FUZZING JAVASCRIPT ENGINES FOR FUN & PROFIT

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CONTENTS

WHAT WE AIMED TO DO

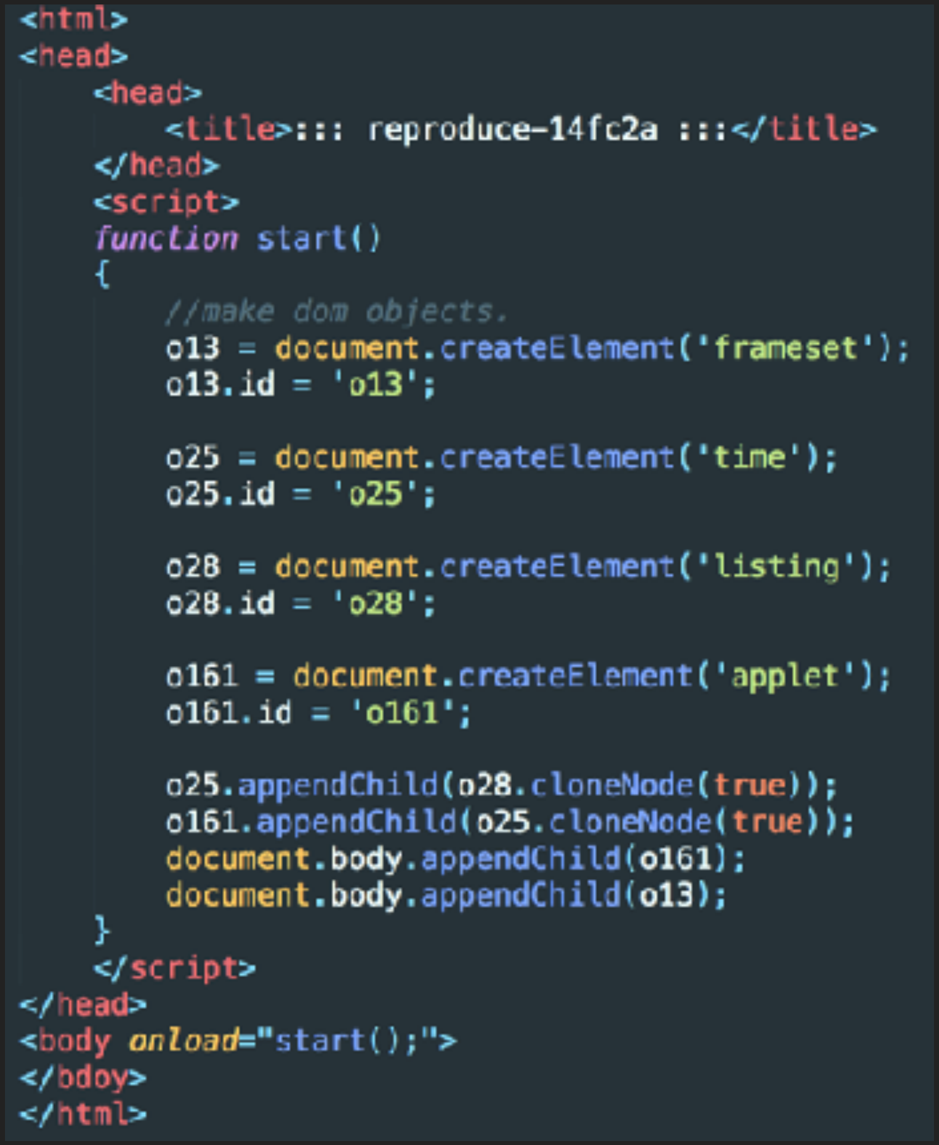
1. Find vulnerabilities in browser javascript engines!
    - v8
    - javascript core
    - chakra core
    - spider monkey
2. Utilize fuzzer!

WHY TARGET BROWSERS?

- Everyone uses web browsers.
  - If a browser is vulnerable, a lot of people are prone to attacks.
- Web standards are continuously being updated.
  New features are added continuously.
  - More changes to code. So more chance of bugs?
- Web browser security is super important.

WHY JAVASCRIPT?

- Javascript is easier to exploit compared to DOM objects



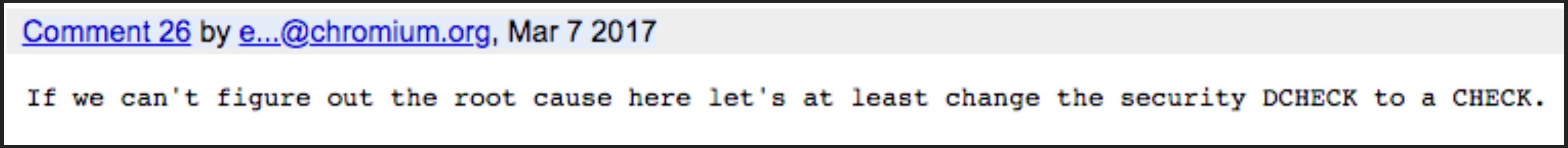
```
<html>
<head>
    <head>
        <title>::: reproduce-14fc2a :::</title>
    </head>
    <script>
    function start()
    {
        //make dom objects.
        o13 = document.createElement('frameset');
        o13.id = 'o13';

        o25 = document.createElement('time');
        o25.id = 'o25';

        o28 = document.createElement('listing');
        o28.id = 'o28';

        o161 = document.createElement('applet');
        o161.id = 'o161';

        o25.appendChild(o28.cloneNode(true));
        o161.appendChild(o25.cloneNode(true));
        document.body.appendChild(o161);
        document.body.appendChild(o13);
    }
    </script>
</head>
<body onload="start();">
</bdoy>
</html>
```



Comment 26 by e...@chromium.org, Mar 7 2017

```
If we can't figure out the root cause here let's at least change the security DCHECK to a CHECK.
```

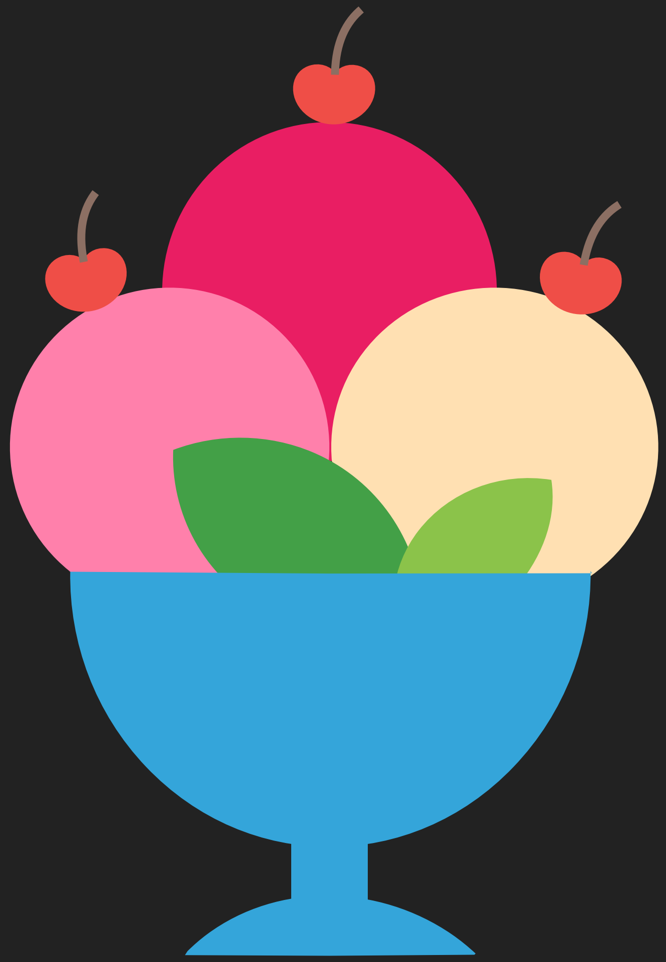
WHY JAVASCRIPT?

