



Coding Standards and MISRA C:2012 Overview

LDRA Standards Experience & Pedigree

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- Member of SC-205 / WG-71 (DO-178C) formal methods subgroup
- Member of MISRA C committee and MISRA C++ committee
- Member of the working group drafting a proposed secureC annex for the C language definition (SC 22 / WG14)

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Agenda

- Part 1:
  - What is a coding standard?
  - Why use a coding standard?
  - Which coding standard?
- Part 2:
  - MISRA C:2012
  - Checking Compliance
  - Questions & Answers

What is a Coding Standard?

Coding Standards

- Roughly 80% of software defects when using the C or C++ language, are attributable to the incorrect usage of 20% of the language constructs
- If the usage of the language can be restricted to avoid this subset that is known to be problematic, then the quality of the ensuing software is going to greatly increase

If you don't want defects in your code, then don't put them there!

Keep It Simple

- It is easy to write code that is difficult to read
- Prevent developers from writing "*clever*" code

```
void clever_copy (char* to, const char* from, const int count)
{
  int n = (count + 7) / 8;
  switch (count % 8) {
  case 0: do { *to = *from++;
  case 7:      *to = *from++;
  case 6:      *to = *from++;
  case 5:      *to = *from++;
  case 4:      *to = *from++;
  case 3:      *to = *from++;
  case 2:      *to = *from++;
  case 1:      *to = *from++;
            } while (--n > 0);
  }
}
```

```
void copy (char* to, const char* from, const int count)
{
   int n = count;
  do
  {
     *to = *from++;
  } while (--n > 0);
}
```

- Write code that is easy to understand, easy to maintain and easy to test

Style Guidelines

- Tools can be used to verify coding standards, but there is always a need for some manual code review

C:\LDRA\LDRA_Demos\VisualDSP50_Workspace\VisualDSP50_C_Dice\bsp.c

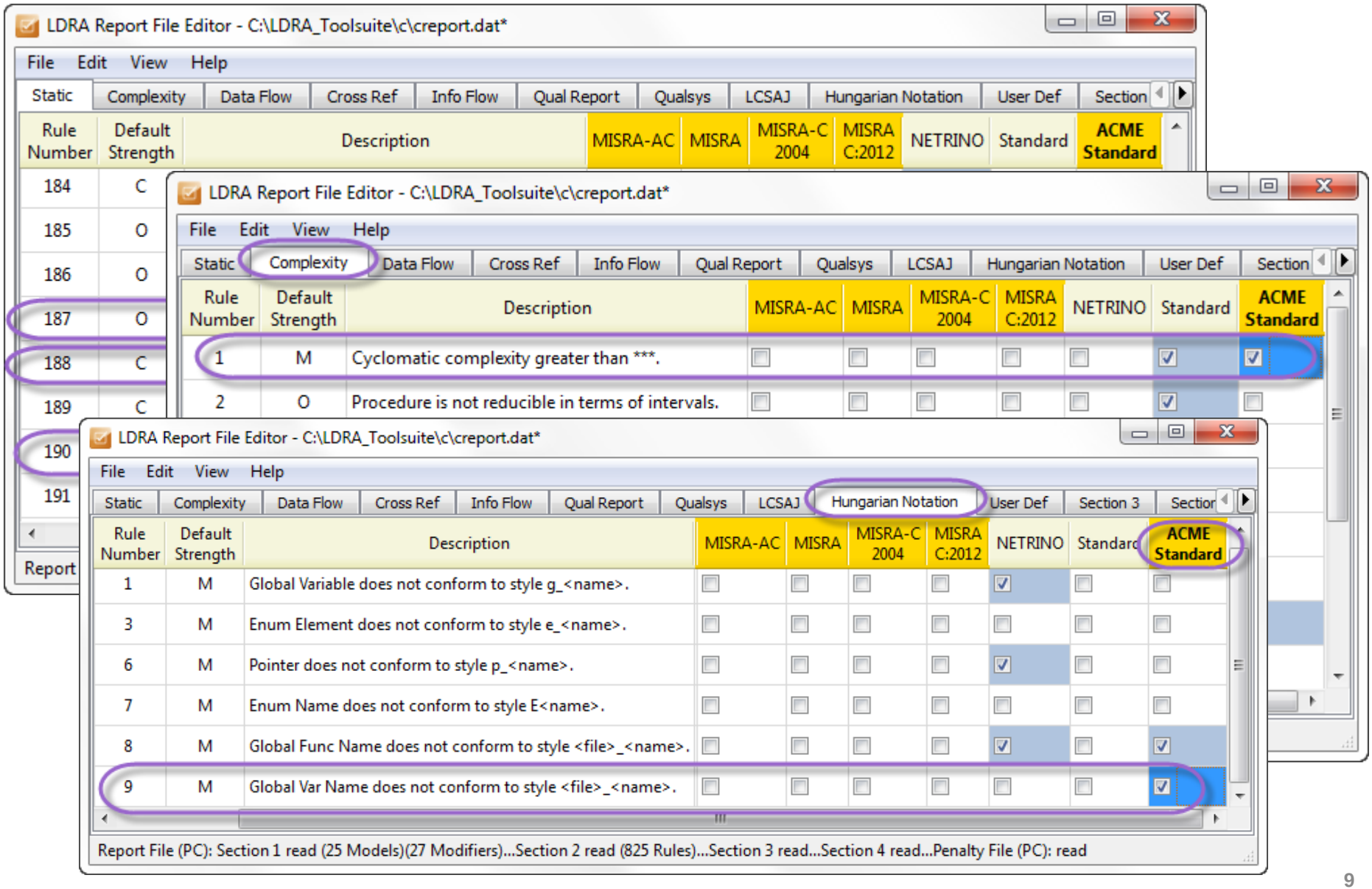
```
26  /*-------------------------------------------------------------------------*/
27  /* Function:  init_flags                                                   */
28  /*                                                                         */
29  /* Parameters:  None                                                       */
30  /*                                                                         */
31  /* Return:    None                                                         */
32  /*                                                                         */
33  /* Description: This function configures PF8 as input for edge sensitive  */
34  /*        interrupt generation.                                            */
35  /*        The switch connected to PF8 (SW7) can be used to change the */
36  /*        direction of the moving light.                                   */
37  /*-------------------------------------------------------------------------*/
38  static void init_flags(void)
```

- Style guidelines ensure that the code is always written in the same style, facilitating code reviews

Configure Standard

- Coding Standards can be made up of:
  - Common sense rules
    - Don’t mix signed and unsigned types
  - Reduced language subset
    - Ensure that “goto” or “malloc” is not used
  - Style guidelines
    - Ensure that the “tab” character is not used
  - Naming conventions
    - Ensure that all public functions start with <filename>_
  - Quality & complexity metrics
    - Ensure that all functions have a low cyclomatic complexity

Configure Standard: Example



Automation

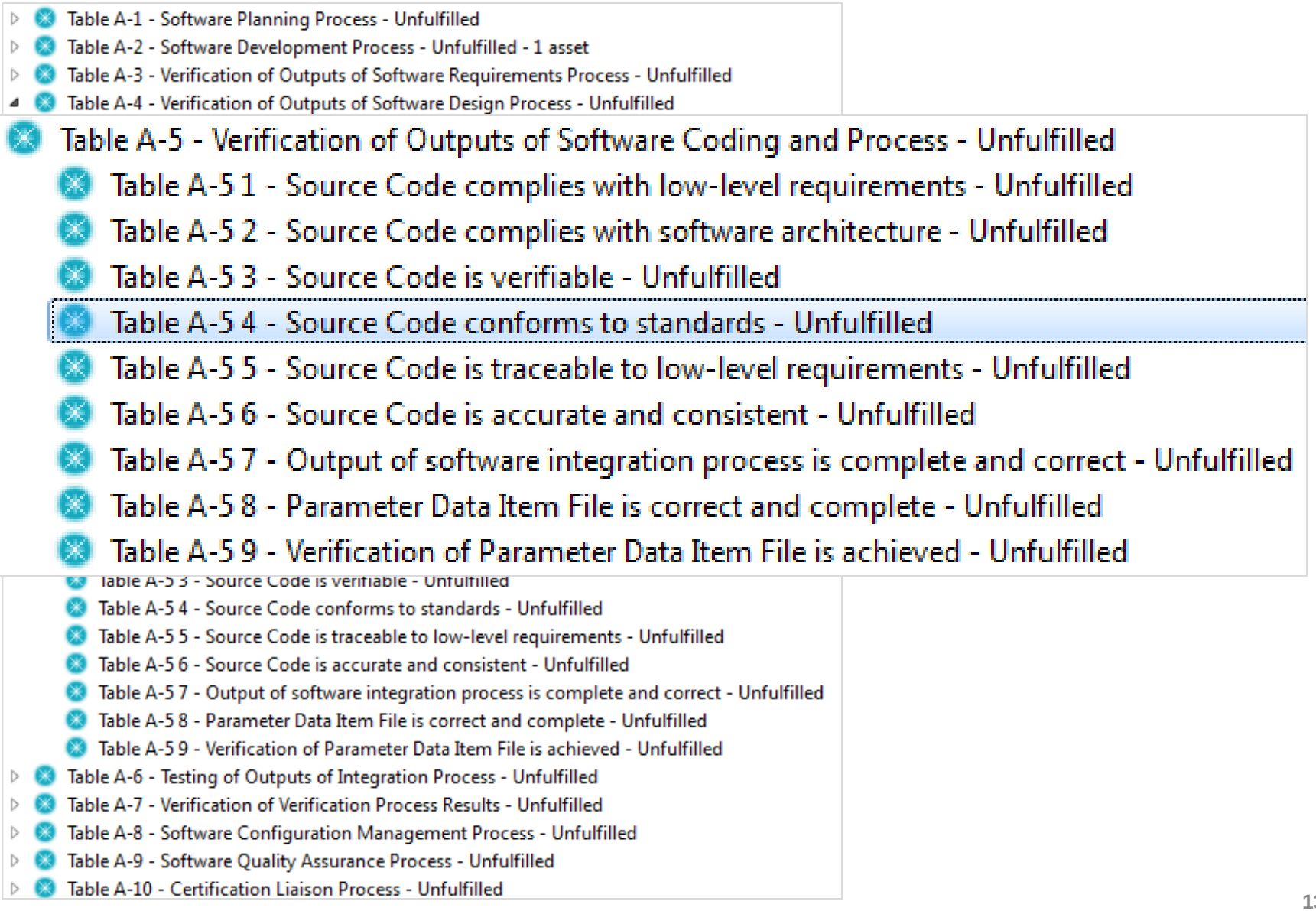
- Use of tools for automation of standards can greatly improve the efficiency of their application
- Over time engineers will quickly tend to alter their habits and write compliant code
- Coding Standards should be adopted from the outset of the project
- If a coding standard is used with existing code that has a proven track record, then the benefits of using the coding standard may be outweighed by the risk of introducing defects in making the code compliant!

