A Maze of Twisty Passages all Alike:

A Bottom-Up Exploration of Open Source Fuzzing Tools and Frameworks

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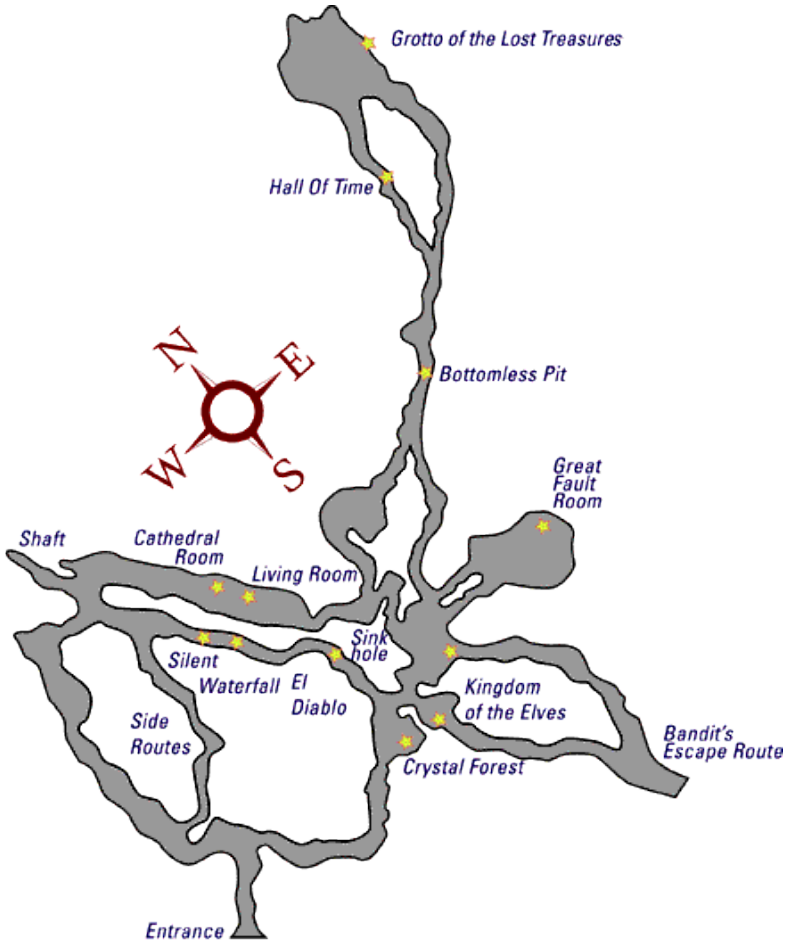
Agenda

- Introduction
- Beyond smart & dumb fuzzers
- A Case Study in Fuzzer Selection
- Conclusions (and stuff I ran out of time on)



Source: http://www.colossalcave.com/cavetour.html

Where I'm coming from…

- Lots of "big company" security QA/R&D during early-mid 2000s
  - Primarily dealt with binary protocols on embedded devices
  - Wrote a variety of protocol-specific fuzzers and two attempts at block-based multi-protocol fuzzing frameworks (in Python/C#)
  - Used some commercial tools near the end
- Some on-the side (mostly unbillable) vuln research in a small SCADA security consulting firm
  - If Amap and Nessus find bugs, your fuzzers can be pretty crude
  - Still somewhat traumatized by the SCADA disclosure debate
- Enjoyed a sabbatical from vuln research & pen-testing from late 2006 to mid-2009, but slowly getting back into it again
  - Sneak some robustness testing in compliance engagements
  - Focusing Smart Grid (AMI), SCADA redux, etc.
  - Trying to resist the temptation of writing new tools from scratch

Fuzzing in 2010

- No longer exotic/boutique
  - Responsible for some non-trivial % of vulns discovered
  - Even integrated into commercial singature based vuln scanners
- Over 100 fuzzers on Jeremy Brown's list
  - Range of capabilities and usability/usefulness
  - Dormant to active development
  - Crude Perl hacks to well-defined documented APIs
- Can there be too many choices?