- Documentation of ECMA Script is well maintained
- If a zero-day is found, it will work on similar js engine versions

WHY FUZZING?

- It saves time!
  - It creates many test cases in a short time
  - You can focus on other work while the computer runs the fuzzer.
  - If you can't find bugs via source code auditing, you have somewhere to turn to. 😜

HOW WE DID IT



- Create a Javascript Fuzzing Factory
- Manage fuzzing nodes using Docker
- Make fuzzer create test cases based on existing 1day cases.
- Test case does not need to have any meaning to it. Just needs to create crashes!

CHARACTERISTICS & ENVIRONMENT

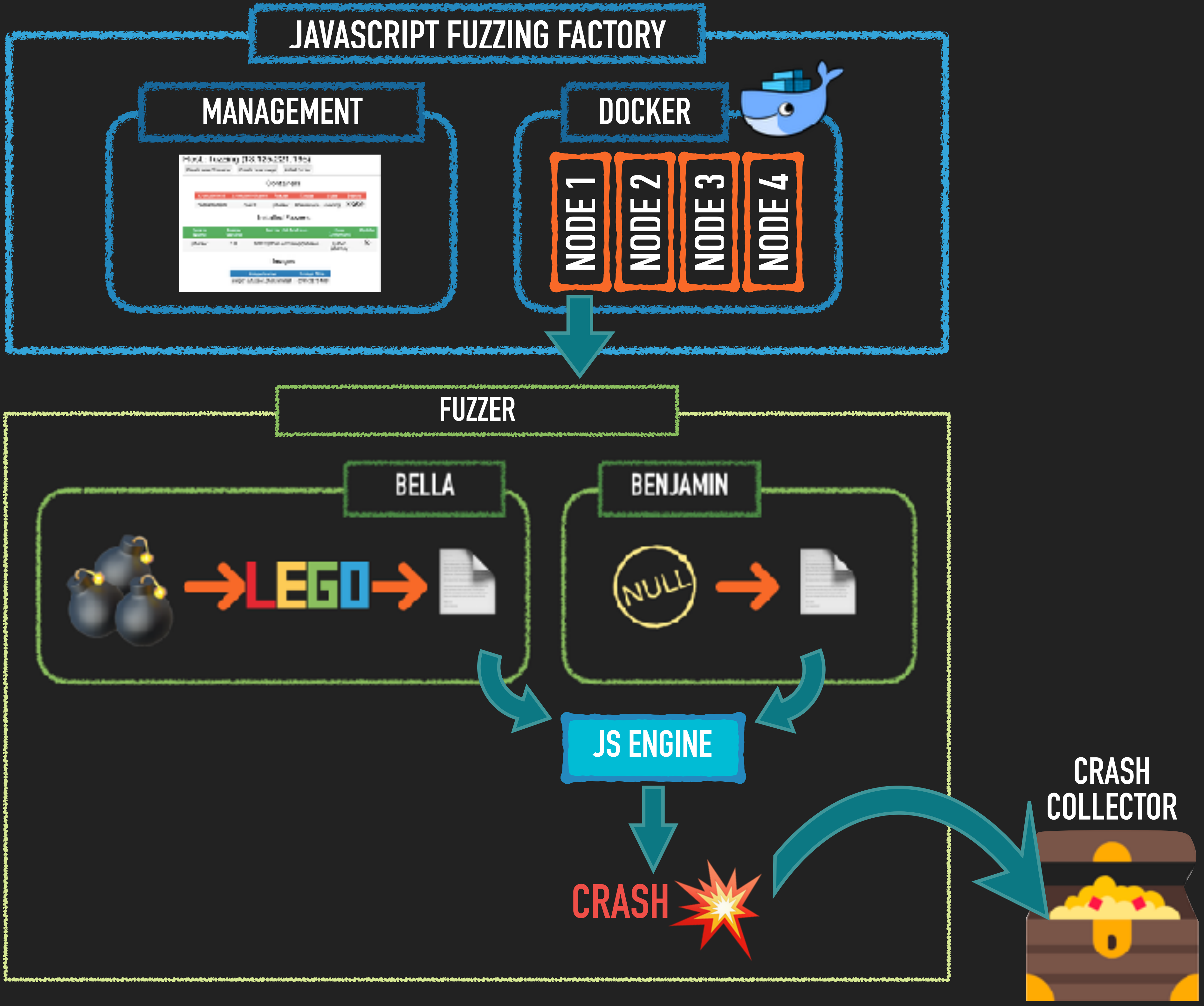
[CHARACTERISTICS]

- Fuzzing
  - In-memory fuzzing
- Management
  - use Docker!
- Creation of Test Case
  - Mutation based on existing 1days
  - Generation using dictionary for javascript syntax

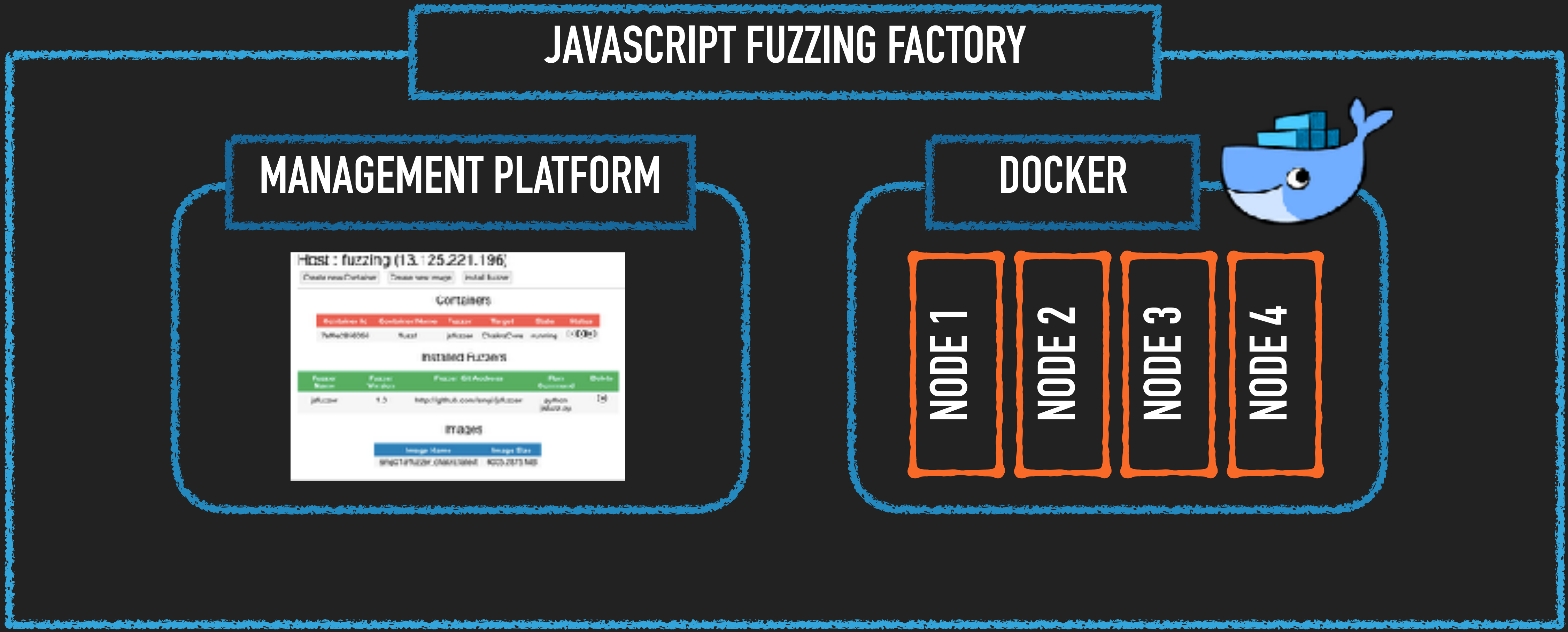
[ENVIRONMENT]

