ADVANCED HEAP MANIPULATION IN WINDOWS 8

Who Am I

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Previous:

Dissecting Adobe ReaderX's Sandbox:
Breeding Sandworms@BlackHat EU 2012

Agenda

0x01:
Why start this research

0x02:
Quick View of The Idea

0x03:
Implementations
(Kernel Poll / User heap)

Intro

Why start this research. (Motivation)

Exploiting Memory corruption vulnerability are more difficult today

Windows 8: Exploit mitigation improvements.

Possible ways for Sandbox bypassing

- *Kernel Vulnerability*
- *3rd-party plug-ins Vulnerability*
- *Sandbox flaws*

Windows 8 Kernel

-- The patched Win 7 Kernel

A: *NULL Dereference protection*

B: *Kernel pool integrity checks*

C: *Non-paged pool NX*

D: *Enhanced ASLR*

E: *SMEP/PXN*

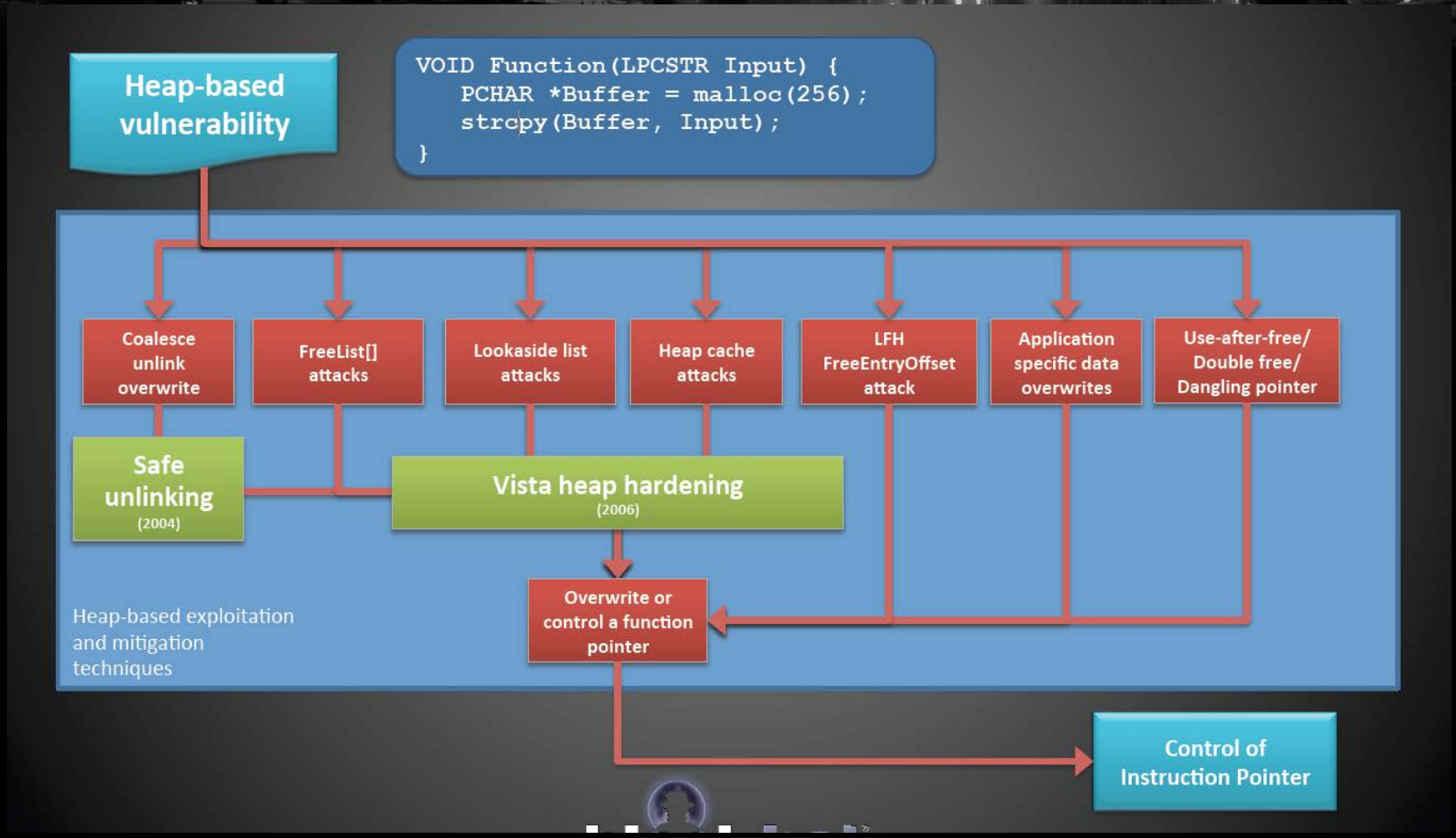
Windows 8 User Heap

-- determinism is at a all time low

A: High entropy Randomized LFH allocator

B: Guard pages

What's left



Matt Miller

http://media.blackhat.com/bh-us-12/Briefings/M_Miller/BH_US_12_Miller_Exploit_Mitigation_Slides.pdf

Why Application Specific Data attacking?

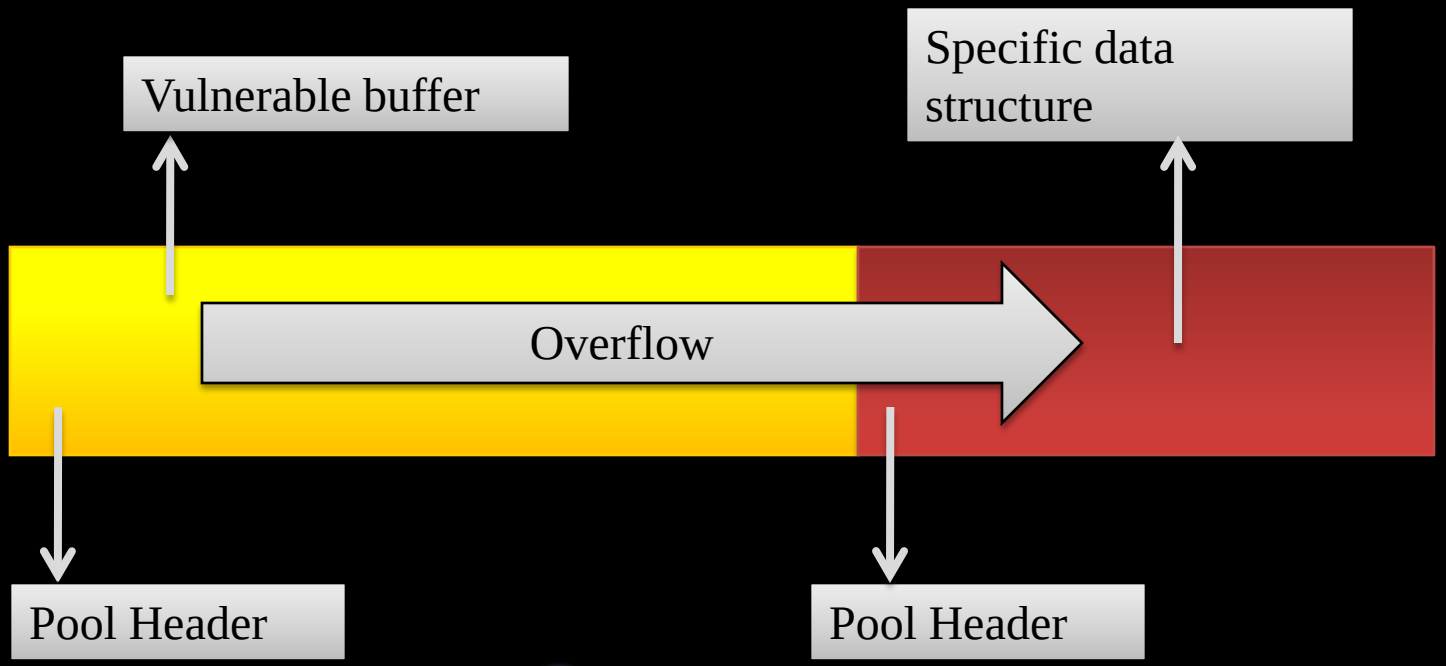
Application Specific data attacking are the future.
- Ben Hawkes

Compromising Application Specific data are facilitated by heap manipulation

What is ..

Overflow the target application's data stored on the heap.

Adjacent is the key!



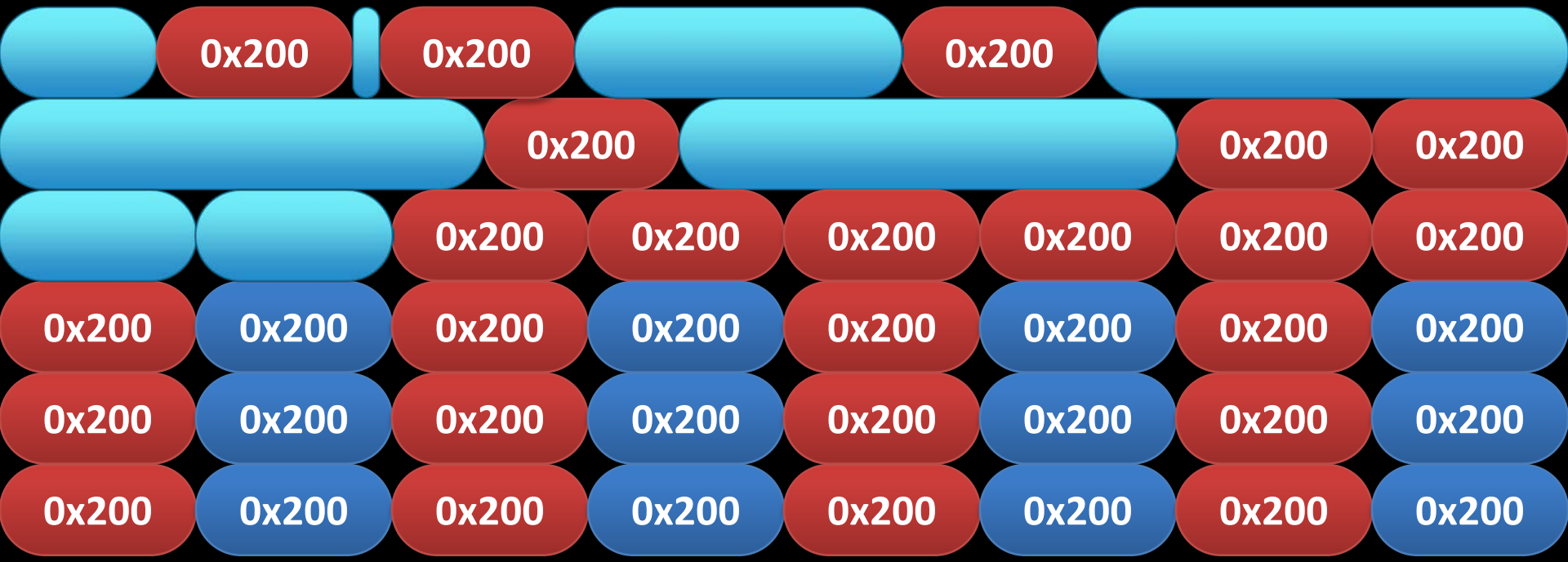
风水 feng shui

Taken | Noise | Free | Vul buffer

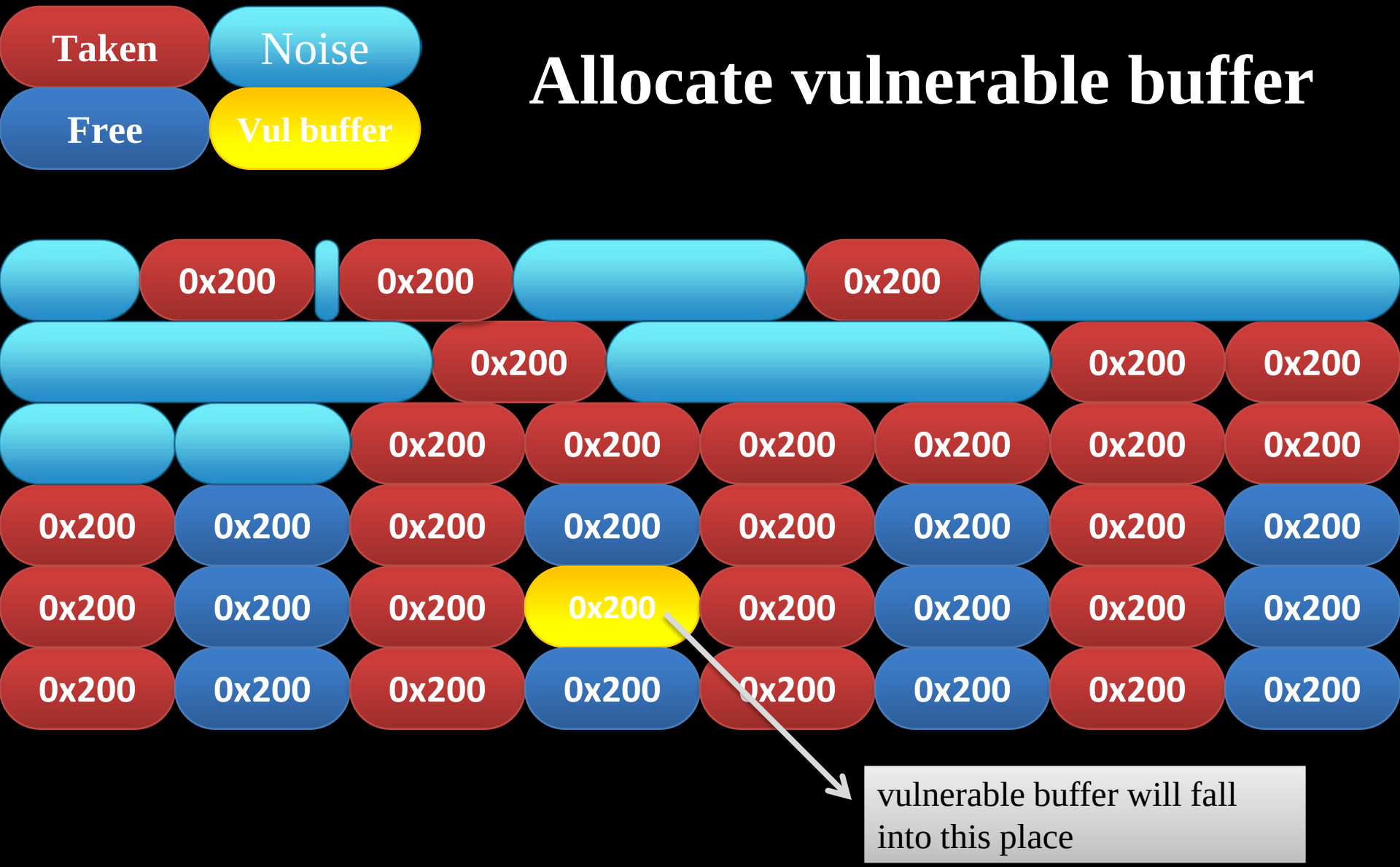
Defragment

Taken | Noise | Free | Vul buffer

Make Holes



Allocate vulnerable buffer



The limitations 1:

Arbitrary size of vulnerable buffer?

We can not always find kernel object which size is the same as the vulnerable buffer, and it also contains the data structure for exploitation.

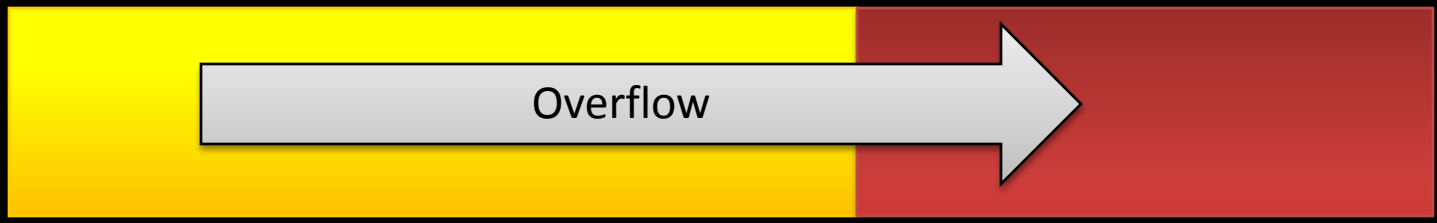
The limitations 2:

Randomized LFH makes it fail

Defragment will trigger Randomized LFH, vulnerable buffer will not fall into the hole we made.

Target of This Reasearch

- let the arbitrary vulnerable buffer adjacent with arbitrary data structure.
- without triggering the LFH in user heap.



0x01:
Quick View of The Idea

Windows Objects in Kernel Vulnerability Exploitation

- How to place a desired object just behind the vulnerable buffer?

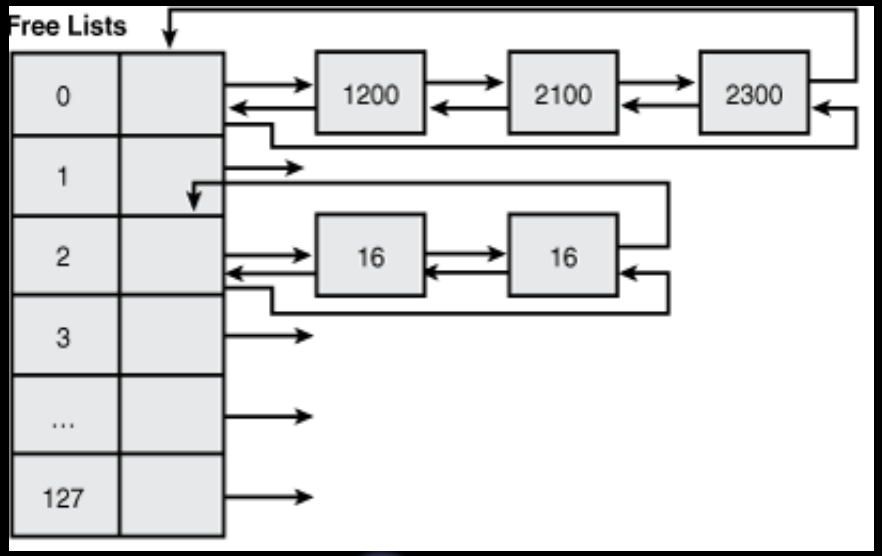
- Can we place something else other than object?