Objectives & Non-Objectives of this Talk

- Try to untangle the “maze” of FOSS fuzzers by:
  - Isolating the discrete feature-sets most useful for performing efficient software security testing
  - Developing a framework for evaluating and selecting tools for specific users & use cases
  - Identifying common (and useful) design & implementation approaches and highlight some standouts and areas for development
- Avoiding some more interesting problems
  - Coverage metrics
  - Effectiveness and track record of tools
  - Fuzzing bake-off vs. reference implementations
  - Commercial vs. Open Source capabilities

Who uses Fuzzers and why do we care?

- QA/test engineers
  - "Click on start" and give me a traffic light when done
  - Coverage, repeatability, test case reduction are a major concern
- Pen-testers of various shapes & sizes
  - That probably know how to do a little scripting
  - That should know how protocols work on the wire
  - A single bug might be good enough
- Hard core bug hunters
  - That could implement the protocols they are testing (in .asm)

This diversity of objectives, backgrounds, requirements, programming/scripting languages has led to the "the maze"

Exploration Approach

- Biases
  - Religious conviction that C (and Perl) should be avoided at all costs and that simple small lightweight tools are always best
  - Selfish interest in binary & proprietary network protocols
  - Which tools would be the most useful for some upcoming projects and that could be used by members of my team (who have less experience with robustness testing)
- Evaluation criteria
  - Tools had to support multiple protocols /applications/file format
  - Compiled relatively easily on a recent version of Ubuntu
  - Open Source only (wasn't anal about license terms)
  - Web client/server tools were sufficiently different to exclude them
- Analysis process
  - Too much time reading through source code and trying to get them to work
  - Not enough time fully testing all the features on real protocols
  - Focus was on a identifying discrete attributes (see the .xls for the raw data)
  - Validated scheme based on a larger number of tools and then narrowed down

