]: SL.con.1: Prefer using STL `array` or `vector` instead of a C array.

**Rule A18-1-2 (required, implementation, automated) The `std::vector<bool>` specialization shall not be used.**

## Rationale

The `std::vector<bool>` specialization does not work with all STL algorithms as expected. In particular, `operator[]()` does not return a contiguous sequence of elements as it does for the primary template `std::vector<T>`.

The C++ Language Standard guarantees that distinct elements of an STL container can be safely modified concurrently, except when the container is a `std::vector<bool>`.

Note that `std::bitset<N>`, `std::array<bool, N>`, `std::deque<bool>`, or using `std::vector` with a value type which wraps `bool` are possible alternatives.

## Example

```
// $Id: A18-1-2.cpp 312108 2018-03-16 17:56:49Z jan.babst $
#include <cstdint>
#include <vector>
4
class BoolWrapper
{
7 public:
8     BoolWrapper() = default;
9     constexpr BoolWrapper(bool b) : b_(b) {} // implicit by design
10    constexpr operator bool() const { return b_; } // implicit by design
11 private:
12     bool b_{};
13 };
14
void Fn() noexcept
{
17     std::vector<std::uint8_t> v1; // Compliant
18     std::vector<bool> v2; // Non-compliant
std::vector<BoolWrapper> v3{true, false, true, false}; // Compliant
}
```

## See also



HIC++ v4.0 [9]: 17.1.1: Do not use `std::vector<bool>`.

**Rule A18-1-3 (required, implementation, automated)**  
**The `std::auto_ptr` type shall not be used.**

### Rationale

The `std::auto_ptr` type has been deprecated since the C++11 Language Standard and is removed from the C++17 Language Standard. Due to the lack of move semantics in pre C++11 standards, it provides unusual copy semantics and cannot be placed in STL containers.

The correct alternative is `std::unique_ptr`, which shall be used instead.

### Example

```
// $Id: A18-1-3.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <cstdint>
#include <memory>
#include <vector>
void Fn() noexcept
{
    std::auto_ptr<std::int32_t> ptr1(new std::int32_t(10)); // Non-compliant
    std::unique_ptr<std::int32_t> ptr2 =
    9         std::make_unique<std::int32_t>(10);           // Compliant
    std::vector<std::auto_ptr<std::int32_t>> v; // Non-compliant
}
```

### See also

HIC++ v4.0 [9]: 1.3.4: Do not use deprecated STL library features.

cppreference.com [16]:

`std::auto_ptr`. [A1-1-1](#) in section [6.1.1](#)

**Rule A18-1-4 (required, implementation, automated)**  
**A pointer pointing to an element of an array of objects shall not be passed to a smart pointer of single object type.**

### Rationale

A dynamically allocated array of objects needs a corresponding deallocation function, e.g. allocation by `new[]` requires deallocation by `delete[]`, see also rule [A18-5-3](#) in section [6.18.5](#). Smart pointers of a single object type, e.g. `std::unique_ptr<T>` and `std::shared_ptr<T>`, by default have a deleter associated with them which is only capable of deleting a single object. Therefore, it is undefined behavior if a pointer pointing to an element of an array of objects is passed to such a

smart pointer. With the standard library smart pointer templates `std::unique_ptr` and `std::shared_ptr`, this is possible when calling the constructor or the reset function.

Note that the standard library provides a specialization of the `std::unique_ptr` template for array types, `std::unique_ptr<T[]>`, and corresponding overloads for `std::make_unique`. Usage of these features is conforming to this rule.

Note that corresponding features for `std::shared_ptr` are only available in C++17 (usage of `std::shared_ptr<T[]>` with C++11 and C++14 will lead to compilation errors). The overloads for `std::make_shared` will only be available in C++20.

Furthermore, note that it is possible to create a smart pointer of single object type with a custom deleter handling an array of objects. This is well behaving as long as this smart pointer is actually managing an array of objects. However, such a use is error-prone, since the smart pointer can be assigned a single object again in the reset function; it may no longer be possible in C++17 (moving a `std::unique_ptr<T[]>` into a `std::shared_ptr<T>` is no longer allowed); and it is superseded by better alternatives in C++17 (availability of `std::shared_ptr<T[]>`). Therefore such usage is considered not compliant to this rule.

In many cases, using a container such as `std::array` or `std::vector` or a smart pointer to a container, e.g. `std::shared_ptr<std::vector<T>>`, is a better alternative than a smart pointer to an array of objects.

### Example

```
// $Id: A18-1-4.cpp 313638 2018-03-26 15:34:51Z jan.babst $
#include <memory>
class A
{
};
void F1()
{
// Create a dynamically allocated array of 10 objects of type A.
auto up1 = std::make_unique<A[]>(10); // Compliant
10
std::unique_ptr<A> up2{up1.release()}; // Non-compliant
}
void F2()
{
auto up1 = std::make_unique<A[]>(10); // Compliant
16
std::unique_ptr<A> up2;
up2.reset(up1.release()); // Non-compliant
}
void F3()
{
auto up = std::make_unique<A[]>(10); // Compliant
23
std::shared_ptr<A> sp{up.release()}; // Non-compliant
}
```

```

void F4()
{
  auto up = std::make_unique<A[]>(10); // Compliant
29
  std::shared_ptr<A> sp;
  sp.reset(up.release()); // Non-compliant
}
void F5()
{
  auto up = std::make_unique<A[]>(10); // Compliant
36
  // sp will obtain its deleter from up, so the array will be correctly
  // deallocated. However, this is no longer allowed in C++17.
  std::shared_ptr<A> sp{std::move(up)}; // Non-compliant
40      sp.reset(new A{}); // leads to undefined behavior
}
void F6()
{
  auto up = std::make_unique<A[]>(10); // Compliant
45
  // Well behaving, but error-prone
  std::shared_ptr<A> sp{up.release(),
48      std::default_delete<A[]>{}}; // Non-compliant
  sp.reset(new A{}); // leads to undefined behavior
}

```

## See also

HIC++ v4.0 [9]: 17.3.4: Do not create smart pointers of array type.

ISO/IEC 14882:2014 [3]: 20.8 Smart pointers: [smartptr]

Rule [A18-5-3](#) in section [6.18.5](#)

**Rule A18-1-6 (required, implementation, automated)**  
**All `std::hash` specializations for user-defined types shall have a `noexcept` function call operator.**

## Rationale

Some of standard library containers use `std::hash` indirectly. Function call operator should be defined as `noexcept` to prevent container simple access from throwing an exception.

Note: Consider own hash specializations to use standard library specializations combined with XOR (^) operation as implemented by `boost::hash_combine`: `seed ^= std::hash< decltype (v)>{}(v) + 0x9e3779b9 + (seed << 6) + (seed >> 2);`

## Example

```
// $Id: A18-1-6.cpp 311792 2018-03-15 04:15:08Z christof.meerwald $
```

```
#include <cstdint>
#include <functional>
#include <string>
#include <unordered_map>
6
class A
{
public:
A(uint32_t x, uint32_t y) noexcept : x(x), y(y) {}
11
uint32_t GetX() const noexcept { return x; }
uint32_t GetY() const noexcept { return y; }
14
friend bool operator == (const A &lhs, const A &rhs) noexcept
{ return lhs.x == rhs.x && lhs.y == rhs.y; }
private:
uint32_t x;
uint32_t y;
};
21
class B
{
public:
B(uint32_t x, uint32_t y) noexcept : x(x), y(y) {}
26
uint32_t GetX() const noexcept { return x; }
uint32_t GetY() const noexcept { return y; }
29
friend bool operator == (const B &lhs, const B &rhs) noexcept
{ return lhs.x == rhs.x && lhs.y == rhs.y; }
private:
uint32_t x;
uint32_t y;
};
36
namespace std
{
// Compliant
template <>
struct hash<A>
{
std::size_t operator()(const A& a) const noexcept
{
auto h1 = std::hash<decltype(a.GetX())>{}(a.GetX());
std::size_t seed { h1 + 0x9e3779b9 };
auto h2 = std::hash<decltype(a.GetY())>{}(a.GetY());
seed ^= h2 + 0x9e3779b9 + (seed << 6) + (seed >> 2);
return seed;
}
};
52
```

```
// Non-compliant: string concatenation can potentially throw
template <>
struct hash<B>
{
    std::size_t operator()(const B& b) const
    {
        std::string s{std::to_string(b.GetX()) + ',' + std::to_string(b.GetY())};
        return std::hash<std::string>{}(s);
    }
};
}
64
int main()
{
    std::unordered_map<A, bool> m1 { { A{5, 7}, true } };
68
    if (m1.count(A{4, 3}) != 0)
    {
        // ....
    }
73
    std::unordered_map<B, bool> m2 { { B{5, 7}, true } };
75
    // Lookup can potentially throw if hash function throws
    if (m2.count(B{4, 3}) != 0)
    {
        // ....
    }
}
```

## See also

C++ Core Guidelines [11]: C.89: Make a hash noexcept.

### 6.18.2 Implementation properties

**Rule M18-2-1 (required, implementation, automated)**  
**The macro offsetof shall not be used.**

See MISRA C++ 2008 [7]

### 6.18.5 Dynamic memory management

The dynamic memory management provides flexible mechanism of allocating and deallocating blocks of memory during run-time phase of the program. The application is allowed to acquire as much memory as it needs in its current state, and return it once the memory is not used.

Moreover, this is a convenient way of extending lifetime of objects outside the functions where the objects were created. In other words, a function can create objects on dynamic memory and then exit and the objects that were created in the dynamic memory are preserved and can be used subsequently by other functions.

The dynamic memory management uses the Operating System routines to allocate and deallocate memory, what introduces several issues. Therefore, the AUTOSAR C++14 Coding Guidelines defines specific rules for appropriate usage and implementation of dynamic memory management.

### Challenges arising due to dynamic memory usage

Issue:	Solution:
Memory leaks	RAII design pattern usage is highly recommended for managing resource and memory acquisition and release (A18-5-2). It is prohibited to make calls to new and delete operators explicitly, to force programmers to assign each allocated memory block to manager object which deallocates the memory automatically on leaving its scope. Also, the form of delete operator used for memory deallocation needs to match the form of new operator used for memory allocation (A18-5-3).
Memory fragmentation	Memory allocator used in the project needs to guarantee that no memory fragmentation occurs (A18-5-5).
Invalid memory access	C-style functions malloc/calloc/realloc must not be used in the project, so memory block can not be accessed as it would be of another type. Memory allocator used in the project needs to guarantee that objects do not overlap in the physical storage (A18-5-5).
Erroneous memory allocations	The application program needs to define the maximum amount of dynamic memory it needs, so running out of memory must not occur during faultless execution. The memory would be pre-allocated before run-time phase of the program (A18-5-5).
Not deterministic execution time of memory allocation and deallocation	Memory allocator used in the project needs to guarantee that memory allocation and deallocation are executed within defined time constraints that are appropriate for the response time constraints defined for the real-time system and its programs (A18-5-7).

**Table 6.2: Challenged of dynamic memory usage**

## Ownership and smart pointers

Memory allocated dynamically requires strict control of objects or functions that are responsible for deallocating it when it is no longer needed. Such lifetime manipulation and maintenance of managing dynamically allocated memory is called Ownership. Ownership has the following features:

- if it is exclusive, then it is possible to transfer it from one scope to another.

- if it is shared, then memory deletion is typically responsibility of the last owner that releases that ownership.

- if it is temporary, then a non-owning/weak reference has to be converted to shared ownership before accessing the object.

Since C++11, management of Ownership is done by smart pointer types. Smart pointers are allocated on stack, which guarantees destructor execution and possible object deallocation (if that is the last or sole owner) at the end of the scope. Pointer-like behavior is done by overloading `operator->` and `operator*` methods.

The following standard smart pointer classes are available since C++11:

- `std::unique_ptr` wraps a pointer to an object in an exclusive way. Such `std::unique_ptr` object guarantees that only one pointer to the underlying object exists at a time, as `std::unique_ptr` is not copyable. It is movable and such an operation represents ownership transfer. When the `std::unique_ptr` instance is goes out of scope, the underlying pointer is deleted and memory is deallocated.

- `std::shared_ptr` wraps a pointer to an object in a shared way. Multiple `std::shared_ptr` are capable to point at the same object, as `std::shared_ptr` is copyable and it contains a reference counting mechanism. When the last `std::shared_ptr` instance goes out of scope (and the reference counter drops to 0), the underlying pointer is deleted and memory is deallocated.

- `std::weak_ptr` wraps a pointer to an object, but it has to be converted to a `std::shared_ptr` in order to access the referenced object. The main purpose of the `std::weak_ptr` is to break potential circular references among multiple `std::shared_ptr` objects, which would prevent reference counting from dropping to 0 and removing the underlying pointer. If only `std::weak_ptr` objects exist at a time, then conversion to `std::shared_ptr` will return an empty `std::shared_ptr`.

The main purpose of smart pointers is prevent from possible memory leaks to provide limited garbage-collection feature:

- with almost no overhead over raw pointers for `std::unique_ptr`, unless user-specified deleter is used.

- with possibility of sharing ownership among multiple `std::shared_ptr` objects.

However, this solution bases purely on the reference-counting and smart pointers destructors calling and it does not involve independent process that periodically cleans up memory that is no longer referenced.

Usage of smart pointers makes Ownership matters unambiguous and self-documenting. It also facilitates memory management issues and eliminates multiple error types that can be made by developers.

There are also other types of memory managing objects that follow RAII design pattern, e.g. `std::string` and `std::vector`.

**Rule A18-5-1 (required, implementation, automated)**  
**Functions `malloc`, `calloc`, `realloc` and `free` shall not be used.**

### Rationale

C-style allocation/deallocation using `malloc/calloc/realloc/free` functions is not type safe and does not invoke class's constructors and destructors.

Note that invoking `free` function on a pointer allocated with `new`, as well as invoking `delete` on a pointer allocated with `malloc/realloc/calloc` function, result in undefined behavior.

Also, note that `realloc` function should only be used on memory allocated via `malloc` or `calloc` functions.

### Exception

This rule does not apply to dynamic memory allocation/deallocation performed in user-defined overloads of `new` and `delete` operators or `malloc` and `free` functions custom implementations.

### Example

```
// $Id: A18-5-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <cstdint>
#include <cstdlib>
void F1() noexcept(false)
{
// Non-compliant
std::int32_t* p1 = static_cast<std::int32_t*>(malloc(sizeof(std::int32_t)));
*p1 = 0;
9
// Compliant
std::int32_t* p2 = new std::int32_t(0);
12
// Compliant
delete p2;
15
// Non-compliant
free(p1);
18
// Non-compliant
std::int32_t* array1 =
static_cast<std::int32_t*>(calloc(10, sizeof(std::int32_t)));
```



```
22
// Non-compliant
std::int32_t* array2 =
static_cast<std::int32_t*>(realloc(array1, 10 * sizeof(std::int32_t)));
26
// Compliant
std::int32_t* array3 = new std::int32_t[10];
29
// Compliant
delete[] array3;
32
// Non-compliant
free(array2);
35
// Non-compliant
free(array1);
}
void F2() noexcept(false)
{
// Non-compliant
std::int32_t* p1 = static_cast<std::int32_t*>(malloc(sizeof(std::int32_t)));
// Non-compliant - undefined behavior
delete p1;
45
std::int32_t* p2 = new std::int32_t(0); // Compliant
free(p2); // Non-compliant - undefined behavior
}
void operator delete(void* ptr) noexcept
{
std::free(ptr); // Compliant by exception
}
```

## See also

HIC++ v4.0 [9]: 5.3.2 Allocate memory using new and release it using delete.

C++ Core Guidelines [11]: R.10: Avoid malloc() and free().

**Rule A18-5-2 (required, implementation, partially automated)**  
**Non-placement new or delete expressions shall not be used.**

## Rationale

If a resource returned by a non-placement new expression is assigned to a raw pointer, then a developer's mistake, an exception or a return may lead to memory leak.

It is highly recommended to follow RAII design pattern or use manager objects that manage the lifetime of variables with dynamic storage duration, e.g.:

std::unique\_ptr along with std::make\_unique

std::shared\_ptr along with  
std::make\_shared std::string  
std::vector

Note: Functions that do not extend lifetime shall not take parameters as smart pointers, see [A8-4-11](#).

### Exception

If the result of explicit resource allocation using a new expression is immediately passed to a manager object or an RAI class which does not provide a safe alternative for memory allocation, then it is not a violation of this rule.

This rule does not apply to dynamic memory allocation/deallocation performed in user-defined RAI classes and managers.

Placement new expression is allowed, see [A18-5-10](#).

### Example

```
// $Id: A18-5-2.cpp 316977 2018-04-20 12:37:31Z christof.meerwald $
#include <stdint>
#include <memory>
#include <vector>
std::int32_t Fn1()
{
    std::int32_t errorCode{0};
    8
    std::int32_t* ptr =
    new std::int32_t{0}; // Non-compliant - new expression
    // ...
    if (errorCode != 0)
    {
        throw std::runtime_error{"Error"}; // Memory leak could occur here
    }
    // ...
    17
    if (errorCode != 0)
    {
        return 1; // Memory leak could occur here
    }
    22
    // ...
    delete ptr; // Non-compliant - delete expression
    25
    return errorCode;
}
std::int32_t Fn2()
{
    std::int32_t errorCode{0};
    31
    std::unique_ptr<std::int32_t> ptr1 = std::make_unique<std::int32_t>(
```

```

0); // Compliant - alternative for 'new std::int32_t(0)'
34
std::unique_ptr<std::int32_t> ptr2(new std::int32_t{
0}); // Non-compliant - unique_ptr provides make_unique
37         // function which shall be used instead of explicit
38         // new expression
39
std::shared_ptr<std::int32_t> ptr3 =
std::make_shared<std::int32_t>(0); // Compliant
42
std::vector<std::int32_t> array; // Compliant
44                                     // alternative for dynamic array
45
if (errorCode != 0)
{
throw std::runtime_error{"Error"}; // No memory leaks
}
// ...
if (errorCode != 0)
{
return 1; // No memory leaks
}
// ...
return errorCode; // No memory leaks
}
template <typename T>
class ObjectManager
{
public:
explicit ObjectManager(T* obj) : object{obj} {}
~ObjectManager() { delete object; } // Compliant by exception
// Implementation
65
private:
T* object;
};
std::int32_t Fn3()
{
std::int32_t errorCode{0};
72
ObjectManager<std::int32_t> manager{
new std::int32_t{0}}; // Compliant by exception
if (errorCode != 0)
{
throw std::runtime_error{"Error"}; // No memory leak
}
// ...
if (errorCode != 0)
{
return 1; // No memory leak
}
}

```

```
// ...
return errorCode; // No memory leak
}
```

## See also

C++ Core Guidelines [11]: R.11: Avoid calling new and delete explicitly.

C++ Core Guidelines [11]: R.12: Immediately give the result of an explicit resource allocation to a manager object.

C++ Core Guidelines [11]: ES.60: Avoid new and delete outside resource management functions.

**Rule A18-5-3 (required, implementation, automated)**  
**The form of the delete expression shall match the form of the new expression used to allocate the memory.**

## Rationale

Plain and array forms of new and delete expressions must not be mixed. If an array was allocated using a new expression, then an array delete expression must be used to deallocate it and vice versa.

## Example

```
// $Id: A18-5-3.cpp 316977 2018-04-20 12:37:31Z christof.meerwald $
#include <cstdint>
3
void Fn1()
{
std::int32_t* array =
new std::int32_t[10]; // new expression used to allocate an
8                                // array object
// ...
delete array; // Non-compliant - array delete expression supposed
11                                // to be used
}
void Fn2()
{
std::int32_t* object = new std::int32_t{0}; // new operator used to
16                                // allocate the memory for an
17                                // integer type
// ...
delete[] object; // Non-compliant - non-array delete expression supposed
20                                // to be used
}
void Fn3()
{
std::int32_t* object = new std::int32_t{0};
```

```
std::int32_t* array = new std::int32_t[10];  
// ...  
delete[] array; // Compliant  
28 delete object; // Compliant  
}
```

## See also

HIC++ v4.0 [9]: 5.3.3 Ensure that the form of delete matches the form of new used to allocate the memory.

### Rule A18-5-4 (required, implementation, automated)

**If a project has sized or unsized version of operator “delete” globally defined, then both sized and unsized versions shall be defined.**

## Rationale

Since C++14 Language Standard it is allowed to overload both sized and unsized versions of the “delete” operator. Sized version provides more efficient way of memory deallocation than the unsized one, especially when the allocator allocates in size categories instead of storing the size nearby the object.

## Example

```
///  
//% $Id: A18-5-4.cpp 289415 2017-10-04 09:10:20Z piotr.serwa $  
#include <cstdlib>  
void operator delete(  
void* ptr) noexcept // Compliant - sized version is defined  
{  
std::free(ptr);  
}  
void operator delete(  
void* ptr,  
std::size_t size) noexcept // Compliant - unsized version is defined  
{  
std::free(ptr);  
}
```

## See also

none

### Rule A18-5-5 (required, toolchain, partially automated)

**Memory management functions shall ensure the following: (a) deterministic behavior resulting with the existence of worst-case execution time, (b) avoiding memory fragmentation, (c) avoid running out of memory, (d)**

**avoiding mismatched allocations or deallocations, (e) no dependence on non-deterministic calls to kernel.**

### Rationale

Memory management errors occur commonly and they can affect application stability and correctness. The main problems of dynamic memory management are as following:

- Non deterministic worst-case execution time of allocation and deallocation
- Invalid memory access
- Mismatched allocations and deallocations
- Memory fragmentation
- Running out of memory

Custom memory management functions (custom allocators) need to address all of this problems for the project and all libraries used in the project.

To ensure the worst-case execution time, the memory management functions need to be executed without context switch and without syscalls.

To prevent running out of memory, an executable is supposed to define its maximal memory needs, which are pre-allocated for this executable during its startup.

Memory management functions include operators `new` and `delete`, as well as low-level functions `malloc` and `free`. Nevertheless code written in C++ language uses `new` and `delete` operators, and direct use of `malloc` and `free` operations do not occur, some libraries, e.g. exception handling mechanism routines of `libgcc` uses `malloc` and `free` functions directly and omits `new` and `delete` operators usage. Custom memory management functionality needs to provide custom implementation of C++ `new` and `delete` operators, as well as implementation of `malloc` and `free` operations to hide incorrect dynamic memory allocation/deallocation in linked libraries.

Note: If custom memory management requires to use custom `std::new_handler`, its implementation shall perform one of the following:

- make more storage available for allocation and then return
- throw an exception of type `bad_alloc` or a class derived from `bad_alloc`
- terminate execution of the program without returning to the caller

### Example

```
//% $Id: A18-5-5.cpp 289815 2017-10-06 11:19:11Z michal.szczepankiewicz $  
2  
#define __GNU_SOURCE  
#include <dlfcn.h>  
#include <cstdint>  
6
```

```
void* MallocBad(size_t size) // Non-compliant, malloc from libc does not
8                               // guarantee deterministic execution time
{
void* (*libcMalloc)(size_t) = (void* (*)(size_t))dlsym(RTLD_NEXT, "malloc");
return libcMalloc(size);
}
13
void FreeBad(void* ptr) // Non-compliant, malloc from libc does not guarantee
15                       // deterministic execution time
{
void (*libcFree)(void*) = (void (*)(void*))dlsym(RTLD_NEXT, "free");
libcFree(ptr);
}
20
void* MallocGood(size_t size) // Compliant - custom malloc implementation that
22                               // will guarantee deterministic execution time
{
// Custom implementation that provides deterministic worst-case execution
// time
}
27
void FreeGood(void* ptr) // Compliant - custom malloc implementation that will
29                       // guarantee deterministic execution time
{
// Custom implementation that provides deterministic worst-case execution
// time
}
```

## See also

none

### Rule A18-5-6 (required, verification / toolchain, non-automated)

An analysis shall be performed to analyze the failure modes of dynamic memory management. In particular, the following failure modes shall be analyzed: (a) non-deterministic behavior resulting with nonexistence of worst-case execution time, (b) memory fragmentation, (c) running out of memory, (d) mismatched allocations and deallocations, (e) dependence on non-deterministic calls to kernel.

## Rationale

The worst-case execution time and behavior of memory management functions are specific to each implementation. In order to use dynamic memory in the project, an analysis needs to be done to determine possible errors and worst-case execution time of allocation and deallocation functions.

Note that standard C++ implementation violates some of this requirements. However, listed problems can be addressed by implementing or using a custom memory allocator.

## See also

none

### Rule A18-5-7 (required, implementation, non-automated)

If non-realtime implementation of dynamic memory management functions is used in the project, then memory shall only be allocated and deallocated during non-realtime program phases.

## Rationale

If worst-case execution time of memory management functions can not be determined, then dynamic memory usage is prohibited during realtime program phase, but it can be used e.g. during initialization or non-realtime state transitions.

See: [Real-time](#).

## Example

```
//% $Id: A18-5-7.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <cstdlib>
#include <memory>
#include <vector>
std::int8_t AppMainLoop() noexcept
{
    std::int8_t retCode = 0;
    std::int32_t* arr[10];
    while (true)
    {
        for (std::int8_t i = 0; i < 10; ++i)
        {
            13         arr[i] = new std::int32_t{
            14             i}; // Non-compliant - allocation in a phase that
            15                 // requires real-time
        }
        // Implementation
        for (auto& i : arr)
        {
            20             delete i; // Non-compliant - deallocation in a phase that requires
            21                 // real-time
        }
    }
    return retCode;
}

static std::int32_t* object =
new std::int32_t{0}; // Compliant- allocating in start-up phase
28
int main(int, char**)
{
    std::unique_ptr<std::int32_t> ptr =
    std::make_unique<std::int32_t>(0); // Compliant
}
```



```
33     std::vector<std::int32_t> vec;                               // Compliant
34     vec.reserve(10);                                         // Compliant
35
std::int8_t code = AppMainLoop();
return code;
}
```

## See also

none

**Rule A18-5-8 (required, implementation, partially automated)**  
**Objects that do not outlive a function shall have automatic storage duration.**

## Rationale

Creating objects with automatic storage duration implies that there is no additional allocation and deallocation cost, which would occur when using dynamic storage.

Note: This rule applies only to objects created in a function scope, it does not forbid the object to internally allocate additional memory on heap.

## Exception

Objects causing high memory utilization may be allocated on heap using memory managing objects.

## Example

```
/// $Id: A18-5-8.cpp 311792 2018-03-15 04:15:08Z christof.meerwald $
#include <cstdint>
#include <memory>
#include <vector>
5
class StackBitmap
{
public:
constexpr static size_t maxSize = 65535;
using BitmapRawType = std::array<uint8_t, maxSize>;
StackBitmap(const std::string& path, uint32_t bitmapSize)
{
// read bitmapSize bytes from the file path
}
15
const BitmapRawType& GetBitmap() const noexcept { return bmp; }
17
private:
BitmapRawType bmp;
};
21
```

```

void AddWidgetToLayout(int32_t row, int32_t col)
{
    auto idx = std::make_pair(row, col); // Compliant
    auto spldx = std::make_shared<std::pair<int32_t, int32_t>>(
row, col); // Non-compliant
// addWidget to index idx
}
29
uint8_t CalcAverageBitmapColor(const std::string& path, uint32_t bitmapSize)
{
    std::vector<uint8_t> bmp1(bitmapSize); // Compliant
// read bitmap from path
StackBitmap bmp2(path, bitmapSize); // Non-compliant
bmp2.GetBitmap();
}
37
int main(int, char**)
{
    AddWidgetToLayout(5, 8);
    CalcAverageBitmapColor("path/to/bitmap.bmp", 32000);
}

```

## See also

C++ Core Guidelines [11]: R.5: Prefer scoped objects, don't heap-allocate unnecessarily.

**Rule A18-5-9 (required, implementation, automated)**  
**Custom implementations of dynamic memory allocation and deallocation functions shall meet the semantic requirements specified in the corresponding “Required behaviour” clause from the C++ Standard.**

## Rationale

It is possible to provide custom implementations of global dynamic memory allocation/deallocation functions. Requirements for custom implementations for each function declaration are specified in the C++ Standard in the section “Required behaviour”. If the provided function do not implement the required semantics, it can lead to undefined behaviour.

## Example

```

//% $Id: A18-5-9.cpp 305629 2018-01-29 13:29:25Z piotr.serwa $
#include <new>
3
void* operator new(std::size_t count, const std::nothrow_t& tag)
{
    extern void* custom_alloc(std::size_t); // Implemented elsewhere; may return
    nullptr
    if (void *ret = custom_alloc(count))

```

```
8     {
9         return ret;
10    }
11    throw std::bad_alloc(); //non-compliant, this version of new method shall not throw exceptions
}
```

## See also

SEI CERT C++ Coding Standard [10]: MEM55-CPP: Honor replacement dynamic storage management requirements

**Rule A18-5-10 (required, implementation, automated)**  
**Placement new shall be used only with properly aligned pointers to sufficient storage capacity.**

## Rationale

Placement new can be useful for cases in which allocation is required separately from type initialization, e.g. memory allocators, generic containers. Correct usage of placement new requires passing a pointer that:

- is suitably aligned

- provides sufficient storage memory

Violating above constrains will result in an object constructed at a misaligned location or memory initialization outside of the allocated bounds, which leads to undefined behaviour. An initial memory pointer used for placement new shall not be used after the call.

## Example

```
//% $Id: A18-5-10.cpp 305629 2018-01-29 13:29:25Z piotr.serwa $
2
#include <new>
#include <cstdint>
5
void Foo()
{
    uint8_t c;
    uint64_t* ptr = ::new (&c) uint64_t;
    //non-compliant, insufficient storage
}
12
void Bar()
{
    uint8_t c; // Used elsewhere in the function
    uint8_t buf[sizeof(uint64_t)];
    uint64_t* ptr = ::new (buf) uint64_t;
```

```
//non-compliant, storage not properly aligned
}
```

## See also

SEI CERT C++ Coding Standard [10]: MEM54-CPP: Provide placement new with properly aligned pointers to sufficient storage capacity

**Rule A18-5-11 (required, implementation, automated) “operator new” and “operator delete” shall be defined together.**

## Rationale

Providing a custom allocation function (operator new) for a class or program implies the use of a custom memory management scheme different to the default one. It is therefore unlikely that memory allocated using a custom allocation function can be deallocated by the default deallocation function (operator delete).

## Example

```

//% $Id: A18-5-11.cpp 316977 2018-04-20 12:37:31Z christof.meerwald $
#include <cstdlib>
3
class A {
public:
static void * operator new(std::size_t s); // Compliant: operator new
7     static void operator delete(void *ptr); // defined together with
8                                             // operator delete
};
10
class B {
public:
13     static void * operator new(std::size_t s); // Non-compliant: operator
static void * operator new [](std::size_t s); // new defined without
15                                             // corresponding operator
16                                             // delete
};

```

## See also

HIC++ v4.0 [9]: 12.3.1: Correctly declare overloads for operator new and delete

### 6.18.9 Other runtime support

**Rule M18-7-1 (required, implementation, automated)**  
**The signal handling facilities of <csignal> shall not be used.**

See MISRA C++ 2008 [7]

**Rule A18-9-1 (required, implementation, automated)**  
**The `std::bind` shall not be used.**

### Rationale

Using the `std::bind` function makes the function call less readable and may lead to the developer confusing one function parameter with another. Also, compilers are less likely to inline the functions that are created using `std::bind`.

It is recommended to use lambda expressions instead.

### Example

```
// $Id: A18-9-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <cstdint>
#include <functional>
class A
{
// Implementation
};
void Fn(A const& a, double y) noexcept
{
// Implementation
}
void F1() noexcept
{
double y = 0.0;
auto function = std::bind(&Fn, std::placeholders::_1, y); // Non-compliant
// ...
A const a{};
function(a);
}
void F2() noexcept
{
auto lambda = [](A const& a) -> void {
double y = 0.0;
Fn(a, y);
}; // Compliant
// ...
A const a{};
lambda(a);
}
```

### See also

Effective Modern C++ [13]: Item 34: Prefer lambdas to `std::bind`

**Rule A18-9-2 (required, implementation, automated)**

**Forwarding values to other functions shall be done via: (1) `std::move` if the value is an rvalue reference, (2) `std::forward` if the value is forwarding reference.**

**Rationale**

The `std::move` function unconditionally casts an rvalue reference to rvalue, while the `std::forward` function does the same if and only if the argument was initialized with an rvalue. Both functions should be used as follows:

`std::move` should be used for forwarding rvalue references to other functions, as rvalue reference always bounds to rvalue

`std::forward` should be used for forwarding forwarding references to other functions, as forwarding reference might be bound to lvalue or rvalue

Note that parameter of type “`auto&&`” is also considered as a forwarding reference for the purpose of this rule.

**Example**

```
// $Id: A18-9-2.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <cstdint>
#include <string>
#include <utility>
class A
{
public:
explicit A(std::string&& s)
9           : str(std::move(s))           // Compliant - forwarding rvalue reference
{
}
12
private:
std::string str;
};
class B
{
};
void Fn1(const B& lval)
{
}
void Fn1(B&& rval)
{
}
template <typename T>
void Fn2(T&& param)
{
Fn1(std::forward<T>(param)); // Compliant - forwarding forwarding reference
}
template <typename T>
```

```

void Fn3(T&& param)
{
  Fn1(std::move(param)); // Non-compliant - forwarding forwarding reference
                          // via std::move
}
void Fn4() noexcept
{
  B b1;
  B& b2 = b1;
  40   Fn2(b2);           // fn1(const B&) is called
  Fn2(std::move(b1)); // fn1(B&&) is called
  42   Fn3(b2);         // fn1(B&&) is called
  Fn3(std::move(b1)); // fn1(B&&) is called
}

```

### See also

HIC++ v4.0 [9]:17.3.2 Use std::forward to forward universal references

Effective Modern C++ [13]: Item 25. Use std::move on rvalue references, std::forward on universal references.

#### Rule A18-9-3 (required, implementation, automated)

The std::move shall not be used on objects declared const or const&.

### Rationale

If an object is declared const or const&, then it will actually never be moved using the std::move.

### Example

```

// $Id: A18-9-3.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <utility>
class A
{
  // Implementation
};
void F1()
{
  const A a1{};
  10   A a2 = a1;           // Compliant - copy constructor is called
  A a3 = std::move(a1); // Non-compliant - copy constructor is called
                          // implicitly instead of move constructor
  12
}

```

### See also

HIC++ v4.0 [9]: 17.3.1 Do not use std::move on objects declared with const or const& type.

**Rule A18-9-4 (required, implementation, automated)**  
An argument to `std::forward` shall not be subsequently used.

## Rationale

Depending on the value category of parameters used in the call, `std::forward` may result in a move of the parameter. When the value is an lvalue, modifications to the parameter will affect the argument of the caller. If the value is an rvalue, the value may be in indeterminate state after the call to `std::forward`.

## Example

```
// $Id: A18-9-4.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <cstdlib>
#include <iostream>
#include <utility>
template <typename T1, typename T2>
void F1(T1 const& t1, T2& t2){
// ...
};
template <typename T1, typename T2>
void F2(T1&& t1, T2&& t2)
{
f1(std::forward<T1>(t1), std::forward<T2>(t2));
++t2; // Non-compliant
};
```

## See also

HIC++ v4.0 [9]: 17.3.3 Do not subsequently use the argument to `std::forward`.

## 6.19 Diagnostics library - partial

### 6.19.4 Error numbers

**Rule M19-3-1 (required, implementation, automated)**  
The error indicator `errno` shall not be used.

See MISRA C++ 2008 [7]

## 6.20 General utilities library - partial

### 6.20.8 Smart pointers



**Rule A20-8-1 (required, implementation, automated)**  
**An already-owned pointer value shall not be stored in an unrelated smart pointer.**

### Rationale

Smart pointers (e.g. `std::shared_ptr`) that allow to manage the same underlying pointer value using multiple smart pointer objects, shall be created in a way that creates a relationship between two smart pointer objects (e.g. via copy assignment). Unrelated smart pointer objects with a pointer value that is owned by another smart pointer object shall not be created.