FreeLists

A: Doubly linked lists

B: For fast allocation and free

C:LIFO manner



Drawbacks

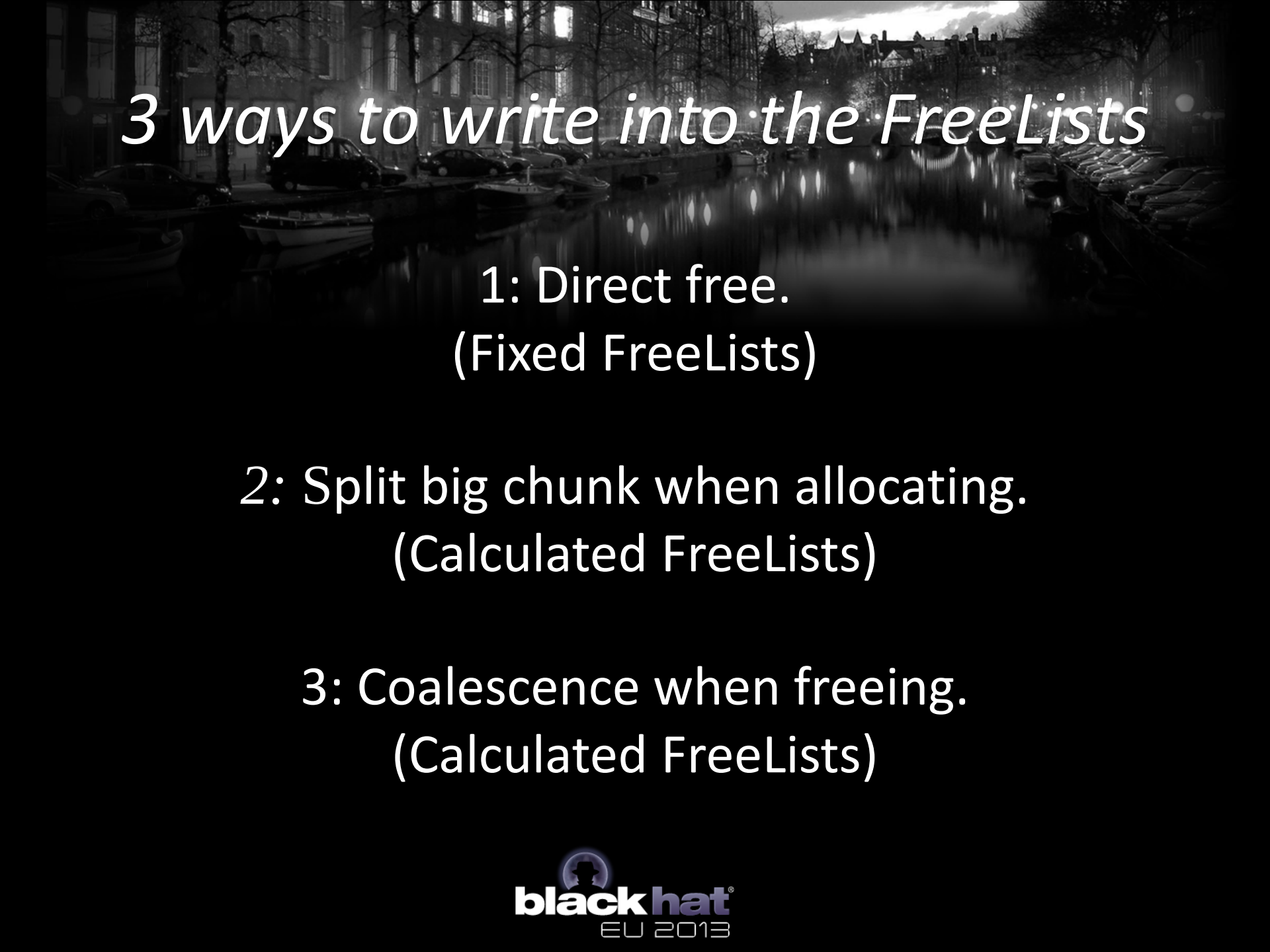
A: Metadata attacking

*B: **0** allocation entropy*

FreeLists are still been used in both kernel pool and user heap as of Windows 8.

Control the FreeLists

http://sushibandit.com/wp-content/uploads/2010/04/belt.jpg



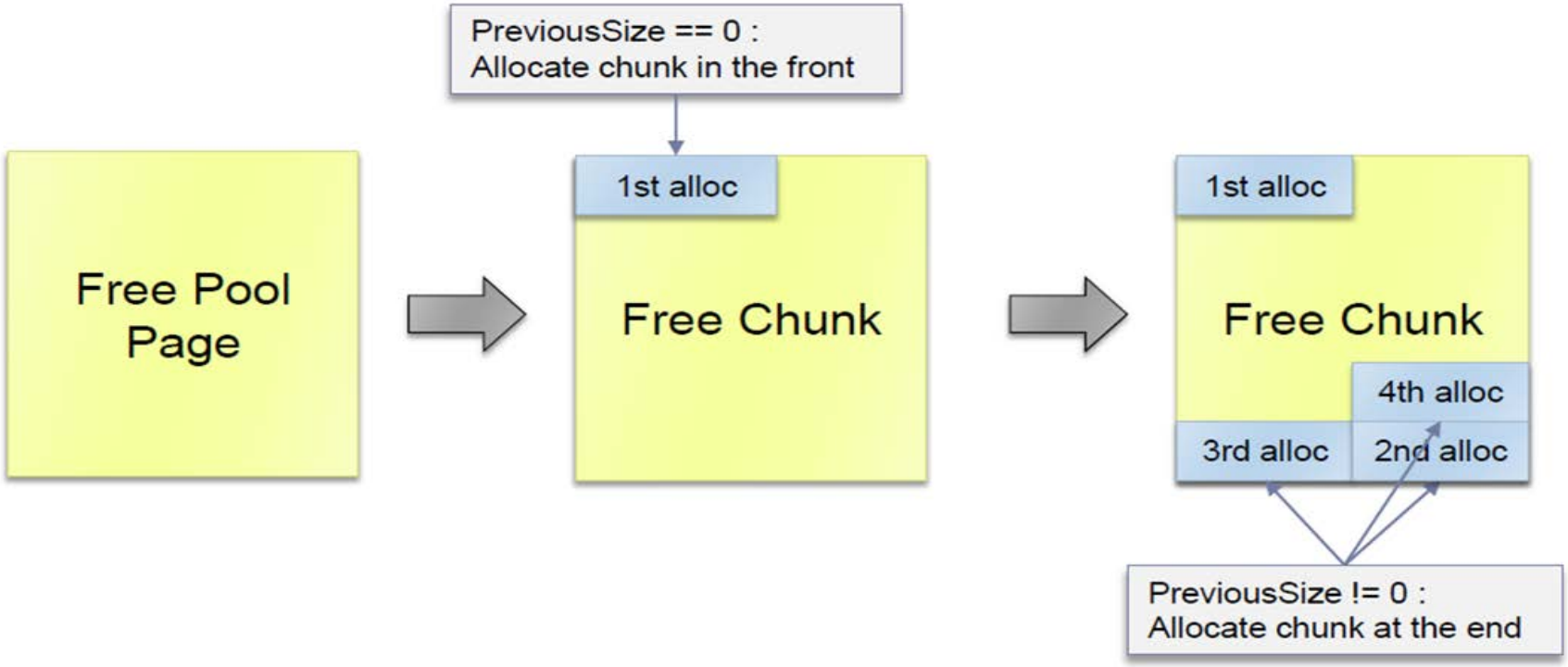
3 ways to write into the FreeLists

1: Direct free.
(Fixed FreeLists)

2: Split big chunk when allocating.
(Calculated FreeLists)

3: Coalescence when freeing.
(Calculated FreeLists)

Splitting Pool Chunks process

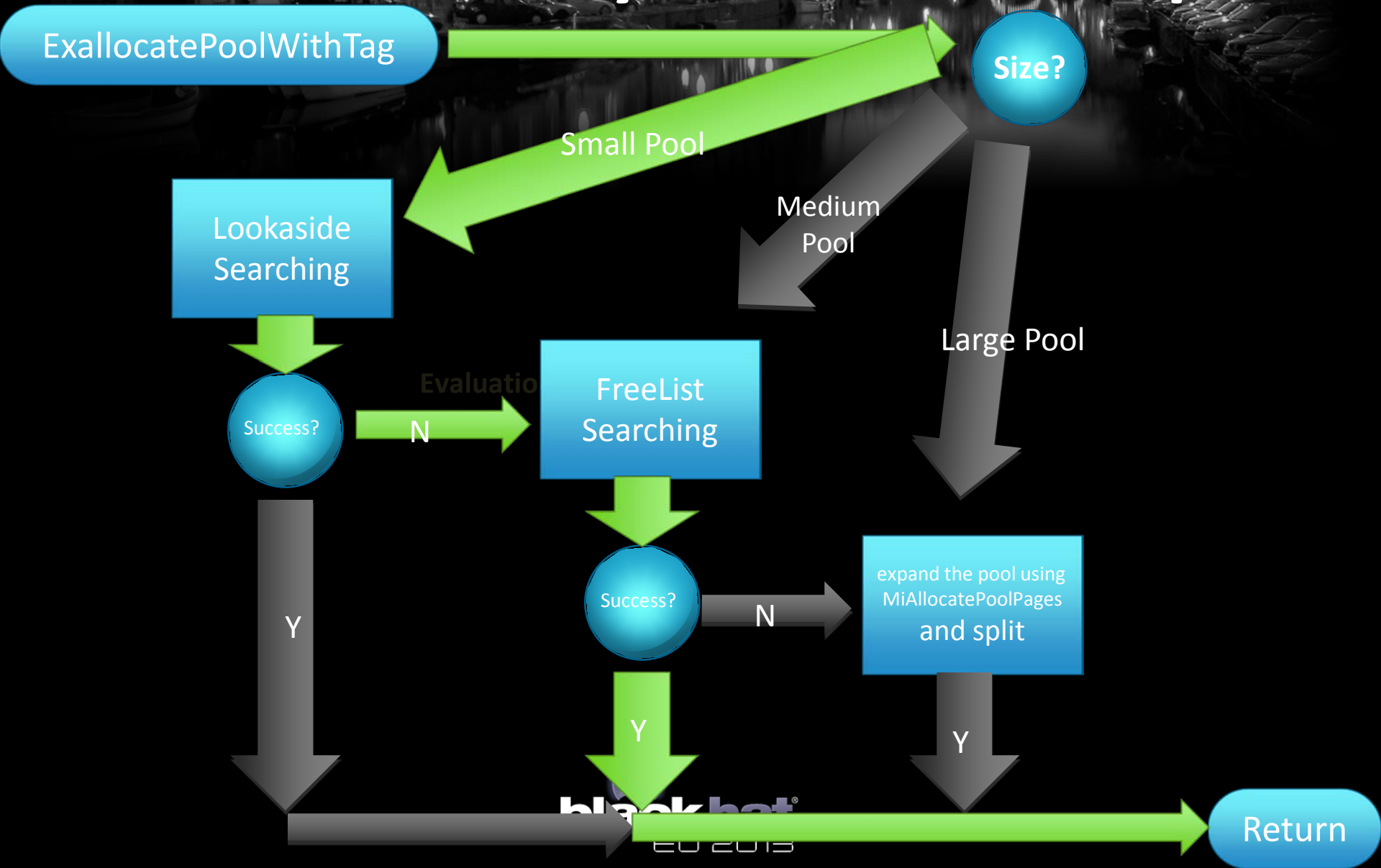


The Mandatory Search Technique

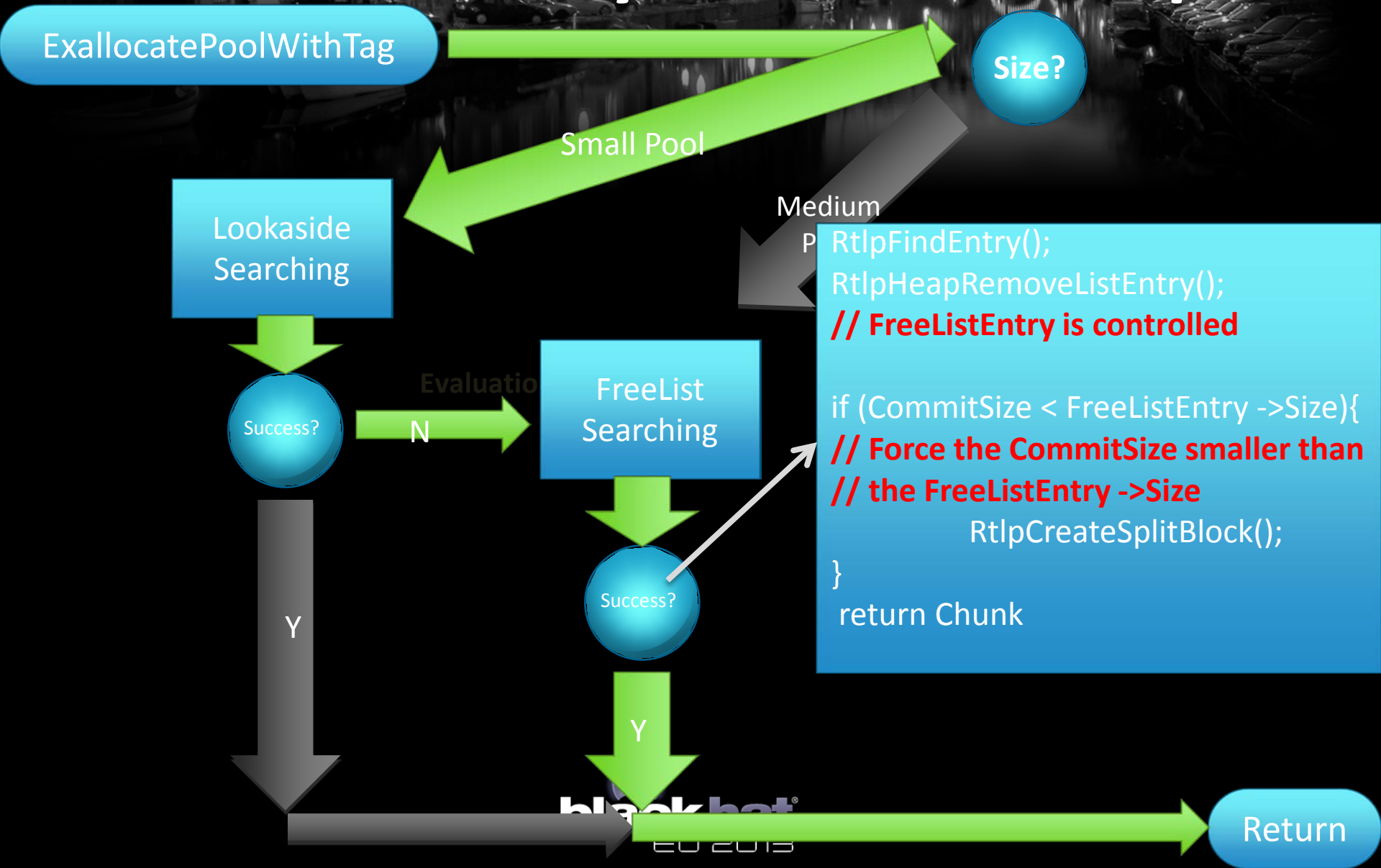
- **Force the FreeLists searching process to take place.**
- **Force the searching result greater than requested.**