Why use a Coding Standard?

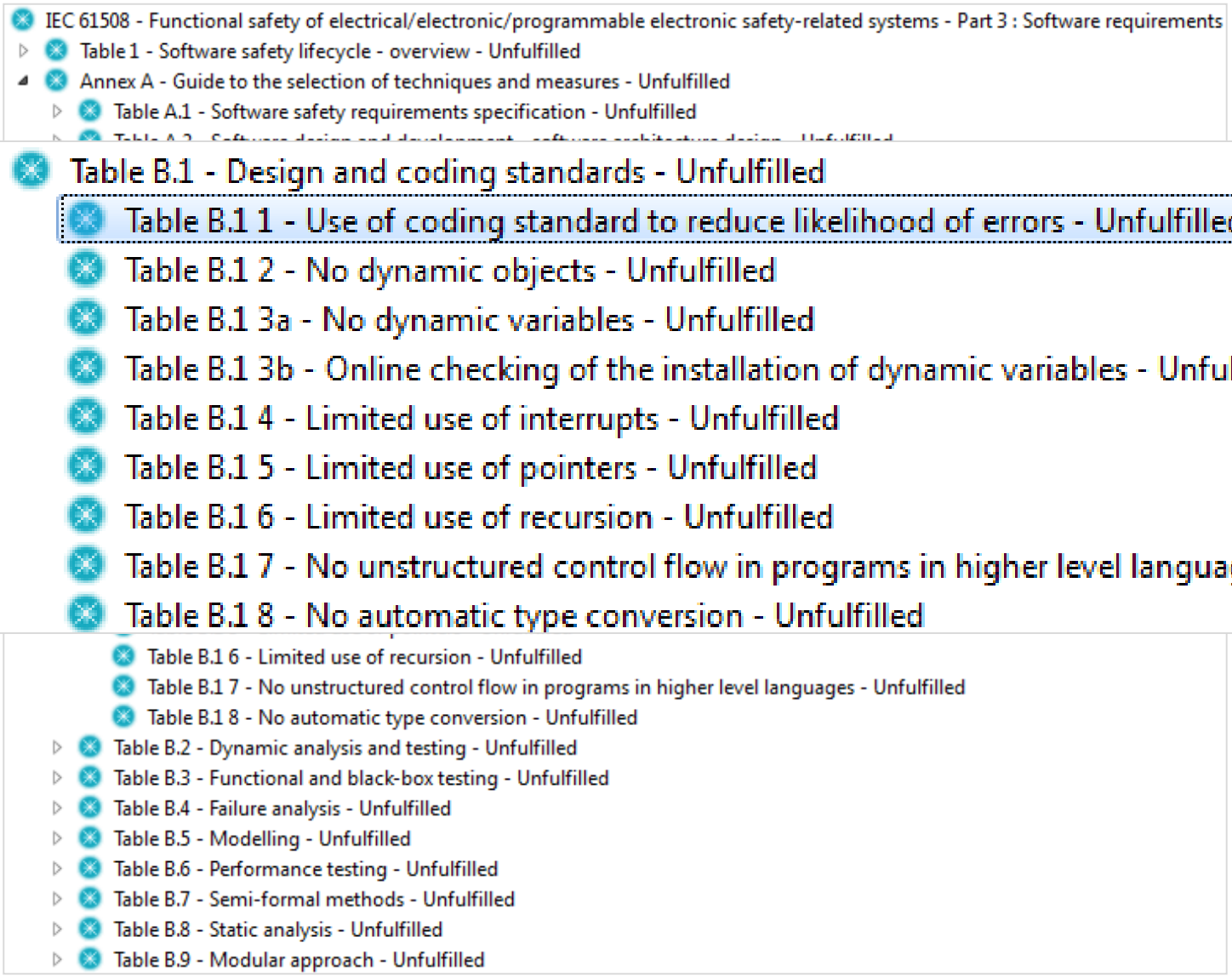
Why Use A Coding Standard?

- Simplest way to avoid numerous potential problems
- Mandated by many industrial standards

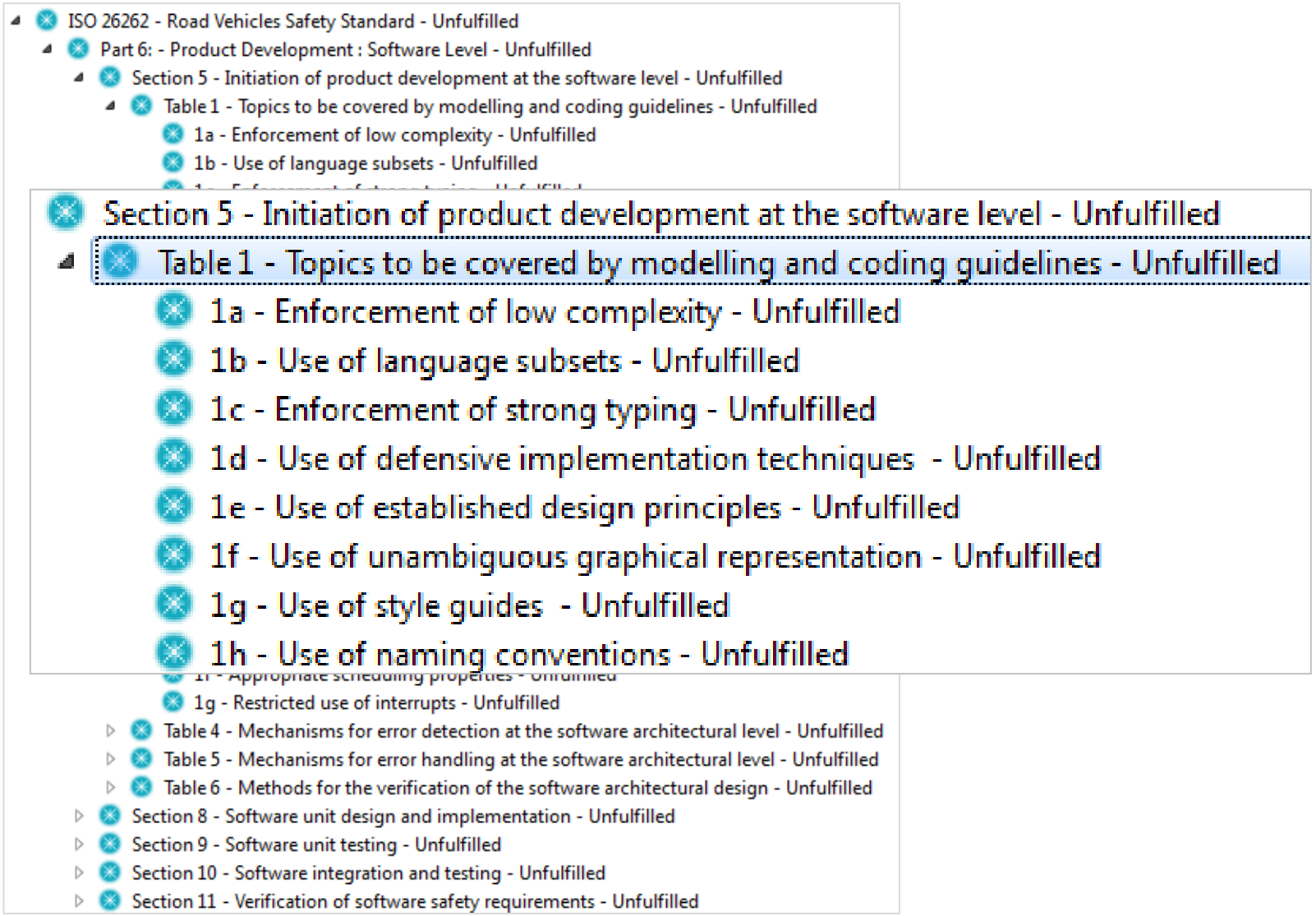
DO-178C Objectives



IEC 61508 Objectives

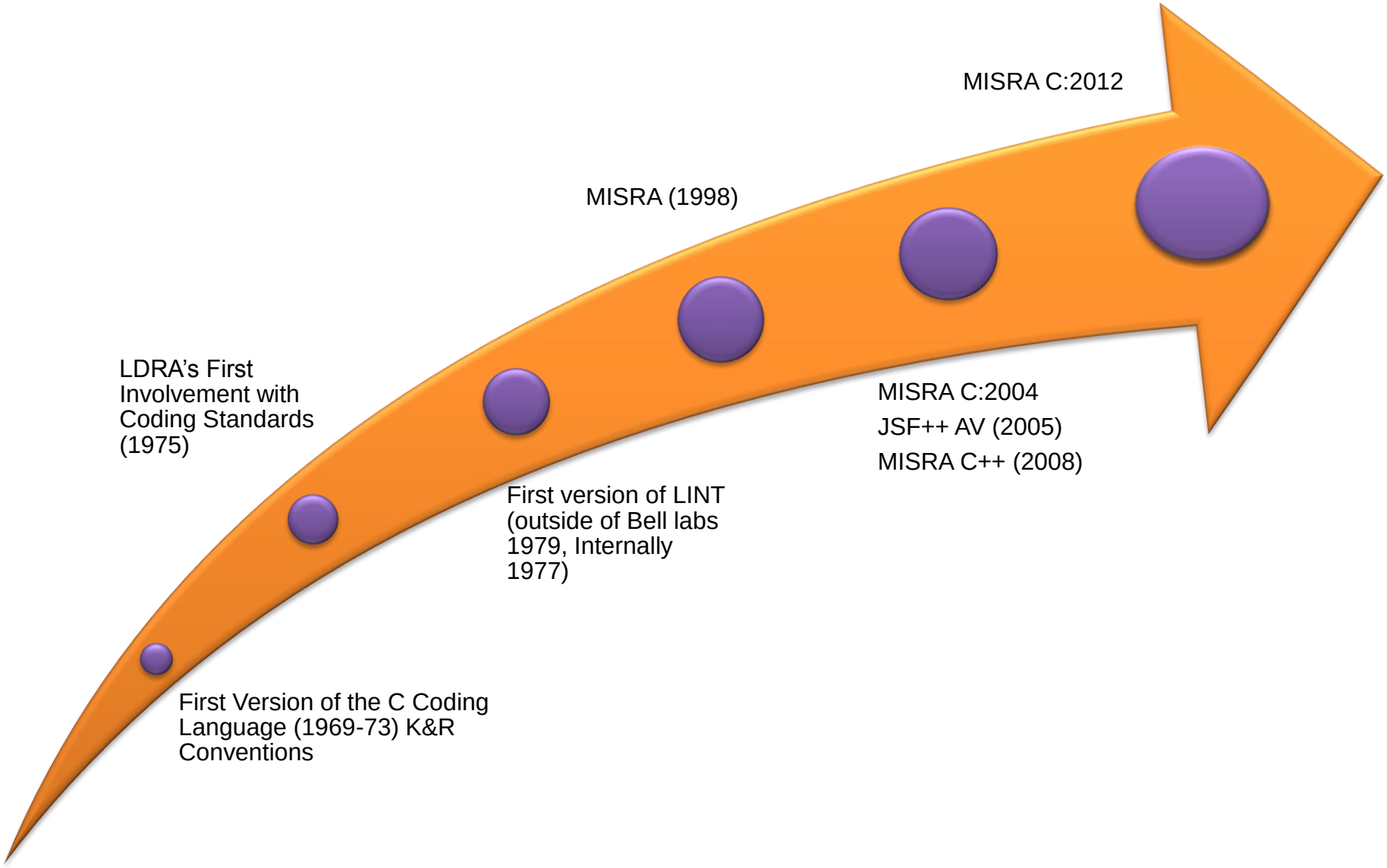


ISO 26262 Objectives



Which Coding Standard?