### Example

```
// $Id: A20-8-1.cpp 305588 2018-01-29 11:07:35Z michal.szczepankiewicz $
2
#include <memory>
4
void Foo()
{
uint32_t *i = new uint32_t{5};
std::shared_ptr<uint32_t> p1(i);
std::shared_ptr<uint32_t> p2(i); // non-compliant
}
11
void Bar()
{
std::shared_ptr<uint32_t> p1 = std::make_shared<uint32_t>(5);
std::shared_ptr<uint32_t> p2(p1); //compliant
}
```

### See also

SEI CERT C++ Coding Standard [10]: MEM56-CPP: Do not store an already-owned pointer value in an unrelated smart pointer

**Rule A20-8-2 (required, implementation, automated)**  
**A `std::unique_ptr` shall be used to represent exclusive ownership.**

### Rationale

`std::unique_ptr` is a smart pointer that owns and manages another object and removes it when it goes out of scope. It has almost no overhead over a raw pointer and clearly states developers intentions and ownership status of the object.

Note: Further usage of the instance of `std::unique_ptr` in another scope requires transferring ownership using move semantics.

### Example

```
// $Id: A20-8-2.cpp 308981 2018-02-26 08:11:52Z michal.szczepankiewicz $
2
#include <thread>
#include <memory>
5
struct A
{
A(std::uint8_t xx, std::uint8_t yy) : x(xx), y(yy) {}
std::uint8_t x;
std::uint8_t y;
};
12
//consumes object obj or just uses it
void Foo(A* obj) { }
void Bar(std::unique_ptr<A> obj) { }
16
int main(void)
{
A* a = new A(3,5); //non-compliant with A18-5-2
std::unique_ptr<A> spA = std::make_unique<A>(3,5);
21
//non-compliant, not clear if function assumes
//ownership of the object
std::thread th1{&Foo, a};
std::thread th2{&Foo, a};
//compliant, it is clear that function Bar
//assumes ownership
std::thread th3{&Bar, std::move(spA)};
29
th1.join();
th2.join();
th3.join();
return 0;
}
```

## See also

JSF December 2005 [8]: AV Rule 112: Function return values should not obscure resource ownership.

C++ Core Guidelines [11]: F.26: Use a `unique_ptr<T>` to transfer ownership where a pointer is needed

C++ Core Guidelines [11]: R.20: Use `unique_ptr` or `shared_ptr` to represent ownership

**Rule A20-8-3 (required, implementation, automated)**  
**A `std::shared_ptr` shall be used to represent shared ownership.**

## Rationale

`std::shared_ptr` allows to retain shared ownership by keeping multiple `std::shared_ptr` instances pointing at the same object. The object is removed when the last `std::shared_ptr` instance goes out of scope. Although reference counting mechanism included brings some overhead over a raw pointer, it clearly states ownership status of the object and effectively prevents from possible memory leaks.

## Example

```
// $Id: A20-8-3.cpp 308507 2018-02-21 13:23:57Z michal.szczepankiewicz $
2
#include <memory>
#include <cstdint>
#include <thread>
6
struct A
{
  A(std::uint8_t xx, std::uint8_t yy) : x(xx), y(yy) {}
  std::uint8_t x;
  std::uint8_t y;
};
13
void Foo(A* obj) {}
void Bar(A* obj) {}
16
void Foo2(std::shared_ptr<A> obj) {}
void Bar2(std::shared_ptr<A> obj) {}
19
int main(void)
{
  A* a = new A(3,5); //non-compliant with A18-5-2
  std::shared_ptr<A> spA = std::make_shared<A>(3,5);
24
  //non-compliant, not clear who is responsible
  //for deleting object a
  std::thread th1{&Foo, a};
  std::thread th2{&Bar, a};
29
  //compliant, object spA gets deleted
  //when last shared_ptr gets destructed
  std::thread th3{&Foo2, spA};
  std::thread th4{&Bar2, spA};
34
  th1.join();
  th2.join();
  th3.join();
  th4.join();
39
  return 0;
}
```

## See also

JSF December 2005 [8]: AV Rule 112: Function return values should not obscure resource ownership.

C++ Core Guidelines [11]: F.27: Use a `shared_ptr<T>` to share ownership

C++ Core Guidelines [11]: R.20: Use `unique_ptr` or `shared_ptr` to represent ownership

**Rule A20-8-4 (required, implementation, automated)**  
**A `std::unique_ptr` shall be used over `std::shared_ptr` if ownership sharing is not required.**

## Rationale

`std::unique_ptr` is more predictable in terms of its destruction, as it happens at the end of the scope unless ownership transfer occurred. It also has lower overhead than a `std::shared_ptr`, as it does not keep internal reference counting.

## Example

```
// $Id: A20-8-4.cpp 308507 2018-02-21 13:23:57Z michal.szczepankiewicz $
2
#include <memory>
#include <cstdint>
#include <thread>
6
struct A
{
  A(std::uint8_t xx, std::uint8_t yy) : x(xx), y(yy) {}
  std::uint8_t x;
  std::uint8_t y;
};
13
void Func()
{
  auto spA = std::make_shared<A>(3,5);
  //non-compliant, shared_ptr used only locally
  //without copying it
}
20
void Foo(std::unique_ptr<A> obj) { }
void Bar(std::shared_ptr<A> obj) { }
23
int main(void)
{
  std::shared_ptr<A> spA = std::make_shared<A>(3,5);
  std::unique_ptr<A> upA = std::make_unique<A>(4,6);
28
  //compliant, object accesses in parallel
```

```
std::thread th1{&Bar, spA};
std::thread th2{&Bar, spA};
std::thread th3{&Bar, spA};
33
//compliant, object accesses only by 1 thread
std::thread th4{&Foo, std::move(upA)};
36
th1.join();
th2.join();
th3.join();
th4.join();
41
return 0;
}
```

## See also

C++ Core Guidelines [11]: R.21: Prefer `unique_ptr` over `shared_ptr` unless you need to share ownership

**Rule A20-8-5 (required, implementation, automated)**  
**`std::make_unique` shall be used to construct objects owned by `std::unique_ptr`.**

## Rationale

Using `std::make_unique` to create instances of `std::unique_ptr<T>` provides object allocation without explicit call of `new` function, see [A18-5-2](#). It also ensures exception safety in complex expressions and prevents from memory leaks caused by unspecified-evaluation order-expressions.

## Exception

It is allowed to use explicit `new` function call to create an instance of `std::unique_ptr<T>`, if it requires a custom deleter.

## Example

```
// $Id: A20-8-5.cpp 308507 2018-02-21 13:23:57Z michal.szczepankiewicz $
#include <memory>
#include <cstdint>
#include <functional>
5
struct A
{
  A() { throw std::runtime_error("example"); }
  A(std::uint8_t xx, std::uint8_t yy) : x(xx), y(yy) {}
  std::uint8_t x;
  std::uint8_t y;
};
```

```
13 void Foo(std::unique_ptr<A> a, std::unique_ptr<A> b) { }
15 int main(void)
{
//compliant
std::unique_ptr<A> upA = std::make_unique<A>(4,6);
//non-compliant
std::unique_ptr<A> upA2 = std::unique_ptr<A>(new A(5,7));
22 //non-compliant, potential memory leak, as A class constructor throws
Foo(std::unique_ptr<A>(new A()), std::unique_ptr<A>(new A()));
//non-compliant, potential memory leak, as A class constructor throws
Foo(std::make_unique<A>(4,6), std::unique_ptr<A>(new A()));
//compliant, no memory leaks
Foo(std::make_unique<A>(4,6), std::make_unique<A>(4,6));
29 //compliant by exception
std::unique_ptr<A, std::function<void(A*)>> ptr(new A(4,5), [(A* b) { delete
    b; }]);
32 return 0;
}
```

## See also

C++ Core Guidelines [11]: R.23: Use `make_unique()` to make `unique_ptr`s

C++ Core Guidelines [11]: C.150: Use `make_unique()` to construct objects owned by `unique_ptr`s

**Rule A20-8-6 (required, implementation, automated)**  
**`std::make_shared` shall be used to construct objects owned by `std::shared_ptr`.**

## Rationale

`std::shared_ptr` manages two entities: a control block (for meta data such as reference counter or type-erased deleter) and an allocated object. Using `std::make_shared` typically performs a single heap allocation (as it is recommended by the Standard) for both control block and allocated object. `std::make_shared` function also provides object allocation without explicit call of `new` function, see [A18-5-2](#). It also ensures exception safety and prevents from memory leaks caused by unspecified-evaluation-order expressions.

## Exception

It is allowed to use explicit `new` function call to create an instance of `std::shared_ptr`, if it requires a custom deleter. It is also allowed to construct objects owned by `std::shared_ptr` using `std::allocate_shared`.

## Example

```
// $Id: A20-8-6.cpp 308507 2018-02-21 13:23:57Z michal.szczepankiewicz $
#include <memory>
#include <cstdint>
#include <functional>
5
struct A
{
A() { throw std::runtime_error("example"); }
A(std::uint8_t xx, std::uint8_t yy) : x(xx), y(yy) {}
std::uint8_t x;
std::uint8_t y;
};
13
void Foo(std::shared_ptr<A> a, std::shared_ptr<A> b) { }
15
int main(void)
{
//compliant
std::shared_ptr<A> upA = std::make_shared<A>(4,6);
//non-compliant
std::shared_ptr<A> upA2 = std::shared_ptr<A>(new A(5,7));
22
//non-compliant, potential memory leak, as A class constructor throws
Foo(std::shared_ptr<A>(new A()), std::shared_ptr<A>(new A()));
//non-compliant, potential memory leak, as A class constructor throws
Foo(std::make_shared<A>(4,6), std::shared_ptr<A>(new A()));
//compliant, no memory leaks
Foo(std::make_shared<A>(4,6), std::make_shared<A>(4,6));
29
//compliant by exception
std::shared_ptr<A> ptr(new A(4,5), [](A* b) { delete b; });
32
return 0;
}
```

## See also

C++ Core Guidelines [11]: R.22: Use `make_shared()` to make `shared_ptr`s.

C++ Core Guidelines [11]: C.151: Use `make_shared()` to construct objects owned by `shared_ptr`s

### Rule A20-8-7 (required, implementation, non-automated)

**A `std::weak_ptr` shall be used to represent temporary shared ownership.**

## Rationale

A cyclic structure of `std::shared_ptr` results in reference counting mechanism never dropping to zero, which prevents from pointed object deallocation. Breaking such

cycles is done using `std::weak_ptr` which must be converted to `std::shared_ptr` in order to access the referenced object.

### Example

```
// $Id: A20-8-7.cpp 308795 2018-02-23 09:27:03Z michal.szczepankiewicz $
2
#include <memory>
4
template <template <typename> class T, typename U>
struct Base
{
T<U> sp;
};
10
template <typename T>
using Shared = Base<std::shared_ptr, T>;
13
template <typename T>
using Weak = Base<std::weak_ptr, T>;
16
struct SBarSFoo;
struct SFooSBar : public Shared<SBarSFoo> {};
struct SBarSFoo : public Shared<SFooSBar> {};
20
struct A : public Shared<A> {};
22
struct WBarSFoo;
struct SFooWBar : public Shared<WBarSFoo> {};
struct WBarSFoo : public Weak<SFooWBar> {};
26
int main()
{
std::shared_ptr<SFooSBar> f = std::make_shared<SFooSBar>();
std::shared_ptr<SBarSFoo> b = std::make_shared<SBarSFoo>();
f->sp = b;
b->sp = f;
//non-compliant, both f and b have ref_count() == 2
//destructors of f and b reduce ref_count() to 1,
//destructors of underlying objects are never called,
//so destructors of shared_ptrs sp are not called
//and memory is leaked
38
std::shared_ptr<A> a = std::make_shared<A>();
a->sp = a;
//non-compliant, object 'a' destructor does not call
//underlying memory destructor
43
std::shared_ptr<SFooWBar> f2 = std::make_shared<SFooWBar>();
std::shared_ptr<WBarSFoo> b2 = std::make_shared<WBarSFoo>();
f2->sp = b2;
b2->sp = f2;
```



```
//compliant, b2->sp holds weak_ptr to f2, so f2 destructor
//is able to properly destroy underlying object
```

```
50
return 0;
}
```

## See also

C++ Core Guidelines [11]: R.24: Use `std::weak_ptr` to break cycles of `shared_ptrs`

## 6.21 Strings library

### 6.21.8 Null-terminated sequence utilities

**Rule A21-8-1 (required, implementation, automated)**  
**Arguments to character-handling functions shall be representable as an unsigned char.**

### Rationale

This rule applies to the character handling functions in `<cctype>`. They all take an int parameter as input and specify that its value either shall be EOF or otherwise shall be representable as an unsigned char. On platforms where `char` is signed, it can have negative values that are not representable as an unsigned char, so that passing a `char` to such a function can result in undefined behavior.

Thus, this rule mandates that all character arguments passed to such functions shall be explicitly cast to unsigned char.

Note: Of all the functions in `<cctype>`, `isdigit` and `isxdigit` are the only ones whose behavior does not depend on the currently installed locale. See [A18-0-3](#) in section [6.18.0](#) for a rule concerning the `setlocale` function.

### Example

```
// $Id: A21-8-1.cpp 312606 2018-03-21 09:52:14Z jan.babst $
#include <algorithm>
#include <cctype>
#include <string>
5
void RemoveDigits_Bad(std::string& s)
{
s.erase(std::remove_if(s.begin(),
9                               s.end(),
10                              [](char c) {
11                                return std::isdigit(c); // non-compliant
12                              })),
```

```

13         s.cend());
14     }
15 void RemoveDigits_Good(std::string& s)
16 {
17     s.erase(std::remove_if(s.begin(),
18                           s.end(),
19                           [](char c) {
20                               return std::isdigit(
21                                   static_cast<unsigned char>(c)); // compliant
22                           }
23                           ),
24           s.cend());
25 }

```

### See also

SEI CERT C++ Coding Standard [10]: STR37-C: Arguments to character-handling functions must be representable as an unsigned char.

cppreference.com [16]: Standard library header <cctype>.

Rule [A18-0-3](#) in section [6.18.0](#)

## 6.23 Containers library - partial

### 6.23.1 General

**Rule A23-0-1 (required, implementation, automated)**  
An iterator shall not be implicitly converted to `const_iterator`.

#### Rationale

The Standard Template Library introduced methods for returning `const` iterators to containers. Making a call to these methods and immediately assigning the value they return to a `const_iterator`, removes implicit conversions.

#### Example

```

//% $Id: A23-0-1.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <cstdlib>
#include <vector>
4
void Fn1(std::vector<std::int32_t>& v) noexcept
{
    for (std::vector<std::int32_t>::const_iterator iter{v.cbegin()},
        end{v.cend()};
        iter != end;
        ++iter) // Compliant
    {

```

```
// ...
}
}
15
void Fn2(std::vector<std::int32_t>& v) noexcept
{
for (auto iter{v.cbegin()}, end{v.cend()}; iter != end;
++iter) // Compliant
{
// ...
}
}
24
void Fn3(std::vector<std::int32_t>& v) noexcept
{
for (std::vector<std::int32_t>::const_iterator iter{v.begin()},
end{v.end()};
iter != end;
++iter) // Non-compliant
{
// ...
}
}
```

## See also

HIC++ v4.0 [9]: 17.4.1 Use const container calls when result is immediately converted to a const iterator.

**Rule A23-0-2 (required, implementation, automated)**  
**Elements of a container shall only be accessed via valid references, iterators, and pointers.**

## Rationale

Some operations on standard library containers invalidate references, iterators, and pointers to container elements which were previously stored.

The behavior of the standard library containers and their operations with respect to the invalidation of references, iterators, and pointers is well documented, e.g. in [16].

## Example

```
// $Id: A23-0-2.cpp 309868 2018-03-02 10:47:23Z jan.babst $
#include <algorithm>
#include <cstdint>
#include <list>
#include <vector>
6
void f()
```

```
{
std::vector<int32_t> v{0, 1, 2, 3, 4, 5, 6, 7};
10
auto it = std::find(v.begin(), v.end(), 5); // *it is 5
12
// These calls may lead to a reallocation of the vector storage
// and thus may invalidate the iterator it.
v.push_back(8);
v.push_back(9);
17
*it = 42; // Non-compliant
}
20
void g()
{
std::list<int32_t> l{0, 1, 2, 3, 4, 5, 6, 7};
24
auto it = std::find(l.begin(), l.end(), 5); // *it is 5
l.remove(7);
l.push_back(9);
*it = 42; // Compliant - previous operations do not invalidate iterators
// l is now {0, 1, 2, 3, 4, 42, 6, 9 }
}
```

## See also

SEI CERT C++ Coding Standard [10]: CTR51-CPP: Use valid references, pointers, and iterators to reference elements of a container.

SEI CERT C++ Coding Standard [10]: STR52-CPP: Use valid references, pointers, and iterators to reference elements of a basic\_string.

cppreference.com [16]: Containers library. Iterator invalidation.

## 6.25 Algorithms library

### 6.25.1 General

**Rule A25-1-1 (required, implementation, automated) Non-static data members or captured values of predicate function objects that are state related to this object's identity shall not be copied.**

### Rationale

Generic algorithms available in the C++ Standard Library accept a predicate function object. The ISO/IEC 14882:2014 C++ Language Standard states that it is implementation-defined whether predicate function objects can be copied by the STL algorithms.

To prevent from unexpected results while using predicate function objects, any such object shall either:

be passed to an STL algorithm wrapped as a `std::reference_wrapper`.

implement a function call operator that is `const` and does not modify any data members or captured values that have a mutable specifier.

### Example

```
//% $Id: A25-1-1.cpp 309784 2018-03-01 20:18:29Z michal.szczepankiewicz $
2
#include <iostream>
#include <vector>
#include <algorithm>
#include <functional>
#include <iterator>
8
class ThirdElemPred : public std::unary_function<int, bool>
{
public:
ThirdElemPred() : timesCalled(0) {}
bool operator()(const int &) { return (++timesCalled) == 3; }
//non-compliant, non-const call operator that
//modifies the predicate object field
private:
size_t timesCalled;
};
19
class ThirdElemPred2 : public std::unary_function<int, bool>
{
public:
ThirdElemPred2() : timesCalled(0) {}
bool operator()(const int &) const { return (++timesCalled) == 3; }
//non-compliant, const call operator that
//modifies the mutable predicate object field
private:
mutable size_t timesCalled;
};
30
class ValueFivePred: public std::unary_function<int, bool>
{
public:
bool operator()(const int& v) const { return v == 5; }
//compliant, const call operator that does not
//modify the predicate object state
};
38
void F1(std::vector<int> v)
{
//non-compliant, predicate object state modified
int timesCalled = 0;
//display values that are NOT to be removed
```

```

std::copy(v.begin(), std::remove_if(v.begin(), v.end(), [timesCalled](const int & mutable { return
    (++timesCalled) == 3; })), std::ostream_iterator<std::vector<int>::value_type>(std::cout, " "));

std::cout << std::endl;
}
47
void F2(std::vector<int> v)
{
//non-compliant, predicate object state modified
std::copy(v.begin(), std::remove_if(v.begin(), v.end(), ThirdElemPred()), std
    ::ostream_iterator<std::vector<int>::value_type>(std::cout, " "));
std::cout << std::endl;
}
54
void F22(std::vector<int> v)
{
//non-compliant, predicate object state modified
std::copy(v.begin(), std::remove_if(v.begin(), v.end(), ThirdElemPred2()),
    std::ostream_iterator<std::vector<int>::value_type>(std::cout, " "));
std::cout << std::endl;
}
61
void F3(std::vector<int> v)
{
//compliant, predicate object that has its state
//modified is passed as a std::reference_wrapper
ThirdElemPred pred;
std::copy(v.begin(), std::remove_if(v.begin(), v.end(), std::ref(pred)), std
    ::ostream_iterator<std::vector<int>::value_type>(std::cout, " "));
std::cout << std::endl;
}
70
int main(void)
{
std::vector<int> v{0, 1, 2, 3, 4, 5, 6, 7, 8, 9};
74
F1(v);
F2(v);
F22(v);
F3(v);
//output for g++-5.5, correct result only for F3
80 //F1      0 1 3 4 6 7 8 9
81 //F2      0 1 3 4 6 7 8 9
82 //F22     0 1 3 4 6 7 8 9
83 //F3      0 1 3 4 5 6 7 8 9
return 0;
}

```

## See also

SEI CERT C++ Coding Standard [10]: CTR58-CPP: Predicate function objects should not be mutable

cppreference.com [16]: C++ concepts: Predicate

## 6.25.4 Sorting and related operations

**Rule A25-4-1 (required, implementation, non-automated)**  
**Ordering predicates used with associative containers and STL sorting and related algorithms shall adhere to a strict weak ordering relation.**

### Rationale

Ordering predicates that can be passed to associative containers or sorting STL algorithms and related operations must fulfill requirements for a strict weak ordering, e.g.:

irreflexivity: FOR ALL  $x$ :  $x < x == \text{false}$

assymetry: FOR ALL  $x, y$ : if  $x < y$  then  $!(y < x)$

transitivity: FOR ALL  $x, y, z$ : if  $x < y$  &&  $y < z$  then  $x < z$

Ordering predicates not adhering to these requirements will result in these algorithms not working correctly, which may include infinite loops and other erratic behavior.

### Example

```
1  // % $Id: A25-4-1.cpp 309738 2018-03-01 15:08:00Z michal.szczepankiewicz $
2
3  #include <functional>
4  #include <iostream>
5  #include <set>
6
7  int main(void)
8  {
9      //non-compliant, given predicate does not return false
10     //for equal values
11     std::set<int, std::greater_equal<int>> s{2, 5, 8};
12     auto r = s.equal_range(5);
13     //returns 0
14     std::cout << std::distance(r.first, r.second) << std::endl;
15
16     //compliant, using default std::less<int>
17     std::set<int> s2{2, 5, 8};
18     auto r2 = s2.equal_range(5);
19     //returns 1
20     std::cout << std::distance(r2.first, r2.second) << std::endl;
21
22     return 0;

```

}

## See also

SEI CERT C++ Coding Standard [10]: CTR57-CPP: Provide a valid ordering predicate

cppreference.com [16]: C++ concepts: Compare

## 6.26.5 Random number generation

**Rule A26-5-1 (required, implementation, automated) Pseudorandom numbers shall not be generated using `std::rand()`.**

### Rationale

Using a pseudo-random sequence of numbers requires that it is generated with good statistical properties. Some implementations of `std::rand()` function have a comparatively short cycle, as a result the numbers can be predictable. Using functionalities from `<random>` is recommended instead of using `std::rand()`.

Note: `std::random_shuffle` should not be used, as it is deprecated since C++14 (see [A1-1-1](#)) and one of the available overloads is often implemented in terms of `std::rand`.

### Example

```
// $Id: A26-5-1.cpp 311495 2018-03-13 13:02:54Z michal.szczepankiewicz $
2
#include <cstdlib>
#include <cstdlib>
#include <ctime>
#include <iostream>
#include <random>
8
int main()
{
std::srand(std::time(nullptr));
int r1 = std::rand() % 100; //non-compliant
std::cout << "Random value using std::rand(): " << r1 << std::endl;
14
std::random_device rd;
std::default_random_engine eng{rd()};
std::uniform_int_distribution<int> ud{0, 100};
int r2 = ud(eng); //compliant
std::cout << "Random value using std::random_device: " << r2 << std::endl;
20
return 0;
}
```



## See also

SEI CERT C++ Coding Standard [10]: MSC50-CPP: Do not use `std::rand()` for generating pseudorandom numbers.

**Rule A26-5-2 (required, implementation, automated)**  
**Random number engines shall not be default-initialized.**

## Rationale

Using a pseudo-random number generator gives different results that depend on a used seed value. Initializing random number engines by default initializes pseudo-random generator with a `default_seed` constant value. However, this can be not obvious for a developer and can lead to unexpected program behaviour (generating the same random sequences among different program executions).

## Exception

For consistent testing purposes it can be convenient to seed the random number engine with a fixed value to get a deterministic sequence, but never within production code where real randomness is required, e.g. for security reasons.

## Example

```
// $Id: A26-5-2.cpp 311495 2018-03-13 13:02:54Z michal.szczepankiewicz $
2
#include <iostream>
#include <random>
5
int main()
{
    std::random_device rd;
    std::default_random_engine eng{rd()}; //compliant
    std::uniform_int_distribution<int> ud{0, 100};
    int r1 = ud(eng);
    std::cout << "Random value using std::random_device: " << r1 << std::endl;
13
14
    std::default_random_engine eng2{}; //non-compliant
    std::uniform_int_distribution<int> ud2{0, 100};
    int r2 = ud2(eng);
    std::cout << "Random value using std::random_device: " << r2 << std::endl;
19
return 0;
}
```

## See also

SEI CERT C++ Coding Standard [10]: MSC51-CPP: Ensure your random number generator is properly seeded.

## 6.27 Input/output library - partial

### 6.27.1 General

**Rule M27-0-1 (required, implementation, automated)**  
**The stream input/output library <cstdio> shall not be used.**

See MISRA C++ 2008 [7]

**Rule A27-0-1 (required, implementation, non-automated)**  
**Inputs from independent components shall be validated.**

#### Rationale

An “attacker” who fully or partially controls the content of an application’s buffer can crash the process, view the content of the stack, view memory content, write to random memory locations or execute code with permissions of the process.

This rule concerns network inputs, as well as inputs that are received from other processes or other software components over IPC or through component APIs.

Note: If more advanced style formatting is required, this can be done using C++ dedicated libraries (e.g. boost::format OR libfmt).

#### Example

```

// $Id: A27-0-1.cpp 311495 2018-03-13 13:02:54Z michal.szczepankiewicz $
#include <cstring>
#include <cstdint>
#include <cstdio>
void F1(const char* name) // name restricted to 256 or fewer characters
{
    static const char format[] = "Name: %s .";
    size_t len = strlen(name) + sizeof(format);
    char* msg = new char[len];
10
    if (msg == nullptr)
    {
        // Handle an error
    }
15
    std::int32_t ret =
    snprintf(msg,
18                len,
19                format,
20                name); // Non-compliant - no additional check for overflows
21
    if (ret < 0)

```

```

{
// Handle an error
}
else if (ret >= len)
{
// Handle truncated output
}
30
fprintf(stderr, msg);
delete[] msg;
}
void F2(const char* name)
{
static const char format[] = "Name: %s .";
fprintf(stderr, format, name); // Compliant - untrusted input passed as one
38                                     // of the variadic arguments, not as part of
39                                     // vulnerable format string
}
void F3(const std::string& name)
{
//compliant, untrusted input not passed
//as a part of vulnerable format string
std::cerr << "Name: " << name;
}

```

## See also

SEI CERT C++ [10]: FIO30-C. Exclude user input from format strings.

**Rule A27-0-4 (required, implementation, automated)**  
**C-style strings shall not be used.**

## Rationale

It is required that an underlying buffer for a C-style string needs to be of sufficient size to hold character data and a null terminator. In addition, a C-style string implies all other disadvantages of built-in arrays (see [A18-1-1](#) in section [6.18.1](#)). Using `std::string` provides correct memory allocation, copying, gradual expansion and iteration. It is self-explanatory in terms of ownership and offers more readable interface.

## Example

```

// $Id: A27-0-4.cpp 311495 2018-03-13 13:02:54Z michal.szczepankiewicz $
#include <iostream>
#include <string>
#include <list>
5
void F1()
{
std::string string1;

```

```
std::string string2;
std::cin >> string1 >> string2; // Compliant - no buffer overflows
}
12
std::list<std::string> F2(const std::string& terminator)
{
std::list<std::string> ret;
//read a single word until it is different from the given terminator sequence
for (std::string s; std::cin >> s && s != terminator; )
{
ret.push_back(s);
}
return ret;
}
```

## See also

C++ Core Guidelines [11]: SL.str.1: Use `std::string` to own character sequences.

**Rule A27-0-2 (advisory, implementation, automated)**  
**A C-style string shall guarantee sufficient space for data and the null terminator.**

## Rationale

To prevent buffer overflows, it needs to be ensured that the destination is of sufficient size to hold the character data to be copied and the null terminator.

Note that C-style string requires additional space for null character to indicate the end of the string, while the C++ `std::basic_string` does that implicitly.

Note: This rule is deliberately redundant, in case the rule [A27-0-4](#) is disabled in a project.

## Example

```
// $Id: A27-0-2.cpp 289436 2017-10-04 10:45:23Z michal.szczepankiewicz $
#include <iostream>
#include <string>
void F1() noexcept
{
char buffer[10];
std::cin >> buffer; // Non-compliant - this could lead to a buffer overflow
}
void F2() noexcept
{
std::string string1;
std::string string2;
std::cin >> string1 >> string2; // Compliant - no buffer overflows
}
void F3(std::istream& in) noexcept
```

```
{
char buffer[32];
18
try
{
in.read(buffer, sizeof(buffer));
}
23
catch (std::ios_base::failure&)
{
// Handle an error
}
28
std::string str(buffer); // Non-compliant - if 'buffer' is not null
30                                     // terminated, then constructing std::string leads
31                                     // to undefined behavior.
}
void F4(std::istream& in) noexcept
{
char buffer[32];
36
try
{
in.read(buffer, sizeof(buffer));
}
41
catch (std::ios_base::failure&)
{
// Handle an error
}
46
std::string str(buffer, in.gcount()); // Compliant
}
```

## See also

SEI CERT C++ [10]: STR50-CPP. Guarantee that storage for strings has sufficient space for character data and the null terminator.

**Rule A27-0-3 (required, implementation, automated)**  
**Alternate input and output operations on a file stream shall not be used without an intervening flush or positioning call.**

## Rationale

There are following restrictions on reading and writing operations called for an object of class `basic_filebuf<charT, traits>`:

output shall not be directly followed by input without an intervening call to the `fflush` function or to a file positioning function (`fseek`, `fsetpos`, or `rewind`).

input shall not be directly followed by output without an intervening call to a file positioning function, unless the input operation encounters end-of-file.

It is recommended to use a file stream either for output (`std::ofstream`) or input(`std::ifstream`) and not for both in the same context. This avoids the mentioned problem altogether.

### Example

```
// $Id: A27-0-3.cpp 311495 2018-03-13 13:02:54Z michal.szczepankiewicz $
2
#include <fstream>
#include <string>
5
int main(void)
{
std::fstream f("testfile");
9
f << "Output";
std::string str1;
f >> str1; // non-compliant
13
f << "More output";
std::string str2;
f.seekg(0, std::ios::beg);
f >> str2; //compliant
18
return 0;
}
```

### See also

SEI CERT C++ Coding Standard [10]: FIO39-C: Do not alternately input and output from a stream without an intervening flush or positioning call

SEI CERT C++ Coding Standard [10]: FIO50-CPP: Do not alternately input and output from a file stream without an intervening positioning call

## 7 References

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## A Allocation of rules to work products

This chapter lists the rules that are allocated to ISO 26262 work products or activities that are impacted by the usage of C++ (in particular for software architectural design specification, software unit design specification, toolchain and others).

The rules listed below can be used as guidelines for performing those activities or as checklists for performing reviews. For example, it can be used for performing the review of software architectural design specification.

### A.1 Rules allocated to architecture

A2-3-1 .....	37
A2-8-1 .....	43
A2-8-2 .....	44
M2-10-1 .....	44
A2-10-1 .....	44
A2-13-1 .....	50
A2-13-6 .....	50
M2-13-2 .....	51
M2-13-3 .....	51
M2-13-4 .....	52
A2-13-3 .....	53
A2-13-4 .....	53
A3-1-1 .....	54
A3-1-2 .....	55
A3-1-3 .....	56
A4-10-1 .....	73
A15-0-1 .....	260
A15-0-2 .....	264
A15-0-4 .....	268
A15-0-5 .....	271

## A.2 Rules allocated to design

A2-3-1 .....	37
A2-8-1 .....	43
A2-8-2 .....	44
M2-10-1 .....	44
A2-10-1.....	44
A2-10-5.....	48
A2-11-1.....	49
A2-13-1.....	50
A2-13-6.....	50
M2-13-2 .....	51
M2-13-3 .....	51
M2-13-4 .....	52
A2-13-3.....	53
A2-13-4.....	53
A3-1-1 .....	54
A3-1-2 .....	55
A3-1-3 .....	56
A3-1-4 .....	56
A3-1-5 .....	56
A3-1-6 .....	59
A4-10-1.....	73
A7-2-5.....	142
A8-4-3.....	156
A8-4-4.....	157
A8-4-5.....	158
A8-4-6.....	159
A8-4-7.....	161
A8-4-8.....	162
A8-4-9.....	163

A8-4-10	164
A8-4-11	165
A8-4-12	167
A8-4-13	168
A8-4-14	170
A9-6-1	184
A9-6-2	185
A10-0-1	186
A10-0-2	187
A10-4-1	196
A14-5-2	250
A14-5-3	251
A15-0-1	260
A15-0-2	264
A15-0-4	268
A15-0-5	271

### A.3 Rules allocated to toolchain

A0-4-1	30
A0-4-3	32
M1-0-2	35
A1-1-2	35
A1-1-3	35
A1-2-1	36
A15-0-6	274
A15-0-7	274
A15-0-8	276
A18-5-5	350
A18-5-6	351

## A.4 Rules allocated to infrastructure

A0-4-1 .....	30
--------------	----

## A.5 Rules allocated to analysis

## A.6 Rules allocated to hardware

## A.7 Rules allocated to management

## A.8 Rules allocated to verification

M0-3-1 .....	29
A1-4-1 .....	36
A15-0-6 .....	274
A15-0-7 .....	274
A15-0-8 .....	276
A18-5-6 .....	351

## A.9 Rules allocated to implementation

M0-1-1 .....	20
M0-1-2 .....	20
M0-1-3 .....	20
M0-1-4 .....	20
A0-1-1 .....	20
A0-1-2 .....	22
M0-1-8 .....	23
M0-1-9 .....	23
M0-1-10 .....	24
A0-1-3 .....	24
A0-1-4 .....	25
A0-1-5 .....	27

A0-1-6 .....	29
M0-2-1 .....	29
M0-3-1 .....	29
M0-3-2 .....	30
M0-4-1 .....	30
M0-4-2 .....	30
A0-4-2 .....	31
A0-4-4 .....	32
A1-1-1 .....	34
A1-1-2 .....	35
A1-4-1 .....	36
A1-4-3 .....	37
A2-3-1 .....	37
A2-5-1 .....	38
A2-5-2 .....	39
M2-7-1 .....	40
A2-7-1 .....	40
A2-7-2 .....	40
A2-7-3 .....	42
A2-7-5 .....	43
A2-8-1 .....	43
A2-8-2 .....	44
M2-10-1 .....	44
A2-10-1 .....	44
A2-10-6 .....	46
A2-10-4 .....	47
A2-10-5 .....	48
A2-11-1 .....	49
A2-13-1 .....	50
A2-13-6 .....	50

A2-13-5.....	51
M2-13-2.....	51
M2-13-3.....	51
M2-13-4.....	52
A2-13-2.....	52
A2-13-3.....	53
A2-13-4.....	53
A3-1-1.....	54
A3-1-2.....	55
A3-1-3.....	56
M3-1-2.....	56
A3-1-4.....	56
M3-2-1.....	59
M3-2-2.....	60
M3-2-3.....	60
M3-2-4.....	60
A3-3-1.....	60
A3-3-2.....	62
M3-3-2.....	64
M3-4-1.....	64
A3-8-1.....	65
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A3-9-1.....	67
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A4-5-1.....	69
M4-5-3.....	71
A4-7-1.....	71
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A4-10-1.....	73

M4-10-2 .....	74
A5-0-1 .....	75
M5-0-2 .....	78
M5-0-3 .....	78
M5-0-4 .....	78
M5-0-5 .....	79
M5-0-6 .....	79
M5-0-7 .....	79
M5-0-8 .....	79
M5-0-9 .....	79
M5-0-10 .....	80
M5-0-11 .....	80
M5-0-12 .....	80
A5-0-2 .....	80
M5-0-14 .....	82
M5-0-15 .....	82
M5-0-16 .....	82
M5-0-17 .....	82
A5-0-4 .....	83
M5-0-18 .....	85
A5-0-3 .....	85
M5-0-20 .....	86
M5-0-21 .....	87
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A5-1-2 .....	89
A5-1-3 .....	90
A5-1-4 .....	90
A5-1-6 .....	91
A5-1-7 .....	92
A5-1-8 .....	93

A5-1-9 .....	94
M5-2-2 .....	95
M5-2-3 .....	95
A5-2-1 .....	96
A5-2-2 .....	97
A5-2-3 .....	98
M5-2-6 .....	99
A5-2-4 .....	99
A5-2-6 .....	100
M5-2-8 .....	101
M5-2-9 .....	101
M5-2-10 .....	102
M5-2-11 .....	102
A5-2-5 .....	102
M5-2-12 .....	104
M5-3-1 .....	104
M5-3-2 .....	104
M5-3-3 .....	105
M5-3-4 .....	105
A5-3-1 .....	105
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M5-8-1 .....	111
A5-10-1 .....	111
M5-14-1 .....	112
A5-16-1 .....	112
M5-17-1 .....	113
M5-18-1 .....	113



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M6-2-1 .....	113
A6-2-1.....	114
A6-2-2.....	116
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M6-3-1 .....	117
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M6-4-4 .....	118
M6-4-5 .....	118
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M6-4-7 .....	119
A6-4-1.....	119
A6-5-1.....	120
A6-5-2.....	122
M6-5-2 .....	123
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M6-5-4 .....	123
M6-5-5 .....	123
M6-5-6 .....	123
A6-5-3.....	124
A6-5-4.....	125
A6-6-1.....	126
M6-6-1 .....	127
M6-6-2 .....	127
M6-6-3 .....	127
A7-1-1.....	127
A7-1-2.....	128

M7-1-2 .....	129
A7-1-3 .....	130
A7-1-4 .....	131
A7-1-5 .....	131
A7-1-6 .....	133
A7-1-7 .....	134
A7-1-8 .....	135
A7-1-9 .....	136
A7-2-1 .....	137
A7-2-2 .....	139
A7-2-3 .....	140
A7-2-4 .....	141
M7-3-1 .....	143
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M7-5-2 .....	147
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A7-6-1 .....	151
M8-0-1 .....	152
A8-2-1 .....	152
M8-3-1 .....	153

A8-4-1	154
M8-4-2	154
A8-4-2	155
M8-4-4	156
A8-5-0	171
A8-5-1	173
M8-5-2	174
A8-5-2	175
A8-5-3	177
A8-5-4	178
M9-3-1	179
A9-3-1	180
M9-3-3	182
A9-5-1	182
M9-6-1	183
M9-6-4	186
A10-1-1	187
M10-1-1	188
M10-1-2	189
M10-1-3	189
M10-2-1	189
A10-2-1	189
A10-3-1	191
A10-3-2	192
A10-3-3	194
A10-3-5	194
M10-3-3	196
M11-0-1	197
A11-0-1	197
A11-0-2	199

A11-3-1 .....	200
A12-0-1 .....	201
A12-0-2 .....	204
A12-1-1 .....	206
M12-1-1 .....	207
A12-1-2 .....	207
A12-1-3 .....	209
A12-1-4 .....	210
A12-1-5 .....	211
A12-1-6 .....	212
A12-4-1 .....	213
A12-4-2 .....	215
A12-6-1 .....	216
A12-7-1 .....	218
A12-8-1 .....	220
A12-8-2 .....	222
A12-8-3 .....	223
A12-8-4 .....	225
A12-8-5 .....	226
A12-8-6 .....	228
A12-8-7 .....	231
A13-1-2 .....	233
A13-1-3 .....	233
A13-2-1 .....	235
A13-2-2 .....	236
A13-2-3 .....	237
A13-3-1 .....	238
A13-5-1 .....	239
A13-5-2 .....	240
A13-5-3 .....	241

A13-5-4	242
A13-5-5	243
A13-6-1	245
A14-1-1	246
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## B Traceability to existing standards

This section demonstrates the traceability of AUTOSAR C++14 rules to existing important C++ coding standards and to ISO 26262.

