Secure Software Development

Defensive Programming

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Defense-in-Depth

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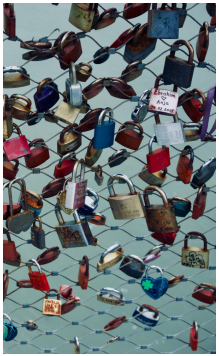
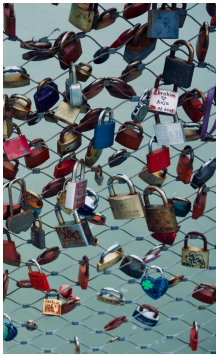


- Understand the attacker's perspective

Defense-in-Depth



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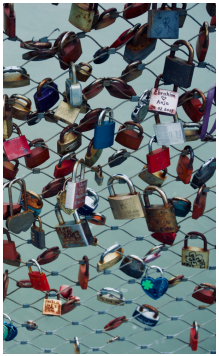

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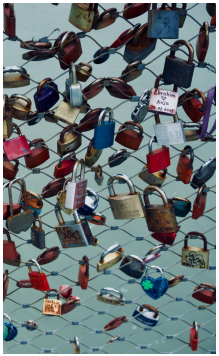

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- Defend on all layers
  - The weakest link will break first

Defense-In-Depth

Attacker's perspective

- Vulnerability discovery ☑
- Exploitation ☑
- Privilege elevation ☑

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- Vulnerability discovery
  - buffer/integer overflow, use-after-free, format strings, type confusion
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Defender's perspective

- Vulnerability prevention
  - Code quality, memory safety, type safety, error handling ...
- Exploit prevention
  - Compiler/runtime defenses, hardware defenses
- Privilege minimization
  - System call filtering, sandboxing, virtualization

Vulnerability Prevention: Goals I

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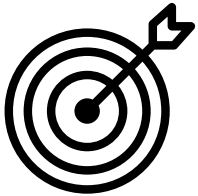

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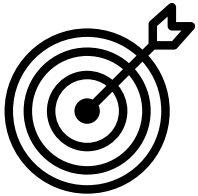

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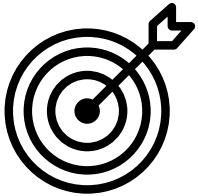

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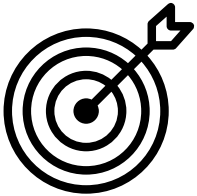
  - Model-based Testing, Verification and Testing

Vulnerability Prevention: Goals II



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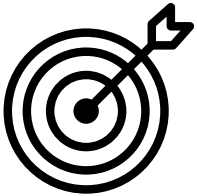

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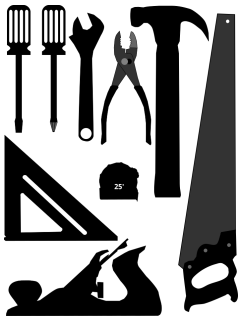
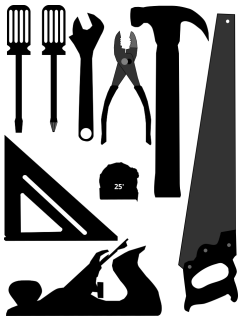
🏁 Overall goal II: Make exploitation as hard as possible (System hardening)

Defensive Programming Overview



Vulnerabilities

Defensive Programming: Goals & Principles



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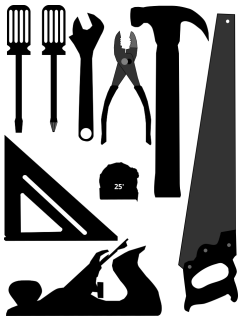

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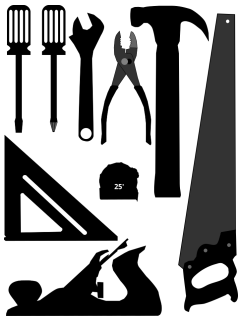

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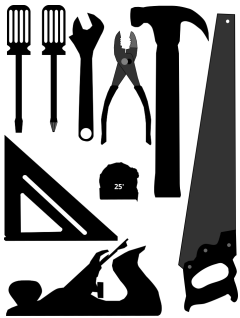

