The Year In Flash

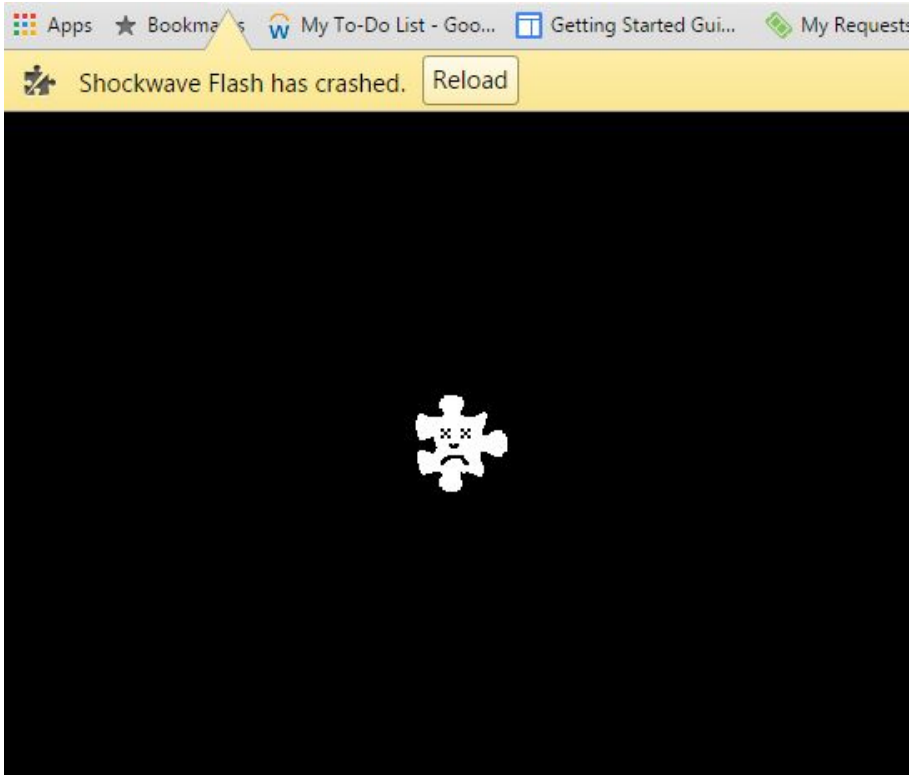
The year in Flash bugs, exploits and mitigations

Natalie Silvanovich

@natashenka

About me

- Natalie Silvanovich
  AKA natashenka AKA Flashtasha
- Project Zero member
- Previously did mobile security on Android and BlackBerry
- Flash enthusiast
- Reporter of ⅓ of Flash vulnerabilities



My goal

My goal

- Bug finding is my top priority
  - Mostly code review
  - Some fuzzing (with Mateusz Jurczyk AKA j00ru)
  - 1 bug per day -> 1 bug per week
  - Flash bugs stay gone
- Analyze external bugs and exploits

My goal

- Occasionally exploit bugs to answer questions
  - Is exploitation possible?
  - Is exploitation reliable?
  - How does X impact exploitability
- Work on mitigations (with James Forshaw and Mark Brand)

This talk

- Attack surface
- The year in Flash
  - New bugs and bug classes
  - 0-days, 1-days and other exploits
  - Mitigations
- The future?

Flash is ...

- AS2 -- ActionScript 2
  - Interpreted legacy Flash Scripts with own VM
  - Reduced API set
  - Generally more bugs with lower exploitability
  - Blurry boundaries between VM and APIs

Flash is ...

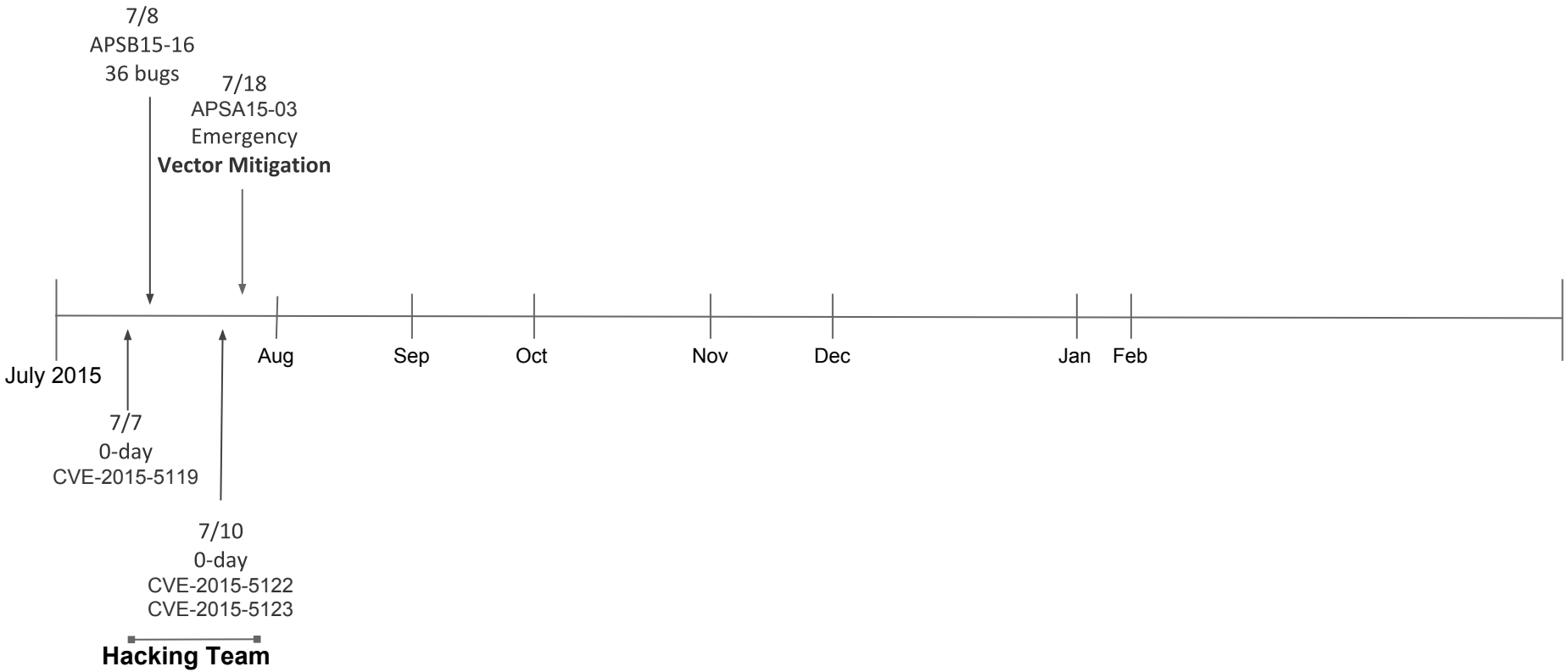
- AS3 -- ActionScript 3
  - Modern VM with JIT and interpreter
    - Extendible
    - GC Heap / Fixed Heap
    - Optimized for Flash
  - Open source VM
  - Open and closed source APIs
  - Bugs are less dense but more exploitable

Flash is ...