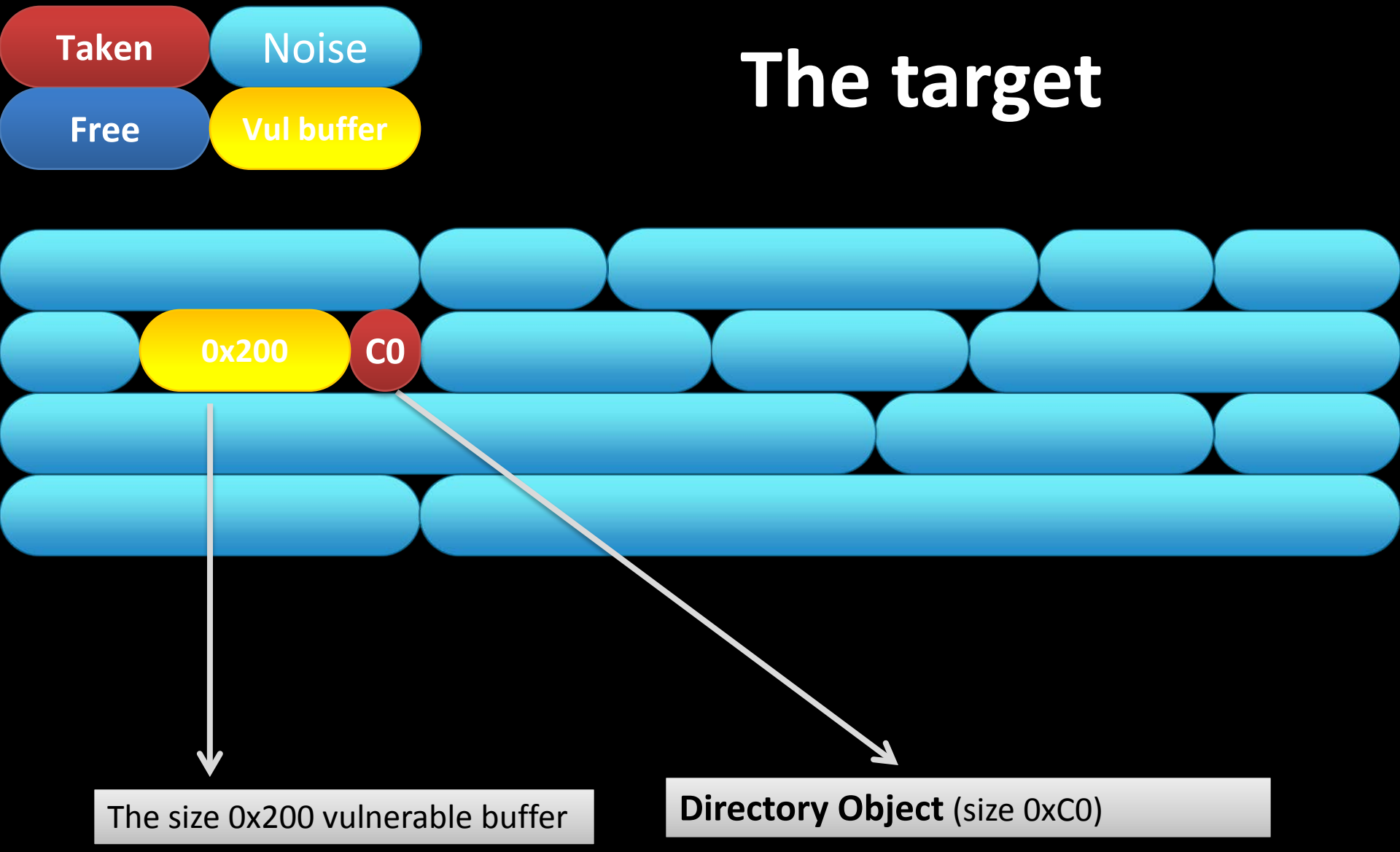
--To control the Freelists dynamically when allocating

The Mandatory Search Technique



The Mandatory Search Technique



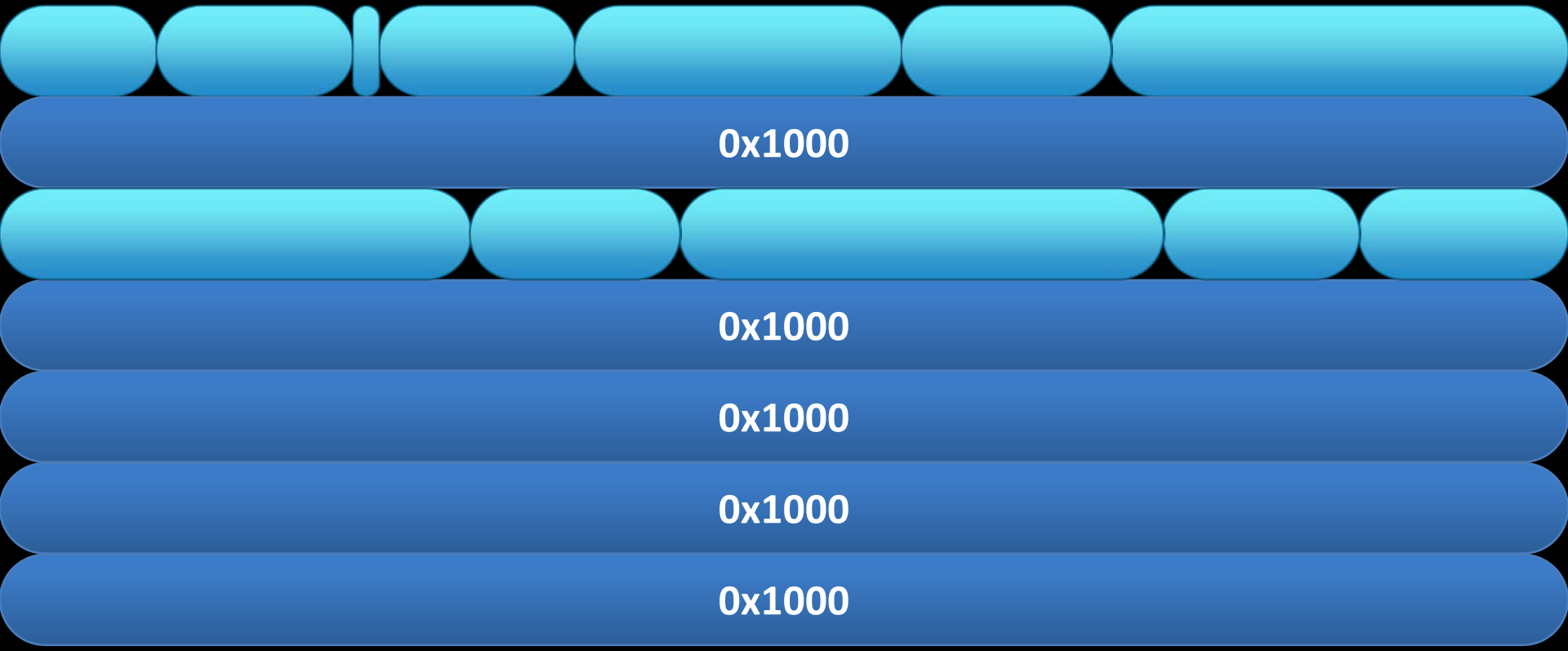

Taken
Noise
Free
Vul buffer
The target
0x200
C0
The size 0x200 vulnerable buffer
Directory Object (size 0xC0)

