Construction and Implementation of CERT Secure Coding Rules Improving Automation of Secure Coding

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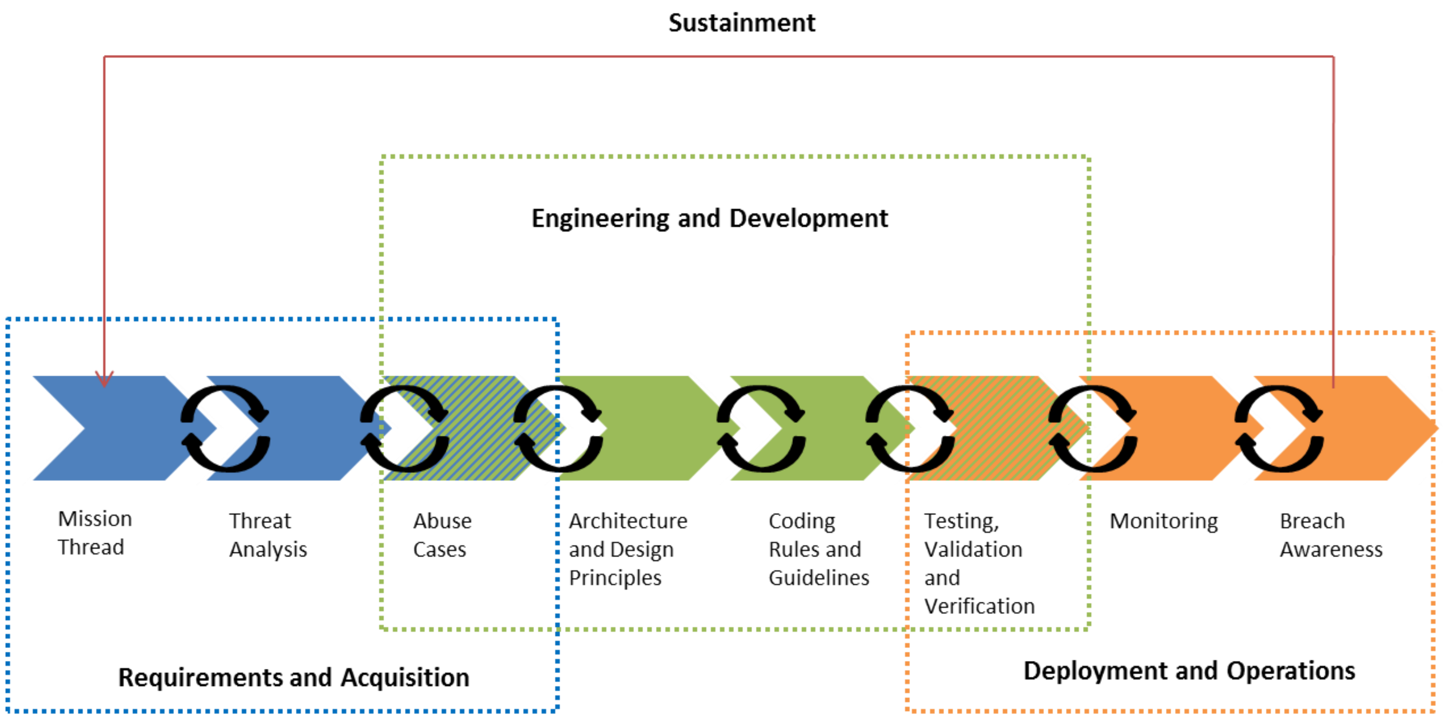
Agenda

- Need for secure coding standards
- Common rule development methodology
- Creating rules is difficult
- Systematic rule development
- CERT Coding Standards
- Summary