- Fuzzing Server
  - Amazon EC2 service
  - 8 GB RAM
  - 4 CPU core

OVERALL STRUCTURE



JFF - JAVASCRIPT FUZZING FACTORY



Host : fuzzing (13.125.221.196)

Create new Container | Create new image | Install fuzzer

Containers

Container Id	Container Name	Fuzzer	Target	State	Status
[illegible]	[illegible]	jsfuzzer	ChakraCore	running	[illegible]

Installed Fuzzers

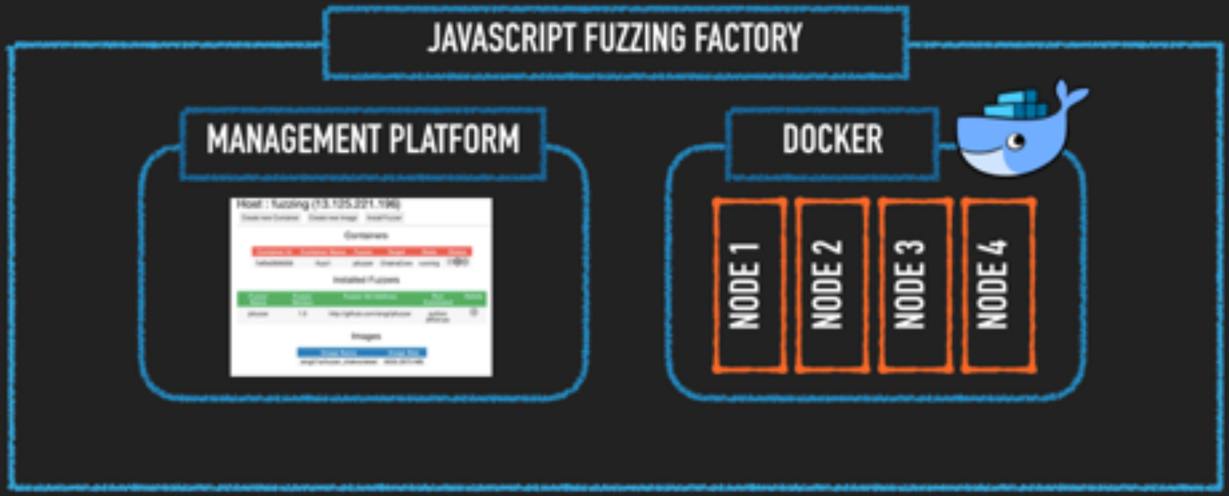
Fuzzer Name	Fuzzer Version	Fuzzer Git Address	Run Command	Delete
jsfuzzer	1.5	http://github.com/[illegible]/jsfuzzer	python [illegible]	[illegible]

Images

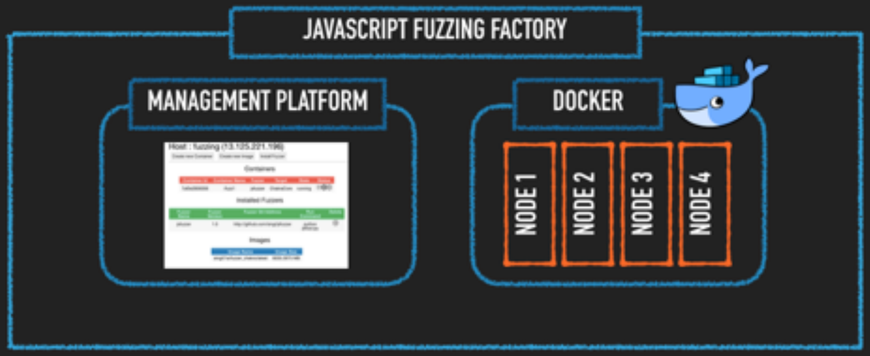
Image Name	Image Size
[illegible]	[illegible] MB

JFF - JAVASCRIPT FUZZING FACTORY

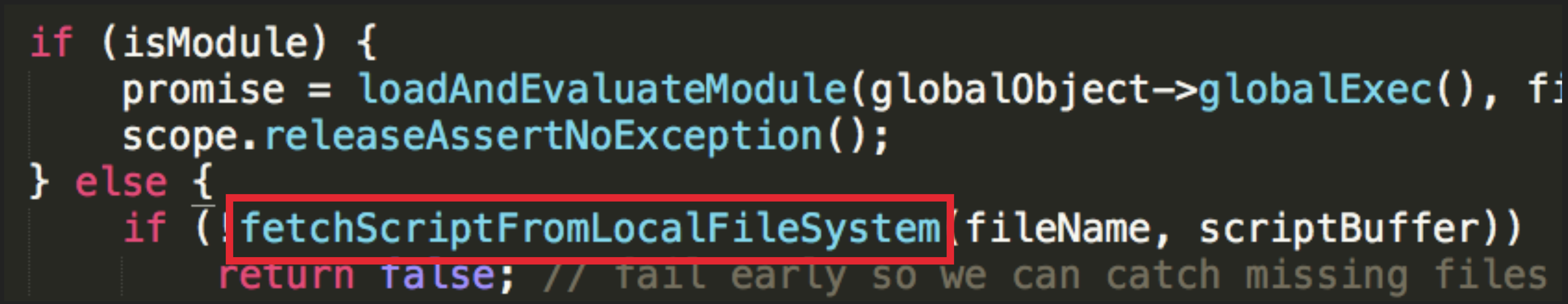
- Comprises of :
  1. Docker
     - js engines and fuzzer run within the docker nodes
  2. Web management platform
     - Use node js API to control the docker



