BLUEHAT SHANGHAI 2019

Liar Game

The Secret of Mitigation Bypass Techniques

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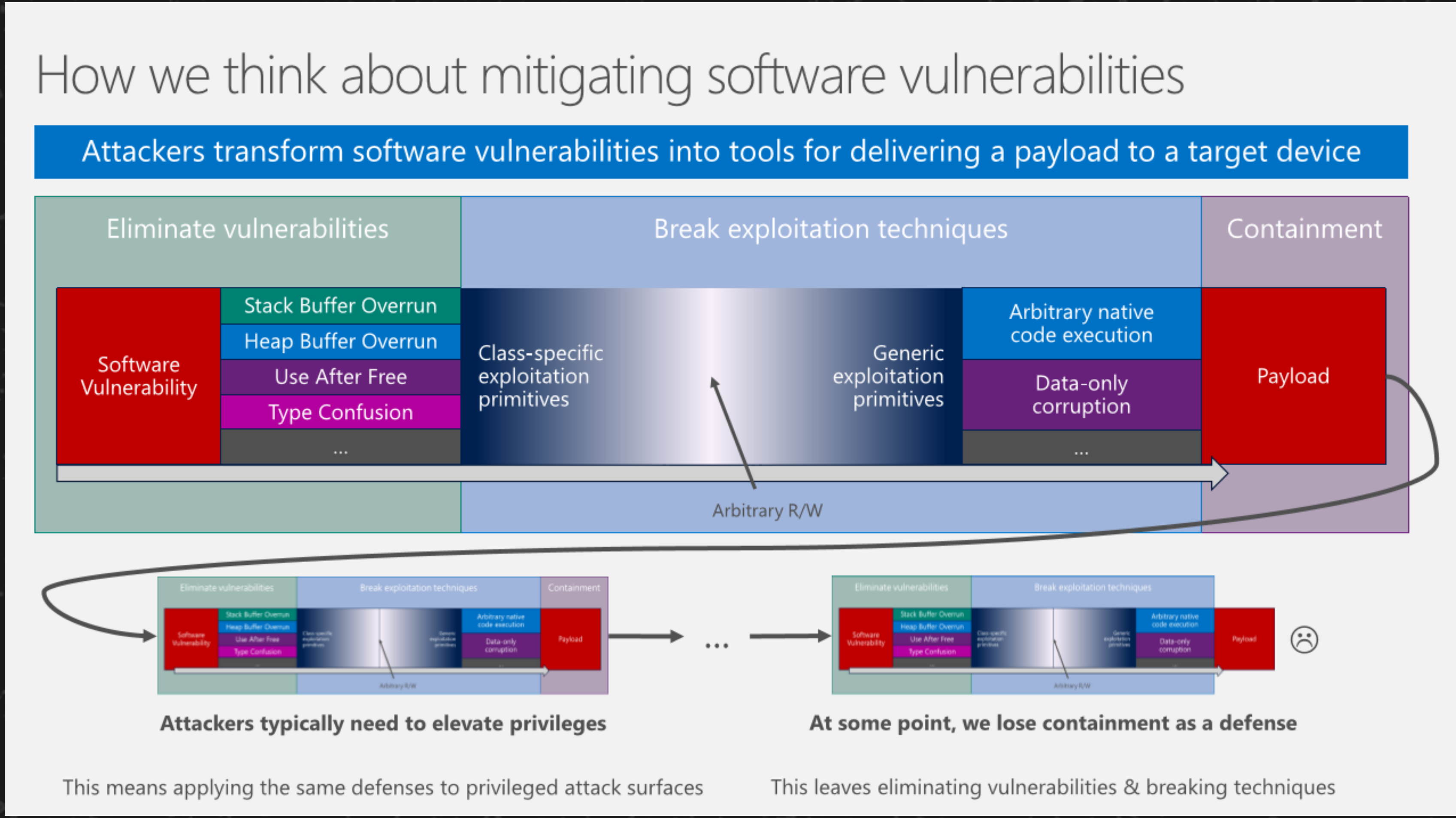
安全研究员

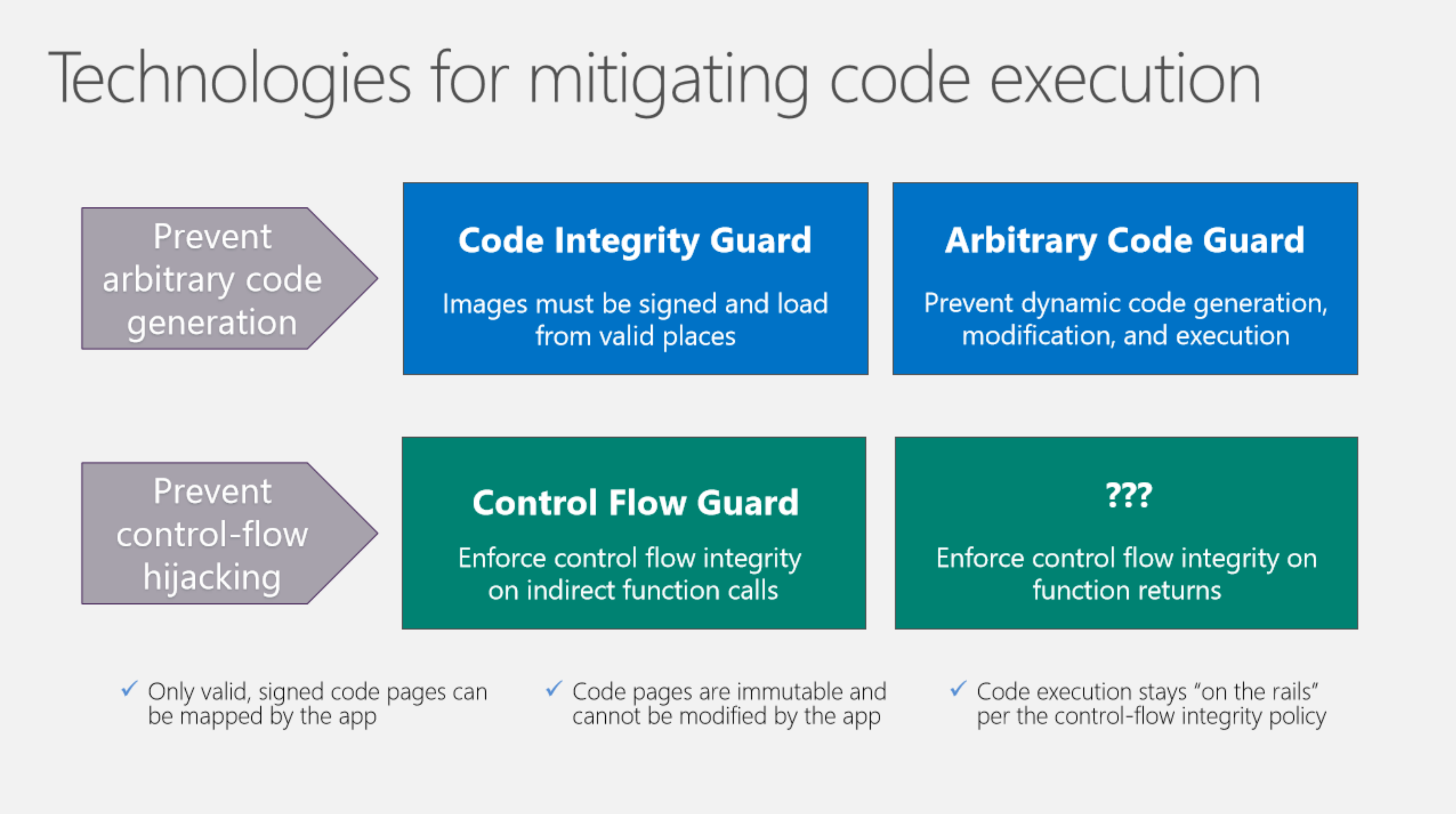
Microsoft 缓解绕过赏金获得者

缓解措施是什么



How we think about mitigating software vulnerabilities
Attackers transform software vulnerabilities into tools for delivering a payload to a target device
Eliminate vulnerabilities
Break exploitation techniques
Containment
Software Vulnerability
Stack Buffer Overrun
Heap Buffer Overrun
Use After Free
Type Confusion
...
Class-specific exploitation primitives
Generic exploitation primitives
Arbitrary native code execution
Data-only corruption
...
Payload
Arbitrary R/W
...
Attackers typically need to elevate privileges
At some point, we lose containment as a defense
This means applying the same defenses to privileged attack surfaces
This leaves eliminating vulnerabilities & breaking techniques