- Anticorpus
  - Functionality outside of script
  - MP4 parser, zlib, regex, image decoders, etc

Warning

Timeline


7/8
APSB15-16
36 bugs
7/18
APSA15-03
Emergency
Vector Mitigation
July 2015
Aug
Sep
Oct
Nov
Dec
Jan
Feb
7/7
0-day
CVE-2015-5119
7/10
0-day
CVE-2015-5122
CVE-2015-5123
Hacking Team

July 2015

- Large update (36 bugs)
- Hacking Team dump
- Mitigations

July 2015

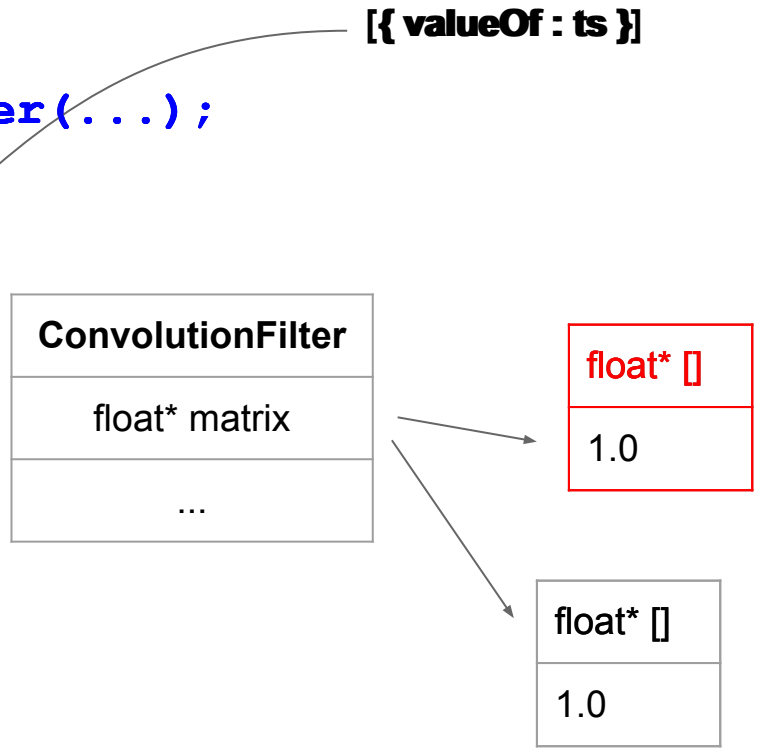
- Hacking Team dump contained two 0-days and two fixed bugs
  - ByteArray/OpaqueBackground -- 0-day UaFs due to valueOf redefinition (CVE-2015-0349 and CVE-2015-05122)
  - ConvolutionFilter issue shown earlier (CVE-2015-3039/CVE-2015-0349)
  - Integer overflow in Function.apply -- reported via Chromium VRP before use (CVE-2015-0387)
  - NULL pointer in BitmapData, not exploitable (CVE-2015-05123)

CVE-2015-3039

- Redefinition issue in ConvolutionFilter (also reported by bilou)
- AS2 allows any method to be redefined in script (monkey-patching)
- Generally native methods accept any type and convert objects with valueOf, toString, object constructor, etc.

CVE-2015-3039

```
var filter = new ConvolutionFilter(...);
var n = { valueOf : ts };
var a = [];
a[0] = n;
filter.matrix = a;
function ts(){
        filter.matrix = [1];
}
```



July 2015

- valueOf/toString bugs receive increased attention
  - Many similar bugs reported in next few months
  - Adobe starts efforts to pre-emptively fix similar bugs
- 33 bugs in regular update
- Vector mitigations implemented

Vector Mitigation

"I don't afraid Adobe analysts at all" -- Vitaly Toropov

- Adds checksums to Vectors that are checked before doing sensitive functions
- Some Vectors are also on their own heap page
- Reduced the reusability of exploit code
- Generally increases the quality of bug needed for an exploit
- Substitution of ByteArray or BitmapData is possible, but not as good

CVE-2015-3130

- Redefinition issue involving valueOf

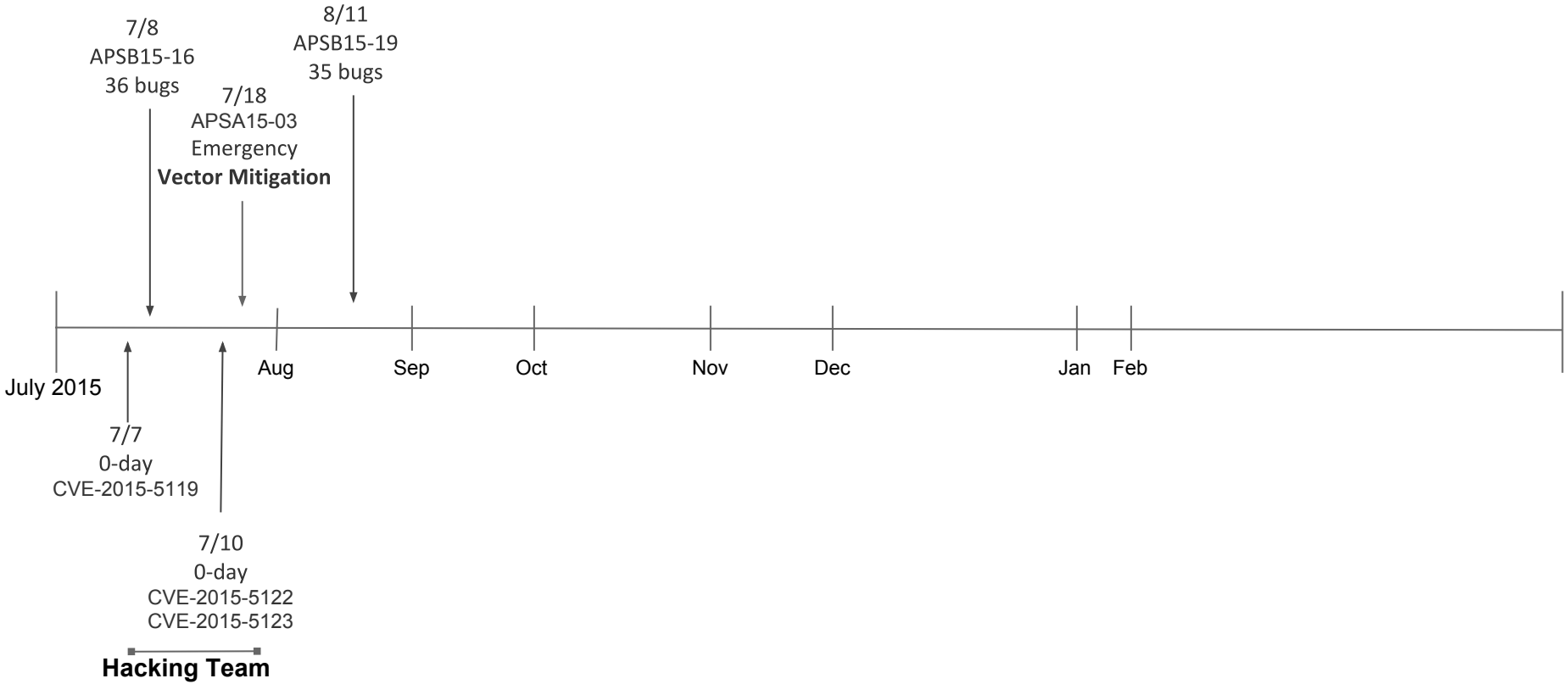
CVE-2015-3130

```
[{name: "john", city: "omaha"},
{name: "bob", city: "omaha"},
{valueOf : gl}]
```

```
var s = 1;
var rec_array:Array = new Array();
rec_array.push({name: "john", city: "omaha"});
rec_array.push({name: "bob", city: "omaha"});
rec_array.length = {valueOf : gl};

rec_array.sortOn(["name", "city"]);

function gl(){
    if(s< 3){
        s++;
        return 100000;
    }else{
        return 2;
        }
    }
```

```
if (array->getLength() == 0){ return; }

int length = array->getLength();

char** s = new char*[array->getLength()]

memcpy(s, array->items, length);
```