Security is a lifecycle issue



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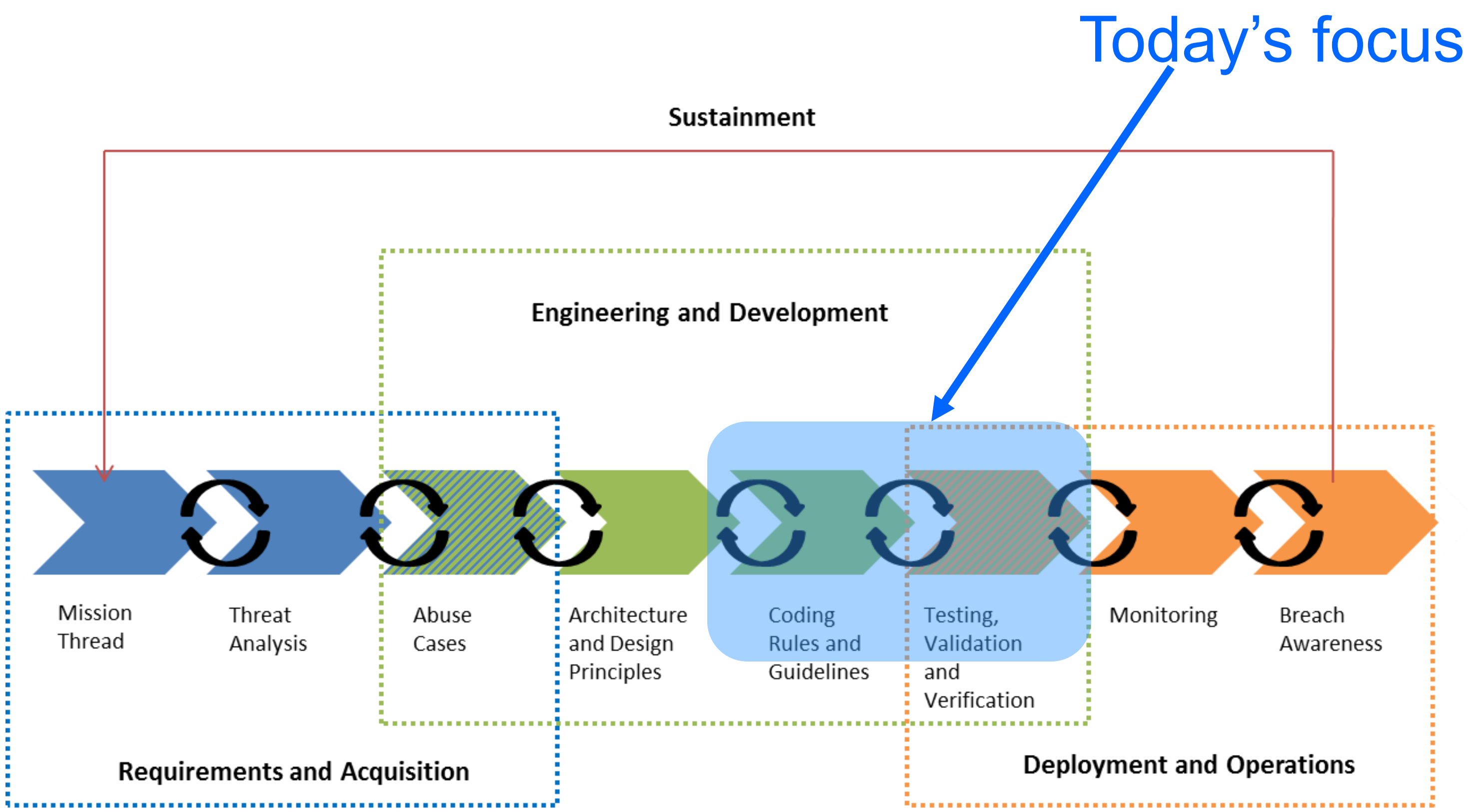
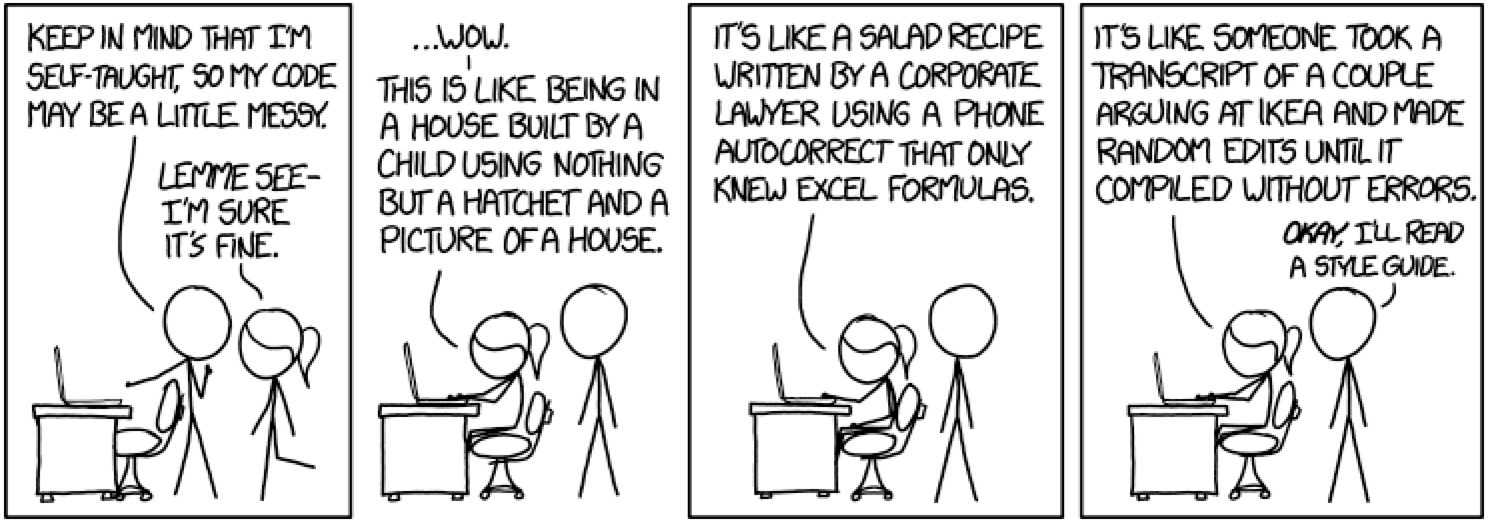
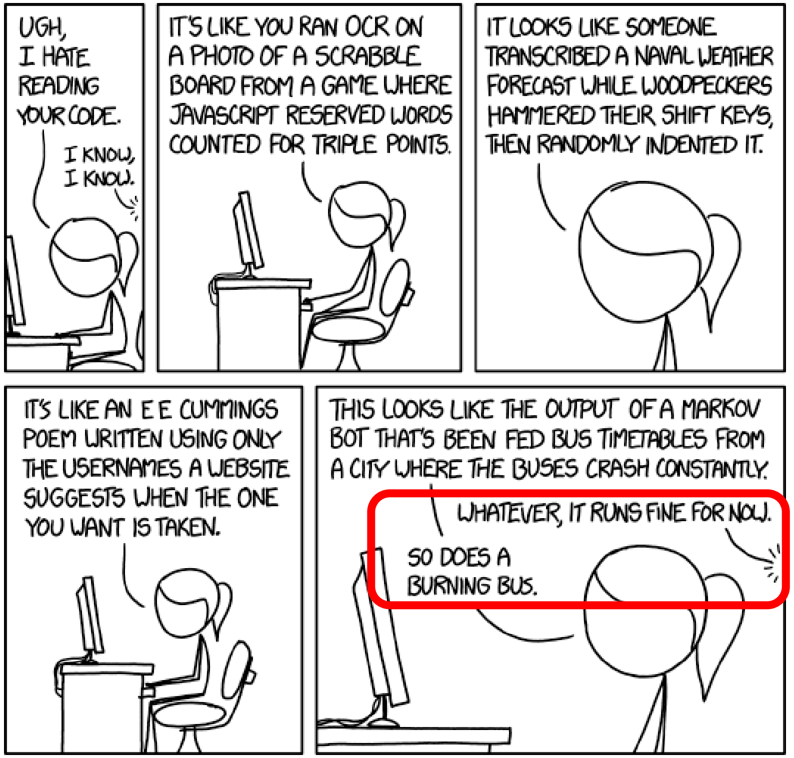


Code security quality reviews generally reveal problems



Source: http://xkcd.com/1513/

Code security quality reviews generally reveal problems – that manifest as vulnerabilities



Source: http://xkcd.com/1695/

Most Vulnerabilities Are Caused by Programming Errors

64% of the vulnerabilities in the National Vulnerability Database were due to programming errors

- 51% of those were due to classic errors like buffer overflows, cross-site scripting, injection flaws

Top 25 CWE includes

- Integer overflow
- Buffer overflow
- Missing authentication
- Missing or incorrect authorization
- Reliance on untrusted inputs (aka tainted inputs)

Sources: Heffley/Meunier (2004): Can Source Code Auditing Software Identify Common Vulnerabilities and Be Used to Evaluate Software Security?; cwe.mitre.org/top25 Jan 6, 2015

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Another crises occurs

Posts are written: CWE Guidance

Common Weakness Enumeration
A Community-Developed Dictionary of Software Weakness Types

CWSS
CWRAF

Home > CWE List > CWE- Individual Dictionary Definition (2.9)   Search by ID: Go

CWE List
Full Dictionary View
Development View
Research View
Fault Pattern View
Reports
Mapping & Navigation
About
Sources
Process
Documents
FAQs
Community
Use & Citations
SwA On-Ramp
Discussion List
Discussion Archives
Contact Us
Scoring
Prioritization
CWSS
CWRAF
CWE/SANS Top 25
Compatibility
Requirements
Coverage Claims Representation
Compatible Products
Make a Declaration
News
Calendar
Free Newsletter
Search the Site

Presentation Filter: --None--

CWE-120: Buffer Copy without Checking Size of Input ('Classic Buffer Overflow')

Buffer Copy without Checking Size of Input ('Classic Buffer Overflow')

Weakness ID: 120 *(Weakness Base)*   **Status:** Incomplete

Description

Description Summary

The program copies an input buffer to an output buffer without verifying that the size of the input buffer is less than the size of the output buffer, leading to a buffer overflow.

……

Detection Methods

Automated Static Analysis

This weakness can often be detected using automated static analysis tools. Many modern tools use data flow analysis or constraint-based techniques to minimize the number of false positives.

Automated static analysis generally does not account for environmental considerations when reporting out-of-bounds memory operations. This can make it difficult for users to determine which warnings should be investigated first. For example, an analysis tool might report buffer overflows that originate from command line arguments in a program that is not expected to run with setuid or other special privileges.

Effectiveness: High

Detection techniques for buffer-related errors are more mature than for most other weakness types.

Automated Dynamic Analysis

This weakness can be detected using dynamic tools and techniques that interact with the software using large test suites with many diverse inputs, such as fuzz testing (fuzzing), robustness testing, and fault injection. The software's operation may slow down, but it should not become unstable, crash, or generate incorrect results.