缓解措施是什么


Technologies for mitigating code execution
Prevent arbitrary code generation
Code Integrity Guard
Images must be signed and load from valid places
Arbitrary Code Guard
Prevent dynamic code generation, modification, and execution
Prevent control-flow hijacking
Control Flow Guard
Enforce control flow integrity on indirect function calls
???
Enforce control flow integrity on function returns
✓ Only valid, signed code pages can be mapped by the app
✓ Code pages are immutable and cannot be modified by the app
✓ Code execution stays "on the rails" per the control-flow integrity policy

缓解措施如何工作

机制

```
if (is_allowed_by_mitigation_policy()) {
        do_sensitive_action();
} else {
        fail_fast();
}
```

假设

缓解措施能有效工作的前提条件

操作系统能正常工作的例外规则

缓解措施：DEP

机制

```
if (PTE(address).NX == 0) {
        execute(address);
} else {
        fail_fast();
}
```

假设

代码段中的代码是可信的

严格遵守 W^X 原则

缓解绕过

代码段中的代码都是可信的吗？

```
f3 0f 59 c3 f3 0f 58 86-8c 00 00 00 f3 0f 11 86

f30f59c3         mulss   xmm0,xmm3
f30f58868c000000 addss   xmm0,dword ptr [rsi+8Ch]

59               pop     rcx
c3               ret
```

缓解绕过

严格遵守 W^X 原则

- 避免使用可读写执行 (PAGE_EXECUTE_READWRITE) 内存
- 在内存的整个生命周期中保持 W^X

缓解绕过

ATL Thunk Pool 问题

- 函数 __AllocStdCallThunk_cmn 会分配可读写执行内存用于保存 Thunk

```
mem = VirtualAlloc(0i64, 0x1000ui64, 0x1000u, 0x40u);
if ( !mem )
  return 0i64;
next = *mem;
thunk = InterlockedPopEntrySList(__AtlThunkPool);
if ( thunk )
{
  VirtualFree(mem, 0i64, 0x8000u);
}
else
{
  end = mem + 0xFE0;
  do
  {
    InterlockedPushEntrySList(__AtlThunkPool, mem);
    mem += 0x20;
  }
  while ( mem < end );
  thunk = mem;
}
return thunk;
```

缓解绕过

ATL Thunk Pool 问题修复

- 引入 atlthunk.dll 实现数据与代码的分离
  - AtlThunk_AllocateData
  - AtlThunk_InitData
  - AtlThunk_DataToCode
  - AtlThunk_FreeData

```
FARPROC __fastcall GetProcAddressAll_AtlThunkData()
{
  HMODULE atlthunk; // rax MAPDST
  int v1; // [rsp+0h] [rbp-28h]

  if ( loaded )
    return DecodePointer(AllocateData);
  atlthunk = LoadLibraryExA("atlthunk.dll", 0i64, 0x800u);
  if ( atlthunk
    && GetProcAddressSingle(atlthunk, "AtlThunk_AllocateData", &AllocateData)
    && GetProcAddressSingle(atlthunk, "AtlThunk_InitData", &InitData)
    && GetProcAddressSingle(atlthunk, "AtlThunk_DataToCode", &DataToCode)
    && GetProcAddressSingle(atlthunk, "AtlThunk_FreeData", &FreeData) )
  {
    _InterlockedOr(&v1, 0);
    loaded = 1;
    return DecodePointer(AllocateData);
  }
  return 0i64;
}
```

缓解绕过

ATL Thunk Pool 问题修复

- 用函数 AtlThunk_AllocateData 代替函数 __AllocStdCallThunk_cmn 来分配 Thunk

```
ThunkData *AtlThunk_AllocateData()
{
  HANDLE heap; // rax MAPDST
  ThunkData *data; // rbx
  __int64 (*AllocateData)(void); // rax
  Thunk *Thunk; // rax

  heap = GetProcessHeap();
  data = HeapAlloc(heap, 8u, 0x10ui64);
  if ( data )
  {
    AllocateData = GetProcAddressAll_AtlThunkData();
    data->fallbck = AllocateData == 0i64;
    if ( AllocateData )
      Thunk = AllocateData();
    else
      Thunk = __AllocStdCallThunk_cmn();
    data->thunk = Thunk;
    if ( Thunk )
      return data;
    heap = GetProcessHeap();
    HeapFree(heap, 0, data);
  }
  return 0i64;
}
```

缓解绕过

ATL Thunk Pool 问题修复

- 兼容性处理
  - 新控件在新系统中
    - 调用函数 AtlThunk_AllocateData
  - 新控件在旧系统中
    - 调用函数 __AllocStdCallThunk_cmn
  - 旧控件在新系统中
    - 调用函数 __AllocStdCallThunk_cmn

缓解绕过

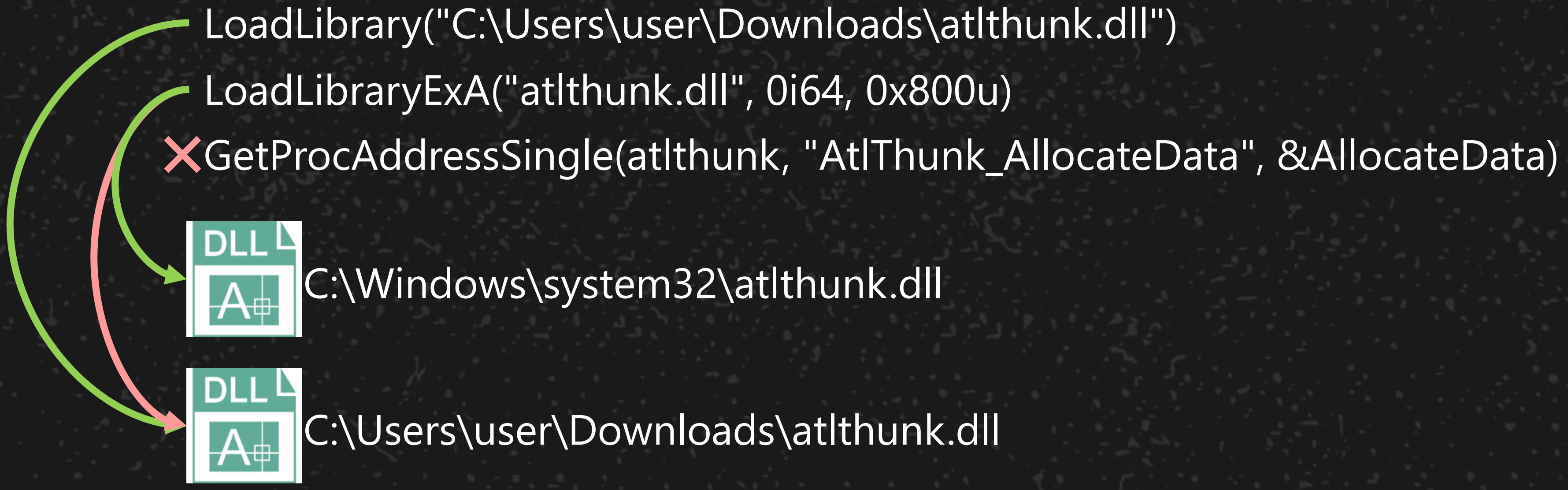
ATL Thunk Pool 回退攻击

- 修复方案的假设
  - 调用函数 GetProcAddressAll_AtlThunkData 成功
    - LoadLibraryExA("atlthunk.dll", 0i64, 0x800u) 成功
    - GetProcAddressSingle(atlthunk, "AtlThunk_AllocateData", &AllocateData) 成功
    - GetProcAddressSingle(atlthunk, "AtlThunk_InitData", &InitData) 成功
    - GetProcAddressSingle(atlthunk, "AtlThunk_DataToCode", &DataToCode) 成功
    - GetProcAddressSingle(atlthunk, "AtlThunk_FreeData", &FreeData) 成功