JFF - JAVASCRIPT FUZZING FACTORY

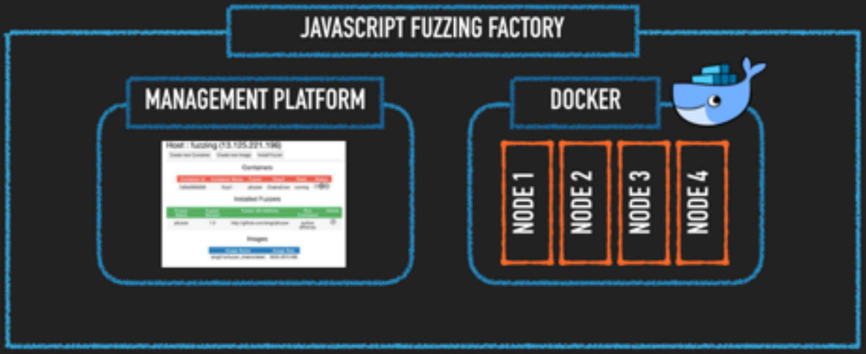


- In-memory fuzzing
  - make changes to javascript engine code

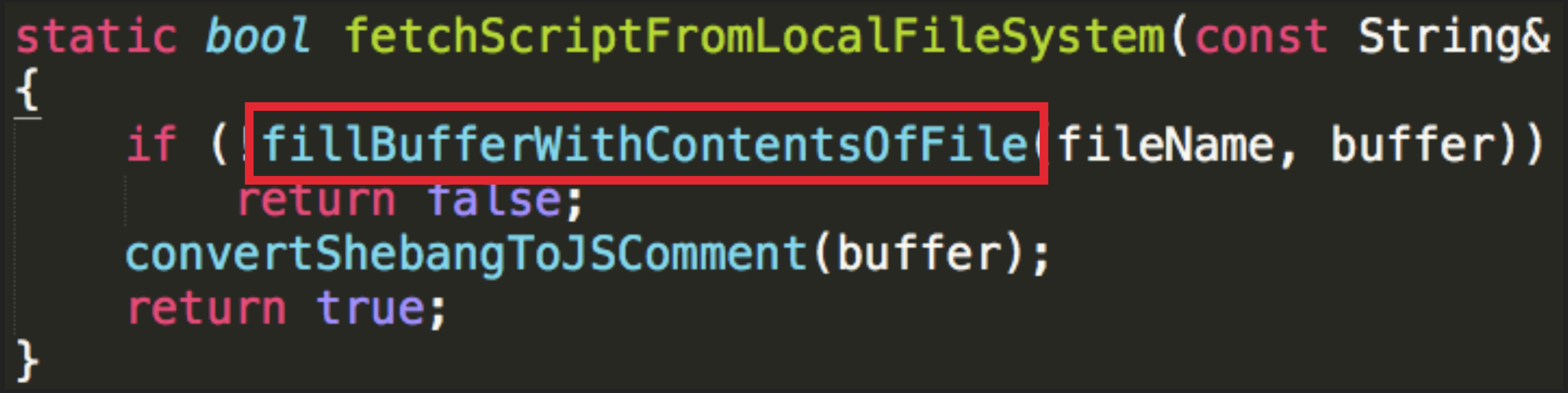


```
if (isModule) {
    promise = loadAndEvaluateModule(globalObject->globalExec(), fi
    scope.releaseAssertNoException();
} else {
    if (!fetchScriptFromLocalFileSystem(fileName, scriptBuffer))
        return false; // fail early so we can catch missing files
```

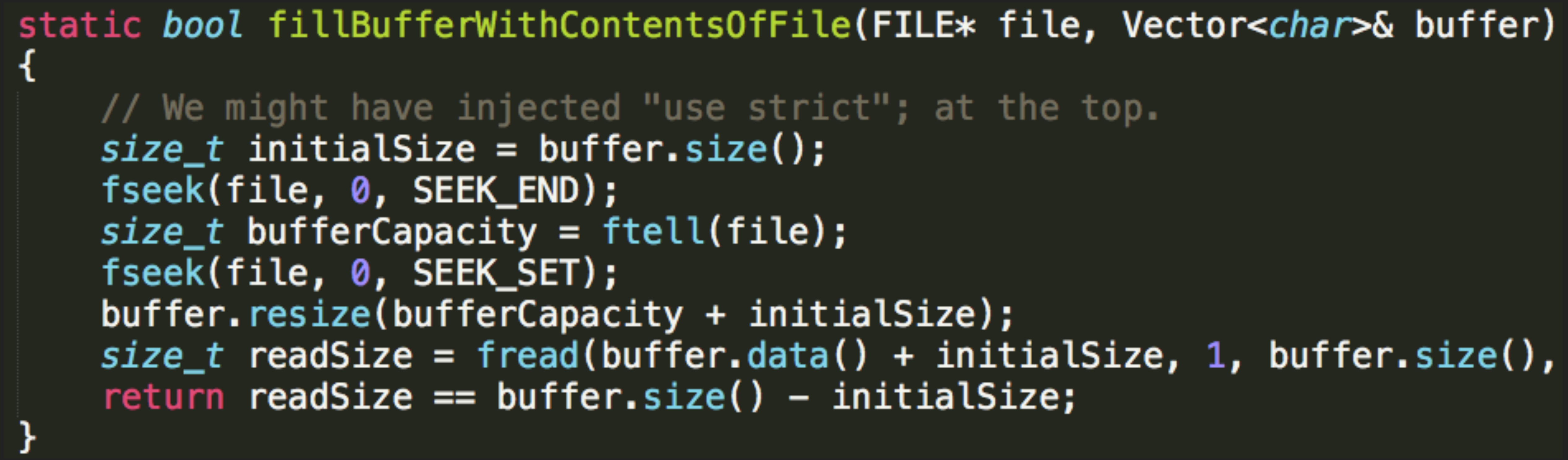
JFF - JAVASCRIPT FUZZING FACTORY



- In-memory fuzzing

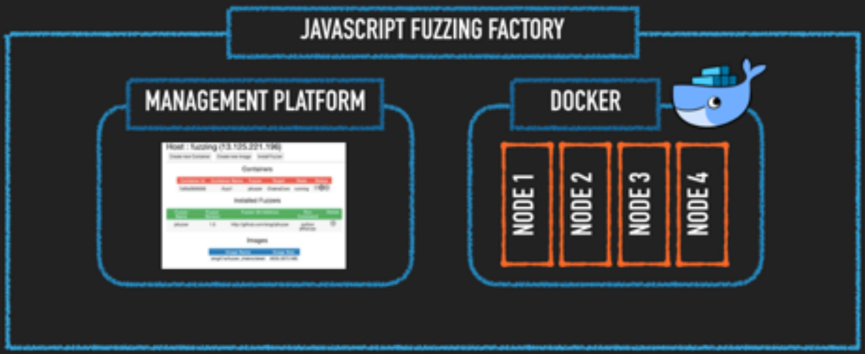


```
static bool fetchScriptFromLocalFileSystem(const String&
{
    if (!fillBufferWithContentsOfFile(fileName, buffer))
        return false;
    convertShebangToJSComment(buffer);
    return true;
}
```

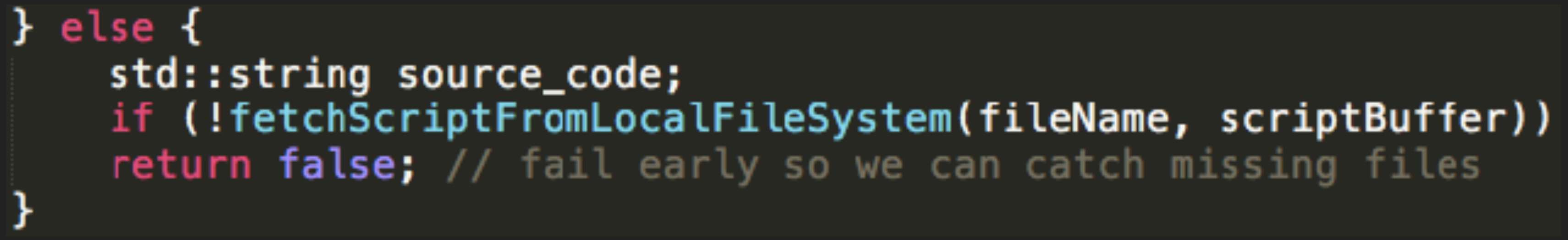


```
static bool fillBufferWithContentsOfFile(FILE* file, Vector<char>& buffer)
{
    // We might have injected "use strict"; at the top.
    size_t initialSize = buffer.size();
    fseek(file, 0, SEEK_END);
    size_t bufferCapacity = ftell(file);
    fseek(file, 0, SEEK_SET);
    buffer.resize(bufferCapacity + initialSize);
    size_t readSize = fread(buffer.data() + initialSize, 1, buffer.size(),
    return readSize == buffer.size() - initialSize;
}
```