For each rule, the relation is identified:



Identical (only for MISRA C++): the rule text, rationale, exceptions, code example are identical. Only the rule classification can be different. There can be also an additional note with clarifications.

Small differences: the content of the rule is included by AUTOSAR C++14 rules with minor differences.

Significant differences: the content of the rule is included by AUTOSAR C++14 rules with significant differences.

Rejected: the rule in the referred document is rejected by AUTOSAR C++14 guidelines.

Not yet analyzed: The rule is not yet analyzed in the current release.

Implemented (only for ISO 26262): A clause is implemented by the AUTOSAR C++14 rules.

Partially implemented (only for ISO 26262): A clause covered to some extent that is in scope of this document.

Not applicable (only for ISO 26262): A clause that is out of scope of this document.

## B.1 Traceability to MISRA C++:2008

MISRA C++:2008 [7] is a required prerequisite for readers of the document. MISRA C++:2008 can be purchased over MISRA web store.

The following table demonstrates the traceability to MISRA C++:2008. This is not considered as a reproduction of a part of MISRA C++:2008, but a mean to compare the two standards.

MISRA Rule:	Relation type:	Related rule:	Comment:
0-1-1 (Required) A project shall not contain unreachable code.	1 - Identical	<a href="#">M0-1-1</a>	-
0-1-2 (Required) A project shall not contain infeasible paths.	2 - Small differences	<a href="#">M0-1-2</a>	Note about constexpr functions added.
0-1-3 (Required) A project shall not contain unused variables.	1 - Identical	<a href="#">M0-1-3</a>	-
0-1-4 (Required) A project shall not contain non-volatile POD variables having only one use.	1 - Identical	<a href="#">M0-1-4</a>	-
0-1-5 (Required) A project shall not contain unused type declarations.	3 - Significant differences	<a href="#">A0-1-6</a>	Obligation level changed to "Advisory".

0-1-6 (Required) A project shall not contain instances of non-volatile variables being given values that are never subsequently used.	2 - Small differences	<a href="#">A0-1-1</a>	Example reworked.
0-1-7 (Required) The value returned by a function having a non-void return type that is not an overloaded operator shall always be used.	2 - Small differences	<a href="#">A0-1-2</a>	Rationale reformulated.
0-1-8 (Required) All functions with void return type shall have external side effect(s).	1 - Identical	<a href="#">M0-1-8</a>	-
0-1-9 (Required) There shall be no dead code.	1 - Identical	<a href="#">M0-1-9</a>	-
0-1-10 (Required) Every defined function shall be called at least once.	3 - Significant differences	<a href="#">M0-1-10</a> , <a href="#">A0-1-2</a>	Rule divided into: (1) Identical rule with obligation level "Advisory", (2) Rule with obligation level "Required" which applies to static functions and private methods.
0-1-11 (Required) There shall be no unused parameters (named or unnamed) in non-virtual functions.	3 - Significant differences	<a href="#">A0-1-4</a>	Unused parameters are allowed to be unnamed.
0-1-12 (Required) There shall be no unused parameters (named or unnamed) in the set of parameters for a virtual function and all the functions that override it.	3 - Significant differences	<a href="#">A0-1-5</a>	Unused parameters are allowed to be unnamed.
0-2-1 (Required) An object shall not be assigned to an overlapping object.	1 - Identical	<a href="#">M0-2-1</a>	-
0-3-1 (Document) Minimization of run-time failures shall be ensured by the use of at least one of: (a) static analysis tools/techniques; (b) dynamic analysis tools/techniques; (c) explicit coding of checks to handle run-time faults.	1 - Identical	<a href="#">M0-3-1</a>	-
0-3-2 (Required) If a function generates error information, then that error information shall be tested.	1 - Identical	<a href="#">M0-3-2</a>	-
0-4-1 (Document) Use of scaled-integer or fixed-point arithmetic shall be documented.	1 - Identical	<a href="#">M0-4-1</a>	-
0-4-2 (Document) Use of floating-point arithmetic shall be documented.	1 - Identical	<a href="#">M0-4-2</a>	-

0-4-3 (Document) Floating-point implementations shall comply with a defined floating-point standard.	3 - Significant differences	A0-4-1	Specified that floating-point implementations need to comply with IEEE 754 standard.
1-0-1 (Required) All code shall conform to ISO/IEC 14882:2003 "The C++ Standard Incorporating Technical Corrigendum 1".	2 - Small differences	A1-1-1	Specified that the code shall conform to ISO/IEC 14882:2014.
1-0-2 (Document) Multiple compilers shall only be used if they have a common, defined interface.	1 - Identical	M1-0-2	-
1-0-3 (Document) The implementation of integer division in the chosen compiler shall be determined and documented.	3 - Significant differences	A0-4-2	Specified that the implementation of integer division shall comply with the C++ Language Standard.
2-2-1 (Document) The character set and the corresponding encoding shall be documented.	3 - Significant differences	A2-3-1	
2-3-1 (Required) Trigraphs shall not be used.	2 - Small differences	A2-5-1	All trigraphs listed in rationale. Example extended.
2-5-1 (Advisory) Digraphs should not be used.	3 - Significant differences	A2-5-2	Obligation level changed to "Required".
2-7-1 (Required) The character sequence /* shall not be used within a C-style comment.	1 - Identical	M2-7-1	-
2-7-2 (Required) Sections of code shall not be commented out using C-style comments.	2 - Small differences	A2-7-1	Commenting-out code sections is not allowed.
2-7-3 (Advisory) Sections of code should not be "commented out" using C++ comments.	2 - Small differences	A2-7-1	Obligation level changed to "Required". Commenting-out code sections is not allowed.
2-10-1 (Required) Different identifiers shall be typographically unambiguous.	1 - Identical	M2-10-1	-
2-10-2 (Required) Identifiers declared in an inner scope shall not hide an identifier declared in an outer scope.	2 - Small differences	A2-10-1	Added a note to rationale. Example extended.

2-10-3 (Required) A typedef name (including qualification, if any) shall be a unique identifier.	4 - Rejected		This rule is considered as too restrictive.
2-10-4 (Required) A class, union or enum name (including qualification, if any) shall be a unique identifier.	4 - Rejected		This rule is considered as too restrictive.
2-10-5 (Advisory) The identifier name of a non-member object or function with static storage duration should not be reused.	3 - Significant differences	<a href="#">A2-10-4</a>	Obligation level changed to "Required". Scope of the rule changed.
2-10-6 (Required) If an identifier refers to a type, it shall not also refer to an object or a function in the same scope.	2 - Small differences	<a href="#">A2-10-6</a>	
2-13-1 (Required) Only those escape sequences that are defined in ISO/IEC 14882:2003 shall be used.	2 - Small differences	<a href="#">A2-13-1</a>	Standard changed to ISO/IEC 14882:2014.
2-13-2 (Required) Octal constants (other than zero) and octal escape sequences (other than "\0" ) shall not be used.	1 - Identical	<a href="#">M2-13-2</a>	-
2-13-3 (Required) A "U" suffix shall be applied to all octal or hexadecimal integer literals of unsigned type.	1 - Identical	<a href="#">M2-13-3</a>	-
2-13-4 (Required) Literal suffixes shall be upper case.	1 - Identical	<a href="#">M2-13-4</a>	-
2-13-5 (Required) Narrow and wide string literals shall not be concatenated.	2 - Small differences	<a href="#">A2-13-2</a>	Example extended.
3-1-1 (Required) It shall be possible to include any header file in multiple translation units without violating the One Definition Rule.	3 - Significant differences	<a href="#">A3-1-1</a>	Rationale reformulated. Example extended.
3-1-2 (Required) Functions shall not be declared at block scope.	1 - Identical	<a href="#">M3-1-2</a>	-
3-1-3 (Required) When an array is declared, its size shall either be stated explicitly or defined implicitly by initialization.	2 - Small differences	<a href="#">A3-1-4</a>	Specified that this rule applies to arrays with external linkage only.
3-2-1 (Required) All declarations of an object or function shall have compatible types.	1 - Identical	<a href="#">M3-2-1</a>	-
3-2-2 (Required) The One Definition Rule shall not be violated.	1 - Identical	<a href="#">M3-2-2</a>	-
3-2-3 (Required) A type, object or function that is used in multiple translation units shall be declared in one and only one file.	1 - Identical	<a href="#">M3-2-3</a>	-

3-2-4 (Required) An identifier with external linkage shall have exactly one definition.	1 - Identical	M3-2-4	-
3-3-1 (Required) Objects or functions with external linkage shall be declared in a header file.	2 - Small differences	A3-3-1	Added a note to rationale. Example extended.
3-3-2 (Required) If a function has internal linkage then all re-declarations shall include the static storage class specifier.	1 - Identical	M3-3-2	-
3-4-1 (Required) An identifier declared to be an object or type shall be defined in a block that minimizes its visibility.	1 - Identical	M3-4-1	-
3-9-1 (Required) The types used for an object, a function return type, or a function parameter shall be token-for-token identical in all declarations and re-declarations.	1 - Identical	M3-9-1	-
3-9-2 (Advisory) typedefs that indicate size and signedness should be used in place of the basic numerical types.	3 - Significant differences	M3-9-1	Rule title and rationale reformulated to use types from <stdint> header file. All types that should be used were listed. Example changed.
3-9-3 (Required) The underlying bit representations of floating-point values shall not be used.	1 - Identical	M3-9-3	-
4-5-1 (Required) Expressions with type bool shall not be used as operands to built-in operators other than the assignment operator =, the logical operators &&,   , !, the equality operators == and !=, the unary & operator, and the conditional operator.	1 - Identical	M4-5-1	-
4-5-2 (Required) Expressions with type enum shall not be used as operands to built-in operators other than the subscript operator [ ], the assignment operator =, the equality operators == and !=, the unary & operator, and the relational operators <, <=, >, >=.	3 - Significant differences	A4-5-1	Changed the rule so it applies to enum classes too. Rationale reformulated. Example extended.
4-5-3 (Required) Expressions with type (plain) char and wchar_t shall not be used as operands to built-in operators other than the assignment operator =, the equality operators == and !=, and the unary & operator.	1 - Identical	M4-5-3	-
4-10-1 (Required) NULL shall not be used as an integer value.	1 - Identical	M4-10-1	-

4-10-2 (Required) Literal zero (0) shall not be used as the null-pointer-constant.	1 - Identical	<a href="#">M4-10-2</a>	-
5-0-1 (Required) The value of an expression shall be the same under any order of evaluation that the standard permits.	1 - Identical	<a href="#">A5-0-1</a>	Example rewritten to compile with C++ compiler
5-0-2 (Advisory) Limited dependence should be placed on C++ operator precedence rules in expressions.	1 - Identical	<a href="#">M5-0-2</a>	-
5-0-3 (Required) A cvalue expression shall not be implicitly converted to a different underlying type.	1 - Identical	<a href="#">M5-0-3</a>	-
5-0-4 (Required) An implicit integral conversion shall not change the signedness of the underlying type.	1 - Identical	<a href="#">M5-0-4</a>	-
5-0-5 (Required) There shall be no implicit floating-integral conversions.	1 - Identical	<a href="#">M5-0-5</a>	-
5-0-6 (Required) An implicit integral or floating-point conversion shall not reduce the size of the underlying type.	1 - Identical	<a href="#">M5-0-6</a>	-
5-0-7 (Required) There shall be no explicit floating-integral conversions of a cvalue expression.	1 - Identical	<a href="#">M5-0-7</a>	-
5-0-8 (Required) An explicit integral or floating-point conversion shall not increase the size of the underlying type of a cvalue expression.	1 - Identical	<a href="#">M5-0-8</a>	-
5-0-9 (Required) An explicit integral conversion shall not change the signedness of the underlying type of a cvalue expression.	1 - Identical	<a href="#">M5-0-9</a>	-
5-0-10 (Required) If the bitwise operators <code>&amp;</code> and <code>«</code> are applied to an operand with an underlying type of unsigned char or unsigned short, the result shall be immediately cast to the underlying type of the operand.	1 - Identical	<a href="#">M5-0-10</a>	-
5-0-11 (Required) The plain char type shall only be used for the storage and use of character values.	1 - Identical	<a href="#">M5-0-11</a>	-
5-0-12 (Required) signed char and unsigned char type shall only be used for the storage and use of numeric values.	1 - Identical	<a href="#">M5-0-12</a>	-
5-0-13 (Required) The condition of an if-statement and the condition of an iteration statement shall have type bool.	2 - Small differences	<a href="#">A5-0-2</a>	Example extended.
5-0-14 (Required) The first operand of a conditional-operator shall have type bool.	1 - Identical	<a href="#">M5-0-14</a>	-
5-0-15 (Required) Array indexing shall be the only form of pointer arithmetic.	1 - Identical	<a href="#">M5-0-15</a>	-

5-0-16 (Required) A pointer operand and any pointer resulting from pointer arithmetic using that operand shall both address elements of the same array.	1 - Identical	<a href="#">M5-0-16</a>	-
5-0-17 (Required) Subtraction between pointers shall only be applied to pointers that address elements of the same array.	1 - Identical	<a href="#">M5-0-17</a>	-
5-0-18 (Required) $>$ , $>=$ , $<$ , $<=$ shall not be applied to objects of pointer type, except where they point to the same array.	1 - Identical	<a href="#">M5-0-18</a>	-
5-0-19 (Required) The declaration of objects shall contain no more than two levels of pointer indirection.	2 - Small differences	<a href="#">A5-0-3</a>	Example changed - typedef replaced with using.
5-0-20 (Required) Non-constant operands to a binary bitwise operator shall have the same underlying type.	1 - Identical	<a href="#">M5-0-20</a>	-
5-0-21 (Required) Bitwise operators shall only be applied to operands of unsigned underlying type.	1 - Identical	<a href="#">M5-0-21</a>	-
5-2-1 (Required) Each operand of a logical $\&\&$ or $\ \ $ shall be a postfix expression.	3 - Significant differences	<a href="#">A5-2-6</a>	Rule formulation simplified.
5-2-2 (Required) A pointer to a virtual base class shall only be cast to a pointer to a derived class by means of <code>dynamic_cast</code> .	1 - Identical	<a href="#">M5-2-2</a>	-
5-2-3 (Advisory) Casts from a base class to a derived class should not be performed on polymorphic types.	1 - Identical	<a href="#">M5-2-3</a>	-
5-2-4 (Required) C-style casts (other than void casts) and functional notation casts (other than explicit constructor calls) shall not be used.	3 - Significant differences	<a href="#">A5-2-2</a>	Rule title and rationale reformulated, detailed explanation and possible alternatives added. Example reworked.
5-2-5 (Required) A cast shall not remove any const or volatile qualification from the type of a pointer or reference.	2 - Small differences	<a href="#">A5-2-3</a>	Added a note to rationale. Example reworked.
5-2-6 (Required) A cast shall not convert a pointer to a function to any other pointer type, including a pointer to function type.	1 - Identical	<a href="#">M5-2-6</a>	-



5-2-7 (Required) An object with pointer type shall not be converted to an unrelated pointer type, either directly or indirectly.	3 - Significant differences	<a href="#">A5-2-4</a>	Rule title and rationale reformulated to prohibit reinterpret_cast usage. Example reworked.
5-2-8 (Required) An object with integer type or pointer to void type shall not be converted to an object with pointer type.	1 - Identical	<a href="#">M5-2-8</a>	-
5-2-9 (Advisory) A cast shall not convert a pointer type to an integral type.	2 - Small differences	<a href="#">M5-2-9</a>	Obligation level changed to "Required".
5-2-10 (Advisory) The increment (++) and decrement (-) operators shall not be mixed with other operators in an expression.	2 - Small differences	<a href="#">M5-2-10</a>	Obligation level changed to "Required".
5-2-11 (Required) The comma operator, && operator and the operator shall not be overloaded.	1 - Identical	<a href="#">M5-2-11</a>	-
5-2-12 (Required) An identifier with array type passed as a function argument shall not decay to a pointer.	1 - Identical	<a href="#">M5-2-12</a>	-
5-3-1 (Required) Each operand of the ! operator, the logical && or the logical    operators shall have type bool.	1 - Identical	<a href="#">M5-3-1</a>	-
5-3-2 (Required) The unary minus operator shall not be applied to an expression whose underlying type is unsigned.	1 - Identical	<a href="#">M5-3-2</a>	-
5-3-3 (Required) The unary & operator shall not be overloaded.	1 - Identical	<a href="#">M5-3-3</a>	-
5-3-4 (Required) Evaluation of the operand to the sizeof operator shall not contain side effects.	1 - Identical	<a href="#">M5-3-4</a>	-
5-8-1 (Required) The right hand operand of a shift operator shall lie between zero and one less than the width in bits of the underlying type of the left hand operand.	1 - Identical	<a href="#">M5-8-1</a>	-
5-14-1 (Required) The right hand operand of a logical && or    operator shall not contain side effects.	1 - Identical	<a href="#">M5-14-1</a>	-
5-17-1 (Required) The semantic equivalence between a binary operator and its assignment operator form shall be preserved.	1 - Identical	<a href="#">M5-17-1</a>	-
5-18-1 (Required) The comma operator shall not be used.	1 - Identical	<a href="#">M5-18-1</a>	-



5-19-1 (Required) Evaluation of constant unsigned integer expressions shall not lead to wrap-around.	2 - Small differences	M5-19-1	Obligation level changed to "Required".
6-2-1 (Required) Assignment operators shall not be used in subexpressions.	1 - Identical	M6-2-1	-
6-2-2 (Required) Floating-point expressions shall not be directly or indirectly tested for equality or inequality.	1 - Identical	M6-2-2	-
6-2-3 (Required) Before preprocessing, a null statement shall only occur on a line by itself; it may be followed by a comment, provided that the first character following the null statement is a white-space character.	1 - Identical	M6-2-3	-
6-3-1 (Required) The statement forming the body of a switch, while, do ... while or for statement shall be a compound statement.	1 - Identical	M6-3-1	-
6-4-1 (Required) An if ( condition ) construct shall be followed by a compound statement. The else keyword shall be followed by either a compound statement, or another if statement.	1 - Identical	M6-4-1	-
6-4-2 (Required) All if ... else if constructs shall be terminated with an else clause.	1 - Identical	M6-4-2	-
6-4-3 (Required) A switch statement shall be a well-formed switch statement.	1 - Identical	M6-4-3	-
6-4-4 (Required) A switch-label shall only be used when the most closely-enclosing compound statement is the body of a switch statement.	1 - Identical	M6-4-4	-
6-4-5 (Required) An unconditional throw or break statement shall terminate every non-empty switch clause.	1 - Identical	M6-4-5	-
6-4-6 (Required) The final clause of a switch statement shall be the default-clause.	1 - Identical	M6-4-6	-
6-4-7 (Required) The condition of a switch statement shall not have bool type.	1 - Identical	M6-4-7	-
6-4-8 (Required) Every switch statement shall have at least one case-clause.	3 - Significant differences	A6-4-1	Rule reformulated. Example reworked.

6-5-1 (Required) A for loop shall contain a single loop-counter which shall not have floating type.	2 - Small differences	<a href="#">A6-5-2</a>	Additional note about floating types added. Rule extended.
6-5-2 (Required) If loop-counter is not modified by – or ++, then, within condition, the loop-counter shall only be used as an operand to <=, <, > or >=.	1 - Identical	<a href="#">M6-5-2</a>	-
6-5-3 (Required) The loop-counter shall not be modified within condition or statement.	1 - Identical	<a href="#">M6-5-3</a>	-
6-5-4 (Required) The loop-counter shall be modified by one of: –, ++, -=n, or +=n; where n remains constant for the duration of the loop.	1 - Identical	<a href="#">M6-5-4</a>	-
6-5-5 (Required) A loop-control-variable other than the loop-counter shall not be modified within condition or expression.	1 - Identical	<a href="#">M6-5-5</a>	-
6-5-6 (Required) A loop-control-variable other than the loop-counter which is modified in statement shall have type bool.	1 - Identical	<a href="#">M6-5-6</a>	-
6-6-1 (Required) Any label referenced by a goto statement shall be declared in the same block, or in a block enclosing the goto statement.	1 - Identical	<a href="#">M6-6-1</a>	-
6-6-2 (Required) The goto statement shall jump to a label declared later in the same function body.	1 - Identical	<a href="#">M6-6-2</a>	-
6-6-3 (Required) The continue statement shall only be used within a well-formed for loop.	1 - Identical	<a href="#">M6-6-3</a>	-
6-6-4 (Required) For any iteration statement there shall be no more than one break or goto statement used for loop termination.	4 - Rejected		The goto statement shall not be used, see: <a href="#">A6-6-1</a> . There can be more than one break in an iteration statement.
6-6-5 (Required) A function shall have a single point of exit at the end of the function.	4 - Rejected		See <a href="#">Single-point-of-exit</a> .
7-1-1 (Required) A variable which is not modified shall be const qualified.	3 - Significant differences	<a href="#">A7-1-1</a> , <a href="#">A7-1-2</a>	constexpr and const specifiers are recommended.

7-1-2 (Required) A pointer or reference parameter in a function shall be declared as pointer to const or reference to const if the corresponding object is not modified.	1 - Identical	M7-1-2	-
7-2-1 (Required) An expression with enum underlying type shall only have values corresponding to the enumerators of the enumeration.	2 - Small differences	A7-1-2	Example extended.
7-3-1 (Required) The global namespace shall only contain main, namespace declarations and extern "C" declarations.	1 - Identical	M7-3-1	-
7-3-2 (Required) The identifier main shall not be used for a function other than the global function main.	1 - Identical	M7-3-2	-
7-3-3 (Required) There shall be no unnamed namespaces in header files.	1 - Identical	M7-3-3	-
7-3-4 (Required) Using-directives shall not be used.	1 - Identical	M7-3-4	-
7-3-5 (Required) Multiple declarations for an identifier in the same namespace shall not straddle a using-declaration for that identifier.	2 - Small differences	A7-3-1	
7-3-6 (Required) using-directives and using-declarations (excluding class scope or function scope using-declarations) shall not be used in header files.	1 - Identical	M7-3-6	-
7-4-1 (Document) All usage of assembler shall be documented.	1 - Identical	M7-4-1	-
7-4-2 (Required) Assembler instructions shall only be introduced using the asm declaration.	1 - Identical	M7-4-2	-
7-4-3 (Required) Assembly language shall be encapsulated and isolated.	1 - Identical	M7-4-3	-
7-5-1 (Required) A function shall not return a reference or a pointer to an automatic variable (including parameters), defined within the function.	1 - Identical	M7-5-1	-
7-5-2 (Required) The address of an object with automatic storage shall not be assigned to another object that may persist after the first object has ceased to exist.	2 - Small differences	M7-5-2	Added a note saying that the rule applies to std::unique_ptr, std::shared_ptr and std::weak_ptr too.

7-5-3 (Required) A function shall not return a reference or a pointer to a parameter that is passed by reference or const reference.	3 - Significant differences	<a href="#">A7-5-2</a>	Rule reformulated so it is allowed to return a reference or a pointer to non-const reference parameter. Rationale reformulated. Example reworked.
7-5-4 (Advisory) Functions should not call themselves, either directly or indirectly.	2 - Small differences	<a href="#">A7-5-1</a>	Obligation level changed to "Required". Example reworked.
8-0-1 (Required) An init-declarator-list or a member-declarator-list shall consist of a single init-declarator or member-declarator respectively.	1 - Identical	<a href="#">M8-0-1</a>	-
8-3-1 (Required) Parameters in an overriding virtual function shall either use the same default arguments as the function they override, or else shall not specify any default arguments.	1 - Identical	<a href="#">M8-3-1</a>	-
8-4-1 (Required) Functions shall not be defined using the ellipsis notation.	3 - Significant differences	<a href="#">A8-4-1</a>	Rationale reformulated. Added a note that variadic templates should be used instead. Example extended.
8-4-2 (Required) The identifiers used for the parameters in a re-declaration of a function shall be identical to those in the declaration.	1 - Identical	<a href="#">M8-4-2</a>	-
8-4-3 (Required) All exit paths from a function with non-void return type shall have an explicit return statement with an expression.	2 - Small differences	<a href="#">A8-4-2</a>	Rule reformulated so it applies to void return type functions. Example reworked so there is no throwing an exception of type int.
8-4-4 (Required) A function identifier shall either be used to call the function or it shall be preceded by &.	1 - Identical	<a href="#">M8-4-4</a>	-
8-5-1 (Required) All variables shall have a defined value before they are used.	2 - Small differences	<a href="#">A8-5-0</a>	Rule reworded to also include objects with dynamic storage.

8-5-2 (Required) Braces shall be used to indicate and match the structure in the non-zero initialization of arrays and structures.	1 - Identical	<a href="#">M8-5-2</a>	-
8-5-3 (Required) In an enumerator list, the = construct shall not be used to explicitly initialize members other than the first, unless all items are explicitly initialized.	3 - Significant differences	<a href="#">A7-2-4</a>	Rule and rationale reformulated. Example reworked.
9-3-1 (Required) const member functions shall not return non-const pointers or references to class-data.	1 - Identical	<a href="#">M9-3-1</a>	-
9-3-2 (Required) Member functions shall not return non-const handles to class-data.	2 - Small differences	<a href="#">A9-3-1</a>	Explanation improved. Example reworked.
9-3-3 (Required) If a member function can be made static then it shall be made static, otherwise if it can be made const then it shall be made const.	1 - Identical	<a href="#">M9-3-3</a>	-
9-5-1 (Required) Unions shall not be used.	2 - Small differences	<a href="#">A9-5-1</a>	-
9-6-1 (Required) When the absolute positioning of bits representing a bit-field is required, then the behavior and packing of bit-fields shall be documented.	1 - Identical	<a href="#">M9-6-1</a>	-
9-6-2 (Required) Bit-fields shall be either bool type or an explicitly unsigned or signed integral type.	3 - Significant differences	<a href="#">A9-6-1</a>	Only types with a defined size are allowed to be used for bit-fields, also see <a href="#">A9-6-2</a> .
9-6-3 (Required) Bit-fields shall not have enum type.	4 - Rejected	-	Permitted types changed. New rule introduced: <a href="#">A9-6-1</a> .
9-6-4 (Required) Named bit-fields with signed integer type shall have a length of more than one bit.	1 - Identical	<a href="#">M9-6-4</a>	
10-1-1 (Advisory) Classes should not be derived from virtual bases	1 - Identical	<a href="#">M10-1-1</a>	-
10-1-2 (Required) A base class shall only be declared virtual if it is used in a diamond hierarchy.	1 - Identical	<a href="#">M10-1-2</a>	
10-1-3 (Required) An accessible base class shall not be both virtual and non-virtual in the same hierarchy.	1 - Identical	<a href="#">M10-1-3</a>	-
10-2-1 (Advisory) All accessible entity names within a multiple inheritance hierarchy should be unique.	1 - Identical	<a href="#">M10-2-1</a>	-

10-3-1 (Required) There shall be no more than one definition of each virtual function on each path through the inheritance hierarchy.	4 - Rejected	-	Rule already covered by <a href="#">A10-1-1</a> .
10-3-2 (Required) Each overriding virtual function shall be declared with the virtual keyword.	3 - Significant differences	<a href="#">A10-3-2</a>	Rule and rationale reformulated so the override specifier should be used instead of virtual keyword. Example reworked.
10-3-3 (Required) A virtual function shall only be overridden by a pure virtual function if it is itself declared as pure virtual.	1 - Identical	<a href="#">M10-3-3</a>	-
11-0-1 (Required) Member data in non-POD class types shall be private.	1 - Identical	<a href="#">M11-0-1</a>	-
12-1-1 (Required) An object's dynamic type shall not be used from the body of its constructor or destructor.	1 - Identical	<a href="#">M12-1-1</a>	-
12-1-2 (Advisory) All constructors of a class should explicitly call a constructor for all of its immediate base classes and all virtual base classes.	3 - Significant differences	<a href="#">A12-1-1</a>	Obligation level changed to "Required". Rule reformulated to cover non-static class data members. Rationale reformulated. Example reworked.
12-1-3 (Required) All constructors that are callable with a single argument of fundamental type shall be declared explicit.	2 - Small differences	<a href="#">A12-1-4</a>	Example reworked.
12-8-1 (Required) A copy constructor shall only initialize its base classes and the non-static members of the class of which it is a member.	3 - Significant differences	<a href="#">A12-8-1</a>	Rule reformulated to cover move constructors, too. Rationale reformulated. Example reworked.
12-8-2 (Required) The copy assignment operator shall be declared protected or private in an abstract class.	3 - Significant differences	<a href="#">A12-8-6</a>	Rule reformulated to cover move assignment operators and all base classes. Rationale reformulated. Example reworked.

12-8-2 (Required) The copy assignment operator shall be declared protected or private in an abstract class.	3 - Significant differences	A12-8-1	Rule reformulated to cover move constructors, too. Rationale reformulated. Example reworked.
14-5-1 (Required) A non-member generic function shall only be declared in a namespace that is not an associated namespace.	3 - Significant differences	A14-5-3	Changed the scope of the rule from all generic functions to operators only, as most problematic case. Changed severity to Advisory.
14-5-2 (Required) A copy constructor shall be declared when there is a template constructor with a single parameter that is a generic parameter.	3 - Significant differences	A14-5-1	Avoids the ambiguity by requiring the template parameter to be constrained to never match a copy/move constructor.
14-5-3 (Required) A copy assignment operator shall be declared when there is a template assignment operator with a parameter that is a generic parameter.	1 - Identical	M14-5-3	-
14-6-1 (Required) In a class template with a dependent base, any name that may be found in that dependent base shall be referred to using a qualified-id or this->.	1 - Identical	M14-6-1	-
14-6-2 (Required) The function chosen by overload resolution shall resolve to a function declared previously in the translation unit.	4 - Rejected	-	Usage of the ADL functionality is allowed. It is also used in STL for overloaded operators lookup in e.g. out streams, STL containers.
14-7-1 (Required) All class templates, function templates, class template member functions and class template static members shall be instantiated at least once.	4 - Rejected	-	It is allowed to not use all of the public methods of a class.

14-7-2 (Required) For any given template specialization, an explicit instantiation of the template with the template-arguments used in the specialization shall not render the program ill-formed.	3 - Significant differences	A14-7-1	Rule reformulated to explicitly state what is required. Example reworked.
14-7-3 (Required) All partial and explicit specializations for a template shall be declared in the same file as the declaration of their primary template.	3 - Significant differences	A14-7-2	Allowed to declare in a header file that declares user-defined type, for which the specialization is declared.
14-8-1 (Required) Overloaded function templates shall not be explicitly specialized.	3 - Significant differences	A14-8-2	Function templates specialization is forbidden.
14-8-2 (Advisory) The viable function set for a function call should either contain no function specializations, or only contain function specializations.	3 - Small differences	A14-8-2	Function templates specialization is forbidden.
15-0-1 (Document) Exceptions shall only be used for error handling.	3 - Significant differences	A15-0-1	Rule reformulated, example significantly extended.
15-0-2 (Advisory) An exception object should not have pointer type.	3 - Significant differences	A15-1-2	Obligation level changed, rule reformulated.
15-0-3 (Required) Control shall not be transferred into a try or catch block using a goto or a switch statement.	1 - Identical	M15-0-3	-
15-1-1 (Required) The assignment-expression of a throw statement shall not itself cause an exception.	1 - Identical	M15-1-1	-
15-1-2 (Required) NULL shall not be thrown explicitly.	1 - Identical	M15-1-2	-
15-1-3 (Required) An empty throw (throw;) shall only be used in the compound-statement of a catch handler.	1 - Identical	M15-1-3	-
15-3-1 (Required) Exceptions shall be raised only after start-up and before termination of the program.	1 - Identical	M15-3-1	-
15-3-2 (Advisory) There should be at least one exception handler to catch all otherwise unhandled exceptions.	2 - Small differences	A15-3-3	Obligation level changed. Rule extended to cover multi-threading.