缓解绕过

ATL Thunk Pool 回退攻击

- 修复方案的假设
  - 调用函数 GetProcAddressAll_AtlThunkData 成功



缓解绕过

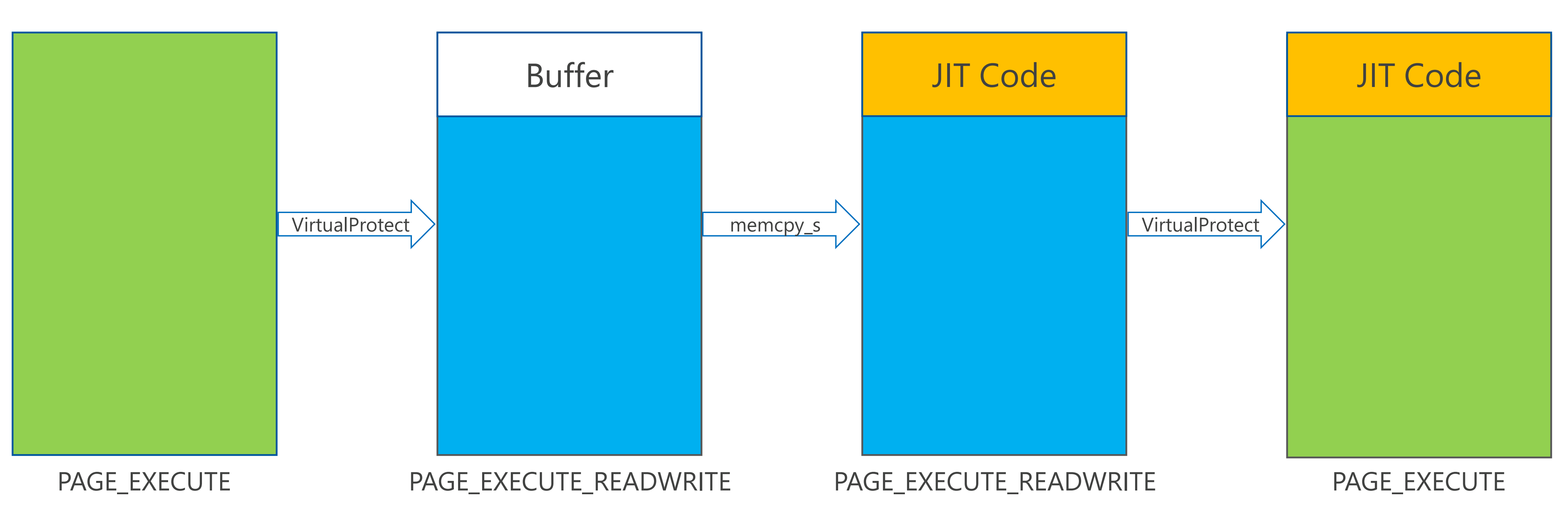
JIT 编译问题

- 主流浏览器已经做到在 JIT 编译时避免使用可读写执行内存
  - Microsoft Edge 不常驻可读写执行内存
  - Firefox 从 46.0 开始不常驻可读写执行内存
  - Chrome 从 64.0 开始不常驻可读写执行内存