JFF - JAVASCRIPT FUZZING FACTORY

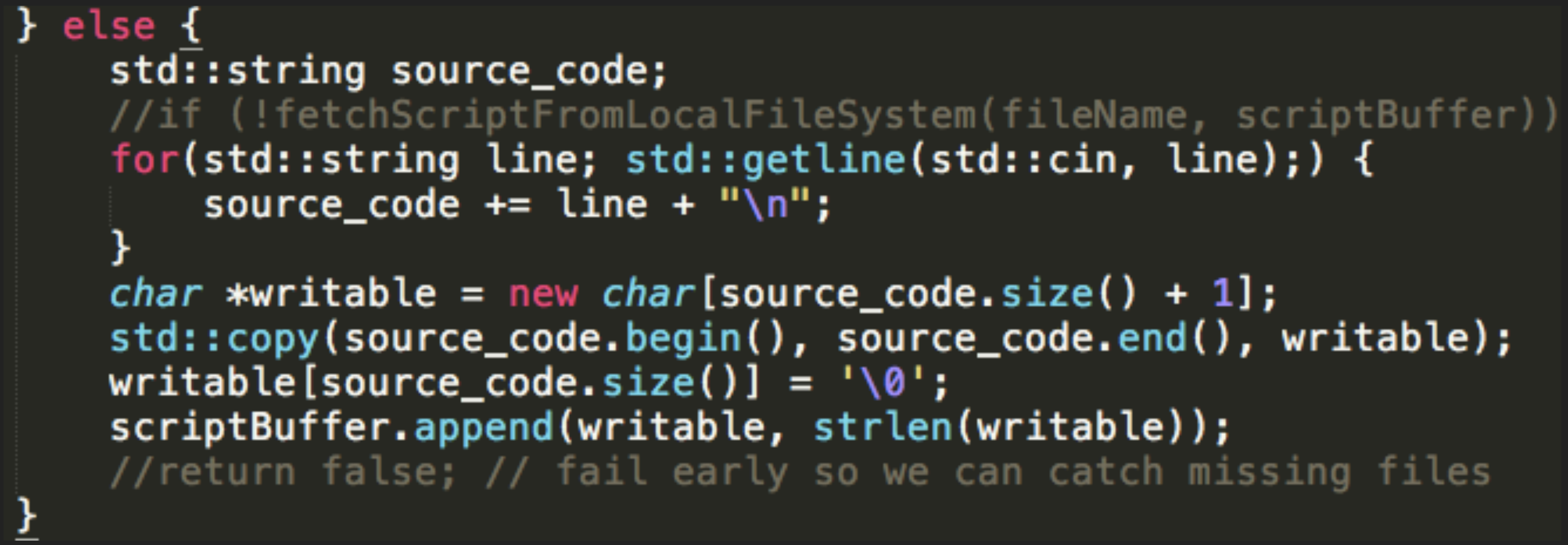


- In-memory fuzzing
  - Before



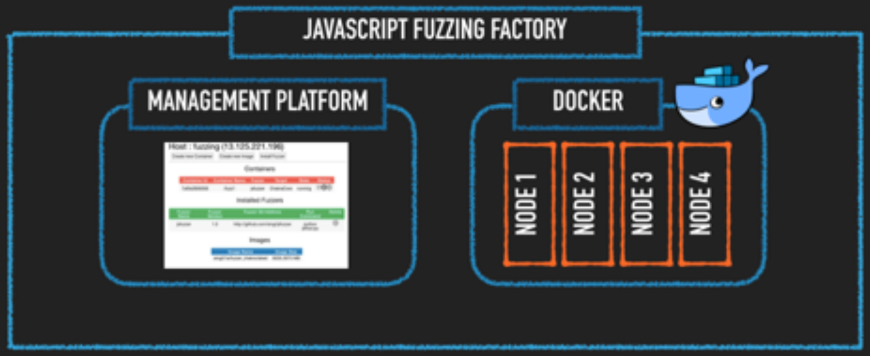
```
} else {
    std::string source_code;
    if (!fetchScriptFromLocalFileSystem(fileName, scriptBuffer))
    return false; // fail early so we can catch missing files
}
```

  - After

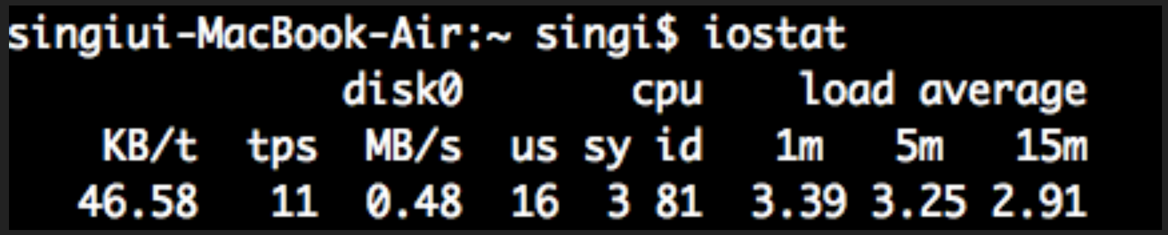


```
} else {
    std::string source_code;
    //if (!fetchScriptFromLocalFileSystem(fileName, scriptBuffer))
    for(std::string line; std::getline(std::cin, line);) {
        source_code += line + "\n";
    }
    char *writable = new char[source_code.size() + 1];
    std::copy(source_code.begin(), source_code.end(), writable);
    writable[source_code.size()] = '\0';
    scriptBuffer.append(writable, strlen(writable));
    //return false; // fail early so we can catch missing files
}
```

JFF - JAVASCRIPT FUZZING FACTORY

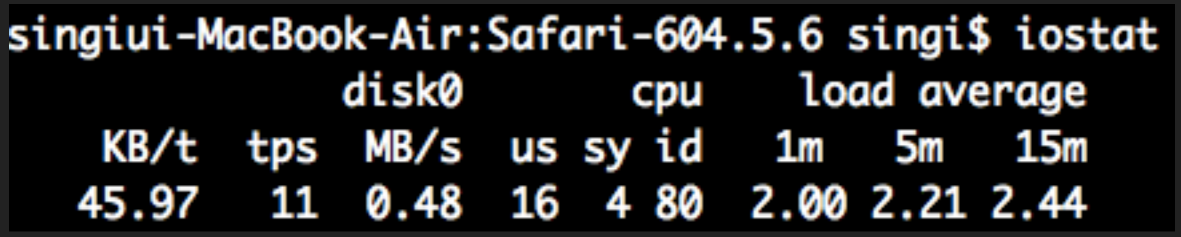


- In-memory fuzzing
  - Before



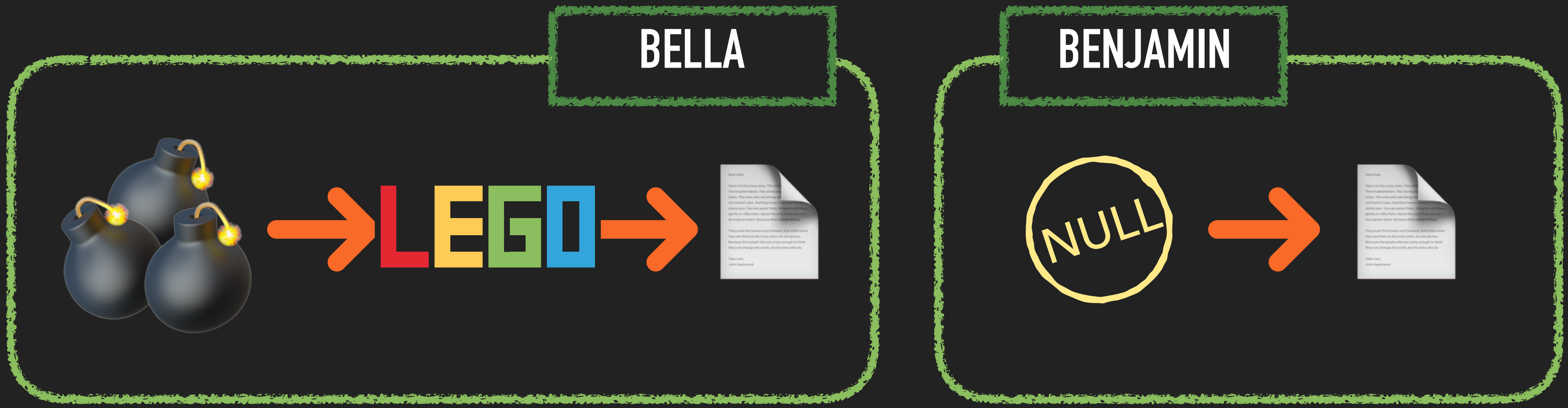
```
singiui-MacBook-Air:~ singi$ iostat
              disk0           cpu     load average
    KB/t  tps  MB/s   us sy id   1m   5m   15m
   46.58   11  0.48   16  3 81  3.39 3.25 2.91
```