15-3-3 (Required) Handlers of a function-try-block implementation of a class constructor or destructor shall not reference non-static members from this class or its bases.	1 - Identical	M15-3-3	-
15-3-4 (Required) Each exception explicitly thrown in the code shall have a handler of a compatible type in all call paths that could lead to that point.	1 - Identical	M15-3-4	-
15-3-5 (Required) A class type exception shall always be caught by reference.	2 - Small differences	A15-3-5	Possibility to catch by const reference added
15-3-6 (Required) Where multiple handlers are provided in a single try-catch statement or function-try-block for a derived class and some or all of its bases, the handlers shall be ordered most-derived to base class.	1 - Identical	M15-3-6	-
15-3-7 (Required) Where multiple handlers are provided in a single try-catch statement or function-try-block, any ellipsis (catch-all) handler shall occur last.	1 - Identical	M15-3-7	-
15-4-1 (Required) If a function is declared with an exception-specification, then all declarations of the same function (in other translation units) shall be declared with the same set of type-ids.	3 - Significant differences	A15-4-3	Dynamic exception specification was prohibited. Rule was reformulated in terms of the noexcept specification.
15-5-1 (Required) A class destructor shall not exit with an exception.	3 - Significant differences	A15-5-1	Rule significantly extended with other special functions and operators.
15-5-2 (Required) Where a function's declaration includes an exception-specification, the function shall only be capable of throwing exceptions of the indicated type(s).	3 - Significant differences	A15-4-2	Dynamic exception specification was prohibited. Rule was reformulated in terms of the noexcept specification.
15-5-3 (Required) The <code>std::terminate()</code> function shall not be called implicitly.	2 - Small differences	A15-5-3	Rationale and example extended.
16-0-1 (Required) <code>#include</code> directives in a file shall only be preceded by other preprocessor directives or comments.	1 - Identical	M16-0-1	-

16-0-2 (Required) Macros shall only be #define'd or #undef'd in the global namespace.	1 - Identical	M16-0-2	-
16-0-3 (Required) #undef shall not be used.	4 - Rejected	-	The rule replaced with global rule: A16-0-1.
16-0-4 (Required) Function-like macros shall not be defined.	4 - Rejected	-	The rule replaced with global rule: A16-0-1.
16-0-5 (Required) Arguments to a function-like macro shall not contain tokens that look like preprocessing directives.	1 - Identical	M16-0-5	-
16-0-6 (Required) In the definition of a function-like macro, each instance of a parameter shall be enclosed in parentheses, unless it is used as the operand of # or ##.	1 - Identical	M16-0-6	-
16-0-7 (Required) Undefined macro identifiers shall not be used in #if or #elif preprocessor directives, except as operands to the defined operator.	1 - Identical	M16-0-7	-
16-0-8 (Required) If the # token appears as the first token on a line, then it shall be immediately followed by a pre-processing token.	1 - Identical	M16-0-8	-
16-1-1 (Required) The defined preprocessor operator shall only be used in one of the two standard forms.	1 - Identical	M16-1-1	-
16-1-2 (Required) All #else, #elif and #endif pre-processor directives shall reside in the same file as the #if or #ifdef directive to which they are related.	1 - Identical	M16-1-2	-
16-2-1 (Required) The pre-processor shall only be used for file inclusion and include guards.	4 - Rejected	-	The rule replaced with global rule: A16-0-1.
16-2-2 (Required) C++ macros shall only be used for include guards, type qualifiers, or storage class specifiers.	4 - Rejected	-	The rule replaced with global rule: A16-0-1.
16-2-3 (Required) Include guards shall be provided	1 - Identical	M16-2-3	-

16-2-4 (Required) The ', ", /* or // characters shall not occur in a header file name.	2 - Small differences	<a href="#">A16-2-1</a>	Merged with MISRA Rule 16-2-5.
16-2-5 (Advisory) The character \ should not occur in a header file name.	2 - Small differences	<a href="#">A16-2-1</a>	Obligation level changed to "Required". Merged with MISRA Rule 16-2-4.
16-2-6 (Required) The #include directive shall be followed by either a <filename> or "filename" sequence.	4 - Rejected	-	These are the only forms allowed by the C++ Language Standard; No need for a new rule.
16-3-1 (Required) There shall be at most one occurrence of the # or ## operators in a single macro definition.	1 - Identical	<a href="#">M16-3-1</a>	-
16-3-2 (Advisory) The # and ## operators should not be used.	1 - Identical	<a href="#">M16-3-2</a>	-
16-6-1 (Required) All uses of the #pragma directive shall be documented.	4 - Rejected	-	The #pragma directive shall not be used, see: <a href="#">A16-7-1</a> .
17-0-1 (Required) Reserved identifiers, macros and functions in the standard library shall not be defined, redefined or undefined.	2 - Small differences	<a href="#">A17-0-1</a>	Example extended.
17-0-2 (Required) The names of standard library macros and objects shall not be reused.	1 - Identical	<a href="#">M17-0-2</a>	-
17-0-3 (Required) The names of standard library functions shall not be overridden.	1 - Identical	<a href="#">M17-0-3</a>	-
17-0-4 (Required) All library code shall conform to MISRA C++.	4 - Rejected	-	The rule replaced with <a href="#">A17-0-2</a> saying that all code shall conform to AUTOSAR C++14 Coding Guidelines.
17-0-5 (Required) The setjmp macro and the longjmp function shall not be used.	1 - Identical	<a href="#">M17-0-5</a>	-
18-0-1 (Required) The C library shall not be used.	2 - Small differences	<a href="#">A18-0-1</a>	Rule reformulated.
18-0-2 (Required) The library functions atof, atoi and atol from library <cstdlib> shall not be used.	2 - Small differences	<a href="#">A18-0-2</a>	

18-0-3 (Required) The library functions abort, exit, getenv and system from library <cstdlib> shall not be used.	1 - Identical	<a href="#">M18-0-3</a>	-
18-0-4 (Required) The time handling functions of library <ctime> shall not be used.	1 - Identical	<a href="#">M18-0-4</a>	-
18-0-5 (Required) The unbounded functions of library <cstring> shall not be used.	1 - Identical	<a href="#">M18-0-5</a>	-
18-2-1 (Required) The macro offsetof shall not be used.	1 - Identical	<a href="#">M18-2-1</a>	-
18-4-1 (Required) Dynamic heap memory allocation shall not be used.	4 - Rejected	-	Dynamic heap memory allocation usage is allowed conditionally, see: <a href="#">A18-5-1</a> , <a href="#">A18-5-2</a> , <a href="#">A18-5-3</a> .
18-7-1 (Required) The signal handling facilities of <csignal> shall not be used.	1 - Identical	<a href="#">M18-7-1</a>	-
19-3-1 (Required) The error indicator errno shall not be used.	1 - Identical	<a href="#">M19-3-1</a>	-
27-0-1 (Required) The stream input/output library <cstdio> shall not be used.	1 - Identical	<a href="#">M27-0-1</a>	-

**Table B.1: MISRA C++**

## B.2 Traceability to HIC++ v4.0

The following table demonstrates the traceability to High Integrity C++ Coding Standard Version 4.0 [9]. This is not considered as a reproduction, but a mean to compare the two standards.

This document complies with the conditions of use of HIC++ v4.0, as any rule in this document that is based on HIC++ v4.0 refers to the related HIC++ v4.0 rule.

HIC++ Rule:	Relation type:	Related rule:	Comment:
1.1.1 Ensure that code complies with the 2011 ISO C++ Language Standard.	2 - Small differences	<a href="#">A1-1-1</a>	Specified that the code shall conform to ISO/IEC 14882:2014
1.2.1 Ensure that all statements are reachable.	2 - Small differences	<a href="#">M0-1-1</a>	
1.2.2 Ensure that no expression or sub-expression is redundant.	2 - Small differences	<a href="#">M0-1-9</a>	
1.3.1 Do not use the increment operator (++) on a variable of type bool	2 - Small differences	<a href="#">M4-5-1</a>	
1.3.2 Do not use the register keyword.	2 - Small differences	<a href="#">A7-1-4</a>	

1.3.3 Do not use the C Standard Library .h headers	2 - Small differences	<a href="#">A18-0-1</a>	
1.3.4 Do not use deprecated STL library features	2 - Small differences	<a href="#">A1-1-1</a> , <a href="#">A18-1-3</a> , <a href="#">A18-9-1</a>	
1.3.5 Do not use throw exception specifications.	2 - Small differences	<a href="#">A15-4-1</a>	
2.1.1 Do not use tab characters in source files.	4 - Rejected		AUTOSAR C++ Coding Guidelines does not introduce rules related to coding style or naming convention.
2.2.1 Do not use digraphs or trigraphs.	2 - Small differences	<a href="#">A2-5-1</a> , <a href="#">A2-5-2</a>	
2.3.1 Do not use the C comment delimiters /* ... */.	2 - Small differences	<a href="#">M2-7-1</a>	
2.3.2 Do not comment out code.	2 - Small differences	<a href="#">A2-7-2</a>	
2.4.1 Ensure that each identifier is distinct from any other visible identifier.	2 - Small differences	<a href="#">M2-10-1</a>	
2.5.1 Do not concatenate strings with different encoding prefixes.	2 - Small differences	<a href="#">A2-13-2</a>	
2.5.2 Do not use octal constants (other than zero).	2 - Small differences	<a href="#">M2-13-2</a>	
2.5.3 Use nullptr for the null pointer constant.	2 - Small differences	<a href="#">A4-10-1</a>	
3.1.1 Do not hide declarations.	2 - Small differences	<a href="#">A2-10-1</a> , <a href="#">A2-10-6</a>	
3.2.1 Do not declare functions at block scope.	2 - Small differences	<a href="#">M3-1-2</a>	
3.3.1 Do not use variables with static storage duration.	3 - Significant differences	<a href="#">A3-3-2</a>	Limited to constant-initialized objects only.
3.4.1 Do not return a reference or a pointer to an automatic variable defined within the function.	2 - Small differences	<a href="#">M7-5-1</a>	
3.4.2 Do not assign the address of a variable to a pointer with a greater lifetime.	2 - Small differences	<a href="#">M7-5-2</a>	
3.4.3 Use RAII for resources.	4 - Rejected		AUTOSAR C++ Coding Guidelines does not define rules for coding patterns. Note that usage of RAII is recommended, see: <a href="#">A15-1-4</a> .

3.5.1 Do not make any assumptions about the internal representation of a value or object.	2 - Small differences	A3-9-1, M3-9-3, M5-0-15, M5-0-21, A9-5-1, M18-2-1	
4.1.1 Ensure that a function argument does not undergo an array-to-pointer conversion.	2 - Small differences	M5-2-12	
4.2.1 Ensure that the U suffix is applied to a literal used in a context requiring an unsigned integral expression.	2 - Small differences	M2-13-2	
4.2.2 Ensure that data loss does not demonstrably occur in an integral expression.	2 - Small differences	A4-7-1, M5-0-4, M5-0-6, M5-0-9	
4.3.1 Do not convert an expression of wider floating point type to a narrower floating point type.	2 - Small differences	A4-7-1, M5-0-6	
4.4.1 Do not convert floating values to integral types except through use of standard library functions.	4 - Rejected		Rules that are related: M5-0-3, M5-0-5, M5-0-6, M5-0-7,
5.1.1 Use symbolic names instead of literal values in code.	2 - Small differences	A5-1-1	
5.1.2 Do not rely on the sequence of evaluation within an expression.	2 - Small differences	A5-0-1	
5.1.3 Use parentheses in expressions to specify the intent of the expression.	2 - Small differences	A5-0-1, A5-2-6, M5-2-10,	
5.1.4 Do not capture variables implicitly in a lambda.	2 - Small differences	A5-1-2	
5.1.5 Include a (possibly empty) parameter list in every lambda expression.	2 - Small differences	A5-1-3	
5.1.6 Do not code side effects into the right-hand operands of: &&,   , sizeof, typeid or a function passed to condition_variable::wait.	3 - Significant differences	A5-3-1, M5-3-4, M5-14-1	The condition_variable::wait is not yet covered, this will be addressed in future when C++ libraries are analyzed.
5.2.1 Ensure that pointer or array access is demonstrably within bounds of a valid object.	2 - Small differences	A5-2-5	
5.2.2 Ensure that functions do not call themselves, either directly or indirectly.	2 - Small differences	A7-5-2	
5.3.1 Do not apply unary minus to operands of unsigned type.	2 - Small differences	M5-3-2	

5.3.2 Allocate memory using new and release it using delete.	2 - Small differences	<a href="#">A18-5-1</a>	Note that operators new and delete shall not be used explicitly, see: <a href="#">A18-5-2</a> .
5.3.3 Ensure that the form of delete matches the form of new used to allocate the memory.	2 - Small differences	<a href="#">A18-5-3</a>	Note that operators new and delete shall not be used explicitly, see: <a href="#">A18-5-2</a> .
5.4.1 Only use casting forms: static_cast (excl. void*), dynamic_cast or explicit constructor call.	2 - Small differences	<a href="#">A5-2-1</a> , <a href="#">A5-2-2</a> , <a href="#">A5-2-3</a> , <a href="#">A5-2-4</a>	
5.4.2 Do not cast an expression to an enumeration type.	4 - Rejected		It is allowed to cast an expression to an enumeration type, but an expression shall have a value that corresponds to an enumerator of the enumeration, see: <a href="#">A7-2-1</a> .
5.4.3 Do not convert from a base class to a derived class.	3 - Small differences	<a href="#">M5-2-2</a> , <a href="#">M5-2-3</a> , <a href="#">A5-2-1</a>	Note that the dynamic_cast is unsuitable for use with real-time systems.
5.5.1 Ensure that the right hand operand of the division or remainder operators is demonstrably non-zero.	2 - Small differences	<a href="#">A5-6-1</a>	
5.6.1 Do not use bitwise operators with signed operands.	2 - Small differences	<a href="#">M5-0-21</a>	
5.7.1 Do not write code that expects floating point calculations to yield exact results.	2 - Small differences	<a href="#">M6-2-2</a>	
5.7.2 Ensure that a pointer to member that is a virtual function is only compared (==) with nullptr.	2 - Small differences	<a href="#">A5-10-1</a>	
5.8.1 Do not use the conditional operator (?:) as a sub-expression.	2 - Small differences	<a href="#">A5-16-1</a>	
6.1.1 Enclose the body of a selection or an iteration statement in a compound statement.	2 - Small differences	<a href="#">M6-3-1</a> , <a href="#">M6-4-1</a>	
6.1.2 Explicitly cover all paths through multi-way selection statements.	2 - Small differences	<a href="#">M6-4-2</a>	
6.1.3 Ensure that a non-empty case statement block does not fall through to the next label.	2 - Small differences	<a href="#">M6-4-5</a>	

6.1.4 Ensure that a switch statement has at least two case labels, distinct from the default label.	2 - Small differences	<a href="#">A6-4-1</a>	
6.2.1 Implement a loop that only uses element values as a range-based loop.	2 - Small differences	<a href="#">A6-5-1</a>	
6.2.2 Ensure that a loop has a single loop counter, an optional control variable, and is not degenerate.	2 - Small differences	<a href="#">A6-5-2</a>	
6.2.3 Do not alter a control or counter variable more than once in a loop.	3 - Significant differences	<a href="#">M6-5-3</a>	It is prohibited to alter a control or counter variable within condition or statement of a loop.
6.2.4 Only modify a for loop counter in the for expression.	2 - Small differences	<a href="#">M6-5-3</a>	
6.3.1 Ensure that the label(s) for a jump statement or a switch condition appear later, in the same or an enclosing block.	2 - Small differences	<a href="#">M6-6-1</a>	
6.3.2 Ensure that execution of a function with a non-void return type ends in a return statement with a value.	2 - Small differences	<a href="#">A8-4-2</a>	
6.4.1 Postpone variable definitions as long as possible.	2 - Small differences	<a href="#">M3-4-1</a>	
7.1.1 Declare each identifier on a separate line in a separate declaration.	2 - Small differences	<a href="#">A7-1-7</a>	
7.1.2 Use const whenever possible.	2 - Small differences	<a href="#">A7-1-1</a> , <a href="#">A7-1-2</a>	
7.1.3 Do not place type specifiers before non-type specifiers in a declaration.	2 - Small differences	<a href="#">A7-1-8</a>	
7.1.4 Place CV-qualifiers on the right hand side of the type they apply to.	3 - Significant differences	<a href="#">A7-1-3</a>	Placement of cv-qualifiers is only restricted for typedefs.
7.1.5 Do not inline large functions.	4 - Rejected		Code metrics are not covered by AUTOSAR C++ Coding Guidelines.
7.1.6 Use class types or typedefs to abstract scalar quantities and standard integer types.	3 - Significant differences	<a href="#">A3-9-1</a>	AUTOSAR C++ Coding Guidelines forces to use typedefs for built-in numerical types.
7.1.7 Use a trailing return type in preference to type disambiguation using typename.	2 - Small differences	<a href="#">A8-2-1</a>	



7.1.8 Use <code>auto id = expr</code> when declaring a variable to have the same type as its initializer function call.	3 - Significant differences	<a href="#">A7-1-5</a>	The rule is formulated differently.
7.1.9 Do not explicitly specify the return type of a lambda.	4 - Rejected		To avoid implicit type conversion return type of lambda expression needs to be specified explicitly, see: <a href="#">A5-1-6</a> .
7.1.10 Use <code>static_assert</code> for assertions involving compile time constants.	3 - Significant differences	<a href="#">A16-6-1</a>	It is recommended to use the <code>static_assert</code> instead of <code>#error</code> directive.
7.2.1 Use an explicit enumeration base and ensure that it is large enough to store all enumerators.	2 - Small differences	<a href="#">A7-2-2</a>	
7.2.2 Initialize none, the first only or all enumerators in an enumeration.	2 - Small differences	<a href="#">A7-2-4</a>	
7.3.1 Do not use using directives.	2 - Small differences	<a href="#">M7-3-4</a>	
7.4.1 Ensure that any objects, functions or types to be used from a single translation unit are defined in an unnamed namespace in the main source file.			
7.4.2 Ensure that an inline function, a function template, or a type used from multiple translation units is defined in a single header file.	2 - Small differences	<a href="#">A3-1-1</a> , <a href="#">M3-2-2</a>	
7.4.3 Ensure that an object or a function used from multiple translation units is declared in a single header file.	2 - Small differences	<a href="#">A3-1-1</a> , <a href="#">M3-2-4</a>	
7.5.1 Do not use the <code>asm</code> declaration.	2 - Small differences	<a href="#">A7-4-1</a>	
8.1.1 Do not use multiple levels of pointer indirection.	3 - Significant differences	<a href="#">A5-0-3</a>	At most two levels of pointer indirection are allowed.
8.2.1 Make parameter names absent or identical in all declarations.	2 - Small differences	<a href="#">M3-9-1</a>	
8.2.2 Do not declare functions with an excessive number of parameters.	4 - Rejected		Code metrics are not covered by AUTOSAR C++ Coding Guidelines.
8.2.3 Pass small objects with a trivial copy constructor by value.	4 - Rejected		The rule is vague, "small" has no technical meaning.

8.2.4 Do not pass <code>std::unique_ptr</code> by const reference.	3 - Significant differences	<a href="#">A8-4-11</a> , <a href="#">A8-4-12</a>	<a href="#">A8-4-12</a> covers how to pass a <code>std::unique_ptr</code> , <a href="#">A8-4-11</a> covers when not to pass by <code>std::unique_ptr</code> .
8.3.1 Do not write functions with an excessive McCabe Cyclomatic Complexity.	4 - Rejected		Code metrics are not covered by AUTOSAR C++ Coding Guidelines.
8.3.2 Do not write functions with a high static program path count.	4 - Rejected		Code metrics are not covered by AUTOSAR C++ Coding Guidelines.
8.3.3 Do not use default arguments.	4 - Rejected		Using default arguments is allowed with some restrictions, see e.g. <a href="#">M8-3-1</a> .
8.3.4 Define <code>=delete</code> functions with parameters of type rvalue reference to const.	2 - Small differences	<a href="#">A13-3-1</a> , <a href="#">A18-9-3</a>	
8.4.1 Do not access an invalid object or an object with indeterminate value.	2 - Small differences	<a href="#">A8-5-0</a> , <a href="#">A12-8-3</a>	
8.4.2 Ensure that a braced aggregate initializer matches the layout of the aggregate object.	2 - Small differences	<a href="#">M8-5-2</a>	
9.1.1 Declare static any member function that does not require this. Alternatively, declare const any member function that does not modify the externally visible state of the object.	2 - Small differences	<a href="#">M9-3-3</a>	
9.1.2 Make default arguments the same or absent when overriding a virtual function.	2 - Small differences	<a href="#">M8-3-1</a>	
9.1.3 Do not return non-const handles to class data from const member functions.	2 - Small differences	<a href="#">M9-3-1</a> , <a href="#">A9-3-1</a>	
9.1.4 Do not write member functions which return non-const handles to data less accessible than the member function.	3 - Significant differences	<a href="#">A9-3-1</a>	It is allowed to return non-const handles to static data.
9.1.5 Do not introduce virtual functions in a final class.	2 - Small differences	<a href="#">A10-3-3</a>	

9.2.1 Declare bit-fields with an explicitly unsigned integral or enumeration type.	3 - Significant differences	<a href="#">A9-6-1</a>	Any type with a defined size is allowed to be used for a bit-field.
10.1.1 Ensure that access to base class subobjects does not require explicit disambiguation.	3 - Significant differences	<a href="#">A10-1-1</a>	Inheritance from more than one base class is prohibited.
10.2.1 Use the override special identifier when overriding a virtual function.	2 - Small differences	<a href="#">A10-3-2</a>	
10.3.1 Ensure that a derived class has at most one base class which is not an interface class.	2 - Small differences	<a href="#">A10-1-1</a>	Note that the definition of an interface changed, see: <a href="#">Interface-Class</a> .
11.1.1 Declare all data members private.	2 - Small differences	<a href="#">M11-0-1</a>	
11.2.1 Do not use friend declarations.	2 - Small differences	<a href="#">A11-3-1</a>	
12.1.1 Do not declare implicit user defined conversions.	3 - Significant differences	<a href="#">A12-1-4</a> , <a href="#">A13-5-2</a>	
12.2.1 Declare virtual, private or protected the destructor of a type used as a base class.	3 - Significant differences	<a href="#">A12-4-1</a>	Destructor of a base class shall be public virtual, public override or protected non-virtual.
12.3.1 Correctly declare overloads for operator new and delete.	2 - Small differences	<a href="#">A18-5-11</a>	
12.4.1 Do not use the dynamic type of an object unless the object is fully constructed.	2 - Small differences	<a href="#">M12-1-1</a>	
12.4.2 Ensure that a constructor initializes explicitly all base classes and non-static data members.	2 - Small differences	<a href="#">A12-1-1</a>	
12.4.3 Do not specify both an NSDMI and member initializer in a constructor for the same non static member.	2 - Significant differences	<a href="#">A12-1-2</a>	Using both NSDMI and member initializer list in one class is not allowed.
12.4.4 Write members in an initialization list in the order in which they are declared.	2 - Small differences	<a href="#">A8-5-1</a>	
12.4.5 Use delegating constructors to reduce code duplication.	2 - Small differences	<a href="#">A12-1-5</a>	

12.5.1 Define explicitly =default or =delete implicit special member functions of concrete classes.	3- Significant differences	A12-0-1	
12.5.2 Define special members =default if the behavior is equivalent.	2- Small differences	A12-7-1	
12.5.3 Ensure that a user defined move/copy constructor only moves/copies base and member objects.	2- Small differences	A12-8-1	
12.5.4 Declare noexcept the move constructor and move assignment operator.	3- Significant differences	A15-5-1	AUTOSAR C++ Coding Guidelines requires additional functions to be noexcept.
12.5.5 Correctly reset moved-from handles to resources in the move constructor.	2- Small differences	A12-8-1	
12.5.6 Use an atomic, non-throwing swap operation to implement the copy and move assignment operators.	2- Small differences	A12-8-2	
12.5.7 Declare assignment operators with the ref-qualifier &.	2- Small differences	A12-8-7	
12.5.8 Make the copy assignment operator of an abstract class protected or define it =delete.	3- Significant differences	A12-8-6	AUTOSAR C++ Coding Guidelines requires additional functions to be comply with this rule.
13.1.1 Ensure that all overloads of a function are visible from where it is called.	2- Small differences	A7-3-1	
13.1.2 If a member of a set of callable functions includes a universal reference parameter, ensure that one appears in the same position for all other members.	3- Significant differences	A13-3-1	A function taking "forwarding reference" shall not be overloaded.
13.2.1 Do not overload operators with special semantics.	2- Small differences	M5-2-11, M5-3-3	
13.2.2 Ensure that the return type of an overloaded binary operator matches the built-in counterparts.	2- Small differences	A13-2-1, A13-2-2, A13-2-3	
13.2.3 Declare binary arithmetic and bitwise operators as non-members.	4- Rejected		Non-generic design principle; There is no need for a new rule.
13.2.4 When overloading the subscript operator (operator[]) implement both const and non-const versions.	2- Small differences	A13-5-1	

13.2.5 Implement a minimal set of operators and use them to implement all other related operators.	4 - Rejected		Non-generic design principle; There is no need for a new rule.
14.1.1 Use variadic templates rather than an ellipsis.	3 - Significant differences	<a href="#">A8-4-1</a>	AUTOSAR C++ Coding Guidelines prohibits usage of variadic arguments.
14.2.1 Declare template specializations in the same file as the primary template they specialize.	3 - Significant differences	<a href="#">A14-7-2</a>	Allowed to declare in a header file that declares user-defined type, for which the specialization is declared.
14.2.2 Do not explicitly specialize a function template that is overloaded with other templates.	3 - Significant differences	<a href="#">A14-8-2</a>	Function templates specialization is forbidden.
14.2.3 Declare extern an explicitly instantiated template.	4 - Rejected		
15.1.1 Only use instances of <code>std::exception</code> for exceptions.	2 - Small differences	<a href="#">A15-1-1</a>	
15.2.1 Do not throw an exception from a destructor.	2 - Small differences	<a href="#">A15-5-1</a>	
15.3.1 Do not access non-static members from a catch handler of constructor/destructor function try block.	2 - Small differences	<a href="#">M15-3-3</a>	
15.3.2 Ensure that a program does not result in a call to <code>std::terminate</code> .	2 - Small differences	<a href="#">A15-5-2</a> , <a href="#">A15-5-3</a>	
16.1.1 Use the preprocessor only for implementing include guards, and including header files with include guards.	3 - Significant differences	<a href="#">A16-0-1</a>	Conditional and unconditional file inclusion is allowed.
16.1.2 Do not include a path specifier in filenames supplied in <code>#include</code> directives.	3 - Significant differences	<a href="#">A16-2-1</a>	Path specifier <code>/</code> is allowed to specify a path relative to path passed to the compiler.
16.1.3 Match the filename in a <code>#include</code> directive to the one on the file system.	4 - Rejected		

16.1.4 Use <> brackets for system and standard library headers. Use quotes for all other headers.	4 - Rejected		The rule defines a coding style. Anyway, these are the only forms allowed by the C++ Language Standard. No need for a new rule.
16.1.5 Include directly the minimum number of headers required for compilation.	4 - Rejected		There shall be no unused include directives, however all needed headers shall be included explicitly. See: <a href="#">A16-2-2</a> , <a href="#">A16-2-3</a> .
17.1.1 Do not use <code>std::vector&lt;bool&gt;</code> .	2 - Small differences	<a href="#">A18-1-2</a>	
17.2.1 Wrap use of the C Standard Library.	2 - Small differences	<a href="#">A17-1-1</a>	
17.3.1 Do not use <code>std::move</code> on objects declared with <code>const</code> or <code>const &amp;</code> type.	2 - Small differences	<a href="#">A18-9-3</a>	
17.3.2 Use <code>std::forward</code> to forward universal references.	2 - Small differences	<a href="#">A18-9-2</a>	
17.3.3 Do not subsequently use the argument to <code>std::forward</code> .	2 - Small differences	<a href="#">A18-9-4</a>	
17.3.4 Do not create smart pointers of array type.	3 - Significant differences	<a href="#">A18-1-4</a>	Rule reformulated to better capture the problem cases and to allow use of smart pointer specializations for array types.
17.3.5 Do not create an rvalue reference of <code>std::array</code> .	4 - Rejected		The rule is only a hint saying that passing <code>std::array</code> by rvalue reference would be less efficient than passing it by reference. However, usage depends on the case, and it should be allowed to pass <code>std::array</code> by rvalue reference.
17.4.1 Use <code>const</code> container calls when result is immediately converted to a <code>const</code> iterator.	2 - Small differences	<a href="#">A23-0-1</a>	

17.4.2 Use API calls that construct objects in place.	3 - Significant differences	A18-5-2	A18-5-2 prohibits explicit calls to new and delete operators, std::make_shared, std::make_unique and similar constructions are recommended.
17.5.1 Do not ignore the result of std::remove, std::remove_if or std::unique.	2 - Small differences	A0-1-2	
18.1.1 Do not use platform specific multi-threading facilities.	5 - Not yet analyzed		The "Concurrency" chapter is not yet covered, this will be addressed in future.
18.2.1 Use high_integrity::thread in place of std::thread.	4 - Rejected		The high_integrity::thread is not part of the C++ Language Standard.
18.2.2 Synchronize access to data shared between threads using a single lock.	5 - Not yet analyzed		The "Concurrency" chapter is not yet covered, this will be addressed in future.
18.2.3 Do not share volatile data between threads.	3 - Significant differences	A2-11-1	Volatile keyword forbidden.
18.2.4 Use std::call_once rather than the Double-Checked Locking pattern.	5 - Not yet analyzed		The "Concurrency" chapter is not yet covered, this will be addressed in future.
18.3.1 Within the scope of a lock, ensure that no static path results in a lock of the same mutex.	5 - Not yet analyzed		The "Concurrency" chapter is not yet covered, this will be addressed in future.
18.3.2 Ensure that order of nesting of locks in a project forms a DAG.	5 - Not yet analyzed		The "Concurrency" chapter is not yet covered, this will be addressed in future.

18.3.3 Do not use std::recursive_mutex.	5 - Not yet analyzed		The “Concurrency” chapter is not yet covered, this will be addressed in future.
18.3.4 Only use std::unique_lock when std::lock_guard cannot be used.	5 - Not yet analyzed		The “Concurrency” chapter is not yet covered, this will be addressed in future.
18.3.5 Do not access the members of std::mutex directly.	5 - Not yet analyzed		The “Concurrency” chapter is not yet covered, this will be addressed in future.
18.3.6 Do not use relaxed atomics.	5 - Not yet analyzed		The “Concurrency” chapter is not yet covered, this will be addressed in future.
18.4.1 Do not use std::condition_variable_any on a std::mutex	5 - Not yet analyzed		The “Concurrency” chapter is not yet covered, this will be addressed in future.

**Table B.2: HIC++ v4.0**

### B.3 Traceability to JSF

The following table demonstrates the traceability to Joint Strike Fighter Air Vehicle C++ Coding Standard [8]. This is not considered as a reproduction, but a mean to compare the two standards.

Note that the copyright of JSF-AV 2005 allows an unlimited distribution anyway.

JSF Rule:	Relation type:	Related rule:	Comment:
AV Rule 8 All code shall conform to ISO/IEC 14882:2002(E) standard C++.	2 - Small differences	<a href="#">A1-1-1</a>	
AV Rule 9 Only those characters specified in the C++ basic source character set will be used. [...].	2 - Small differences	<a href="#">A2-3-1</a>	



AV Rule 10 Values of character types will be restricted to a defined and documented subset of ISO 10646-1.	4 - Rejected		Source files encoding is too restrictive and not covered by AUTOSAR C++ Coding Guidelines.
AV Rule 11 Trigraphs will not be used.	2 - Small differences	<a href="#">A2-5-1</a>	
AV Rule 12 The following digraphs will not be used [...].	2 - Small differences	<a href="#">A2-5-2</a>	
AV Rule 13 Multi-byte characters and wide string literals will not be used.	4 - Rejected		Agreed for wchar_t type only, <a href="#">A2-13-3</a> .
AV Rule 14 Literal suffixes shall use uppercase rather than lowercase letters.	2 - Small differences	<a href="#">M2-13-4</a>	
AV Rule 15 Provision shall be made for run-time checking (defensive programming).	2 - Small differences	<a href="#">M0-3-1</a>	
AV Rule 16 Only DO-178B level A [15] certifiable or SEAL 1 C/C++ libraries shall be used with safety-critical (i.e. SEAL 1) code.	4 - Rejected		JSF-specific rule.
AV Rule 17 The error indicator errno shall not be used.	2 - Small differences	<a href="#">M19-3-1</a>	
AV Rule 18 The macro offsetof, in library <stddef.h>, shall not be used.	2 - Small differences	<a href="#">M18-2-1</a>	
AV Rule 19 <locale.h> and the setlocale function shall not be used.	2 - Small differences	<a href="#">A18-0-3</a>	
AV Rule 20 The setjmp macro and the longjmp function shall not be used.	2 - Small differences	<a href="#">M17-0-5</a>	
AV Rule 21 The signal handling facilities of <signal.h> shall not be used.	2 - Small differences	<a href="#">M18-7-1</a>	
AV Rule 22 The input /output library <stdio.h> shall not be used.	2 - Small differences	<a href="#">M27-0-1</a>	
AV Rule 23 The library functions atof, atoi and atol from library <stdlib.h> shall not be used.	2 - Small differences	<a href="#">A18-0-2</a>	
AV Rule 24 The library functions abort, exit, getenv and system from library <stdlib.h> shall not be used.	2 - Small differences	<a href="#">M18-0-3</a>	
AV Rule 25 The time handling functions of library <time.h> shall not be used.	2 - Small differences	<a href="#">M18-0-4</a>	
AV Rule 26 Only the following pre-processor directives shall be used: 1. #ifndef 2. #define 3. #endif 4. #include.	2 - Small differences	<a href="#">A16-0-1</a>	

AV Rule 27 #ifndef, #define and #endif will be used to prevent multiple inclusions of the same header file. Other techniques to prevent the multiple inclusions of header files will not be used.	2 - Small differences	A16-0-1, M16-2-3	
AV Rule 28 The #ifndef and #endif pre-processor directives will only be used as defined in AV Rule 27 to prevent multiple inclusions of the same header file.	2 - Small differences	A16-0-1	
AV Rule 29 The #define pre-processor directive shall not be used to create inline macros. Inline functions shall be used instead.	2 - Small differences	A16-0-1	
AV Rule 30 The #define pre-processor directive shall not be used to define constant values. Instead, the const qualifier shall be applied to variable declarations to specify constant values.	2 - Small differences	A16-0-1	
AV Rule 31 The #define pre-processor directive will only be used as part of the technique to prevent multiple inclusions of the same header file.	2 - Small differences	A16-0-1	
AV Rule 32 The #include pre-processor directive will only be used to include header (*.h) files.	2 - Small differences	A16-0-1	
AV Rule 33 The #include directive shall use the <filename.h> notation to include header files.	4 - Rejected		Including files using quotes is also possible.
AV Rule 34 Header files should contain logically related declarations only.	2 - Small differences	A3-3-1	
AV Rule 35 A header file will contain a mechanism that prevents multiple inclusions of itself.	2 - Small differences	M16-2-3	
AV Rule 36 Compilation dependencies should be minimized when possible.	4 - Rejected		The rule is vague; more precisely explained by AV Rules 37 and 38.
AV Rule 37 Header (include) files should include only those header files that are required for them to successfully compile. Files that are only used by the associated .cpp file should be placed in the .cpp file - not the .h file.	2 - Small differences	A16-2-2, A16-2-3	

AV Rule 38 Declarations of classes that are only accessed via pointers (*) or references (&) should be supplied by forward headers that contain only forward declarations.	3 - Significant differences	<a href="#">A16-2-3</a>	Forward declarations considered as a possible solution for unnecessary inclusions.
AV Rule 39 Header files (*.h) will not contain non-const variable definitions or function definitions.	2 - Small differences	<a href="#">M3-2-4</a> , <a href="#">A3-3-1</a>	
AV Rule 40 Every implementation file shall include the header files that uniquely define the inline functions, types, and templates used.	2 - Small differences	<a href="#">M3-2-4</a> , <a href="#">A3-3-1</a>	
AV Rule 41 Source lines will be kept to a length of 120 characters or less.	4 - Rejected		Coding style is not covered by AUTOSAR C++ Coding Guidelines.
AV Rule 42 Each expression-statement will be on a separate line.	2 - Small differences	<a href="#">A7-1-7</a>	
AV Rule 43 Tabs should be avoided.	4 - Rejected		Coding style is not covered by AUTOSAR C++ Coding Guidelines.
AV Rule 44 All indentations will be at least two spaces and be consistent within the same source file.	4 - Rejected		Coding style is not covered by AUTOSAR C++ Coding Guidelines.
AV Rule 45 All words in an identifier will be separated by the “_” character.	4 - Rejected		Coding style is not covered by AUTOSAR C++ Coding Guidelines.
AV Rule 46 User-specified identifiers (internal and external) will not rely on significance of more than 64 characters.	4 - Rejected		Coding style is not covered by AUTOSAR C++ Coding Guidelines.
AV Rule 47 Identifiers will not begin with the underscore character “_”.	3 - Significant differences	<a href="#">A17-0-1</a>	