BEYOND SMART & DUMB FUZZERS

Attributes of Fuzzers/Frameworks

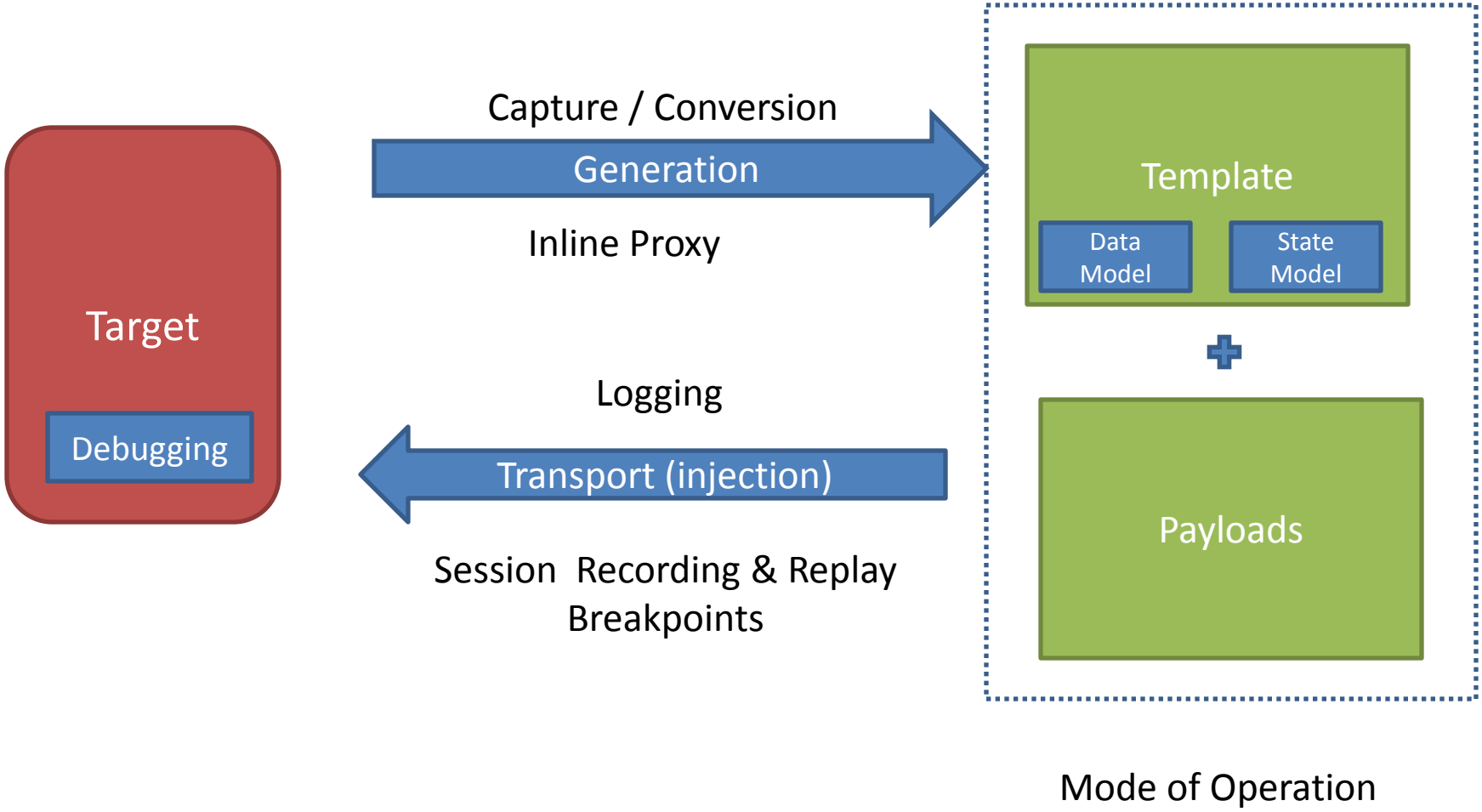
- Target – external interface under test
  - Client, Server, Parser, Kernel, Protocol, etc.
- Mode of Operation
  - API
  - Executable
- Language – Python, C, Ruby, etc.
- Transport – you can inject test cases into the application/protocol (TCP, IP, UDP, SSL, IPv6)
- Template
  - Generation – manual automated, inline, from traces, file source
  - Data Model – representation of messages and protocol state
  - Built-in Functions – crypto, checksum, hashes, encoding, etc.

Attributes of Fuzzers & Frameworks (cont.)

- Fault Payloads
  - “canned” vs. programmatic
  - buffer overflow, format string, bit shifting, etc.
- Debugging & Instrumentation
  - Fault detection
  - Control and monitoring of target (both internal
- Session Handling
  - Capture, storage, replay
  - Logging
  - Interactive vs. Unattended
  - Pause, stop restart, breakpoints
- Documentation & Examples

See the spreadsheet for the details…

Attributes & Workflow (all features)



Operating Modes

- Approaches
  - API-based
    - Write code in a scripting language
    - Extend existing processers
    - **Examples**: sulley, ruckus, peach, fuzzled
  - Executable
    - Execute fuzzing engine against a more/less complex configuration file with more/less complex command-line options
    - **Examples:** peach, GPF, autodafe
- Primary consideration: time to test/develop
  - Go with executable if you have limited time
  - If you have to partially implement the protocol anyway you should probably go with API
  - Some configurations files (templates) are more convoluted that coding