Timeline



Google

August 2016

- Many more bugs similar to HT bugs
- MC UaFs pour in

CVE-2015-5550 (MovieClip UaFs)

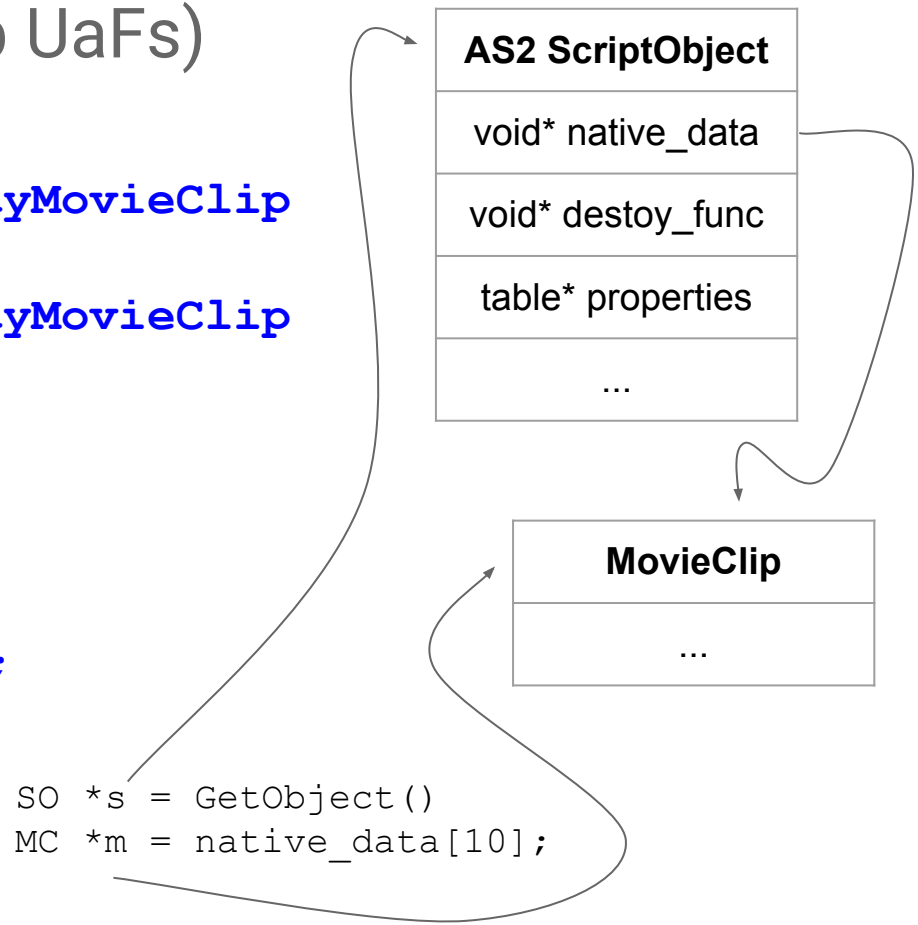
- Very common AS2 bug, 100+ reported this year
  - Small variety of freed object
- Also works with TextFields
- Root cause is that display fields are freed outside of garbage collection
  - Always, for real, even if there are references (in AS2)

CVE-2015-5550 (MovieClip UaFs)

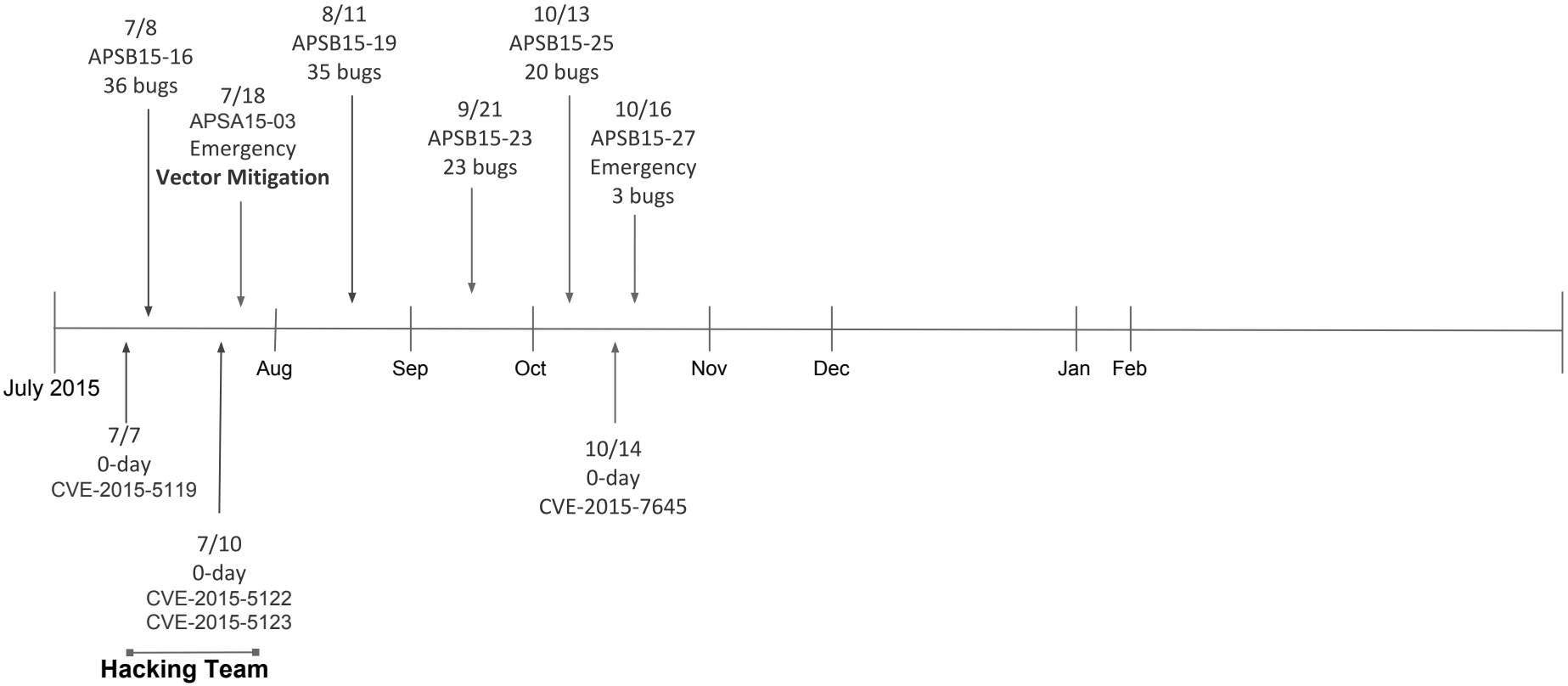
- Happens when function parameters are converted after local variables are initialized, but before they are used
- Fixed by enforcing convert -> intialize -> use order