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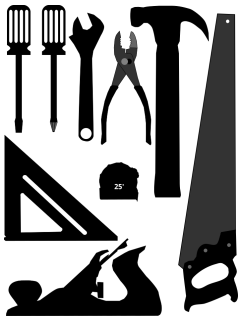

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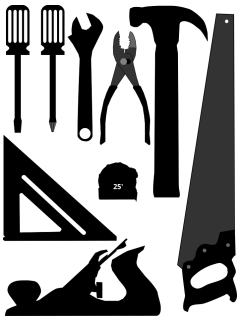

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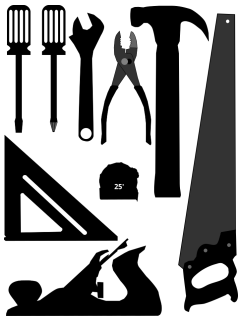

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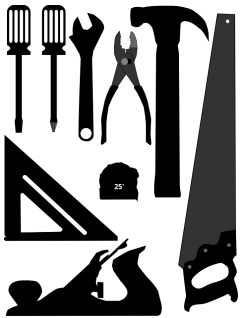

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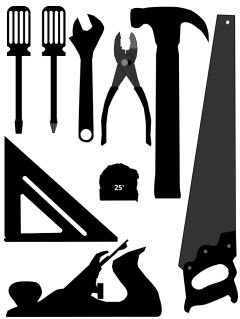

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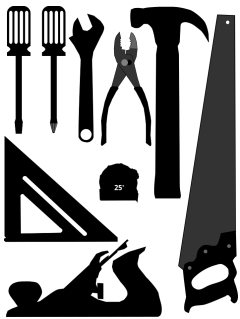

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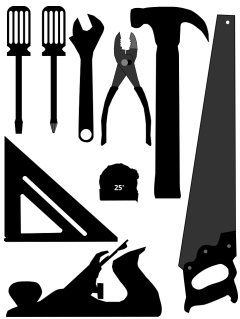

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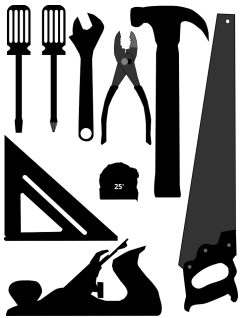

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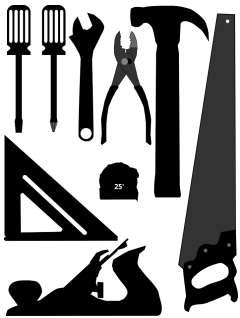

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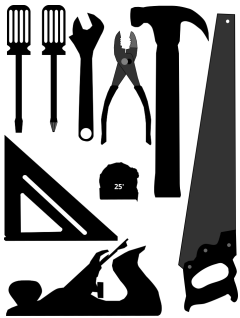

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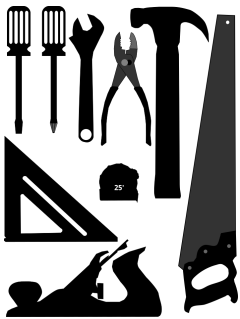

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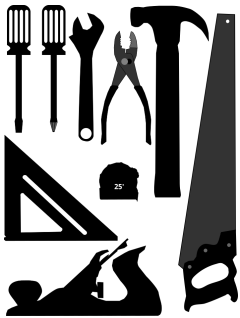

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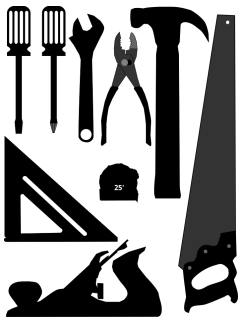

Sub-goals

- Memory safety
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  - Memory-safe languages: Compiler can optimize out unnecessary bounds checks