缓解绕过

JIT 编译问题

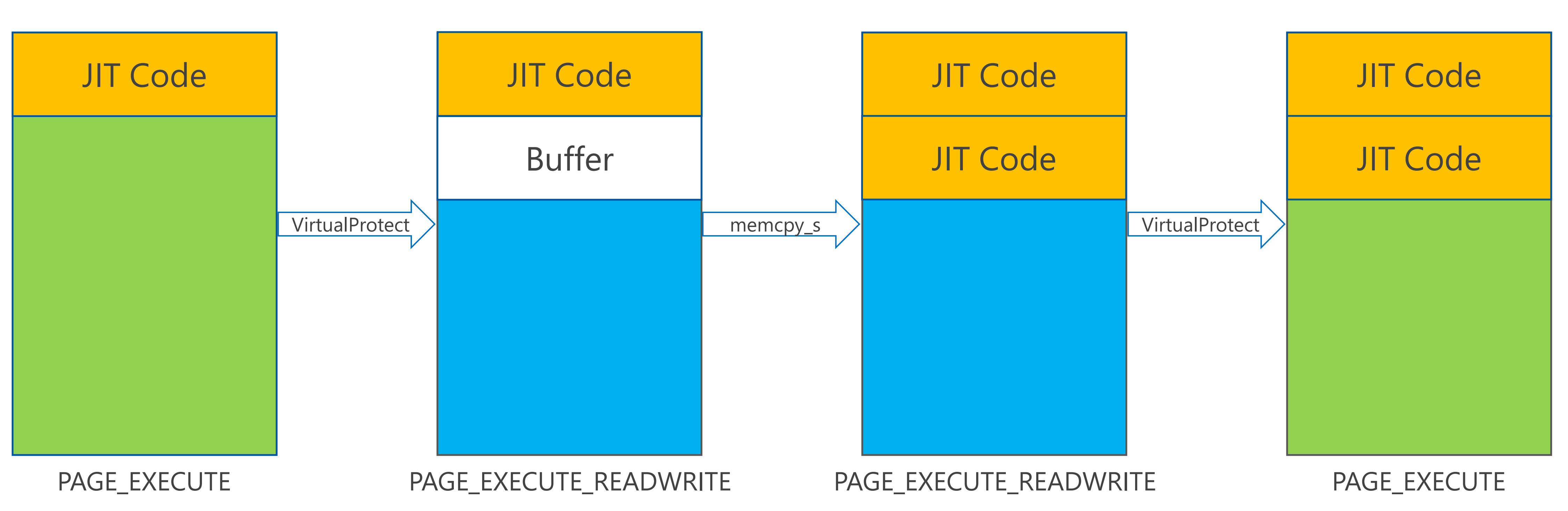
- JIT 编译如何使用内存



缓解绕过

JIT 编译问题

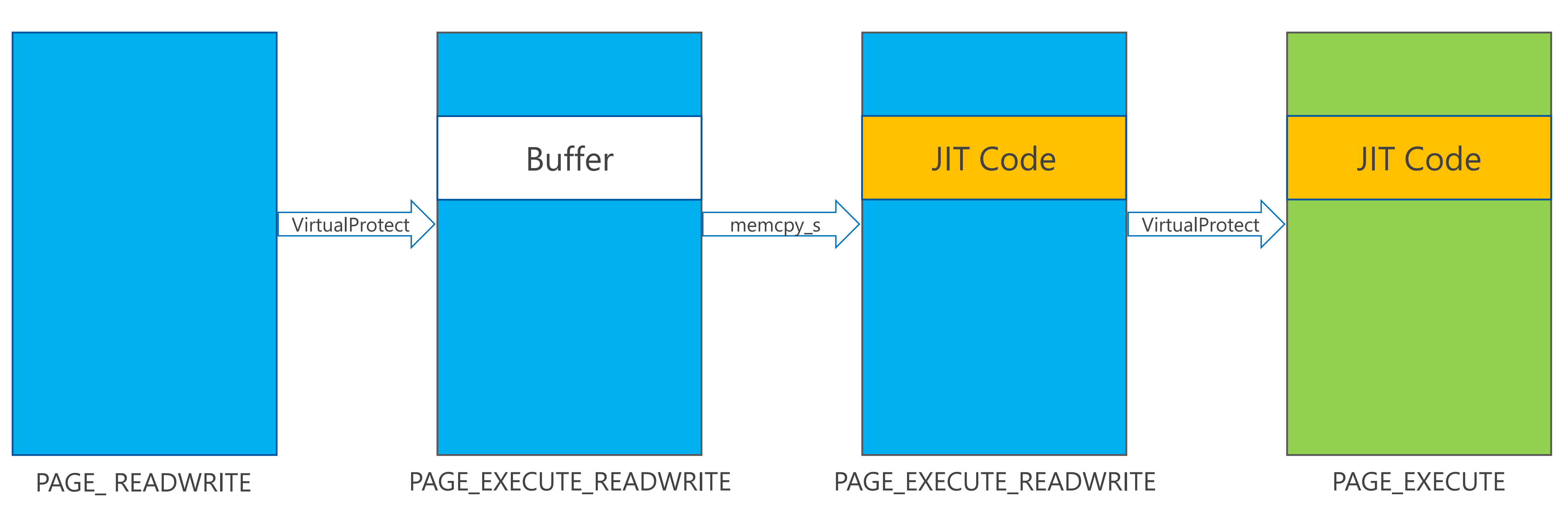
- JIT 编译如何使用内存



缓解绕过

JIT 编译问题

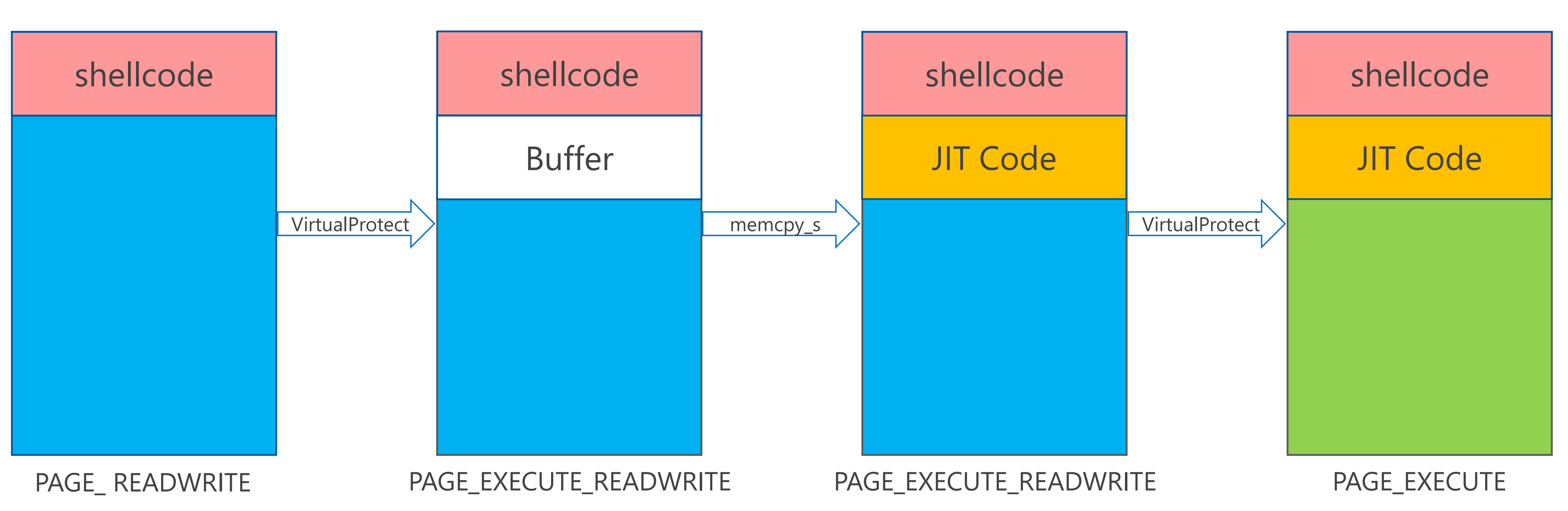
- 欺骗浏览器替换 JIT 编译使用的内存



缓解绕过

JIT 编译问题

- 事先写入的数据将变为可执行的代码



缓解措施：CFG

机制

```
if (CFG_Bitmap[address] == 1) {
		call(address);
} else {
		fail_fast();
}
```

假设

CFG Bitmap 中置位的地址是可信的

CFG 使用的指针是可信的

缓解绕过

CFG Bitmap 中置位的地址都是可信的吗？

- 未启用 CFG 的模块
- 导出函数
- JIT 编译生成的代码

缓解绕过

CFG Bitmap 中置位的地址都是可信的吗？

- 未启用 CFG 的模块
  - CFG Bitmap 中所有对应位都被置位

缓解绕过

CFG Bitmap 中置位的地址都是可信的吗？

- 未启用 CFG 的模块
  - CFG Strict Mode 阻止加载未启用 CFG 的模块

缓解绕过

CFG Bitmap 中置位的地址都是可信的吗？

- 导出函数
  - CFG Bitmap 中导出函数对应位会置位
  - 敏感的导出函数
    - NtContinue
    - WinExec
    - LoadLibrary
    - …

缓解绕过

CFG Bitmap 中置位的地址都是可信的吗？

- 导出函数
  - CFG Export Suppression 在一定程度上解决导出函数问题

缓解绕过

CFG Bitmap 中置位的地址都是可信的吗？

- JIT 编译生成的代码
  - 分配可执行内存或变更为可执行内存时默认会将 CFG Bitmap 中所有对应位置位

缓解绕过

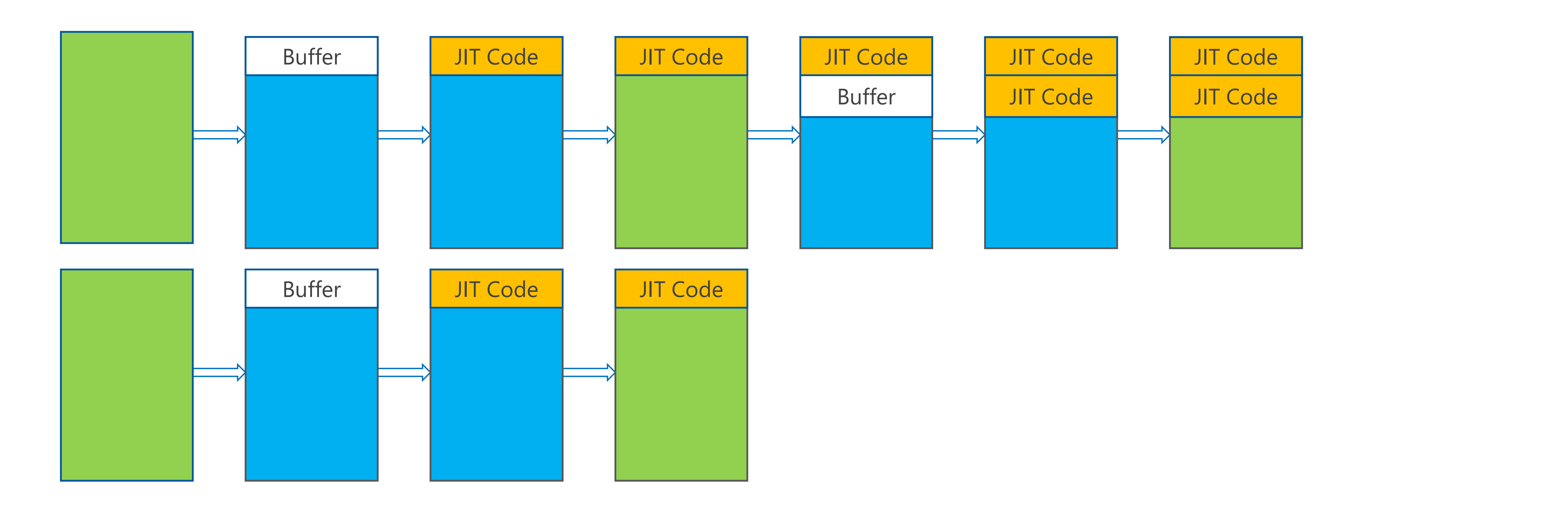
CFG Bitmap 中置位的地址都是可信的吗？

- JIT 编译生成的代码
  - 通过设置 PAGE_TARGETS_NO_UPDATE 来禁止置位
  - 显示调用 SetProcessValidCallTargets 进行置位

