Abusing GDI for ring0 exploit primitives: Evolution

By Nicolas A. Economou

Who I am

- Senior Security Researcher at Blue Frost Security
- Worked 12 years as an exploit writer
- The last 10 years, specialized in Windows Kernel exploitation
- +17 years of low level programming (ASM/C)

Agenda

1. EoPs
2. Sandbox mitigations
3. Bitmap exploitation
4. GDI exploitation in Win10 RS3
5. ACG bypass
6. Demo – MS Edge sandbox escape

EoPs

EoPs

- EoP (Elevation of Privilege) … aka *"Privilege Escalation"*

- Usually, attacks are done locally

- Historically, used to elevate privileges from unprivileged users

EoPs

- Becoming privileged user (classic)
  - Windows: guest -> system (Administrator)
  - Linux: guest (uid=501) -> root (uid=0)

- Escape from virtual machines
  - Guest (VM) -> Host (Physical Computer)

- Elevate privileges in a Windows Domain
  - From a computer joined to the DC

EoPs

- Becoming a privileged user (classic) became more important with the introduction of sandbox technology

- Sandboxed browsers:
  - Chrome, Edge, IE, Firefox

- Sandboxed office tools:
  - Word, PowerPoint, Excel, Adobe Reader, etc

Sandbox mitigations

Sandbox Mitigations

- If the app is owned, the attacker has less privileges

- Sandboxes usually run in Low Integrity Level/AppContainer

- The idea is to restrict the access to the system and mitigate some kind of EoPs

Sandbox Mitigations

- Execution restrictions
  - No program can't be executed from the sandbox (Edge/Chrome)

- Library restrictions (ProcessSignaturePolicy)
  - Only system libraries can be loaded from the sandbox (Edge/Chrome)

- File system restrictions
  - Dir writable: *"C:\Users\XXX\AppData\Local\Temp\Low"*

Sandbox Mitigations

- Call restrictions
  - E.g. *NtQuerySystemInformation* can't get kernel base address

- Syscall restrictions (ProcessSystemCallDisablePolicy)
  - E.g. "win32k" syscall prohibition (used by the Chrome renderer process)

Sandbox Mitigations

- Attackers usually want to escape from sandboxes ;-)

- Kernel Privilege Escalation exploits are ideal for that

- E.g. May 2017: 0-day exploit for MS Word was detected in the wild (EPS exploit + Kernel exploit (CVE-2017-0263))

Arbitrary write

Arbitrary write

- Aka: Write What Where (www)

- Result of exploiting a binary bug

- Write one value (controllable or not) at an arbitrary address

Arbitrary write

- Used a lot in Kernel EoPs

- Usually combined with some kind of memory leak (bypass KASLR!)