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```
memset(ptr, 0, size); free(ptr); ptr = NULL;
```

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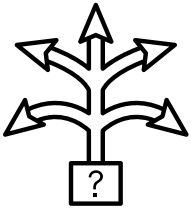

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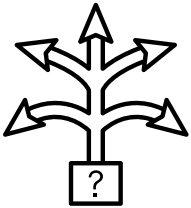

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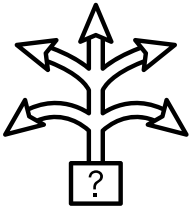

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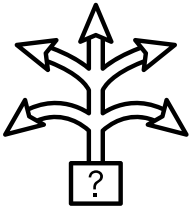

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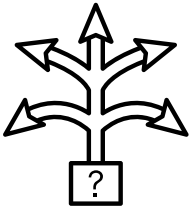

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  - Avoid C++ `reinterpret_cast`

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☹ Typically consume 2–5 times more memory per pointer

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int y = ...;
long long x = y + 2;    // int-addition might overflow
long long x = (long long)y + 2LL;
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long long x = (long long)y + 2LL;
```

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int x = ...;
if (x > SHORT_MAX) error();
short y = (short)x;
```

Integer Safety III

🏴 Goal 3: prevent undefined behavior

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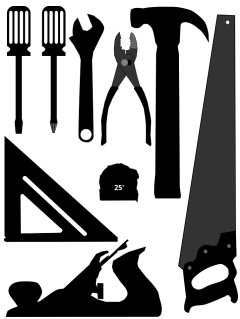
  - Left-shift by a negative number (architecture!)
  - Unsequenced modifications:

```
int f(int i) {
    return i++ + i++; /* undefined behavior: two unsequenced
    modifications to i */
}
```

Defensive Programming: Goals & Principles



Sub-goals

- Memory safety
- Type safety
- Integer safety
- Secure data flow
  - Input sanitization
- Secure control flow
  - Error handling

General principles

- Choose appropriate language
- Improve code quality:
  - Coding standard
  - Source code reuse
  - Assumptions
  - Documentation
  - Testing & Assertions
  - Compiler assistance

Secure Data Flow

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  - Better: Check *every* input
  - 👉 **Input sanitization**

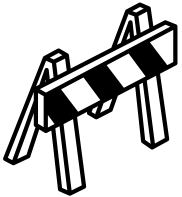
by **Michael Mimoso** Follow @mike_mimoso January 28, 2016 , 9:04 am

Stepankin said he was able to execute arbitrary shell commands on PayPal servers by taking advantage of insecure Java object deserialization. He wrote in a blog post that he was able to access PayPal's production servers.

"I realized that I could execute arbitrary OS commands on manager.paypal.com web servers and moreover, I could establish a back connection to my own internet server and, for example, upload and execute a backdoor," he wrote. "[As a] result, I could get access to production databases used by manager.paypal.com application."

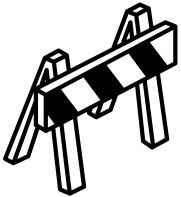
"I just read "/etc/passwd" file by sending it to my server as a proof of the vulnerability," he wrote.

Secure Data Flow: Input Sanitization



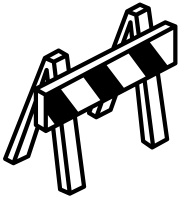
- Goal: sanitize dangerous input

Secure Data Flow: Input Sanitization



- Goal: sanitize dangerous input
  - Detect and reject

Secure Data Flow: Input Sanitization



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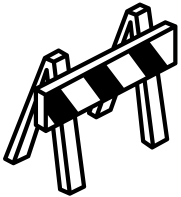
Secure Data Flow: Input Sanitization



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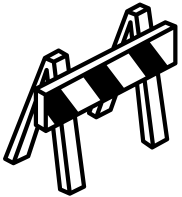

- Goal: sanitize dangerous input
  - Detect and reject
  - Filtering
  - Character escaping
  - Use existing sanitizers wherever possible!

Secure Data Flow: Canonicalization I

- Issue: equivalent representations make sanitization a pain

Secure Data Flow: Canonicalization I

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Example: equivalent Unix paths