缓解绕过

CFG Bitmap 中置位的地址都是可信的吗？

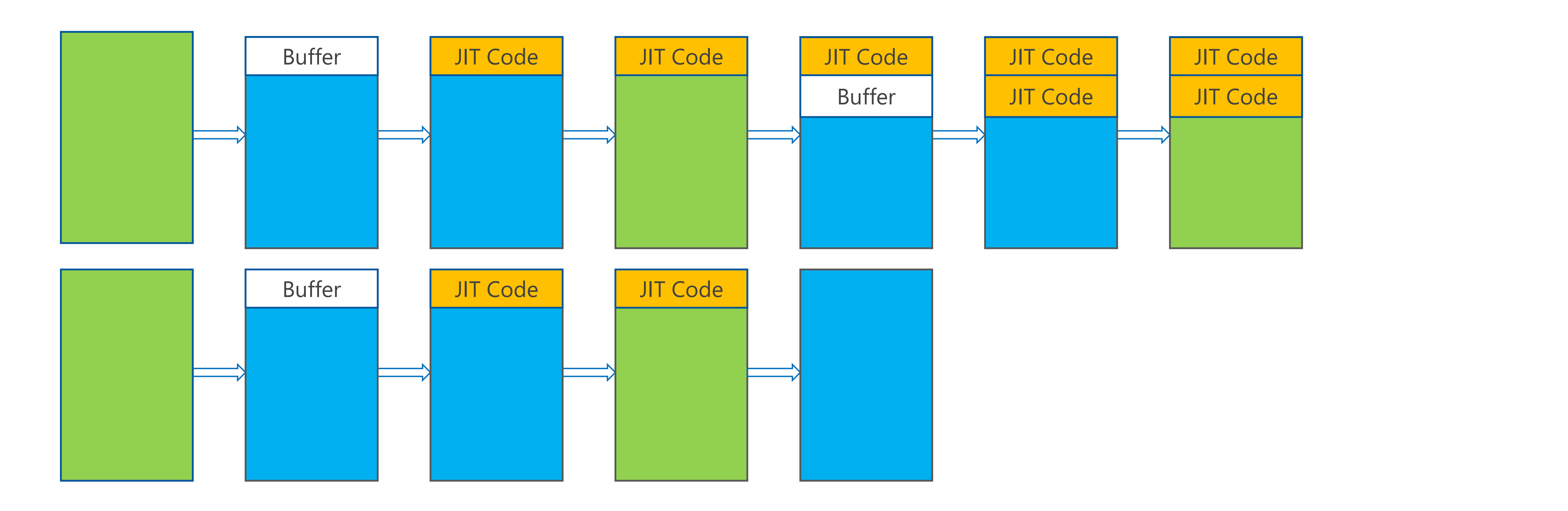
- 创建两个 JavaScript 引擎进行 JIT 编译



缓解绕过

CFG Bitmap 中置位的地址都是可信的吗？

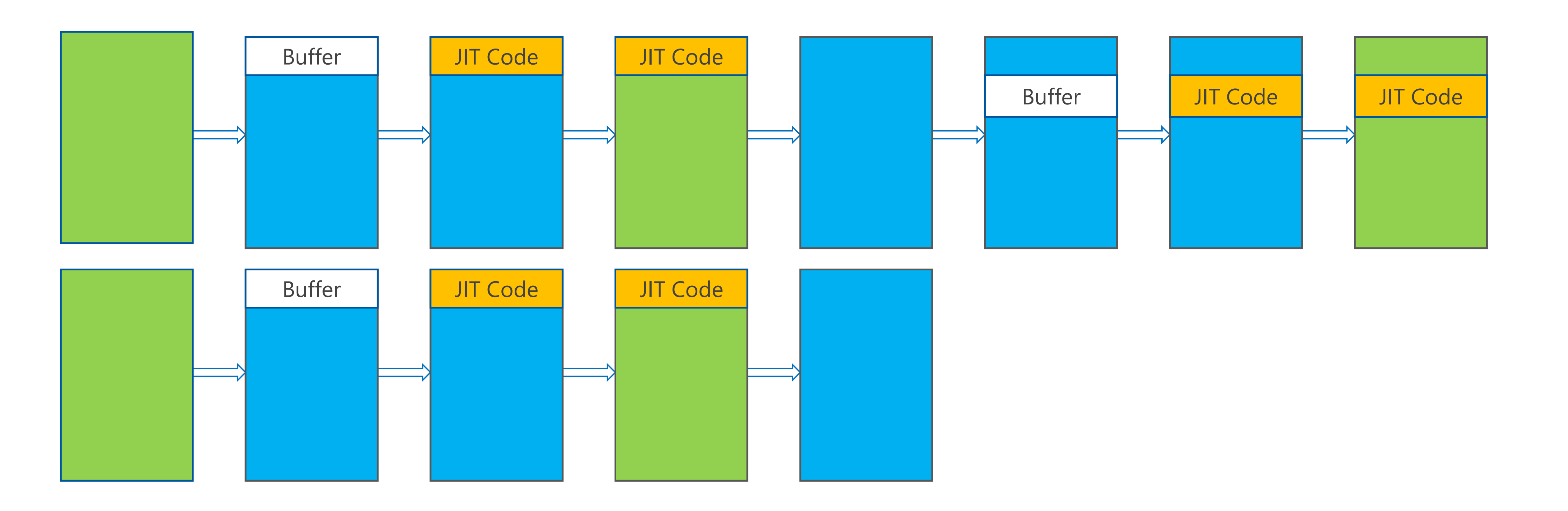
- 释放其中一个引擎，其使用的内存将变更为可读写



缓解绕过

CFG Bitmap 中置位的地址都是可信的吗？

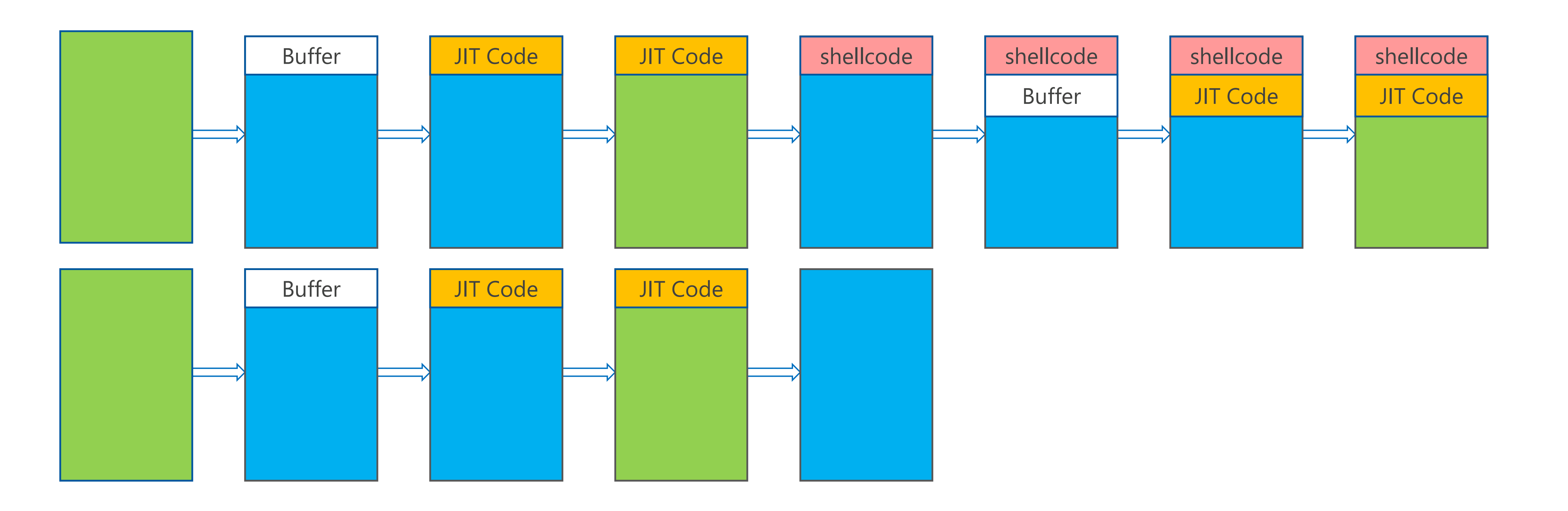
- 欺骗浏览器让两个引擎使用同一内存



缓解绕过

CFG Bitmap 中置位的地址都是可信的吗？

- 事先写入的数据将变为可执行的代码，并且 CFG Bitmap 中有置位



缓解绕过

CFG 使用的指针都是可信的吗？

- 关键指针仅仅通过只读进行保护
  - __guard_check_icall_fptr
  - __guard_dispatch_icall_fptr

```
.rdata:00000001805B42F8 ; ===========================================================================
.rdata:00000001805B42F8
.rdata:00000001805B42F8 ; Segment type: Pure data
.rdata:00000001805B42F8 ; Segment permissions: Read
.rdata:00000001805B42F8 _rdata          segment para public 'DATA' use64
.rdata:00000001805B42F8                 assume cs:_rdata
.rdata:00000001805B42F8                 ;org 1805B42F8h
.rdata:00000001805B42F8 __guard_check_icall_fptr dq offset Js::JavascriptFunction::CheckAlignment(void)
.rdata:00000001805B42F8                                         ; DATA XREF: IR::GetNonTableMethodAddres
.rdata:00000001805B42F8                                         ; Js::InterpreterStackFrame::DelayDynam
.rdata:00000001805B4300 __guard_dispatch_icall_fptr dq offset _guard_dispatch_icall_nop
```