- The idea is to get a kernel read/write primitive from user mode

Arbitrary write

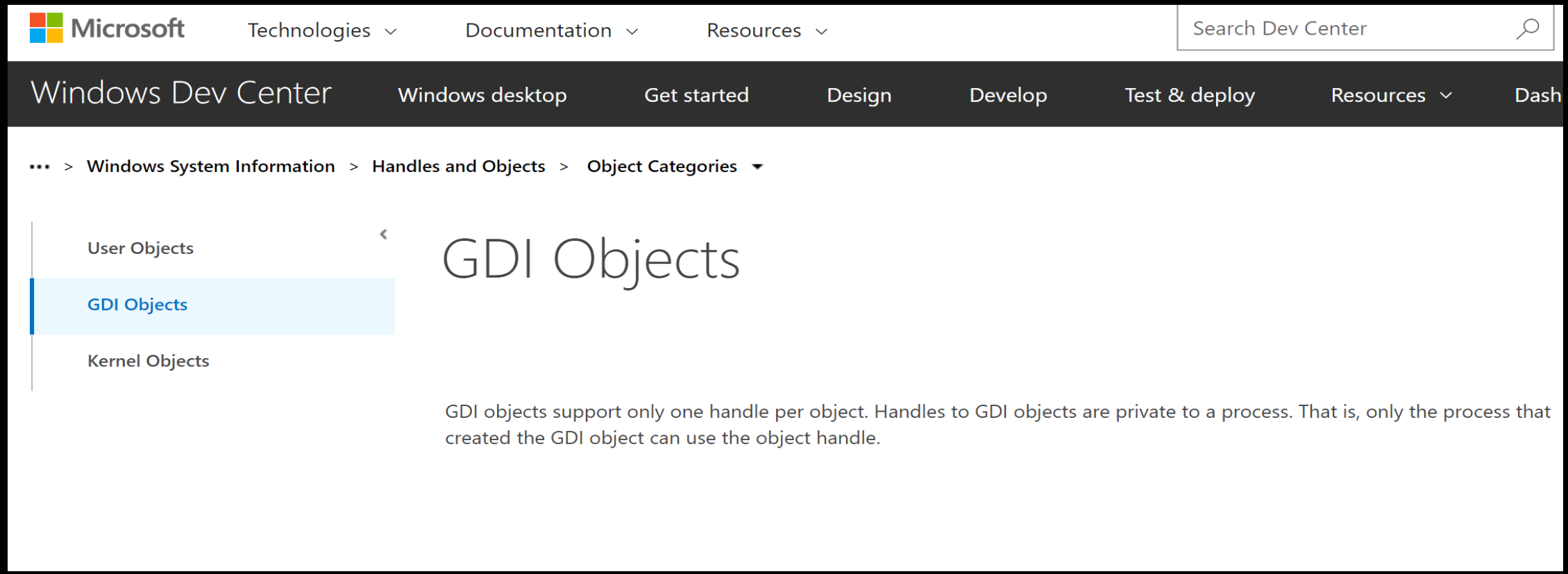
- Getting a r/w primitive avoid to deal with SMEP (non EIP/RIP manipulation)

- Finally, get SYSTEM privileges (Token Stealer technique)

GDI objects

GDI objects

https://msdn.microsoft.com/en-us/library/windows/desktop/ms724291(v=vs.85).aspx



GDI objects

- Graphic Objects used by Windows
- Instanced via APIs (user mode)
- Processed in kernel mode
- Bitmaps, Brushes, DCs, Metafiles, Fonts, Palettes, Pens and Regions

GDI exploitation history

- In April 2015, Keen Team mentioned GDI objects in *"This Time Font hunt you down in 4 bytes"*

- A TTF kernel heap overflow was described

- Bitmaps were used for the exploitation

GDI exploitation history

-In July 2015, Hacking Team was hacked

-Some kernel 0-day exploits were leaked

-One of them used GDI objects for the exploitation

GDI exploitation history

- In October 2015, Diego Juarez (Pnx) from Core Security presented the Bitmaps technique in detail at *Ekoparty*

- In September 2016, Diego Juarez (Pnx) and I presented memory leaks and improvements at *Ekoparty*

- The names of the talks were *"Abusing GDI for ring0 exploit primitives"* and *"Abusing GDI ... Reloaded"*

Bitmaps

Bitmaps

- Created by CreateBitmap (gdi32.dll)

The **CreateBitmap** function creates a bitmap with the specified width, height, and color format (color planes and bits-per-pixel).

Syntax

C++

```
HBITMAP CreateBitmap(
  _In_       int  nWidth,
  _In_       int  nHeight,
  _In_       UINT cPlanes,
  _In_       UINT cBitsPerPel,
  _In_ const VOID *lpvBits
);
```

Bitmaps

- *nWidth* x *nHeight* x *cBitsPerPel* = data size

- *lpvBits* parameter contains our data

- Our data is allocated in kernel space

Bitmaps

- Bitmaps in kernel (SURFACE.SURFOBJ structure)

```
HBITMAP CreateBitmap(
  _In_       int   nWidth,
  _In_       int   nHeight,
  _In_       UINT cPlanes,
  _In_       UINT cBitsPerPel,
  _In_ const VOID *lpvBits
);
```