  - After

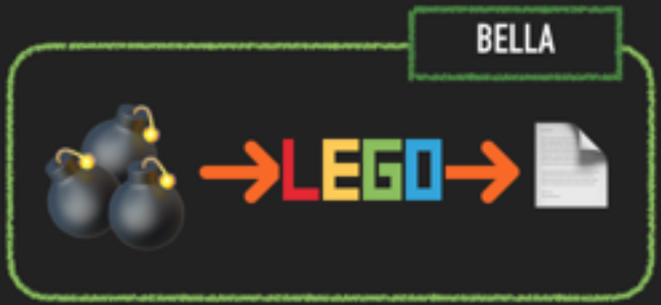


```
singiui-MacBook-Air:Safari-604.5.6 singi$ iostat
              disk0           cpu     load average
    KB/t  tps  MB/s   us sy id   1m   5m   15m
   45.97   11  0.48   16  4 80  2.00 2.21 2.44
```

THE FUZZERS

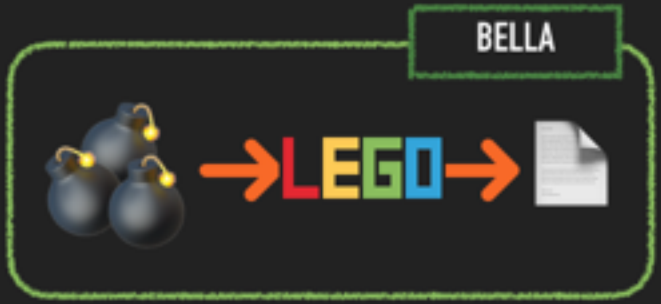


BELLA



- Mutation based
  - Apply mutations on existing 1days by finding patterns
- Why?
  - There are too many cases.
  - Hard to find pattern by hand.
- How?
  - Create template from existing 1days.
  - Make minimal changes to create random JS file.

LEGO



- Our approach to create JS syntax
- Name given to the template created from 1days.

- Parse 1-day PoCs for making LEGO file
- Parse LEGO file to make a new JS file.

- Excluded whatever was not important

BENJAMIN

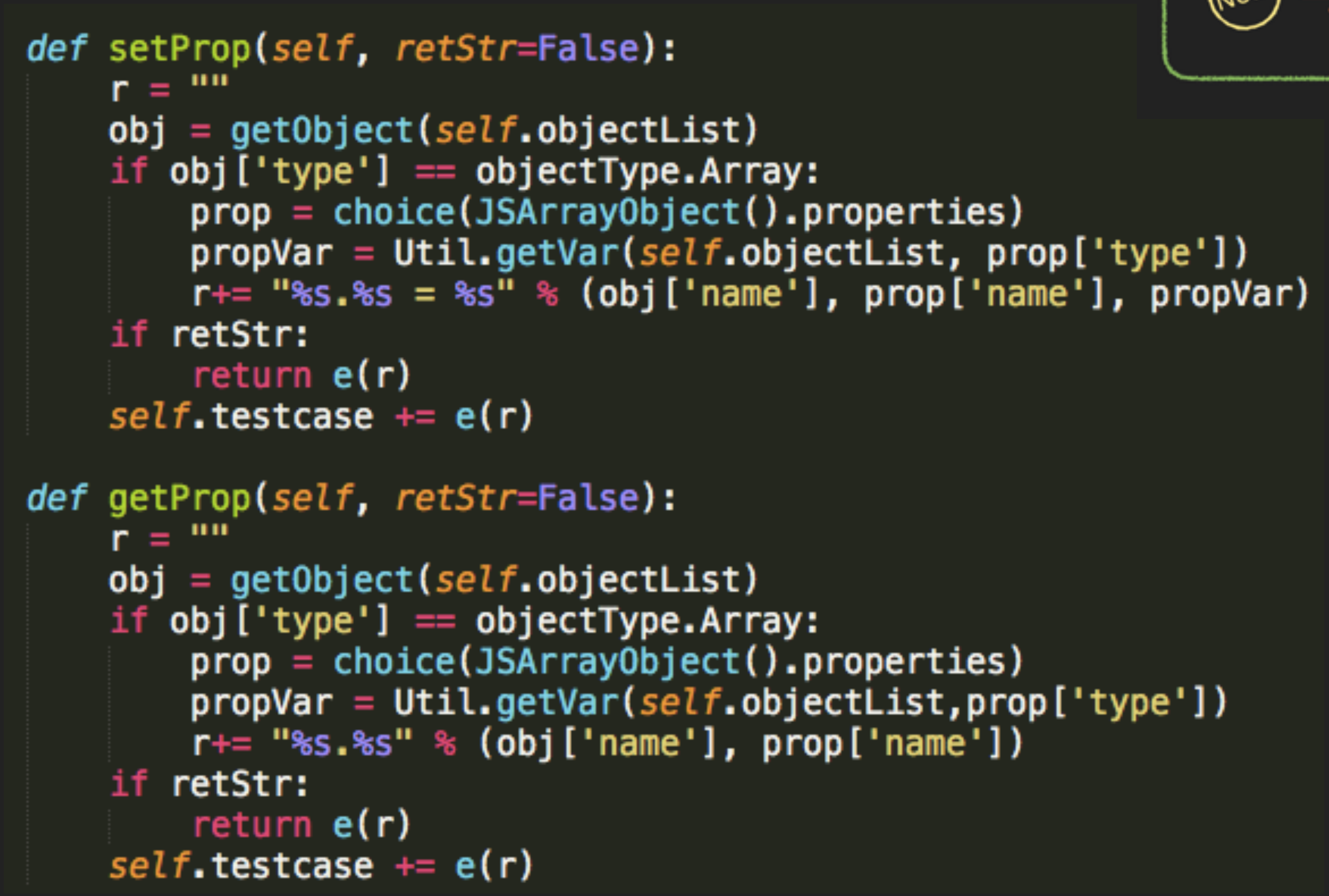
BENJAMIN
NULL

- Generation based
    - make by using input grammar
- How?
- Create input grammar by using library

BENJAMIN

- Problem!
  - Test cases have fixed form
  - Have to be randomized
- Solution
  - Make API!