CVE-2015-5550 (MovieClip UaFs)

```
var clip1 = this.createEmptyMovieClip
("clip1", 1);
var clip2 = this.createEmptyMovieClip
("clip2", 2);
var n = {toString: func};
clip1.swapDepths(n);

function func(){
    clip1.removeMovieClip();
    return "clip2";
}
```



Timeline


7/8
APSB15-16
36 bugs
7/18
APSA15-03
Emergency
Vector Mitigation
8/11
APSB15-19
35 bugs
9/21
APSB15-23
23 bugs
10/13
APSB15-25
20 bugs
10/16
APSB15-27
Emergency
3 bugs
July 2015
Aug
Sep
Oct
Nov
Dec
Jan
Feb
7/7
0-day
CVE-2015-5119
7/10
0-day
CVE-2015-5122
CVE-2015-5123
Hacking Team
10/14
0-day
CVE-2015-7645

September/October 2015

- 23 bugs in September updates and 20 in October
  - Mostly UaFs and other redefinition bugs
- 0-day immediately after October update (reported by TrendMicro, NATO targets)

CVE-2015-7645

- Reported two weeks before it was found in the wild
- Type confusion in serializations, due to weird AVM behaviour
- Two other variants also reported and fixed in emergency patch
- None of these bugs compile

CVE-2015-7645

From the AVM:

```
// In theory we should reject duplicate slots here;
// in practice we don't, as it causes problems with some existing content
//if (basetb->findBinding(name, ns) != BIND_NONE)
//  toplevel->throwVerifyError(kIllegalOverrideError, toplevel->core()->toErrorString(qn), toplevel->core()->toErrorString(this));
```

tl;dr a method can be overridden by a var

Most natives don’t make assumptions, but some do. Especially interfaces.

CVE-2015-7645

```
class superclass{
    …
    public function writeExternal(){
        return 1;
    }
}

class subclass extends superclass{
    public var writeExternal:uint = 7;
    ...
}
```

CVE-2015-7645

From the AVM:

```
Multiname mn(core->getPublicNamespace(t->pool),
        core->internConstantStringLatin1(kWriteExternal));
m_functionBinding = toplevel->getBinding(t, &mn);
```

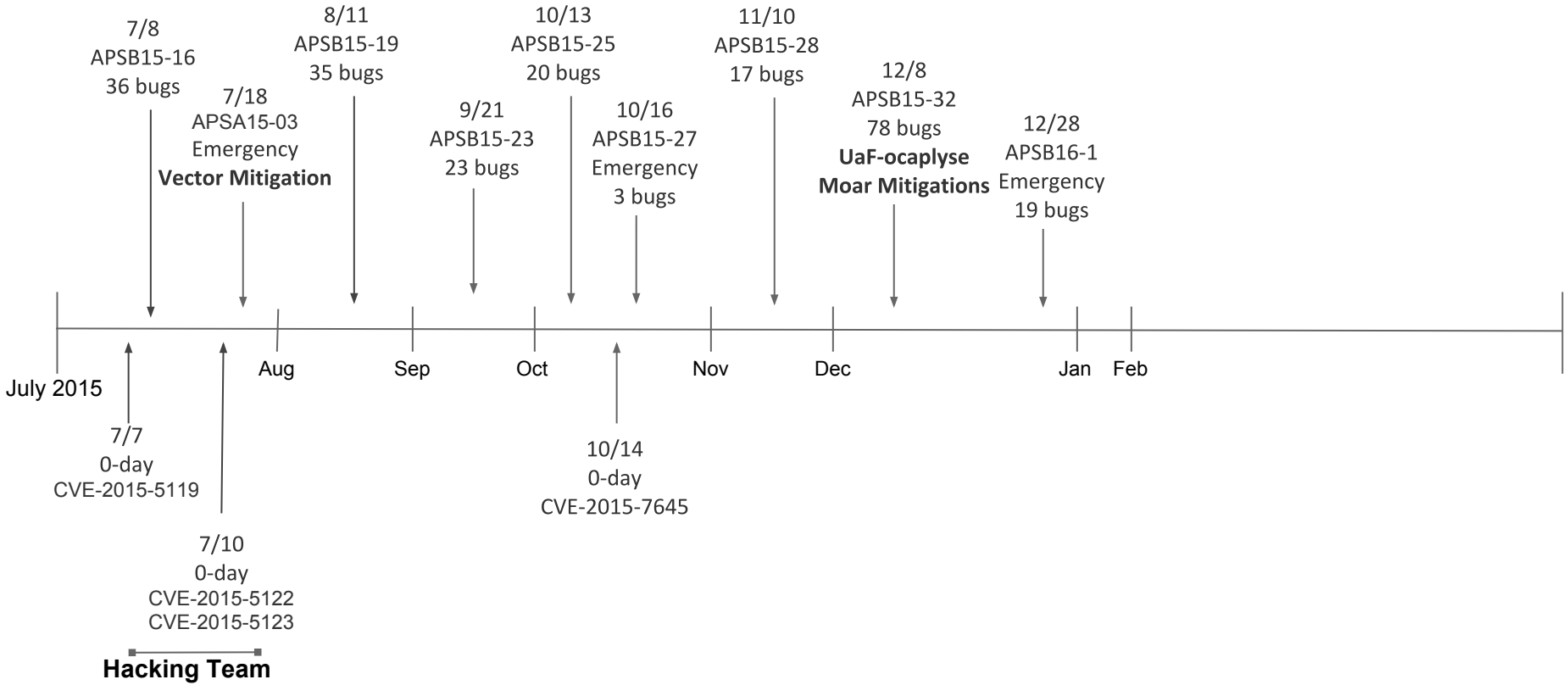
and later:

```
MethodEnv* method =
   obj->vtable->methods[AvmCore::bindingToMethodId(info->get_functionBinding())];
method->coerceEnter(argc, argv);
```

How was this bug exploited?