SURFOBJ

```
typedef struct _SURFOBJ
{
    DHSURF dhsurf;
    HSURF  hsurf;
    DHPDEV dhpdev;
    HDEV   hdev;
    SIZEL  sizlBitmap;
    ULONG  cjBits;
    PVOID  pvBits;
    PVOID  pvScan0;
    LONG   lDelta;
    ULONG  iUniq;
    ULONG  iBitmapFormat;
    USHORT iType;
    USHORT fjBitmap;
  // size
} SURFOBJ, *PSURFOBJ;
```

Bitmaps

- PvBits/PvScan0 properties point to our data

- The data is consecutive to the SURFACE structure (header + data)

- It means that only a kernel allocation is needed to contain a Bitmap (until now …)

Bitmaps

- Our kernel data can be read/written by using GetBitmapBits/SetBitmapBits

- Bitmaps variants:
  - CreateCompatibleBitmap
  - CreateBitmapIndirect
  - CreateDiscardableBitmap
  - CreateDIBitmap

Abusing Bitmaps

Abusing Bitmaps

- Used to get read/write primitives

- Easy to manipulate/abuse

- Their addresses can be leaked from user mode at any integrity level

Abusing Bitmaps

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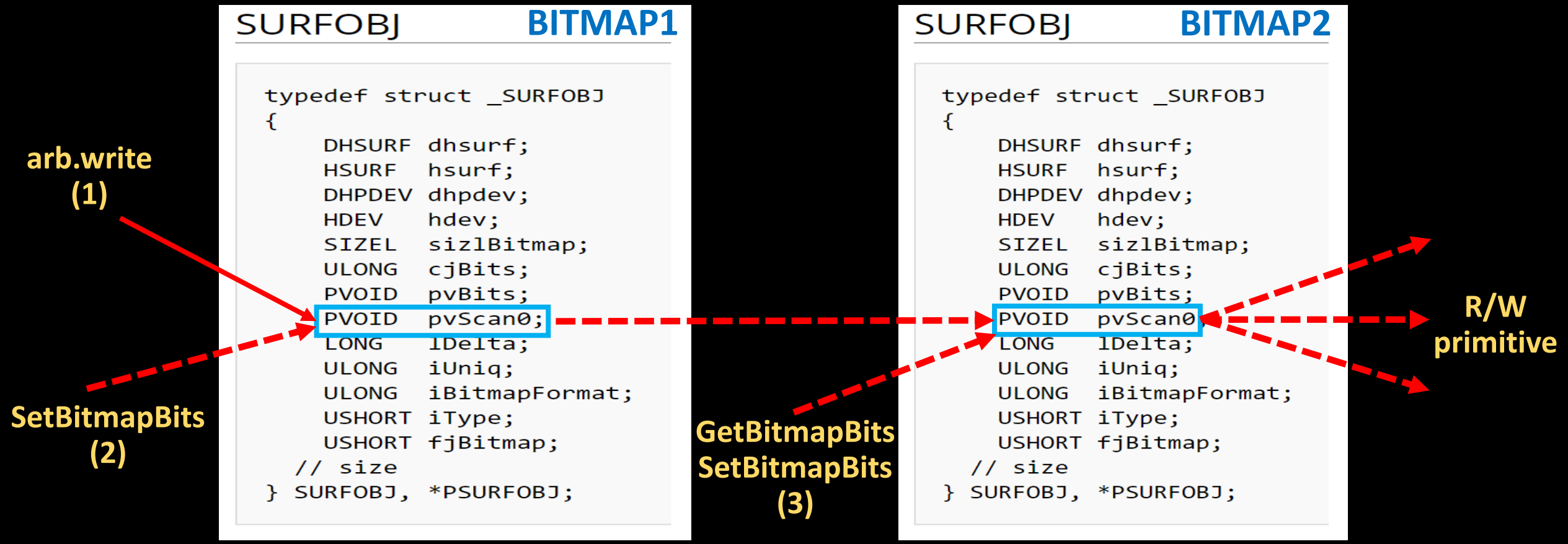
PvScan0 technique (2015)



