Don’t Feed the Bugzilla: Squash (Heisen)bugs Before Release

Klaas van Gend

The dynamic analysis experts

klaas@vectorfabrics.com

http://www.vectorfabrics.com

Wake-up call... *it's only 10:30am*

Quiz: Find the **5** issues in below pseudo-C code?

Thread 0

```
t1 = t2 = sum = 0;
spawn Thread 1;
spawn Thread 2;
while (!t1 && !t2)
   /* nothing */ ;
print sum;
```

Thread 1

```
repeat 100:
   sum++;
t1 = 1;
```

Thread 2

```
repeat 100:
   sum++;
t2 = 1;
```

Woken up? The answers!

1. BUG: && should be ||
2. `sum++` translates to load-inc-store
   - not thread-safe and constitutes a data race.
3. Loads/stores of `t1` and `t2` can be optimized away by the compiler (to processor registers).
   - The `while` will hang and print nothing at all.
   - The `while` may be optimized away as well
   - `volatile` can address the hang but not many other issues.
4. A non-sequential memory consistency model of the processor can break the 'barrier' based on `while`.
5. Code likely to run slower than sequential version
   - amount of overhead versus little workload (200 increments).

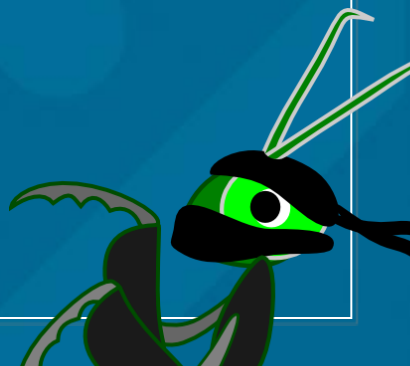
Outline

- What's a Heisenbug?
- How do you find (Heisen)bugs?
- When/Where do you find bugs?
- Summary

Throughout the presentation, we will show examples of bugs found in mature, professional, high-quality open source projects

What is a Heisenbug?

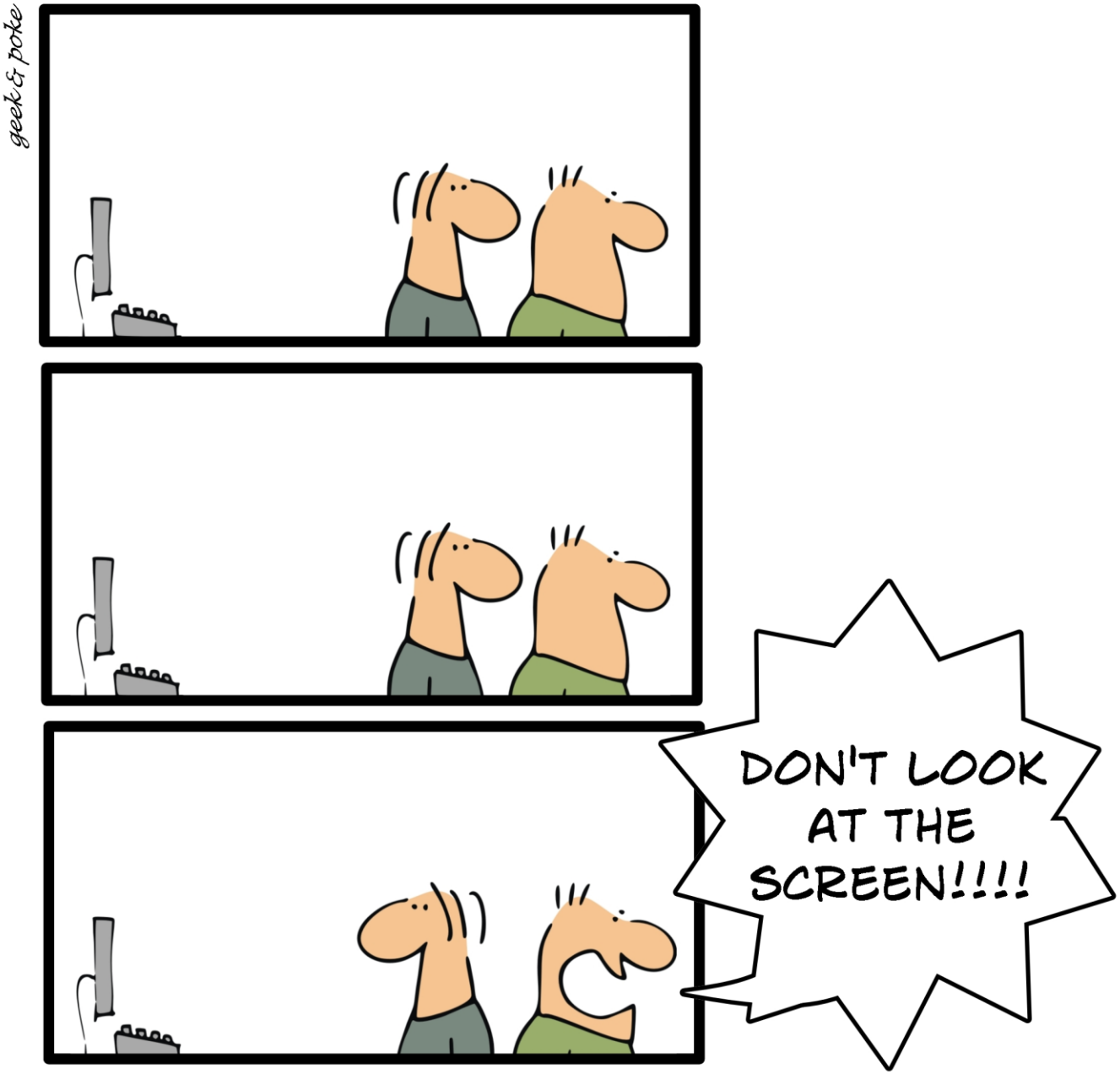
Vector Fabrics



What's a "Heisenbug"?

