



The Problems and Promise of WebAssembly

About Me

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What is WebAssembly?

- Format for writing assembly-like code in JavaScript
- Motivated by need for greater efficiency and safety
- Compilability is a major goal
- WC3 standard
- Applications beyond browsers



What *Is* WebAssembly

- WebAssembly starts as a binary
 - ArrayBuffer or TypedArray
 - Can load using fetch (or not)

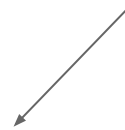
```
var wasm = new Uint8Array(123);  
wasm[0] = 0x0;  
wasm[1] = 0x61;  
wasm[2] = 0x73;  
wasm[3] = 0x6d;  
wasm[4] = 0x1;  
wasm[5] = 0x0;  
wasm[6] = 0x0;  
wasm[7] = 0x0;  
wasm[8] = 0x1;  
wasm[9] = 0xa;
```

WebAssembly Binary Format

- Consists of sections of various types (some optional)
- Mandatory order and duplicates forbidden

Field	Type	Description
magic number	uint32	Magic number 0x6d736100 (i.e., "\0asm")
version	uint32	Version number, 0x1

section



Field	Type	Description
id	varuint7	section code
payload_len	varuint32	size of this section in bytes
name_len	varuint32 ?	length of name in bytes, present if id == 0
name	bytes ?	section name: valid UTF-8 byte sequence, present if id == 0
payload_data	bytes	content of this section, of length payload_len - sizeof(name) - sizeof(name_len)

Section Types

Section Name	Code	Description
Type	1	Function signature declarations
Import	2	Import declarations
Function	3	Function declarations
Table	4	Indirect function table and other tables
Memory	5	Memory attributes
Global	6	Global declarations
Export	7	Exports
Start	8	Start function declaration
Element	9	Elements section
Code	10	Function bodies (code)
Data	11	Data segments

WebAssembly Module

- First step is parsing binary format and loading it into Module

```
var m = new WebAssembly.Module(wasm) ;
```

What could go wrong?

CVE-2018-4121 – WebKit: WebAssembly parsing does not correctly check section order

- Order check can be bypassed

```
static inline bool validateOrder(Section previous, Section next)
{
    if (previous == Section::Custom)
        return true;
    return static_cast<uint8_t>(previous) < static_cast<uint8_t>(next);
}
```


What could go wrong?

CVE-2018-6092 – V8: Integer Overflow when Processing WebAssembly Locals

- Integer overflow

```
if ((count + type_list->size()) > kV8MaxWasmFunctionLocals)
{
    decoder->error(decoder->pc() - 1, "local count too
large");
    return false;
}
```

What could go wrong?

CVE-2018-4222 – WebKit: Info leak in WebAssembly Compilation

- Can read out of bounds of the wasm buffer

```
var b2 = new ArrayBuffer(1000);  
var view = new Int8Array(b2, 700);  
var mod = new WebAssembly.Module(a);
```

WebAssembly Instance

- Loads module into runnable form
 - Loads imports
 - Initializes imports
 - Creates exports

WebAssembly Imports

- Three import types
 - Function: JavaScript or WebAssembly function
 - Memory: memory page object
 - Table: function table object
- If two wasm Modules have the same Memory and Table, they are in the same compartment
- There is no practical reason for a Module to share one of these objects but not the other

WebAssembly Memory

- Memory page for WebAssembly code
- Has a initial and max size, and can be expanded by calling grow in WebAssembly or JavaScript
- Accessed by WebAssembly instructions

```
var memory = new WebAssembly.Memory({initial:10, maximum:100});  
memory.grow(10);
```

What could go wrong?

- Overflows in expanding Memory
 - CVE-2018-5093 -- FireFox: Buffer overflow in WebAssembly during Memory/Table resizing (found by OSS-Fuzz)
 - CVE-2017-15399 -- V8: UaF in Growing Memory (Zhao Qixun of Qihoo 360 Vulcan Team)

What could go wrong?

- Surprisingly few OOB issues
 - Limited and known set of WebAssembly instructions
 - Limited threading
 - Safe signal buffers

Tables

- Function table for WebAssembly
- Can only contain WebAssembly functions
- Only need to set at startup in practice, but can be changed any time
- Can grow similar to a Memory page

```
var t = new WebAssembly.Table({initial:2, element:"anyfunc"});
```


What could go wrong?

- Overflows in expanding Table
 - CVE-2018-5093 -- Buffer overflow in WebAssembly during Memory/Table resizing (found by OSS-Fuzz)
 - CVE-2017-5122: OOB access in v8 wasm after Symbol.toPrimitive overwrite (found by Choongwoo Han of Naver Corporation working with Chromium Vulnerability Rewards)

Initialization

- Data segments from WebAssembly binary are used to initialize Memory
- Element segments from WebAssembly binary are use to initialize Elements

What could go wrong?

- No OOB issues seen so far!
- V8: 826434: UaF in Calling Table
 - If a table is changed during a call to a function in the table, there is a UaF, as it drops the handle to its instance
 - Fixed by preventing table change during call
 - Still possible due to element initialization

Exports

- End result of creating Module and then creating an Instance is exported WebAssembly functions ready to call!

```
var mod = new WebAssembly.Module(wasm);  
var i = new WebAssembly.Instance(mod,  
    {imported : {func : f}, js : {table : t, mem : m} });  
  
i.exports.exported_func(); // WebAssembly happens!
```

Runtime Issues?

- Instructions do wrong thing*
- Incorrect bounds checking
- Incorrect handles / UaF

Future Issues

- Concurrency
- WebAssembly-GC

Conclusion

- Several vulnerabilities have been found in WebAssembly implementations
- WebAssembly has features that make vulnerabilities less likely
- The future direction of WebAssembly features will determine its security

Questions and Discussion



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