Abusing Bitmaps

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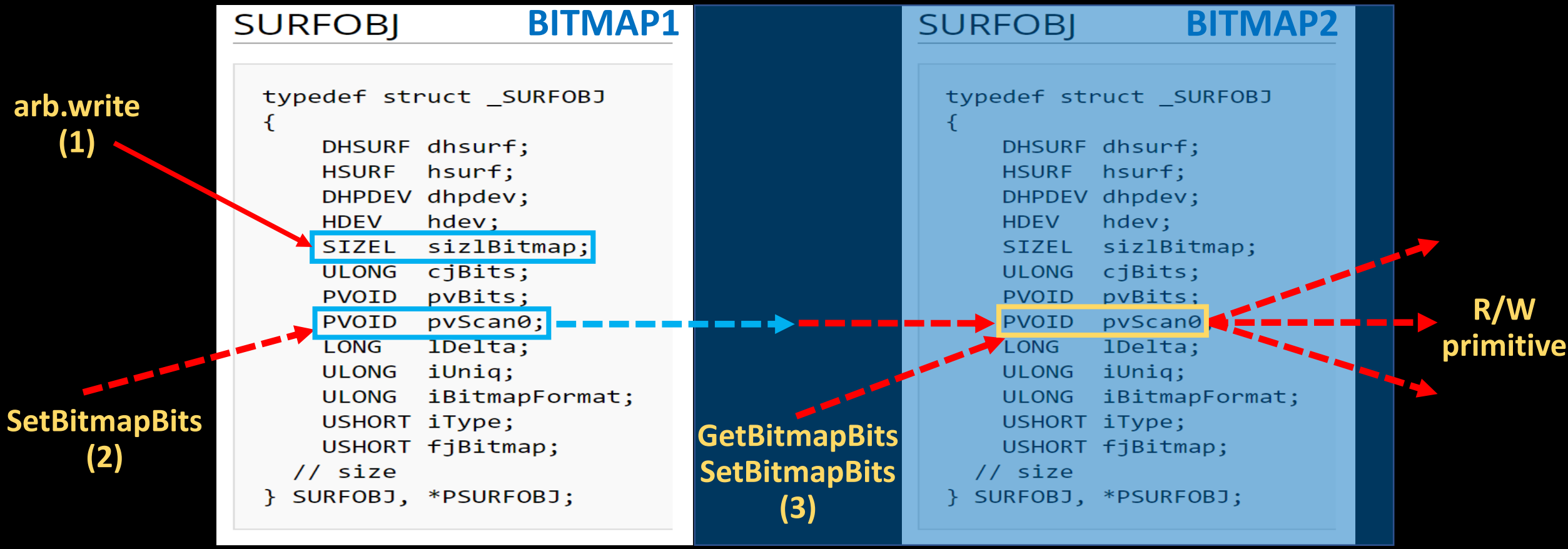
Extending Consecutive Bitmaps technique (2016)



Leaking Bitmaps

Leaking Bitmaps

- Until Windows 10 v1511 (Threshold 2)

- Leaking kernel addresses by reading user32!gSharedInfo structure

- Killed in RS1

Leaking Bitmaps

- Until Windows 10 RS1 (Anniversary Update)
- Indirect leak by using AcceleratorTables (Free List abusing)
- Leaking by reading user32!gSharedInfo structure
- Killed in RS2

Leaking Bitmaps

- Until Windows 10 RS2 (Creators Update)

- Indirect leak by using RegisterClass with WNDCLASSEX.lpszMenuName (Free List abusing) and associating this one to a windows handle

- Leaking by reading user32!gSharedInfo structure and more until you find tagCLS.lpszMenuName

- To be killed in RS3

Fall Creators Update (RS3)

Fall Creators Update

-To be released in October, 2017

-Current version: Insider Preview 16296.0

-Some security mitigations added

Fall Creators Update

- Bitmap headers separated from Bitmap data

- Data is no longer contiguous to header

- PvScan0/PvBits now point to a different pool type (heap)

Fall Creators Update

- Bitmap headers moved to some kind of heap isolation!