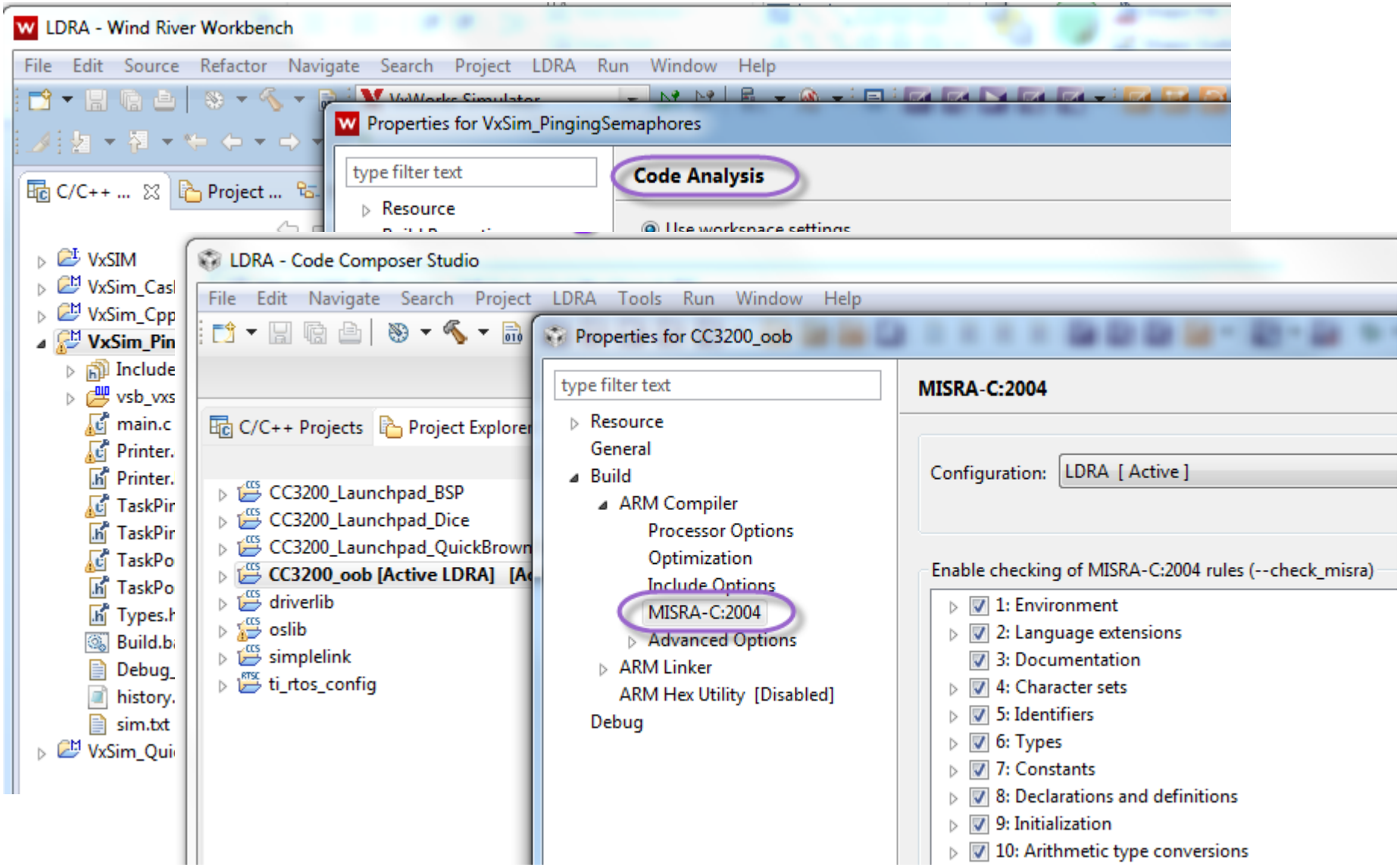
Progression of Coding Standards



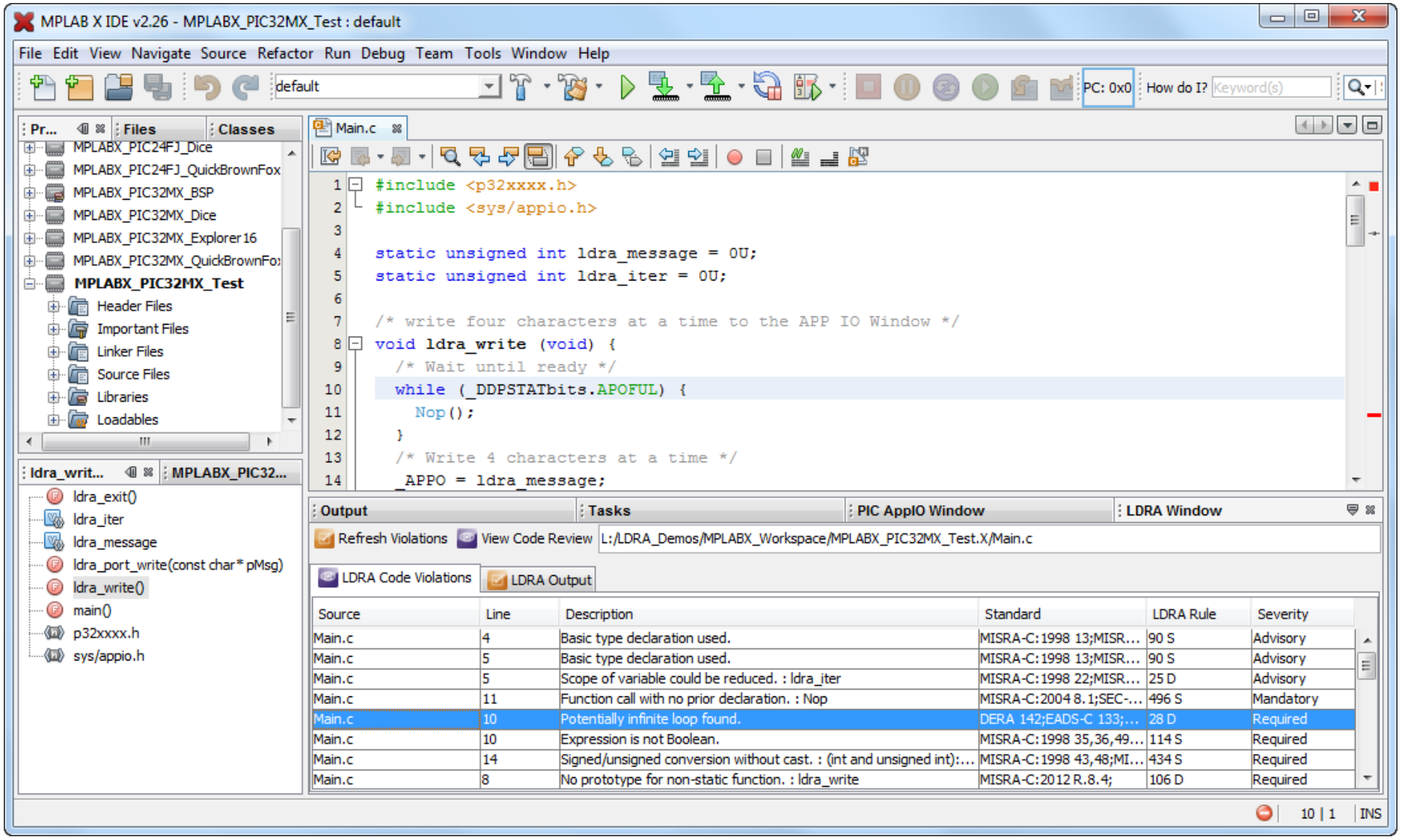
Which “C” Coding Standard?

- MISRA C
  - 1998, 2004, 2012
- NETRINO
- CERT C Secure Coding Standard
- HIS (Hersteller Initiative Software)
- …
- Company Specific Standard