In computer programming jargon, a **Heisenbug** is a software bug that seems to disappear or alter its behavior when one attempts to study it.
The term is a pun on the name of Werner Heisenberg, the physicist who first asserted the **observer effect** of quantum mechanics, which states that *the act of observing a system inevitably alters its state.*

THE ART OF BUGFIXING



HOW TO DEBUG HEISENBUGS

~~printf~~

~~gdb~~

Heisenbugs: Typology

General problems:

- Timing Issues
- Use of Stale Data
- Use of Random Data

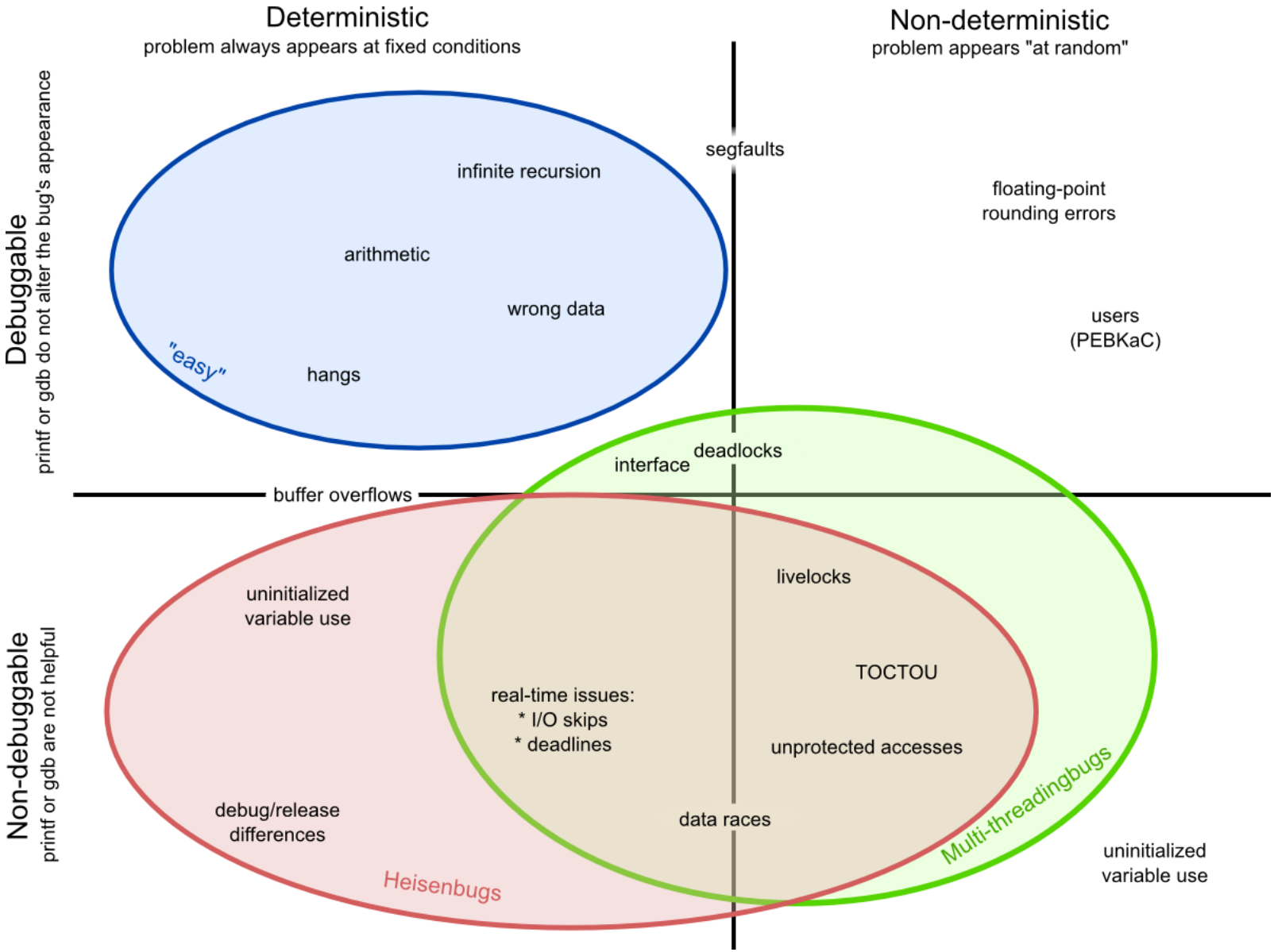
Usually “reproducible”

Not “debuggable”

Causes:

- Use of Uninitialized Data
- Buffer Overflows
- Use after Free
- Data Races
- Memory Ordering issues
- Debug-Release Differences
- TOCTOU