- No way to predict its address until now

- Bitmap technique killed :-(

Evolution

Evolution

- In Defcon 2017, "*Demystifying Kernel Exploitation by Abusing GDI Objects*"

- *Saif El-Sherei* from SensePost presented a GDI object alternative for Bitmap exploitation

- It's still working in RS3

Evolution

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-Bitmaps are replaced by Palettes

CreatePalette function

The **CreatePalette** function creates a logical palette.

Syntax

C++

```
HPALETTE CreatePalette(
  _In_ const LOGPALETTE *lplgpl
);
```

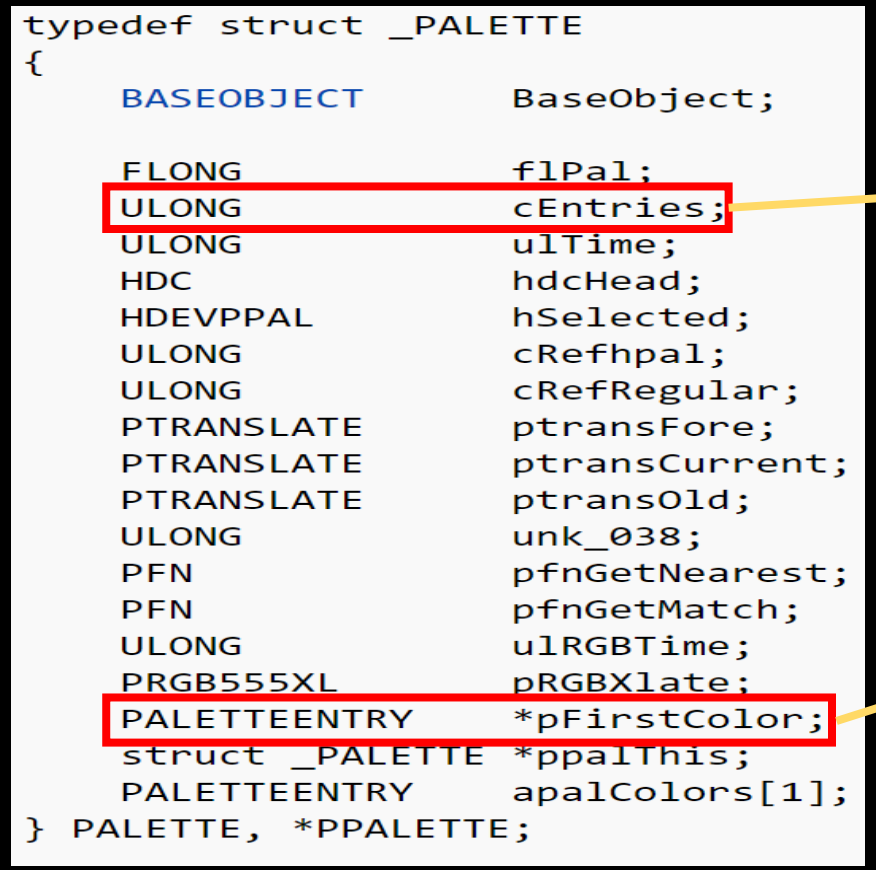
Evolution

-Same idea/techniques as for Bitmaps

-Same way to leak their kaddresses

-Header + data placed together

Evolution



```
typedef struct _PALETTE
{
    BASEOBJECT      BaseObject;

    FLONG           flPal;
    ULONG           cEntries;
    ULONG           ulTime;
    HDC             hdcHead;
    HDEVPPAL        hSelected;
    ULONG           cRefhpal;
    ULONG           cRefRegular;
    PTRANSLATE      ptransFore;
    PTRANSLATE      ptransCurrent;
    PTRANSLATE      ptransOld;
    ULONG           unk_038;
    PFN             pfnGetNearest;
    PFN             pfnGetMatch;
    ULONG           ulRGBTime;
    PRGB555XL       pRGBXlate;
    PALETTEENTRY    *pFirstColor;
    struct _PALETTE *ppalThis;
    PALETTEENTRY    apalColors[1];
} PALETTE, *PPALETTE;
```

```
kd> dd ffff9d55`84484000
ffff9d55`84484000  92080be4 ffffffff 00000000 00000000
ffff9d55`84484010  b7915280 ffffd68e 00000501 00000700
ffff9d55`84484020  0010fd50 00000000 00000000 00000000
ffff9d55`84484030  00000000 00000000 00000000 00000000
ffff9d55`84484040  00000000 00000000 00000000 00000000
ffff9d55`84484050  00000000 00000000 00000000 00000000
ffff9d55`84484060  00000002 00000001 00000000 00000000
ffff9d55`84484070  00000000 00000000 84484088 ffff9d55
kd> d
ffff9d55`84484080  84484000 ffff9d55 41414141 41414141
ffff9d55`84484090  41414141 41414141 41414141 41414141
ffff9d55`844840a0  41414141 41414141 41414141 41414141
ffff9d55`844840b0  41414141 41414141 41414141 41414141
ffff9d55`844840c0  41414141 41414141 41414141 41414141
ffff9d55`844840d0  41414141 41414141 41414141 41414141
ffff9d55`844840e0  41414141 41414141 41414141 41414141
ffff9d55`844840f0  41414141 41414141 41414141 41414141
```

Evolution

- pFirstColor property points to our PALETTE (our data)

- cEntries property is the PALETTE size

- pFirstColor/cEntries = Pvscan0/sizlBitmap

Evolution

-GetPaletteEntries for reading

-SetPaletteEntries for writing

-iStartIndex parameter offset from pFirstColor

Leaking Palettes

Leaking Palettes

- lpszMenuName is the way to leak them

- Alloc/Free/Alloc works perfect for Palettes >= 0x1000 bytes (LARGE POOL)

- If size < 0x1000 bytes, the same address is never repeated in the next allocation