Eclipse IDEs

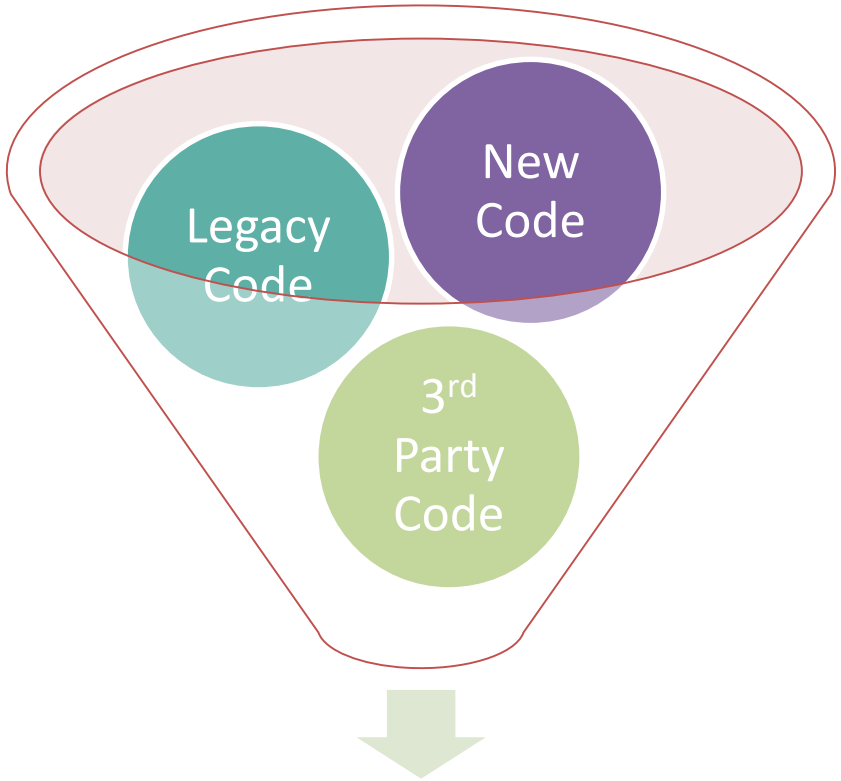


Compilers


MPLAB X IDE v2.26 - MPLABX_PIC32MX_Test : default
File Edit View Navigate Source Refactor Run Debug Team Tools Window Help
default
PC: 0x0
How do I?
Keyword(s)
Pr... Files Classes
MPLABX_PIC24FJ_Dice
MPLABX_PIC24FJ_QuickBrownFox
MPLABX_PIC32MX_BSP
MPLABX_PIC32MX_Dice
MPLABX_PIC32MX_Explorer16
MPLABX_PIC32MX_QuickBrownFox
MPLABX_PIC32MX_Test
Header Files
Important Files
Linker Files
Source Files
Libraries
Loadables
ldra_writ... MPLABX_PIC32...
ldra_exit()
ldra_iter
ldra_message
ldra_port_write(const char* pMsg)
ldra_write()
main()
p32xxxx.h
sys/appio.h
Main.c
1 #include <p32xxxx.h>
2 #include <sys/appio.h>
3
4 static unsigned int ldra_message = 0U;
5 static unsigned int ldra_iter = 0U;
6
7 /* write four characters at a time to the APP IO Window */
8 void ldra_write (void) {
9 /* Wait until ready */
10 while (_DDPSTATbits.APOFUL) {
11 Nop();
12 }
13 /* Write 4 characters at a time */
14 _APPO = ldra_message;
Output
Tasks
PIC AppIO Window
LDRA Window
Refresh Violations
View Code Review
L:/LDRA_Demos/MPLABX_Workspace/MPLABX_PIC32MX_Test.X/Main.c
LDRA Code Violations
LDRA Output
Source Line Description Standard LDRA Rule Severity
Main.c 4 Basic type declaration used. MISRA-C:1998 13;MISR... 90 S Advisory
Main.c 5 Basic type declaration used. MISRA-C:1998 13;MISR... 90 S Advisory
Main.c 5 Scope of variable could be reduced. : ldra_iter MISRA-C:1998 22;MISR... 25 D Advisory
Main.c 11 Function call with no prior declaration. : Nop MISRA-C:2004 8.1;SEC-... 496 S Mandatory
Main.c 10 Potentially infinite loop found. DERA 142;EADS-C 133;... 28 D Required
Main.c 10 Expression is not Boolean. MISRA-C:1998 35,36,49... 114 S Required
Main.c 14 Signed/unsigned conversion without cast. : (int and unsigned int):... MISRA-C:1998 43,48;MI... 434 S Required
Main.c 8 No prototype for non-static function. : ldra_write MISRA-C:2012 R.8.4; 106 D Required
10 | 1
INS

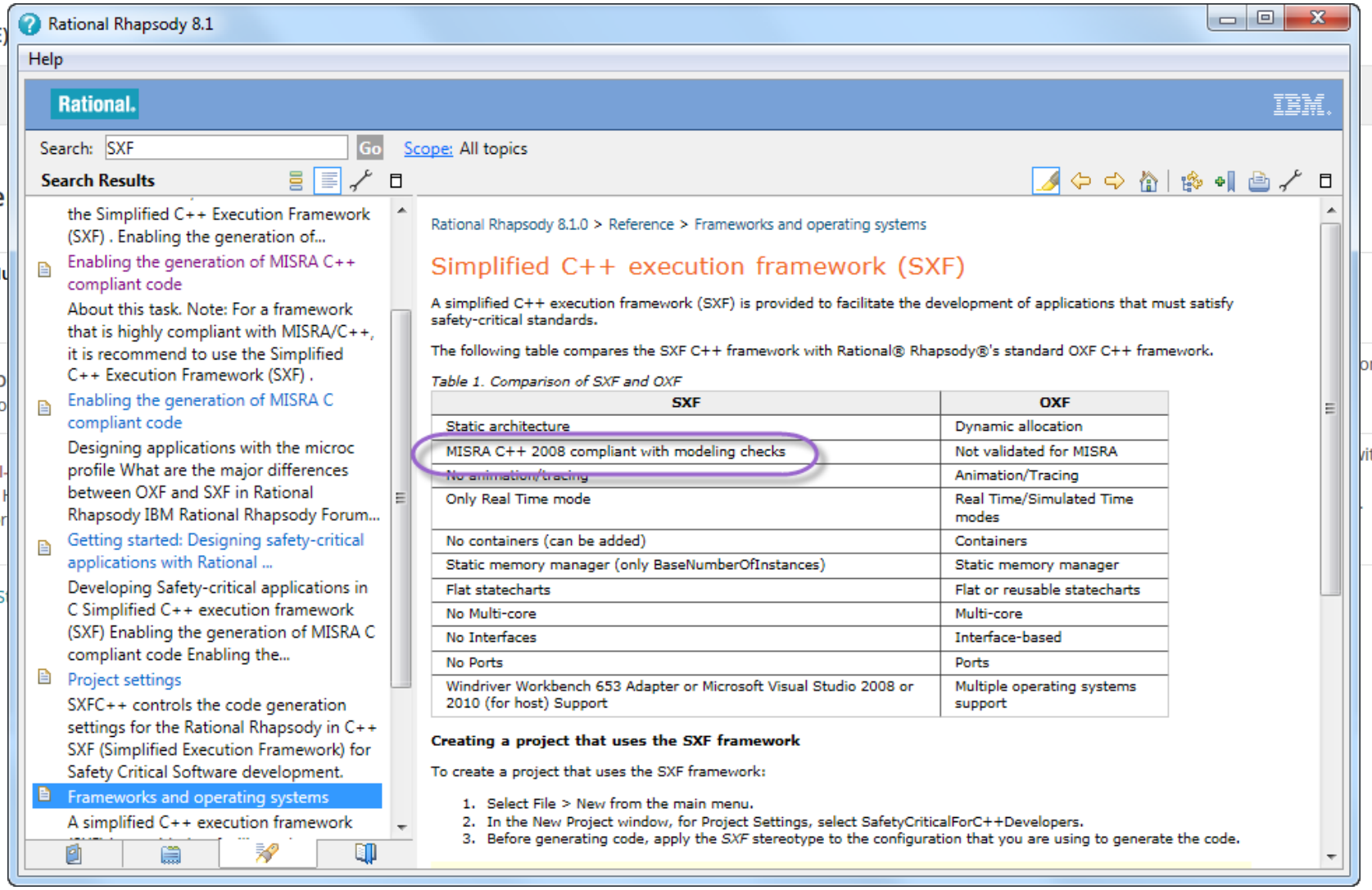
Which “C” Coding Standard?

- New Code
  - MISRA C:2012
    - + Style Guidelines
    - + Naming Conventions
    - + Complexity Guidelines
- 3rd Party Code
  - Custom Standard
- Legacy Code
  - Run-Time Error Standard



3rd Party Code

HAL Code Generator tool



MISRA C:2012


LDRA
Tool Suite
Delivering Software Quality and Security through
Test, Analysis & Requirements Traceability

What is MISRA C?

- It is a language subset
- Prevents undefined and unspecified behaviour
- Controls implementation-defined behaviour
- Gives predictable behaviour

What is Unspecified Behaviour?

Code

```
int     a = 5;
short *b = &a;

*b = 6;

printf( a );
```

Result

Compiler is allowed to assume that modification of a *short* will not affect an *int* **even when they are the same size**, so printf(a) could print “5” or “6”

Another Example:

Code

```
uint16_t a;
uint16_t b;
uint32_t c;
uint32_t x;

x = a + b + c;
```

Result

Depends on the size of *int* used by the compiler. If it is 16-bit, then there may be loss of Most Significant Bits for a + b

Array Bounds Exceeded

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Code

```
 int32_t a[ 10 ];
uint32_t i;

for ( i = 0; i <= 10; ++i )
{
   a[ i ] = 0;
}
```

Result

Depending on the runtime environment (OS, etc.), this will result in an exception or overwrite unrelated memory.

Myths and Legends

Does NOT

- Say the rules must be followed all the time
- Define style or metric guidelines
- Stop developers writing code

Does

- Require controlled deviations
- Require style and metrics be applied
- Force developers to think

MISRA C Versions

1998

- MISRA C first released in 1998 to target C90
- Produced by automotive organizations as part of a government-funded project

2004

- Produced by and for diverse industrial sectors
- As compatible as possible with the previous version but more precise / specific
- Introduced the concept of “underlying type”
- Exemplar suite launched in 2007