Taken

Noise

Free

0x01: Initial status

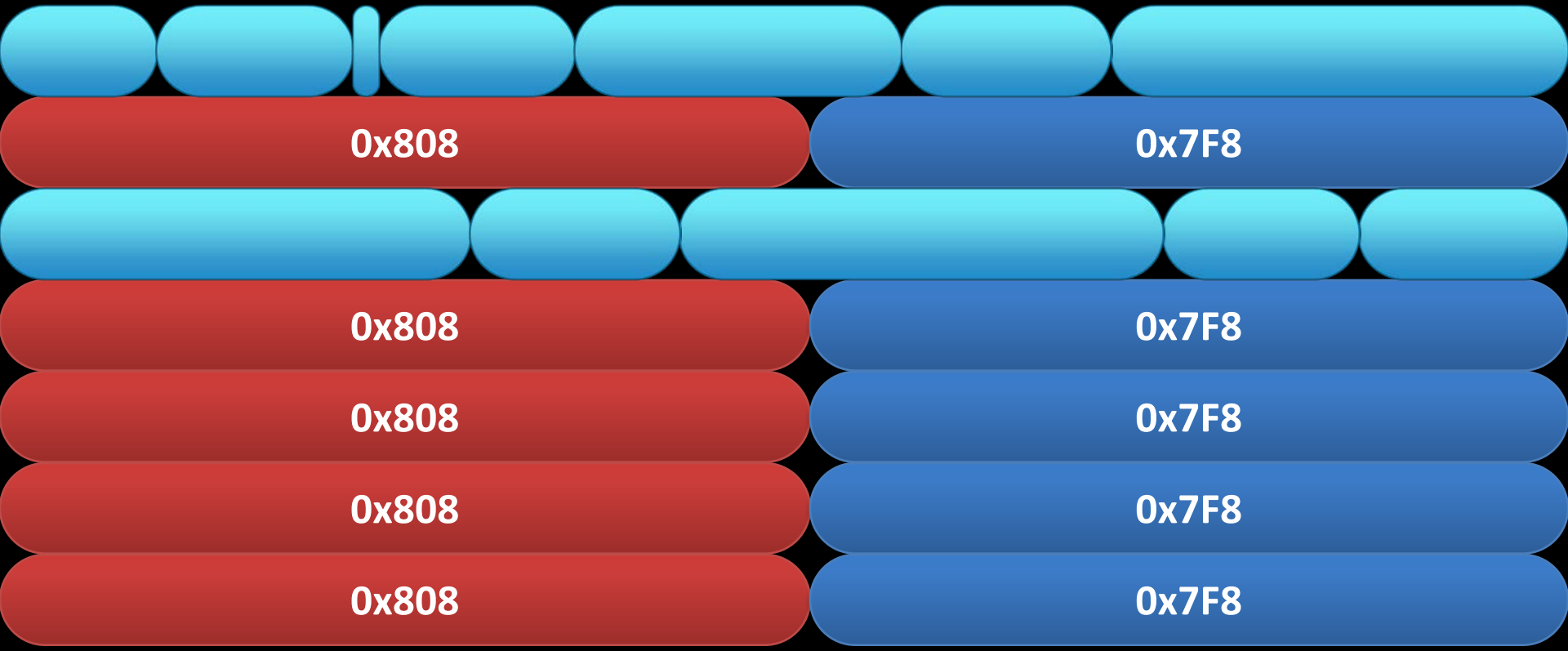


Taken

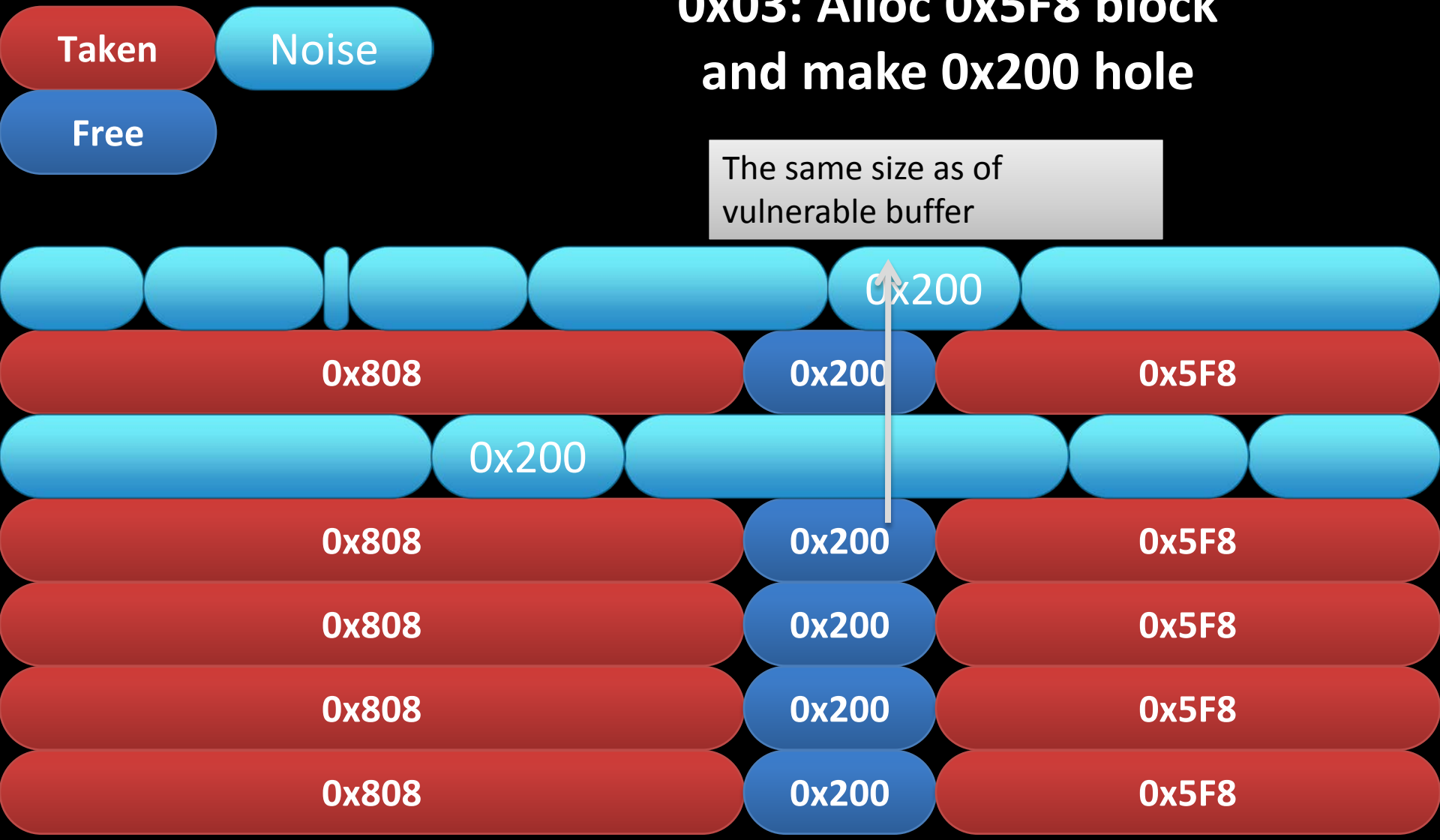
Noise

Free

0x02: Alloc 0x808 block



0x03: Alloc 0x5F8 block and make 0x200 hole

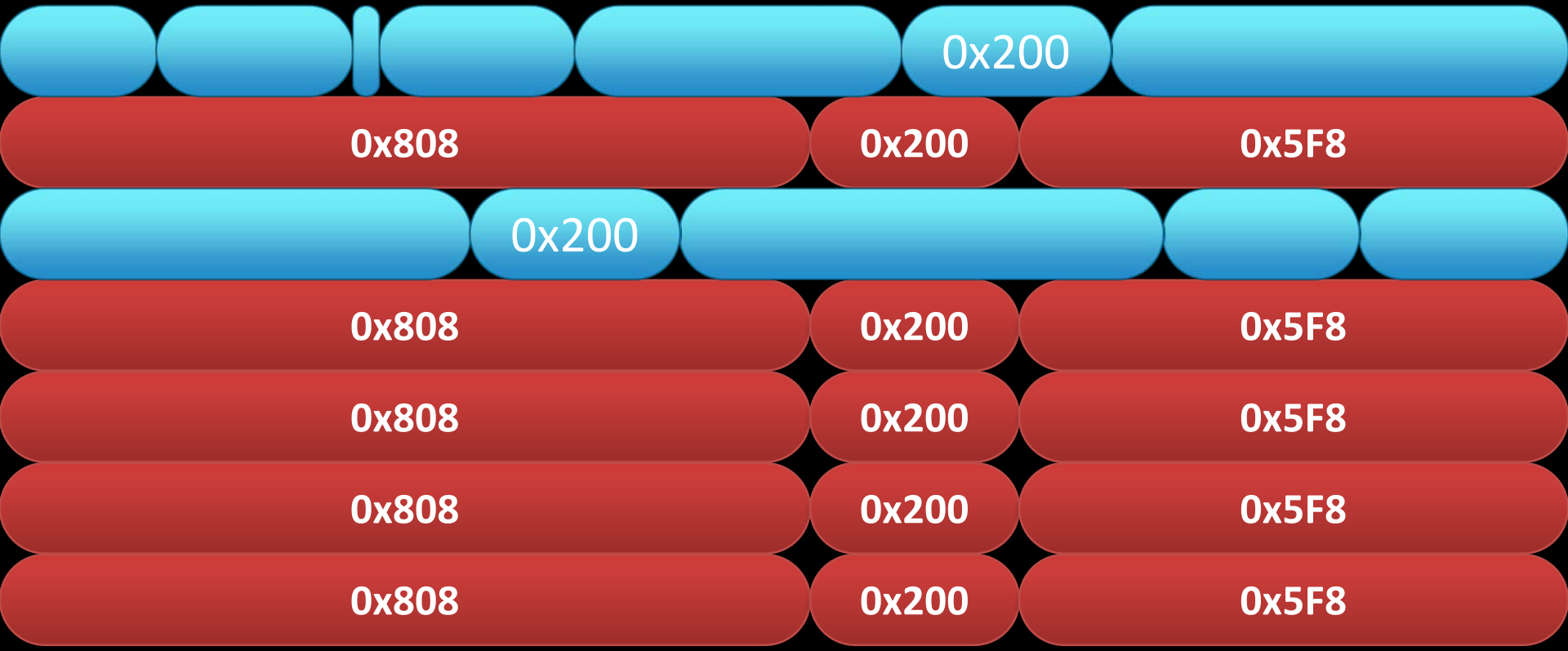


Taken

Noise

Free

0x04: Alloc 0x200 block

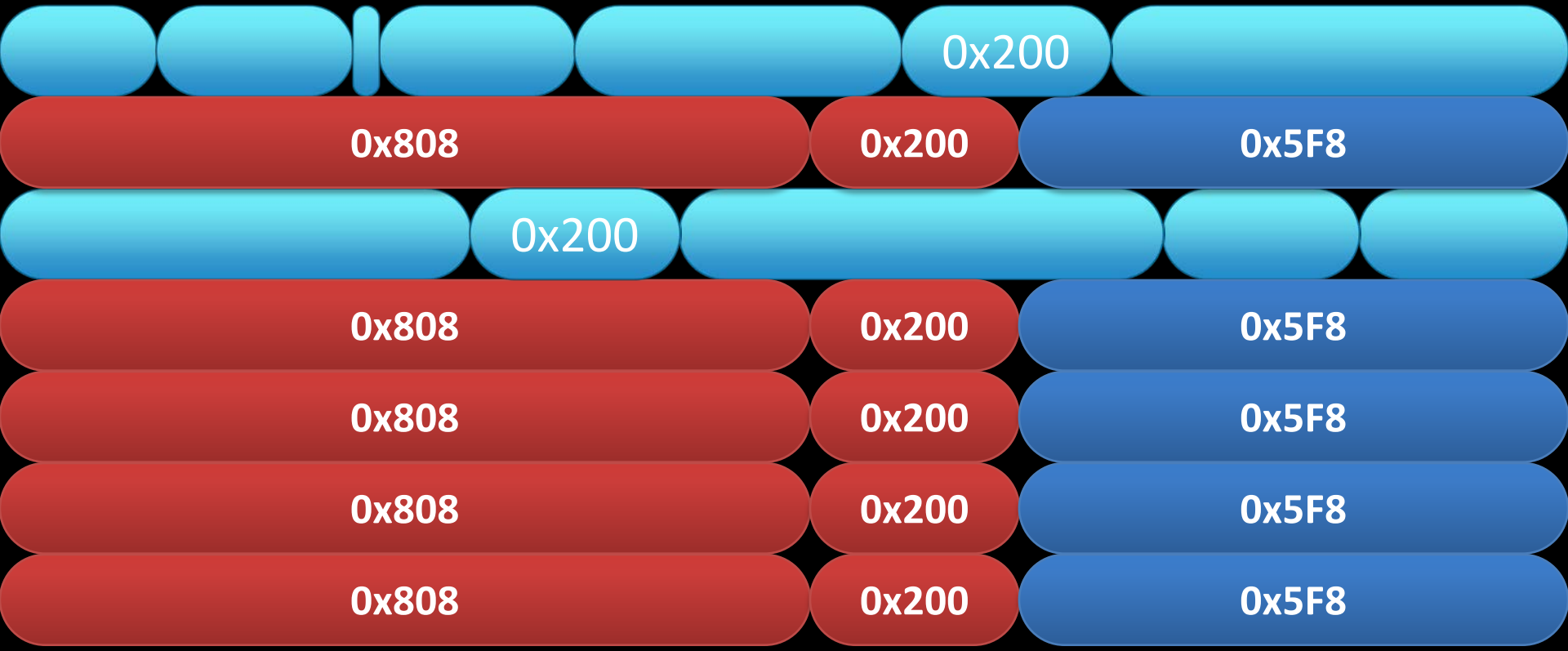


Taken

Noise

Free

0x05: Free 0x5F8 block



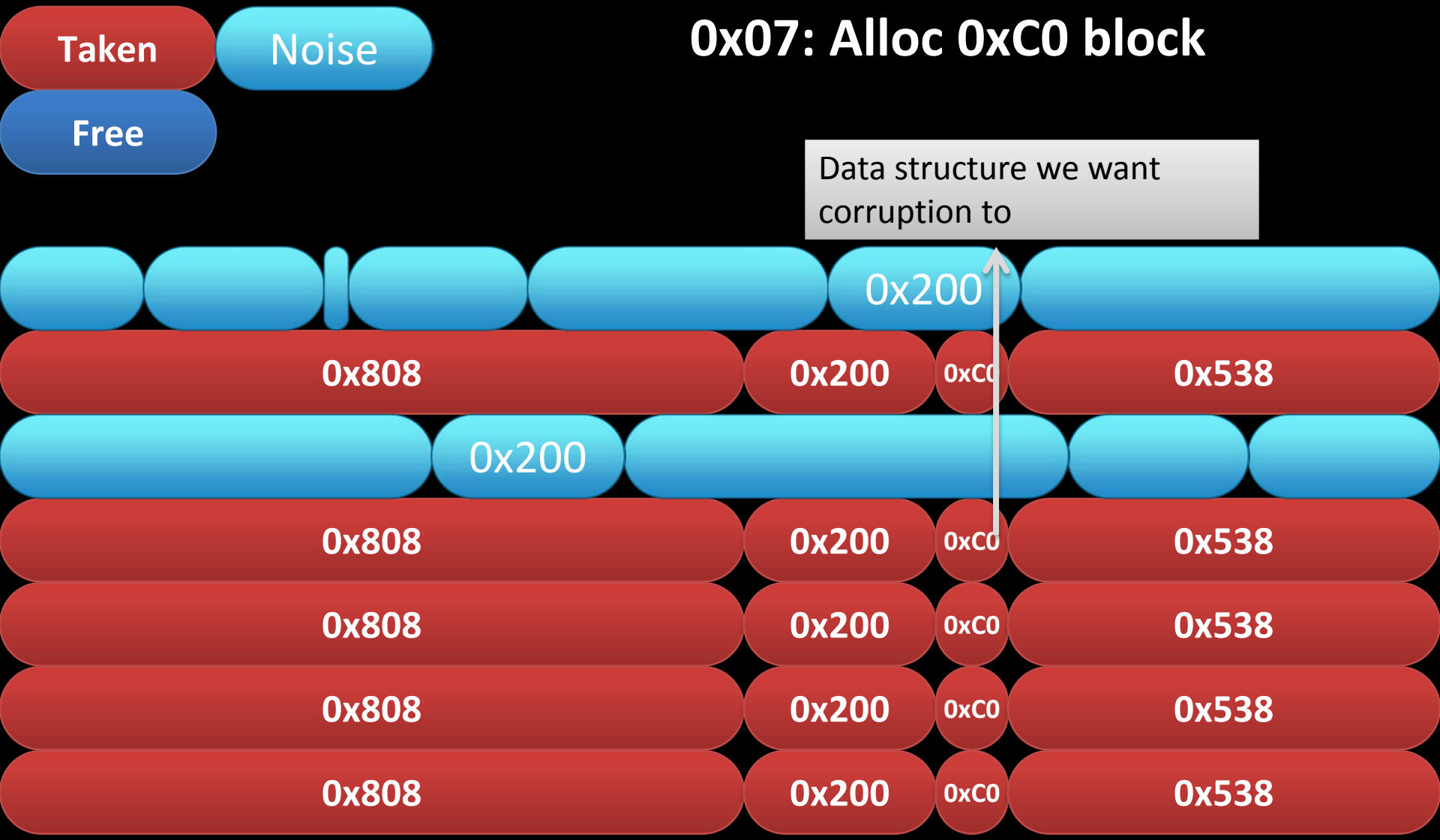
Taken

Noise

Free

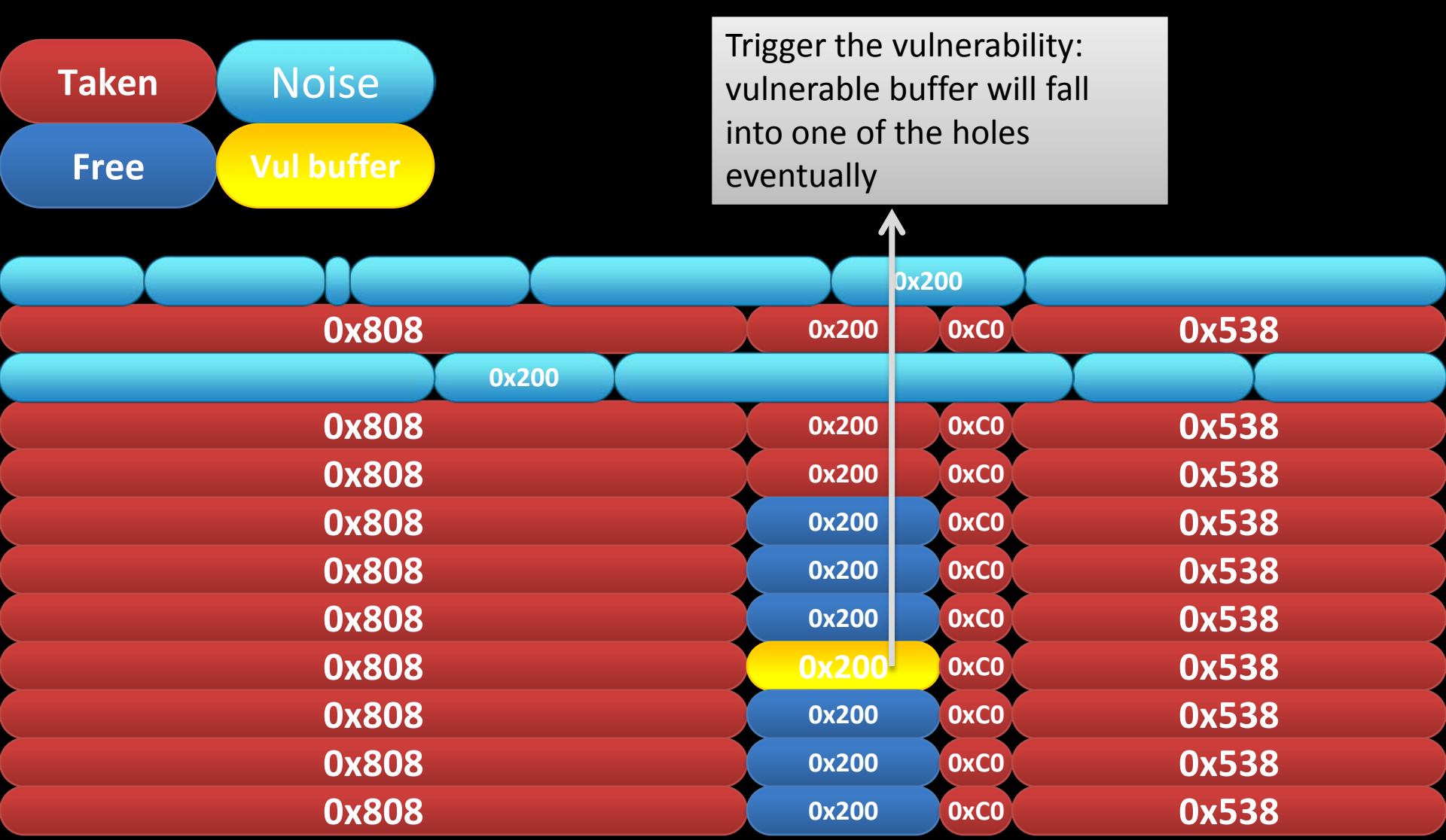
0x06: Alloc 0x538 block and make 0xC0 hole

0x07: Alloc 0xC0 block



Taken | Noise | Free | Vul buffer

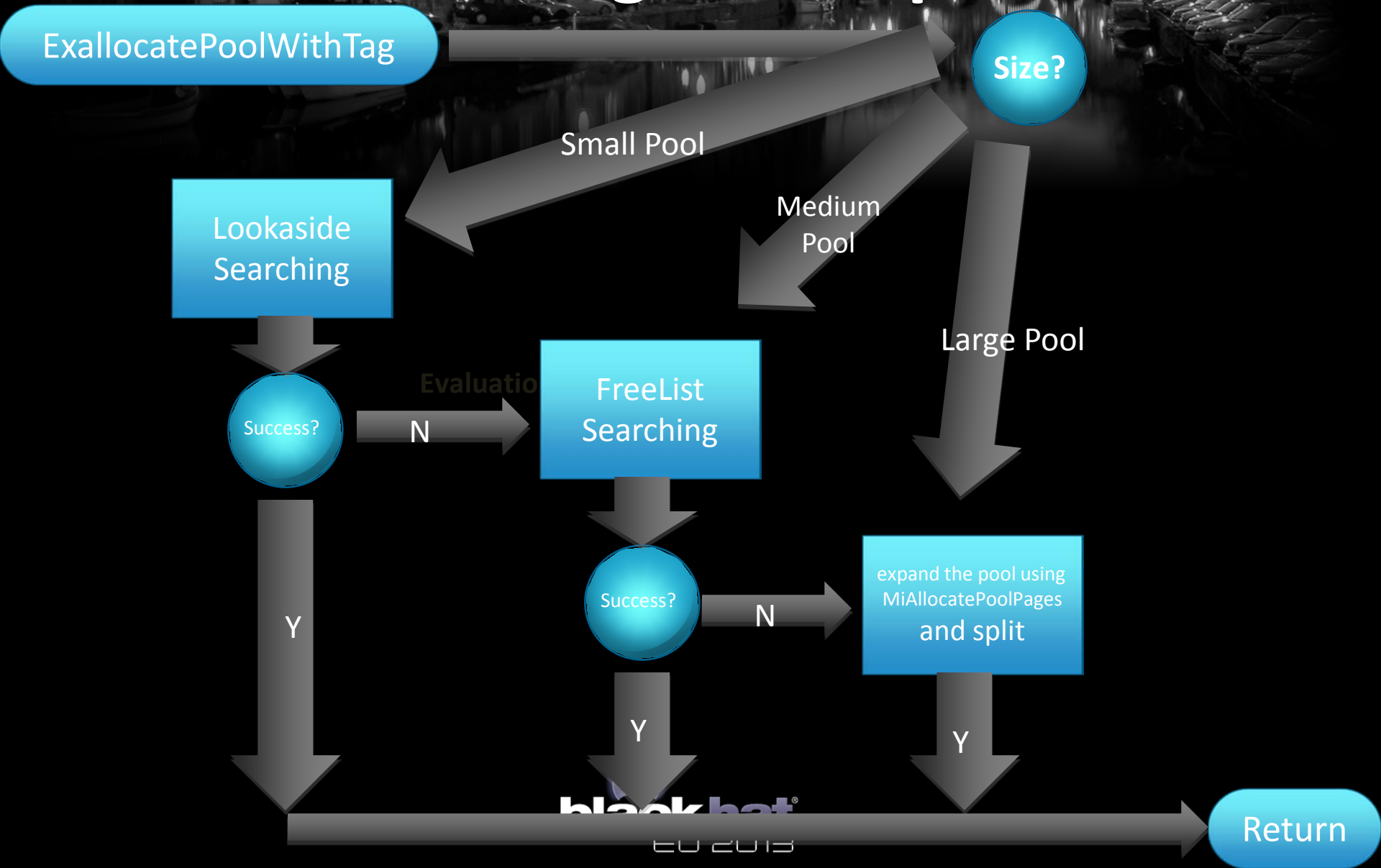
0x08: Make 0x200 Holes


Taken
Noise
Free
Vul buffer
Trigger the vulnerability: vulnerable buffer will fall into one of the holes eventually
0x200
0x808
0x200
0xC0
0x538
0x200
0x808
0x200
0xC0
0x538
0x808
0x200
0xC0
0x538
0x808
0x200
0xC0
0x538
0x808
0x200
0xC0
0x538
0x808
0x200
0xC0
0x538
0x808
0x200
0xC0
0x538
0x808
0x200
0xC0
0x538
0x808
0x200
0xC0
0x538
0x808
0x200
0xC0
0x538

Demo of this section

0x02:
Implementation in Kernel Pool

Allocation Algorithm pre-view



Prerequisites

- Allocate Buffer of Arbitrary Size
- Free Buffer of Arbitrary Size
- Control Allocations and Frees using user code.

Example Alloc Proxy

Alloc (paged)

```
HANDLE UserAlloc(int size){
                        HANDLE LinkHandle;
                        std::wstring s((size - 2) / 2, 'a');
                        UNICODE_STRING TargetName;
                        MyRtlInitUnicodeString (&TargetName, s.c_str());
                        OBJECT_ATTRIBUTES Test1;
                        InitializeObjectAttributes(&Test1, NULL,0, NULL, NULL);

                        int Status = MyCreateSymbolicLinkObject(&LinkHandle,
                                                                1,
                                                                &Test1,
                                                                &TargetName);
                        return LinkHandle;

}
```

Example Free Proxy

Free

```
void UserFree(HANDLE Handle){
        if (Handle){
                CloseHandle(Handle);
        }
}
```

Massage the Kernel Pool

ExAllocatePoolWithTag()
When FreeList search failed, allocation will come from a new page.

```
82928443 bf00100000     mov    edi,1000h
82928448 57             push   edi
82928449 ff742424       push   dword ptr [esp+24h]
8292844d e8b3ebffff     call   nt!MiAllocatePoolPages (82927005)
```

As 1000h is hard coded which leads to allocation aligned by 0x1000 (Paged , NonPaged, NonPagedNX,)