```
/proc/self/maps
~/../../proc/self/maps
~/../../../../../proc/1/maps
/proc/1/./maps
/proc/1/./////maps
/proc/../proc/1/maps
...
```

Secure Data Flow: Canonicalization II

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```
../../etc/passwd --> /etc/passwd --> DENY
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More issues to consider

- Newlines: `\r\n` vs. `\n`

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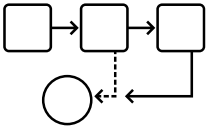
Use existing libraries

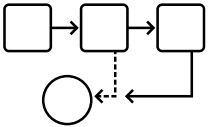
Secure Control Flow

Secure Control Flow: Proper Error Handling



- Return error codes

Secure Control Flow: Proper Error Handling



- Return error codes
- Exception handling

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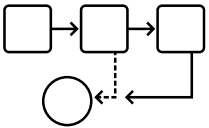

- Return error codes
- Exception handling
- Goto

Secure Control Flow: Return Error Codes I

```
1  FILE* f = fopen("report.log", "a");
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4  fclose(f);
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- Exceptions
  - If there's nothing you can do in case of an error
  - In particular cleanup routines `fclose`, `munmap`, (`free`)

Secure Control Flow: Return Error Codes II

```
1  FILE* f = fopen("report.log", "a");
2  if (NULL == f) { perror("Unable to open file"); return; }
3  assert(0 > fprintf(f, "Server started\n"));
4  printf("DEBUG: we're running\n");
5  fclose(f);
```

Secure Control Flow: Return Error Codes II

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Compiler might optimize out `asserts` (line 3)

- `fprintf` is never executed!
- Compile flag `-DNDEBUG`

Never use `assert` to check for actual error codes

Secure Control Flow: Return Error Codes III

```
1  char* tmp = realloc(buffer, newsize);
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Secure Control Flow: Return Error Codes III

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> The realloc() function returns a pointer to the newly allocated memory, which is suitably aligned for any built-in type and may be different from ptr, or NULL if the request fails. If size was equal to 0, either NULL or a pointer suitable to be passed to free() is returned. If realloc() fails, the original block is left untouched; it is not freed or moved.

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```
1  char* tmp = realloc(buffer, newsize);
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```

- Make sure your own functions return proper error codes

Secure Control Flow: Return Error Codes IV

```c
#include <stdio.h>
#include <errno.h>
#include <string.h>
FILE* f = fopen("foo","rb");
if(f == NULL) {
  //prints:
  //Error Number: 2 No such file or directory
  fprintf(stderr,"Error Number: %d %s", errno, strerror(errno));
  exit(errno);
}
```


EXCEPTIONS
EXCEPTIONS EVERYWHERE
makeameme.org

Secure Control Flow: Exceptions II

- Exceptions can make your code clean

Image source: `https://www.viva64.com/en/b/0426/`

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  - *"The internal SRI software exception was caused during execution of a data conversion from 64-bit floating point to 16-bit signed integer value."*

`http://sunnyday.mit.edu/nasa-class/Ariane5-report.html`

Image source: `https://www.viva64.com/en/b/0426/`

Secure Control Flow: C++ Exceptions I

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  MyClass* a = new MyClass();              // std::bad_alloc exception
  MyClass& b = dynamic_cast<MyClass&>(c); // std::bad_cast exception
}
catch (std::exception& e)
{
  std::cout << "Exception: " << e.what() << std::endl;
}
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- Exceptions do not save you from thinking through all possibilities

Secure Control Flow: C++ Exceptions II

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Secure Control Flow: C++ Exceptions II

- Only use exceptions for error cases
- Specify which exceptions your function throws
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- Catch exceptions at the correct location
  - `main` is likely the wrong location
- Watch out for information leakage if your webserver publicly dumps the exception trace ;)

Secure Control Flow: C goto for the Rescue I

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- Use `goto` for nothing else
  - Only jump forward, not backward

Secure Control Flow: C goto for the Rescue II