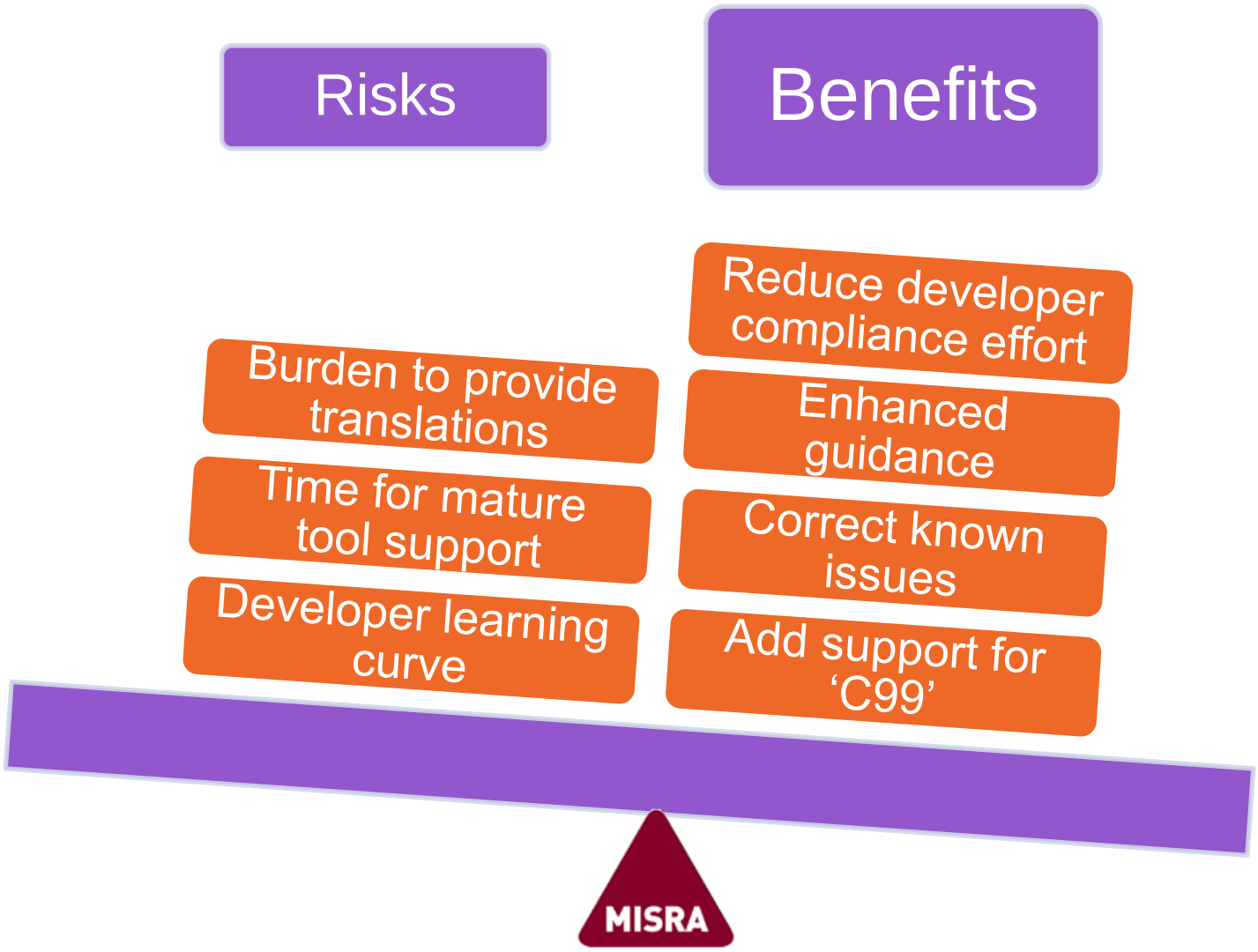
2012

- Adds support for C99, retains support for C90 and corrects issues with 2004 version
- As compatible as possible with the previous version
- All guidelines include a detailed rationale and comprehensive examples
- Includes guidance on the applicability of guidelines to automatically generated code

C99: (*ISO/IEC 9899:1999*)

- Introduced new features such as:
  - Inline functions
  - New data types ex: _Bool, long long int
  - Variable length arrays
  - C++ style variable declarations
  - C++ style comments //
  - New library functions, ex: snprintf
  - New header files, ex: stdbool.h
  - Improved support for IEEE floating point
  - Macros with a variable number of arguments
- Many compilers have already implemented some if not all of these features

New Version Cost / Benefit Analysis



Objectives

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Enhance

- C99 support
- Prefer decidable rules

Improve

- Correct issues with 2004 version
- Ensure rules have strong rationale

Expand

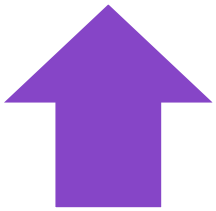
- Type safety of non numeric types
- State rule applicability to auto code

Guideline Considerations

Language	• Applies to C90 and/or C99?
Behaviour	• How should undefined / unspecified behaviour be covered? • One rule for each / specific guidelines?
Precision	• Make the guideline target the danger as precisely as possible • Try not to prevent reasonable use of the language

Undefined / Unspecified Behaviour

- Anything at all can happen since the standard imposes no requirements
- The program may:
  - Miraculously do what the programmer intended!
  - Execute incorrectly
  - Fail to compile



Many specific guidelines would be needed to cover all issues

Single rule would make it more difficult for tools to give meaningful diagnostics

Mixed Approach

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General

- Undefined / unspecified behaviour for which no practical guidance can be given
- Only reasonable action is to avoid the behaviour

Specific

- Undefined / unspecified behaviours for which advice can be given for a specific compiler
- In this case, it may be possible to justify a deviation for use

Rule Decidability

Decidable

- An ideal analysis tool can always determine compliance or non-compliance
- Preferred as code review effort lower

Undecidable

- Compliance cannot be determined, generally due to control flow variability
- False-negatives are possible, so code review is essential
- Tool behaviour will vary, leading to more false-positives

Rule 2.2	There shall be no *dead code*
	[IEC 61508-7 Section C.5.10], [ISO 26262-6 Section 9.4.5], [DO-178C Section 6.4.4.3.c]
Category	Required
Analysis	Undecidable, System
Applies to	C90, C99

Amplification

Any operation that is executed but whose removal would not affect program behaviour constitutes *dead code*. Operations that are introduced by language extensions are assumed always to have an effect on program behaviour.

Note: The behaviour of an embedded system is often determined not just by the nature of its actions, but also by the time at which they occur.

Note: unreachable code is not *dead code* as it cannot be executed.

Rationale

The presence of *dead code* may be indicative of an error in the program's logic. Since *dead code* may be removed by a compiler, its presence may cause confusion.

Exception

A cast to *void* is assumed to indicate a value that is intentionally not being *used*. The cast is therefore not *dead code* itself. It is treated as using its operand which is therefore also not *dead code*.

Enforcement

Headline	• Some headlines are wider / narrower than the behaviour they target to, makes it shorter / easier to understand
Amplification	• Normative text within an Amplification can be used to weaken / strengthen the headline to increase its precision
Exception	• Exceptions are sometimes given to allow restricted use of an otherwise prohibited behaviour

Enforcement

LDRA

More Precise	• Some MISRA C:2004 guidance was much stronger than needed to protect against a particular issue, making it difficult to achieve what was needed
Tighter Specification	• MISRA C:2004 12.1 "*Limited dependence* should be placed on C's operator precedence rules in expressions" • More guidance for tools to be able to make consistent decisions

Guideline Classes

Directives

- It is not possible to provide the full description necessary to perform a check for compliance
- E.g., Dir 4.4 “Sections of code should not be commented out”

Rules

- A complete description of the requirement can be provided
- Each guideline is classified as *decidable* or *undecidable*

Dir 4.4	Sections of code should not be “commented out”
Category	Advisory
Applies to	C90, C99

Amplification

This rule applies to both `//` and `/* ... */` styles of comment.

Rationale

Where it is required for sections of source code not to be compiled then this should be achieved by use of conditional compilation (e.g. *#if* or *#ifdef* constructs with a comment). Using start and end comment markers for this purpose is dangerous because C does not support nested comments, and any comments already existing in the section of code would change the effect.

See also

Rule 3.1, Rule 3.2

Type Checking

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Underlying type

- MISRA C:2004 introduced “Underlying Type” to support stricter type enforcement
- Applicable to numeric types
- Limited (plain) char and Boolean support

Essential type

- MISRA C:2012 introduces the “Essential Type Model”
- Enumeration and bit-field types included
- Boolean type support improved
- Un-suffixed non-negative integer constant expressions with signed type may now be used in some unsigned contexts
- Better support for (plain) char data type

MISRA C:2012 Highlights

MISRA C:2012

- Includes support for C99
- Gives a reasoned rationale for each rule
- Prefers the use of decidable rules, helping to reduce manual code review requirements
- Allows programmers to spend more time on coding and less on MISRA compliance

Checking Compliance

Checking Compliance

- Check the code manually
  - Needs to be done on the “undecidable” rules
  - But don’t really want to do it on all the code!
- Use a lightweight tool, such as is often built into compilers
  - Fast (*Checks just a subset*)
  - Detects the easy to find defects
  - Tends to be “Optimistic” – False Negatives

- Use a heavyweight tool
  - Slow (*Deep analysis*)
  - Detects the easy and hard to find defects
  - Tends to be “Pessimistic” – False Positives

Compliance Document

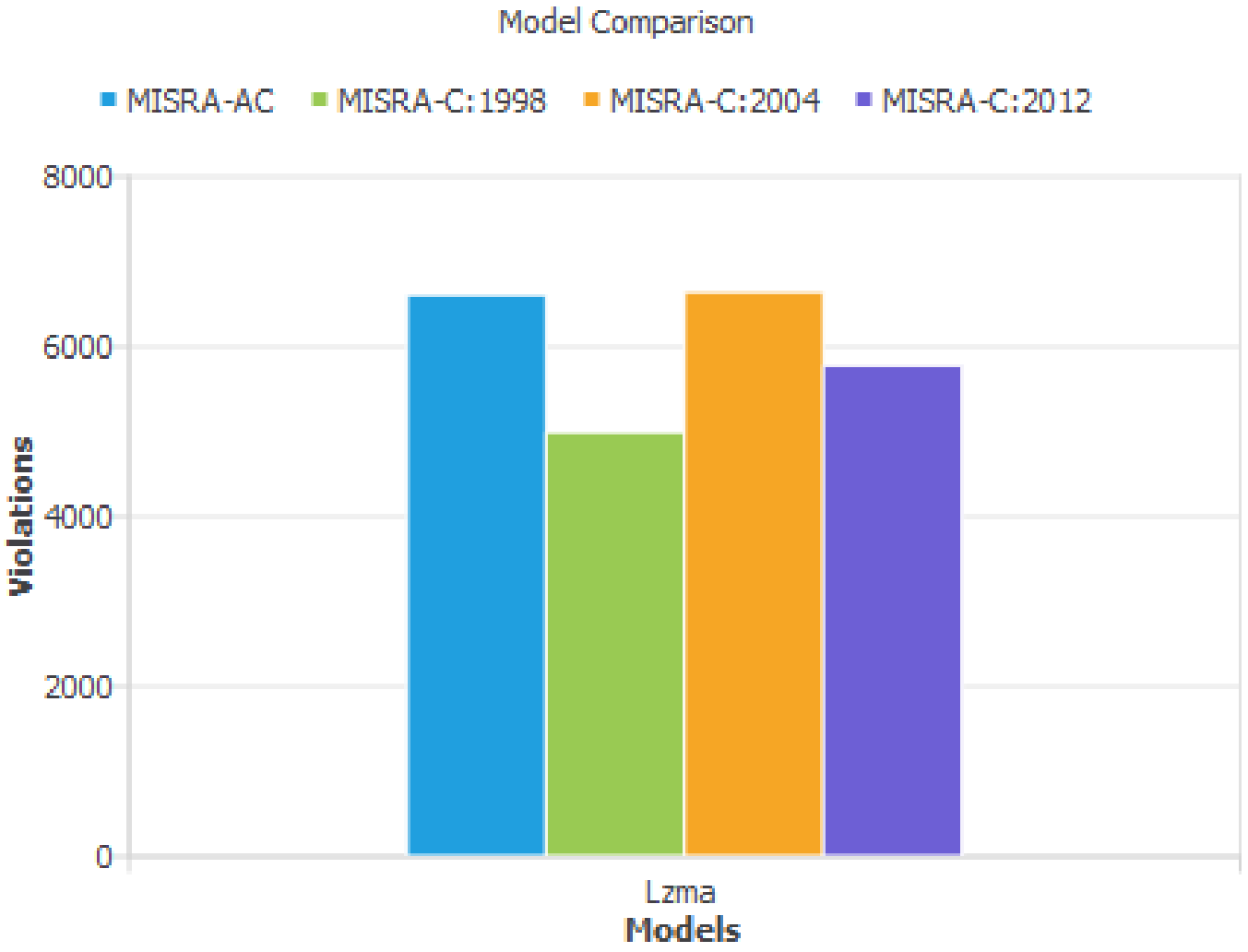
LDRA

LDRA TBbrowse - [Mingw_c_cashregister.ovs.html]