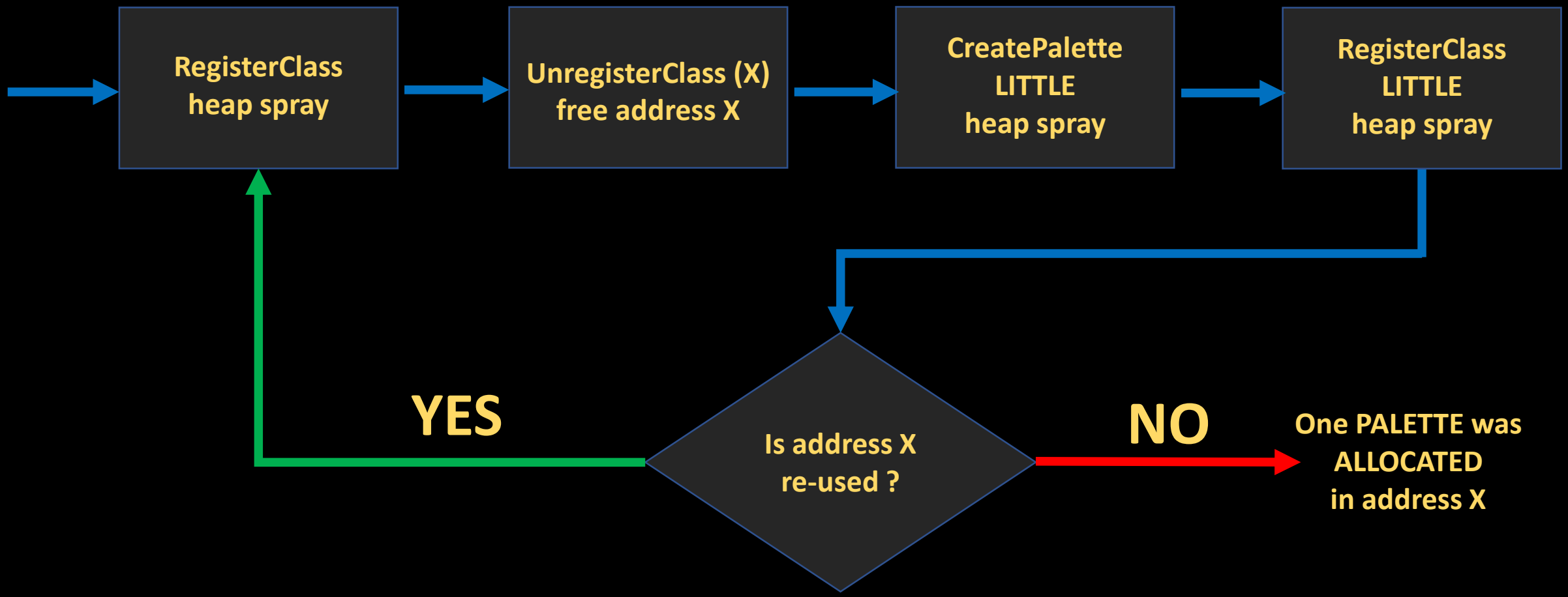
Leaking Palettes

- The idea is to maximize the predictability for sizes smaller than 4KB

- Addresses can be predicted by “Non repetition” detection

- It consist of adding one step to the alloc/free/alloc way

Leaking Palettes



Demo  Time

Demo

- Target OS: “Windows 10” x64 Insider Preview 16296.0

- Target browser: Microsoft Edge

- Objective: Escape from sandbox

Demo

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- Exploitation steps:
  - 1. Inject “fake exploit” in MicrosoftEdgeCP.exe
  - 2. Simulate kernel exploitation
  - 3. Corrupt a Palette object
  - 4. Get a read/write primitive
  - 5. Get SYSTEM privileges by Token Stealer
  - 6. Bypass ACG (next slide)
  - 7. Escape from sandbox
  - 8. Execute “notepad.exe” as SYSTEM

ACG

ACG

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- Arbitrary Code Guard

- Prevents allocation of executable code in the same process and to other processes

- VirtualAlloc/VirtualAllocEx + PAGE_EXECUTE_READWRITE is not allowed

ACG

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- CreateRemoteThread often combined with a ROP chain to allocate rwx memory in the target process

- The lpParameter argument is used to pass the memory address of our allocated data to make the “stack pivoting”

- Registers rcx, rdx, r8 and r9 have to be set with the VirtualAlloc parameters

- At the end of the steps, our data can be executed