Kernel Virtual Address Space Allocation

nt!MiAllocatePoolPages

-- RtlFindClearBitsAndSet

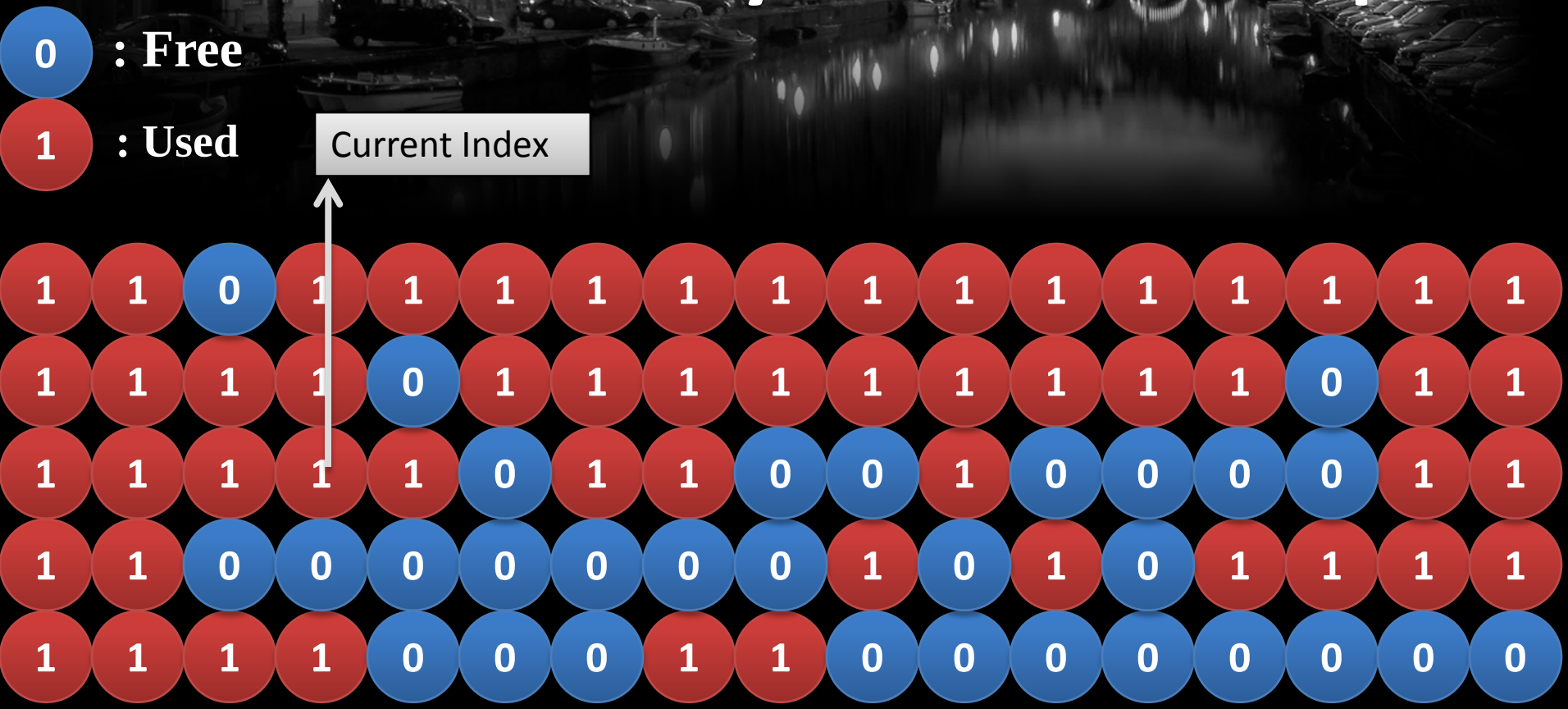
-- MiObtainSystemVa

- kd> dt ntkrpamp!_RTL_BITMAP 827a1194

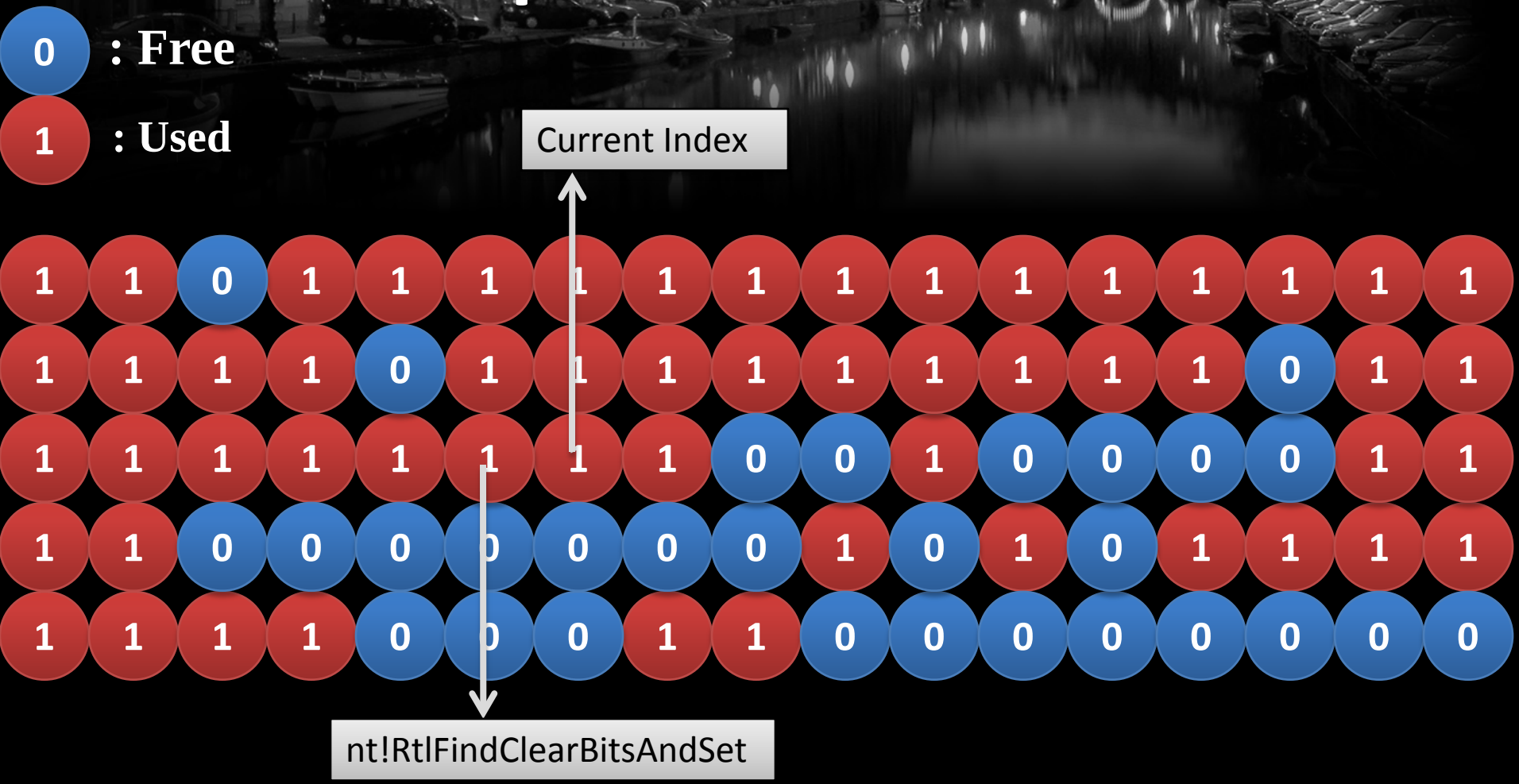
  +0x000 SizeOfBitMap : 0x7fc00

  +0x004 Buffer : 0x80731000 -> 0xffffffff

Kernel Pool Layout and Bitmap



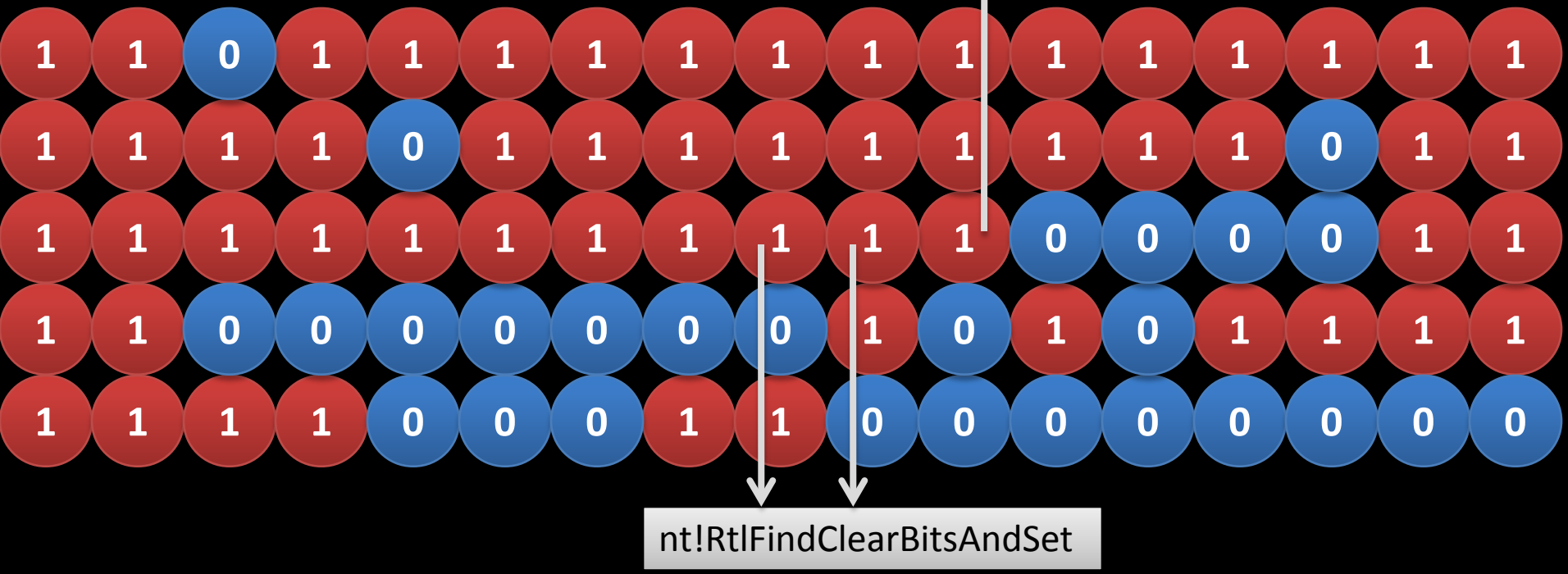
Request For 1 block



Request For 2 blocks

0 : Free

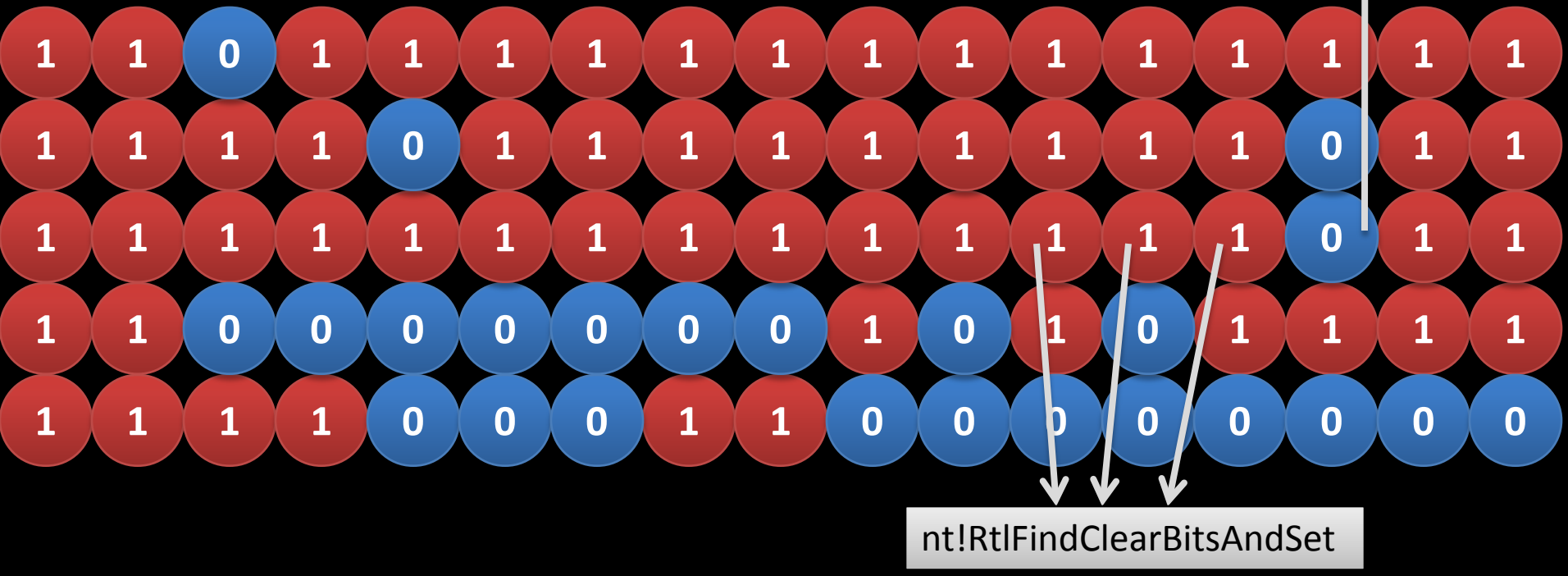
1 : Used



Request For 3 blocks

0 : Free

1 : Used



If all searches failed

0 : Free

1 : Used

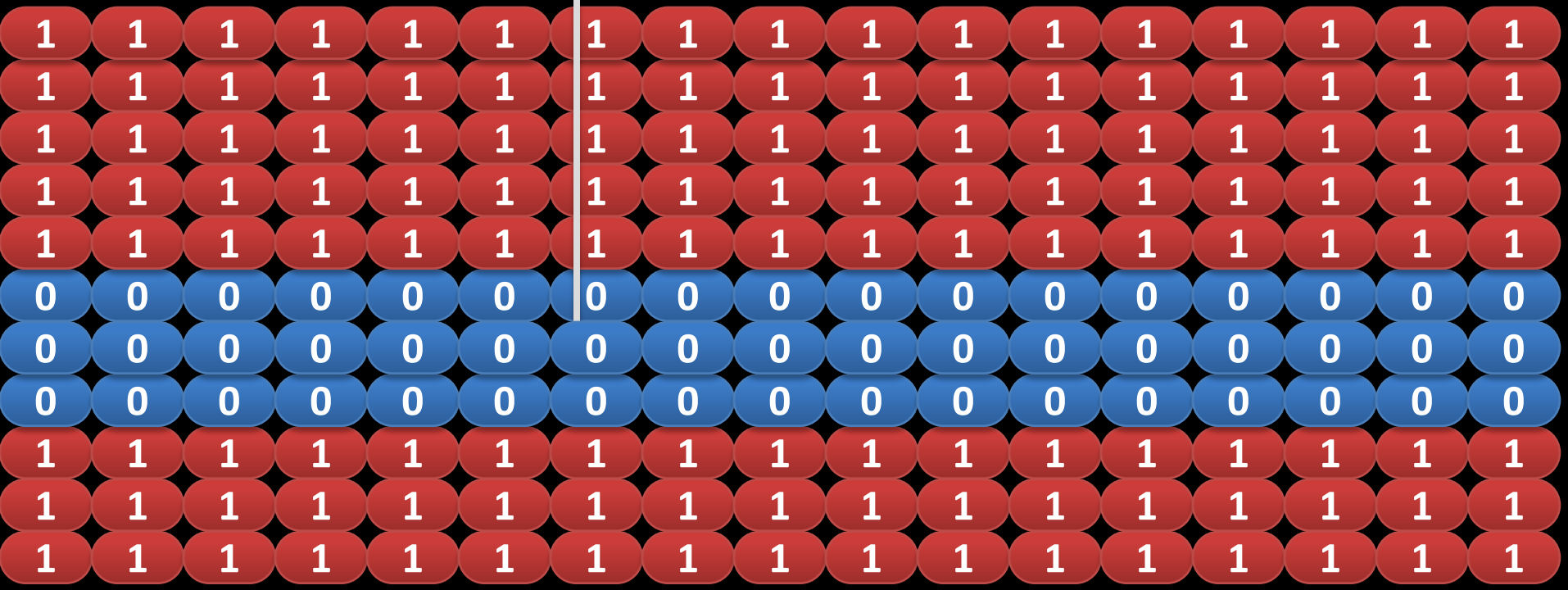
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Kernel VA dynamic allocate will taken (32bit)

0 : Free

1 : Used

MiObtainSystemVa is used to dynamically allocate VA range



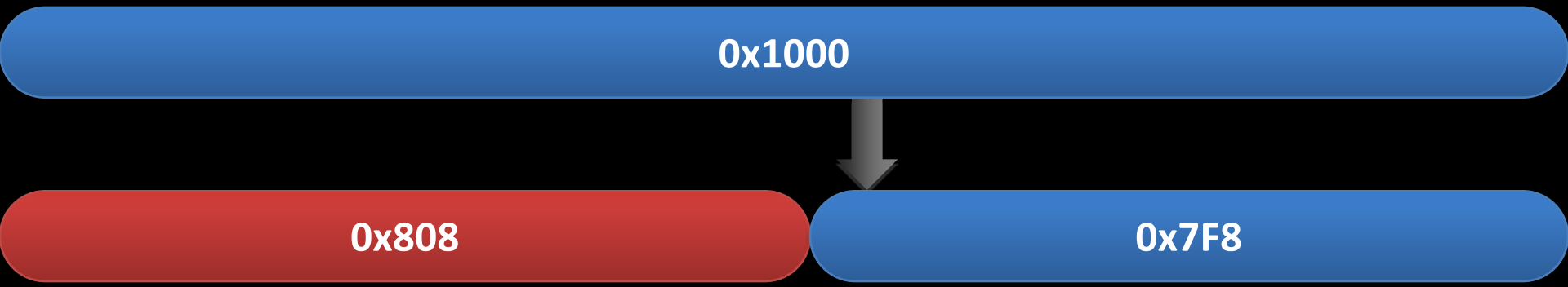
Interesting picking sequence

An empty page:

0x1000

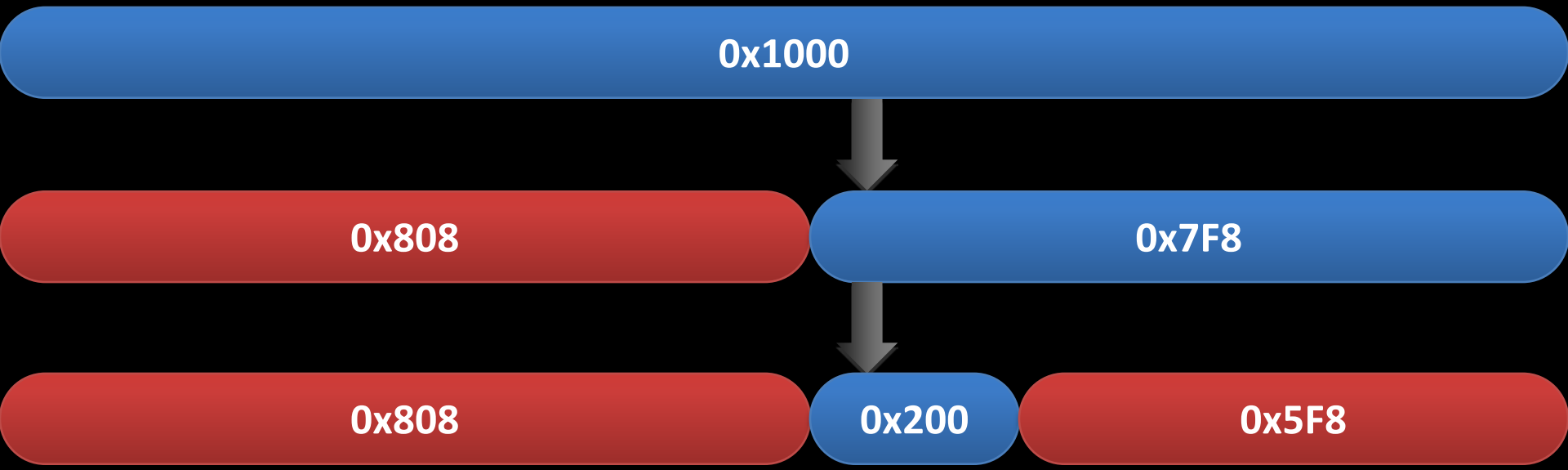
Interesting picking sequence

1st allocation picked from front:

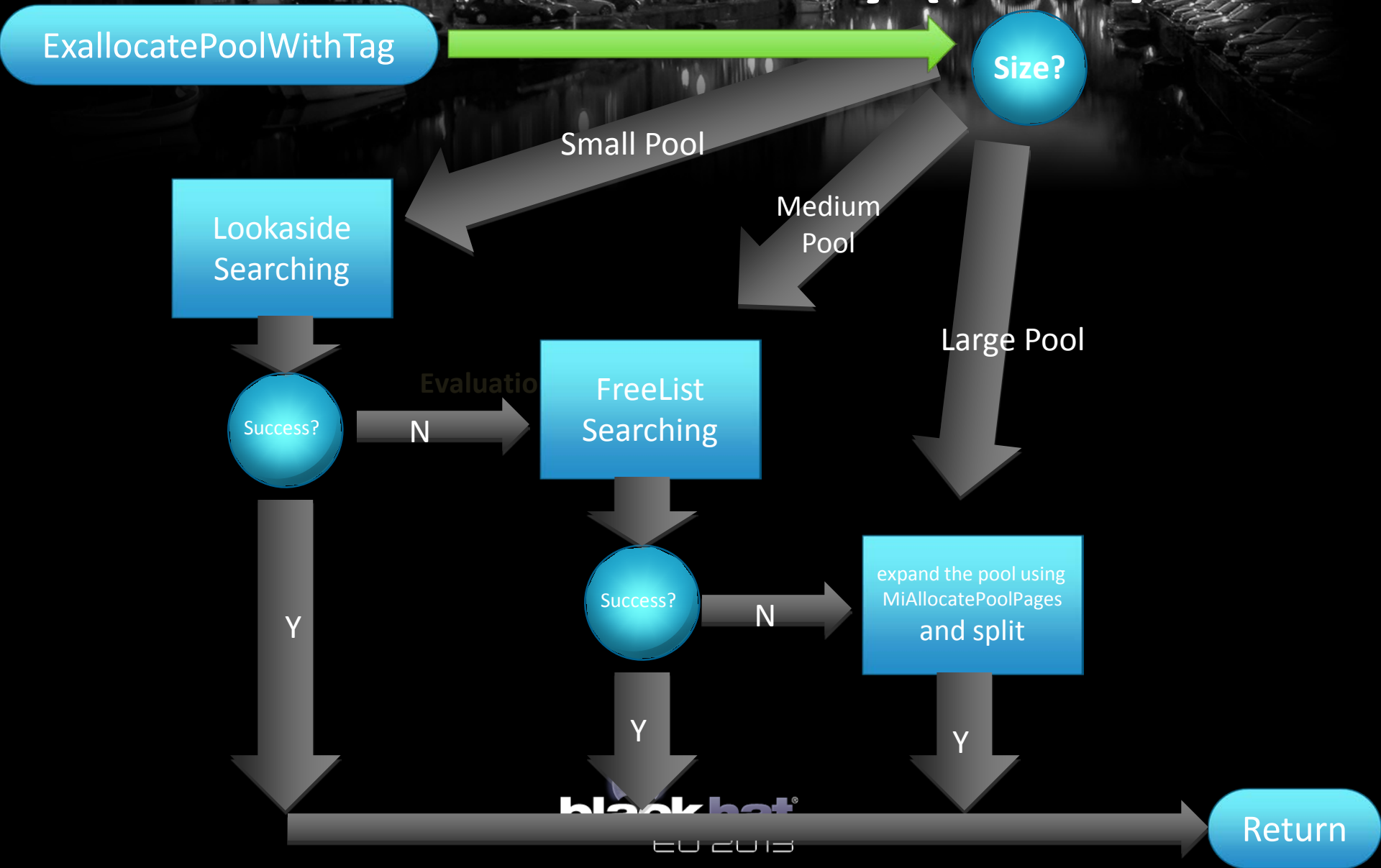


Interesting picking sequence

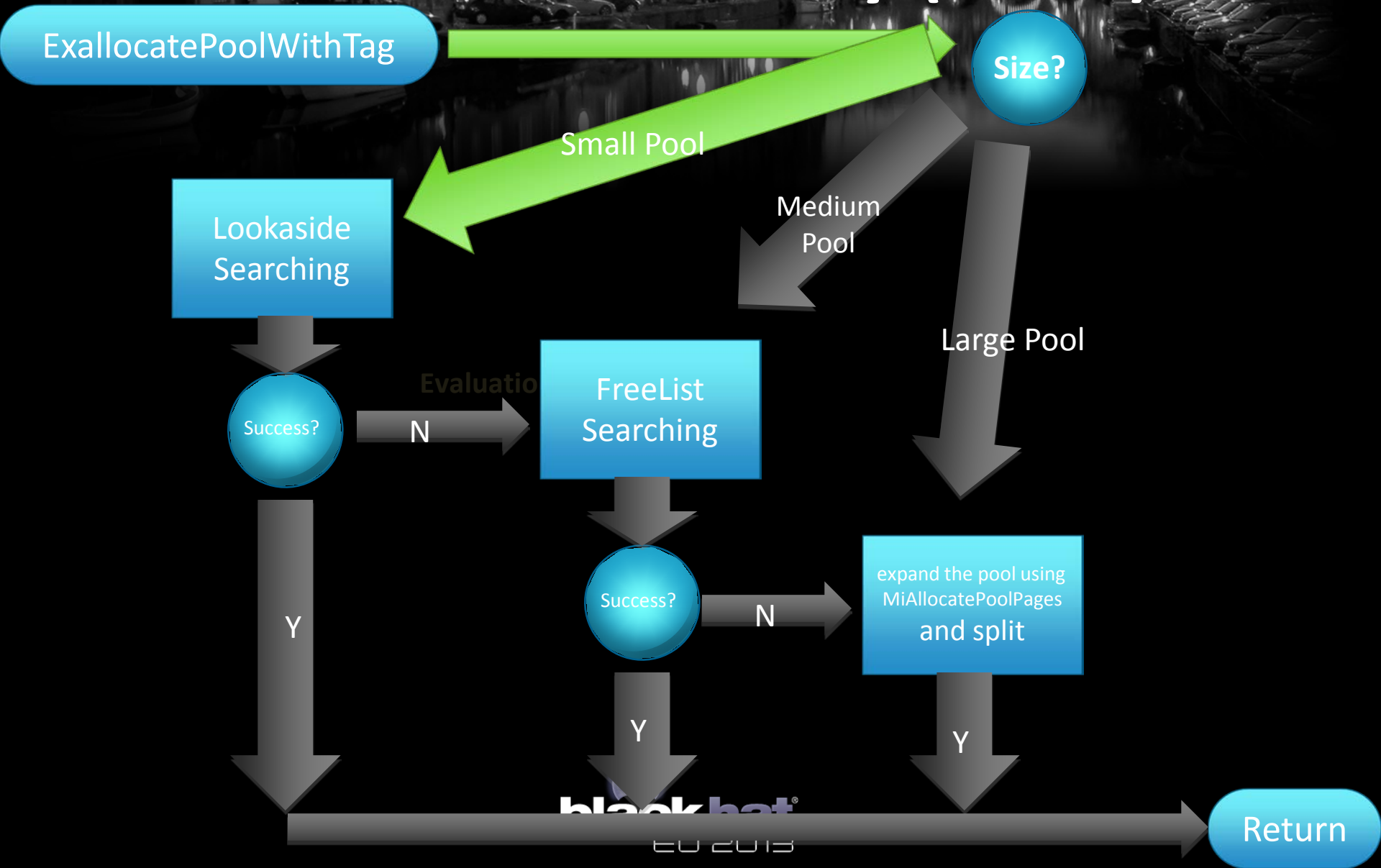
2nd allocation picked from end:



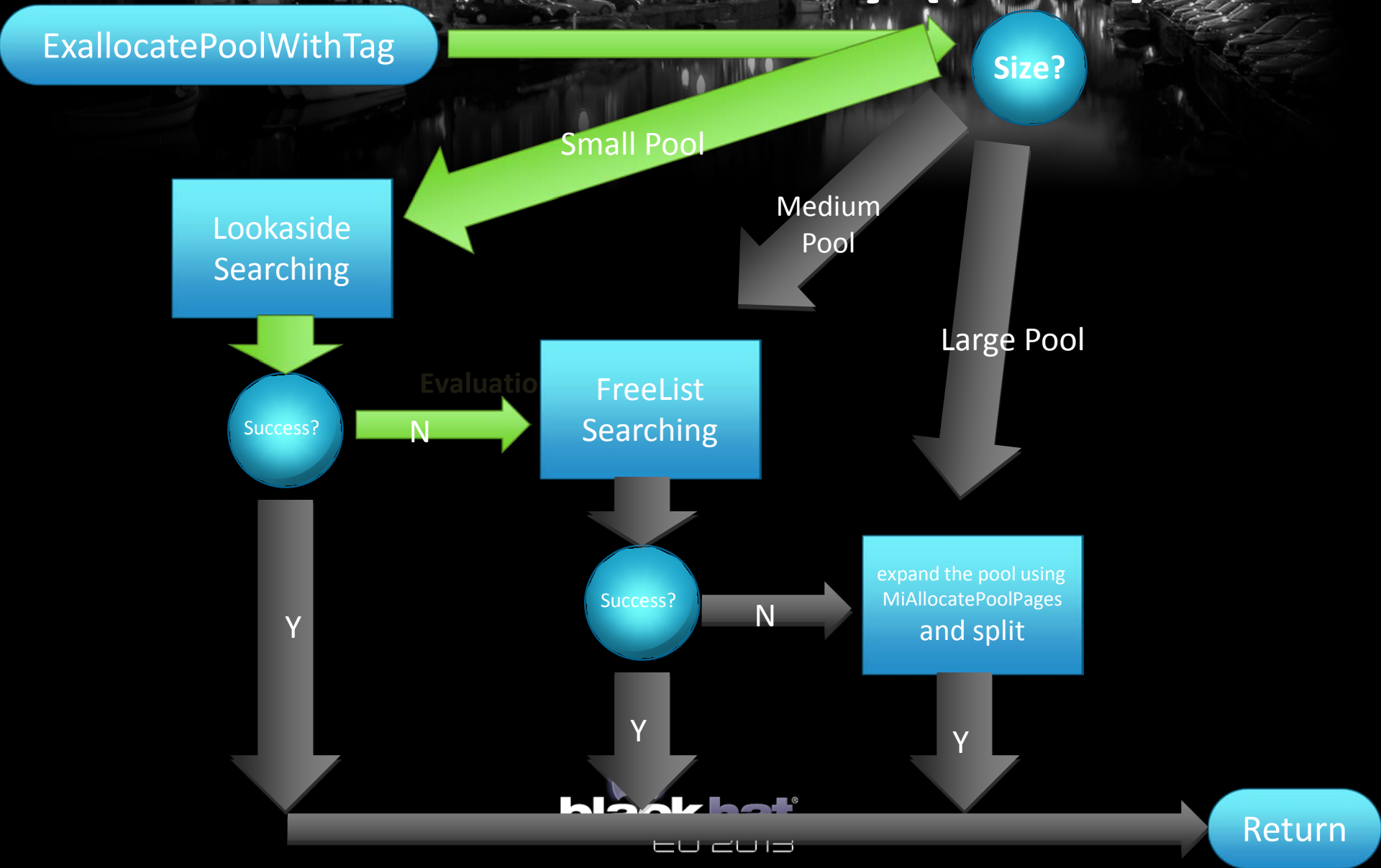
Our controlled way (small)



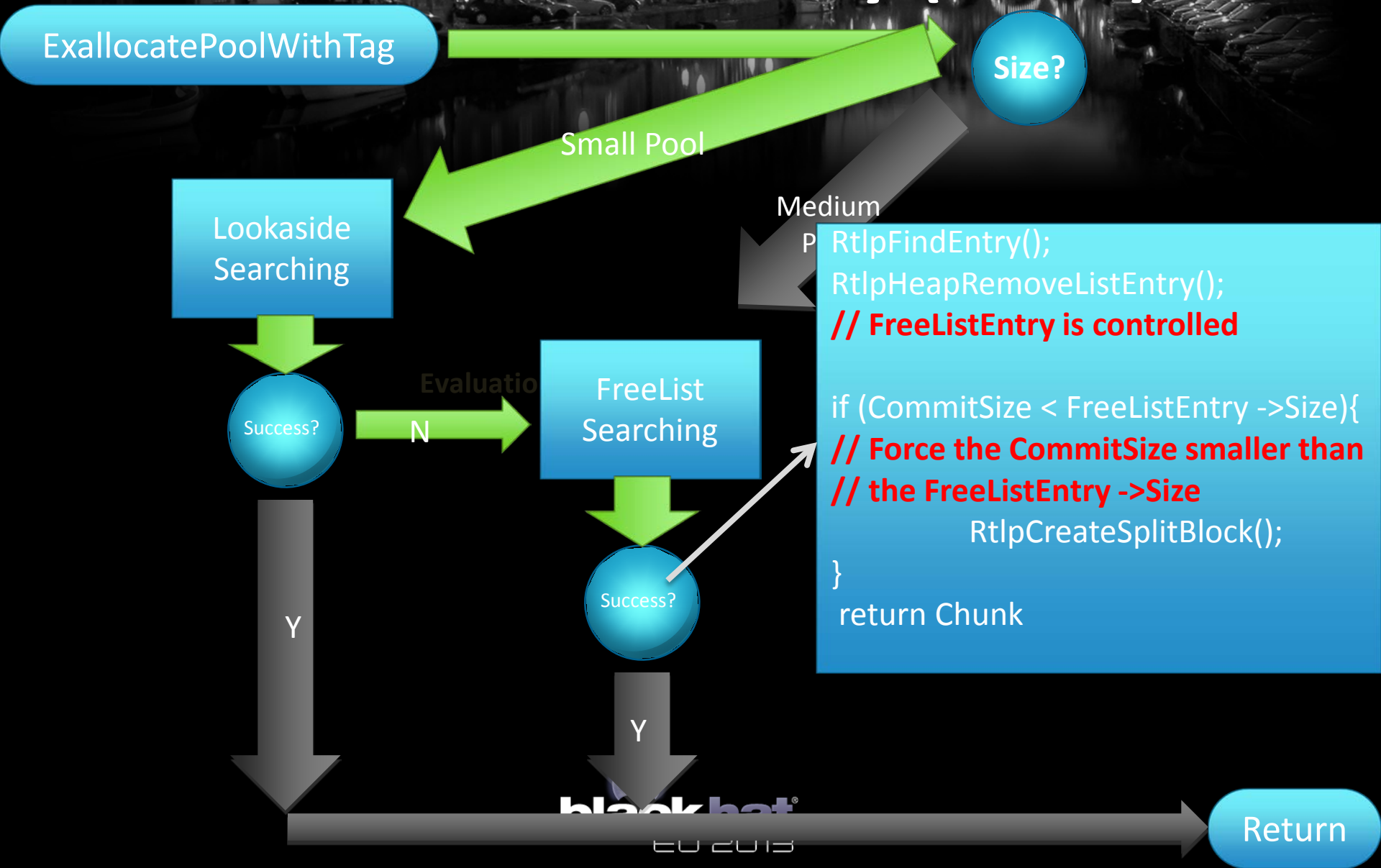
Our controlled way (small)