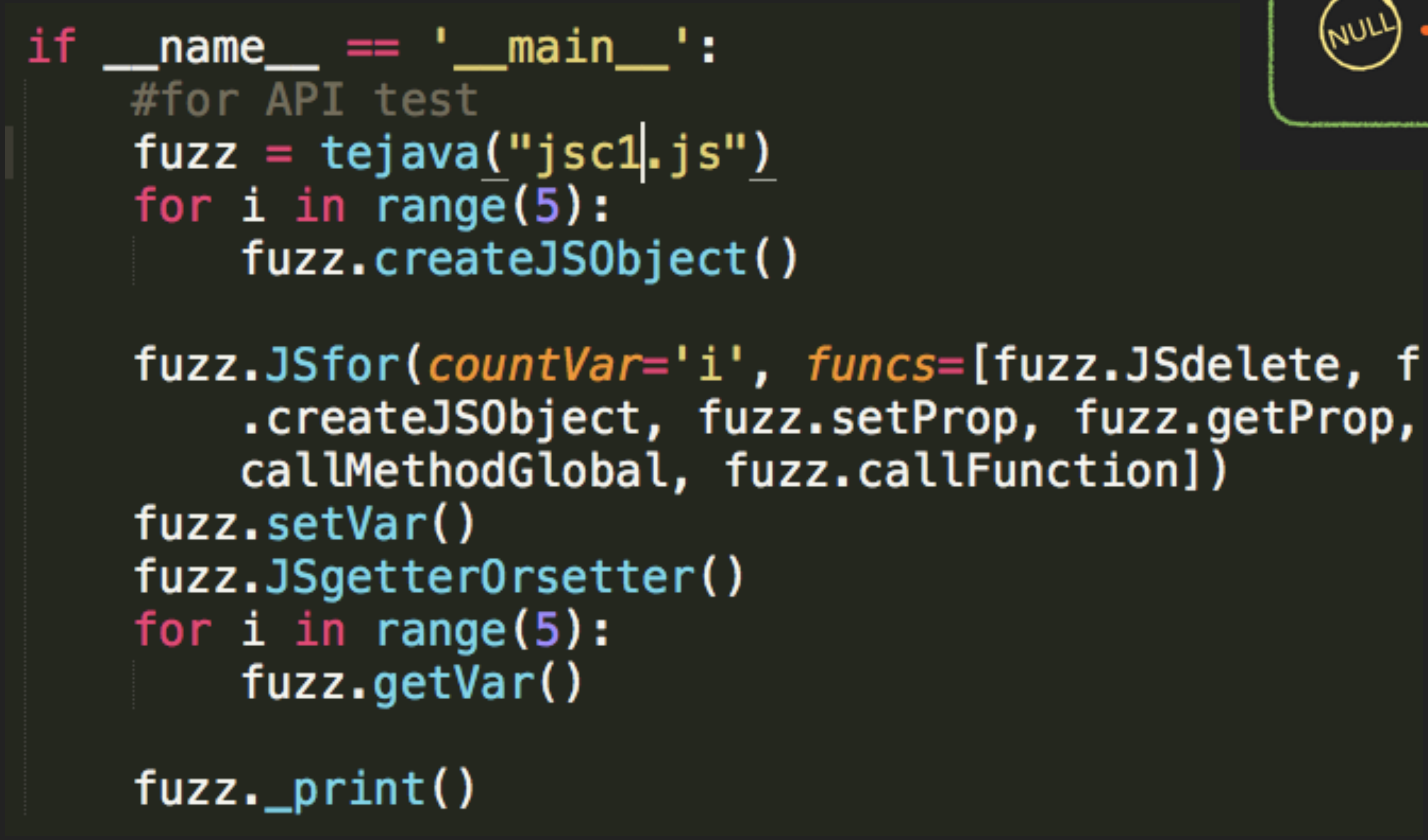
API



```python
def setProp(self, retStr=False):
    r = ""
    obj = getObject(self.objectList)
    if obj['type'] == objectType.Array:
        prop = choice(JSArrayObject().properties)
        propVar = Util.getVar(self.objectList, prop['type'])
        r+= "%s.%s = %s" % (obj['name'], prop['name'], propVar)
    if retStr:
        return e(r)
    self.testcase += e(r)

def getProp(self, retStr=False):
    r = ""
    obj = getObject(self.objectList)
    if obj['type'] == objectType.Array:
        prop = choice(JSArrayObject().properties)
        propVar = Util.getVar(self.objectList,prop['type'])
        r+= "%s.%s" % (obj['name'], prop['name'])
    if retStr:
        return e(r)
    self.testcase += e(r)
```

API



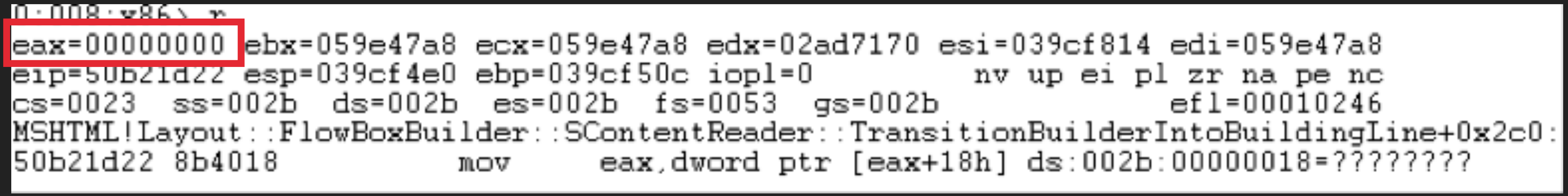
```
if __name__ == '__main__':
    #for API test
    fuzz = tejava("jsc1.js")
    for i in range(5):
        fuzz.createJSObject()

    fuzz.JSfor(countVar='i', funcs=[fuzz.JSdelete, f
        .createJSObject, fuzz.setProp, fuzz.getProp,
        callMethodGlobal, fuzz.callFunction])
    fuzz.setVar()
    fuzz.JSgetterOrsetter()
    for i in range(5):
        fuzz.getVar()

    fuzz._print()
```

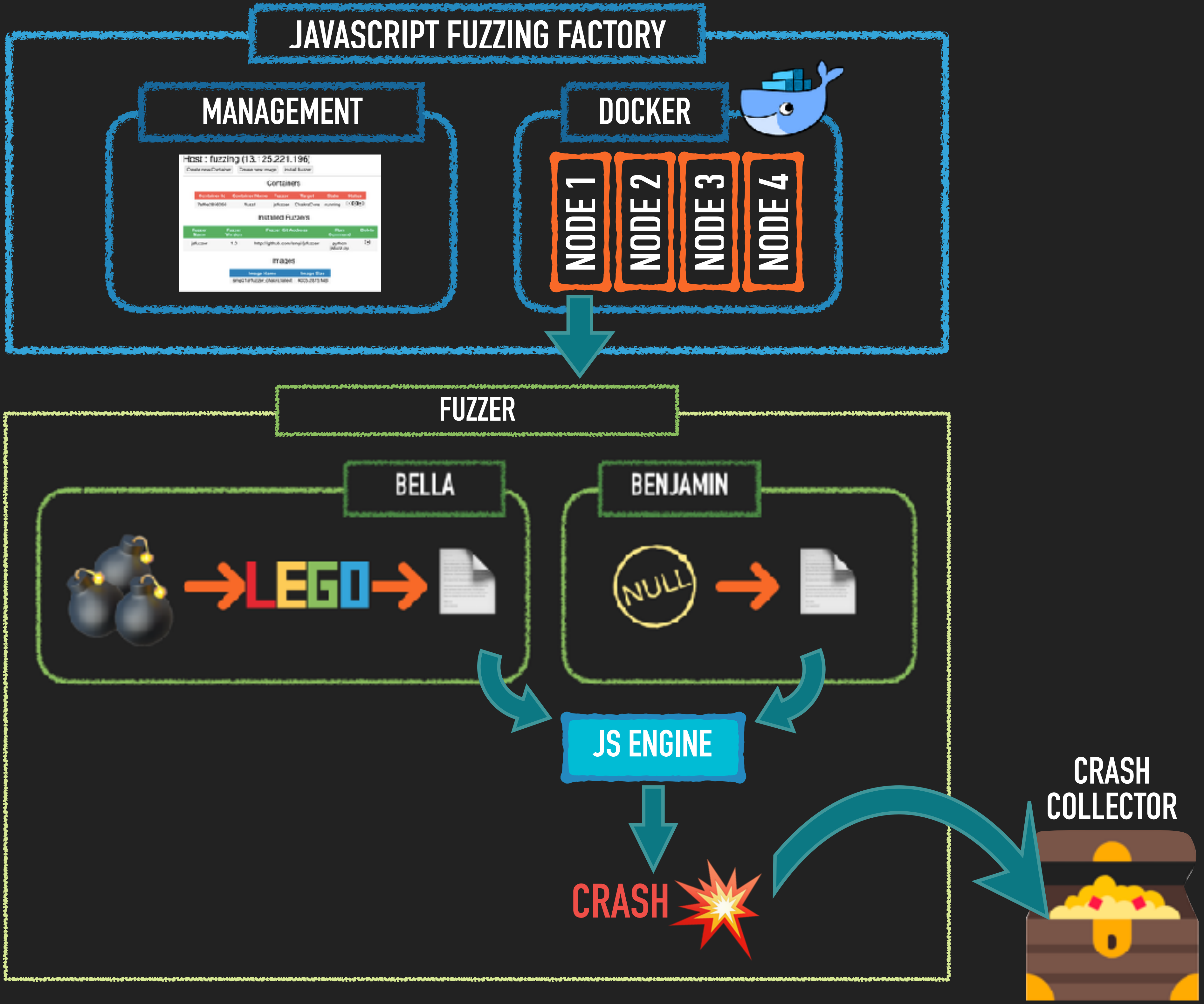
CRASH COLLECTOR

- Use regex
- \s*\s[0-9A-F]{8}\s\|.*\|.*\[(eax|ebx|ecx|edx|esi|edi|ebp|esp|eip).*\]

