Fuzz Testing for Dummies
ICSJWG May 2011
Art Manion
Michael Orlando
Introduction

Art Manion
Michael Orlando
CERT Vulnerability Analysis team

• Analysis and research
• Coordination and disclosure
  – Vendors, researchers, other CSIRTs (including ICS-CERT)
• Discovery
  – Tools and methods to find vulnerabilities
Outline

Fuzz testing
• Tools
• ICS application

Exploit mitigation
• Microsoft Windows
  – EMET
  – ISV guidance
• UNIX-like platforms
Fuzz Testing

Providing unexpected, invalid, or random data to an application with the intention of triggering a bug

• Unexpected behavior
• Crashes
  – Buffer overflows
  – Integer overflows
  – Memory corruption
  – Format string bugs
Fuzzing Methods

Smart (generational) fuzzing
  • Requires in-depth knowledge of target and specialized tools
    – Dranzer ActiveX fuzzer
  • Results
    – Less crash analysis required
    – Less duplication of findings

Dumb (mutational) fuzzing
  • Requires no knowledge of target, existing tools
  • Results
    – More crash analysis required
    – More duplication of findings
Dumb(est) Fuzzing

Charlie Miller’s “five lines of python” dumb fuzzer

• Found vulnerabilities in PDF readers and Office presentation software

```python
numwrites=random.randrange(math.ceil((float(len(buf)) / FuzzFactor)))+1
for j in range(numwrites):
    rbyte = random.randrange(256)
    rn = random.randrange(len(buf))
    buf[rn] = '%c' % (rbyte);

<http://securityevaluators.com/files/slides/cmiller_CSW_2010.ppt>
```
Fuzzing Framework Requirements

Features required for an effective fuzzing framework

• Test case generation
• Application execution
• Anomaly detection
• Crash reporting
CERT Fuzzing Tools

Dranzer: Smart ActiveX fuzzer

File format fuzzers

- BFF: Basic Fuzzing Framework
- FOE: Failure Observation Engine
- Most effective against uncompressed binary formats
BFF

Debian Linux virtual machine (VMware)
  • Uses zzuf, valgrind
  • OS configuration optimized for fuzzing
  • Software watchdog

Fuzzing scripts
  • Test case generation
  • Process killer
  • Crash verification
  • Crash de-duplication
  • Crash minimization
BFF (2)

Rangefinder

- Focus on areas (bytes) in the test case that are resulting in crashes

Minimizer

- Find the least changed test case (bytes) that causes the same crash
- Inspired by fuzzdiff
- Many crashes caused by 1-3 byte changes
BFF in Action
FOE

Python on Windows XP

• Built from scratch
• Configurable mutators
  – bytemut, bitmut, wave, swap, copy
• Hook or full debug modes
• Output bucketing
  – Severity determination using Windows debugging extension called !exploitable ("bang exploitable")
    ○ EXPLOITABLE, PROBABLY_EXPLOITABLE, PROBABLY_NOT_EXPLOITABLE, UNKNOWN
FOE in Action
Fuzzing Office Suites

A Security Comparison: Microsoft Office vs Oracle OpenOffice
Fuzzing ICS File Formats

Rockwell EDS Hardware Installation Tool (.eds)
  • Previous EDS vulnerability
    <http://rockwellautomation.custhelp.com/app/answers/detail/a_id/67272>

Ecava IntegraXor Editor (.igx)

Automated Solutions OPC Server (.tbd)
Test Setup

Downloadable/demo software
VMware
FOE uses !exploitable to determine severity
One crash does not equal one vulnerability
250K+ iterations

Seed files
- Can affect code coverage
- Created one seed file each for .igx and .tbd
- Found ~25 .eds seed files
Results

Rockwell EDS Hardware Installation Tool (2 crashes)
  • 2 EXPLOITABLE

Ecava IntegraXor Editor (127 crashes)
  • 26 EXPLOITABLE
  • 22 PROBABLY_EXPLOITABLE
  • 3 PROBABALY_NOT_EXPLOITABLE
  • 76 UNKNOWN

Automated Solutions OPC Server (43 crashes)
  • 11 EXPLOITABLE
  • 15 PROBABLY_EXPLOITABLE
  • 11 PROBABLY_NOT_EXPLOITABLE
  • 6 UNKNOWN
Results (2)

- **.eds**
  - UNKNOWN: 140
  - PROBABLY NOT EXPLOITABLE: 50
  - PROBABLY EXPLOITABLE: 10
  - EXPLOITABLE: 0

- **.igx**
  - UNKNOWN: 120
  - PROBABLY NOT EXPLOITABLE: 50
  - PROBABLY EXPLOITABLE: 10
  - EXPLOITABLE: 0

- **.tbd**
  - UNKNOWN: 40
  - PROBABLY NOT EXPLOITABLE: 50
  - PROBABLY EXPLOITABLE: 10
  - EXPLOITABLE: 0
Vulnerability Mitigation

What are realistic attack vectors using ICS configuration files?

- Dangerous to load an arbitrary configuration file even in the absence of any vulnerabilities
  - "Configuration files that are written by one user and read by another."