Bug categories



Navigation software

EXAMPLE

Features:

- Map display in 2D
- Route planning
- Route guidance
- Speech instructions

Made effort to get high quality code:

- Open source: peer reviewed
- Code quality confirmed by **Coverity** (static analysis)

http://sourceforge.net/projects/navit/

1) Read from uninitialized stack object

```
void
tracking_update(struct tracking *tr, struct vehicle *v, struct vehicleprofile *vehicleprofile, enum
projection pro)
{
    ...
    struct coord cin;
    ...
    transform_distance_line_sq(&sd->c[i], &sd->c[i+1], &cin, &lpnt_tmp),
    ...
}

int transform_distance_line_sq(struct coord *l0, struct coord *l1, struct coord *ref, struct coord *lpnt)
{
    ...
    wx=ref->x-l0->x;
    wy=ref->y-l0->y;

    if (transform_overflow_possible_if_squared(4, vx, vy, wx, wy)) {
        return INT_MAX;
    }

    c1=vx*wx+vy*wy;
    if ( c1 <= 0 ) {
        if (lpnt)
            *lpnt=*l0;
        return transform_distance_sq(l0, ref);
    }
```

Stack object is NOT set to zero

'cin' passed as 'ref'

Memory read here

Decision here

Side effects

2) Use after deallocation

binmap_search_new() , navit/map/binfile/binfile.c 2128-2140

```
...
map_rec = map_rect_new_binfile(map, NULL);
town = map_rect_get_item_byid_binfile(map_rec, map->last_searched_town_id_hi,
                                      map->last_searched_town_id_lo);
...

map_rect_destroy_binfile(map_rec);

if (msp->boundaries)
    dbg(lvl_debug, "using map town boundaries\n");

if (!msp->boundaries && town)
    {
        binmap_get_estimated_boundaries(town, &msp->boundaries);
        if (msp->boundaries)
            dbg(lvl_debug, "using estimated boundaries\n");
    }
```