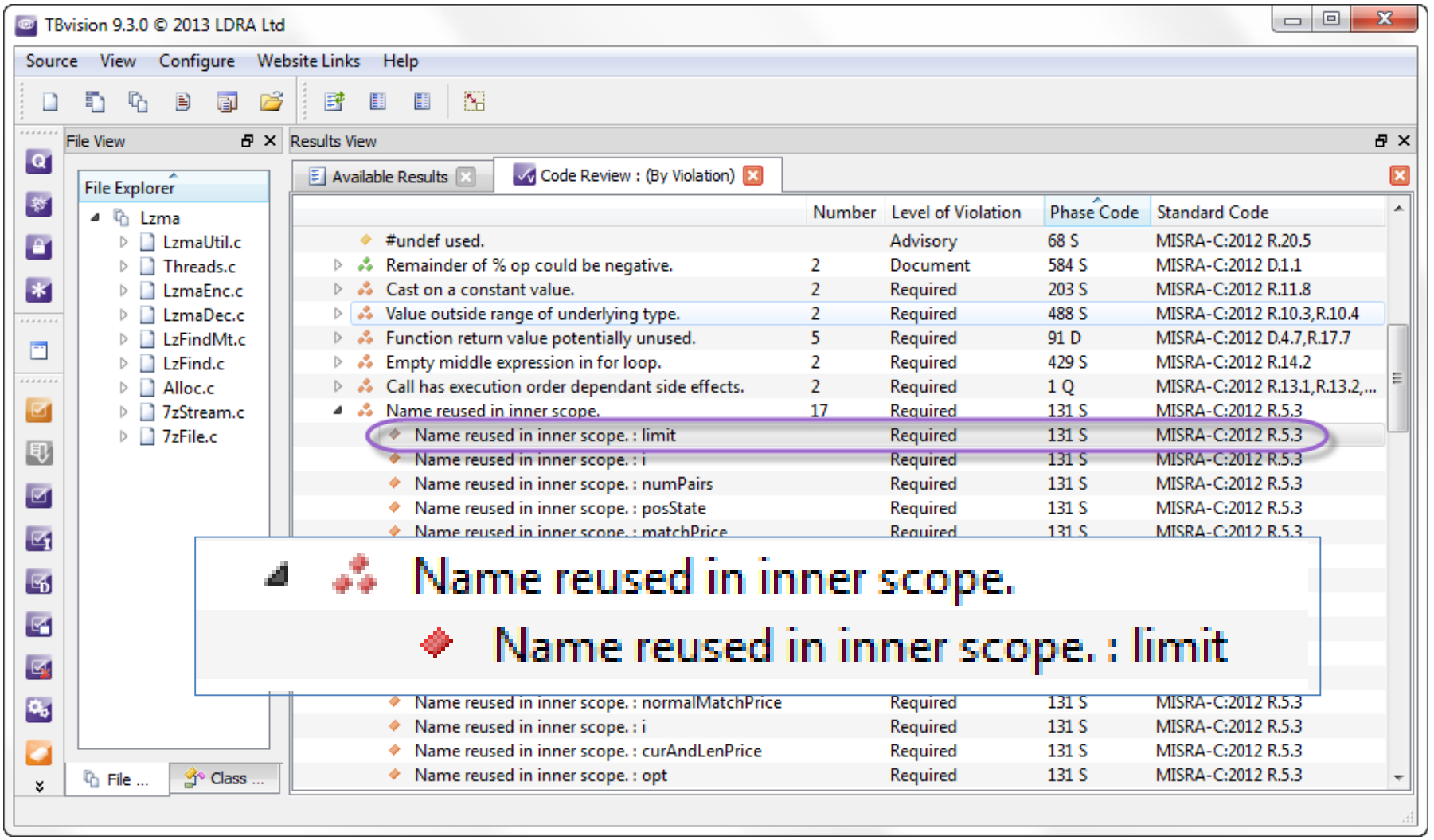
Number of Violations	LDRA Code	(M) Mandatory Standards	MISRA-C:2012 Code
0	36 S	Function has no return statement.	MISRA-C:2012 R.17.4
0	54 S	Sizeof operator with side effects.	MISRA-C:2012 R.13.6
0	66 S	Function with empty return expression.	MISRA-C:2012 R.17.4
0	407 S	free used on string.	MISRA-C:2012 R.22.2
0	480 S	String function params access same variable.	MISRA-C:2012 R.19.1
0	483 S	free parameter is not heap item.	MISRA-C:2012 R.22.2
0	484 S	Attempt to use already freed object.	MISRA-C:2012 R.22.2
0	496 S	Function call with no prior declaration.	MISRA-C:2012 R.17.3
0	545 S	Assignment of overlapping storage.	MISRA-C:2012 R.19.1
0	591 S	Inappropriate use of file pointer.	MISRA-C:2012 R.22.5
0	614 S	Use of static keyword in array parameter.	MISRA-C:2012 R.17.6
0	631 S	Declaration not reachable.	MISRA-C:2012 R.9.1
0	2 D	Function does not return a value on all paths.	MISRA-C:2012 R.17.4
0	48 D	Attempt to write to unopened file.	MISRA-C:2012 R.22.6
0	51 D	Attempt to read from freed memory.	MISRA-C:2012 R.22.2
0	53 D	Attempt to use uninitialised pointer.	MISRA-C:2012 R.9.1
0	69 D	Procedure contains UR data flow anomalies.	MISRA-C:2012 R.9.1
0	98 D	Attempt to write to file opened read only.	MISRA-C:2012 R.22.4

NUM

MISRA Standards Comparison



Code Review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Source View Configure Website Links Help
File View
Results View
File Explorer
Lzma
LzmaUtil.c
Threads.c
LzmaEnc.c
LzmaDec.c
LzFindMt.c
LzFind.c
Alloc.c
7zStream.c
7zFile.c
Available Results
Code Review : (By Violation)
Number
Level of Violation
Phase Code
Standard Code
#undef used. Advisory 68 S MISRA-C:2012 R.20.5
Remainder of % op could be negative. 2 Document 584 S MISRA-C:2012 D.1.1
Cast on a constant value. 2 Required 203 S MISRA-C:2012 R.11.8
Value outside range of underlying type. 2 Required 488 S MISRA-C:2012 R.10.3,R.10.4
Function return value potentially unused. 5 Required 91 D MISRA-C:2012 D.4.7,R.17.7
Empty middle expression in for loop. 2 Required 429 S MISRA-C:2012 R.14.2
Call has execution order dependant side effects. 2 Required 1 Q MISRA-C:2012 R.13.1,R.13.2,...
Name reused in inner scope. 17 Required 131 S MISRA-C:2012 R.5.3
Name reused in inner scope. : limit Required 131 S MISRA-C:2012 R.5.3
Name reused in inner scope. : i Required 131 S MISRA-C:2012 R.5.3
Name reused in inner scope. : numPairs Required 131 S MISRA-C:2012 R.5.3
Name reused in inner scope. : posState Required 131 S MISRA-C:2012 R.5.3
Name reused in inner scope. : matchPrice Required 131 S MISRA-C:2012 R.5.3
Name reused in inner scope.
Name reused in inner scope. : limit
Name reused in inner scope. : normalMatchPrice Required 131 S MISRA-C:2012 R.5.3
Name reused in inner scope. : i Required 131 S MISRA-C:2012 R.5.3
Name reused in inner scope. : curAndLenPrice Required 131 S MISRA-C:2012 R.5.3
Name reused in inner scope. : opt Required 131 S MISRA-C:2012 R.5.3
File ...
Class ...