More on Templates

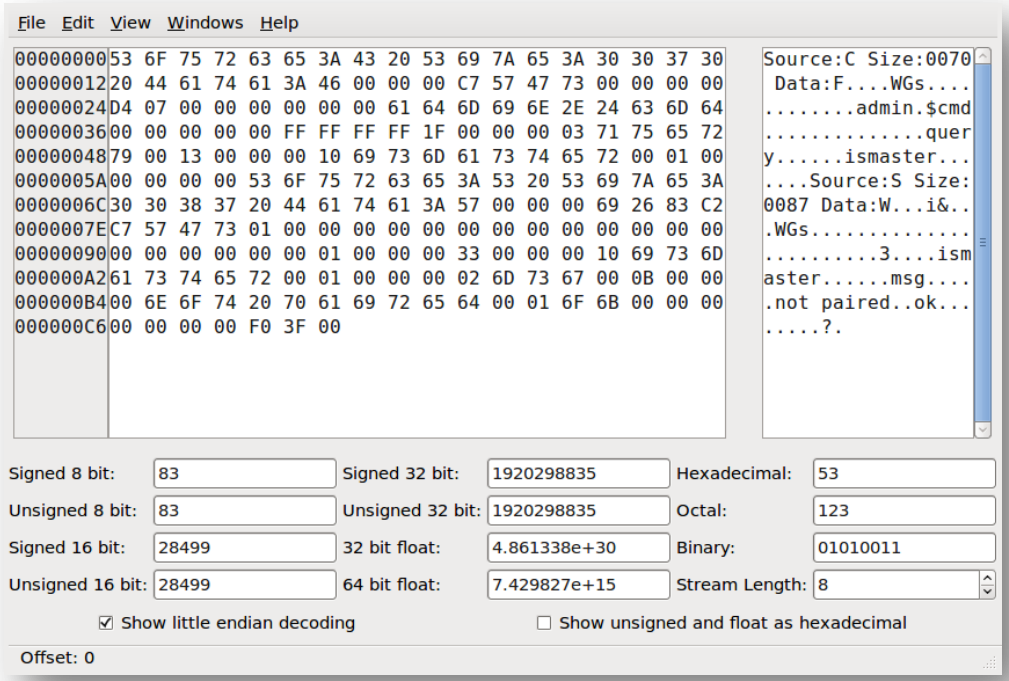
- Template development is the most tedious (and sometimes difficult) process of modeling the valid/invalid data
- Auto generation of an “unknown” protocol remains a “holy grail” problem
  - This is was the point of the protocol informatics (PI) project

Example Template Files

```
block_begin("packet_3");
block_end("packet_3");
send("packet_3");  /* tcp */

block_begin("packet_4");
   block_begin("packet_4.6.54.mbtcp");
      // name    : modbus_tcp.trans_id
      // showname: transaction identifier: 0
      // show    : 0
      // size: 0x2 (2)
      hex(
      00 00
      );
      // name    : modbus_tcp.prot_id
      // showname: protocol identifier: 0
      // show    : 0
      // size: 0x2 (2)
      hex(
      00 00
      );
      // name    : modbus_tcp.len
      // showname: length: 6
      // show    : 6
      // size: 0x2 (2)
      hex(
      00 06
      );
      // name    : modbus_tcp.unit_id
      // showname: unit identifier: 1
      // show    : 1
      // size: 0x1 (1)
      hex(
      01
```

Autodafe (Modbus/TCP)



GPF (MongoDB)

A Peach Template

```
<!-- Create a simple data template containing a single string -->
<DataModel name="HttpRequest">

        <!-- The HTTP request line: GET http://foo.com HTTP/1.0 -->
        <Block name="RequestLine">

                <!-- Defaults can be optionally specified via the
                     value attribute -->
                <String name="Method"/>
                <String value=" " type="char"/>
                <String name="RequestUri"/>
                <String value=" "/>
                <String name="HttpVersion"/>
                <String value="\r\n"/>
        </Block>

        <!-- This block uses the Header block as a base
                        and overrides one field -->
        <Block name="HeaderHost" ref="Header">
                <String name="Header" value="Host" isStatic="true"/>
        </Block>

        <!-- This block uses the Header block as a base
                        and overrides two fields -->
        <Block name="HeaderContentLength" ref="Header">
                <String name="Header" value="Content-Length" isStatic="true"/
                <String name="Value">
                        <!-- Indicate a relation between this field
                                        and the "Body" field. -->
                        <Relation type="size" of="Body"/>
                </String>
        </Block>

        <String value="\r\n"/>

        <Blob name="Body" minOccurs="0" maxOccurs="1"/>

</DataModel>
```

```
<StateModel name="State2" initialState="Initial">
        <State name="Initial">
                <Action type="output">
                        <DataModel ref="HttpRequest" />
                        <Data ref="HttpOptions" />
                </Action>
        </State>
</StateModel>


<!-- Create a simple test to run -->
<Test name="HttpGetRequestTest" description="HTTP Request GET Test">
        <StateModel ref="State1"/>

        <!-- Target a local web server on port 80 -->
        <Publisher class="tcp.Tcp">
                <Param name="host" value="127.0.0.1" />
                <Param name="port" value="80" />
        </Publisher>
</Test>

<Test name="HttpOptionsRequestTest" description="HTTP Request OPTIONS Test">
        <StateModel ref="State2"/>

        <!-- Target a local web server on port 80 -->
        <Publisher class="tcp.Tcp">
                <Param name="host" value="127.0.0.1" />
                <Param name="port" value="80" />
        </Publisher>
</Test>

<!-- Configure a single run -->
<Run name="DefaultRun" description="HTTP Request Run">

        <!-- The set of tests to run -->
        <Test ref="HttpGetRequestTest" />
        <Test ref="HttpOptionsRequestTest" />

</Run>
```