AV Rule 48 Identifiers will not differ by: (a) Only a mixture of case, (b) The presence/absence of the underscore character, (c) The interchange of the letter "O", with the number "0" or the letter "D", (d) The interchange of the letter "l", with the number "1" or the letter "I", (e) The interchange of the letter "S" with the number "5", (f) The interchange of the letter "Z" with the number "2", (g) The interchange of the letter "n" with the letter "h".	4 - Rejected		Coding style is not covered by AUTOSAR C++ Coding Guidelines.
AV Rule 49 All acronyms in an identifier will be composed of uppercase letters.	4 - Rejected		Coding style is not covered by AUTOSAR C++ Coding Guidelines.
AV Rule 50 The first word of the name of a class, structure, namespace, enumeration, or type created with typedef will begin with an uppercase letter. All others letters will be lowercase.	4 - Rejected		Coding style is not covered by AUTOSAR C++ Coding Guidelines.
AV Rule 51 All letters contained in function and variable names will be composed entirely of lowercase letters.	4 - Rejected		Coding style is not covered by AUTOSAR C++ Coding Guidelines.
AV Rule 52 Identifiers for constant and enumerator values shall be lowercase.	4 - Rejected		Coding style is not covered by AUTOSAR C++ Coding Guidelines.
AV Rule 53 Header files will always have a file name extension of ".h".	3 - Significant differences	<a href="#">A3-1-2</a>	
AV Rule 53.1 The following character sequences shall not appear in header file names: ', \, /*, //, or ".	2 - Small differences	<a href="#">A16-2-1</a>	
AV Rule 54 Implementation files will always have a file name extension of ".cpp".	2 - Small differences	<a href="#">A3-1-3</a>	
AV Rule 55 The name of a header file should reflect the logical entity for which it provides declarations.	2 - Small differences	<a href="#">A2-8-1</a>	
AV Rule 56 The name of an implementation file should reflect the logical entity for which it provides definitions and have a ".cpp" extension (this name will normally be identical to the header file that provides the corresponding declarations.)	2 - Small differences	<a href="#">A2-8-2</a>	

AV Rule 57 The public, protected, and private sections of a class will be declared in that order (the public section is declared before the protected section which is declared before the private section).	4 - Rejected		Coding style is not covered by AUTOSAR C++ Coding Guidelines.
AV Rule 58 When declaring and defining functions with more than two parameters, the leading parenthesis and the first argument will be written on the same line as the function name. Each additional argument will be written on a separate line (with the closing parenthesis directly after the last argument).	4 - Rejected		Coding style is not covered by AUTOSAR C++ Coding Guidelines.
AV Rule 59 The statements forming the body of an if, else if, else, while, do...while or for statement shall always be enclosed in braces, even if the braces form an empty block.	2 - Small differences	M6-3-1	
AV Rule 60 Braces (“{}”) which enclose a block will be placed in the same column, on separate lines directly before and after the block.	4 - Rejected		Coding style is not covered by AUTOSAR C++ Coding Guidelines.
AV Rule 61 Braces (“{}”) which enclose a block will have nothing else on the line except comments (if necessary).	4 - Rejected		Coding style is not covered by AUTOSAR C++ Coding Guidelines.
AV Rule 62 The dereference operator “*” and the address-of operator “&” will be directly connected with the type-specifier.	4 - Rejected		Coding style is not covered by AUTOSAR C++ Coding Guidelines.
AV Rule 63 Spaces will not be used around “.” or “->”, nor between unary operators and operands.	4 - Rejected		Coding style is not covered by AUTOSAR C++ Coding Guidelines.
AV Rule 64 A class interface should be complete and minimal.	4 - Rejected		Code metrics are not covered by AUTOSAR C++ Coding Guidelines.
AV Rule 65 A structure should be used to model an entity that does not require an invariant.	3 - Significant differences	A11-0-2	
AV Rule 66 A class should be used to model an entity that maintains an invariant.	3 - Significant differences	A11-0-1	
AV Rule 67 Public and protected data should only be used in structs - not classes.	2 - Small differences	M11-0-1	

AV Rule 68 Unneeded implicitly generated member functions shall be explicitly disallowed.	3 - Significant differences	<a href="#">A12-0-1</a>	It is allowed to follow both "Rule of zero" and "Rule of five".
AV Rule 69 A member function that does not affect the state of an object (its instance variables) will be declared const.	2 - Small differences	<a href="#">M9-3-3</a>	
AV Rule 70 A class will have friends only when a function or object requires access to the private elements of the class, but is unable to be a member of the class for logical or efficiency reasons.	4 - Rejected		Friend declarations are prohibited, see: <a href="#">A11-3-1</a> .
AV Rule 70.1 An object shall not be improperly used before its lifetime begins or after its lifetime ends.	2 - Small differences	<a href="#">A3-8-1</a> , <a href="#">A5-1-4</a> , <a href="#">M7-5-1</a> , <a href="#">M7-5-2</a> , <a href="#">A7-5-1</a> , <a href="#">M12-1-1</a>	
AV Rule 71 Calls to an externally visible operation of an object, other than its constructors, shall not be allowed until the object has been fully initialized.	2 - Small differences	<a href="#">A12-1-1</a> , <a href="#">M12-1-1</a>	
AV Rule 71.1 A class's virtual functions shall not be invoked from its destructor or any of its constructors.	2 - Small differences	<a href="#">M12-1-1</a>	
AV Rule 72 The invariant for a class should be: (a) a part of the postcondition of every class constructor, (b) a part of the precondition of the class destructor (if any), (c) a part of the precondition and postcondition of every other publicly accessible operation.	3 - Significant differences	<a href="#">A15-2-2</a> , <a href="#">M11-0-1</a> , <a href="#">M9-3-1</a> , <a href="#">A9-3-1</a>	No enforcement on pre/postcondition checking in the Coding Guidelines
AV Rule 73 Unnecessary default constructors shall not be defined.	4 - Rejected		No rule needed.
AV Rule 74 Initialization of nonstatic class members will be performed through the member initialization list rather than through assignment in the body of a constructor.	2 - Small differences	<a href="#">A12-6-1</a>	
AV Rule 75 Members of the initialization list shall be listed in the order in which they are declared in the class.	2 - Small differences	<a href="#">A8-5-1</a>	
AV Rule 76 A copy constructor and an assignment operator shall be declared for classes that contain pointers to data items or nontrivial destructors.	2 - Small differences	<a href="#">A12-7-1</a>	

AV Rule 77 A copy constructor shall copy all data members and bases that affect the class invariant (a data element representing a cache, for example, would not need to be copied).	2 - Small differences	<a href="#">A12-8-1</a>	
AV Rule 77.1 The definition of a member function shall not contain default arguments that produce a signature identical to that of the implicitly-declared copy constructor for the corresponding class/structure.	4 - Rejected		No ambiguity in C++14, see ISO/IEC 14882:2014 C++14 12.8 [class.copy]2
AV Rule 78 All base classes with a virtual function shall define a virtual destructor.	2 - Small differences	<a href="#">A12-4-1</a>	
AV Rule 79 All resources acquired by a class shall be released by the class's destructor.	2 - Small differences	<a href="#">A15-1-4</a> , <a href="#">A18-5-2</a>	
AV Rule 80 The default copy and assignment operators will be used for classes when those operators offer reasonable semantics.	2 - Small differences	<a href="#">A12-0-1</a>	
AV Rule 81 The assignment operator shall handle self-assignment correctly.	2 - Small differences	<a href="#">A12-8-5</a>	
AV Rule 82 An assignment operator shall return a reference to *this.	2 - Small differences	<a href="#">A13-2-1</a>	
AV Rule 83 An assignment operator shall assign all data members and bases that affect the class invariant (a data element representing a cache, for example, would not need to be copied).	2 - Small differences	<a href="#">A6-2-1</a>	
AV Rule 84 Operator overloading will be used sparingly and in a conventional manner.	4 - Rejected		The rule is vague. Design principle; There is no need for a new rule.
AV Rule 85 When two operators are opposites (such as == and !=), both will be defined and one will be defined in terms of the other.	2 - Small differences	<a href="#">A13-5-4</a>	
AV Rule 86 Concrete types should be used to represent simple independent concepts.	4 - Rejected		The rule is vague. Design principle; There is no need for a new rule.
AV Rule 87 Hierarchies should be based on abstract classes.	2 - Small differences	<a href="#">A10-4-1</a>	
AV Rule 88 Multiple inheritance shall only be allowed in the following restricted form: n interfaces plus m private implementations, plus at most one protected implementation.	3 - Significant differences	<a href="#">A10-1-1</a>	

AV Rule 88.1 A stateful virtual base shall be explicitly declared in each derived class that accesses it.	4 - Rejected		Virtual inheritance should not be used, see: <a href="#">M10-1-1</a> .
AV Rule 89 A base class shall not be both virtual and non-virtual in the same hierarchy.	2 - Small differences	<a href="#">M10-1-3</a>	
AV Rule 90 Heavily used interfaces should be minimal, general and abstract.	4 - Rejected		The rule is vague. Design principle; There is no need for a new rule.
AV Rule 91 Public inheritance will be used to implement "is-a" relationships.	2 - Small differences	<a href="#">A10-0-1</a>	
AV Rule 92 A subtype (publicly derived classes) will conform to the following guidelines with respect to all classes involved in the polymorphic assignment of different subclass instances to the same variable or parameter during the execution of the system: (1) Preconditions of derived methods must be at least as weak as the preconditions of the methods they override. (2) Postconditions of derived methods must be at least as strong as the postconditions of the methods they override. In other words, subclass methods must expect less and deliver more than the base class methods they override. This rule implies that subtypes will conform to the Liskov Substitution Principle.	4 - Rejected		The rule is vague. Design principle; There is no need for a new rule.
AV Rule 93 "has-a" or "is-implemented-in-terms-of" relationships will be modeled through membership or non-public inheritance.	2 - Small differences	<a href="#">A10-0-2</a>	
AV Rule 94 An inherited nonvirtual function shall not be redefined in a derived class.	2 - Small differences	<a href="#">A10-2-1</a>	
AV Rule 95 An inherited default parameter shall never be redefined.	2 - Small differences	<a href="#">M8-3-1</a>	
AV Rule 96 Arrays shall not be treated polymorphically.	2 - Small differences	<a href="#">A5-0-4</a>	
AV Rule 97 Arrays shall not be used in interfaces. Instead, the Array class should be used.	2 - Small differences	<a href="#">M5-2-12</a>	
AV Rule 97.1 Neither operand of an equality operator (== or !=) shall be a pointer to a virtual member function.	3 - Significant differences	<a href="#">A5-10-1</a>	Testing for equality with null-pointer-constant is allowed.



AV Rule 98 Every nonlocal name, except main(), should be placed in some namespace.	2 - Small differences	<a href="#">M7-3-1</a>	
AV Rule 99 Namespaces will not be nested more than two levels deep.	4 - Rejected		Not compliant with the AUTOSAR general requirements.
AV Rule 100 Elements from a namespace should be selected as follows: (a) using declaration or explicit qualification for few (approximately five) names, (b) using directive for many names.	3 - Significant differences	<a href="#">M7-3-4</a> , <a href="#">M7-3-6</a>	
AV Rule 101 Templates shall be reviewed as follows: (1) with respect to the template in isolation considering assumptions or requirements placed on its arguments, (2) with respect to all functions instantiated by actual arguments.	4 - Rejected		Rule concerns code review process.
AV Rule 102 Template tests shall be created to cover all actual template instantiations.	4 - Rejected		Rule concerns test process.
AV Rule 103 Constraint checks should be applied to template arguments.	2 - Small differences	<a href="#">A14-1-1</a>	
AV Rule 104 A template specialization shall be declared before its use.	2 - Small differences	<a href="#">A14-7-2</a>	
AV Rule 105 A template definition's dependence on its instantiation contexts should be minimized.	4 - Rejected		This rule is vague. "Minimized" has no technical meaning.
AV Rule 106 Specializations for pointer types should be made where appropriate.	4 - Rejected		This rule is vague. "Where appropriate" has no technical meaning.
AV Rule 107 Functions shall always be declared at file scope.	2 - Small differences	<a href="#">M3-1-2</a>	
AV Rule 108 Functions with variable numbers of arguments shall not be used.	2 - Small differences	<a href="#">A8-4-1</a>	
AV Rule 109 A function definition should not be placed in a class specification unless the function is intended to be inlined.	3 - Significant differences	<a href="#">A3-1-5</a>	Also included template methods and methods of template classes.
AV Rule 110 Functions with more than 7 arguments will not be used.	4 - Rejected		Code metrics are not covered by AUTOSAR C++ Coding Guidelines.

AV Rule 111 A function shall not return a pointer or reference to a non-static local object.	2 - Small differences	<a href="#">M7-5-2</a>	
AV Rule 112 Function return values should not obscure resource ownership.	2 - Small differences	<a href="#">M9-3-1</a> , <a href="#">A9-3-1</a> , <a href="#">A20-8-2</a> , <a href="#">A20-8-3</a>	
AV Rule 113 Functions will have a single exit point.	4 - Rejected		See <a href="#">Single-point-of-exit</a> .
AV Rule 114 All exit points of value-returning functions shall be through return statements.	2 - Small differences	<a href="#">A8-4-2</a>	
AV Rule 115 If a function returns error information, then that error information will be tested.	2 - Small differences	<a href="#">A8-4-2</a>	
AV Rule 116 Small, concrete-type arguments (two or three words in size) should be passed by value if changes made to formal parameters should not be reflected in the calling function.	2 - Small differences	<a href="#">A8-4-7</a>	
AV Rule 117 Arguments should be passed by reference if NULL values are not possible.	2 - Small differences	<a href="#">A8-4-10</a>	
AV Rule 117.1 An object should be passed as const T& if the function should not change the value of the object.	2 - Small differences	<a href="#">A8-4-7</a>	
AV Rule 117.2 An object should be passed as T& if the function may change the value of the object.	2 - Small differences	<a href="#">A8-4-9</a>	
AV Rule 118 Arguments should be passed via pointers if NULL values are possible.	3 - Significant differences	<a href="#">A8-4-10</a>	
AV Rule 118.1 An object should be passed as const T* if its value should not be modified.	3 - Significant differences	<a href="#">A8-4-10</a>	
AV Rule 118.2 An object should be passed as T* if its value may be modified.	3 - Significant differences	<a href="#">A8-4-10</a>	
AV Rule 119 Functions shall not call themselves, either directly or indirectly (i.e. recursion shall not be allowed).	2 - Small differences	<a href="#">A7-5-2</a>	
AV Rule 120 Overloaded operations or methods should form families that use the same semantics, share the same name, have the same purpose, and that are differentiated by formal parameters.	4 - Rejected		This rule is vague. It is not a coding rule.
AV Rule 121 Only functions with 1 or 2 statements should be considered candidates for inline functions.	4 - Rejected		Code metrics are not covered by AUTOSAR C++ Coding Guidelines.

AV Rule 122 Trivial accessor and mutator functions should be inlined.	2 - Small differences	<a href="#">A3-1-6</a>	
AV Rule 123 The number of accessor and mutator functions should be minimized.	4 - Rejected		This rule is vague. It is not a coding rule.
AV Rule 124 Trivial forwarding functions should be inlined.	4 - Rejected		Forwarding functions are mostly templates and they most likely will be inlined.
AV Rule 125 Unnecessary temporary objects should be avoided.	2 - Small differences	<a href="#">M0-1-9</a> , <a href="#">A1-4-3</a>	
AV Rule 126 Only valid C++ style comments ( <code>//</code> ) shall be used.	2 - Small differences	<a href="#">M2-7-1</a>	
AV Rule 127 Code that is not used (commented out) shall be deleted.	2 - Small differences	<a href="#">A2-7-2</a>	
AV Rule 128 Comments that document actions or sources (e.g. tables, figures, paragraphs, etc.) outside of the file being documented will not be allowed.	2 - Small differences	<a href="#">A2-7-5</a>	
AV Rule 129 Comments in header files should describe the externally visible behavior of the functions or classes being documented.	3 - Significant differences	<a href="#">A2-7-3</a>	
AV Rule 130 The purpose of every line of executable code should be explained by a comment, although one comment may describe more than one line of code.	4 - Rejected		
AV Rule 131 One should avoid stating in comments what is better stated in code (i.e. do not simply repeat what is in the code).	4 - Rejected		
AV Rule 132 Each variable declaration, typedef, enumeration value, and structure member will be commented.	4 - Rejected		
AV Rule 133 Every source file will be documented with an introductory comment that provides information on the file name, its contents, and any program-required information (e.g. legal statements, copyright information, etc).	4 - Rejected		
AV Rule 134 Assumptions (limitations) made by functions should be documented in the function's preamble.	3 - Significant differences	<a href="#">A2-7-3</a>	
AV Rule 135 Identifiers in an inner scope shall not use the same name as an identifier in an outer scope, and therefore hide that identifier.	2 - Small differences	<a href="#">A2-10-1</a>	

AV Rule 136 Declarations should be at the smallest feasible scope.	2 - Small differences	<a href="#">M3-4-1</a>	
AV Rule 137 All declarations at file scope should be static where possible.	3 - Significant differences	<a href="#">A3-3-1</a>	
AV Rule 138 Identifiers shall not simultaneously have both internal and external linkage in the same translation unit.	2 - Small differences	<a href="#">M3-3-2</a>	
AV Rule 139 External objects will not be declared in more than one file.	2 - Small differences	<a href="#">M3-2-3</a>	
AV Rule 140 The register storage class specifier shall not be used.	2 - Small differences	<a href="#">A7-1-4</a>	
AV Rule 141 A class, structure, or enumeration will not be declared in the definition of its type.	2 - Small differences	<a href="#">A7-1-9</a>	
AV Rule 142 All variables shall be initialized before use.	2 - Small differences	<a href="#">A8-5-0</a>	
AV Rule 143 Variables will not be introduced until they can be initialized with meaningful values.	2 - Small differences	<a href="#">M3-4-1</a>	
AV Rule 144 Braces shall be used to indicate and match the structure in the non-zero initialization of arrays and structures.	2 - Small differences	<a href="#">M8-5-2</a>	
AV Rule 145 In an enumerator list, the “=” construct shall not be used to explicitly initialize members other than the first, unless all items are explicitly initialized.	2 - Small differences	<a href="#">A7-2-4</a>	
AV Rule 146 Floating point implementations shall comply with a defined floating point standard. The standard that will be used is the ANSI/IEEE Std 754	2 - Small differences	<a href="#">A0-4-1</a>	
AV Rule 147 The underlying bit representations of floating point numbers shall not be used in any way by the programmer.	2 - Small differences	<a href="#">M3-9-3</a>	
AV Rule 148 Enumeration types shall be used instead of integer types (and constants) to select from a limited series of choices.	2 - Small differences	<a href="#">A7-2-5</a>	
AV Rule 149 Octal constants (other than zero) shall not be used.	2 - Small differences	<a href="#">M2-13-2</a>	
AV Rule 150 Hexadecimal constants will be represented using all uppercase letters.	2 - Small differences	<a href="#">A2-13-5</a>	
AV Rule 151 Numeric values in code will not be used; symbolic values will be used instead.	2 - Small differences	<a href="#">A5-1-1</a>	
AV Rule 151.1 A string literal shall not be modified.	2 - Small differences	<a href="#">A2-13-4</a>	

AV Rule 152 Multiple variable declarations shall not be allowed on the same line.	2 - Small differences	<a href="#">A7-1-7</a>	
AV Rule 153 Unions shall not be used.	2 - Small differences	<a href="#">A9-5-1</a>	
AV Rule 154 Bit-fields shall have explicitly unsigned integral or enumeration types only.	3 - Significant differences	<a href="#">A9-6-1</a>	Any type with a defined size is allowed to be used for a bit-field.
AV Rule 155 Bit-fields will not be used to pack data into a word for the sole purpose of saving space.	2 - Small differences	<a href="#">A9-6-2</a>	
AV Rule 156 All the members of a structure (or class) shall be named and shall only be accessed via their names.	2 - Small differences	<a href="#">A12-0-2</a>	
AV Rule 157 The right hand operand of a && or   operator shall not contain side effects.	2 - Small differences	<a href="#">M5-14-1</a>	
AV Rule 158 The operands of a logical && or   shall be parenthesized if the operands contain binary operators.	2 - Small differences	<a href="#">A5-2-6</a>	
AV Rule 159 Operators   , &&, and unary & shall not be overloaded.	2 - Small differences	<a href="#">M5-2-11</a> , <a href="#">M5-3-3</a>	
AV Rule 160 An assignment expression shall be used only as the expression in an expression statement.	2 - Small differences	<a href="#">M6-2-1</a>	
AV Rule 162 Signed and unsigned values shall not be mixed in arithmetic or comparison operations.	2 - Small differences	<a href="#">M5-0-4</a> , <a href="#">M5-0-9</a>	
AV Rule 163 Unsigned arithmetic shall not be used.	2 - Small differences	<a href="#">M5-0-4</a> , <a href="#">M5-0-9</a>	
AV Rule 164 The right hand operand of a shift operator shall lie between zero and one less than the width in bits of the left-hand operand (inclusive).	2 - Small differences	<a href="#">M5-8-1</a>	
AV Rule 164.1 The left-hand operand of a right-shift operator shall not have a negative value.	2 - Small differences	<a href="#">M5-8-1</a>	
AV Rule 165 The unary minus operator shall not be applied to an unsigned expression.	2 - Small differences	<a href="#">M5-3-2</a>	
AV Rule 166 The sizeof operator will not be used on expressions that contain side effects.	2 - Small differences	<a href="#">M5-3-4</a>	
AV Rule 167 The implementation of integer division in the chosen compiler shall be determined, documented and taken into account.	3 - Significant differences	<a href="#">A0-4-2</a>	
AV Rule 168 The comma operator shall not be used.	2 - Small differences	<a href="#">M5-18-1</a>	
AV Rule 169 Pointers to pointers should be avoided when possible.	3 - Significant differences	<a href="#">A5-0-3</a>	

AV Rule 170 More than 2 levels of pointer indirection shall not be used.	3- Significant differences	<a href="#">A5-0-3</a>	
AV Rule 171 Relational operators shall not be applied to pointer types except where both operands are of the same type and point to: (a) the same object, (b) the same function, (c) members of the same object, or (d) elements of the same array (including one past the end of the same array).	2- Small differences	<a href="#">M5-0-18</a>	
AV Rule 173 The address of an object with automatic storage shall not be assigned to an object which persists after the object has ceased to exist.	2- Small differences	<a href="#">M7-5-2</a>	
AV Rule 174 The null pointer shall not be de-referenced.	2- Small differences	<a href="#">A5-3-2</a>	
AV Rule 175 A pointer shall not be compared to NULL or be assigned NULL; use plain 0 instead.	4- Rejected		Only <code>nullptr</code> constant shall be used, see: <a href="#">A4-10-1</a> .
AV Rule 176 A typedef will be used to simplify program syntax when declaring function pointers.	4- Rejected		Implementation principle. There is no need for a new rule.
AV Rule 177 User-defined conversion functions should be avoided.	2- Small differences	<a href="#">A13-5-3</a>	
AV Rule 178 Down casting (casting from base to derived class) shall only be allowed through one of the following mechanism: (a) Virtual functions that act like dynamic casts (most likely useful in relatively simple cases), (b) Use of the visitor (or similar) pattern (most likely useful in complicated cases)	2- Small differences	<a href="#">M5-2-2</a> , <a href="#">A5-2-6</a>	
AV Rule 179 A pointer to a virtual base class shall not be converted to a pointer to a derived class.	2- Small differences	<a href="#">M5-2-3</a>	
AV Rule 180 Implicit conversions that may result in a loss of information shall not be used.	2- Small differences	<a href="#">A4-7-1</a>	
AV Rule 181 Redundant explicit casts will not be used.	2- Small differences	<a href="#">M0-1-9</a>	
AV Rule 182 Type casting from any type to or from pointers shall not be used.	3- Significant differences	<a href="#">M5-2-9</a>	Not fully covered.
AV Rule 183 Every possible measure should be taken to avoid type casting.	4- Rejected		It is not a coding rule.

AV Rule 184 Floating point numbers shall not be converted to integers unless such a conversion is a specified algorithmic requirement or is necessary for a hardware interface.	2 - Small differences	<a href="#">M5-0-5</a>	
AV Rule 185 C++ style casts (const_cast, reinterpret_cast, and static_cast) shall be used instead of the traditional C-style casts.	2 - Small differences	<a href="#">A5-2-2</a>	
AV Rule 186 There shall be no unreachable code.	2 - Small differences	<a href="#">M0-1-1</a>	
AV Rule 187 All non-null statements shall potentially have a side-effect.	2 - Small differences	<a href="#">M0-1-9</a>	
AV Rule 188 Labels will not be used, except in switch statements.	3 - Significant differences	<a href="#">A6-6-1</a>	
AV Rule 189 The goto statement shall not be used.	2 - Small differences	<a href="#">A6-6-1</a>	
AV Rule 190 The continue statement shall not be used.	4 - Rejected		The continue statement usage is allowed within for-loops, see: <a href="#">M6-6-3</a> .
AV Rule 191 The break statement shall not be used (except to terminate the cases of a switch statement).	2 - Small differences	<a href="#">M6-4-5</a>	
AV Rule 192 All if, else if constructs will contain either a final else clause or a comment indicating why a final else clause is not necessary.	2 - Small differences	<a href="#">M6-4-2</a>	
AV Rule 193 Every non-empty case clause in a switch statement shall be terminated with a break statement.	2 - Small differences	<a href="#">M6-4-3</a> , <a href="#">M6-4-5</a>	
AV Rule 194 All switch statements that do not intend to test for every enumeration value shall contain a final default clause.	2 - Small differences	<a href="#">M6-4-6</a>	
AV Rule 195 A switch expression will not represent a Boolean value.	2 - Small differences	<a href="#">M6-4-7</a>	
AV Rule 196 Every switch statement will have at least two cases and a potential default.	2 - Small differences	<a href="#">A6-4-1</a>	
AV Rule 197 Floating point variables shall not be used as loop counters.	2 - Small differences	<a href="#">M6-5-2</a>	
AV Rule 198 The initialization expression in a for loop will perform no actions other than to initialize the value of a single for loop parameter.	2 - Small differences	<a href="#">A6-5-4</a>	
AV Rule 199 The increment expression in a for loop will perform no action other than to change a single loop parameter to the next value for the loop.	2 - Small differences	<a href="#">A6-5-4</a>	



AV Rule 200 Null initialize or increment expressions in for loops will not be used; a while loop will be used instead.	3- Significant differences	<a href="#">A6-5-2</a>	
AV Rule 201 Numeric variables being used within a for loop for iteration counting shall not be modified in the body of the loop.	2- Small differences	<a href="#">M6-5-3</a>	
AV Rule 202 Floating point variables shall not be tested for exact equality or inequality.	2- Small differences	<a href="#">M6-2-2</a>	
AV Rule 203 Evaluation of expressions shall not lead to overflow/underflow (unless required algorithmically and then should be heavily documented).	2- Small differences	<a href="#">M5-19-1</a> , <a href="#">A7-1-2</a>	
AV Rule 204 A single operation with side-effects shall only be used in the following contexts: 1. by itself 2. the right-hand side of an assignment 3. a condition 4. the only argument expression with a side-effect in a function call 5. condition of a loop 6. switch condition 7. single part of a chained operation.	3- Significant differences	<a href="#">M6-2-1</a>	Some of presented examples are not misleading and some of them are already covered.
AV Rule 204.1 The value of an expression shall be the same under any order of evaluation that the standard permits.	2- Small differences	<a href="#">A5-0-1</a>	
AV Rule 205 The volatile keyword shall not be used unless directly interfacing with hardware.	3- Significant differences	<a href="#">A2-11-1</a>	Volatile keyword forbidden.
AV Rule 206 Allocation/deallocation from/to the free store (heap) shall not occur after initialization.	2- Small differences	<a href="#">A18-5-3</a>	
AV Rule 207 Unencapsulated global data will be avoided.	3- Significant differences	<a href="#">A3-3-2</a>	Restriction to constant-initialized objects only.
AV Rule 208 C++ exceptions shall not be used (i.e. throw, catch and try shall not be used.)	4- Rejected		C++ exceptions may be used conditionally.
AV Rule 209 The basic types of int, short, long, float and double shall not be used, but specific-length equivalents should be typedef'd accordingly for each compiler, and these type names used in the code.	2- Small differences	<a href="#">A3-9-1</a>	



AV Rule 210 Algorithms shall not make assumptions concerning how data is represented in memory (e.g. big endian vs. little endian, base class subobject ordering in derived classes, nonstatic data member ordering across access specifiers, etc.)	2 - Small differences	<a href="#">A12-0-2</a>	
AV Rule 210.1 Algorithms shall not make assumptions concerning the order of allocation of nonstatic data members separated by an access specifier.	2 - Small differences	<a href="#">A12-0-2</a>	
AV Rule 211 Algorithms shall not assume that shorts, ints, longs, floats, doubles or long doubles begin at particular addresses.	2 - Small differences	<a href="#">A12-0-2</a>	
AV Rule 212 Underflow or overflow functioning shall not be depended on in any special way.	2 - Small differences	<a href="#">A4-7-1</a>	
AV Rule 213 No dependence shall be placed on C++'s operator precedence rules, below arithmetic operators, in expressions.	2 - Small differences	<a href="#">A5-0-1</a>	
AV Rule 214 Assuming that non-local static objects, in separate translation units, are initialized in a special order shall not be done.	2 - Small differences	<a href="#">A3-3-2</a>	Intent of the rule achieved by restriction to constant-initialized objects.
AV Rule 215 Pointer arithmetic will not be used.	3 - Significant differences	<a href="#">M5-0-15</a>	Pointer arithmetic may be used for array indexing.
AV Rule 216 Programmers should not attempt to prematurely optimize code.	4 - Rejected		It is not a coding rule.
AV Rule 217 Compile-time and link-time errors should be preferred over run-time errors.	4 - Rejected	<a href="#">A16-6-1</a> , <a href="#">A14-1-1</a> , <a href="#">A1-4-3</a>	This rule is too generic, some cases are covered.
AV Rule 218 Compiler warning levels will be set in compliance with project policies.	3 - Significant differences	<a href="#">A1-1-2</a>	
AV Rule 219 All tests applied to a base class interface shall be applied to all derived class interfaces as well. If the derived class poses stronger postconditions/invariants, then the new postconditions /invariants shall be substituted in the derived class tests.	4 - Rejected		It is not a coding rule.
AV Rule 220 Structural coverage algorithms shall be applied against flattened classes.	4 - Rejected		It is not a coding rule.

AV Rule 221 Structural coverage of a class within an inheritance hierarchy containing virtual functions shall include testing every possible resolution for each set of identical polymorphic references.	4 - Rejected		It is not a coding rule.
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**Table B.3: JSF**

## B.4 Traceability to SEI CERT C++

The following table demonstrates the traceability to SEI CERT C++ Coding Standard. This is not considered as a reproduction, but a mean to compare the two standards.

Note that the copyright of SEI CERT C++ Coding Standard allows an unlimited distribution anyway.

SEI CERT Rule:	Relation type:	Related rule:	Comment:
DCL30-C. Declare objects with appropriate storage durations.	2 - Small differences	<a href="#">M7-5-2</a>	
DCL40-C. Do not create incompatible declarations of the same function or object.	2 - Small differences	<a href="#">M3-9-1</a>	
DCL50-CPP. Do not define a C-style variadic function.	2 - Small differences	<a href="#">A8-4-1</a>	
DCL51-CPP. Do not declare or define a reserved identifier.	2 - Small differences	<a href="#">A13-1-2</a> , <a href="#">A17-0-1</a>	
DCL52-CPP. Never qualify a reference type with const or volatile.	2 - Small differences	<a href="#">A1-1-1</a>	Covered by a more general rule.
DCL53-CPP. Do not write syntactically ambiguous declarations.	2 - Small differences	<a href="#">A8-5-2</a>	
DCL54-CPP. Overload allocation and deallocation functions as a pair in the same scope.	3 - Significant differences	<a href="#">A18-5-3</a> , <a href="#">A18-5-4</a>	
DCL55-CPP. Avoid information leakage when passing a class object across a trust boundary.	5 - Not yet analyzed		The Security chapter is not yet covered, this will be addressed in future.
DCL56-CPP. Avoid cycles during initialization of static objects.	2 - Small differences	<a href="#">A3-3-2</a>	Intent of the rule achieved by restriction to constant-initialized objects.