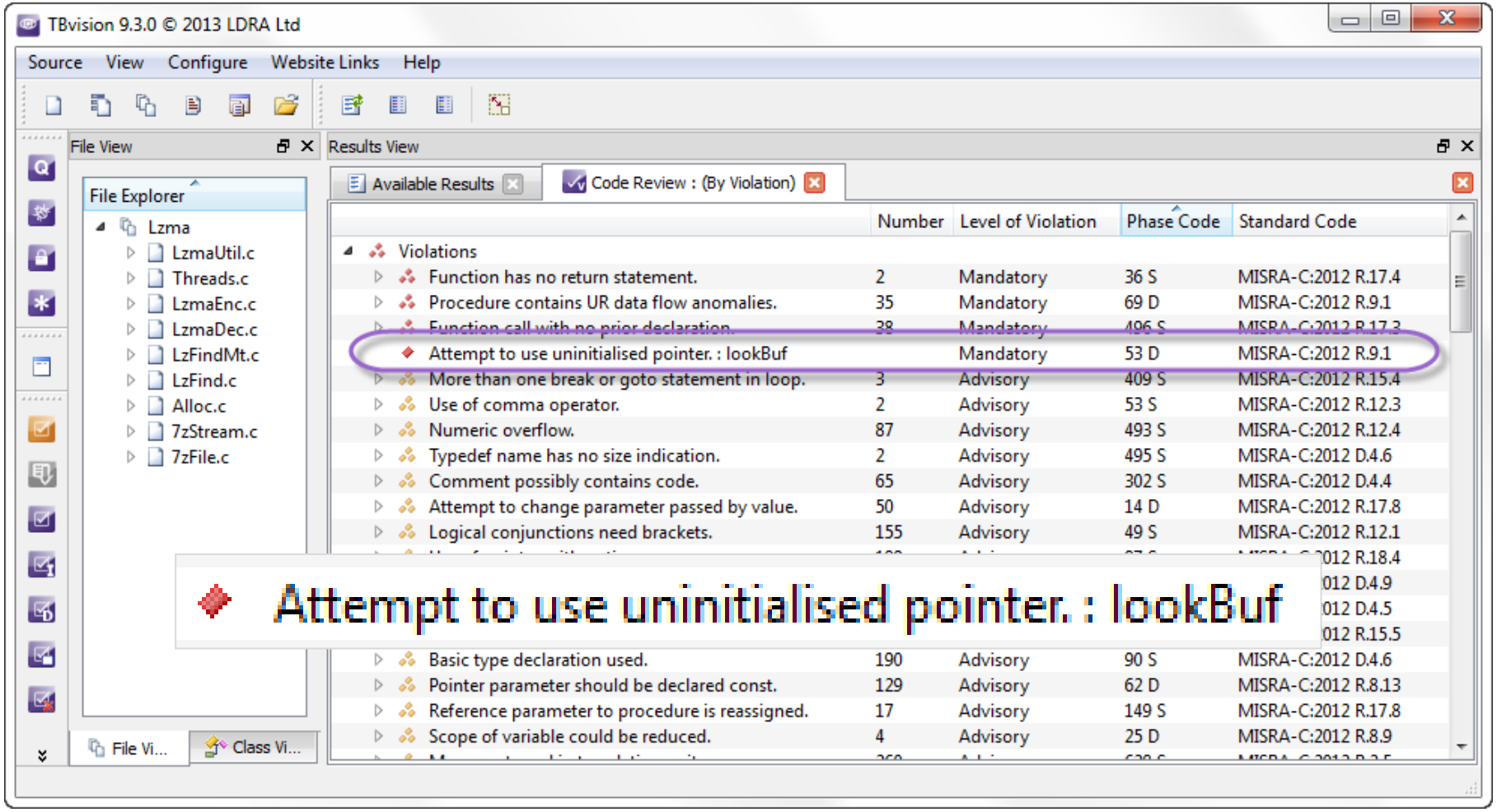
MISRA Rule 5.3 : Violation

Rule 5.3	An identifier declared in an inner scope shall not hide an identifier declared in an outer scope
Category	Required
Analysis	Decidable, Single Translation Unit
Applies to	C90, C99

```
static int MY_FAST_CALL LzmaDec_DecodeReal(CLzmaDec *p, SizeT limit, const Byte *bufLimit
{
  CLzmaProb *probs = p->probs;

  unsigned state = p->state;
  UInt32 rep0 = p->reps[0], rep1 = p->reps[1], rep2 = p->reps[2], rep3 = p->reps[3];
  unsigned pbMask = ((unsigned)1 << (p->prop.pb)) - 1;
  unsigned lpMask = ((unsigned)1 << (p->prop.lp)) - 1;
  unsigned lc = p->prop.lc;

  Byte *dic = p->dic;
  SizeT dicBufSize = p->dicBufSize;
  SizeT dicPos = p->dicPos;

  UInt32 processedPos = p->processedPos;
  UInt32 checkDicSize = p->checkDicSize;
  unsigned len = 0;

  const Byte *buf = p->buf;
  UInt32 range = p->range;
  UInt32 code = p->code;
```

```
      state = state < kNumLitStates ? 8 : 11;
      prob = probs + RepLenCoder;
    }
    {
      unsigned limit, offset;
      CLzmaProb *probLen = prob + LenChoice;
      IF_BIT_0(probLen)
      {
        UPDATE_0(probLen);
        probLen = prob + LenLow + (posState << kLenNumLowBits);
        offset = 0;
        limit = (1 << kLenNumLowBits);
      }
```

Code Review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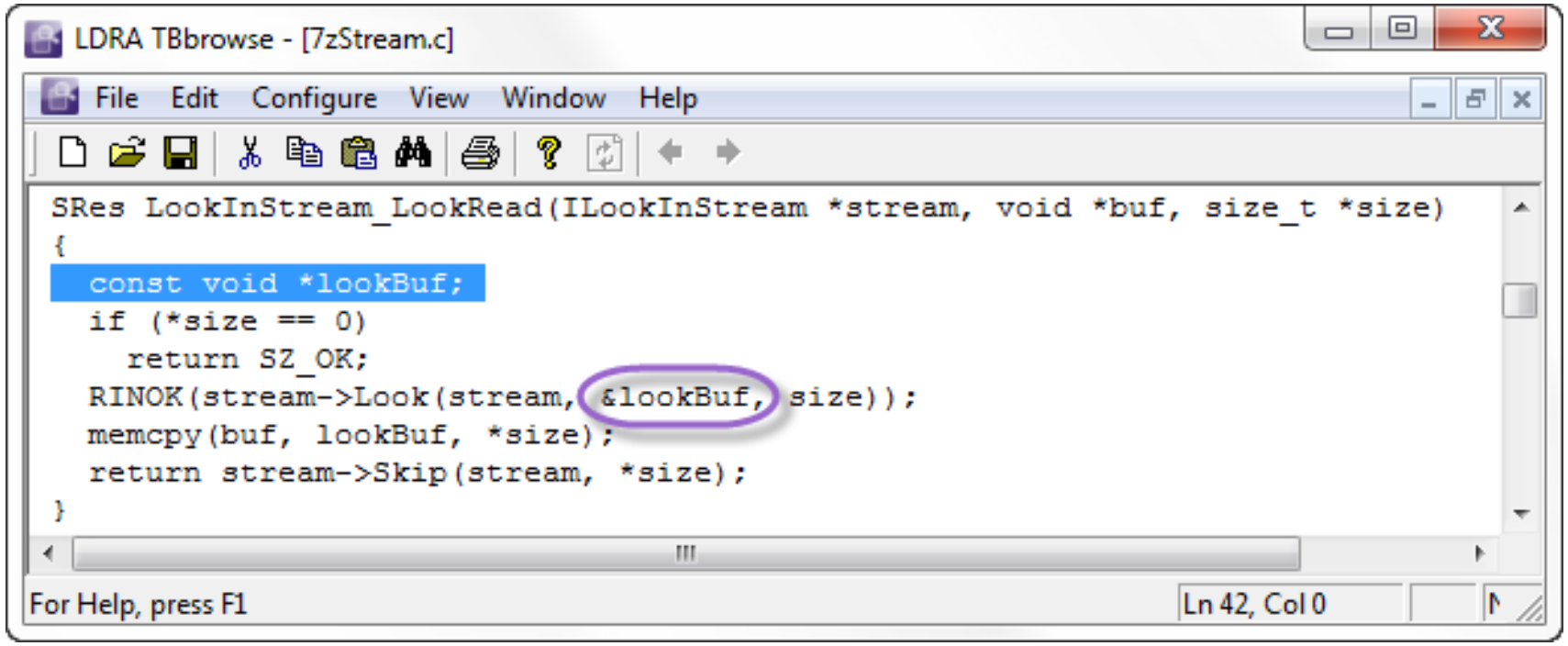
File View
Results View
File Explorer
Lzma
LzmaUtil.c
Threads.c
LzmaEnc.c
LzmaDec.c
LzFindMt.c
LzFind.c
Alloc.c
7zStream.c
7zFile.c
Available Results
Code Review : (By Violation)
Number
Level of Violation
Phase Code
Standard Code
Violations
Function has no return statement. 2 Mandatory 36 S MISRA-C:2012 R.17.4
Procedure contains UR data flow anomalies. 35 Mandatory 69 D MISRA-C:2012 R.9.1
Attempt to use uninitialised pointer. : lookBuf Mandatory 53 D MISRA-C:2012 R.9.1
More than one break or goto statement in loop. 3 Advisory 409 S MISRA-C:2012 R.15.4
Use of comma operator. 2 Advisory 53 S MISRA-C:2012 R.12.3
Numeric overflow. 87 Advisory 493 S MISRA-C:2012 R.12.4
Typedef name has no size indication. 2 Advisory 495 S MISRA-C:2012 D.4.6
Comment possibly contains code. 65 Advisory 302 S MISRA-C:2012 D.4.4
Attempt to change parameter passed by value. 50 Advisory 14 D MISRA-C:2012 R.17.8
Logical conjunctions need brackets. 155 Advisory 49 S MISRA-C:2012 R.12.1
Basic type declaration used. 190 Advisory 90 S MISRA-C:2012 D.4.6
Pointer parameter should be declared const. 129 Advisory 62 D MISRA-C:2012 R.8.13
Reference parameter to procedure is reassigned. 17 Advisory 149 S MISRA-C:2012 R.17.8
Scope of variable could be reduced. 4 Advisory 25 D MISRA-C:2012 R.8.9
Attempt to use uninitialised pointer. : lookBuf
File Vi...
Class Vi...

MISRA Rule 9.1 : False Positive

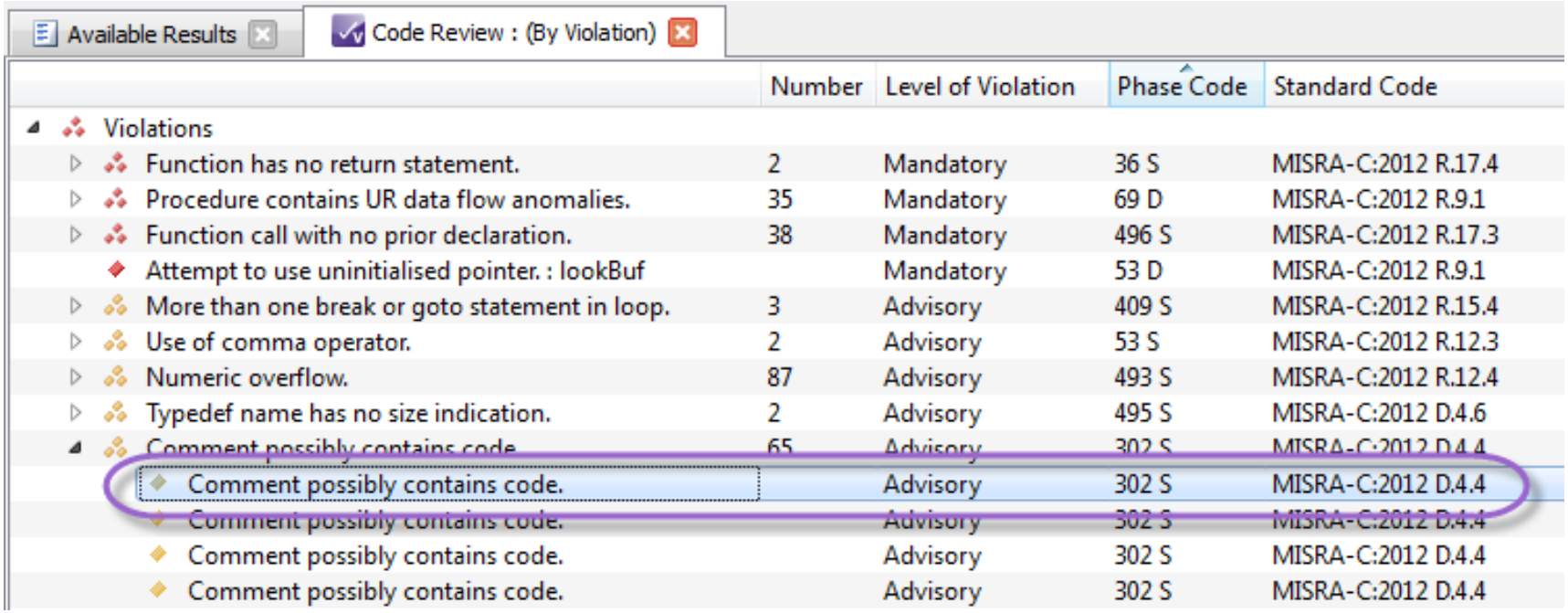
Rule 9.1	The value of an object with automatic storage duration shall not be read before it has been set