Single XML file contains message format, states, and injection commands

Auto Template Generation

- Approaches
  - PDML*
    - Autodafe - pdml2ad generates block based description based on
    - Peach – allows creation of Peach pit
  - Pcap
    - GPF – creates text file (.gpf) that is replayed (with multiple malformation options)
  - Inline
    - Taof
- Caveats
  - Best to just use a single stream
  - PDML requires a Wireshark dissector

* Not Open Source but pcapr.net does this and JSON file that you can run with `mudos` to inject the packets against a target

Payload Generation

- Approaches
  - Primitive randomization
    - Tcpjunk, isic, GPF pure mode
  - “CGI-Scanner”-style dictionary of known bad requests (format strings, strings and numeric input to test boundary conditions
    - 4f,autodafe, SPIKE
  - Various mutation APIs
    - Peaches, Ruckus, Antiparser

Tools by Development Status (Last Release)

Recent Development

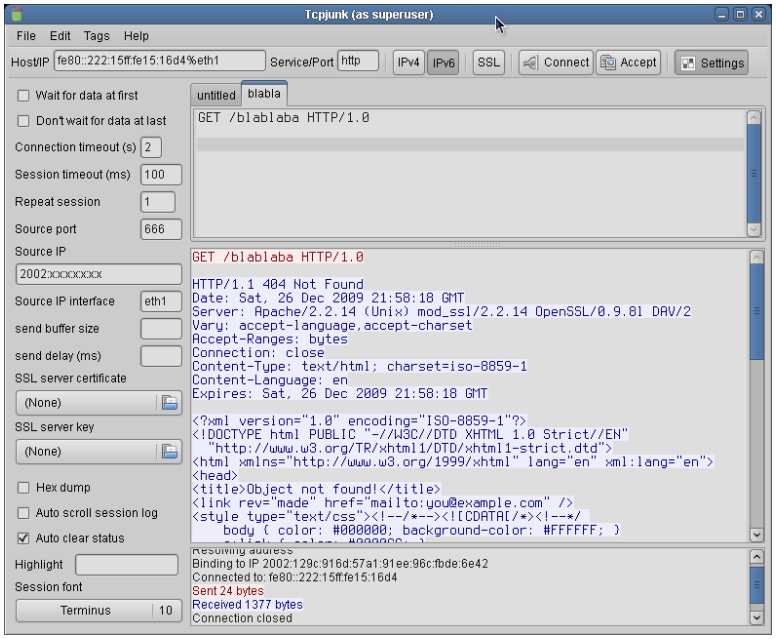
- Tcpjunk (1/2010)
- Peach (1/2010)
- Sulley (2/2009)
- Ruckus (4/2009)

Apparently Dormant

- Fuzzled (10/2007)
- Autodafe (8/2006)
- Scratch (9/2004)
- SPIKE (4/2004)
- SMUDGE (9/2004)
- GPF (Jared?)