map_rec allocated

town is ptr to field inside map_rec

map_rec freed,
town now points to unallocated

town used again

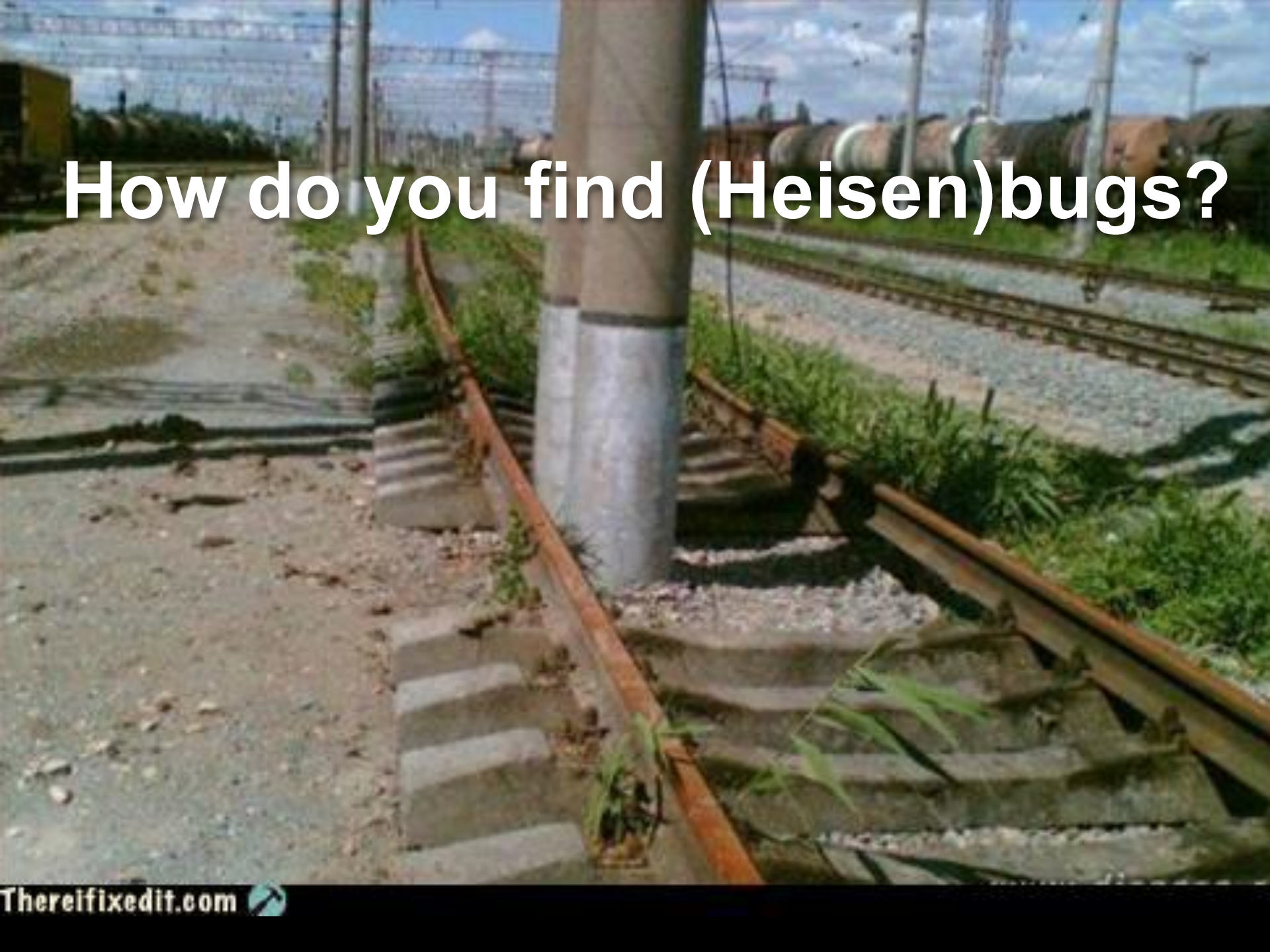
Dynamic Analysis is a good companion

We (lzm) filed a bug: http://trac.navit-project.org/ticket/1316

NAVIT developer (KaZeR) on IRC #navit; Aug 26 2015:

< KaZeR> lzm: thanks for that bug report!
< KaZeR> we are also using Coverity for this kind of analysis
< KaZeR> interesting.. I can't find this one in our Coverity's report
<lzm> probably because Coverity does static analysis on the source code, while Pareon Verify does dynamic analysis on a running program on the target platform (x86/arm/android)
< KaZeR> which makes it a really good companion

Bug was fixed day after reporting


How do you find (Heisen)bugs?
Thereifixedit.com

How to find Heisenbugs?

Heisenbugs are “non-debuggable”:

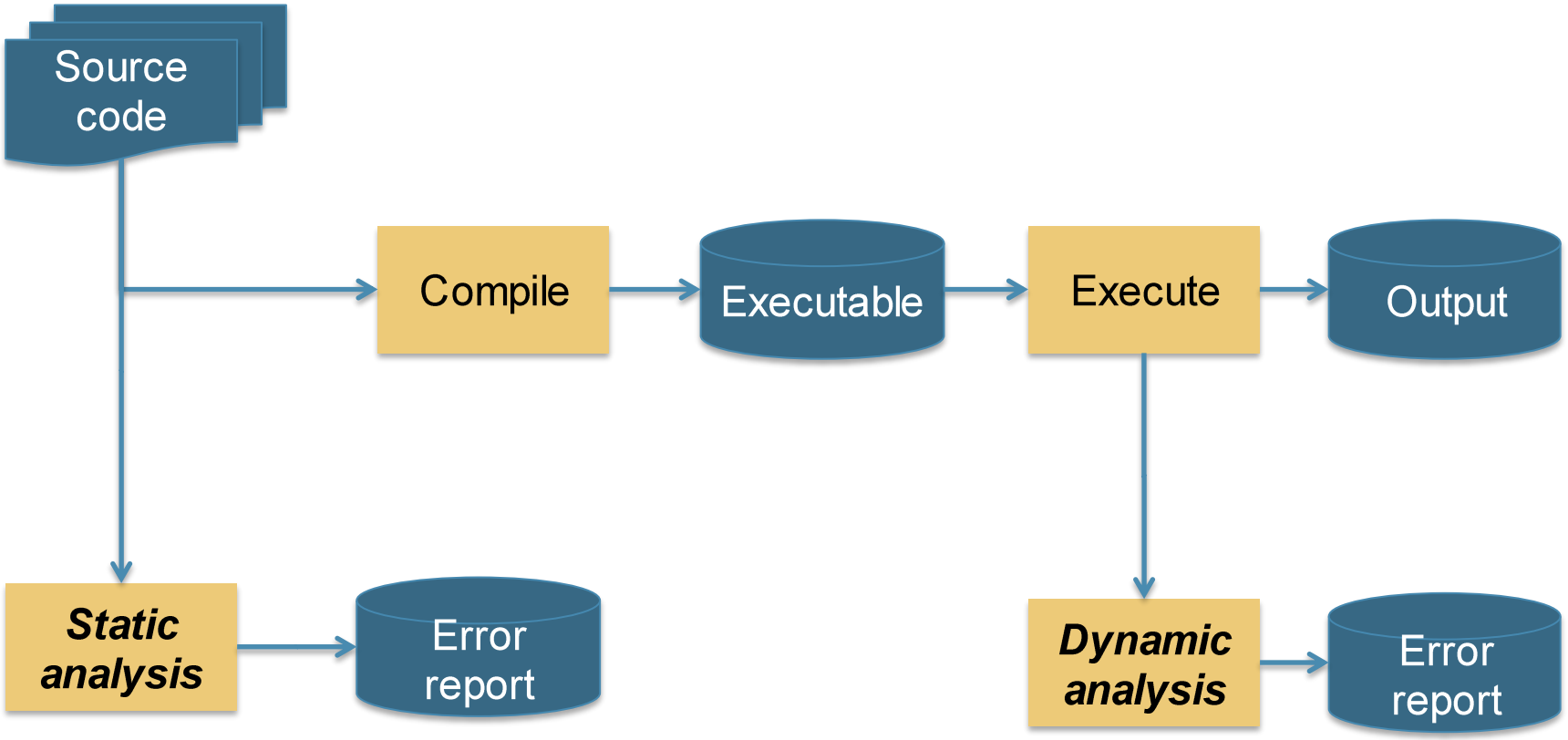
- Direct observation doesn’t work

~~printf~~
~~gdb~~

Solution: use ‘non-invasive’ tools:

- **Static analysis:**
  - Compile time: parse code and understand flow
  - Examples: cppcheck, PClint, Coverity, Klockwork, CodeSonar, QAC
- **Dynamic analysis:**
  - During execution, analyze (instrumented) binary
  - Examples: Valgrind/Memcheck/Helgrind, TSAN/MSAN/ASAN, Vector Fabrics’ **Pareon Verify**

Static Analysis vs Dynamic Analysis

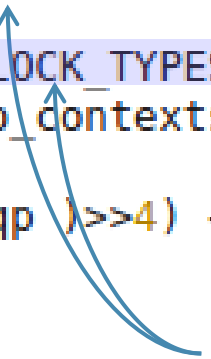


“JMDecode” H.264 reference software

- H.264 - video coding standard
- Golden reference implementation maintained by Fraunhofer
- Mature open-source project
- 117K lines of C
- http://iphome.hhi.de/suehring/tml

H.264 reference software

```
char INIT_FLD_MAP_I[1][8][15][2];
...
IBIARI_CTX_INIT2 (NUM_BLOCK_TYPES, NUM_MAP_CTX,
                  tc->map_contexts[1], INIT_FLD_MAP, model_number, qp);
...
int pstate = ((ini[0]* qp )>>4) + ini[1];
```



value 22, in macro mapped to 2nd index

- Multi-dimensional array
  - accessed inside its boundaries
  - with a wrong index
  - getting wrong data via a pointer
  - from a valid data element
- Test case succeeds!

Pareon Verify error message

```
[M0193] Static-buffer overflow(s) detected:
  the read in
    function biari_init_context at biaridecod.c:299
    called from function init_contexts at context_ini.c:90
    called from function decode_one_frame image.c:943
    called from function DecodeOneFrame at ldecod.c:1254
    called from function main at decoder_test.c:245
  performed 210 access of size 1 between the offsets of 240 and 658 bytes of
  the object of size 240 allocated as `INIT_FLD_MAP_I' at ctx_tables.h:879
  where array index 21 is outside of array `INIT_FLD_MAP_I[][0..7][][]' in
    function init_contexts at context_ini.c:90
    called from function decode_one_frame at image.c:943
    called from function DecodeOneFrame at ldecod.c:1254
    called from function main at decoder_test.c:245
```

- Exact specification of the faulty index in the array
- Bug fixed two days after the submission
- https://ipbt.hhi.fraunhofer.de/mantis/view.php?id=348


Where/When to find bugs?

Where do you find bugs?

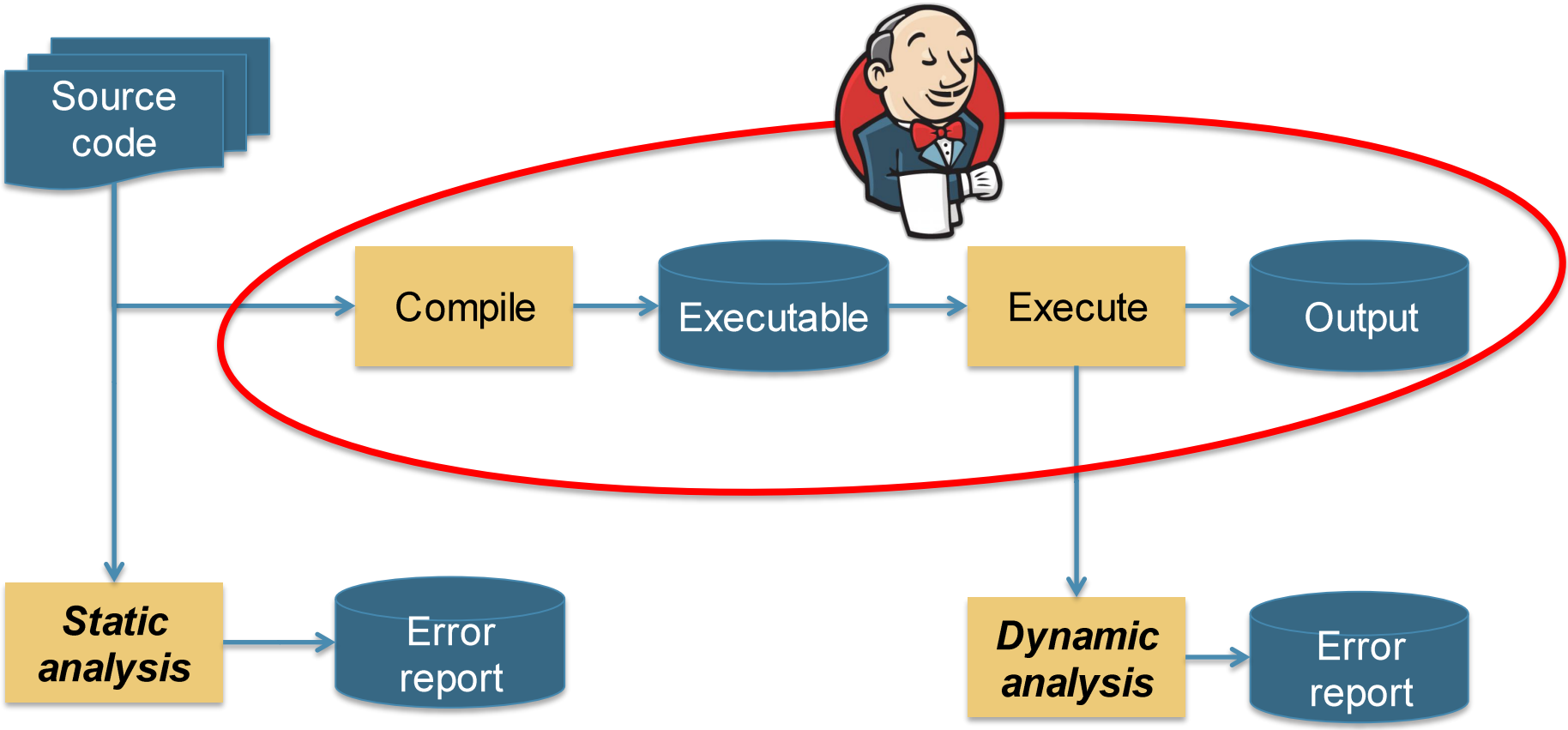
In a bugtracker,
because users found it…