缓解绕过

CFG 使用的指针都是可信的吗？

- 欺骗系统来修改只读内存并不困难

缓解措施：ACG

机制

```
if (W^X(address, flNewProtect)) {
        change_protection(address, flNewProtect);
} else {
        fail_fast();
}
```

假设

加载动态链接库时例外

缓解绕过

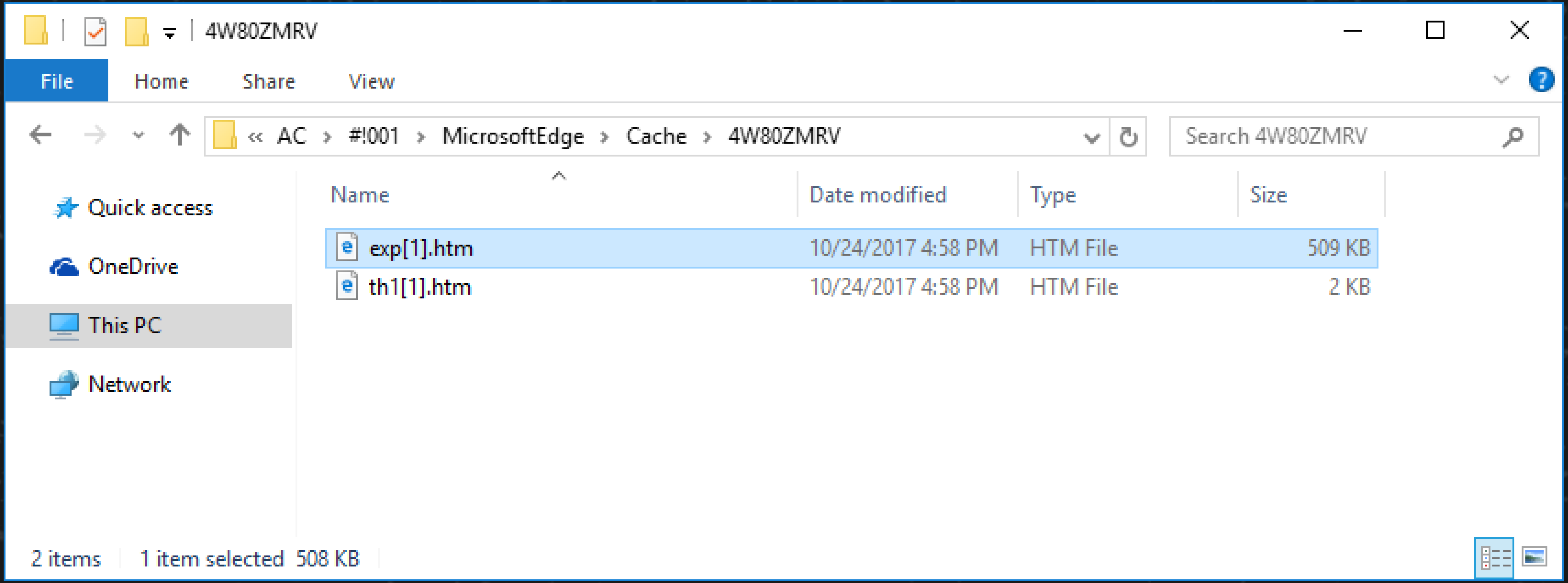
可以加载任意动态链接库么？

- NoRemoteImages 阻止加载远程文件

缓解绕过

可以加载任意动态链接库么？

- 利用浏览器缓存将动态链接库保存到本地后加载



缓解措施：CIG

机制

```
if (is_signed_by_microsoft(file)) {
        create_section(file);
} else {
        fail_fast();
}
```

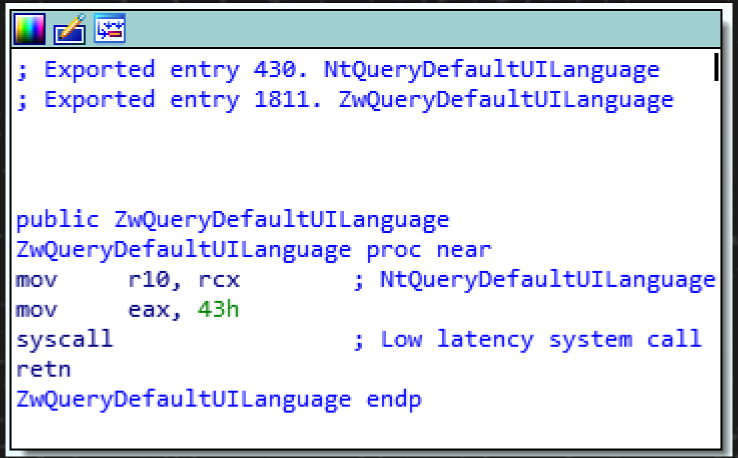
假设

微软签名的动态链接库是可信的

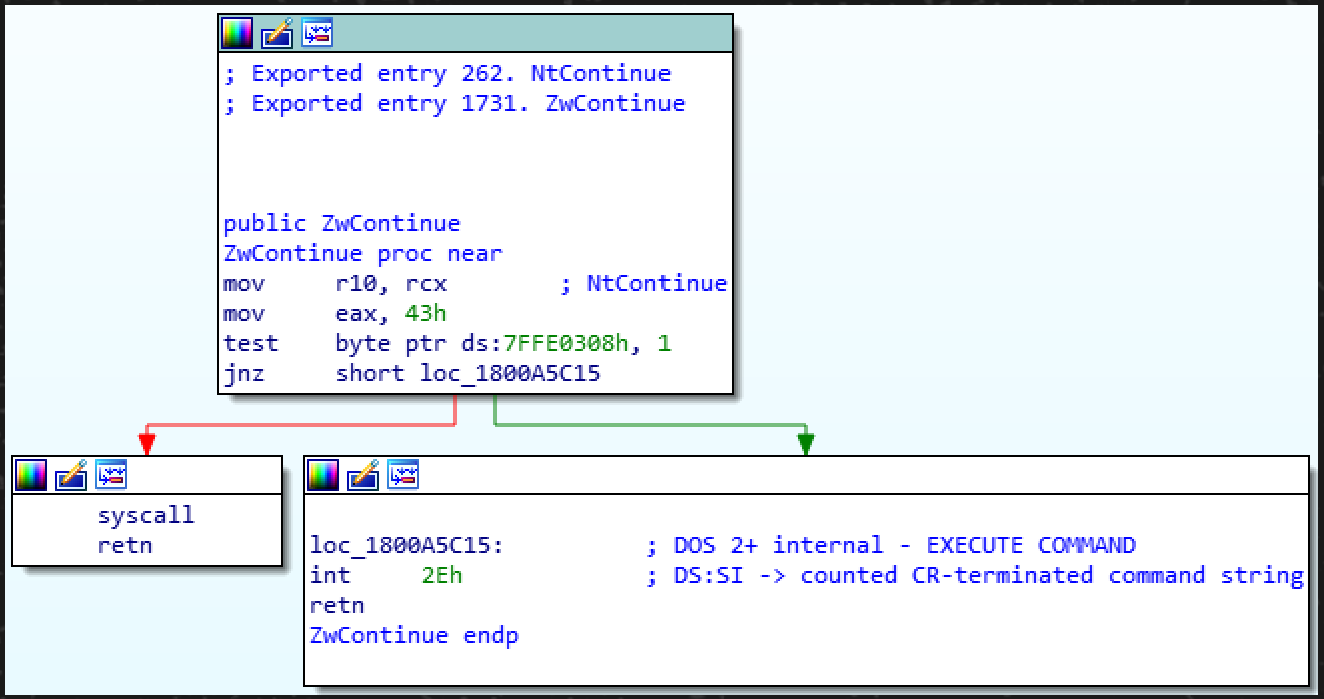
缓解绕过

微软签名的动态链接库是可信的吗？

- 系统调用的版本差异



ntdll.dll version 6.3.9600.17936



ntdll.dll version 10.0.15063.0

缓解绕过

微软签名的动态链接库是可信的吗？

- 用旧版的 ntdll.dll 来欺骗系统
  - 调用 6.3.9600.17936 的 NtQueryDefaultUILanguage
  - 等同于调用 10.0.15063.0 的 NtContinue