Manual Analysis

Manual analysis can be useful for finding this weakness, but it might not achieve desired code coverage within limited time constraints. This becomes difficult for weaknesses that must be considered for all inputs, since the attack surface can be too large.

Automated Static Analysis - Binary / Bytecode

According to SOAR, the following detection techniques may be useful:

More guidance is generated

Page Discussion

Buffer Overflows

......

General Prevention Techniques

A number of general techniques to prevent buffer overflows include:

- Code auditing (automated or manual)
- Developer training – bounds checking, use of unsafe functions, and group standards
- Non-executable stacks – many operating systems have at least some support for this
- Compiler tools – StackShield, StackGuard, and Libsafe, among others
- Safe functions – use strncat instead of strcat, strncpy instead of strcpy, etc
- Patches – Be sure to keep your web and application servers fully patched, and be aware of bug reports relating to applications upon which your code is dependent.
- Periodically scan your application with one or more of the commonly available scanners that look for buffer overflow flaws in your server products and your custom web applications.

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Writing rules is hard

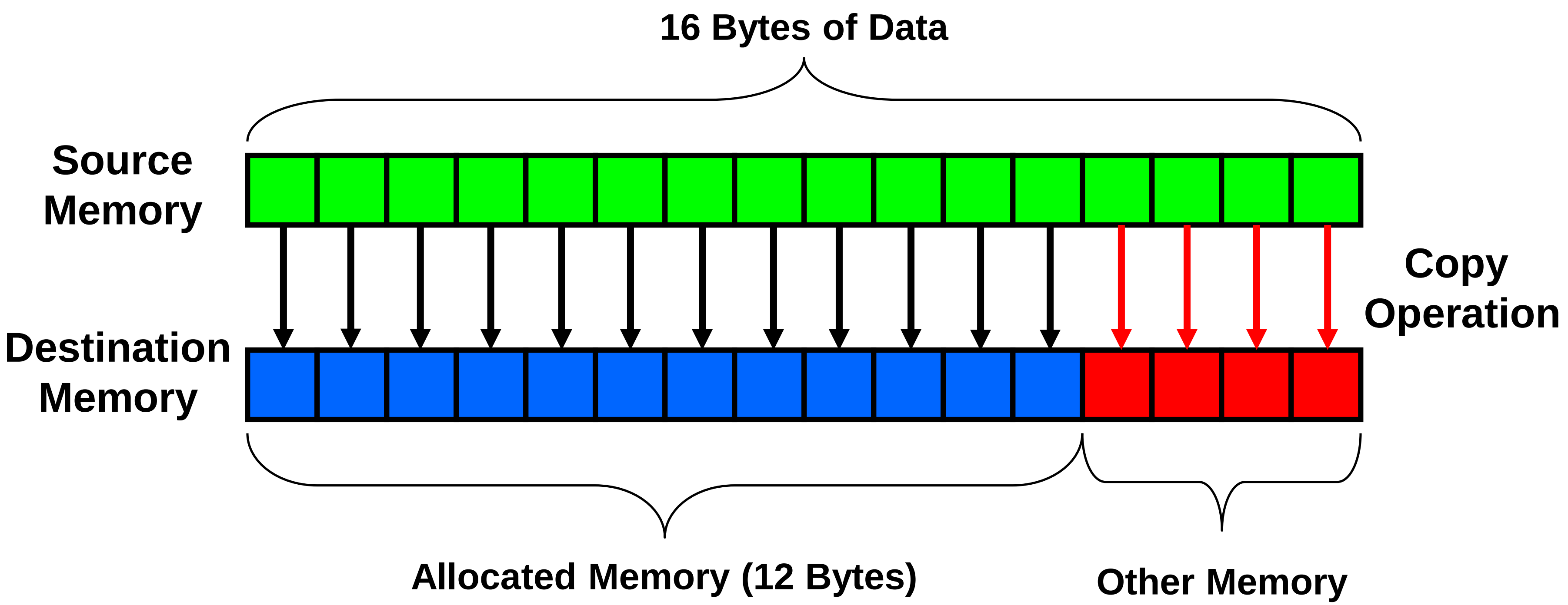
You know it when you see it

Turn up sensitivity => False positives

Turn up selectivity => False negatives

What Is a Buffer Overflow?

A buffer overflow occurs when data is written (or accessed) outside of the boundaries of the memory allocated to a particular data structure.



Buffer overflow: check your bounds

A programmer might code a bounds-check such as

```
char *ptr; // ptr to start of array
char *max; // ptr to end of array
size_t pos; // index input unknown to programmer
if (ptr + pos > max)
  return EINVAL;
```

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If `pos` is very large, it can cause `ptr + pos` to overflow, which typically wraps around — pointing to an address that is actually *lower* in memory than `ptr` (and `max`).

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If `pos` is very large, it can cause `ptr + pos` to overflow, which typically wraps around — pointing to an address that is actually *lower* in memory than `ptr` (and `max`).

Since (overflowed) `ptr + pos` is less than `max`, execution proceeds

Buffer overflow: surprising code elimination

One might write a check like this:

```
if (ptr + len < ptr || ptr + len > max)
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- Programs are well defined
- Hence `ptr + len` will not overflow
- Hence, since `len` is unsigned, `ptr + len` must be greater than or equal to (not less than) `ptr`
- Hence `ptr + len < ptr` is always true and can be removed as dead code

Buffer overflow: surprising optimization

In our example:

```
if (ptr + len < ptr || ptr + len > max)
  return EINVAL;
```

This optimization proceeds as follows:

```
ptr + len < ptr
```

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if (ptr + len < ptr || ptr + len > max)
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This optimization proceeds as follows:

```
ptr + len < ptr
ptr + len < ptr + 0
```

Buffer overflow: surprising optimization

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```
if (ptr + len < ptr || ptr + len > max)
    return EINVAL;
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This optimization proceeds as follows:

`ptr + len < ptr`

`ptr + len < ptr + 0`

~~ptr~~ + len < ~~ptr~~ + 0

Buffer overflow: surprising optimization

In our example:

```
if (ptr + len < ptr || ptr + len > max)
    return EINVAL;
```

This optimization proceeds as follows:

`ptr + len < ptr`

`ptr + len < ptr + 0`

~~ptr~~ `+ len <` ~~ptr~~ `+ 0`

`len < 0 (impossible, len is unsigned)`

The rewritten `len < 0` is removed.

Mitigation

This problem is easy to remediate, once it is called to the attention of the programmer, such as by a diagnostic message when dead code is eliminated.

For example, if `ptr` is less-or-equal-to `max`, then the programmer could write:

```
if (len > max - ptr)
  return EINVAL;
```

This conditional expression eliminates the possibility of undefined behavior.

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An alternative methodology for rule creation

Exploit language ambiguities

Analyze vulnerable programs

Systematically test the rules

And still consult with experts

Examine language definitions and standards for undefined, unspecified and implementation-defined behavior

3.4.3

1 **undefined behavior**

behavior, upon use of a nonportable or erroneous program construct or of erroneous data, for which this International Standard imposes no requirements

2 NOTE Possible undefined behavior ranges from ignoring the situation completely with unpredictable results, to behaving during translation or program execution in a documented manner characteristic of the environment (with or without the issuance of a diagnostic message), to terminating a translation or execution (with the issuance of a diagnostic message).

3 EXAMPLE An example of undefined behavior is the behavior on integer overflow.

3.4.4

1 **unspecified behavior**

use of an unspecified value, or other behavior where this International Standard provides two or more possibilities and imposes no further requirements on which is chosen in any instance

2 EXAMPLE An example of unspecified behavior is the order in which the arguments to a function are evaluated.

Source: http://www.open-std.org/jtc1/sc22/wg14/www/docs/n1124.pd (ISO 9899 - Programming Languages – C draft)

Examine vulnerable code for patterns

Malware repository with millions of unique, tagged artifacts

CERT Secure Coding Team has evaluated over 100M LOC

CERT | Software Engineering Institute | Carnegie Mellon University

Vulnerability Notes Database

Advisory and mitigation information about software vulnerabilities

CERT Knowledgebase

The CERT Knowledgebase is a collection of internet security information related to incidents and vulnerabilities. The CERT Knowledgebase houses the public Vulnerability Notes Database as well as two restricted-access components:

- Vulnerability Card Catalog contains descriptive and referential information regarding thousands of vulnerabilities reported to the CERT Coordination Center.
- Special Communications Database contains briefs that provide advance warning and important information about vulnerabilities, intruder activity, or other critical security threats.

Implement candidate rules and run against sample code

- Focus rule when possible to
  - maximize true positive of weakness (tag bad code)
  - minimize false negative of weakness (don't tag good code)

- Write program to evaluate source code for particular rule

- Run program against collection of known bad source code and a collection of other (suspected good) code to check sensitivity and specificity of results

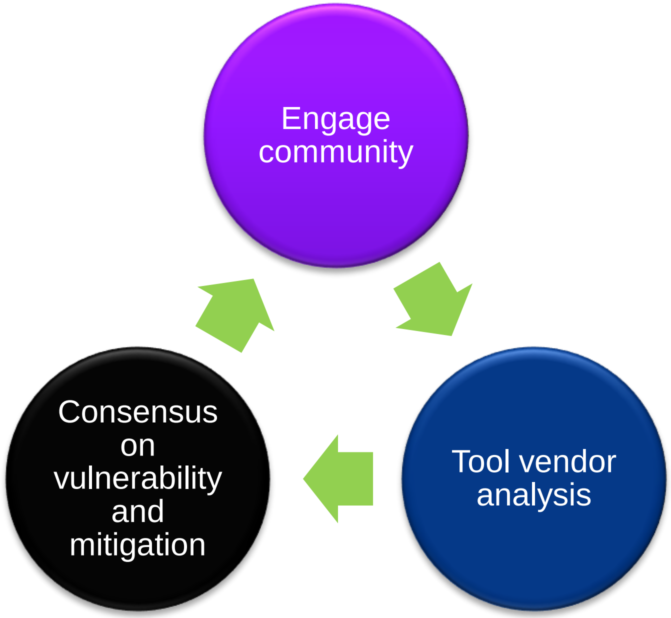
Experience with systematic testing

- Candidate rule typical evaluation
  - 10 iterations of proposed rule and associated checker
    - 7 internal evaluations
    - 3 external evaluations

- Each evaluation iteration carried out against > 10M lines of representative code
  - Variety of domains
  - Variety of code quality

- As part of creating C++ standard, general methodology applied to generate 46 rules and corresponding Clang C++ checkers
  - 19 by CERT researchers, 27 by others

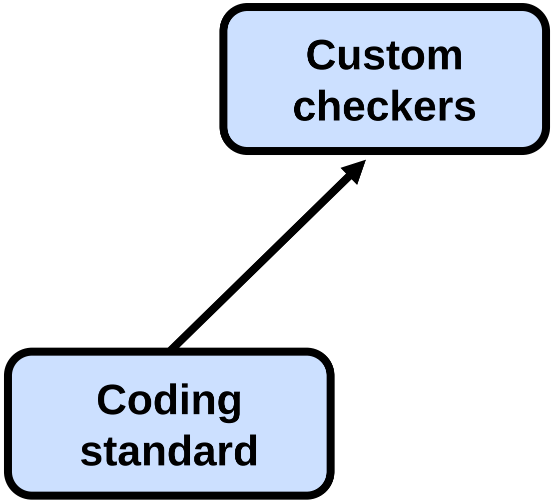
Tapping into expert knowledge for developing CERT coding standards



Evolution of coding support

Coding standard

Evolution of coding support



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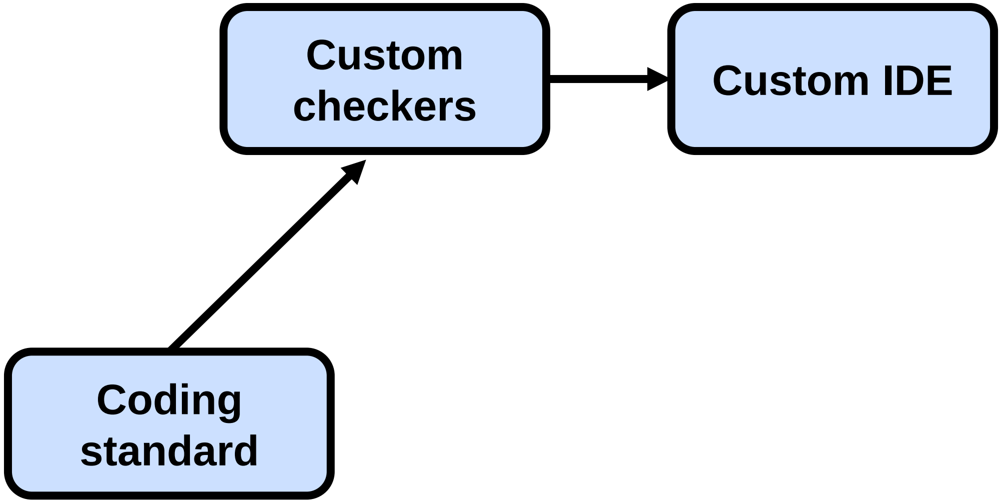

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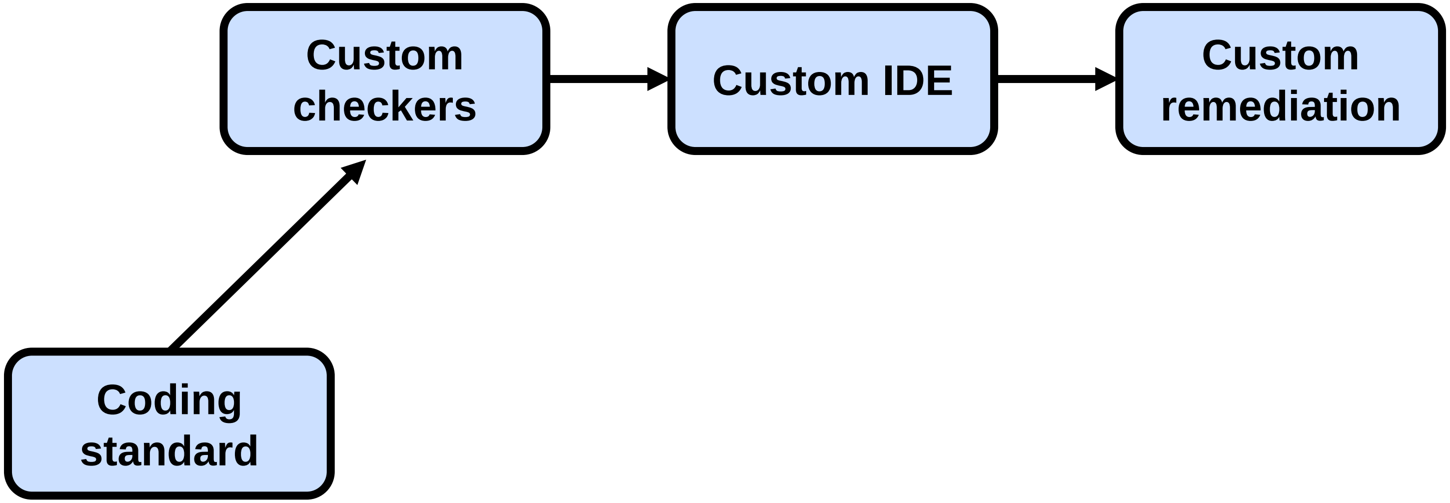

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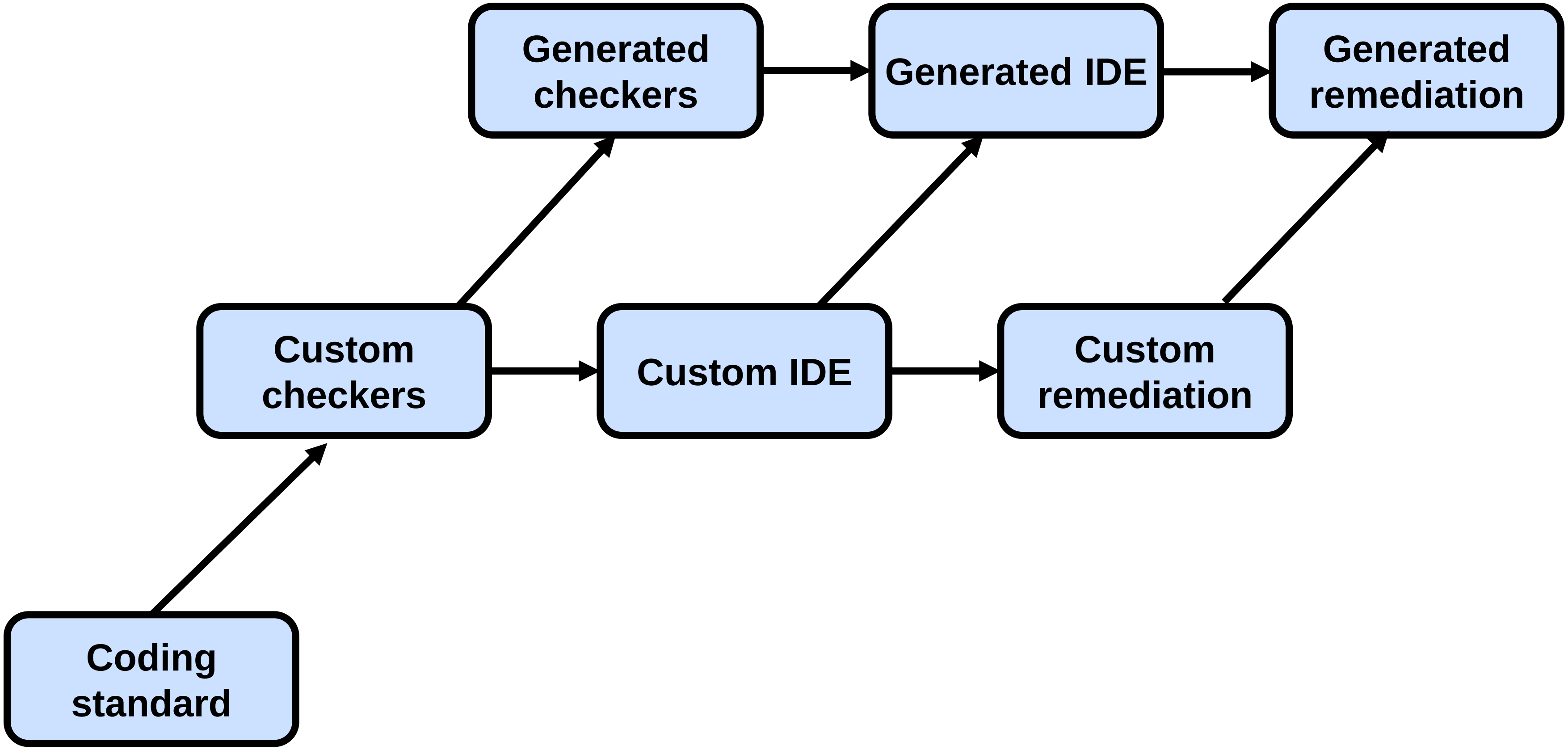

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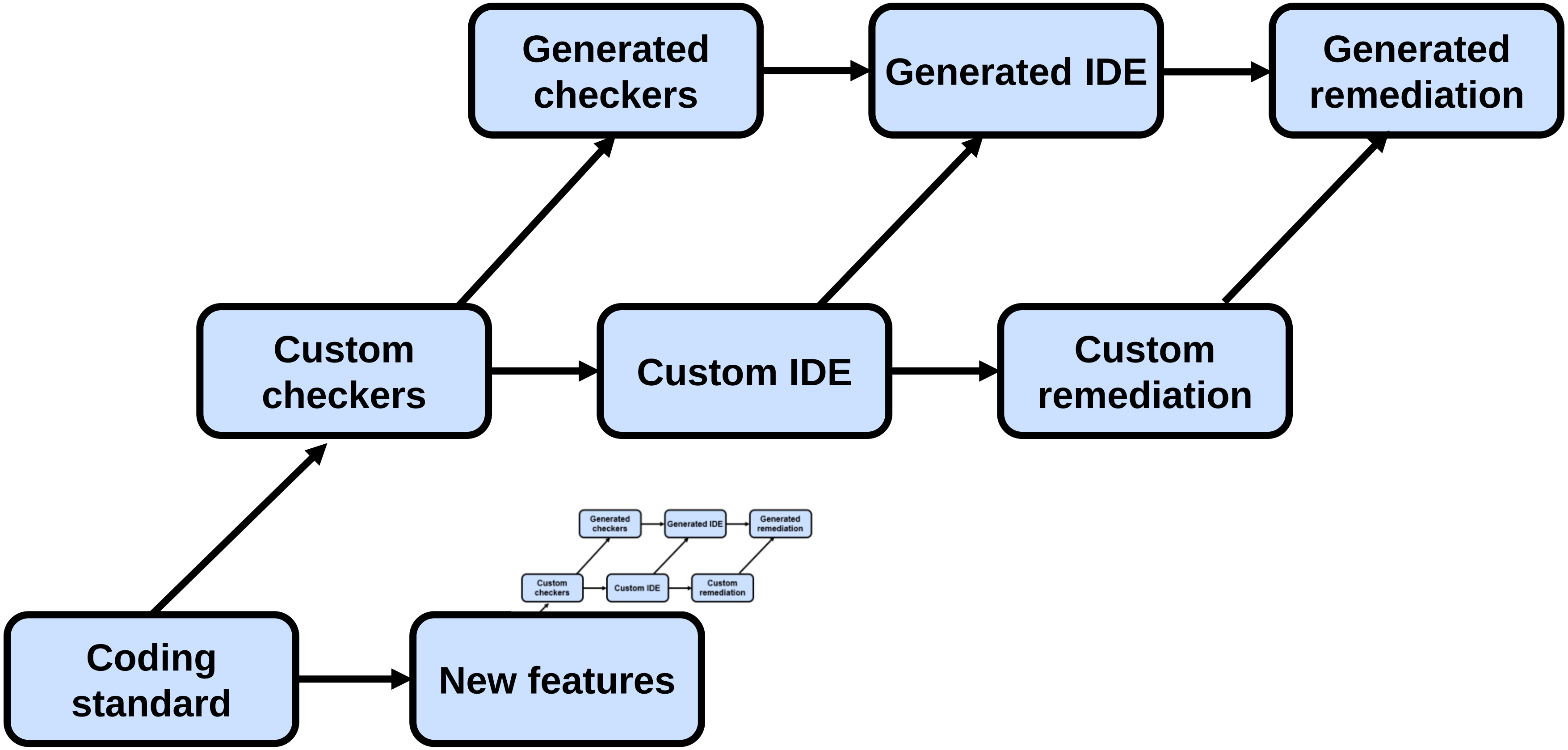

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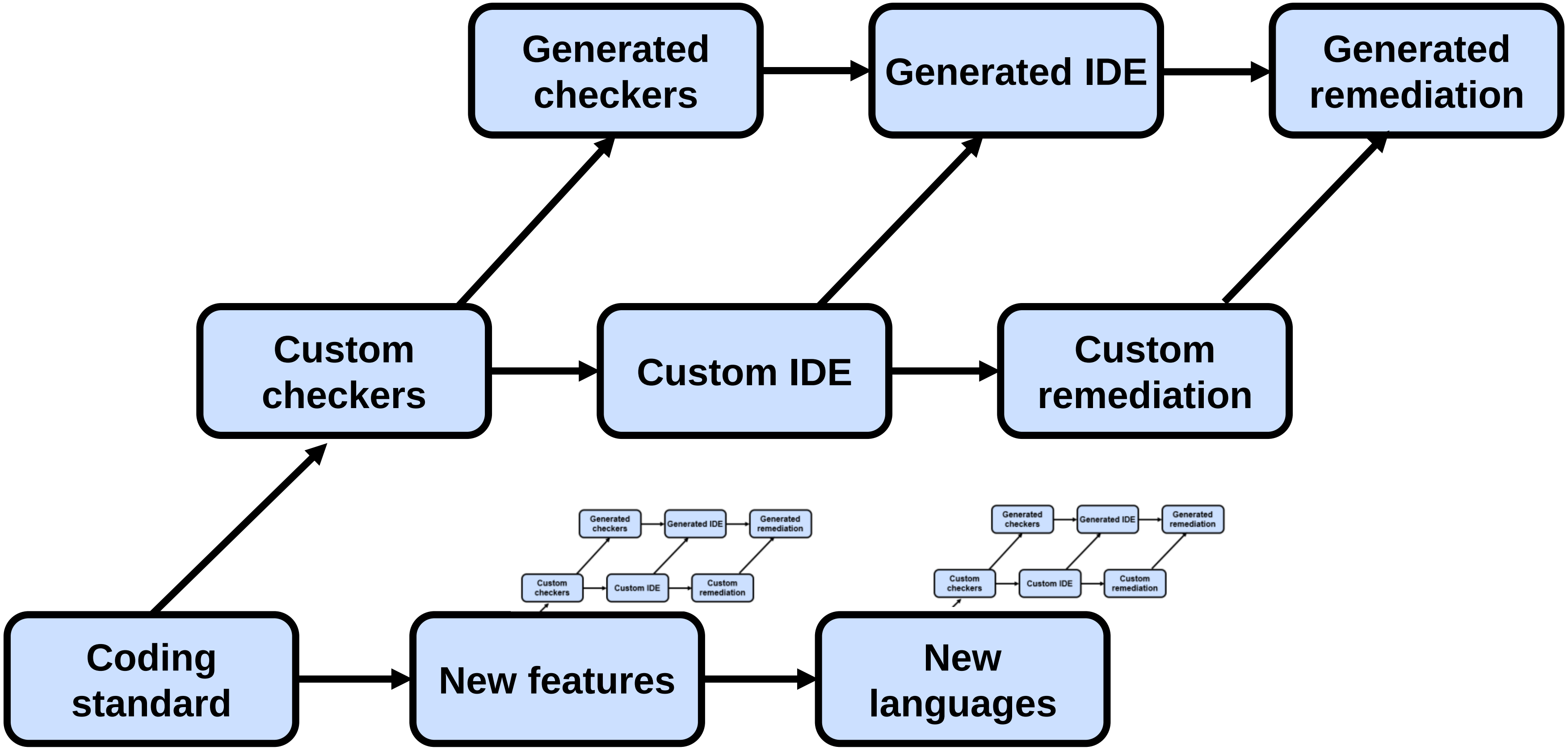

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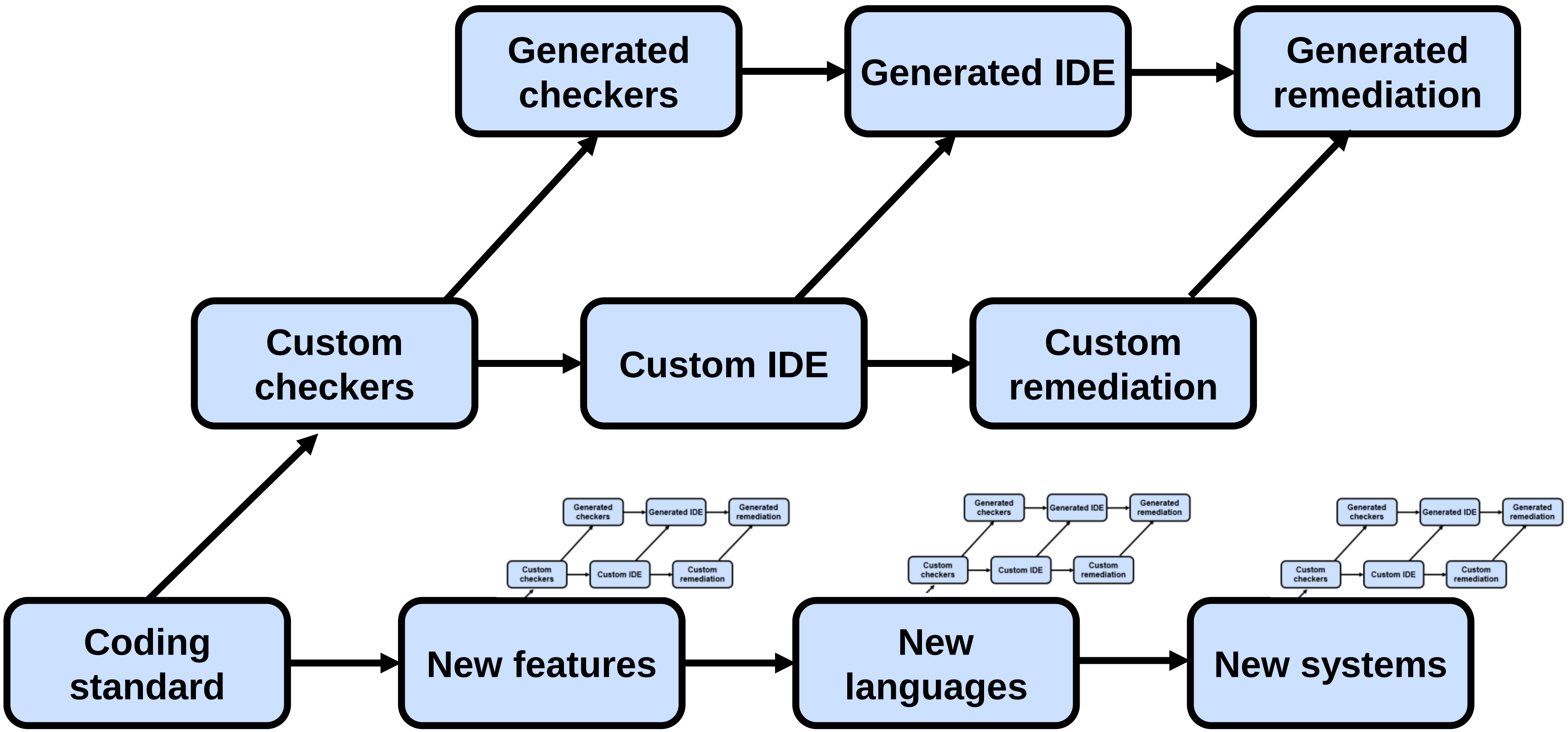

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CERT Secure Coding Standards