- Traits property array is variable-sized
- Corrupted ByteArray to get R/W access to entire memory space

Timeline


7/8
APSB15-16
36 bugs
7/18
APSA15-03
Emergency
Vector Mitigation
8/11
APSB15-19
35 bugs
9/21
APSB15-23
23 bugs
10/13
APSB15-25
20 bugs
10/16
APSB15-27
Emergency
3 bugs
11/10
APSB15-28
17 bugs
12/8
APSB15-32
78 bugs
UaF-ocaplyse
Moar Mitigations
12/28
APSB16-1
Emergency
19 bugs
July 2015
Aug
Sep
Oct
Nov
Dec
Jan
Feb
7/7
0-day
CVE-2015-5119
7/10
0-day
CVE-2015-5122
CVE-2015-5123
10/14
0-day
CVE-2015-7645
Hacking Team

November and December 2015

- Huge Dec update, 79 bugs, mostly MC UaF
  - Structural changes to AS2 to make broad fixes
- New mitigations
  - Checksumming on ByteArray
  - Isolated Heap
  - NOP slide mitigations
- Exploit kit 1-day and 0-day

CVE-2015-8446

- 1-day in Angler
- Similar to CVE-2015-5560
- Integer overflow in ID3 allocation
  - Controllable size
  - Controllable overwrite
- Exploited using BitmapData

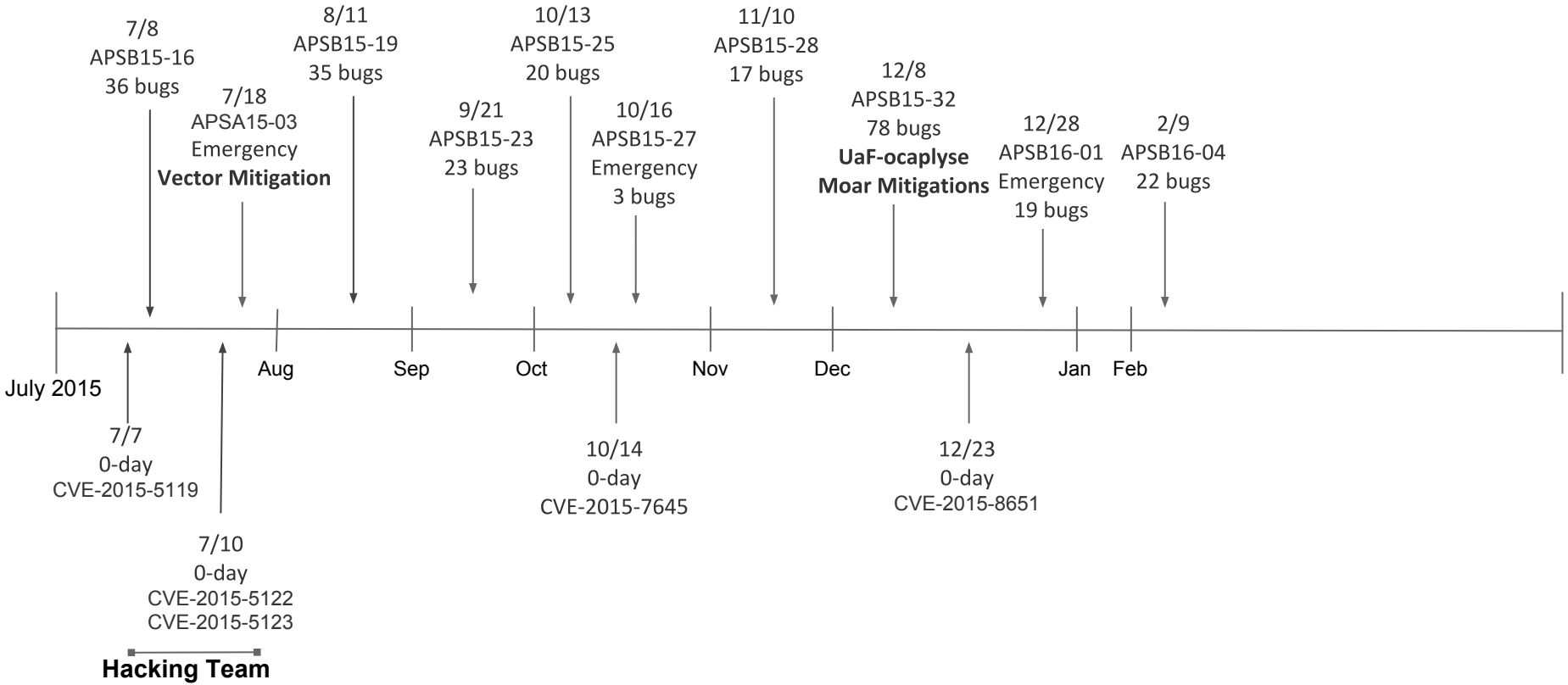
CVE-2015-8651

- Integer overflow leading to heap overflow in JIT (reported by Huawei)

CVE-2015-8651

- SWF contained two exploits
  - Typical vector exploit
  - Post Isolated Heap exploit including such elements as
    - Long if statements nested almost 100 times
    - Using both a media file and an image to fill heap slots at different points in the exploit
    - Triggering the bug ~600 times
    - Final results was memory space access via ByteArray

Timeline


7/8
APSB15-16
36 bugs
7/18
APSA15-03
Emergency
Vector Mitigation
8/11
APSB15-19
35 bugs
9/21
APSB15-23
23 bugs
10/13
APSB15-25
20 bugs
10/16
APSB15-27
Emergency
3 bugs
11/10
APSB15-28
17 bugs
12/8
APSB15-32
78 bugs
UaF-ocaplyse
Moar Mitigations
12/28
APSB16-01
Emergency
19 bugs
2/9
APSB16-04
22 bugs
July 2015
Aug
Sep
Oct
Nov
Dec
Jan
Feb
7/7
0-day
CVE-2015-5119
7/10
0-day
CVE-2015-5122
CVE-2015-5123
Hacking Team
10/14
0-day
CVE-2015-7645
12/23
0-day
CVE-2015-8651

February 2016

- 22 bugs fixed
  - UaF straglers
  - Fuzz bugs, mostly media
  - Exception-related bugs

CVE-2016-0985

- Unusual type confusion in AS3
- Occurs due to catching an exception
  - Should have been fatal error

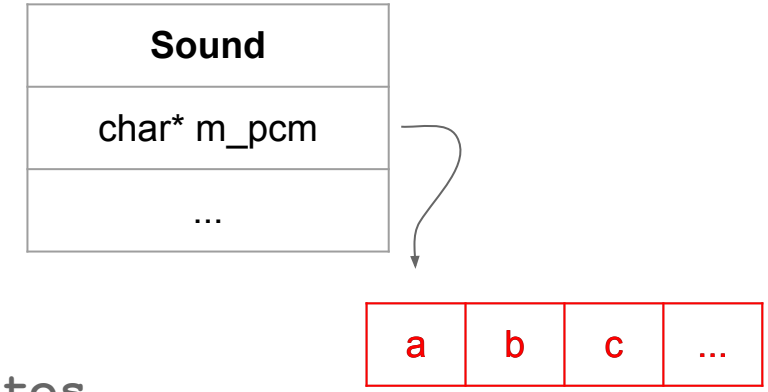
CVE-2016-0985

```
try{
      var t = new TextField();
} catch(e:Error){
      var t2 = new TextField();
}
```