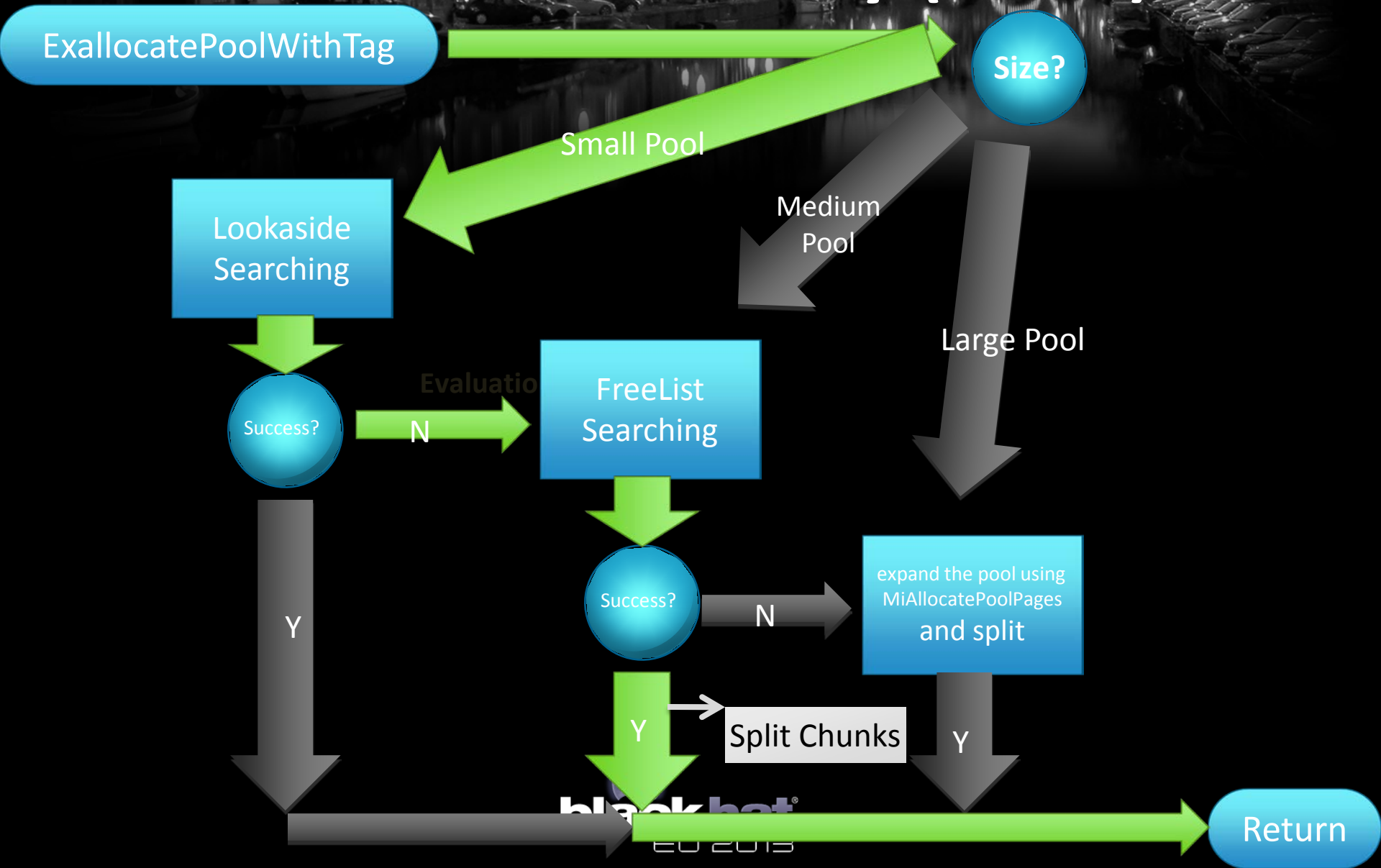
Our controlled way (small)



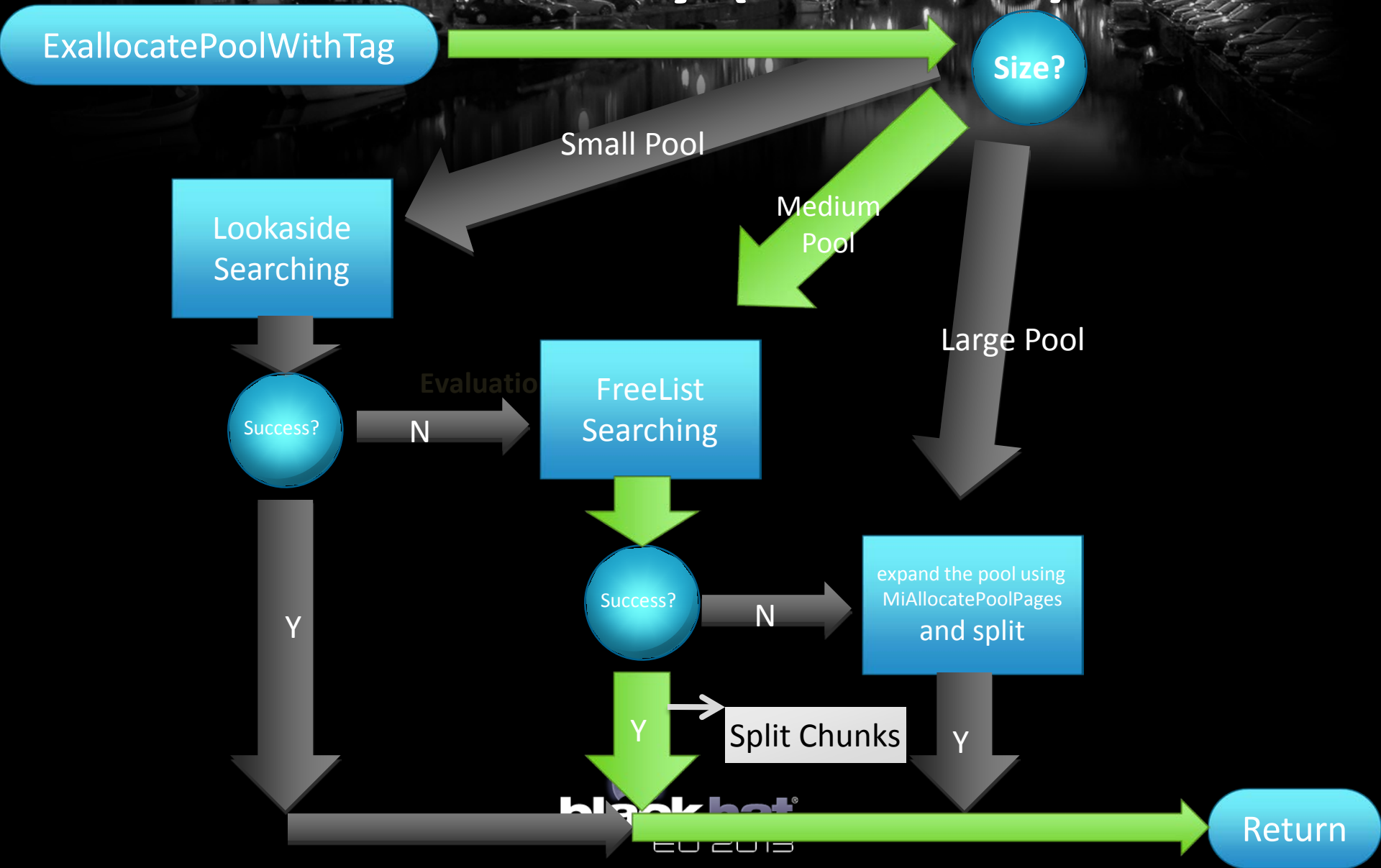
Our controlled way (small)



Our controlled way (small)



Or this way (Medium)



What about size > 0xFF0?

Daniel: Yes it will. There's always a way out...

-Quotes from Stargate SG-1 "Abyss"

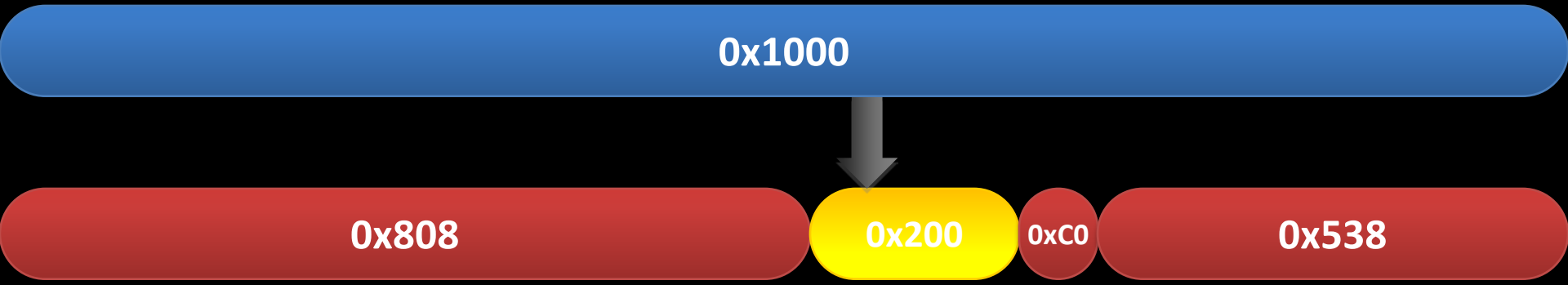
A: if (size_t < 0x400)

B: if ((size_t >= 0x400) & (size_t < 0x800))

C: if ((size_t >= 0x800) & (size_t < 0xFF0))

D: if (size_t >= 0xFF0)

A: if (size_t < 0x400)
Make holes on size 0x1000 chopping board



B: if ((size_t < 0x400) & (size_t < 0x800))
Make holes on size 0x2000 chopping board

C: if ((size_t > 0x800) & (size_t < 0xFF0))
Make holes on size 0x3000 chopping board

D: if (size_t > 0xFF0)

Vulnerable buf will be allocated by MiAllocatePoolPages directly

Demo of this section

2.01:
Windows Objects in Kernel Vulnerability Exploitation

Exploitation in Windows 7 (Bonus)

- kd> dt nt!_OBJECT_HEADER
  +0x000 PointerCount : Int4B
  +0x004 HandleCount : Int4B
  +0x004 NextToFree : Ptr32 Void
  +0x008 Lock : _EX_PUSH_LOCK
  +0x00c TypeIndex : Uchar // used to be a Ptr in XP
  +0x00d TraceFlags : UChar
  +0x00e InfoMask : UChar
  +0x00f Flags : UChar
  +0x010 ObjectCreateInfo : Ptr32 _OBJECT_CREATE_INFORMATION
  +0x010 QuotaBlockCharged : Ptr32 Void
  +0x014 SecurityDescriptor : Ptr32 Void
  +0x018 Body : _QUAD

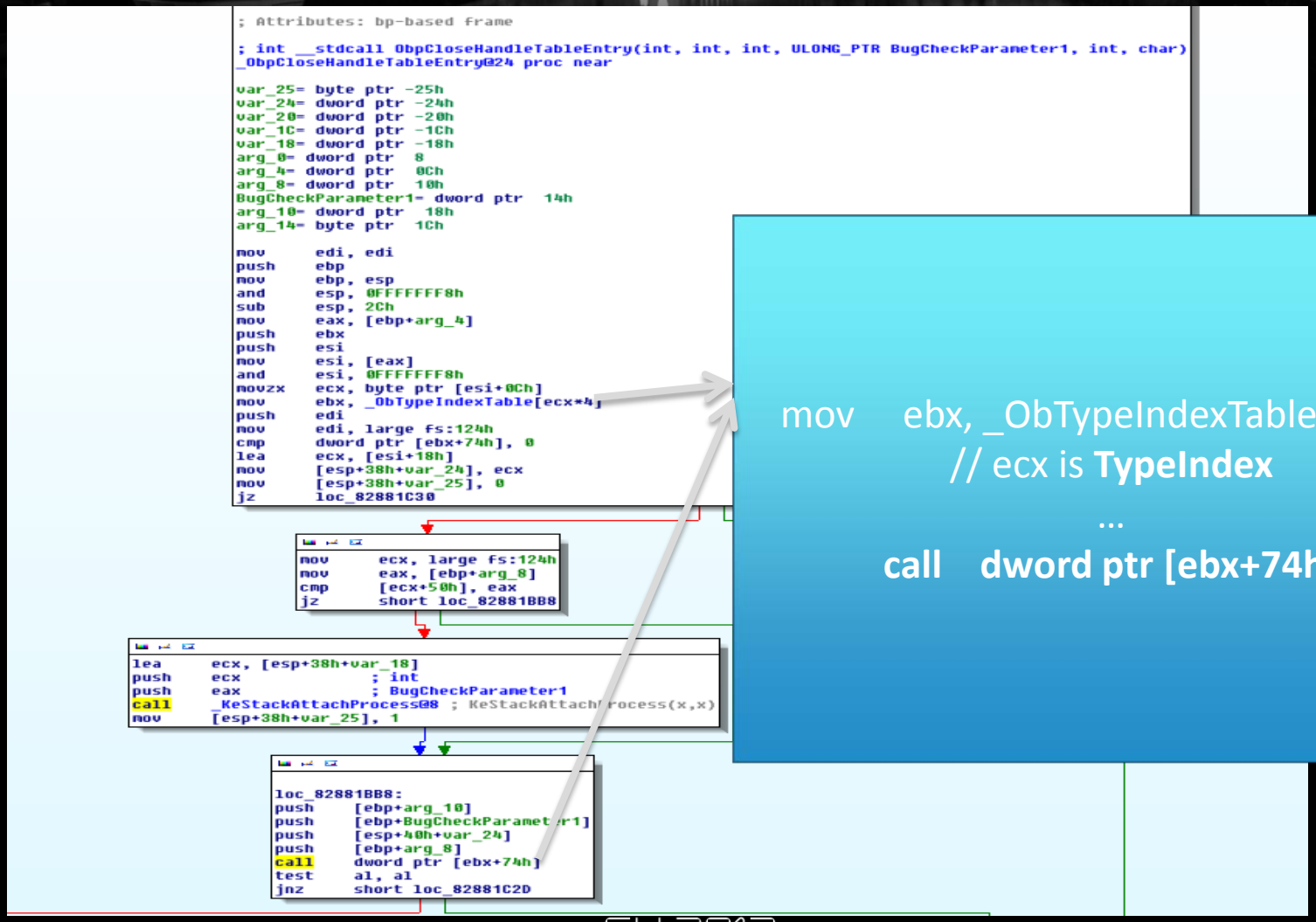
Exploitation in Windows 7 (Bonus)

0x01: InitTrampoline:
Mapping VA 0x0 through NtAllocateVirtualMemory

0x02: Modify **TypeIndex**

Then..

0x03:
Jump into shellcode when CloseHandle()



Exploitation in Windows 8 (Mateusz ‘j00ru’ Jurczyk way)

- kd> dt nt!_KTIMER 84247538

  +0x000 Header : _DISPATCHER_HEADER

  +0x010 DueTime : _ULARGE_INTEGER 0x4`9b8e6360

  +0x018 TimerListEntry : _LIST_ENTRY [0x85360160 - 0x82765ce4]

  +0x020 Dpc : 0x84247590 _KDPC

  +0x024 Period : 0x7d0

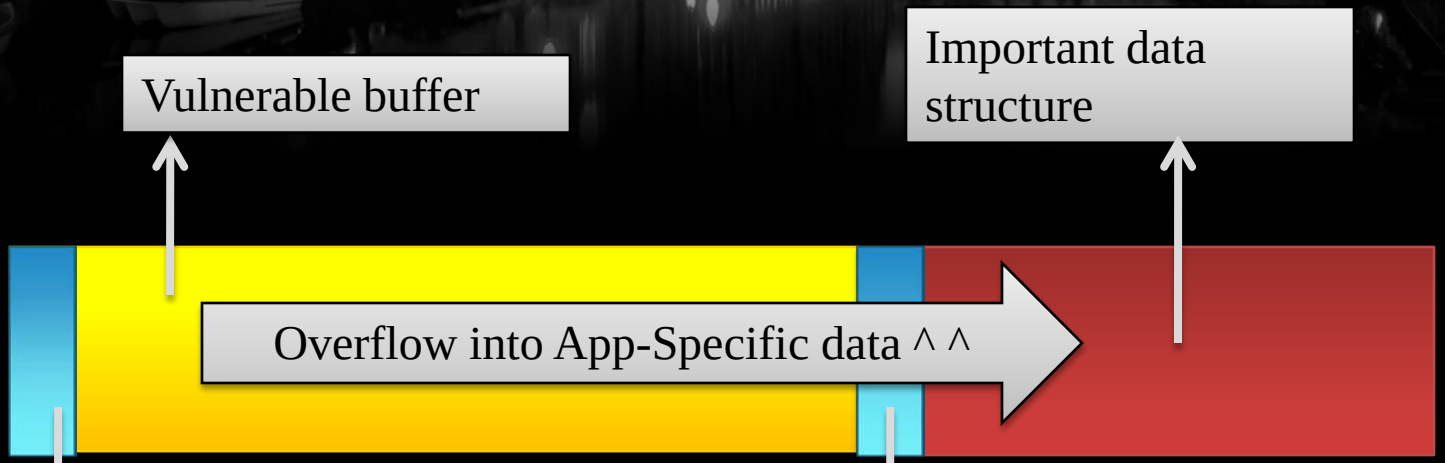
Exploitation in Windows 8 (Mateusz ‘j00ru’ Jurczyk way)

- kd> dt nt!_KDPC

```
+0x000 Type             : UChar
+0x001 Importance       : UChar
+0x002 Number           : Uint2B
+0x004 DpcListEntry     : _LIST_ENTRY
+0x00c DeferredRoutine  : Ptr32     void
+0x010 DeferredContext  : Ptr32 Void
+0x014 SystemArgument1  : Ptr32 Void
+0x018 SystemArgument2  : Ptr32 Void
+0x01c DpcData          : Ptr32 Void
```