CERT C Secure Coding Standard

- Version 1.0 (C99) published in 2009
- Version 2.0 (C11) published in 2014
- ISO/IEC TS 17961 C Secure Coding Rules Technical Specification
- Conformance Test Suite

CERT C++ Secure Coding Standard

- Version 1.0 under development

CERT Oracle Secure Coding Standard for Java

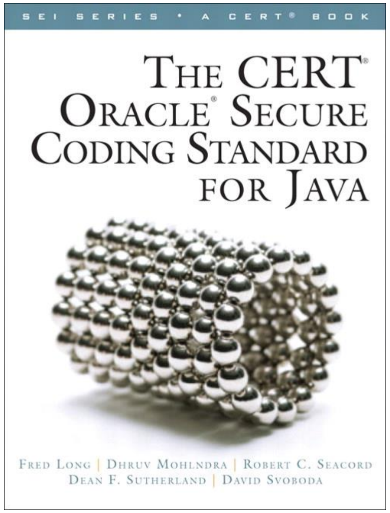
- Version 1.0 (Java 7) published in 2011
- Java Secure Coding Guidelines
- Subset applicable to Android development
- Android Annex

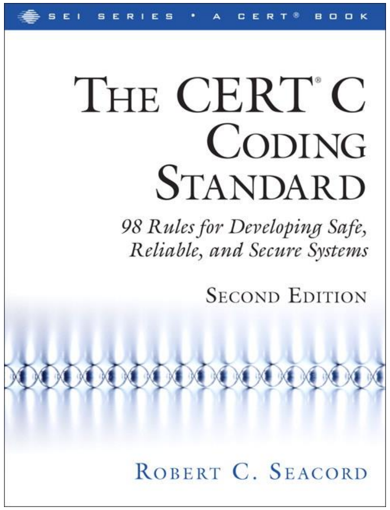
The CERT Perl Secure Coding Standard

- Version 1.0 under development

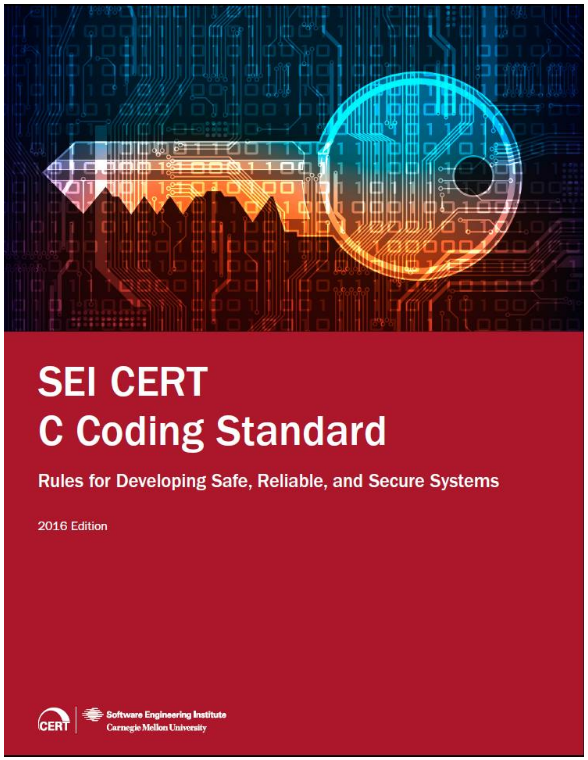
CERT Python Secure Coding Standard

- Version 1.0 under development





Coding rules – 2016 Edition



- Collected wisdom of programmers and tools vendors
  - Fed by community wiki started in Spring 2006
  - Over 1,500 registered contributors
- Available as downloadable eBook

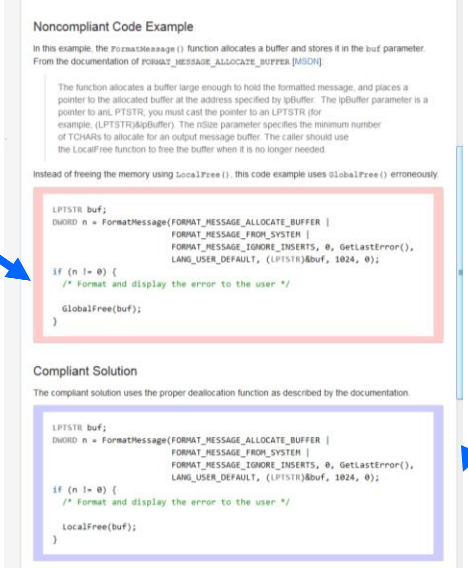
http://cert.org/secure-coding/products-services/secure-coding-download.cfm

Learning from rules and recommendations

Rules and recommendations in the secure coding standards focus to improve behavior

The “Ah ha” moment:

Noncompliant code examples or antipatterns in a pink frame—do not copy and paste into your code



Noncompliant Code Example

In this example, the `FormatMessage()` function allocates a buffer and stores it in the `buf` parameter. From the documentation of `FORMAT_MESSAGE_ALLOCATE_BUFFER` [MSDN]:

> The function allocates a buffer large enough to hold the formatted message, and places a pointer to the allocated buffer at the address specified by lpBuffer. The lpBuffer parameter is a pointer to anL PTSTR; you must cast the pointer to an LPTSTR (for example, (LPTSTR)&lpBuffer). The nSize parameter specifies the minimum number of TCHARs to allocate for an output message buffer. The caller should use the LocalFree function to free the buffer when it is no longer needed.

Instead of freeing the memory using `LocalFree()`, this code example uses `GlobalFree()` erroneously.