- "ABC doesn't work"
- "I click on the OK button,
but it's not OK"

- Of course, users that know how to write good bug reports DO exist!

But do you want your users to find *your* bugs?

Continuous Integration



Continuous Integration

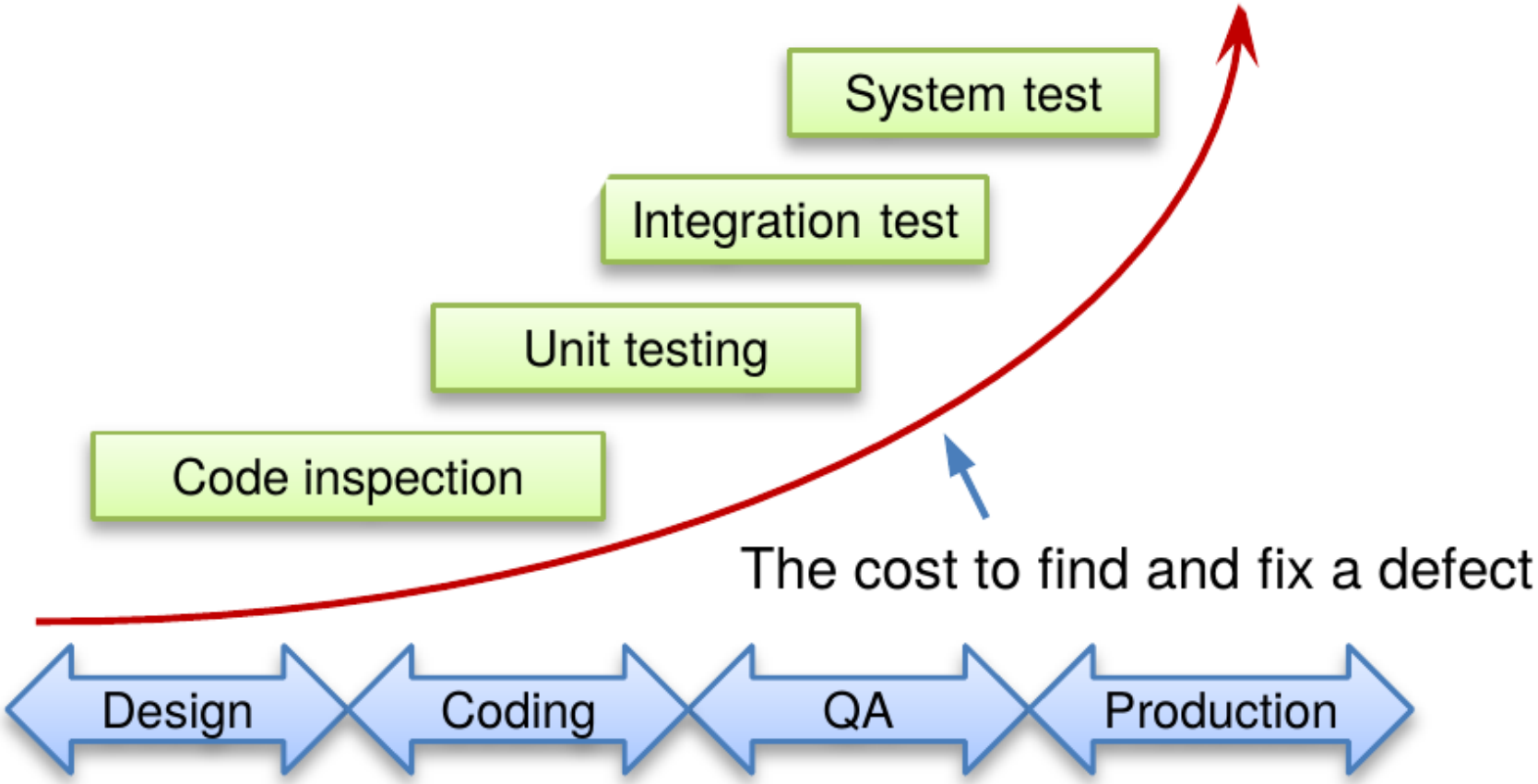
Continuous Integration tools, like Jenkins:

After each check-in or every night:

- Checkout,
- Compile application + tests
- Run all tests
- Scream if tests break
  (i.e. tests return “fail”)

Sounds like a great opportunity to do dynamic analysis

Cost of a bug *(commercial environment)*



Find Heisenbugs before they appear

Bugs found when running unit/integration tests with dynamic analysis:

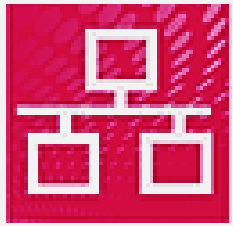
- The night after commit
- Developer still has the code fresh in mind
- Instead of e.g. 4 months later

Current state of open source dynamic analysis tools for use in regression runs:

- **Valgrind/Memcheck/Helgrind:**
  - huge memory overheads on test PC,
  - output interspersed with test output, need to adjust test code
- **Google (T/A/M)SAN:**
  - stop at first error found – no indication how many errors would be found in total run
- If many test binaries need mechanism to merge reports

TCP/IP stack

EXAMPLE



picoTCP

SUPPORTING YOUR INTERNET OF THINGS

ABOUT NEWS PROJECTS CONTACT

picoTCP is the answer for a size, speed and feature conscious open source TCP/IP stack for embedded devices.

https://github.com/tass-belgium/picotcp

High Quality of PicoTCP

- Deploy Continuous Integration
- Have an excellent set of unit tests and integration tests
- Have a (manual) set of tests that cover the applicable RFCs really well
- Use code coverage measurements to improve and add new tests
- Use static analysis tools and fix all issues

- Yet still real issues left in the code

TCP/IP stack on GitHub

17 test/examples/dhcp_client.c

```
@@ -7,7 +7,6 @@
 /*** START DHCP Client ***/
 #ifdef PICO_SUPPORT_DHCPC
 static uint8_t dhcpclient_devices = 0;
-static uint32_t dhcpclient_xid = 0;
...
 void app_dhcp_client(char *arg)
 {
     char *sdev = NULL;
     char *nxt = arg;
     struct pico_device *dev = NULL;
+    uint32_t dhcpclient_xid;
...
            printf("Starting negotiation\n");

            if (pico_dhcp_initiate_negotiation(dev, &callback_dhcpclient, &dhcpclient_xid) < 0) {
...
```

Patch:

- Global variable moved to stack
- Pointer to stack variable passed to a callback function
- Pointer dereferenced after stack deallocation

TCP/IP bug fixes on GitHub

tass-belgium / **picotcp**

SNTP: Fixed short allocation for server string

```
When the sntp cookie is created, the server string was being allocated
using strlen(), which would overflow when a strcpy is used from the same
source by putting the string terminators out of the allocated object
bounds.

Bug discovered by Pareon Verify.
```

master v1.5.1 ··· v1.4.2

danielinux authored on May 21

tass-belgium / **picotcp**

IPv4: Check packet len before processing

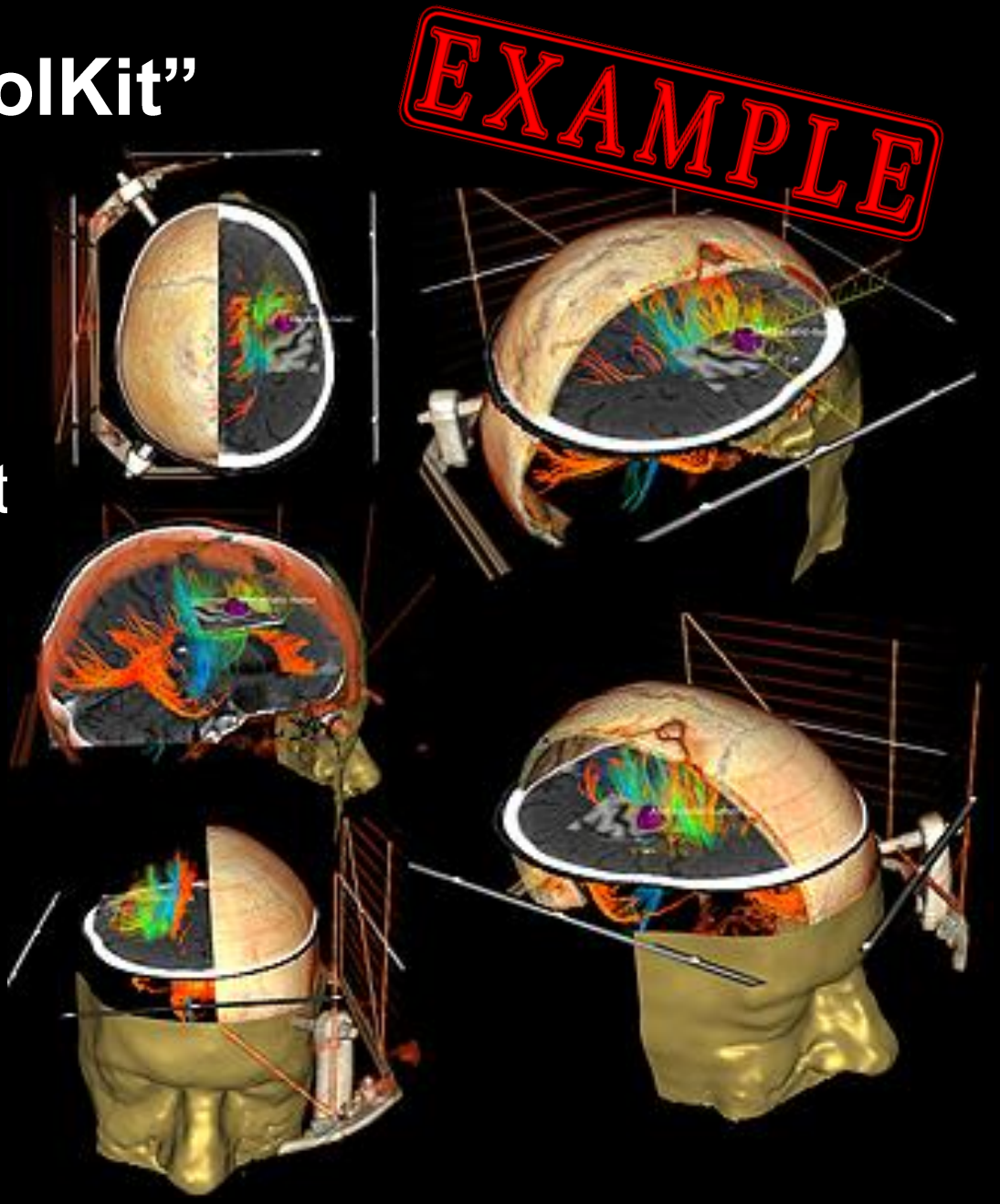
```
When a packet is received, the length in the header must be checked
against the actual IP buffer length. If the header length has been
altered, or it's set to a bigger value on purpose by an attacker, the
CRC function may violate the heap memory boundaries.

Discovered using Pareon Verify.
```