```c
char *resourceA = NULL;
FILE *resourceB = NULL;
void *resourceC = MAP_FAILED;
int err = SUCCESS;

resourceA = malloc(10);
if (NULL == resourceA) {
    err = ERROR_A; goto failed;
}
resourceB = fopen(...);
if (NULL == resourceB) {
    err = ERROR_B; goto failed;
}
resourceC = mmap(...);
if (MAP_FAILED == resourceC) {
    err = ERROR_C; goto failed;
}
return SUCCESS;
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if (MAP_FAILED == resourceC) {
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return SUCCESS;
```
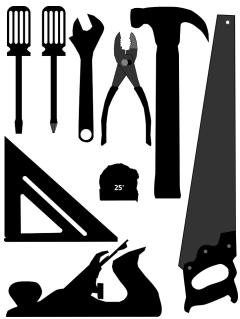

```c
failed:
    if (MAP_FAILED != resourceC) {
        munmap(resourceC);
    }
    if (NULL != resourceB) {
        fclose(resourceB);
    }
    free(resourceA);
    return err;
```

Defensive Programming: Goals & Principles



Sub-goals

- Memory safety
- Type safety
- Integer safety
- Secure data flow
  - Input sanitization
- Secure control flow
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General principles

- Choose appropriate language
- Improve code quality:
  - Coding standard
  - Source code reuse
  - Assumptions
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Defensive Programming: Choose Appropriate Language

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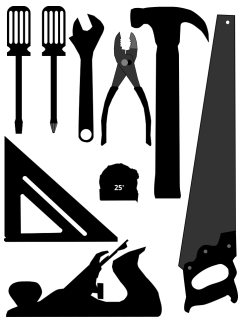
Defensive Programming: Goals & Principles



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```
int readPassword(const char* path_password) {
    if (NULL == path_password) {
        return ERROR;
    }
    FILE* file_password = fopen(path_password, "r");
    if (NULL != file_password) {
        return ERROR;
    }
    ...
```

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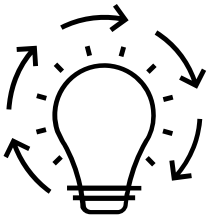
```
#define CHECK_RETURN_ON_ERROR(stmt, err_msg) do { \
  int result = (int)(stmt); \
  if (result < 0) { \
      printf("CHECK failed with %d: %s", result, (err_msg)); \
      return result; \
  } \
} while(0)
```

Improve Code Quality: Intelligent Source Code Reuse



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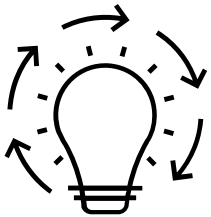

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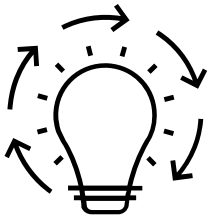

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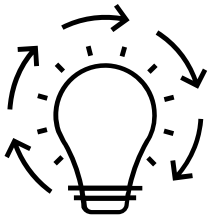

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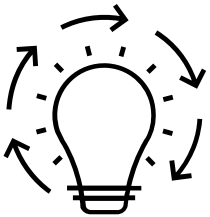

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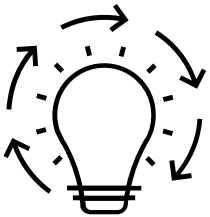

- ✋ "Do not rewrite your own $THING", especially
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- 👉 Reuse **established** libraries
  - Stackoverflow/Copilot should be taken with care

PENTEST .BLOG

ADVISORIES OPERATING SYSTEM APPLICATION SECURITY NETWORK TOOLS

One ring to rule them all – Same RCE on multiple Trend Micro products

October 8, 2017 Mehmet Ince Research

One ~~ring~~ bug to rule them all – Widgets of Trend Micro's Products

Most of the Trend Micro's products have a widgets for administrator web page. Although core system written with Java/.NET, this widget mechanism had implemented with PHP. That means, they somehow need to put PHP interpreter on product whenever they decided to use widgets. Which makes it a perfect spot to what we need: a single code base, exist across the different product and awesome way to implement reliable exploit once we have an vulnerability.

For the reasons that I've mentioned above, I performed a code audit for widget system of **Trend Micro OfficeScan** product. Result is quite interesting as well as unfortunate for me. I've found 6 different vulnerability but only 2 of them is **0day**.