C90 [Undefined 41], C99 [Undefined 10, 17]

Category	Mandatory
Analysis	Undecidable, System
Applies to	C90, C99



Code Review


Available Results
Code Review : (By Violation)
Number
Level of Violation
Phase Code
Standard Code
Violations
Function has no return statement. 2 Mandatory 36 S MISRA-C:2012 R.17.4
Procedure contains UR data flow anomalies. 35 Mandatory 69 D MISRA-C:2012 R.9.1
Function call with no prior declaration. 38 Mandatory 496 S MISRA-C:2012 R.17.3
Attempt to use uninitialised pointer. : lookBuf Mandatory 53 D MISRA-C:2012 R.9.1
More than one break or goto statement in loop. 3 Advisory 409 S MISRA-C:2012 R.15.4
Use of comma operator. 2 Advisory 53 S MISRA-C:2012 R.12.3
Numeric overflow. 87 Advisory 493 S MISRA-C:2012 R.12.4
Typedef name has no size indication. 2 Advisory 495 S MISRA-C:2012 D.4.6
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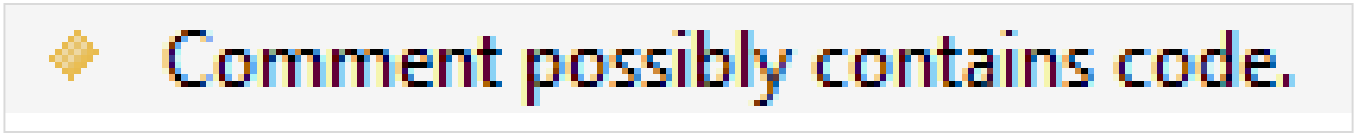
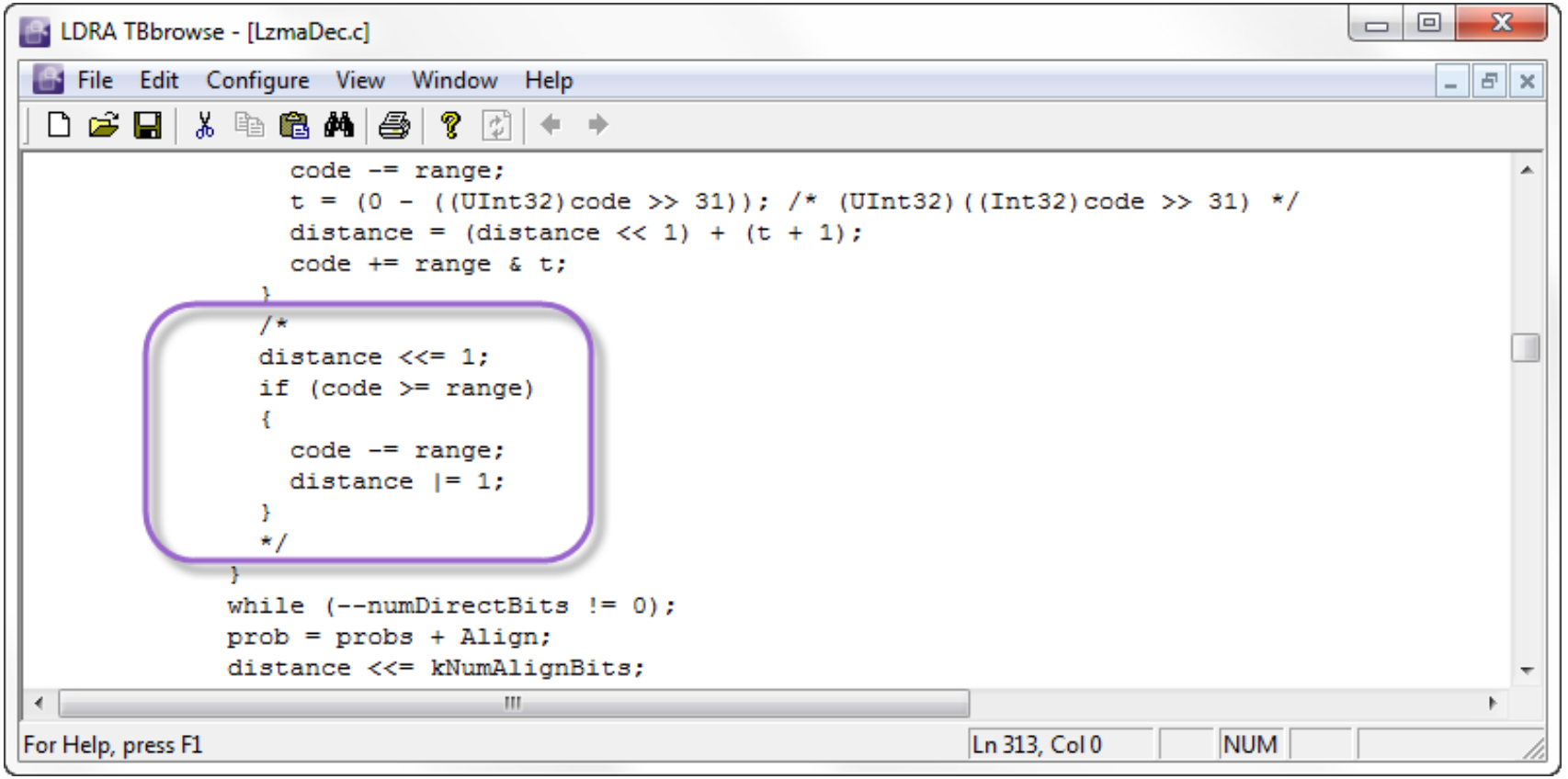

Comment possibly contains code.

MISRA Dir 4.4 : Violation

Dir 4.4	Sections of code should not be “commented out”
Category	Advisory
Applies to	C90, C99

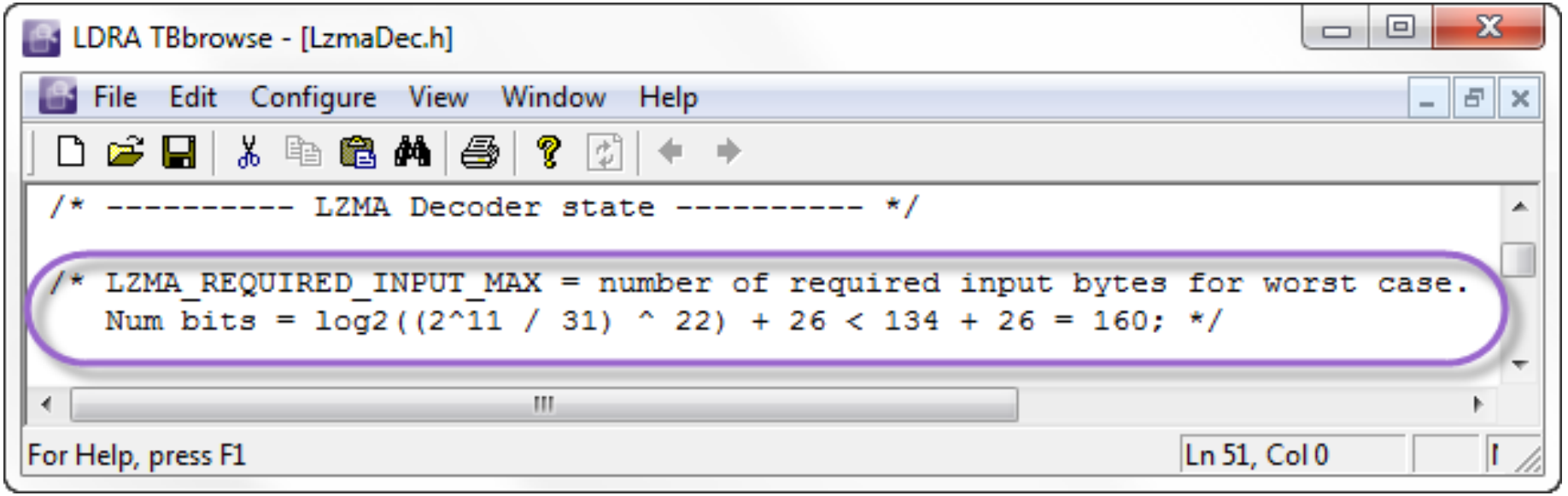


MISRA Dir 4.4 : False Positive

Dir 4.4	Sections of code should not be “commented out”
Category	Advisory
Applies to	C90, C99

Amplification

This rule applies to both // and /* ... */ styles of comment.



Deviation

Rule 18.6	The address of an object with automatic storage shall not be copied to another object that persists after the first object has ceased to exist

C90 [Undefined 9, 26], C99 [Undefined 8, 9, 40]

Category	Required
Analysis	Undecidable, System
Applies to	C90, C99

```
/*
 * Get the produc
 * If no product
 */
const struct Prod
{
  LDRA_uint32_t pIter = 0U;
  const struct Product* theProduct = NULL_POINTER;

  while (pIter < MAX_PRODUCTS)
  {
    if (ProductList[pIter].barcode == bCode)
    {
      theProduct = &ProductList[pIter];
      pIter = MAX_PRODUCTS; /* found it so exit loop */
    }
    else
    {
      pIter++;
    }
  }
  /*LDRA_INSPECTED 71 S: ACSD_004: MISRA C:2012 Rule 18.6 : Returned pointer is ok */
  return theProduct;
}
```

```
/*LDRA_INSPECTED 71 S: ACSD_004:
return theProduct;
```

Deviation Justification Document

ACME Coding Standard Deviations

Deviation	File	LDRA Rule	MISRA C:2012 Rule	Justification
ACSD_001	CashRegister.c	130 S	R.21.5 Required	Ideally <stdio.h> should not be used, but as this code is just used for demonstration purposes, this include was added so that the code can print something out when it runs.
ACSD_004	Productdatabase.c	71 S	R.18.6 Required	**Undecidable rule:** Returned pointer has been checked and is ok.
ACSD_005	Productdatabase.c	71 S	R.18.6 Required	**Undecidable rule:** Returned pointer has been checked and is ok.
ACSD_006	Productdatabase.c	71 S	R.18.6 Required	**Undecidable rule:** Returned pointer has been checked and is ok.

Summary

- Coding Standard
  - If you don't want errors in your code, don't put them there!
  - Mandated by numerous industrial standards
- MISRA C:2012
  - Generic coding standard
  - Extend by adding style, naming conventions, complexity guidelines, … specific to the project
  - Support for C90 and C99
  - Rules / Directives
  - Decidable / Undecidable rules
  - Compliance checking

For further information:

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