master v1.5.1 ··· v1.4.2

danielinux authored on May 26 1 parent 2d712fa

“Visualization ToolKit”



a.k.a. “VTK”

- Mature OSS project
- 1.5M lines of C++
- 800k lines of C
- http://www.vtk.org

Visualization ToolKit

```
memcpy (cword, "abcdefgh", 8);
Swap2BERange(cword,8);
...
void Swap2BERange(T* first, size_t num)
{
  // Swap one value at a time.
  T* last = first + num;
  for(T* p=first; p != last; ++p) {
    Swap(reinterpret_cast<char*>(p));
  }
}
```

T is not char!

- Pointers and casts, C++ templates and classes
- But the code looks OK and...
- Test succeeds

Pareon Verify error message

```
[M0203] Read(s) from uninitialized stack object detected:
  the read in
    function vtkByteSwapper<2ul>::Swap at vtkByteSwap.cxx:43
    called from function vtkByteSwapRange<short> at vtkByteSwap.cxx:75
    called from function vtkByteSwapBERange<short> at vtkByteSwap.cxx:193
    called from function vtkByteSwap::SwapBERange at vtkByteSwap.cxx:240
    called from function vtkByteSwap::Swap2BERange at vtkByteSwap.cxx:298
    called from function TestByteSwap at otherByteSwap.cxx:57
    called from function otherByteSwap at otherByteSwap.cxx:160
    called from function main at vtkCommonCoreCxxTests.cxx:372
  performed 1 access of size 1 at an offset of 8 bytes from the start of
  the stack object of size 1024 allocated as `cword' in
    function TestByteSwap at otherByteSwap.cxx:32
    called from function otherByteSwap at otherByteSwap.cxx:160
    called from function main at vtkCommonCoreCxxTests.cxx:372
```

- Easy patch based on the clear error message
- Bug reported in 6.1.0 and fixed in 6.2.0
- http://www.vtk.org/Bug/view.php?id=14997

Summary

Don’t Feed the Bugzilla: Squash (Heisen)bugs Before Release

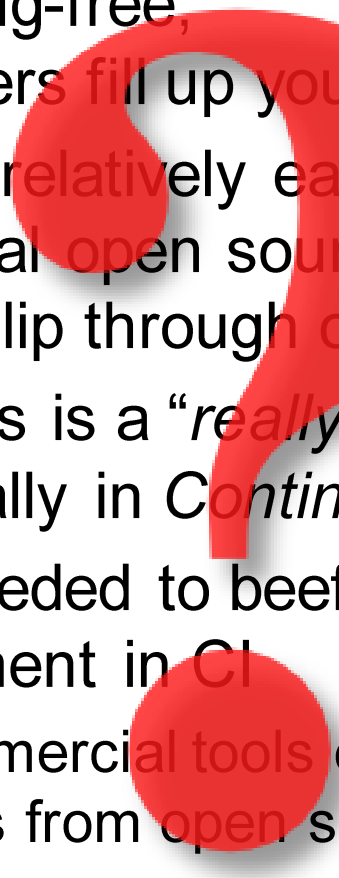
Vector Fabrics

Take-away

1. Code is never bug-free,
   don't let your users fill up your bug tracker
2. Static errors are relatively easy to catch,
   many professional open source projects work on quality;
   dynamic errors slip through or are found late in release
3. Dynamic Analysis is a "*really good companion*" to static analysis, especially in *Continuous Integration*
4. Serious effort needed to beef up existing open source tools for deployment in CI

   Workable commercial tools exist, from Vector Fabrics, with references from open source

Questions?



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