[…]

Conclusion

First of all, I would like to say again, this command injection vulnerability has been patched by Trend Micro for both of these products. If you are a Trend Micro user or your organisation is using any of these products, hurry up! Patch your system.

Having same code base on different products is not something bad. I just wanted to point out that one bug within your framework can cause a massive trouble.

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- E.g., Ariane 5 reused code from old rocket without checking its assumptions

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- Know undefined behavior of your programming language

  `https://wiki.sei.cmu.edu/confluence/display/c/CC.+Undefined+Behavior`

  See no. 51, 52, 53...

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    `http://www.pixelbeat.org/programming/gcc/static_assert.html`
  - ☺ Finally, C11 has native support for static asserts

    ```
    static_assert(sizeof(int) == 4, "int must be 4 bytes");
    ```

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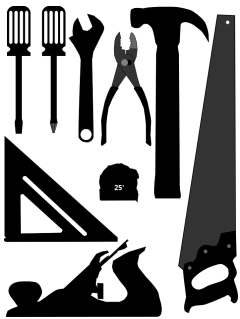

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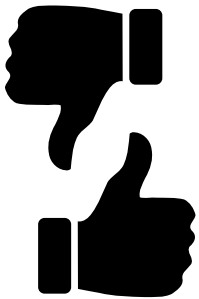

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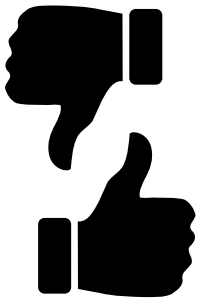

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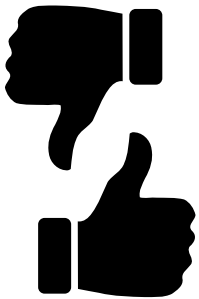

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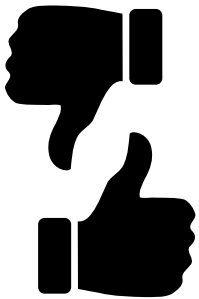

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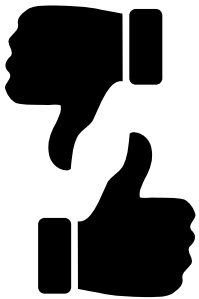

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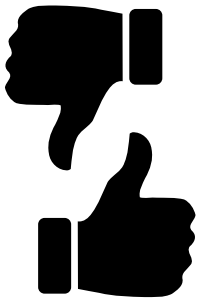

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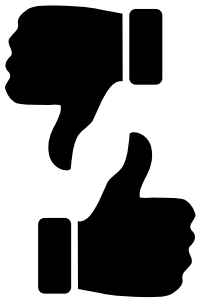

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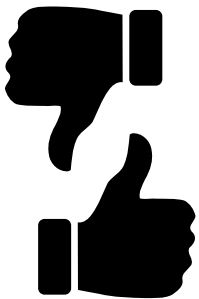

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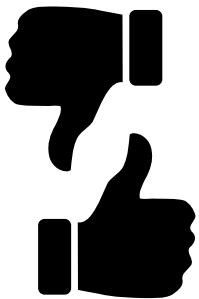

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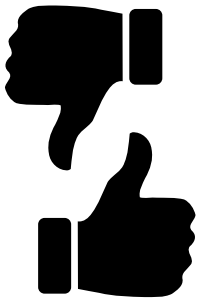

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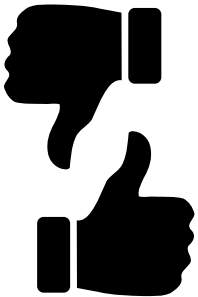
Improve Code Quality: Testing & Assertions II

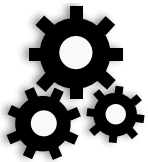


```c
#define TYPE_A   0
#define TYPE_B   1
#define TYPE_MAX 2

typedef struct {
    unsigned int type;
    size_t pos;
    int data[100];
} struct_t;

void internal_print(struct_t* s) {
  assert(s->type < TYPE_MAX); // type must always be valid
  size_t s_len =  sizeof(s->data) / sizeof(s->data[0]);
  assert(s->pos < s_len);   // pos must always be smaller than len
  for (size_t i = 0; i < s->pos; i++) {
      printf("Data: %d\n", s->data[i]);
  }
}
```