Previous Rockwell Automation recommendations

- Obtain product EDS files from trusted sources (e.g. product vendor)
- Restrict physical access to the computer
- Establish policies and procedures such that only authorized individuals have administrative rights on the computer
Fuzzing Conclusions

Everything is vulnerable

• Dumb fuzzing has found vulnerabilities in everything we’ve targeted
• We (and others) have been focusing on common, complicated binary formats
  – PDF
  – Office document formats
  – Flash

0-day isn’t rare

• Assume software you develop and run has vulnerabilities
  – You just don’t know about them yet
0-Day isn’t Rare
Recommendations

1. Fuzz
2. Exploit mitigation
Fuzz

Make fuzz testing part of SDLC

- No SDLC? Make dumb fuzzing the first component of your new SDLC
- CERT fuzzing tools
  - Dranzer and BFF free for download
  - FOE available by request
- Many other free and commercial tools

Somebody else is fuzzing (or is going to fuzz) your software

Vulnerabilities in Iconics GENESIS32 9.21 and GENESIS64 10.51 (SCADA)
21 Mar 2011: adv1 - adv2 - adv3 - adv4 - adv5 - adv6 - adv7 - adv8 - adv9 - adv10 - adv11 - adv12 - adv13

<http://aluigi.org/adv.htm>
Exploit Mitigation: Microsoft Windows

Compile time
- Stack cookies (/GS)
- Structured Exception Handler registration (/SAFESEH)

Runtime
- Data Execution Prevention (DEP)
- Address Space Layout Randomization (ASLR)
  - Build with /DYNAMICBASE
- Heap metadata protection (HeapEnableTerminationOnCorruption)
- Structured Exception Handler Overwrite Protection (SEHOP)

Enhanced Mitigation Experience Toolkit (EMET)
Windows ISV Software Security Defenses
Exploit Mitigation: UNIX-like Platforms

Compile time

- Stack protection (StackGuard/SSP/ProPolice)
- Buffer length checking (-D_FORTIFY_SOURCE=2 -O2)

Runtime

- No-execute/execution disabled (NX/XD)
  - Hardware (PAE) or emulated (segment limits)
- Address randomization
  - exec(), brk(), mmap(), Virtual Dynamically-linked Shared Object (VDSO), Position Independent Executable (PIE)
- Global Offset Table (GOT) overwrite protection
- GNU libc heap memory manager protections
- Also Pax, W^X
Lessons Learned

Dumb fuzzing shouldn’t be so effective

- Software is full of bugs, and some of those bugs are vulnerabilities
- Include fuzz testing as part of SDLC
  - Improve software security
  - Free tools from CERT and others
  - If you don’t, someone else will
- Fuzzing can lead to improvements in software security

Assume everything you create and use has vulnerabilities

- Move focus from 0-day to more proactive security
Lessons Learned (2)

Exploit mitigation

- OS vendors: Implement and document exploit mitigation features
- Application vendors: Take advantage of available platform exploit mitigation features
More Information

Announcing the CERT Basic Fuzzing Framework 2.0
<http://www.cert.org/blogs/certcc/2011/02/cert_basic_fuzzing_framework_b.html>

A Security Comparison: Microsoft Office vs. Oracle OpenOffice

Automated Penetration Testing with White-Box Fuzzing

Windows ISV Software Security Defenses

The Enhanced Mitigation Experience Toolkit
<http://support.microsoft.com/kb/2458544>

Security/Features – Ubuntu Linux
<https://wiki.ubuntu.com/Security/Features>

Fuzz By Number
<http://cansecwest.com/csw08/csw08-miller.pdf>

Babysitting an Army of Monkeys
<http://securityevaluators.com/files/slides/cmiller_CSW_2010.ppt>
NO WARRANTY

THIS MATERIAL OF CARNEGIE MELLON UNIVERSITY AND ITS SOFTWARE ENGINEERING INSTITUTE IS FURNISHED ON AN “AS-IS” BASIS. CARNEGIE MELLON UNIVERSITY MAKES NO WARRANTIES OF ANY KIND, EITHER EXPRESSED OR IMPLIED, AS TO ANY MATTER INCLUDING, BUT NOT LIMITED TO, WARRANTY OF FITNESS FOR PURPOSE OR MERCHANTABILITY, EXCLUSIVITY, OR RESULTS OBTAINED FROM USE OF THE MATERIAL. CARNEGIE MELLON UNIVERSITY DOES NOT MAKE ANY WARRANTY OF ANY KIND WITH RESPECT TO FREEDOM FROM PATENT, TRADEMARK, OR COPYRIGHT INFRINGEMENT.

Use of any trademarks in this presentation is not intended in any way to infringe on the rights of the trademark holder.

This Presentation may be reproduced in its entirety, without modification, and freely distributed in written or electronic form without requesting formal permission. Permission is required for any other use. Requests for permission should be directed to the Software Engineering Institute at permission@sei.cmu.edu.

This work was created in the performance of Federal Government Contract Number FA8721-05-C-0003 with Carnegie Mellon University for the operation of the Software Engineering Institute, a federally funded research and development center. The Government of the United States has a royalty-free government-purpose license to use, duplicate, or disclose the work, in whole or in part and in any manner, and to have or permit others to do so, for government purposes pursuant to the copyright license under the clause at 252.227-7013.