缓解绕过

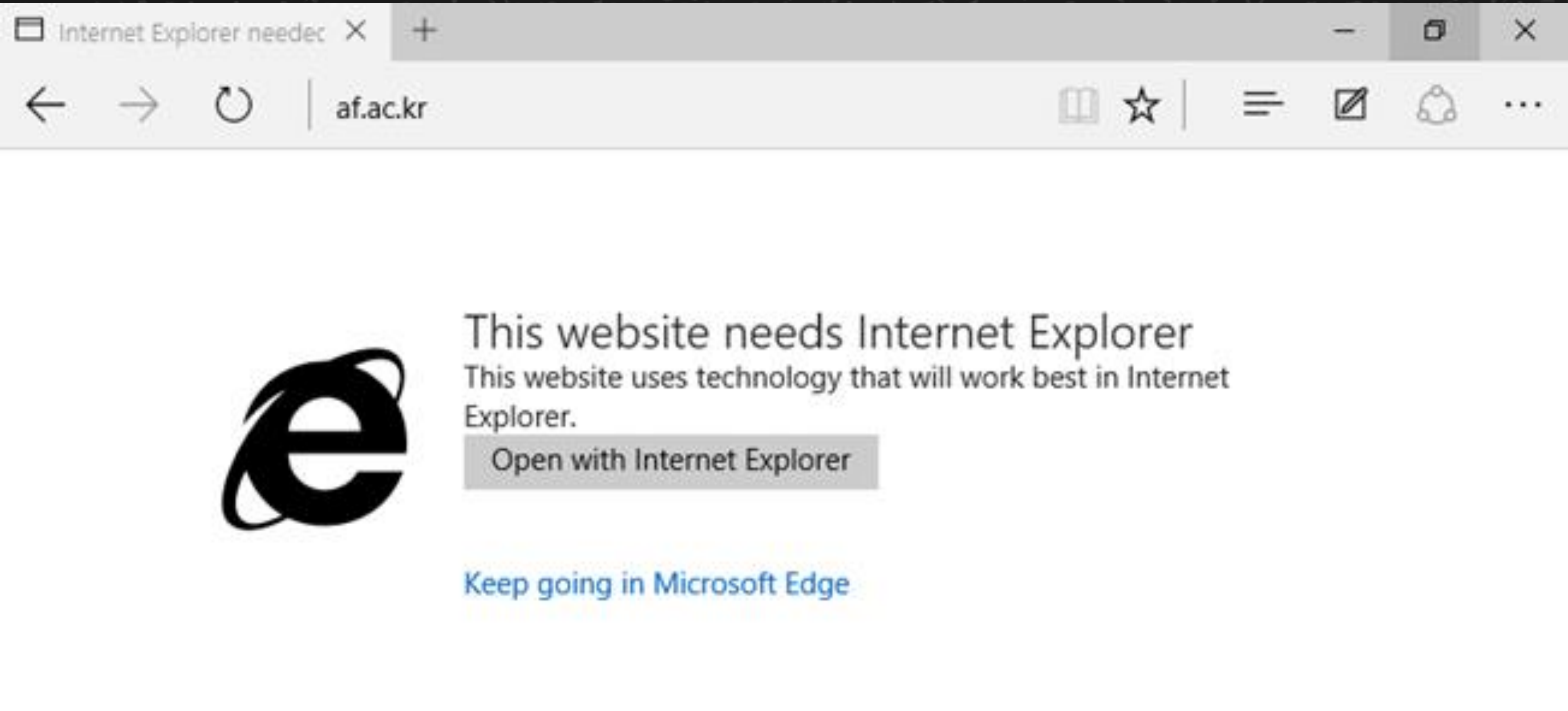
高维欺骗技术

- 不直接与缓解措施进行对抗
- 通过伪造环境来滥用系统功能

缓解绕过

高维欺骗技术

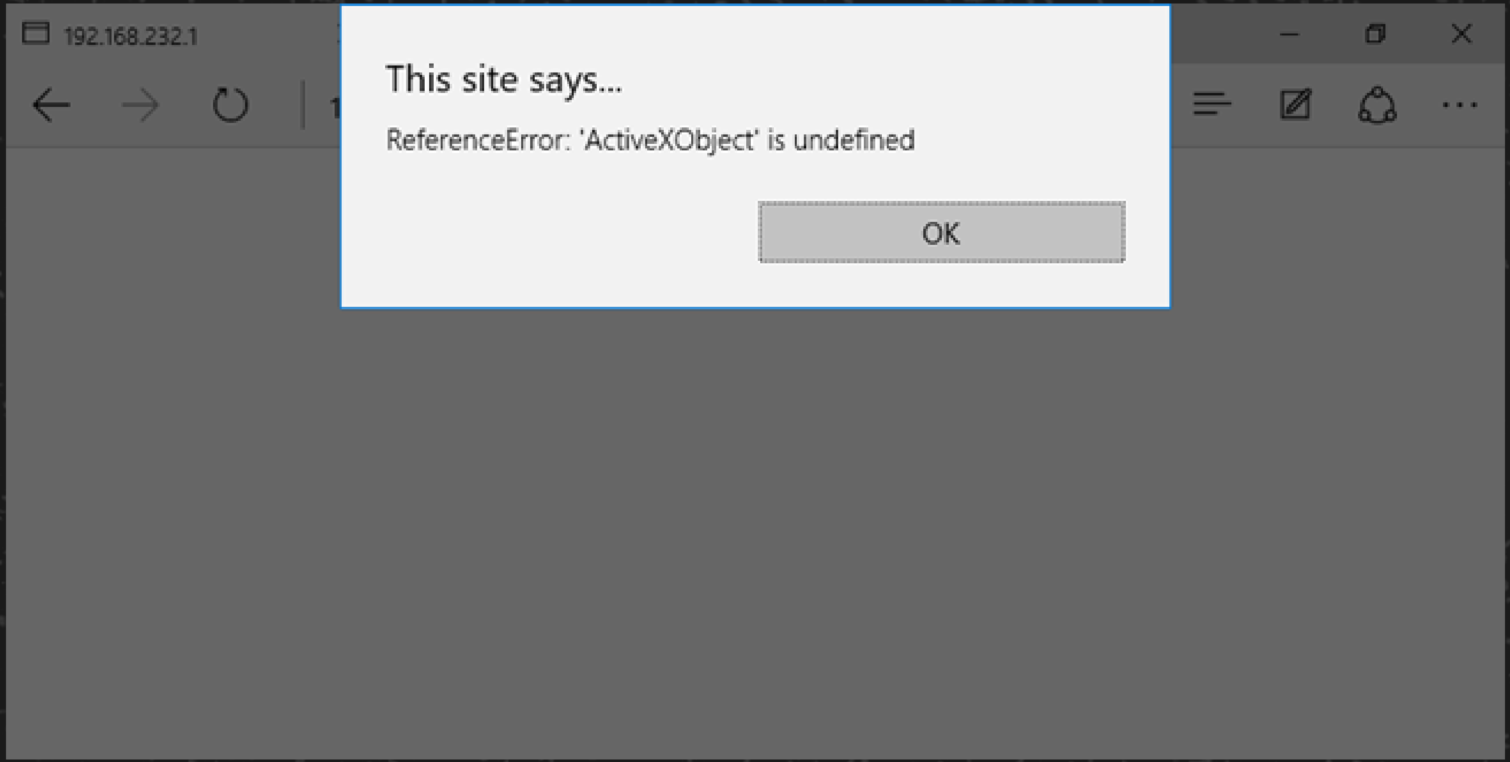
- Launch IE



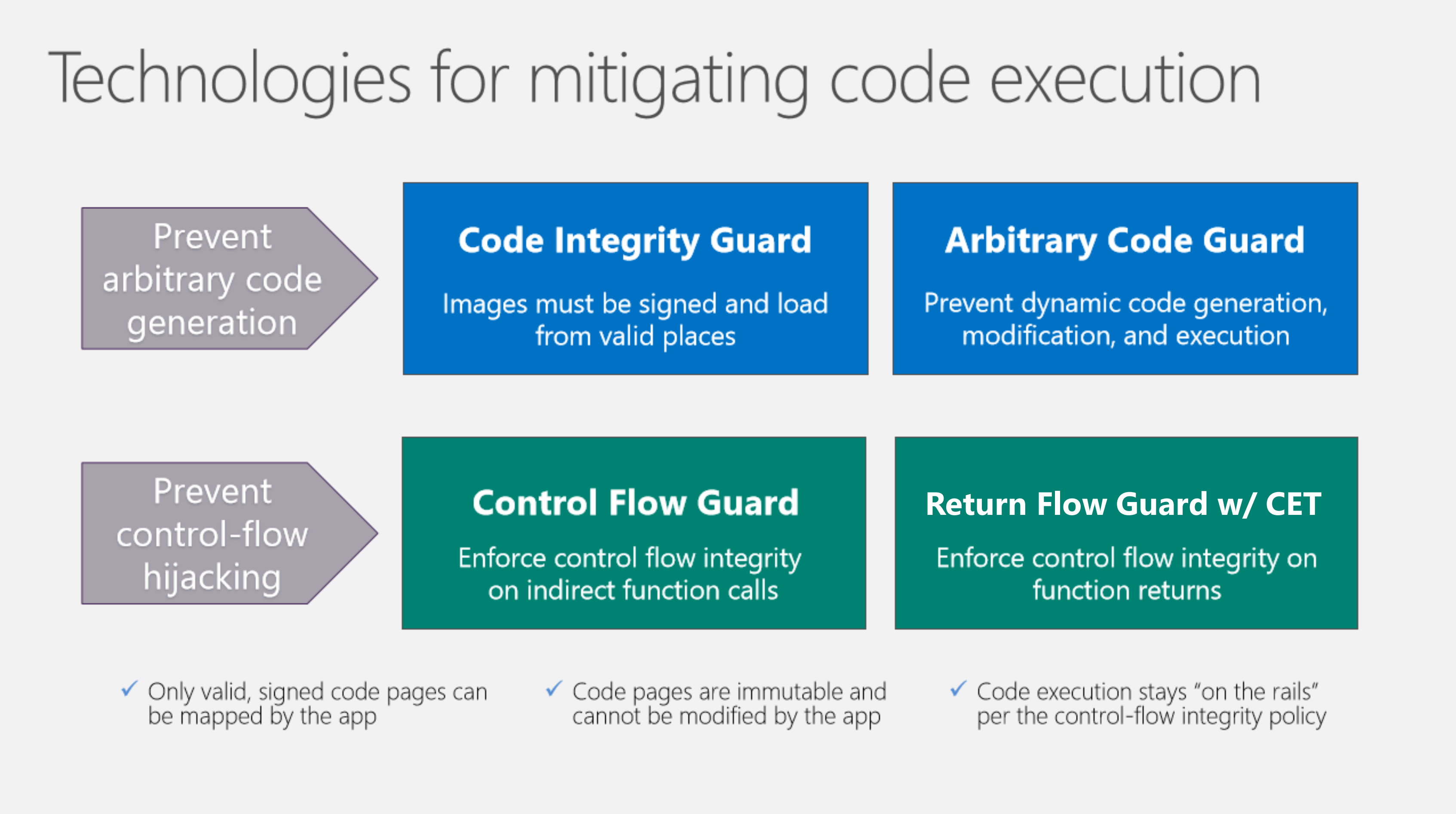
缓解绕过

高维欺骗技术

- ActiveX



未来的缓解措施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Return Flow Guard w/ CET
Enforce control flow integrity on function returns
✓ Only valid, signed code pages can be mapped by the app
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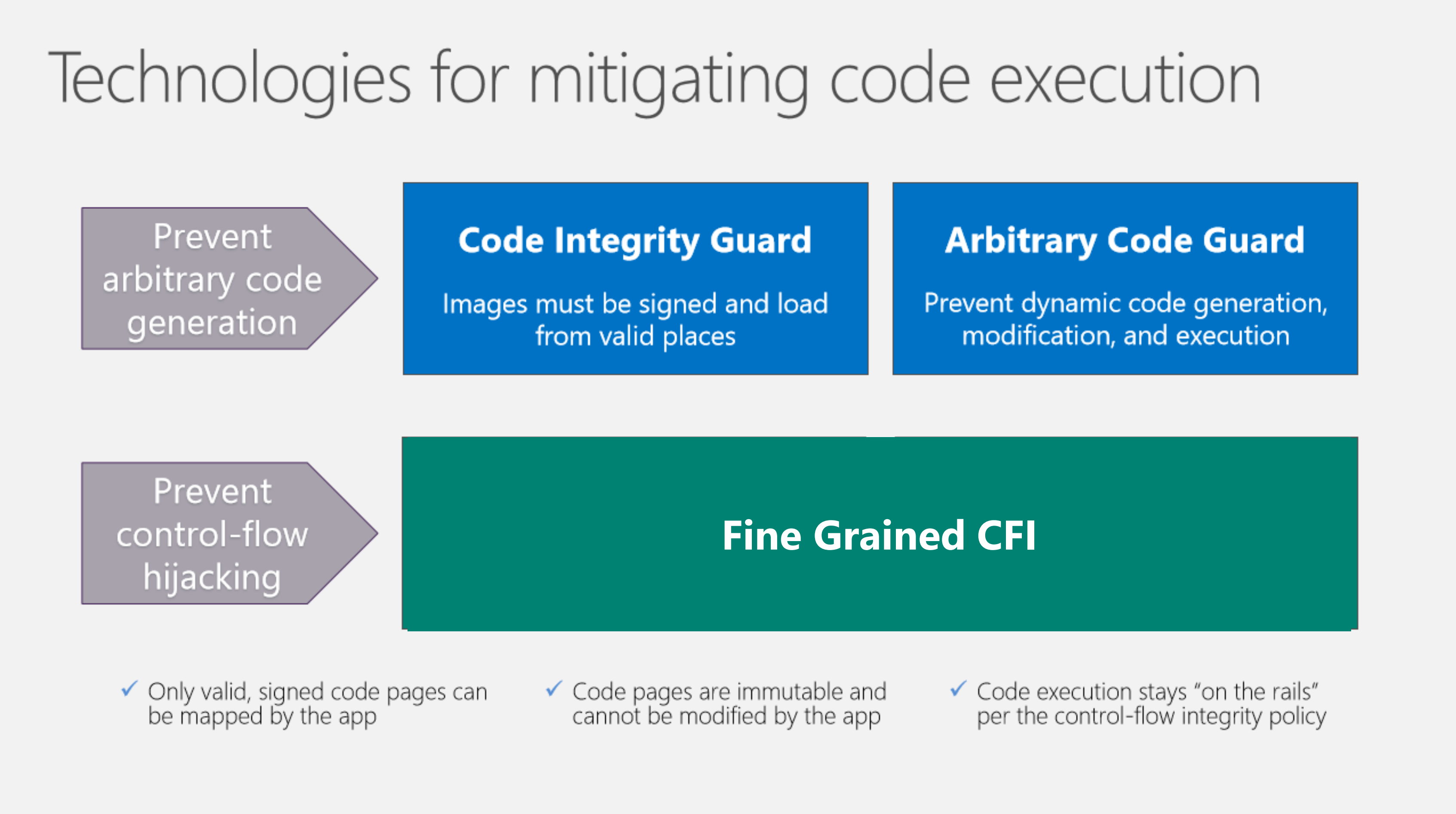
未来的缓解措施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Fine Grained CFI
✓ Only valid, signed code pages can be mapped by the app
✓ Code pages are immutable and cannot be modified by the app
✓ Code execution stays "on the rails" per the control-flow integrity policy

缓解绕过的未来

Fine Grained CFI 并不是银弹

- Fine Grained CFI 的实现中也必然存在假设
- 如何保证这些假设的不变性是关键点

只读内存问题

- 缺少真正的只读内存
- 对关键数据的保护并不可靠

高维欺骗技术

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Q & A

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Liar Game: The Secret of Mitigation Bypass Techniques

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