Improve Code Quality: Compiler Support I



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- Fuzz your software (libAFL)

Improve Code Quality: Compiler Support II

Fortify

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Improve Code Quality: Compiler Support II

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- Compiler adds extra checks to detect buffer overflows
- Compiler internally replaces calls to regular string functions with known-length string functions
- Not always possible

Improve Code Quality: More Resources

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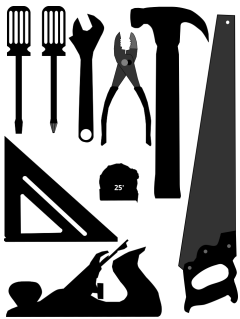
Summary & Outlook

Defensive Programming: Goals & Principles



Sub-goals

- Memory safety
- Type safety
- Integer safety
- Secure data flow
  - Input sanitization
- Secure control flow
  - Error handling

General principles

- Choose appropriate language
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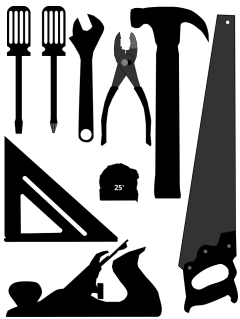

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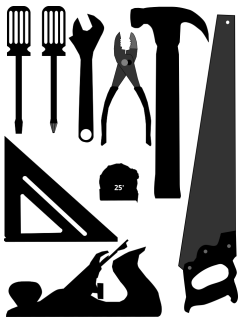

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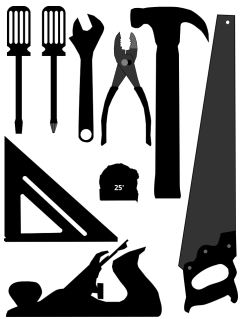

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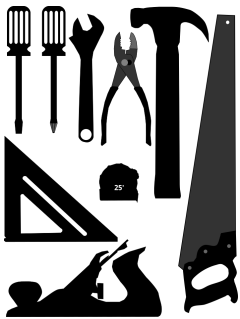

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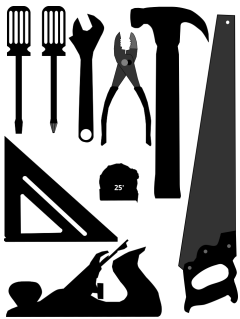

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Defense-In-Depth: Outlook

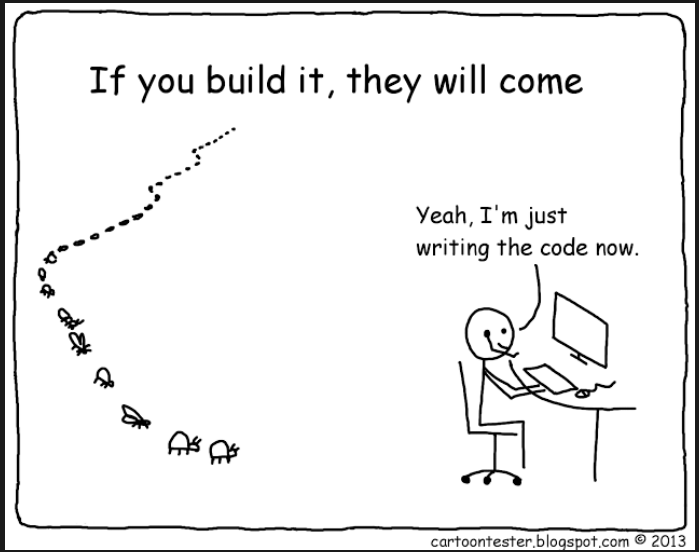
Attacker's perspective

- Vulnerability discovery ☑
- Exploitation ☑
- Privilege elevation ☑

Defender's perspective

- Vulnerability prevention (today) ☑
- Exploit prevention (next time)
- Privilege minimization (next time)

Questions?


If you build it, they will come
Yeah, I'm just writing the code now.
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