```
LPTSTR buf;
DWORD n = FormatMessage(FORMAT_MESSAGE_ALLOCATE_BUFFER |
                        FORMAT_MESSAGE_FROM_SYSTEM |
                        FORMAT_MESSAGE_IGNORE_INSERTS, 0, GetLastError(),
                        LANG_USER_DEFAULT, (LPTSTR)&buf, 1024, 0);
if (n != 0) {
  /* Format and display the error to the user */

  GlobalFree(buf);
}
```

Compliant Solution

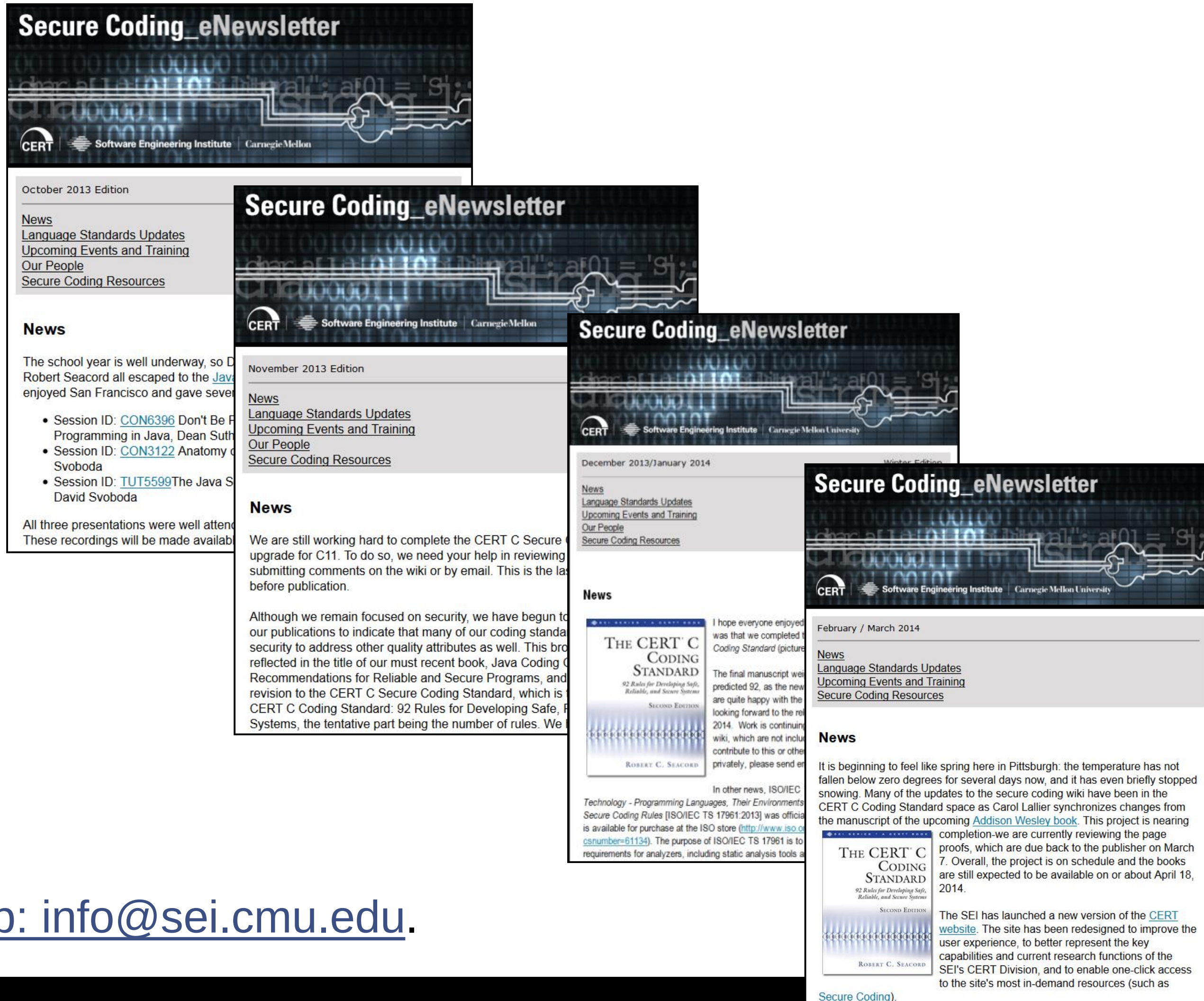
The compliant solution uses the proper deallocation function as described by the documentation.