DCL57-CPP. Do not let exceptions escape from destructors or deallocation functions.	3 - Significant differences	<a href="#">A15-5-1</a>	AUTOSAR C++ Coding Guidelines specify more functions that need to be noexcept.
DCL58-CPP. Do not modify the standard namespaces.	2 - Small differences	<a href="#">A17-6-1</a>	
DCL59-CPP. Do not define an unnamed namespace in a header file.	2 - Small differences	<a href="#">M7-3-3</a>	
DCL60-CPP. Obey the one-definition rule.	2 - Small differences	<a href="#">M3-2-2</a>	
EXP34-C. Do not dereference null pointers.	2 - Small differences	<a href="#">A5-3-2</a>	
EXP35-C. Do not modify objects with temporary lifetime.	4 - Rejected		Not applicable to C++. See EXP54-CPP.
EXP36-C. Do not cast pointers into more strictly aligned pointer types.	2 - Small differences	<a href="#">A5-2-4</a> , <a href="#">M5-2-8</a>	Direct and indirect casting of pointer types is prohibited via existing rules.
EXP37-C. Call functions with the correct number and type of arguments.	2 - Small differences	<a href="#">M5-2-6</a>	The only case possible in C++ is prohibited via existing rule.
EXP39-C. Do not access a variable through a pointer of an incompatible type.	2 - Small differences	<a href="#">A5-2-2</a> , <a href="#">A5-2-4</a>	Effectively prohibited by existing rules.
EXP42-C. Do not compare padding data.	2 - Small differences	<a href="#">A12-0-2</a>	
EXP45-C. Do not perform assignments in selection statements.	2 - Small differences	<a href="#">A5-0-2</a> , <a href="#">M6-2-1</a>	
EXP46-C. Do not use a bitwise operator with a Boolean-like operand.	4 - Rejected		Use of bitwise operators restricted to following cases: <a href="#">M5-0-10</a> , <a href="#">M5-0-20</a> , <a href="#">M5-0-21</a> .
EXP47-C. Do not call <code>va_arg</code> with an argument of the incorrect type.	4 - Rejected		Use of variable arguments are prohibited, see: <a href="#">A8-4-1</a> .
EXP50-CPP. Do not depend on the order of evaluation for side effects.	2 - Small differences	<a href="#">A5-0-1</a>	

EXP51-CPP. Do not delete an array through a pointer of the incorrect type.	2 - Small differences	<a href="#">M5-2-12</a> , <a href="#">A18-1-1</a>	Covered by a combination of existing rules.
EXP52-CPP. Do not rely on side effects in unevaluated operands.	3 - Significant differences	<a href="#">M5-3-4</a> , <a href="#">A5-3-1</a>	
EXP53-CPP. Do not read uninitialized memory.	2 - Small differences	<a href="#">A8-5-0</a>	
EXP54-CPP. Do not access an object outside of its lifetime.	2 - Small differences	<a href="#">A3-8-1</a> , <a href="#">A5-1-4</a> , <a href="#">M7-5-1</a> , <a href="#">M7-5-2</a> , <a href="#">A7-5-1</a> , <a href="#">M12-1-1</a>	
EXP55-CPP. Do not access a cv-qualified object through a cv-unqualified type.	2 - Small differences	<a href="#">A5-2-3</a>	
EXP56-CPP. Do not call a function with a mismatched language linkage.	2 - Small differences	<a href="#">M5-2-6</a>	
EXP57-CPP. Do not cast or delete pointers to incomplete classes.	3 - Significant differences	<a href="#">A5-3-3</a> , <a href="#">A5-2-2</a> , <a href="#">A5-2-4</a>	The first part of EXP57-CPP is entirely covered by <a href="#">A5-3-3</a> , the second part is implicitly rule out by <a href="#">A5-2-2</a> and <a href="#">A5-2-4</a> .
EXP58-CPP. Pass an object of the correct type to va_start.	4 - Rejected		Use of variable arguments are prohibited, see: <a href="#">A8-4-1</a> .
EXP59-CPP. Use offsetof() on valid types and members.	4 - Rejected		Use of offsetof() is prohibited, see: <a href="#">M18-2-1</a> .
EXP60-CPP. Do not pass a nonstandard-layout type object across execution boundaries.	2 - Small differences	<a href="#">M1-0-2</a>	
EXP61-CPP. A lambda object must not outlive any of its reference captured objects.	2 - Small differences	<a href="#">A5-1-4</a>	
EXP62-CPP. Do not access the bits of an object representation that are not part of the object's value representation.	2 - Small differences	<a href="#">A12-0-2</a>	
EXP63-CPP. Do not rely on the value of a moved-from object.	2 - Small differences	<a href="#">A12-8-3</a>	
INT30-C. Ensure that unsigned integer operations do not wrap.	2 - Small differences	<a href="#">A4-7-1</a> , <a href="#">M5-19-1</a>	
INT31-C. Ensure that integer conversions do not result in lost or misinterpreted data.	3 - Significant differences	<a href="#">A4-7-1</a> , <a href="#">M5-0-15</a>	
INT32-C. Ensure that operations on signed integers do not result in overflow.	2 - Small differences	<a href="#">A4-7-1</a>	

INT33-C. Ensure that division and remainder operations do not result in divide-by-zero errors.	2 - Small differences	<a href="#">A5-6-1</a>	
INT34-C. Do not shift an expression by a negative number of bits or by greater than or equal to the number of bits that exist in the operand.	2 - Small differences	<a href="#">M5-8-1</a>	
INT35-C. Use correct integer precisions.	3 - Significant differences	<a href="#">A3-9-1</a>	
INT36-C. Converting a pointer to integer or integer to pointer.	2 - Small differences	<a href="#">M5-2-8</a> , <a href="#">M5-2-9</a>	
INT50-CPP. Do not cast to an out-of-range enumeration value.	2 - Small differences	<a href="#">A7-2-1</a>	
CTR50-CPP. Guarantee that container indices and iterators are within the valid range.	2 - Small differences	<a href="#">A5-2-5</a>	
CTR51-CPP. Use valid references, pointers, and iterators to reference elements of a container.	2 - Small differences	<a href="#">A23-0-2</a>	
CTR52-CPP. Guarantee that library functions do not overflow.	2 - Small differences	<a href="#">A5-2-5</a>	
CTR53-CPP. Use valid iterator ranges.	3 - Significant differences	<a href="#">M5-0-16</a> , <a href="#">M5-0-17</a> , <a href="#">A5-2-5</a>	
CTR54-CPP. Do not subtract iterators that do not refer to the same container.	3 - Significant differences	<a href="#">M5-0-16</a> , <a href="#">M5-0-17</a>	
CTR55-CPP. Do not use an additive operator on an iterator if the result would overflow.	3 - Significant differences	<a href="#">M5-0-16</a> , <a href="#">M5-0-17</a> , <a href="#">A5-2-5</a>	
CTR56-CPP. Do not use pointer arithmetic on polymorphic objects.	2 - Small differences	<a href="#">A5-0-4</a>	
CTR57-CPP. Provide a valid ordering predicate.	2 - Small differences	<a href="#">A25-4-1</a>	
CTR58-CPP. Predicate function objects should not be mutable.	2 - Small differences	<a href="#">A25-1-1</a>	
ARR30-C. Do not form or use out-of-bounds pointers or array subscripts.	3 - Significant differences	<a href="#">A5-2-5</a>	
ARR37-C. Do not add or subtract an integer to a pointer to a non-array object.	3 - Significant differences	<a href="#">M5-0-15</a>	
ARR38-C. Guarantee that library functions do not form invalid pointers.	3 - Significant differences	RuleLinkM5-0-16	
ARR39-C. Do not add or subtract a scaled integer to a pointer.	3 - Significant differences	<a href="#">M5-0-15</a>	
STR30-C. Do not attempt to modify string literals.	4 - Rejected		Use of C-style arrays, apart from static constexpr members, is prohibited. See: <a href="#">A18-1-1</a> .

STR31-C. Guarantee that storage for strings has sufficient space for character data and the null terminator.	3 - Significant differences	<a href="#">A5-2-5</a>	Effectively covered by prohibiting out-of-range array access.
STR32-C. Do not pass a non-null-terminated character sequence to a library function that expects a string	4 - Rejected		Use of functions from <code>&lt;cstring&gt;</code> is prohibited by <a href="#">M18-0-5</a> .
STR34-C. Cast characters to unsigned char before converting to larger integer sizes.	3 - Significant differences	<a href="#">M5-0-4</a>	
STR37-C. Arguments to character-handling functions must be representable as an unsigned char.	2 - Small differences	<a href="#">A21-8-1</a>	
STR38-C. Do not confuse narrow and wide character strings and functions.	3 - Significant differences	<a href="#">A2-13-2</a> , <a href="#">A2-13-3</a>	Use of <code>wchar_t</code> is prohibited.
STR50-CPP. Guarantee that storage for strings has sufficient space for character data and the null terminator.	3 - Significant differences	<a href="#">A5-2-5</a>	Effectively covered by prohibiting out-of-range array access.
STR51-CPP. Do not attempt to create a <code>std::string</code> from a null pointer.	3 - Significant differences	<a href="#">A5-3-2</a>	This is a special case of a more general rule.
STR52-CPP. Use valid references, pointers, and iterators to reference elements of a <code>basic_string</code> .	2 - Small differences	<a href="#">A23-0-2</a>	
STR53-CPP. Range check element access.	3 - Significant differences	<a href="#">A5-2-5</a>	The specific case of <a href="#">A5-2-5</a> .
MEM31-C. Free dynamically allocated memory when no longer needed.	3 - Significant differences	<a href="#">A15-1-4</a> , <a href="#">A18-5-2</a>	Intent of this rule is covered by effectively demanding the use of the RAIL pattern.
MEM34-C. Only free memory allocated dynamically.	4 - Rejected		Use of <code>malloc</code> , <code>calloc</code> and <code>realloc</code> functions is prohibited, see: <a href="#">A18-5-1</a> .
MEM35-C. Allocate sufficient memory for an object.	4 - Rejected		Use of <code>malloc</code> , <code>calloc</code> and <code>realloc</code> functions is prohibited, see: <a href="#">A18-5-1</a> .

MEM36-C. Do not modify the alignment of objects by calling <code>realloc()</code> .	4 - Rejected		Use of <code>malloc</code> , <code>calloc</code> and <code>realloc</code> functions is prohibited, see: <a href="#">A18-5-1</a> .
MEM50-CPP. Do not access freed memory.	2 - Small differences	<a href="#">A3-8-1</a>	
MEM51-CPP. Properly deallocate dynamically allocated resources.	3 - Significant differences	<a href="#">A18-5-3</a>	Use of memory allocation and deallocation operators limited by <a href="#">A18-5-2</a> , <a href="#">A18-5-4</a> .
MEM52-CPP. Detect and handle memory allocation errors.	3 - Significant differences	<a href="#">A15-0-2</a> , <a href="#">A15-2-2</a> , <a href="#">A15-3-3</a> , <a href="#">A15-5-3</a>	
MEM53-CPP. Explicitly construct and destruct objects when manually managing object lifetime.	4 - Rejected	<a href="#">A18-5-2</a>	Explicit use of operators <code>new</code> and <code>delete</code> is prohibited. Managing object lifetime also covered by <a href="#">A18-5-1</a> , <a href="#">A18-5-3</a> .
MEM54-CPP. Provide placement <code>new</code> with properly aligned pointers to sufficient storage capacity.	2 - Small differences	<a href="#">A18-5-10</a>	
MEM55-CPP. Honor replacement dynamic storage management requirements.	2 - Small differences	<a href="#">A18-5-9</a>	
MEM56-CPP. Do not store an already-owned pointer value in an unrelated smart pointer.	2 - Small differences	<a href="#">A20-8-1</a>	
MEM57-CPP. Avoid using default operator <code>new</code> for over-aligned types.	4 - Rejected		Current approach is to use managed memory objects, which does not allow to work on a raw storage, but on a type storage, thus no need for this rule.
FIO50-CPP. Do not alternately input and output from a file stream without an intervening positioning call.	2 - Small differences	<a href="#">A27-0-3</a>	

FIO51-CPP. Close files when they are no longer needed.	4 - Rejected		Usage of RAI solves the problem and is recommended, see: <a href="#">A15-1-4</a> , <a href="#">A18-5-2</a> .
FIO30-C. Exclude user input from format strings.	2 - Small differences	<a href="#">A27-0-1</a>	
FIO32-C. Do not perform operations on devices that are only appropriate for files.	4 - Rejected		Non-generic rule affecting only particular file types on some operating systems.
FIO34-C. Distinguish between characters read from a file and EOF or WEOF.	4 - Rejected	<a href="#">M27-0-1</a>	The C IO library is not used.
FIO37-C. Do not assume that fgets() or fgets() returns a nonempty string when successful.	4 - Rejected	<a href="#">M27-0-1</a>	The C IO library is not used.
FIO38-C. Do not copy a FILE object.	4 - Rejected	<a href="#">M27-0-1</a>	The C IO library is not used.
FIO39-C. Do not alternately input and output from a stream without an intervening flush or positioning call.	2 - Small differences	<a href="#">A27-0-3</a>	
FIO40-C. Reset strings on fgets() or fgets() failure.	4 - Rejected	<a href="#">M27-0-1</a>	The C IO library is not used.
FIO41-C. Do not call getc(), putc(), getwc(), or putwc() with a stream argument that has side effects.	4 - Rejected	<a href="#">M27-0-1</a>	The C IO library is not used.
FIO42-C. Close files when they are no longer needed.	4 - Rejected	<a href="#">M27-0-1</a>	The C IO library is not used.
FIO44-C. Only use values for fsetpos() that are returned from fgetpos().	4 - Rejected	<a href="#">M27-0-1</a>	The C IO library is not used.
FIO45-C. Avoid TOCTOU race conditions while accessing files.	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future. See also CP.2
FIO46-C. Do not access a closed file.	4 - Rejected	<a href="#">M27-0-1</a>	The C IO library is not used.
FIO47-C. Use valid format strings.	4 - Rejected	<a href="#">M27-0-1</a>	The C IO library is not used.



ERR30-C. Set errno to zero before calling a library function known to set errno, and check errno only after the function returns a value indicating failure.	4 - Rejected		Use of the errno is prohibited, see: <a href="#">M19-3-1</a> .
ERR32-C. Do not rely on indeterminate values of errno.	4 - Rejected		Use of the errno is prohibited, see: <a href="#">M19-3-1</a> .
ERR33-C. Detect and handle standard library errors.	3 - Small differences	<a href="#">M0-3-2</a> , <a href="#">A15-0-3</a>	
ERR34-C. Detect errors when converting a string to a number.	2 - Small differences	<a href="#">A18-0-2</a>	
ERR50-CPP. Do not abruptly terminate the program.	2 - Small differences	<a href="#">A15-5-2</a> , <a href="#">A15-5-3</a>	
ERR51-CPP. Handle all exceptions.	2 - Small differences	<a href="#">A15-3-3</a> , <a href="#">A15-5-3</a>	
ERR52-CPP. Do not use setjmp() or longjmp().	2 - Small differences	<a href="#">M17-0-5</a>	
ERR53-CPP. Do not reference base classes or class data members in a constructor or destructor function-try-block handler.	3 - Significant differences	<a href="#">M15-3-3</a>	Use of function-try-blocks is anyway not recommended. See: <a href="#">A15-3-5</a> .
ERR54-CPP. Catch handlers should order their parameter types from most derived to least derived.	2 - Small differences	<a href="#">M15-3-6</a> , <a href="#">M15-3-7</a>	
ERR55-CPP. Honor exception specifications.	3 - Significant differences	<a href="#">A15-4-2</a>	Use of dynamic exception specification is prohibited, see: <a href="#">A15-4-1</a> . The noexcept specifier should be used instead.
ERR56-CPP. Guarantee exception safety.	2 - Small differences	<a href="#">A15-0-2</a>	
ERR57-CPP. Do not leak resources when handling exceptions.	3 - Significant differences	<a href="#">A15-0-2</a> , <a href="#">A15-1-2</a> , <a href="#">A15-1-4</a>	
ERR58-CPP. Handle all exceptions thrown before main() begins executing.	2 - Small differences	<a href="#">A15-2-1</a>	
ERR59-CPP. Do not throw an exception across execution boundaries.	2 - Small differences	<a href="#">A15-1-5</a>	
ERR60-CPP. Exception objects must be nothrow copy constructible.	3 - Significant differences	<a href="#">A15-5-3</a>	
ERR61-CPP. Catch exceptions by lvalue reference.	2 - Small differences	<a href="#">A15-3-5</a>	
ERR62-CPP. Detect errors when converting a string to a number.	2 - Small differences	<a href="#">A18-0-2</a>	

OOP50-CPP. Do not invoke virtual functions from constructors or destructors.	2 - Small differences	M12-1-1	
OOP51-CPP. Do not slice derived objects.	2 - Small differences	A12-8-6, A15-3-5	
OOP52-CPP. Do not delete a polymorphic object without a virtual destructor.	2 - Small differences	A12-4-1, A12-4-2	
OOP53-CPP. Write constructor member initializers in the canonical order.	2 - Small differences	A8-5-1	
OOP54-CPP. Gracefully handle self-copy assignment.	2 - Small differences	A12-8-5	
OOP55-CPP. Do not use pointer-to-member operators to access nonexistent members.	2 - Small differences	A5-5-1	
OOP56-CPP. Honor replacement handler requirements.	3 - Significant differences	A18-5-5, A15-5-2, A15-5-3, A15-4-1	std::terminate and std::unexpected handler forbidden, std::new_handler comments added.
OOP57-CPP. Prefer special member functions and overloaded operators to C Standard Library functions.	2 - Small differences	A12-0-2	
OOP58-CPP. Copy operations must not mutate the source object.	2 - Small differences	A12-8-1	
CON50-CPP. Do not destroy a mutex while it is locked.	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
CON51-CPP. Ensure actively held locks are released on exceptional conditions.	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
CON52-CPP. Prevent data races when accessing bit-fields from multiple threads.	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.

CON53-CPP. Avoid deadlock by locking in a predefined order.	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
CON54-CPP. Wrap functions that can spuriously wake up in a loop.	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
CON55-CPP. Preserve thread safety and liveness when using condition variables.	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
CON56-CPP. Do not speculatively lock a non-recursive mutex that is already owned by the calling thread.	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
CON33-C. Avoid race conditions when using library functions.	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
CON37-C. Do not call signal() in a multithreaded program	4 - Rejected		Use of signal handling facilities of <csignal> is prohibited, see: <a href="#">M18-7-1</a> .
CON40-C. Do not refer to an atomic variable twice in an expression.	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.

CON41-C. Wrap functions that can fail spuriously in a loop.	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
CON43-C. Do not allow data races in multithreaded code.	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
MSC33-C. Do not pass invalid data to the asctime() function.	4 - Rejected		Use of time handling functions of <ctime> is prohibited, see: <a href="#">M18-0-4</a> .
MSC38-C. Do not treat a predefined identifier as an object if it might only be implemented as a macro.	4 - Rejected		Error indicator errno, setjmp() and variadic arguments shall not be used, see: <a href="#">M19-3-1</a> , <a href="#">M17-0-5</a> , <a href="#">A8-4-1</a> .
MSC39-C. Do not call va_arg() on a va_list that has an indeterminate value.	4 - Rejected		Use of variadic arguments is prohibited, see: <a href="#">A8-4-1</a> .
MSC40-C. Do not violate constraints.	2 - Small differences	<a href="#">A1-1-1</a>	
MSC50-CPP. Do not use std::rand() for generating pseudorandom numbers.	2 - Small differences	<a href="#">A26-5-1</a>	
MSC51-CPP. Ensure your random number generator is properly seeded.	2 - Small differences	<a href="#">A26-5-2</a>	
MSC52-CPP. Value-returning functions must return a value from all exit paths.	2 - Small differences	<a href="#">A8-4-2</a>	
MSC53-CPP. Do not return from a function declared [[noreturn]].	2 - Small differences	<a href="#">A7-6-1</a>	
MSC54-CPP. A signal handler must be a plain old function.	4 - Rejected		Use of signal handling facilities of <csignal> is prohibited, see: <a href="#">M18-7-1</a> .
FLP30-C. Do not use floating-point variables as loop counters.	2 - Small differences	<a href="#">A6-5-2</a>	
FLP32-C. Prevent or detect domain and range errors in math functions.	2 - Small differences	<a href="#">A0-4-4</a>	
FLP34-C. Ensure that floating-point conversions are within range of the new type.	3 - Significant differences	<a href="#">M5-0-5</a> , <a href="#">M5-0-6</a> , <a href="#">M5-0-7</a>	

FLP36-C. Preserve precision when converting integral values to floating-point type.	3 - Significant differences	<a href="#">M5-0-5</a> , <a href="#">M5-0-6</a> , <a href="#">M5-0-7</a>	
FLP37-C. Do not use object representations to compare floating-point values.	2 - Small differences	<a href="#">M3-9-3</a>	
ENV30-C. Do not modify the object referenced by the return value of certain functions.	2 - Small differences	<a href="#">M18-0-3</a> , <a href="#">M18-0-4</a> , <a href="#">A18-0-3</a> , <a href="#">A17-1-1</a>	Listed functions are prohibited by separate rules.
ENV31-C. Do not rely on an environment pointer following an operation that may invalidate it.	4 - Rejected		In general, a project shall not rely on environment-specific implementations.
ENV32-C. All exit handlers must return normally.	3 - Significant differences	<a href="#">A15-5-2</a> , <a href="#">A15-5-3</a>	
ENV33-C. Do not call system().	2 - Small differences		Covered by <a href="#">M18-0-3</a>
ENV34-C. Do not store pointers returned by certain functions.	3 - Significant differences	<a href="#">A18-0-3</a> , <a href="#">M19-3-1</a>	
SIG31-C. Do not access shared objects in signal handlers.	4 - Rejected		Use of signal handling facilities of <code>&lt;csignal&gt;</code> is prohibited, see: <a href="#">M18-7-1</a> .
SIG34-C. Do not call signal() from within interruptible signal handlers.	4 - Rejected		Use of signal handling facilities of <code>&lt;csignal&gt;</code> is prohibited, see: <a href="#">M18-7-1</a> .
SIG35-C. Do not return from a computational exception signal handler.	4 - Rejected		Use of signal handling facilities of <code>&lt;csignal&gt;</code> is prohibited, see: <a href="#">M18-7-1</a> .
PRE30-C. Do not create a universal character name through concatenation.	4 - Rejected		Forbidden by <a href="#">A2-3-1</a> .
PRE31-C. Avoid side effects in arguments to unsafe macros.	3 - Significant differences		Defining function-like macros is prohibited, see: <a href="#">A16-0-1</a> .

PRE32-C. Do not use preprocessor directives in invocations of function-like macros.			Defining function-like macros is prohibited, see: <a href="#">A16-0-1</a> .
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**Table B.4: SEI CERT C++**

## B.5 Traceability to C++ Core Guidelines

The following table demonstrates the traceability to C++ Core Guidelines [11]. This is not considered as a reproduction, but a mean to compare the two standards.

Note that the copyright of C++ Core Guidelines allows a derivative work anyway.

C++ Core Guidelines Rule:	Relation type:	Related rule:	Comment:
P.1: Express ideas directly in code.	4 - Rejected		The rule is vague.
P.2: Write in ISO Standard C++.	2 - Small differences	<a href="#">A0-4-3</a>	
P.3: Express intent.	4 - Rejected		The rule is vague.
P.4: Ideally, a program should be statically type safe.	3 - Significant differences		The rule is covered by: <a href="#">A5-2-1</a> , <a href="#">A5-2-2</a> , <a href="#">A5-2-4</a> , <a href="#">M5-2-12</a> , <a href="#">A8-5-2</a> , <a href="#">A9-5-1</a>
P.5: Prefer compile-time checking to run-time checking.	3 - Significant differences	<a href="#">M0-3-1</a>	
P.6: What cannot be checked at compile time should be checkable at run time.	3 - Significant differences	<a href="#">A0-1-2</a> , <a href="#">M0-3-2</a>	
P.7: Catch run-time errors early.	3 - Significant differences	<a href="#">A0-1-2</a> , <a href="#">M0-3-2</a> , <a href="#">A5-2-5</a> , <a href="#">A15-0-4</a> , <a href="#">A15-0-5</a>	
P.8: Don't leak any resources.	3 - Significant differences	<a href="#">A18-5-1</a> , <a href="#">A18-5-2</a> , <a href="#">A15-1-4</a>	
P.9: Don't waste time or space.	3 - Significant differences	<a href="#">M0-1-1</a> , <a href="#">A0-1-1</a> , <a href="#">M0-1-8</a> , <a href="#">M0-1-9</a>	
P.10: Prefer immutable data to mutable data.	2 - Small differences	<a href="#">A7-1-1</a>	
P.11: Encapsulate messy constructs, rather than spreading through the code.	4 - Rejected		The rule is vague.
I.1: Make interfaces explicit.	4 - Rejected		The rule is vague.

I.2 Avoid global variables.	3 - Significant differences	<a href="#">A3-3-2</a>	<a href="#">A3-3-2</a> covers only the initialization of global objects.
I.3: Avoid singletons.	3 - Significant differences	<a href="#">A3-3-2</a>	<a href="#">A3-3-2</a> covers only the initialization of static objects.
I.4: Make interfaces precisely and strongly typed.	2 - Small differences	<a href="#">A8-4-14</a>	-
I.5: State preconditions (if any).	4 - Rejected		The rule is vague.
I.6: Prefer Expects() for expressing preconditions.	4 - Rejected		Expects() is not part of Language Standard.
I.7: State postconditions.	4 - Rejected		The rule is vague.
I.8: Prefer Ensures() for expressing postconditions.	4 - Rejected		Ensures() is not part of Language Standard.
I.9: If an interface is a template, document its parameters using concepts.	3 - Significant differences	<a href="#">A14-1-1</a>	
I.10: Use exceptions to signal a failure to perform a required task.	2 - Small differences	<a href="#">A15-0-1</a>	
I.11: Never transfer ownership by a raw pointer (T*).	2 - Small differences	<a href="#">A8-4-12</a>	
I.12: Declare a pointer that must not be null as not_null.	4 - Rejected		The not_null is not part of Language Standard.
I.13: Do not pass an array as a single pointer.	2 - Small differences	<a href="#">M5-2-12</a>	
I.22: Avoid complex initialization of global objects.	2 - Small differences	<a href="#">A3-3-2</a>	Intent of the rule achieved by restriction to constant-initialized objects.
I.23: Keep the number of function arguments low.	4 - Rejected		AUTOSAR C++ Coding Guidelines does not define code metrics, see: <a href="#">A1-4-1</a> .
I.24: Avoid adjacent unrelated parameters of the same type.	4 - Rejected		Design rule, requiring case-by-case reasoning to apply.
I.25: Prefer abstract classes as interfaces to class hierarchies.	2 - Small differences	<a href="#">A10-4-1</a>	

I.26: If you want a cross-compiler ABI, use a C-style subset.	2 - Small differences	<a href="#">M1-0-2</a>	-
F.1: “Package” meaningful operations as carefully named functions.	5 - Not yet analyzed	-	-
F.2: A function should perform a single logical operation.	5 - Not yet analyzed	-	-
F.3: Keep functions short and simple.	4 - Rejected		AUTOSAR C++ Coding Guidelines does not define code metrics, see: <a href="#">A1-4-1</a> .
F.4: If a function may have to be evaluated at compile time, declare it constexpr.	2 - Small differences	<a href="#">A7-1-2</a>	
F.5: If a function is very small and time-critical, declare it inline.	4 - Rejected		AUTOSAR C++ Coding Guidelines does not define code metrics, see: <a href="#">A1-4-1</a> .
F.6: If your function may not throw, declare it noexcept.	2 - Small differences	<a href="#">A15-4-4</a>	
F.7: For general use, take T* or T& arguments rather than smart pointers.	2 - Small differences	<a href="#">A8-4-11</a>	Added as a reference.
F.8: Prefer pure functions.	4 - Rejected	-	There is no need for a new rule.
F.9: Unused parameters should be unnamed.	2 - Small differences	<a href="#">A0-1-4</a> , <a href="#">A0-1-5</a>	
F.15: Prefer simple and conventional ways of passing information.	2 - Small differences	<a href="#">A8-4-3</a>	
F.16: For “in” parameters, pass cheaply-copied types by value and others by reference to const.	2 - Small differences	<a href="#">A8-4-7</a>	
F.17: For “in-out” parameters, pass by reference to non-const.	2 - Small differences	<a href="#">A8-4-9</a>	
F.18: For “consume” parameters, pass by X&& and std::move the parameter.	2 - Small differences	<a href="#">A8-4-5</a>	
F.19: For “forward” parameters, pass by TP&& and only std::forward the parameter.	2 - Small differences	<a href="#">A8-4-6</a>	
F.20: For “out” output values, prefer return values to output parameters.	2 - Small differences	<a href="#">A8-4-8</a>	
F.21: To return multiple “out” values, prefer returning a tuple or struct.	3 - Significant differences	<a href="#">A8-4-4</a>	Prefer to return as a tuple.
F.22: Use T* or owner<T*> to designate a single object.	3 - Significant differences	<a href="#">M5-2-12</a>	The owner<T*> is not part of Language Standard.



F.23: Use a <code>not_null&lt;T&gt;</code> to indicate that "null" is not a valid value.	4 - Rejected		The <code>not_null&lt;T&gt;</code> is not part of Language Standard.
F.24: Use a <code>span&lt;T&gt;</code> or a <code>span_p&lt;T&gt;</code> to designate a half-open sequence.	4 - Rejected		Neither the <code>span&lt;T&gt;</code> nor the <code>span_p&lt;T&gt;</code> are part of Language Standard.
F.25: Use a <code>zstring</code> or a <code>not_null&lt;zstring&gt;</code> to designate a C-style string.	4 - Rejected		Neither the <code>zstring</code> nor the <code>not_null&lt;zstring&gt;</code> are part of Language Standard.
F.26: Use a <code>unique_ptr&lt;T&gt;</code> to transfer ownership where a pointer is needed.	2 - Small differences	<a href="#">A20-8-2</a>	
F.27: Use a <code>shared_ptr&lt;T&gt;</code> to share ownership.	2 - Small differences	<a href="#">A20-8-3</a>	
F.60: Prefer <code>T*</code> over <code>T&amp;</code> when no argument is a valid option.	3 - Significant differences	<a href="#">A8-4-10</a>	
F.42: Return a <code>T*</code> to indicate a position (only).	3 - Significant differences	<a href="#">M5-0-15</a> , <a href="#">M5-0-16</a> , <a href="#">M5-0-17</a> , <a href="#">M5-0-18</a>	
F.43: Never (directly or indirectly) return a pointer or a reference to a local object.	2 - Small differences	<a href="#">M7-5-2</a>	Added as a note to this rule.
F.44: Return a <code>T&amp;</code> when copy is undesirable and returning no object isn't needed.	3 - Significant differences	<a href="#">A9-3-1</a>	Do not return non-const reference to private fields.
F.45: Don't return a <code>T&amp;&amp;</code> .	2 - Small differences	<a href="#">M7-5-2</a>	Added as a reference to this rule.
F.46: <code>int</code> is the return type for <code>main()</code> .	2 - Small differences	<a href="#">A0-4-3</a>	Added as a reference to this rule.
F.47: Return <code>T&amp;</code> from assignment operators.	2 - Small differences	<a href="#">A13-2-1</a>	Added as a reference to this rule.

F.50: Use a lambda when a function won't do (to capture local variables, or to write a local function).	4 - Rejected		Design principle. Prefer using lambda over functions while variables capture is required or it is defined in a local scope.
F.51: Where there is a choice, prefer default arguments over overloading.	4 - Rejected		Design principle. Prefer default arguments over overloading.
F.52: Prefer capturing by reference in lambdas that will be used locally, including passed to algorithms.	4 - Rejected		This rule is too specific and this is a matter of ownership, not only lambda.
F.53: Avoid capturing by reference in lambdas that will be used nonlocally, including returned, stored on the heap, or passed to another thread.	2 - Small differences	<a href="#">A5-1-4</a>	
F.54: If you capture this, capture all variables explicitly (no default capture).	3 - Significant differences	<a href="#">A5-1-2</a>	AUTOSAR C++ Coding Guidelines prohibits implicit variables capturing into a lambda expression.
F.55: Don't use va_arg arguments.	2 - Small differences	<a href="#">A8-4-1</a>	Added as a reference to this rule.
C.1: Organize related data into structures (structs or classes).	4 - Rejected		Design principle. There is no need for a new rule..
C.2: Use class if the class has an invariant; use struct if the data members can vary independently.	3 - Significant differences		Class shall be used for all non-POD types (see: <a href="#">A11-0-1</a> ), and a struct for types defined in <a href="#">A11-0-2</a> .
C.3: Represent the distinction between an interface and an implementation using a class.	4 - Rejected		This rule is vague.
C.4: Make a function a member only if it needs direct access to the representation of a class.	2 - Small differences	<a href="#">M9-3-3</a>	

C.5: Place helper functions in the same namespace as the class they support.	5 - Not yet analyzed	-	-
C.7: Don't define a class or enum and declare a variable of its type in the same statement.	2 - Small differences	A7-1-9	
C.8: Use class rather than struct if any member is non-public.	2 - Small differences	M11-0-1, A11-0-1	
C.9: Minimize exposure of members.	3 - Significant differences	M9-3-1, A9-3-1, M11-0-1	
C.10 Prefer concrete types over class hierarchies.	4 - Rejected		This rule is vague. Concrete types and class hierarchies are highly context dependent.
C.11: Make concrete types regular.	4 - Rejected		This rule is vague. "Concrete types" has no technical meaning.
C.20: If you can avoid defining default operations, do.	2 - Small differences	A12-0-1	Following "the rule of zero" is permitted if no special member functions need to be defined.
C.21: If you define or =delete any default operation, define or =delete them all.	2 - Small differences	A12-0-1	
C.22: Make default operations consistent.	2 - Small differences	A12-1-1, A12-8-1	
C.30: Define a destructor if a class needs an explicit action at object destruction.	4 - Rejected		Design principle. Destructor shall be defined only if a class needs an explicit action at object destruction.
C.31: All resources acquired by a class must be released by the class's destructor.	4 - Rejected		Implementation principle. There is no need for a new rule.
C.32: If a class has a raw pointer (T*) or reference (T&), consider whether it might be owning.	4 - Rejected		Memory managing objects are recommended.
C.33: If a class has an owning pointer member, define a destructor.	4 - Rejected		Memory managing objects are recommended.

C.34: If a class has an owning reference member, define a destructor.	4 - Rejected		Memory managing objects are recommended.
C.35: A base class destructor should be either public and virtual, or protected and nonvirtual.	2 - Small differences	<a href="#">A12-4-1</a>	
C.36: A destructor may not fail.	2 - Small differences	<a href="#">A15-5-1</a>	
C.37: Make destructors noexcept.	2 - Small differences	<a href="#">A15-5-1</a>	
C.40: Define a constructor if a class has an invariant.	4 - Rejected		Design principle. There is no need for a new rule.
C.41: A constructor should create a fully initialized object.	2 - Small differences	<a href="#">A15-2-2</a> , <a href="#">A12-1-1</a> , <a href="#">A8-5-0</a>	
C.42: If a constructor cannot construct a valid object, throw an exception.	2 - Small differences	<a href="#">A15-2-2</a>	
C.43: Ensure that a class has a default constructor.	4 - Rejected		This rule is vague.
C.44: Prefer default constructors to be simple and non-throwing.	4 - Rejected		Non-generic design principle; There is no need for a new rule.
C.45: Don't define a default constructor that only initializes data members; use in-class member initializers instead.	2 - Small differences	<a href="#">A12-1-3</a> , <a href="#">A12-7-1</a>	
C.46: By default, declare single-argument constructors explicit.	2 - Small differences	<a href="#">A12-1-4</a>	
C.47: Define and initialize member variables in the order of member declaration.	2 - Small differences	<a href="#">A8-5-1</a>	
C.48: Prefer in-class initializers to member initializers in constructors for constant initializers.	3 - Significant differences	<a href="#">A12-1-3</a>	AUTOSAR C++ Coding Guidelines states that NSDMI shall not be mixed with member initializer list of constructors, see: <a href="#">A12-1-2</a> .
C.49: Prefer initialization to assignment in constructors.	2 - Small differences	<a href="#">A12-6-1</a>	
C.50: Use a factory function if you need "virtual behavior" during initialization.	3 - Significant differences	<a href="#">M12-1-1</a>	Added as a reference to this rule, as it has a good example of virtual behaviour during initialization.