CVE-2016-0984

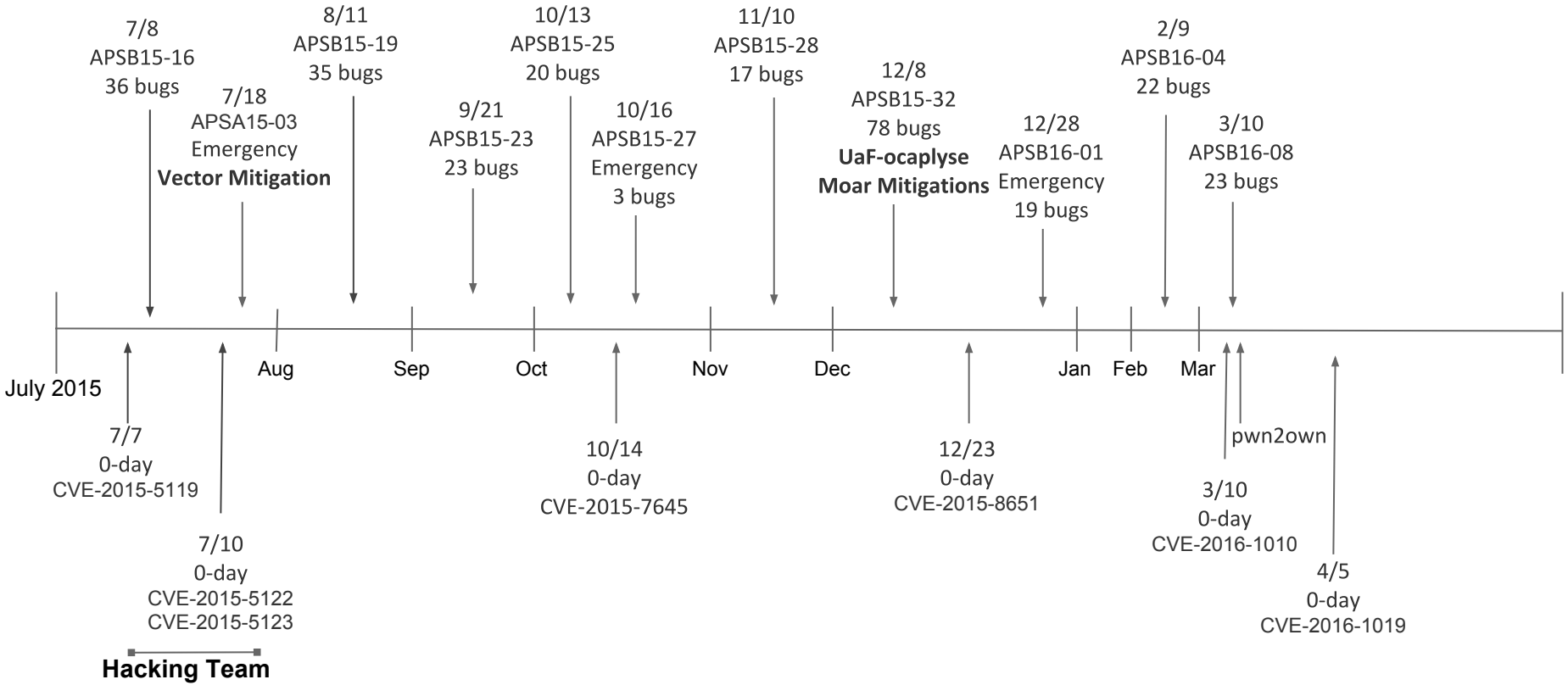
- Read-only UaF in Sound class
- Exception-related

CVE-2016-0984




```
var s = new Sound();
var b = new ByteArray(); // 1000 bytes
s.loadPCMFromByteArray(b, 100, "float", false, 2.0);
var c = new ByteArray(); // size 2
try{
     s.loadPCMFromByteArray(c, 1, "float", false, 2.0);
}catch(e:Error){}
s.extract(b, 1, 0);
```

Timeline


7/8
APSB15-16
36 bugs
7/18
APSA15-03
Emergency
Vector Mitigation
8/11
APSB15-19
35 bugs
9/21
APSB15-23
23 bugs
10/13
APSB15-25
20 bugs
10/16
APSB15-27
Emergency
3 bugs
11/10
APSB15-28
17 bugs
12/8
APSB15-32
78 bugs
UaF-ocaplyse
Moar Mitigations
12/28
APSB16-01
Emergency
19 bugs
2/9
APSB16-04
22 bugs
3/10
APSB16-08
23 bugs
July 2015
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
7/7
0-day
CVE-2015-5119
7/10
0-day
CVE-2015-5122
CVE-2015-5123
Hacking Team
10/14
0-day
CVE-2015-7645
12/23
0-day
CVE-2015-8651
pwn2own
3/10
0-day
CVE-2016-1010
4/5
0-day
CVE-2016-1019

March 2016

- 22 bugs fixed
  - More fuzz bugs
    - Exploited one
  - UaFs
- pwn2own
  - 4 MC UaFs, one parsing bug in JPG
- 0-day
  - Overflow in Bitmap in platform-specific code

CVE-2016-0998

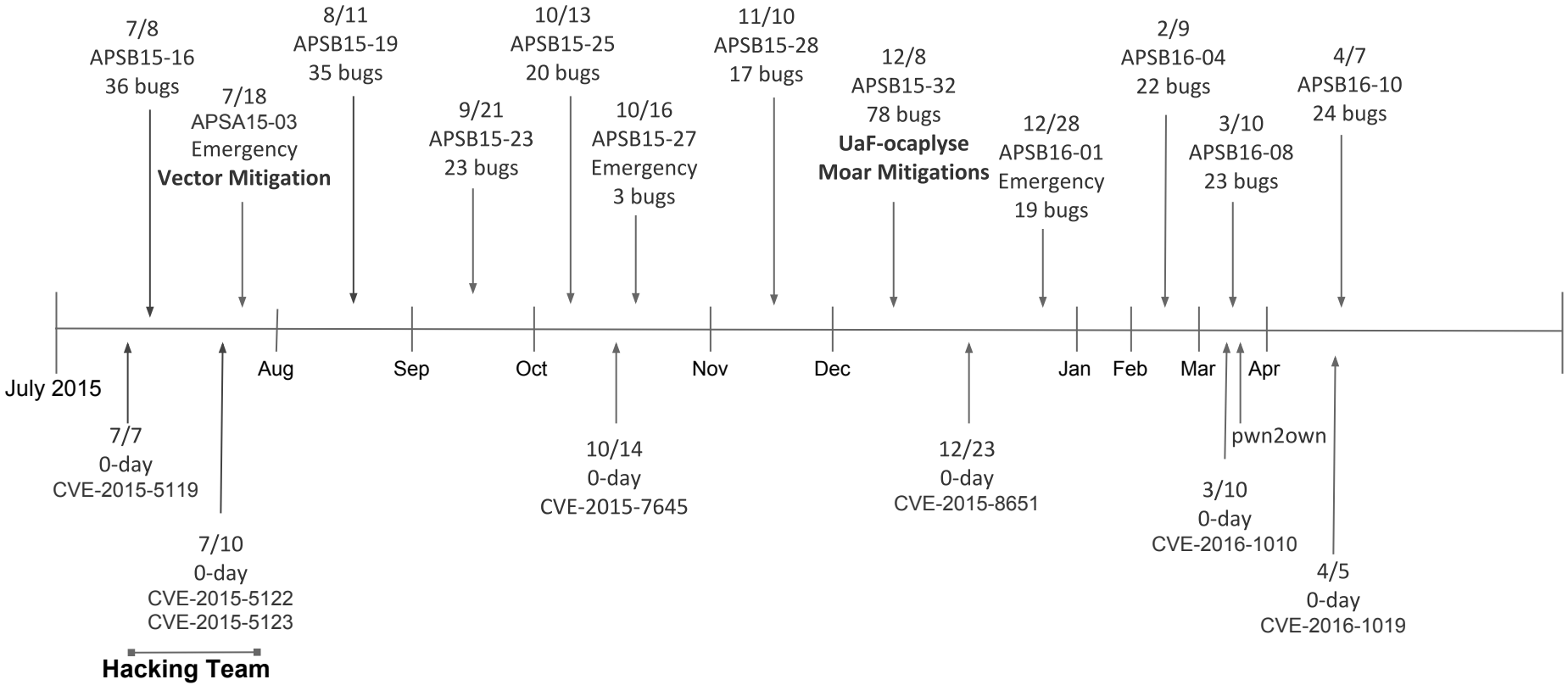
- Exploitable fuzz bug
- Caused by UaF check
- Required ASLR bypass
- Got around IsoHeap with JIT pages