Dealbreakers: Active Projects

- Peach
  - Robust set of features but a huge learning curve and insane dependencies (a 20MB installer?)
  - Not Linux/OSX friendly
  - PDML conversion disappeared/is hidden in 2.3.x
  - Maybe I can reuse some of the APIs
- Tcpjunk
  - No example templates
  - No way to automatically create them
  - ASCII protocol bias



Recommended Improvements for the “Keepers”

- GPF
  - Write some wrappers for command-line arguments
- Taof
  - Better representation of binary protocols and marking of “fuzz points”
- Sulley
  - Automatic generation block descriptions

A CASE STUDY IN TOOL SELECTION

Fuzzing MongoDB in 20 minutes (hypothetically)

- What is MongoDB?
  - Document oriented #nosql database (in the same family as CouchDB)
  - Written in C++ (with broad driver support in various scripting languages)
  - Uses SpiderMonkey (or Google V8) for its .js engine – queries are in JavaScript (and JSON)
  - Has a proprietary JSON like serialization protocol called BSON

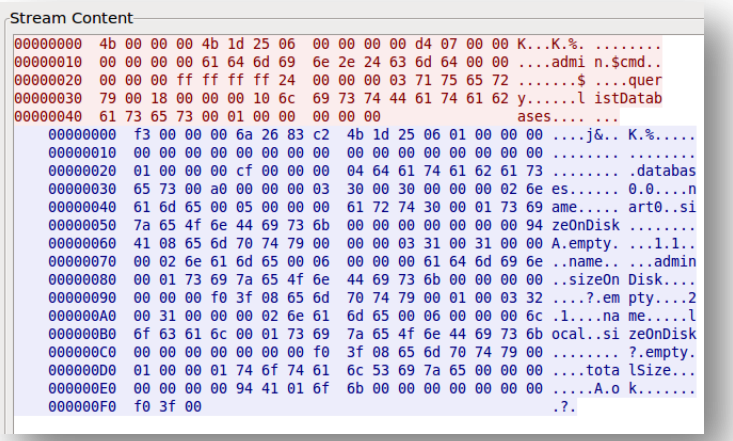
CAVEAT: http://github.com/mongodb/mongo-c-driver/ does show evidence of embedded fuzzing in bson.c

Selecting your fuzzer: info gathering

- Do you have a protocol specification?
- Is your protocol supported by Wireshark?
- What are the data types and representation format? Protocol states?
- Is authentication & encryption required?
- If authentication is required, can you replay?

Info Gathering

- Protocol specification (partial)
  - http://www.mongodb.org/display/DOCS/Mongo+Wire+Protocol
- Not supported by Wireshark
  - PDML doesn't help me here
  - So I need to use GPF or Taof
- No authentication by default
- Mixed Binary + ASCII protocol
- Passes lots of JavaScript/JSON
  - Fusil might be a possibility here
- Build on existing client implementations?



20 Minute Results

- Taof
  - Used proxy mode to connect mongo client to server
  - Logged initial connection
- GPF
  - Server rejected all payloads generated by “simple fuzzing” - bad recv() mostly due to length
  - Converted login sequence and used replay mode
    - Many caught assertions in BSON processing and assertion failures
    - Created “interesting” databases and eventually a malloc failure

CONCLUSIONS

Non-Surprising Conclusions

- There is no single fuzzer (or framework) to “rule them all”
  - All of the tools have tradeoffs & feature/documentation gaps
- Seemingly dead projects (and even those written in C) can still be useful
- Pay me now or may be later
  - You will have to write “code” no matter what
  - Ambivalent about learning/using block-based fuzzing DSLs
  - Generation & mutation is not the only thing you do with the protocols

So going forward…

- For quick best-effort fuzzing, go with GPF
  - or Taof for fuzzing newbies
- Develop protocol specific fuzzers in Python but re-use APIs where possible
  - Sulley, Antiparser, and possibly even Peaches

A Subjective Fuzzer “Magic Quadrant”