C.51: Use delegating constructors to represent common actions for all constructors of a class.	2- Small differences	A12-1-5	
C.52: Use inheriting constructors to import constructors into a derived class that does not need further explicit initialization.	2- Small differences	A12-1-6	
C.60: Make copy assignment non-virtual, take the parameter by const&, and return by non-const&.	2- Small differences	A10-3-5, A13-2-1	
C.61: A copy operation should copy.	2- Small differences	A12-8-1, A12-8-2	
C.62: Make copy assignment safe for self-assignment.	2- Small differences	A12-8-5	
C.63: Make move assignment non-virtual, take the parameter by &&, and return by non-const&.	2- Small differences	A10-3-5, A13-2-1	
C.64: A move operation should move and leave its source in a valid state.	2- Small differences	A12-8-1, A12-8-4	
C.65: Make move assignment safe for self-assignment.	2- Small differences	A12-8-5	
C.66: Make move operations noexcept.	2- Small differences	A15-5-1	
C.67: A base class should suppress copying, and provide a virtual clone instead if copying” is desired.	2- Small differences	A12-8-6	
C.80: Use =default if you have to be explicit about using the default semantics.	2- Small differences	A12-7-1	
C.81: Use =delete when you want to disable default behavior (without wanting an alternative).	2- Small differences	A12-0-1, A12-8-6	
C.82: Don't call virtual functions in constructors and destructors.	2- Small differences	M12-1-1	
C.83: For value-like types, consider providing a noexcept swap function.	3- Significant differences	A12-8-2	The swap function is explicitly recommended for copy and move assignment operators only.
C.84: A swap function may not fail.	2- Small differences	A15-5-1	
C.85: Make swap noexcept.	2- Small differences	A15-5-1	
C.86: Make == symmetric with respect to operand types and noexcept.	2- Small differences	A13-5-5	-
C.87: Beware of == on base classes.	2- Small differences	A13-5-5	This rule is implicitly covered by adhering to A13-5-5.
C.89: Make a hash noexcept.	2- Small differences	A18-1-6	

C.120: Use class hierarchies to represent concepts with inherent hierarchical structure (only).	4 - Rejected		Non-generic design principle; There is no need for a new rule.
C.121: If a base class is used as an interface, make it a pure abstract class.	2 - Small differences		AUTOSAR C++ Coding Guidelines defines an interface class definition, see: <a href="#">Interface-Class</a> .
C.122: Use abstract classes as interfaces when complete separation of interface and implementation is needed.	2 - Small differences	<a href="#">A10-4-1</a>	
C.126: An abstract class typically doesn't need a constructor.	4 - Rejected		Non-generic design principle; There is no need for a new rule.
C.127: A class with a virtual function should have a virtual or protected destructor.	2 - Small differences	<a href="#">A12-4-1</a>	
C.128: Virtual functions should specify exactly one of virtual, override, or final.	2 - Small differences	<a href="#">A10-3-1</a>	
C.129: When designing a class hierarchy, distinguish between implementation inheritance and interface inheritance.	4 - Rejected		Non-generic design principle; There is no need for a new rule.
C.130: Redefine or prohibit copying for a base class; prefer a virtual clone function instead.	2 - Small differences	<a href="#">A12-8-6</a>	
C.131: Avoid trivial getters and setters.	4 - Rejected		All members in non-POD types shall be private.
C.132: Don't make a function virtual without reason.	4 - Rejected		Non-generic design principle; There is no need for a new rule.
C.133: Avoid protected data.	3 - Significant differences	<a href="#">M11-0-1</a>	All members in non-POD types shall be private.
C.134: Ensure all non-const data members have the same access level.	2 - Small differences	<a href="#">M11-0-1</a> , <a href="#">A11-0-2</a>	

C.135: Use multiple inheritance to represent multiple distinct interfaces.	2 - Small differences	<a href="#">A10-1-1</a>	
C.136: Use multiple inheritance to represent the union of implementation attributes.	4 - Rejected		Multiple implementation inheritance is prohibited by AUTOSAR C++ Coding Guidelines, it allows only multiple interface inheritance.
C.137: Use virtual bases to avoid overly general base classes.	4 - Rejected		It is allowed to use virtual inheritance only in a diamond hierarchy, see: <a href="#">M10-1-1</a> , <a href="#">M10-1-2</a> .
C.138: Create an overload set for a derived class and its bases with using.	4 - Rejected		Design principle. There is no need for a new rule.
C.139: Use final sparingly.	3 - Significant differences	<a href="#">A12-4-2</a>	Class shall be declared final if it has a non-virtual destructor.
C.140: Do not provide different default arguments for a virtual function and an overrider.	2 - Small differences	<a href="#">M8-3-1</a>	
C.145: Access polymorphic objects through pointers and references.	3 - Significant differences	<a href="#">A12-8-6</a> , <a href="#">A15-3-5</a>	Functionalities that could lead to slicing are prohibited.
C.146: Use dynamic_cast where class hierarchy navigation is unavoidable.	2 - Small differences	<a href="#">A5-2-1</a>	
C.147: Use dynamic_cast to a reference type when failure to find the required class is considered an error.	4 - Rejected		The dynamic_cast should not be used, see: <a href="#">A5-2-1</a> .
C.148: Use dynamic_cast to a pointer type when failure to find the required class is considered a valid alternative.	4 - Rejected		The dynamic_cast should not be used, see: <a href="#">A5-2-1</a> .
C.149: Use unique_ptr or shared_ptr to avoid forgetting to delete objects created using new.	2 - Small differences	<a href="#">A18-5-2</a>	
C.150: Use make_unique() to construct objects owned by unique_ptrs.	2 - Small differences	<a href="#">A20-8-5</a>	
C.151: Use make_shared() to construct objects owned by shared_ptrs.	2 - Small differences	<a href="#">A20-8-6</a>	

C.152: Never assign a pointer to an array of derived class objects to a pointer to its base.	2 - Small differences	<a href="#">M5-2-12</a>	
C.153: Prefer virtual function to casting.	3 - Significant differences	<a href="#">M5-2-2</a> , <a href="#">M5-2-3</a> , <a href="#">A5-2-1</a>	
C.160: Define operators primarily to mimic conventional usage.	4 - Rejected		Design principle. There is no need for a new rule.
C.161: Use nonmember functions for symmetric operators.	4 - Rejected		Design principle. There is no need for a new rule.
C.162: Overload operations that are roughly equivalent.	4 - Rejected		Design principle. There is no need for a new rule.
C.163: Overload only for operations that are roughly equivalent.	4 - Rejected		Design principle. There is no need for a new rule.
C.164: Avoid conversion operators.	2 - Small differences	<a href="#">A13-5-3</a>	
C.165: Use using for customization points.	4 - Rejected		Implementation principle. There is no need for a new rule.
C.166: Overload unary & only as part of a system of smart pointers and references.	3 - Significant differences	<a href="#">M5-3-3</a>	The unary & operator shall not be overloaded.
C.167: Use an operator for an operation with its conventional meaning.	4 - Rejected		Design principle; There is no need for a new rule.
C.168: Define overloaded operators in the namespace of their operands.	4 - Rejected		Design principle. There is no need for a new rule.
C.170: If you feel like overloading a lambda, use a generic lambda.	4 - Rejected		Design principle; There is no need for a new rule. Creating generic lambda expressions is allowed, see: <a href="#">A7-1-5</a> .



C.180: Use unions to save memory.	4 - Rejected		Unions shall not be used, see: <a href="#">A9-5-1</a> .
C.181: Avoid “naked” unions.	2 - Small differences	<a href="#">A9-5-1</a>	
C.182: Use anonymous unions to implement tagged unions.	2 - Small differences	<a href="#">A9-5-1</a>	Tagged unions allowed as an exception, but only as POD.
C.183: Don't use a union for type punning.	4 - Rejected		Unions shall not be used, see: <a href="#">A9-5-1</a> .
Enum.1: Prefer enumerations over macros.	3 - Significant differences	<a href="#">A16-0-1</a>	Usage of macros is prohibited.
Enum.2: Use enumerations to represent sets of related named constants.	2 - Small differences	<a href="#">A7-2-5</a>	
Enum.3: Prefer class enums over “plain” enums.	2 - Small differences	<a href="#">A7-2-3</a>	
Enum.4: Define operations on enumerations for safe and simple use.	4 - Rejected		Design principle. There is no need for a new rule.
Enum.5: Don't use ALL_CAPS for enumerators.	4 - Rejected		AUTOSAR C++ Coding Guidelines does not introduce rules related to coding style or naming convention.
Enum.6: Avoid unnamed enumerations.	3 - Significant differences	<a href="#">A7-2-3</a>	Enum classes shall be used instead of enums; it is not allowed to declare unnamed enum class.
Enum.7: Specify the underlying type of an enumeration only when necessary.	4 - Rejected		AUTOSAR C++ Coding Guidelines forces a programmer to specify the underlying base type explicitly, as only fixed-width numeric types shall be used. See: <a href="#">A3-9-1</a> .

Enum.8: Specify enumerator values only when necessary.	3 - Significant differences	<a href="#">A7-2-4</a>	It is defined how enumerators values should be specified.
R.1: Manage resources automatically using resource handles and RAI (Resource Acquisition Is Initialization).	4 - Rejected		AUTOSAR C++ Coding Guidelines does not define rules for coding patterns. Note that usage of RAI is recommended, see: <a href="#">A15-1-4</a> , <a href="#">A18-5-2</a> .
R.2: In interfaces, use raw pointers to denote individual objects (only).	2 - Small differences	<a href="#">M5-2-12</a>	
R.3: A raw pointer (a T*) is non-owning.	4 - Rejected		Ownership is covered by memory managing objects, see: <a href="#">A18-5-2</a> .
R.4: A raw reference (a T&) is non-owning.	4 - Rejected		Ownership is covered by memory managing objects, see: <a href="#">A18-5-2</a> .
R.5: Don't heap-allocate unnecessarily.	2 - Small differences	<a href="#">A18-5-8</a>	
R.6: Avoid non-const global variables.	3 - Significant differences	<a href="#">A3-3-2</a>	<a href="#">A3-3-2</a> covers only the initialization of global objects.
R.10: Avoid malloc() and free().	2 - Small differences	<a href="#">A18-5-1</a>	
R.11: Avoid calling new and delete explicitly.	2 - Small differences	<a href="#">A18-5-2</a>	
R.12: Immediately give the result of an explicit resource allocation to a manager object.	2 - Small differences	<a href="#">A18-5-2</a>	
R.13: Perform at most one explicit resource allocation in a single expression statement.	2 - Small differences	<a href="#">A5-0-1</a>	
R.14: ??? array vs. pointer parameter.	2 - Small differences	<a href="#">M5-2-12</a>	
R.15: Always overload matched allocation/deallocation pairs.	3 - Significant differences	<a href="#">A18-5-3</a>	
R.20: Use unique_ptr or shared_ptr to represent ownership.	2 - Small differences	<a href="#">A20-8-2</a> , <a href="#">A20-8-3</a>	
R.21: Prefer unique_ptr over shared_ptr unless you need to share ownership.	2 - Small differences	<a href="#">A20-8-4</a>	
R.22: Use make_shared() to make shared_ptrs.	2 - Small differences	<a href="#">A20-8-6</a>	

R.23: Use <code>make_unique()</code> to make <code>unique_ptr</code> s.	2 - Small differences	<a href="#">A20-8-5</a>	
R.24: Use <code>std::weak_ptr</code> to break cycles of <code>shared_ptr</code> s.	2 - Small differences	<a href="#">A20-8-7</a>	
R.30: Take smart pointers as parameters only to explicitly express lifetime semantics.	2 - Small differences	<a href="#">A8-4-11</a>	
R.31: If you have non-std smart pointers, follow the basic pattern from <code>std</code> .	4 - Rejected		There is no need for a new rule. Smart pointers are a part of Language Standard.
R.32: Take a <code>unique_ptr&lt;widget&gt;</code> parameter to express that a function assumes ownership of a widget.	2 - Small differences	<a href="#">A8-4-12</a>	
R.33: Take a <code>unique_ptr&lt;widget&gt;&amp;</code> parameter to express that a function reseats the widget.	2 - Small differences	<a href="#">A8-4-12</a>	
R.34: Take a <code>shared_ptr&lt;widget&gt;</code> parameter to express that a function is part owner.	2 - Small differences	<a href="#">A8-4-13</a>	
R.35: Take a <code>shared_ptr&lt;widget&gt;&amp;</code> parameter to express that a function might reseat the shared pointer.	2 - Small differences	<a href="#">A8-4-13</a>	
R.36: Take a <code>const shared_ptr&lt;widget&gt;&amp;</code> parameter to express that it might retain a reference count to the object ???.	2 - Small differences	<a href="#">A8-4-13</a>	
R.37: Do not pass a pointer or reference obtained from an aliased smart pointer.	2 - Small differences	<a href="#">A8-4-11</a> , <a href="#">A18-5-2</a>	Added as a reference in these rules and a note in <a href="#">A8-4-11</a> .
ES.1: Prefer the standard library to other libraries and to “handcrafted code”.	4 - Rejected		Design principle; There is no need for a new rule.
ES.2: Prefer suitable abstractions to direct use of language features.	4 - Rejected		Design principle; There is no need for a new rule.
ES.5: Keep scopes small.	2 - Small differences	<a href="#">M3-4-1</a>	
ES.6: Declare names in for-statement initializers and conditions to limit scope.	2 - Small differences	<a href="#">M3-4-1</a>	As an exception from the <a href="#">A7-1-7</a> , it is allowed to declare variables in for-statement initializer.

ES.7: Keep common and local names short, and keep uncommon and nonlocal names longer.	4 - Rejected		AUTOSAR C++ Coding Guidelines does not introduce rules related to coding style or naming convention.
ES.8: Avoid similar-looking names.	2 - Small differences	<a href="#">M2-10-1</a>	
ES.9: Avoid ALL_CAPS names.	4 - Rejected		AUTOSAR C++ Coding Guidelines does not introduce rules related to coding style or naming convention.
ES.10: Declare one name (only) per declaration.	2 - Small differences	<a href="#">A7-1-7</a>	
ES.11: Use auto to avoid redundant repetition of type names.	3 - Significant differences	<a href="#">A7-1-5</a>	It is not recommended to use the auto specifier, but it is allowed.
ES.12: Do not reuse names in nested scopes.	2 - Small differences	<a href="#">A2-10-1</a>	
ES.20: Always initialize an object.	2 - Small differences	<a href="#">A8-5-0</a>	
ES.21: Don't introduce a variable (or constant) before you need to use it.	2 - Small differences	<a href="#">M3-4-1</a>	
ES.22: Don't declare a variable until you have a value to initialize it with.	2 - Small differences	<a href="#">M3-4-1</a> , <a href="#">A8-5-0</a>	
ES.23: Prefer the {} initializer syntax.	2 - Small differences	<a href="#">A8-5-2</a>	
ES.24: Use a unique_ptr<T> to hold pointers.	3 - Significant differences	<a href="#">A18-5-2</a> , <a href="#">A15-1-4</a> , <a href="#">A18-1-3</a>	AUTOSAR C++ Coding Guidelines does not force a programmer to use std::unique_ptr, it is just highly recommended within examples and rationales.
ES.25: Declare an object const or constexpr unless you want to modify its value later on.	2 - Small differences	<a href="#">A7-1-1</a>	
ES.26: Don't use a variable for two unrelated purposes.	4 - Rejected		This rule is vague. "Unrelated" is highly context dependent.

ES.27: Use <code>std::array</code> or <code>stack_array</code> for arrays on the stack.	3 - Significant differences	<a href="#">A18-1-1</a>	C-style arrays shall not be used, and it is recommended to use <code>std::array</code> instead.
ES.28: Use lambdas for complex initialization, especially of const variables.	4 - Rejected		Design principle. There is no need for a new rule.
ES.30: Don't use macros for program text manipulation.	2 - Small differences	<a href="#">A16-0-1</a>	Usage of macros is prohibited.
ES.31: Don't use macros for constants or "functions".	2 - Small differences	<a href="#">A16-0-1</a>	Usage of macros is prohibited.
ES.32: Use ALL_CAPS for all macro names.	4 - Rejected		AUTOSAR C++ Coding Guidelines does not introduce rules related to coding style or naming convention.
ES.33: If you must use macros, give them unique names.	2 - Small differences	<a href="#">M2-10-1</a>	
ES.34: Don't define a (C-style) variadic function.	2 - Small differences	<a href="#">A8-4-1</a>	
ES.70: Prefer a switch-statement to an if-statement when there is a choice.	4 - Rejected		Design principle; The switch statement shall have at least two case-clauses, distinct from the default label. See: <a href="#">A6-4-1</a> .
ES.71: Prefer a range-for-statement to a for-statement when there is a choice.	3 - Significant differences	<a href="#">A6-5-1</a>	It is recommended to use range-based for statement to replace equivalent for-statements.
ES.72: Prefer a for-statement to a while-statement when there is an obvious loop variable.	2 - Small differences	<a href="#">A6-5-2</a>	
ES.73: Prefer a while-statement to a for-statement when there is no obvious loop variable.	3 - Significant differences	<a href="#">A6-5-2</a>	It is required that a for-loop contains a loop-counter.

ES.74: Prefer to declare a loop variable in the initializer part of a for-statement.	3 - Significant differences	<a href="#">M3-4-1</a>	It is required that each identifier is defined in a block that minimizes its visibility.
ES.75: Avoid do-statements.	2 - Small differences	<a href="#">A6-5-3</a>	
ES.76: Avoid goto.	2 - Small differences	<a href="#">A6-6-1</a>	
ES.78: Always end a non-empty case with a break.	2 - Small differences	<a href="#">M6-4-5</a>	
ES.79: Use default to handle common cases (only).	4 - Rejected		There is no need for a new rule.
ES.84: Don't (try to) declare a local variable with no name.	2 - Small differences	<a href="#">A6-2-2</a>	-
ES.85: Make empty statements visible.	2 - Small differences	<a href="#">M6-3-1</a> , <a href="#">M6-4-1</a> , <a href="#">M6-4-1</a>	
ES.86: Avoid modifying loop control variables inside the body of raw for-loops.	2 - Small differences	<a href="#">M6-5-3</a>	
ES.40: Avoid complicated expressions.	4 - Rejected		This rule is vague. Order of evaluation is covered by <a href="#">A5-0-1</a> .
ES.41: If in doubt about operator precedence, parenthesize.	2 - Small differences	<a href="#">A5-2-6</a> , <a href="#">M5-0-2</a>	
ES.42: Keep use of pointers simple and straightforward.	3 - Significant differences	<a href="#">M5-0-15</a> , <a href="#">M5-0-16</a> , <a href="#">A5-2-5</a>	'span' is not covered as it is not part of the language standard.
ES.43: Avoid expressions with undefined order of evaluation.	2 - Small differences	<a href="#">A5-0-1</a>	
ES.44: Don't depend on order of evaluation of function arguments.	2 - Small differences	<a href="#">A5-0-1</a>	
ES.45: Avoid "magic constants"; use symbolic constants.	2 - Small differences	<a href="#">A5-1-1</a>	
ES.46: Avoid lossy (narrowing, truncating) arithmetic conversions.	2 - Small differences	<a href="#">A4-7-1</a> , <a href="#">M5-0-6</a>	
ES.47: Use nullptr rather than 0 or NULL.	2 - Small differences	<a href="#">A4-10-1</a>	
ES.48: Avoid casts.	2 - Small differences	<a href="#">A5-2-1</a> , <a href="#">A5-2-2</a> , <a href="#">A5-2-3</a> , <a href="#">A5-2-4</a>	
ES.49: If you must use a cast, use a named cast.	2 - Small differences	<a href="#">A5-2-2</a>	
ES.50: Don't cast away const.	2 - Small differences	<a href="#">A5-2-3</a>	
ES.55: Avoid the need for range checking.	3 - Significant differences	<a href="#">A6-5-1</a>	<a href="#">A6-5-1</a> only covers for-loops

ES.56: Write <code>std::move()</code> only when you need to explicitly move an object to another scope.	3 - Significant differences	<a href="#">A12-8-3</a> , <a href="#">A18-9-2</a> , <a href="#">A18-9-3</a>	Vulnerabilities of <code>std::move()</code> are explained.
ES.60: Avoid <code>new</code> and <code>delete</code> outside resource management functions.	2 - Small differences	<a href="#">A18-5-2</a>	
ES.61: Delete arrays using <code>delete[]</code> and non-arrays using <code>delete</code> .	2 - Small differences	<a href="#">A18-5-3</a>	
ES.62: Don't compare pointers into different arrays.	2 - Small differences	<a href="#">M5-0-16</a>	
ES.63: Don't slice.	3 - Significant differences	<a href="#">A12-8-6</a> , <a href="#">A15-3-5</a>	The functionalities that could lead to slicing were prohibited.
ES.64: Use the <code>T{e}</code> notation for construction.	2 - Small differences	<a href="#">A8-5-2</a>	
ES.65: Don't dereference an invalid pointer.	2 - Small differences	<a href="#">A5-3-2</a>	
ES.100: Don't mix signed and unsigned arithmetic.	2 - Small differences	<a href="#">M5-0-4</a> , <a href="#">M5-0-9</a>	
ES.101: Use unsigned types for bit manipulation.	2 - Small differences	<a href="#">M5-0-21</a>	
ES.102: Use signed types for arithmetic.	3 - Significant differences	<a href="#">A4-7-1</a> , <a href="#">M5-19-1</a>	
ES.103: Don't overflow.	2 - Small differences	<a href="#">A4-7-1</a>	
ES.104: Don't underflow.	2 - Small differences	<a href="#">A4-7-1</a>	
ES.105: Don't divide by zero.	2 - Small differences	<a href="#">A5-6-1</a>	
Per.1: Don't optimize without reason.	4 - Rejected		Implementation principle; There is no need for a new rule.
Per.2: Don't optimize prematurely.	4 - Rejected		Implementation principle; There is no need for a new rule.
Per.3: Don't optimize something that's not performance critical.	4 - Rejected		Implementation principle; There is no need for a new rule.
Per.4: Don't assume that complicated code is necessarily faster than simple code.	4 - Rejected		Implementation principle; There is no need for a new rule.
Per.5: Don't assume that low-level code is necessarily faster than high-level code.	4 - Rejected		Implementation principle; There is no need for a new rule.

Per.6: Don't make claims about performance without measurements.	4 - Rejected		Implementation principle; There is no need for a new rule.
Per.7: Design to enable optimization.	4 - Rejected		Design principle; There is no need for a new rule.
Per.10: Rely on the static type system.	4 - Rejected		Implementation principle; There is no need for a new rule.
Per.11: Move computation from run time to compile time	2 - Small differences	<a href="#">A3-3-2</a> , <a href="#">A7-1-1</a> , <a href="#">A7-1-2</a>	
Per.12: Eliminate redundant aliases	4 - Rejected		This rule is incomplete.
Per.13: Eliminate redundant indirections	4 - Rejected		This rule is incomplete.
Per.14: Minimize the number of allocations and deallocations	4 - Rejected		This rule is incomplete.
Per.15: Do not allocate on a critical branch	4 - Rejected		This rule is incomplete.
Per.16: Use compact data structures	4 - Rejected		This rule is incomplete.
Per.18: Space is time	4 - Rejected		This rule is incomplete.
Per.19: Access memory predictably.	4 - Rejected		Implementation principle. There is no need for a new rule.
CP.1: Assume that your code will run as part of a multi-threaded program.	5 - Not yet analyzed		The "Concurrency and Parallelism" chapter is not yet covered, this will be addressed in future.
CP.2: Avoid data races.	5 - Not yet analyzed		The "Concurrency and Parallelism" chapter is not yet covered, this will be addressed in future.



CP.3: Minimize explicit sharing of writable data.	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
CP.4: Think in terms of tasks, rather than threads.	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
CP.8: Don’t try to use volatile for synchronization.	3 - Significant differences	<a href="#">A2-11-1</a>	Volatile keyword forbidden.
CP.20: Use RAII, never plain lock()/unlock().	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
CP.21: Use std::lock() to acquire multiple mutexes.	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
CP.22: Never call unknown code while holding a lock (e.g., a callback).	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
CP.23: Think of a joining thread as a scoped container.	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
CP.24: Think of a detached thread as a global container.	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.

CP.25: Prefer <code>gsl::raii_thread</code> over <code>std::thread</code> unless you plan to <code>detach()</code> .	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
CP.26: Prefer <code>gsl::detached_thread</code> over <code>std::thread</code> if you plan to <code>detach()</code> .	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
CP.27: Use plain <code>std::thread</code> for threads that detach based on a run-time condition (only).	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
CP.28: Remember to join scoped threads that are not <code>detach()</code> ed.	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
CP.30: Do not pass pointers to local variables to non- <code>raii_threads</code> .	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
CP.31: Pass small amounts of data between threads by value, rather than by reference or pointer.	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
[CP.32: To share ownership between unrelated threads use <code>shared_ptr</code> .	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.

CP.40: Minimize context switching.	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
CP.41: Minimize thread creation and destruction.	55 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
CP.42: Don't wait without a condition.	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
CP.43: Minimize time spent in a critical section.	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
CP.44: Remember to name your lock_guards and unique_locks.	2 - Small differences	<a href="#">A6-2-2</a>	This is a special case of the more generic rule.
P.50: Define a mutex together with the data it guards.	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
CP.60: Use a future to return a value from a concurrent task.	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.
CP.61: Use a async() to spawn a concurrent task.	5 - Not yet analyzed		The “Concurrency and Parallelism” chapter is not yet covered, this will be addressed in future.

CP.100: Don't use lock-free programming unless you absolutely have to.	5 - Not yet analyzed		The "Concurrency and Parallelism" chapter is not yet covered, this will be addressed in future.
CP.101: Distrust your hardware/compiler combination.	5 - Not yet analyzed		The "Concurrency and Parallelism" chapter is not yet covered, this will be addressed in future.
CP.102: Carefully study the literature.	5 - Not yet analyzed		The "Concurrency and Parallelism" chapter is not yet covered, this will be addressed in future.
CP.110: Do not write your own double-checked locking for initialization.	5 - Not yet analyzed		The "Concurrency and Parallelism" chapter is not yet covered, this will be addressed in future.
CP.111: Use a conventional pattern if you really need double-checked locking.	5 - Not yet analyzed		The "Concurrency and Parallelism" chapter is not yet covered, this will be addressed in future.
CP.200: Use volatile only to talk to non-C++ memory.	3 - Significant differences	<a href="#">A2-11-1</a>	Volatile keyword forbidden.
E.1: Develop an error-handling strategy early in a design.	4 - Rejected		Design principle; There is no need for a new rule.
E.2: Throw an exception to signal that a function can't perform its assigned task.	2 - Small differences	<a href="#">A15-0-1</a>	
E.3: Use exceptions for error handling only.	2 - Small differences	<a href="#">A15-0-1</a>	
E.4: Design your error-handling strategy around invariants.	4 - Rejected		Design principle; There is no need for a new rule.

E.5: Let a constructor establish an invariant, and throw if it cannot.	2 - Small differences	<a href="#">A15-2-2</a>	
E.6: Use RAll to prevent leaks.	4 - Rejected		Design principle; There is no need for a new rule.
E.7: State your preconditions.	4 - Rejected		Design principle; There is no need for a new rule.
E.8: State your postconditions.	4 - Rejected		Design principle; There is no need for a new rule.
E.12: Use noexcept when exiting a function because of a throw is impossible or unacceptable.	2 - Small differences	<a href="#">A15-4-4</a>	
E.13: Never throw while being the direct owner of an object.	3 - Significant differences	<a href="#">A15-1-4</a>	It is required to release all acquired resources and objects before a throw or a return statement.
E.14: Use purpose-designed user-defined types as exceptions (not built-in types).	3 - Significant differences	<a href="#">A15-1-1</a>	It is required that user-defined exceptions inherit from std::exception class.
E.15: Catch exceptions from a hierarchy by reference.	2 - Small differences	<a href="#">A15-3-5</a>	
E.16: Destructors, deallocation, and swap must never fail.	2 - Small differences	<a href="#">A15-5-1</a>	
E.17: Don't try to catch every exception in every function.	2 - Small differences	<a href="#">A15-3-2</a>	AUTOSAR C++ Coding Guidelines introduces checked and unchecked exceptions. Whether an exception should be caught depends if meaningful action can be performed in a given context.

E.18: Minimize the use of explicit try/catch.	4 - Rejected		Implementation principle; There is no need for a new rule.
E.19: Use a final_action object to express cleanup if no suitable resource handle is available.	4 - Rejected		The finally is not part of the C++ Language Standard.
E.25: If you can't throw exceptions, simulate RAII for resource management.	3 - Rejected		the RAII is a coding pattern; There is no need for a new rule. On the other hand, usage of RAII is recommended in the example of the <a href="#">A15-1-4</a> .
E.26: If you can't throw exceptions, consider failing fast.	4 - Rejected		Implementation principle; There is no need for a new rule.
E.27: If you can't throw exceptions, use error codes systematically.	4 - Rejected		AUTOSAR C++ Coding Guidelines does not force any specific error handling mechanism. It requires that every error information will be tested, see: <a href="#">M0-3-2</a> .
E.28: Avoid error handling based on global state (e.g. errno).	2 - Small differences	<a href="#">M19-3-1</a>	
Con.1: By default, make objects immutable.	2 - Small differences	<a href="#">A7-1-1</a>	
Con.2: By default, make member functions const.	2 - Small differences	<a href="#">M9-3-3</a>	
Con.3: By default, pass pointers and references to consts.	2 - Small differences	<a href="#">M7-1-2</a>	
Con.4: Use const to define objects with values that do not change after construction.	2 - Small differences	<a href="#">A7-1-1</a>	
Con.5: Use constexpr for values that can be computed at compile time.	2 - Small differences	<a href="#">A7-1-2</a>	
T.1: Use templates to raise the level of abstraction of code.	4 - Rejected		Design principle; There is no need for a new rule.

T.2: Use templates to express algorithms that apply to many argument types.	4 - Rejected		Design principle; There is no need for a new rule.
T.3: Use templates to express containers and ranges.	4 - Rejected		Design principle; There is no need for a new rule.
T.4: Use templates to express syntax tree manipulation.	4 - Rejected		Design principle; There is no need for a new rule.
T.5: Combine generic and OO techniques to amplify their strengths, not their costs.	4 - Rejected		Design principle; There is no need for a new rule.
T.10: Specify concepts for all template arguments.	4 - Rejected		Concepts are not part of the C++14 Language Standard.
T.11: Whenever possible use standard concepts.	4 - Rejected		Concepts are not part of the C++14 Language Standard.
T.12: Prefer concept names over auto for local variables.	4 - Rejected		Concepts are not part of the C++14 Language Standard.
T.13: Prefer the shorthand notation for simple, single-type argument concepts.	4 - Rejected		Concepts are not part of the C++14 Language Standard.
T.20: Avoid "concepts" without meaningful semantics.	4 - Rejected		Concepts are not part of the C++14 Language Standard.
T.21: Require a complete set of operations for a concept.	4 - Rejected		Concepts are not part of the C++14 Language Standard.

T.22: Specify axioms for concepts.	4 - Rejected		Concepts are not part of the C++14 Language Standard.
T.23: Differentiate a refined concept from its more general case by adding new use patterns..	4 - Rejected		Concepts are not part of the C++14 Language Standard.
T.24: Use tag classes or traits to differentiate concepts that differ only in semantics..	4 - Rejected		Concepts are not part of the C++14 Language Standard.
T.25: Avoid complementary constraints.	4 - Rejected		Concepts are not part of the C++14 Language Standard.
T.26: Prefer to define concepts in terms of use-patterns rather than simple syntax.	4 - Rejected		Concepts are not part of the C++14 Language Standard.
T.40: Use function objects to pass operations to algorithms.	4 - Rejected		Implementation principle; There is no need for a new rule.
T.41: Require only essential properties in a template's concepts.	4 - Rejected		Concepts are not part of the C++14 Language Standard.
T.42: Use template aliases to simplify notation and hide implementation details.	4 - Rejected		Implementation principle. There is no need for a new rule.
T.43: Prefer using over typedef for defining aliases.	2 - Small differences	<a href="#">A7-1-6</a>	
T.44: Use function templates to deduce class template argument types (where feasible).	4 - Rejected		Implementation principle; There is no need for a new rule.
T.46: Require template arguments to be at least Regular or SemiRegular.	4 - Rejected		Implementation principle; There is no need for a new rule.



T.47: Avoid highly visible unconstrained templates with common names.	4 - Rejected	M17-0-2, M17-0-3	This rule is vague. "Highly visible" and "common names" have no technical meaning.
T.48: If your compiler does not support concepts, fake them with enable_if.	4 - Rejected		Implementation principle; There is no need for a new rule.
T.49: Where possible, avoid type-erasure.	4 - Rejected		This rule is incomplete. This rule is vague. "Where possible" has no technical meaning.
T.60: Minimize a template's context dependencies.	4 - Rejected		This rule is vague.
T.61: Do not over-parameterize members (SCARY).	2 - Small differences	A14-1-1, A14-7-1	
T.62: Place non-dependent class template members in a non-templated base class.	2 - Small differences	A14-5-2	-
T.65: Use tag dispatch to provide alternative implementations of a function.	4 - Rejected		Implementation principle; There is no need for a new rule.
T.68: Use rather than () within templates to avoid ambiguities.	2 - Small differences	A8-5-2	
T.69: Inside a template, don't make an unqualified nonmember function call unless you intend it to be a customization point.	4 - Rejected		Implementation principle. There is no need for a new rule.
T.80: Do not naively templatize a class hierarchy.	5 - Not yet analyzed	-	-
T.81: Do not mix hierarchies and arrays.	2 - Small differences	A5-0-4	
T.83: Do not declare a member function template virtual.	4 - Rejected		There is no need for a new rule. Handled by a compiler.
T.84: Use a non-template core implementation to provide an ABI-stable interface.	4 - Rejected		Design principle. There is no need for a new rule.

T.100: Use variadic templates when you need a function that takes a variable number of arguments of a variety of types.	2 - Small differences	<a href="#">A8-4-1</a>	
T.101: How to pass arguments to a variadic template.	4 - Rejected		This rule is incomplete.
T.102: How to process arguments to a variadic template.	4 - Rejected		There is no need for a new rule.
T.103: Don't use variadic templates for homogeneous argument lists.	4 - Rejected		There is no need for a new rule.
T.120: Use template metaprogramming only when you really need to.	4 - Rejected		This rule is vague. "When you really need to" has no technical meaning.
T.121: Use template metaprogramming primarily to emulate concepts.	4 - Rejected		Implementation principle. There is no need for a new rule.
T.122: Use templates (usually template aliases) to compute types at compile time.	4 - Rejected		Implementation principle. There is no need for a new rule.
T.123: Use constexpr functions to compute values at compile time.	4 - Rejected		Implementation principle. There is no need for a new rule.
T.124: Prefer to use standard-library TMP facilities.	4 - Rejected		There is no need for a new rule.
T.125: If you need to go beyond the standard-library TMP facilities, use an existing library.	4 - Rejected		This rule is vague. "beyond the standard-library TMP facilities" has no technical meaning.
T.140: Name all operations with potential for reuse.	4 - Rejected		
T.141: Use an unnamed lambda if you need a simple function object in one place only.	3 - Significant differences	<a href="#">A5-1-9</a>	Only forbids duplication of identical lambda expressions.
T.142: Use template variables to simplify notation.	4 - Rejected		This rule is incomplete.

T.143: Don't write unintentionally nongeneric code.	5 - Not yet analyzed	-	-
T.144: Don't specialize function templates.	2 - Small differences	<a href="#">A14-8-2</a>	
T.150: Check that a class matches a concept using <code>static_assert</code> .	2 - Small differences	<a href="#">A14-1-1</a>	
CPL.1: Prefer C++ to C.	2 - Small differences	<a href="#">A17-1-1</a> , <a href="#">A18-0-1</a>	
CPL.2: If you must use C, use the common subset of C and C++, and compile the C code as C++.	4 - Rejected		There is no need for a new rule.
CPL.3: If you must use C for interfaces, use C++ in the calling code using such interfaces.	5 - Not yet analyzed	-	-
SF.1: Use a <code>.cpp</code> suffix for code files and <code>.h</code> for interface files if your project doesn't already follow another convention.	3 - Significant differences	<a href="#">A3-1-2</a> , <a href="#">A3-1-3</a>	For header file names, AUTOSAR C++ Coding Guidelines allows either <code>.h</code> , <code>.hpp</code> or <code>.hxx</code> extension.
SF.2: A <code>.h</code> file may not contain object definitions or non-inline function definitions.	2 - Small differences	<a href="#">A3-1-1</a>	
SF.3: Use <code>.h</code> files for all declarations used in multiple source files.	2 - Small differences	<a href="#">M3-2-2</a> , <a href="#">A3-3-1</a>	
SF.4: Include <code>.h</code> files before other declarations in a file.	2 - Small differences	<a href="#">M16-0-1</a>	
SF.5: A <code>.cpp</code> file must include the <code>.h</code> file(s) that defines its interface.	5 - Not yet analyzed	-	-
SF.7: Don't write using namespace in a header file.	2 - Small differences	<a href="#">M7-3-6</a>	
SF.8: Use <code>#include</code> guards for all <code>.h</code> files.	2 - Small differences	<a href="#">M16-2-3</a>	
SF.9: Avoid cyclic dependencies among source files.	5 - Not yet analyzed	-	-
SF.21: Don't use an unnamed (anonymous) namespace in a header.	2 - Small differences	<a href="#">M7-3-3</a>	
SF.22: Use an unnamed (anonymous) namespace for all internal/nonexported entities.	5 - Not yet analyzed	-	-
SL.1: Use libraries wherever possible.	4 - Rejected		Design principle; There is no need for a new rule.
SL.2: Prefer the standard library to other libraries.	4 - Rejected		Design principle; There is no need for a new rule.
SL.3: Do not add non-standard entities to namespace <code>std</code> .	2 - Small differences	<a href="#">A17-6-1</a>	

SL.con.1: Prefer using STL array or vector instead of a C array.	2 - Small differences	<a href="#">A18-1-1</a>	
SL.con.2: Prefer using STL vector by default unless you have a reason to use a different container.	4 - Rejected		This rule is vague. "have a reason to" has no technical meaning.
SL.str.1: Use std::string to own character sequences	2 - Small differences	<a href="#">A27-0-4</a>	
SL.io.50: Avoid endl.	5 - Not yet analyzed	-	-
Type.1: Don't use reinterpret_cast.	2 - Small differences	<a href="#">A5-2-4</a>	
Type.2: Don't use static_cast downcasts. Use dynamic_cast instead.	2 - Small differences	<a href="#">M5-2-2</a>	
Type.3: Don't use const_cast to cast away const (i.e., at all).	2 - Small differences	<a href="#">A5-2-3</a>	
Type.4: Don't use C-style (T) expression casts that would perform a static_cast downcast, const_cast, or reinterpret_cast.	2 - Small differences	<a href="#">A5-2-2</a>	
Type.5: Don't use a variable before it has been initialized.	2 - Small differences	<a href="#">A8-5-0</a>	
Type.6: Always initialize a member variable.	2 - Small differences	<a href="#">A12-1-1</a>	
Type.7: Avoid accessing members of raw unions. Prefer variant instead.	2 - Small differences	<a href="#">A9-5-1</a>	
Type.8: Avoid reading from varargs or passing vararg arguments. Prefer variadic template parameters instead.	2 - Small differences	<a href="#">A8-4-1</a>	
Bounds.1: Don't use pointer arithmetic. Use span instead.	2 - Small differences	<a href="#">M5-0-15</a>	
Bounds.2: Only index into arrays using constant expressions.	2 - Small differences	<a href="#">A5-2-5</a>	
Bounds.3: No array-to-pointer decay.	2 - Small differences	<a href="#">M5-2-12</a>	
Bounds.4: Don't use standard library functions and types that are not bounds-checked.	5 - Not yet analyzed	-	-
NL.1: Don't say in comments what can be clearly stated in code.	4 - Rejected		AUTOSAR C++ Coding Guidelines does not introduce rules related to coding style or naming convention.
NL.2: State intent in comments.	4 - Rejected		AUTOSAR C++ Coding Guidelines does not introduce rules related to coding style or naming convention.