ACG

- It requires automating the search for gadgets before the process injection (sandbox escape)

- The gadget finding engine has to be good enough to not fail with multiple libraries versions

- If the process target has ACG enabled or VirtualAlloc is hooked, it will fail

ACG

- This mitigation difficults the sandbox escape
- Classic process injection fails
- Getting SYSTEM privileges is not enough to do that!
- See *“Mitigating arbitrary native code execution in Microsoft Edge”* article

Simple ACG bypass

Simple ACG bypass

- Mitigation flags in RS3 located now in EPROCESS structure (offset 0x828)

```
+0x828 MitigationFlags   : 0x800539
+0x828 MitigationFlagsValues : <unnamed-tag>
+0x82c MitigationFlags2 : 0
+0x82c MitigationFlags2Values : <unnamed-tag>
```

Simple ACG bypass

- Since we have a kernel r/w primitive

- We can modify this flags for the sandboxed process (current process)

- Bypass: Disable this one in EPROCESS.MitigationFlags -> set as 0x38 ;-)

A live demo now!

Conclusions

Conclusions

- Windows 10 RS3 (Fall Creators Update) kernel exploitation is still easy to do

- GDI techniques continue evolving ;-)

- Sandbox escapes are easy when kernel privilege escalations are used

Conclusions

- Bitmap objects will no longer be available in RS3 for kernel exploitation

- Palettes will be the new way

- Leaking GDI object addresses from user mode still remains a problem …

Thanks!