CVE-2016-0998

```
var o = {};
o.unwatch();
```

```
void* args = alloca(numArgs);
…

 convertToString(args[0])
```

Timeline


7/8
APSB15-16
36 bugs
7/18
APSA15-03
Emergency
Vector Mitigation
8/11
APSB15-19
35 bugs
9/21
APSB15-23
23 bugs
10/13
APSB15-25
20 bugs
10/16
APSB15-27
Emergency
3 bugs
11/10
APSB15-28
17 bugs
12/8
APSB15-32
78 bugs
UaF-ocaplyse
Moar Mitigations
12/28
APSB16-01
Emergency
19 bugs
2/9
APSB16-04
22 bugs
3/10
APSB16-08
23 bugs
4/7
APSB16-10
24 bugs
July 2015
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
7/7
0-day
CVE-2015-5119
7/10
0-day
CVE-2015-5122
CVE-2015-5123
Hacking Team
10/14
0-day
CVE-2015-7645
12/23
0-day
CVE-2015-8651
pwn2own
3/10
0-day
CVE-2016-1010
4/5
0-day
CVE-2016-1019

April 2016

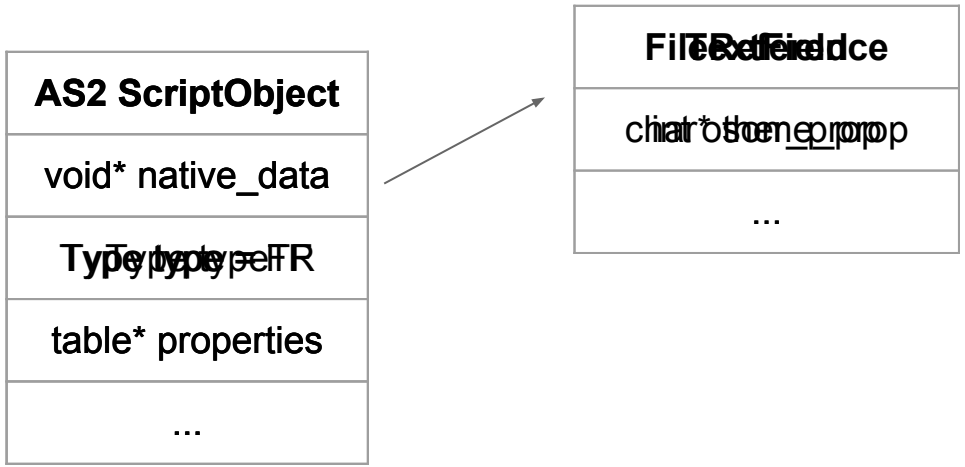
- 24 bugs fixed
  - Fuzzed images
  - The UaFs continue
- 0-day
  - Reported by TrendMicro in Magnitude EK
  - Type confusion in FileReference
  - Did not work on current mitigation set (0 on free)

CVE-2016-1019

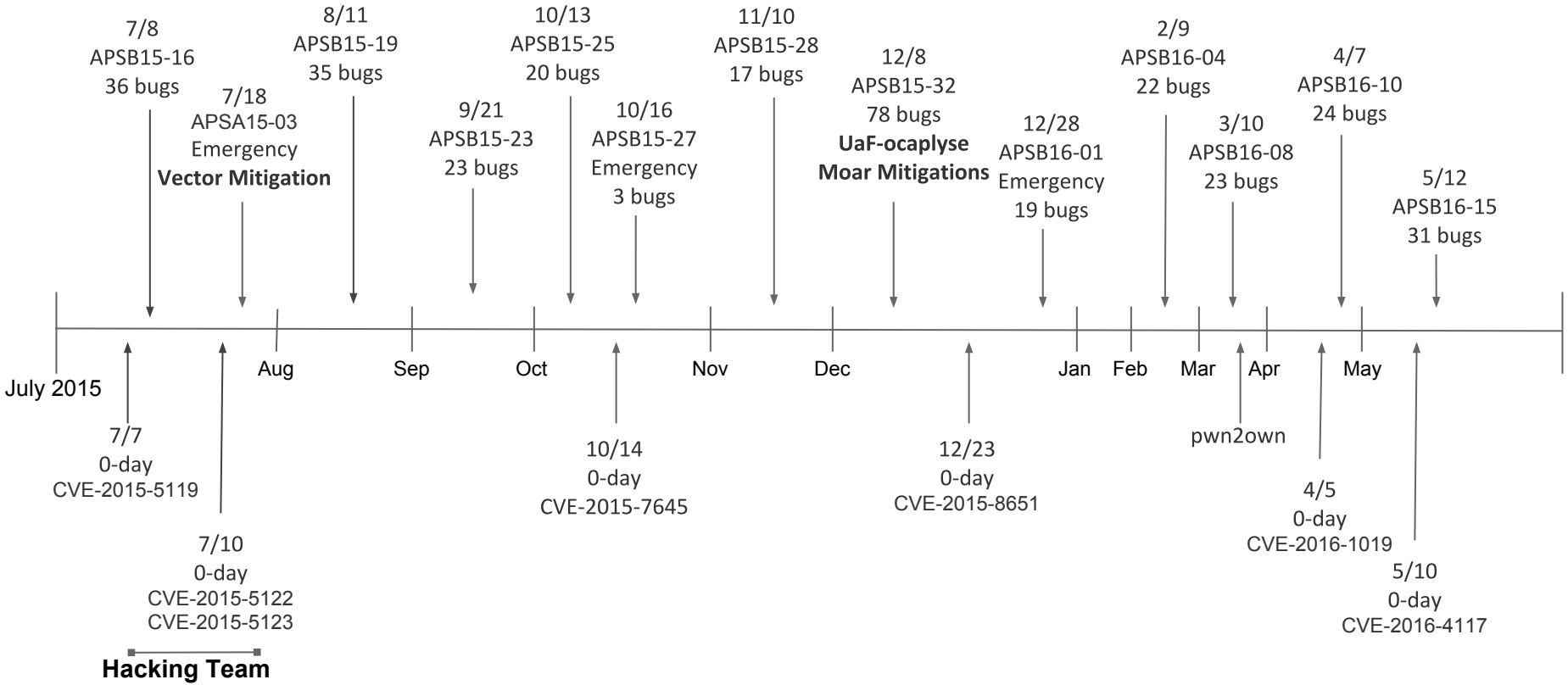
- 0-day vulnerability
- Reported some variants
- Type confusion in AS2