NL.3: Keep comments crisp.	4 - Rejected		AUTOSAR C++ Coding Guidelines does not introduce rules related to coding style or naming convention.
NL.4: Maintain a consistent indentation style.	4 - Rejected		AUTOSAR C++ Coding Guidelines does not introduce rules related to coding style or naming convention.
NL.5 Don't encode type information in names.	4 - Rejected		AUTOSAR C++ Coding Guidelines does not introduce rules related to coding style or naming convention.
NL.7: Make the length of a name roughly proportional to the length of its scope.	4 - Rejected		AUTOSAR C++ Coding Guidelines does not introduce rules related to coding style or naming convention.
NL.8: Use a consistent naming style.	4 - Rejected		AUTOSAR C++ Coding Guidelines does not introduce rules related to coding style or naming convention.
NL.9: Use ALL_CAPS for macro names only.	4 - Rejected		AUTOSAR C++ Coding Guidelines does not introduce rules related to coding style or naming convention.

NL.10: Avoid CamelCase.	4 - Rejected		AUTOSAR C++ Coding Guidelines does not introduce rules related to coding style or naming convention.
NL.15: Use spaces sparingly.	4 - Rejected		AUTOSAR C++ Coding Guidelines does not introduce rules related to coding style or naming convention.
NL.16: Use a conventional class member declaration order.	4 - Rejected		AUTOSAR C++ Coding Guidelines does not introduce rules related to coding style or naming convention.
NL.17: Use K&R-derived layout.	4 - Rejected		AUTOSAR C++ Coding Guidelines does not introduce rules related to coding style or naming convention.
NL.18: Use C++-style declarator layout.	4 - Rejected		AUTOSAR C++ Coding Guidelines does not introduce rules related to coding style or naming convention.
NL.19: Avoid names that are easily misread.	2 - Small differences	<a href="#">M2-10-1</a>	
NL.20: Don't place two statements on the same line.	3 - Significant differences	<a href="#">A7-1-7</a>	It is required for declarations only.
NL.21: Declare one name (only) per declaration.	2 - Small differences	<a href="#">A7-1-7</a>	
NL.25: Don't use void as an argument type.	5 - Not yet analyzed	-	-
NL.26: Use conventional const notation.	5 - Not yet analyzed	-	-

**Table B.5: C++ Core Guidelines**

## B.6 Traceability to ISO 26262

Each method in the tables referenced from the ISO 26262 standard is an entry that is one of the following:

consecutive – all methods shall be applied as recommended, but with different recommendation level that depends on the ASIL level.

alternative – an appropriate combination of methods shall be applied.

Consecutive methods are marked by a sequence number, e.g. 1, 2, 3. Alternative entries are marked by a number followed by a letter, e.g. 1a, 1b, 1c.

This chapter traces mostly principles and recommendations from Section 8 (Software unit design and implementation) of the Part 6 of the ISO 26262. The rest of the document is not applicable to the AUTOSAR C++14 Coding Guidelines. Although AUTOSAR C++14 Coding Guidelines contain multiple rules allocated to other work products (e.g. software architectural design, verification), those are considered as recommendations for doing review of such work products, not as a direct fulfillment of ISO 26262 requirements.

### Part 6: Product development at the software level

#### Initiation of product development at the software level

##### 5.4: Requirements and recommendations

ISO 26262 requirement:	Relation type:	Related rule:	Comment:
1 an unambiguous definition	6 - Implemented	[3, ISO/IEC 14882:2014], A2-13-2, A1-1-1	Syntax and semantics of the language unambiguously defined. Restrictions on using conditionally-supported or deprecated features.
2 the support for embedded real time software and runtime error handling	6 - Implemented	A15-0-1, A15-0-4, A15-0-5, A15-0-6, A15-0-7, A15-0-8, A18-5-5, A18-5-6, A18-5-7	Introduction of Checked and Unchecked Exceptions. Usage of exceptions limited only to error handling. Additional requirements on toolchain support for memory management and exceptions handling.
3 the support for modularity, abstraction and structured constructs	6 - Implemented	A8-4-14, A10-0-1, A10-0-2, A10-4-1	Recommendations on which constructs to use to increase software reusability and hide implementation details.

**Table B.6: The criteria that shall be considered when selecting a suitable modeling or programming language. Paragraph 5.4.6 from [5].**

ISO 26262 requirement:		Relation type:	Related rule:	Comment:
1a	Enforcement of low complexity	6 - Implemented	<a href="#">A1-4-1</a>	Requirements on code metrics. Plenty of AUTOSAR C++14 Coding Guidelines rules forbid constructs that introduce unnecessary complexity and are error-prone, e.g. <a href="#">A9-6-2</a> , <a href="#">M10-2-1</a> , <a href="#">A10-2-1</a> .
1b	Use of language subsets	6 - Implemented	<a href="#">3.1</a>	Plenty of AUTOSAR C++14 Coding Guidelines rules forbid constructs that are allowed from the C++ language perspective, but (1) lead to unstructured designs, (2) are misleading for a developer, (3) are implementation defined. In case some features are to be used in a particular project nonetheless, see chapter <a href="#">5.4</a> .
1c	Enforcement of strong typing	6 - Implemented	<a href="#">M5-2-2</a> , <a href="#">M5-2-3</a> , <a href="#">A5-2-2</a> , <a href="#">A5-2-3</a> , <a href="#">M5-2-6</a> , <a href="#">A5-2-4</a> , <a href="#">M5-2-9</a> , <a href="#">A8-4-14</a> , <a href="#">A7-2-3</a>	Restrictions on type casting. Recommendations on strongly-typed interfaces and scoped enums.
1d	Use of defensive implementation techniques	6 - Implemented	<a href="#">A0-4-4</a> , <a href="#">A4-7-1</a> , <a href="#">A5-2-5</a> , <a href="#">A6-5-1</a> , <a href="#">A14-1-1</a> , <a href="#">A15-3-4</a>	Error checking required for math functions, integer expressions, array access. Limitations on iteration statements. Recommendations on how to cope with external code failures.
1e	Use of established design principles	6 - Implemented	<a href="#">6.18.5</a> , <a href="#">A18-5-2</a> , <a href="#">A0-1-4</a>	Recommendation on RAIL, exception in rules that facilitate correct usage of SFINAE and Concepts. Multiple rules contain references to corresponding rules from multiple standards, which confirms that the provided rule set reflects widely approved coding techniques.



1f	Use of unambiguous graphical representation	8 - Not applicable		Recommendations on graphical representation is out of scope of AUTOSAR C++14 Coding Guidelines.
1g	Use of style guides	8 - Not applicable		AUTOSAR C++14 Coding Guidelines does not introduce rules related to coding style.
1h	Use of naming conventions	8 - Not applicable		AUTOSAR C++14 Coding Guidelines does not introduce rules related to naming convention.

**Table B.7: Topics to be covered by modelling and coding guidelines. Table 1 from [5].**

## Software unit design and implementation 8.4:

### Requirements and recommendations

ISO 26262 requirement:		Relation type:	Related rule:	Comment:
1a	Natural language	7 - Partially implemented	<a href="#">A2-7-3</a> , <a href="#">A2-7-5</a>	Requirements on: providing documentation for user-defined types, content and structure of the documentation.
1b	Informal notations			
1c	Semi-formal notations			
1d	Formal notations			

**Table B.8: Notations for software unit design. Table 7 from [5].**

ISO 26262 requirement:		Relation type:	Related rule:	Comment:
1a	One entry and one exit point in subprograms and functions	6 - Implemented		See <a href="#">Single-point-of-exit</a> . All the benefits from this approach are handled by different measures. Code modularity aspects are also ensured by techniques and limitations that fulfill other ISO26262 requirements, see: <a href="#">Enforcement of low complexity</a> , <a href="#">Readability and comprehensibility</a> , <a href="#">Suitability for modifications</a> .
1b	No dynamic objects or variables, or else online test during their creation	6 - Implemented	<a href="#">A18-5-5</a> , <a href="#">A18-5-6</a> , <a href="#">A18-5-7</a> , <a href="#">A18-5-2</a> , <a href="#">A18-5-9</a> , <a href="#">A18-5-10</a>	Dynamic memory allowed, but under multiple constraints affecting memory management. Allocated objects lifetime maintenance delegated to shared pointers and memory management objects. Restrictions set for custom implementations of dynamic memory allocation and placement new.

1c	Initialization variables	of	6 - Implemented	A8-5-0, A3-3-2, A6-5-4, A8-5-1, A8-5-3, A8-5-4, A12-1-1, A12-1-2, A12-1-6	Required is: memory initialization before access, constant initialization of static and thread-local objects, loop counters initialization. Defined are requirements for: initialization lists, initialization of type auto, user-declared constructors, NSDMI, delegating constructors.
1d	No multiple use of variable names		6 - Implemented	M2-10-1, A2-10-1, A2-10-6, A2-10-4, A2-10-5, M3-4-1	Limitations on identifier hiding and requirements on typographical unambiguity.
1e	Avoid global variables or else justify their usage		7 - Partially implemented	A3-3-2	Global variables shall be constant-initialized.
1f	Limited use of pointers		6 - Implemented	A8-4-11, A8-4-10, M5-0-15, M5-0-16, M5-0-17, M5-0-18, A5-0-4, A5-0-3	Lifetime semantics is to be handled using smart pointers and usage of raw pointers is limited only to passing parameters that are not owned by the pointer (as currently no constructs from C++14 Standard could replace it), which resolves problems with possible memory leaks. Restrictions on pointers arithmetic, no more than two levels of pointer indirection, pointers usage limited only to single objects. Listed rule set fulfills also all the requirements described in [19], chapter C.2.6.6 “Limited use of pointers”, apart from “Data exchange should be done via the operating system”, which is out of scope of this document.
1g	No implicit type conversions		6 - Implemented	A4-5-1, A4-7-1, M4-10-1, M5-0-4, M5-0-5, M5-0-6, A7-2-3, A8-5-2, A13-5-2, A13-5-3, A23-0-1	It is forbidden to use: enums in arithmetic contexts, integer conversions that lead to data loss, NULL as an integer value, non-scoped enumerations, conversion from iterator to const_iterator. It is additionally protected by forcing: braced initialization of variables and restrictions on user-defined conversion operators.

1h	No hidden data or control flow	7 - Partially implemented	A15-0-6, A15-0-7, A15-0-8, 6.15	Usage of exceptions as a method for error handling is not enforced by the AUTOSAR Coding Guidelines. However, if it is to be used in a particular project, it (1) is allowed only if strict requirements on a toolchain are fulfilled, e.g. analysis of failure modes of exception handling, deterministic worst-case execution time. (2) is forbidden as part of the typical program flow and is limited only for handling errors where a function failed to perform its assigned task. (3) requires analysis of maximum execution time constraints for a particular software project. Using Checked Exceptions for signaling recoverable errors brings benefits to completeness of error handling procedure, as it enforces developers to provide a dedicated handling hook for each type of such errors. Rules for stack unwinding are unambiguously defined by [3, ISO/IEC 14882:2014], thus it is possible to establish a matching catch clause for each exception thrown in the software, to which the control flow will jump after exception is thrown. By default, handling of Unchecked Exceptions should lead to proper program termination, therefore stack unwinding ensures correct invocation of destructors for all objects with automatic storage duration, which prevents from possible memory leaks in case of errors (considering no violations of available rules for memory management). However, usage of exceptions still introduces a hidden control flow into a program execution, thus such an approach only partially implements this requirement from the ISO26262-6 [5].
1i	No unconditional jumps	6 - Implemented	A6-6-1, M17-0-2	Lack of exact definition of “unconditional jump” in ISO 26262 [5] and C++14 Standard [3], therefore the statement from IEC 61508 Annex C [19] was assumed: “avoid unconditional jumps (goto) in higher level languages”.
1j	No recursions	6 - Implemented	A7-5-2	

**Table B.9: Design principles for software unit design and implementation. Table 8 from [5].**

ISO 26262 requirement:		Relation type:	Related rule:	Comment:
1a	correct order of execution of subprograms and functions within the software units, based on the software architectural design	6 - Implemented	A15-4-1, A15-4-2, A15-5-2, A15-5-3	Restrictions on constructs that may lead to program termination without calling proper exit handlers and destructors.
1b	consistency of the interfaces between the software units	6 - Implemented	M1-0-2, A15-1-5	Restrictions on: passing non-standard layout type objects and exceptions across execution boundaries.
1c	correctness of data flow and control flow between and within the software units	6 - Implemented	M0-3-1, A15-0-1, A15-0-4, A15-0-5, A15-3-2, A15-3-3, A15-3-4, M15-0-3, A6-6-1	Checked and Unchecked exceptions are to be used only for error handling, they are forbidden for handling the normal control flow. Additional explanation of this property from [19]: "The software design shall include, commensurate with the required safety integrity level, self-monitoring of control flow and data flow. On failure detection, appropriate actions shall be taken."
1d	simplicity	6 - Implemented	A1-4-1, A8-4-3, A10-1-1, A14-7-2	Forcing limitations for cases that limit maintainability and readability.
1e	readability and comprehensibility	6 - Implemented	A1-4-1, A1-4-3, A5-1-1, A5-1-9, A10-2-1, M10-2-1, A12-7-1, A14-7-2	Enforcing code metrics, forbidding constructs that are confusing, lead to code duplication or introduce unnecessary complexity.
1f	robustness	6 - Implemented	M0-3-1, M0-3-2, A1-1-1, A15-0-2, A15-0-3, A15-0-6, A15-0-7, A18-5-6	Checked exceptions concept which facilitates tracking if a particular error type is handled. Recommendations on how to report errors in an application. Requirements on analysis of failure modes and worst-case execution time for exception handling and memory management.

1g	suitability for software modification	6 - Implemented	A8-4-14, A10-0-1, A10-0-2, A10-4-1	Recommending constructs that increase software reusability, eliminate redundancy and hide implementation details.
1h	testability	6 - Implemented	A1-2-1, A1-4-1, A3-3-2	Requirements on: testing error information if this is generated, using code metrics which will increase code quality and modularity. Restrictions on constructs that obscure code maintainability. Suggestions on how to perform extensive testing.

**Table B.10: Properties to be achieved by applying design principles from Table 8. Paragraph 8.4.4 from [5].**

ISO 26262 requirement:		Relation type:	Related rule:	Comment:
1a	Walk-through	8 - Not applicable		Process of system examination to reveal discrepancies between a specification and implementation is out of scope of AUTOSAR C++14 Coding Guidelines.
1b	Inspection	8 - Not applicable		Structured processes (at any level of rigour) of revealing defects in developed software components are out of scope of AUTOSAR C++14 Coding Guidelines.
1c	Semi-formal verification	8 - Not applicable		Aspects of proving the correctness of a program basing on an abstract model are out of scope of AUTOSAR C++14 Coding Guidelines.
1d	Formal verification			
1e	Control flow analysis	7 - Partially implemented	M0-1-1, M0-1-2, M0-1-8, M0-1-9, M0-1-10, A0-1-3	Available are rules oriented on finding suspect areas of code (e.g. inaccessible code, infeasible paths), but analysis of directed program graph (from the definition from paragraph C.5.9 [19]) is out of scope of AUTOSAR C++14 Coding Guidelines.

1f	Data flow analysis	6 - Implemented	M0-1-3, M0-1-4, A0-1-1, A0-1-4, A0-1-5, A0-1-6, A8-5-0	Available are rules oriented on analysis of sequences of creating, referencing and deleting variables.
1g	Static code analysis	6 - Implemented		All automated rules included in AUTOSAR C++14 Coding Guidelines are enforceable by means of static code analysis.
1h	Semantic code analysis	8 - Not applicable		Mathematical source code analysis by use of an abstract representation of possible values is out of scope of AUTOSAR C++14 Coding Guidelines.

**Table B.11: Methods for the verification of software unit design and implementation.**  
Table 9 from [5].

## C Glossary

Abbreviation / Acronym:	Description:
Real-time application (RTA)	A real-time application is a program that guarantees response within defined time constraints. The latency must be less than a defined value, usually measured in seconds or milliseconds. Whether or not a given application program qualifies as an RTA depends on the worst-case execution time (WCET) - the maximum length of time a defined task requires on a given hardware platform.
MISRA	Motor Industry Software Reliability Association.
HIC++	High Integrity C++ Coding Standard.
cvalue expression	An expression that should not undergo further conversions, either implicitly or explicitly, is called a cvalue expression.
Ownership	Ownership of a resource means that the resource's lifetime is fully managed by the single class instance or tied with the class instance lifetime. See also: chapter <a href="#">6.18.5</a>

<p>One definition rule</p>	<p>The rule states that:</p> <p>There shall be one and only one definition of any variable, function, class type, enumeration type, or template in a translation unit. Some of these may have multiple declarations, but only one definition is allowed.</p> <p>There shall be one and only one definition of every non-inline function or variable that is odr-used in the entire program.</p> <p>An inline function definition is required in every translation unit where it is odr-used.</p> <p>There shall be one and only one definition of a class in any translation unit where the class is used in a way that requires it to be complete.</p> <p>There can be more than one definition of any class, enumeration type, inline function with external linkage, class template, non-static function template, static data member of a class template, member function of a class template, partial template specialization in a program, as long as all of the following is true:</p> <ul style="list-style-type: none"> <li>– each definition consists of the same sequence of tokens (typically, appears in the same header file)</li> <li>– name lookup from within each definition finds the same entities (after overload-resolution), except that constants with internal or no linkage may refer to different objects as long as they are not ODR-used and have the same values in every definition.</li> <li>– overloaded operators, including conversion, allocation, and deallocation functions refer to the same function from each definition (unless referring to one defined within the definition)</li> <li>– the language linkage is the same (e.g. the include file isn't inside an extern "C" block)</li> <li>– the three rules above apply to every default argument used in each definition             <ul style="list-style-type: none"> <li>– if the definition is for a class with an implicitly-declared constructor, every translation unit where it is odr-used must call the same constructor for the base and members</li> <li>– if the definition is for a template, then all these requirements apply to both names at the point of definition and dependent names at the point of instantiation</li> </ul> </li> </ul> <p>If all these requirements are satisfied, the program behaves as if there is only one definition in the entire program. Otherwise, the behavior is undefined.</p>
<p>ODR-use</p>	<p>An object is odr-used if its address is taken, or a reference is bound to it. A function is odr-used if a function call to it is made or its address is taken.</p>



<p>POD Type</p>	<p>POD (Plain Old Data) type is the type that is compatible with types used in the C programming language, can be manipulated using C library functions, and can be exchanged with C libraries directly in its binary form.</p>
<p>Trivially Copyable Class</p>	<p>A class (C++ Language Standard [3], chapter 9):</p> <ul style="list-style-type: none"> <li>where each copy constructor, move constructor, copy assignment operator, move assignment operator is either deleted or trivial</li> <li>that has at least one non-deleted copy constructor, move constructor, copy assignment operator, or move assignment operator, and</li> <li>that has a trivial, non-deleted destructor</li> </ul>
<p>Standard-Layout Class</p>	<p>A class that (C++ Language Standard [3], chapter 9):</p> <ul style="list-style-type: none"> <li>has no non-static data members of type non-standard-layout class (or array of such types) or reference</li> <li>has no virtual functions and no virtual base classes</li> <li>has the same access control for all non-static data members</li> <li>has no non-standard-layout base classes</li> <li>has at most one base class subobject of any given type</li> <li>has all non-static data members and bit-fields in the class and its base classes first declared in the same class</li> <li>has no element of the set <math>M(X)</math> of types as a base class where <math>M(X)</math> is defined as follows: <ul style="list-style-type: none"> <li>– If <math>X</math> is a non-union class type, the set <math>M(X)</math> is empty if <math>X</math> has no (possibly inherited) non-static data members; otherwise, it consists of the type of the first non-static data member of <math>X</math> (where said member may be an anonymous union), <math>X0</math>, and the elements of <math>M(X0)</math>.</li> <li>– If <math>X</math> is a union type, the set <math>M(X)</math> is the union of all <math>M(U_i)</math> and the set containing all <math>U_i</math>, where each <math>U_i</math> is the type of the <math>i</math>-th non-static data member of <math>X</math>.</li> <li>– If <math>X</math> is a non-class type, the set <math>M(X)</math> is empty.</li> </ul> </li> </ul>

Dataflow Anomaly	<p>The state of a variable at a point in a program can be described using the following terms:</p> <p>Undefined (U): The value of the variable is indeterminate. Referenced (R): The variable is used in some way (e.g. in an expression).</p> <p>Defined (D): The variable is explicitly initialized or assigned a value.</p> <p>Given the above, the following dataflow anomalies can be defined:</p> <p>UR dataflow anomaly: Variable not assigned a value before the specified use (this may result in undefined behavior).</p> <p>DU dataflow anomaly: Variable is assigned a value that is never subsequently used.</p> <p>DD dataflow anomaly: Variable is assigned a value twice with no intermediate use.</p>
Dead Code	Dead code (also known as redundant code) consists of evaluated expressions whose removal would not affect the output program.
Unreachable Code	Unreachable code is code to which there is no syntactic (control flow) path, e.g. a function which is never called, either directly or indirectly.
Diamond Problem	The “diamond problem” is an ambiguity that arises when two classes B and C inherit from A, and class D inherits from both B and C. If there is a method provided by class A, that is overridden in both B and C and D does not override it, then there is an ambiguity which version of the method does D actually inherit. See: <a href="http://Wikipedia.org">Wikipedia.org</a> for more details.
Interface class	<p>An interface class is a class which has following properties:</p> <p>if there are any, all member functions are public pure virtual</p> <p>if there are any, all data members are public static constexpr</p>
Extended precision format	<p>The IEEE Standard for Floating-Point Arithmetic (IEEE 754) specifies extended precision formats, that are recommended for allowing a greater precision format than that provided by the basic formats.</p> <p>For an extended format the exponent range must be as great as that of the next wider basic format. For instance, 64-bit extended precision binary number must have an “exponent max” of at least 16383, which is equal to “exponent max” of 128-bit binary floating-point. The 80-bit extended format meets this requirement.</p>

Fundamental types		C++ built-in types defined in C++ Language Standard [3] in chapter 3.9.1, e.g. char, signed char, unsigned char, int, long long int, wchar_t, bool, float, double, void, std::nullptr_t, etc.
Scalar types		The following types are scalar types:  integral types floating point types pointers and pointers to members enumerations std::nullptr_t
glvalue		A glvalue is an expression whose evaluation determines the identity of an object, bit-field, or function.
xvalue		An xvalue refers to an object, usually near the end of its lifetime, so that its resources may be moved.
prvalue		A prvalue is an expression whose evaluation initializes an object or a bit-field, or computes the value of the operand of an operator.
rvalue		An rvalue is an xvalue or a prvalue.
lvalue		An lvalue is a glvalue that is not an xvalue.
Implicitly-defined constructor	default	Implicitly-defined default constructor calls default constructors of its base classes and non-static data members. It has exactly the same effect as a user-defined constructor with empty body and empty initializer list.
Implicitly-defined constructor	copy	Implicitly-defined copy constructor of a class type (class or struct) performs full member-wise copy of the object's bases and non-static data members, in their initialization order, using direct initialization.
Implicitly-defined constructor	move	Implicitly-defined move constructor of a class type (class or struct) performs full member-wise move of the object's bases and non-static members, in their initialization order, using direct initialization with an xvalue argument.
Implicitly-defined assignment operator	copy	Implicitly-defined copy assignment operator of a class type (class or struct) performs full member-wise copy assignment of the object's bases and non-static data members, in their initialization order, using built-in assignment for the scalars and copy assignment operator for class types.
Implicitly-defined assignment operator	move	Implicitly-defined move assignment operator of a class type (class or struct) performs full member-wise move assignment of the object's direct bases and immediate non-static data members, in their initialization order, using built-in assignment for the scalars, member-wise move-assignment for arrays, and move assignment operator for class types (called non-virtually).

Implicitly-defined destructor	Implicitly-defined destructor has an empty body. After the body of the destructor is executed, the destructors for all non-static non-variant data members of the class are called, in reverse order of declaration. Then it calls destructors of all direct non-virtual base classes, in reverse order of construction, and then it calls the destructors of all virtual bases.
Is-a relationship	Subsumption relationship between types. If one class B is a subclass of another class A (i.e. B is a more specialized concept than A), then B class specification implies A class specification and a B class object can be used for any expression that requires an A class object.
Has-a relationship	Composition relationship where one object is a part or member of another object with respect to the rules of ownership.

**Table C.1: Acronyms**

Definition:	Description:
Single point of exit	<p>Approach background:</p> <p>IEC 61508 [19], as one of methods for providing modular approach</p> <p>ISO26262 part 6 [5] with the requirement for ASIL A-D.</p> <p>MISRA-C++ 2008 with the rule <a href="#">M6-6-5</a>.</p> <p>AUTOSAR Coding Guidelines consider that the only reason for such an approach is improving robustness of resource handling, e.g. ensuring that resources are properly released in case of an early exit from the function. However, it is fully ensured by other rules existing in the document that:</p> <ul style="list-style-type: none"> <li>enforce usage of smart pointers and memory management objects for expressing lifetime semantics (<a href="#">A18-5-2</a>)</li> <li>enforce allocate local objects on stack (<a href="#">A18-5-8</a>)</li> <li>recommend usage of RAII (<a href="#">A15-1-4</a>, <a href="#">A18-5-2</a>)</li> </ul> <p>Single point of exit is considered to decrease code readability and will not bring any additional benefits for improving coding standards, thus it is not enforced by the AUTOSAR Coding Guidelines.</p>

**Table C.2: Definitions**

## D Changelog

This section shows changes done between document releases.

### D.1 Release 17-10

Type of change:	Modified rules:
Title, example, exceptions	<a href="#">A7-1-7</a> , <a href="#">A15-0-4</a> , <a href="#">A15-0-5</a> , <a href="#">A15-3-1</a> , <a href="#">A18-5-2</a>
Rule classification	<a href="#">A9-3-1</a>
References	<a href="#">A0-4-3</a> , <a href="#">M3-4-1</a> , <a href="#">M5-2-12</a> , <a href="#">A5-0-1</a> , <a href="#">A5-1-2</a> , <a href="#">A5-1-4</a> , <a href="#">A6-5-2</a> , <a href="#">M7-1-2</a> , <a href="#">M7-5-2</a> , <a href="#">A7-1-1</a> , <a href="#">A7-1-7</a> , <a href="#">A8-4-1</a> , <a href="#">M9-3-3</a> , <a href="#">A12-0-1</a> , <a href="#">A12-8-6</a> , <a href="#">A18-5-2</a> , <a href="#">A18-9-2</a>
New rule	<a href="#">A0-1-4</a> , <a href="#">A0-1-5</a> , <a href="#">A6-5-3</a> , <a href="#">A8-4-4</a> , <a href="#">A9-5-1</a> , <a href="#">A12-1-5</a> , <a href="#">A12-1-6</a> , <a href="#">A13-5-2</a> , <a href="#">A18-1-6</a> , <a href="#">A18-5-8</a>
MISRA review changes	<a href="#">A0-1-3</a> , <a href="#">A2-10-5</a> , <a href="#">A5-1-7</a> , <a href="#">M10-1-2</a>
Other	Traceability updated for HIC (see <a href="#">B.2</a> ), CERT (see <a href="#">B.4</a> ), C++ Core Guidelines (see <a href="#">B.5</a> ). Added changelog appendix chapter.

**Table D.1: Changelog for release 17-10.**

### D.2 Release 18-03

Type of change:	Modified rules:
Title, example, exceptions	<a href="#">A1-4-1</a> , <a href="#">A2-3-1</a> , <a href="#">A2-7-3</a> , <a href="#">A2-8-1</a> , <a href="#">A3-3-2</a> , <a href="#">A5-2-5</a> , <a href="#">A12-0-1</a> , <a href="#">A12-8-1</a> , <a href="#">A13-3-1</a> , <a href="#">A15-0-5</a> , <a href="#">A15-3-2</a> , <a href="#">A15-3-3</a> , <a href="#">A15-4-5</a> , <a href="#">A15-5-1</a> , <a href="#">A18-0-2</a> , <a href="#">A18-1-1</a> , <a href="#">A18-1-4</a> , <a href="#">A18-1-6</a> , <a href="#">A18-5-8</a>
Rule classification, numbering	<a href="#">A5-6-1</a> , <a href="#">A2-13-1</a> , <a href="#">A2-13-2</a> , <a href="#">A2-13-3</a> , <a href="#">6.2.5 (A2-5-2)</a> , <a href="#">6.2.8 (A2-8-1)</a> , <a href="#">6.2.10 (A2-10-1, A2-10-4, A2-10-5)</a> , <a href="#">A15-0-6</a> , <a href="#">A15-0-7</a> , <a href="#">A15-0-8</a> , <a href="#">A15-1-1</a> , <a href="#">A15-3-3</a> , <a href="#">A18-1-1</a>
Chapter numbering	<a href="#">6.2.3 (A2-3-1)</a> , <a href="#">6.2.5 (A2-5-2)</a> , <a href="#">6.2.8 (A2-8-1)</a> , <a href="#">6.2.10 (A2-10-1, A2-10-4, A2-10-5)</a>
References, notes	<a href="#">M0-1-9</a> , <a href="#">A2-7-3</a> , <a href="#">A2-8-1</a> , <a href="#">A3-3-2</a> , <a href="#">A4-7-1</a> , <a href="#">A5-0-1</a> , <a href="#">M5-0-2</a> , <a href="#">A5-2-1</a> , <a href="#">A5-2-5</a> , <a href="#">M5-2-2</a> , <a href="#">A6-5-1</a> , <a href="#">A7-1-7</a> , <a href="#">A8-5-2</a> , <a href="#">A9-3-1</a> , <a href="#">A12-1-1</a> , <a href="#">A12-4-1</a> , <a href="#">A12-4-2</a> , <a href="#">A13-5-2</a> , <a href="#">A14-1-1</a> , <a href="#">A15-0-4</a> , <a href="#">A15-0-5</a> , <a href="#">A15-4-1</a> , <a href="#">A15-5-2</a> , <a href="#">A15-5-3</a> , <a href="#">M18-0-4</a> , <a href="#">M18-0-5</a> , <a href="#">A18-5-5</a>

New rule	<a href="#">A0-1-6</a> , <a href="#">A0-4-4</a> , <a href="#">A1-4-3</a> , <a href="#">M2-7-1</a> , <a href="#">A2-7-5</a> , <a href="#">A2-8-2</a> , <a href="#">A2-10-6</a> , <a href="#">A2-11-1</a> , <a href="#">A2-13-4</a> , <a href="#">A2-13-5</a> , <a href="#">A2-13-6</a> , <a href="#">A3-1-5</a> , <a href="#">A3-1-6</a> , <a href="#">A3-8-1</a> , <a href="#">A5-0-4</a> , <a href="#">A5-1-9</a> , <a href="#">A5-2-6</a> , <a href="#">A5-3-2</a> , <a href="#">A5-3-3</a> , <a href="#">A5-5-1</a> , <a href="#">A6-2-1</a> , <a href="#">A6-5-4</a> , <a href="#">A7-1-9</a> , <a href="#">A7-2-5</a> , <a href="#">A7-3-1</a> , <a href="#">A7-6-1</a> , <a href="#">A8-4-5</a> , <a href="#">A8-4-6</a> , <a href="#">A8-4-8</a> , <a href="#">A8-4-9</a> , <a href="#">A8-4-10</a> , <a href="#">A8-4-11</a> , <a href="#">A8-4-12</a> , <a href="#">A8-4-13</a> , <a href="#">A8-5-0</a> , <a href="#">A10-0-1</a> , <a href="#">A10-0-2</a> , <a href="#">A10-4-1</a> , <a href="#">A12-0-2</a> , <a href="#">A13-5-3</a> , <a href="#">A13-5-4</a> , <a href="#">A14-5-1</a> , <a href="#">A14-7-2</a> , <a href="#">A14-8-2</a> , <a href="#">A17-6-1</a> , <a href="#">A18-5-9</a> , <a href="#">A18-5-10</a> , <a href="#">A20-8-1</a> , <a href="#">A20-8-2</a> , <a href="#">A20-8-3</a> , <a href="#">A20-8-4</a> , <a href="#">A20-8-5</a> , <a href="#">A20-8-6</a> , <a href="#">A20-8-7</a> , <a href="#">A21-8-1</a> , <a href="#">A23-0-2</a> , <a href="#">A25-1-1</a> , <a href="#">A25-4-1</a> , <a href="#">A26-5-1</a> , <a href="#">A26-5-2</a> , <a href="#">A27-0-3</a> , <a href="#">A27-0-4</a>
Removed rule	<a href="#">M0-1-5</a> , <a href="#">A1-4-2</a> , <a href="#">A2-7-4</a> , <a href="#">A2-10-2</a> , <a href="#">A2-10-3</a> , <a href="#">M2-10-6</a> , <a href="#">A5-1-5</a> , <a href="#">M5-2-1</a> , <a href="#">M7-3-5</a> , <a href="#">M8-5-1</a> , <a href="#">A13-1-1</a> , <a href="#">M14-5-2</a> , <a href="#">M14-7-3</a> , <a href="#">A14-8-1</a> , <a href="#">M14-8-1</a> , <a href="#">A15-3-1</a> , <a href="#">A15-4-6</a> , <a href="#">A18-1-5</a>
Definitions	<a href="#">Is-a-relationship</a> , <a href="#">Has-a-relationship</a>
Other	Traceability updated for MISRA (see <a href="#">B.1</a> ), HIC++ (see <a href="#">B.2</a> ), JSF (see <a href="#">B.3</a> ), CERT (see <a href="#">B.4</a> ), C++ Core Guidelines (see <a href="#">B.5</a> )

**Table D.2: Changelog for release 18-03.**

### D.3 Release 18-10

Type of change:	Modified rules:
Title, example, exceptions	<a href="#">A8-5-2</a> , <a href="#">A8-5-4</a> , <a href="#">A9-6-1</a> , <a href="#">A10-2-1</a> , <a href="#">A11-3-1</a> , <a href="#">A13-5-4</a> , <a href="#">A15-4-3</a> , <a href="#">A16-2-2</a> , <a href="#">A16-2-3</a> , <a href="#">A18-5-2</a> , <a href="#">A18-5-3</a>
References, notes	<a href="#">A5-0-4</a>
New rule	<a href="#">A6-2-2</a> , <a href="#">A8-4-14</a> , <a href="#">M9-6-4</a> , <a href="#">A13-5-5</a> , <a href="#">A14-5-2</a> , <a href="#">A14-5-3</a> , <a href="#">A18-5-11</a>
Other	Traceability updated for MISRA (see <a href="#">B.1</a> ), C++ Core Guidelines (see <a href="#">B.5</a> ), HIC++ (see <a href="#">B.2</a> ). Traceability added for ISO 26262 (see <a href="#">B.6</a> ).

**Table D.3: Changelog for release 18-10.**