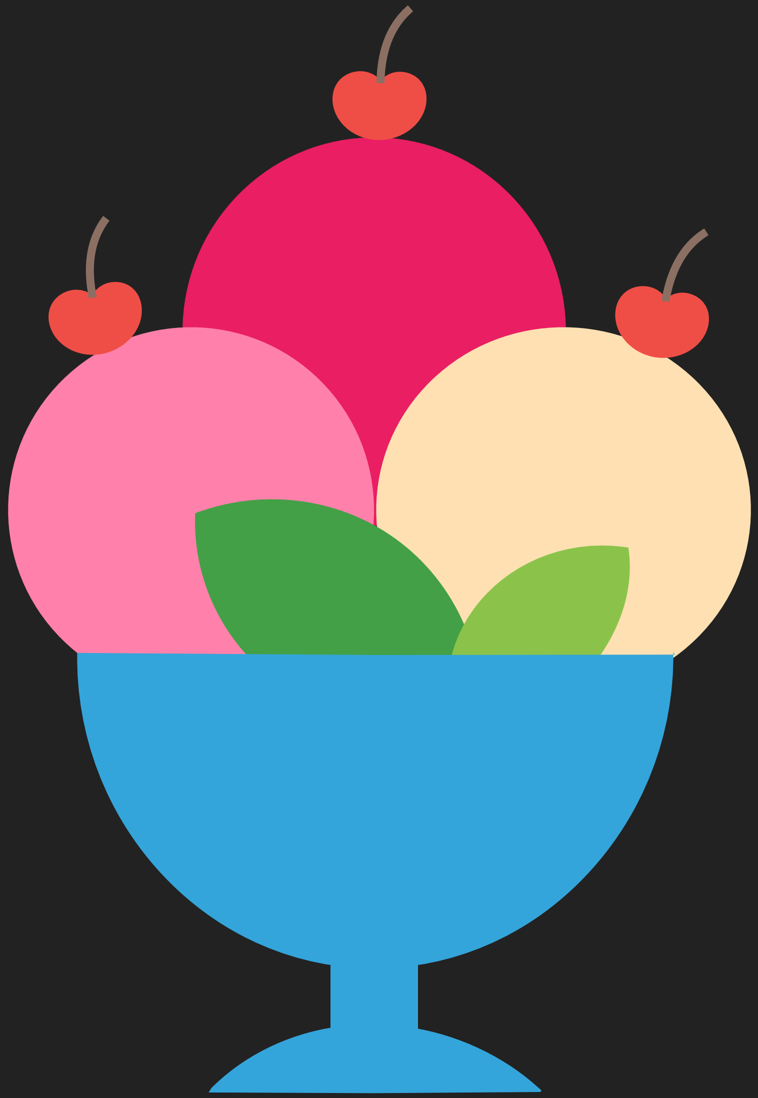


```
0:008:x86> r
eax=00000000 ebx=059e47a8 ecx=059e47a8 edx=02ad7170 esi=039cf814 edi=059e47a8
eip=50b21d22 esp=039cf4e0 ebp=039cf50c iopl=0         nv up ei pl zr na pe nc
cs=0023  ss=002b  ds=002b  es=002b  fs=0053  gs=002b             efl=00010246
MSHTML!Layout::FlowBoxBuilder::SContentReader::TransitionBuilderIntoBuildingLine+0x2c0:
50b21d22 8b4018          mov     eax,dword ptr [eax+18h] ds:002b:00000018=????????
```

OVERALL STRUCTURE (AGAIN)

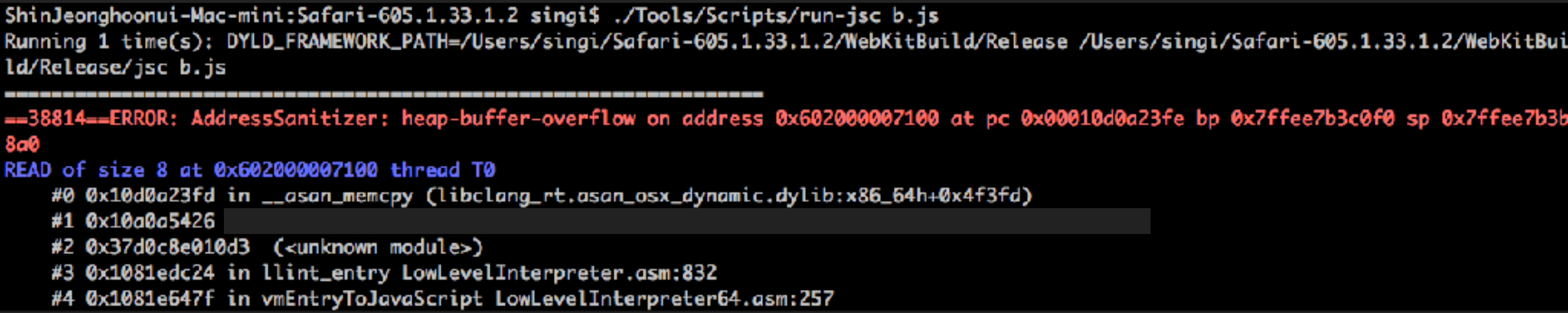


IT'S LIKE AN ICE CREAM SUNDAE!



RESULT

- Crash produced by using Benjamin.
- Target : Safari javascript core



```
ShinJeonghoonui-Mac-mini:Safari-605.1.33.1.2 singi$ ./Tools/Scripts/run-jsc b.js
Running 1 time(s): DYLD_FRAMEWORK_PATH=/Users/singi/Safari-605.1.33.1.2/WebKitBuild/Release /Users/singi/Safari-605.1.33.1.2/WebKitBui
ld/Release/jsc b.js
=================================================================
==38814==ERROR: AddressSanitizer: heap-buffer-overflow on address 0x602000007100 at pc 0x00010d0a23fe bp 0x7ffee7b3c0f0 sp 0x7ffee7b3b
8a0
READ of size 8 at 0x602000007100 thread T0
    #0 0x10d0a23fd in __asan_memcpy (libclang_rt.asan_osx_dynamic.dylib:x86_64h+0x4f3fd)
    #1 0x10a0a5426 [redacted]
    #2 0x37d0c8e010d3  (<unknown module>)
    #3 0x1081edc24 in llint_entry LowLevelInterpreter.asm:832
    #4 0x1081e647f in vmEntryToJavaScript LowLevelInterpreter64.asm:257
```

- Occurred in web assembly due to overflow.

DEMO

WE'RE STILL FAR FROM PERFECT

- We need good code coverage.
- JFF is small-scale compared to those being used in big companies.
- Limitations to creating different types of JS templates.
  - The sequence of API usage may be limited
- We have few minor bugs.

FUTURE PLANS

- Keep track of ECMA Script updates and add to fuzzer
    - ECMA script updates will also be applied to javascript engine
- Enhance JFF to support other vectors

Q&A