CVE-2016-1019

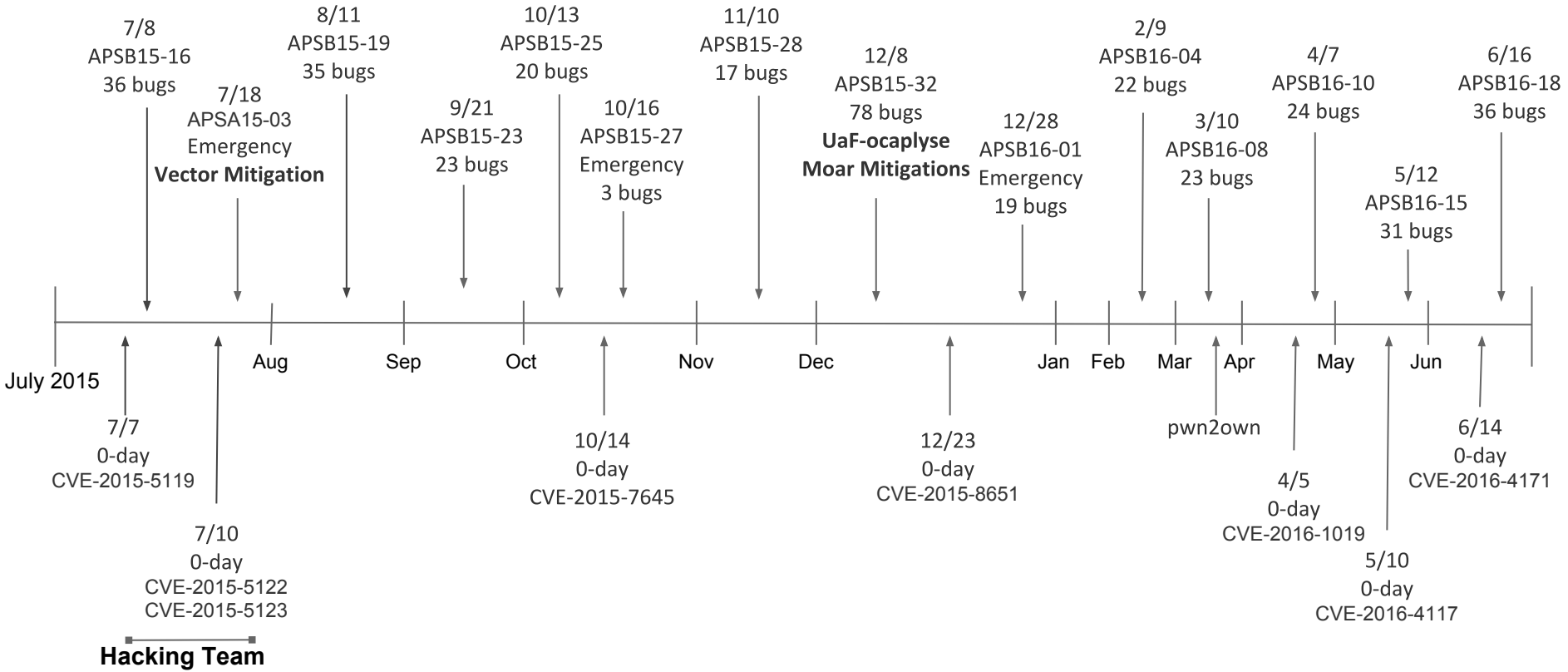
```
var o = { toString : f };
var t = new TextField(o);

function f(){
    var fr = FileReference
    fr.call(this);
}
```



Timeline


7/8
APSB15-16
36 bugs
7/18
APSA15-03
Emergency
Vector Mitigation
8/11
APSB15-19
35 bugs
9/21
APSB15-23
23 bugs
10/13
APSB15-25
20 bugs
10/16
APSB15-27
Emergency
3 bugs
11/10
APSB15-28
17 bugs
12/8
APSB15-32
78 bugs
UaF-ocaplyse
Moar Mitigations
12/28
APSB16-01
Emergency
19 bugs
2/9
APSB16-04
22 bugs
3/10
APSB16-08
23 bugs
4/7
APSB16-10
24 bugs
5/12
APSB16-15
31 bugs
July 2015
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
7/7
0-day
CVE-2015-5119
7/10
0-day
CVE-2015-5122
CVE-2015-5123
10/14
0-day
CVE-2015-7645
12/23
0-day
CVE-2015-8651
pwn2own
4/5
0-day
CVE-2016-1019
5/10
0-day
CVE-2016-4117
Hacking Team

Timeline


7/8
APSB15-16
36 bugs
7/18
APSA15-03
Emergency
Vector Mitigation
8/11
APSB15-19
35 bugs
9/21
APSB15-23
23 bugs
10/13
APSB15-25
20 bugs
10/16
APSB15-27
Emergency
3 bugs
11/10
APSB15-28
17 bugs
12/8
APSB15-32
78 bugs
UaF-ocaplyse
Moar Mitigations
12/28
APSB16-01
Emergency
19 bugs
2/9
APSB16-04
22 bugs
3/10
APSB16-08
23 bugs
4/7
APSB16-10
24 bugs
5/12
APSB16-15
31 bugs
6/16
APSB16-18
36 bugs
July 2015
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
7/7
0-day
CVE-2015-5119
7/10
0-day
CVE-2015-5122
CVE-2015-5123
Hacking Team
10/14
0-day
CVE-2015-7645
12/23
0-day
CVE-2015-8651
pwn2own
4/5
0-day
CVE-2016-1019
5/10
0-day
CVE-2016-4117
6/14
0-day
CVE-2016-4171

June 2016

- 36 bugs fixed
  - MC UaFs (echo from pwn2own)
- 0-day
  - Reported by Kaspersky
  - OOB memory access in open source parser

CVE-2016-4171

```
void AbcParser::parseExecPolicyAttributes(const uint8_t*
metadata, MethodInfo* m)
    {
    ...
        for (int q = 0; q < values_count; ++q)
        {
            Stringp key = pool->getString(readU30(p));
            Stringp val = pool->getString(readU30(p));
```

CVE-2016-4171

```
Stringp PoolObject::getString(int32_t index) const
{
    ConstantStringData* dataP = _abcStrings->data + index;
    if (dataP->abcPtr >= _abcStringStart && dataP->abcPtr <
_abcStringEnd)
    {
        uint32_t len = AvmCore::readU32(dataP->abcPtr);
        Stringp s = core->internStringUTF8((const char*) dataP-
>abcPtr, len, true, false);
        s->Stick();
        dataP->abcPtr = NULL
        WBRC(core->gc, _abcStrings, &dataP->str, s);
        }
    return dataP->str;
}
```

Conclusions

- Finding bugs in Flash is generally getting harder
  - 1 bug per day versus 1 per week
- Certain bug classes are drying up, but others are taking their places
- Flash mitigations are making it more difficult to exploit bugs, especially with low-quality bugs

The Future (What's left?)

- MC UaFs (and AS2) probably still exist, but getting hard to exploit
  - Eventually similar bugs will have marginal utility
  - Display UaFs in AS3?
- Redefinition bugs are no longer 'deep'
- More AS3 bugs?

The Future (What's left?)

- More anticorpus bugs / use of anti-corpus?
  - Media (MP4, FLV)
- Open source AVM?
- Platform-specific code
- Flash deprecation
  - Browsers?

Thank You

- Adobe

Questions?

http://googleprojectzero.blogspot.com/

@natashenka
natalie@natashenka.ca