```
LPTSTR buf;
DWORD n = FormatMessage(FORMAT_MESSAGE_ALLOCATE_BUFFER |
                        FORMAT_MESSAGE_FROM_SYSTEM |
                        FORMAT_MESSAGE_IGNORE_INSERTS, 0, GetLastError(),
                        LANG_USER_DEFAULT, (LPTSTR)&buf, 1024, 0);
if (n != 0) {
  /* Format and display the error to the user */

  LocalFree(buf);
}
```

Compliant solutions in a blue frame that conform with all rules and can be reused in your code

Secure Coding eNewsletter engages community



Signup: info@sei.cmu.edu.

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Application of coding standards can avoid many vulnerabilities seen in the field

Making a standard should be based on more than opinion

Prescriptive standards give

- Developers actionable guidance to create secure code
- Tool makers actionable guidance to create testers for secure code
- Acquirers actionable requirements for licensed or developed code

Contact Information

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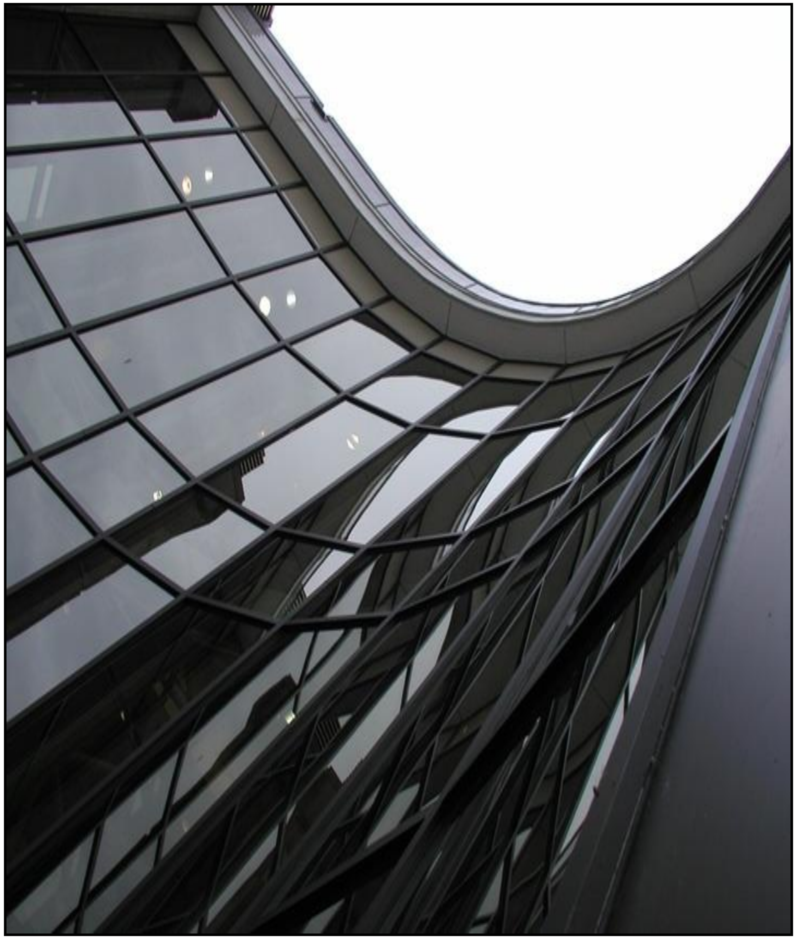

Web Resources (CERT/SEI)

http://www.cert.org/

http://www.sei.cmu.edu/

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