2.02:
Practical exploiting
kernel pool Overflow / Corruption

Exploiting Kernel Pool Overflow / Corruption



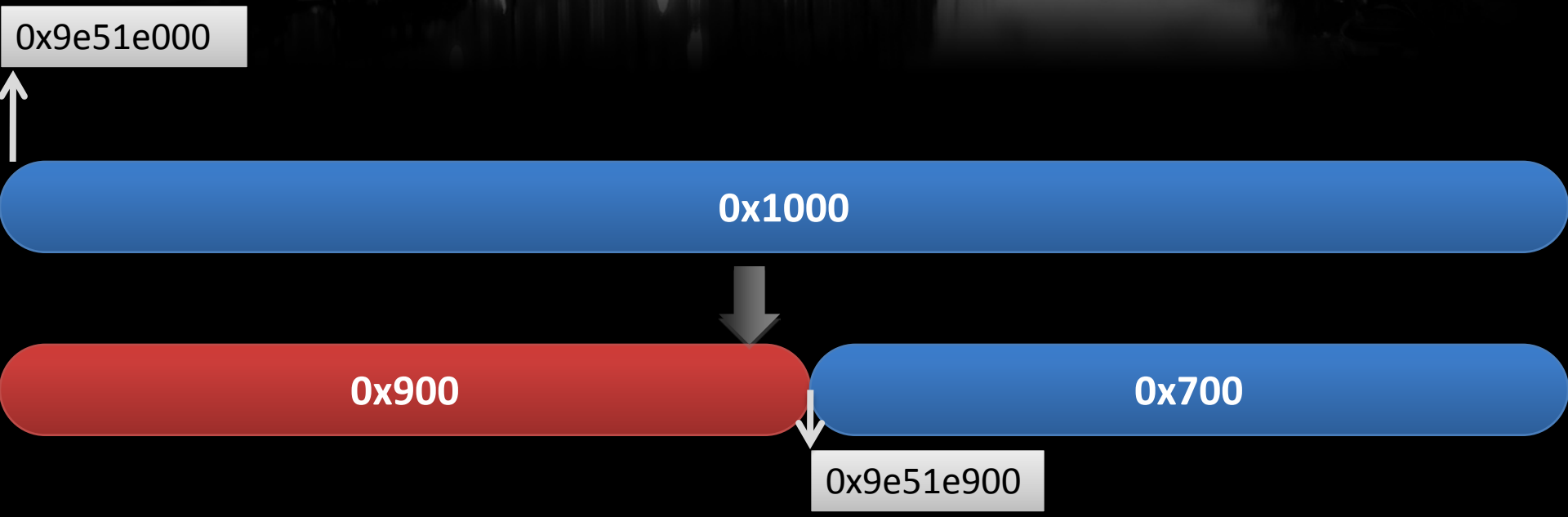
2.03:
Practical Exploiting write-what-where vulnerability

Place object at a predictable address

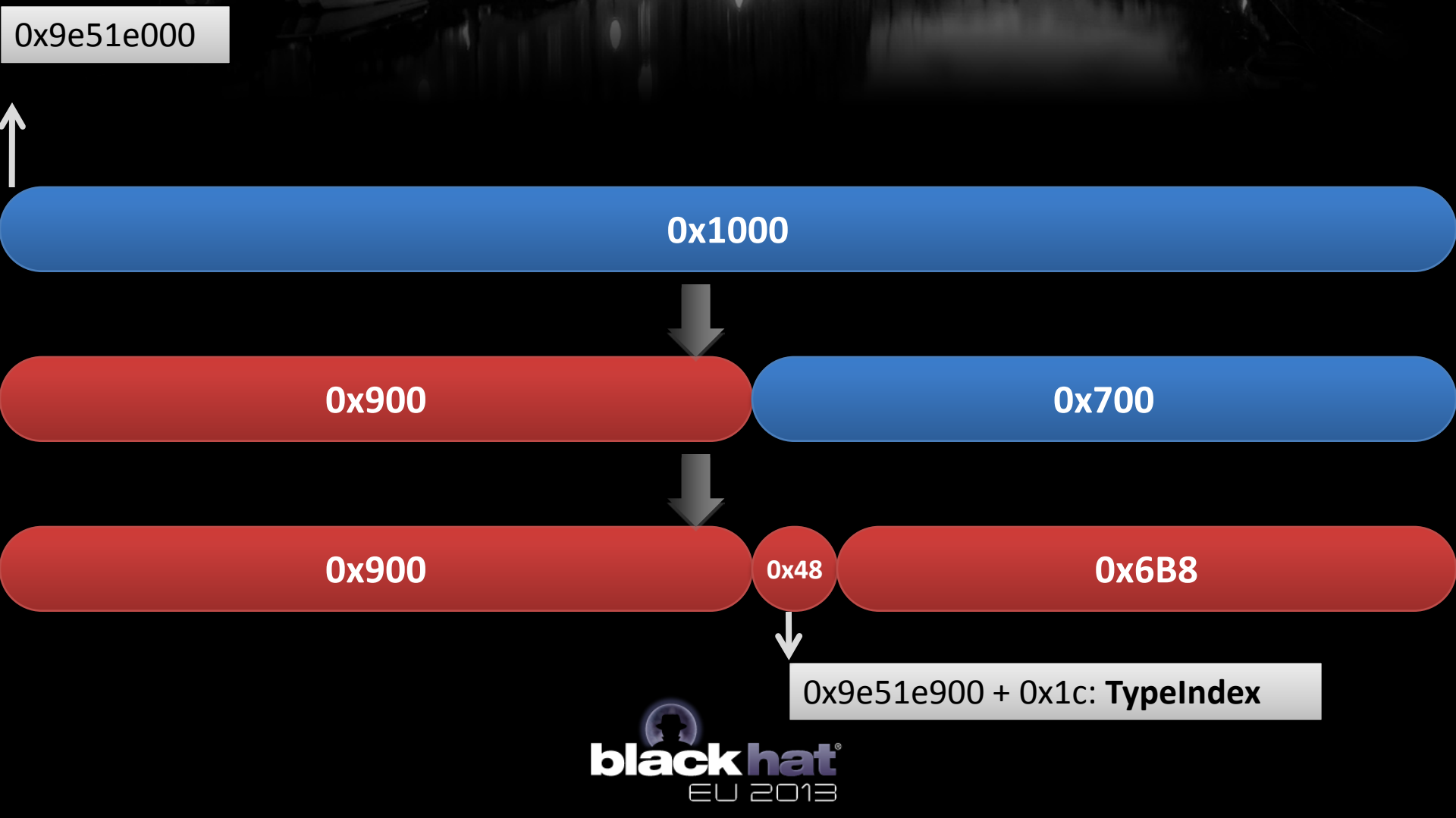
0x9e51e000
(a relative high address, supposed be reached only through heap spray)

0x1000

Place object at a predictable address



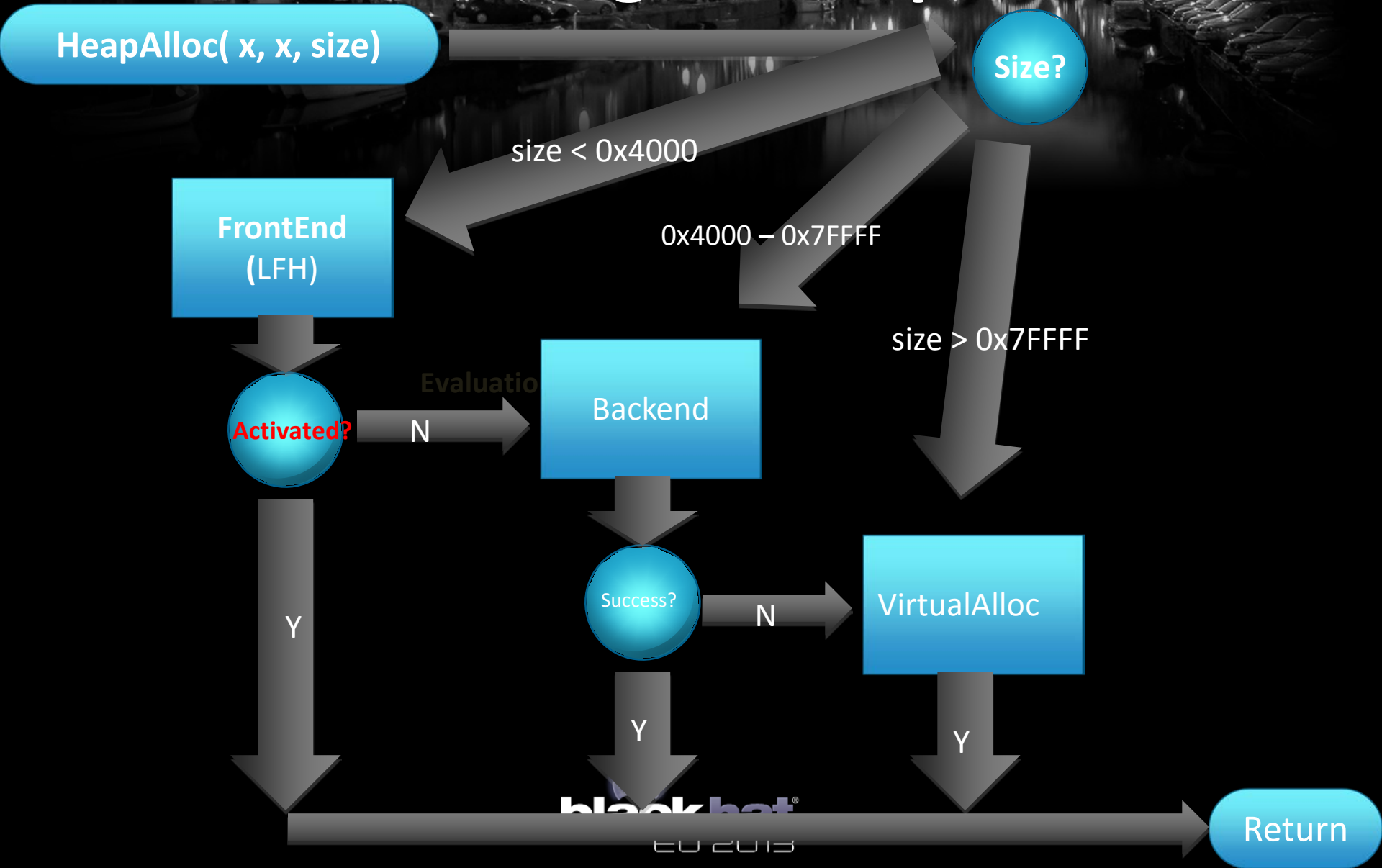
Place object at a predictable address



Demo

0x03:
Implementation in User Heap

Allocation Algorithm pre-view



3.01:
Practical Attacking
_HEAP_USERDATA_HEADER

_HEAP_USERDATA_HEADER

- Idea brought by Chris Valasek

- Chunk = UserBlocks + RandIndex * BlockStride + FirstAllocationOffset

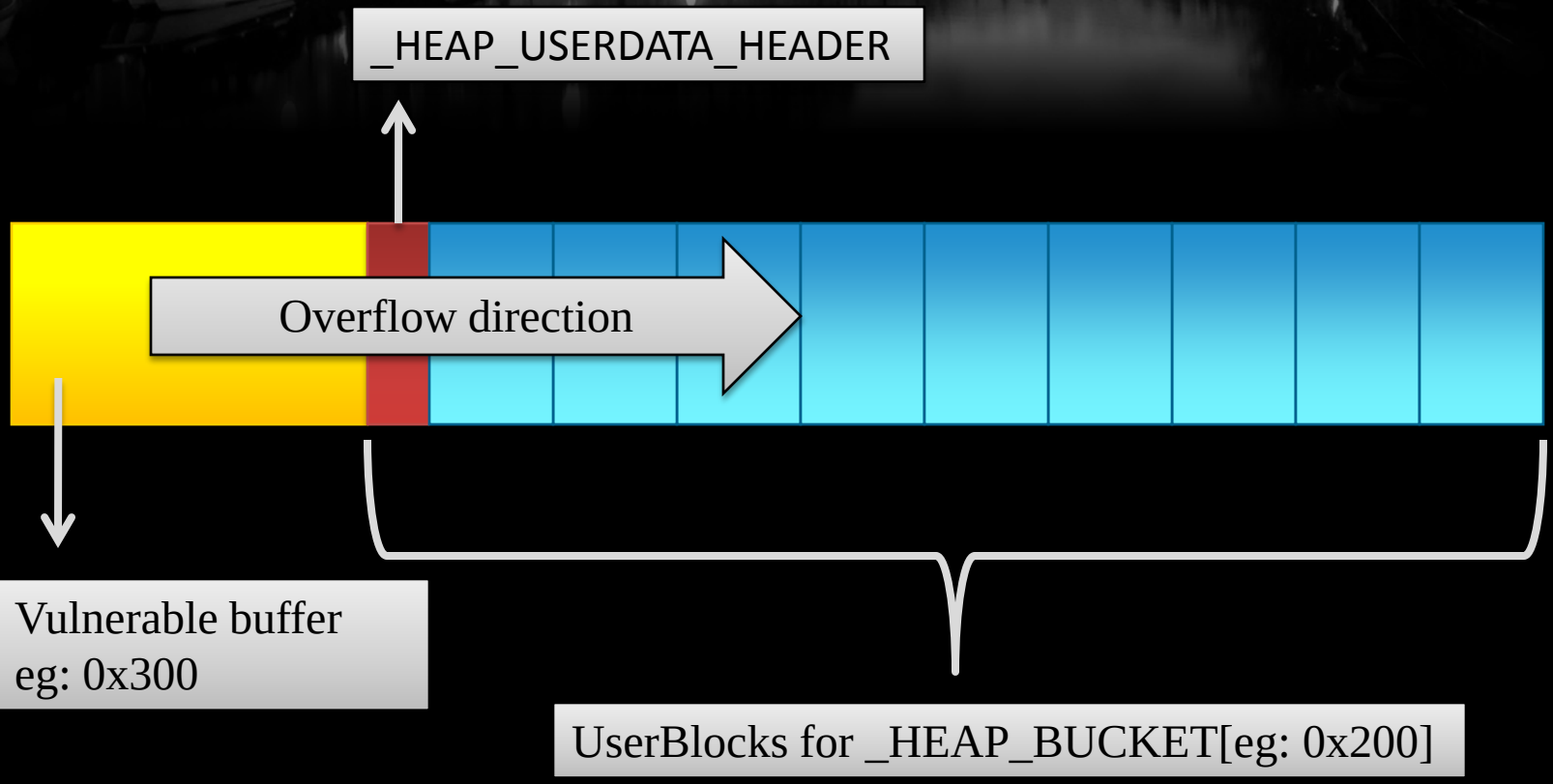
Two Challenges

- 18 times of allocations will trigger LFH

- 400 times of allocations will trigger guard pages.

_HEAP_USERDATA_HEADER	_HEAP_ENTRY	_HEAP_ENTRY	Vul buf	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY
GP – PAGE_NOACCESS						
_HEAP_USERDATA_HEADER	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY
GP – PAGE_NOACCESS						
_HEAP_USERDATA_HEADER	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY

The target



to position the vulnerable buffer just BEFORE an important structure.

Like: _HEAP_USERDATA_HEADER structure

Mandatory Search in Action

- Defragment using chunk 0x4000 - 0x7FFFF.

- Freeing (0x70100) --> Allocating (0x70000)
  Could make 0x100 hole.
  Hey, get out of my way -- LFH

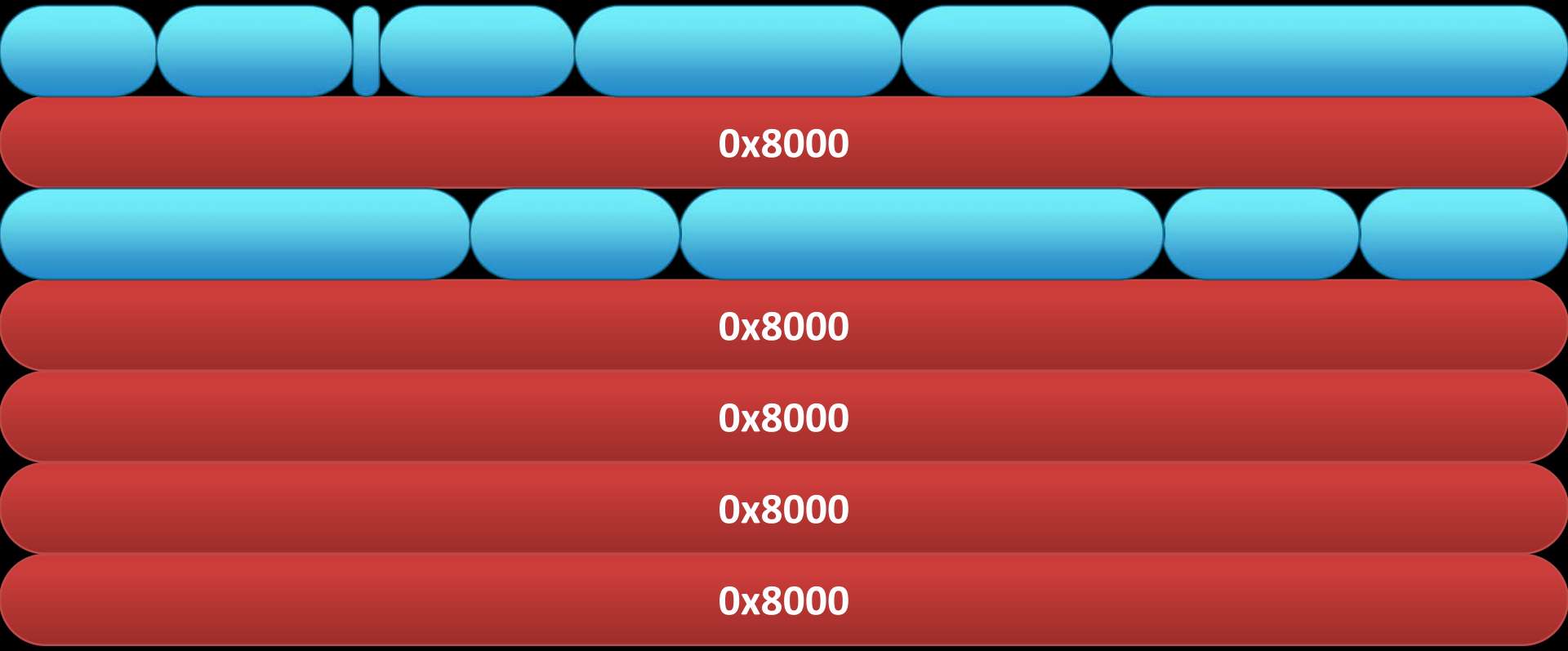
- The size of UserBlocks (total size) is fixed.

Taken

Noise

Free

0x01: Defragment

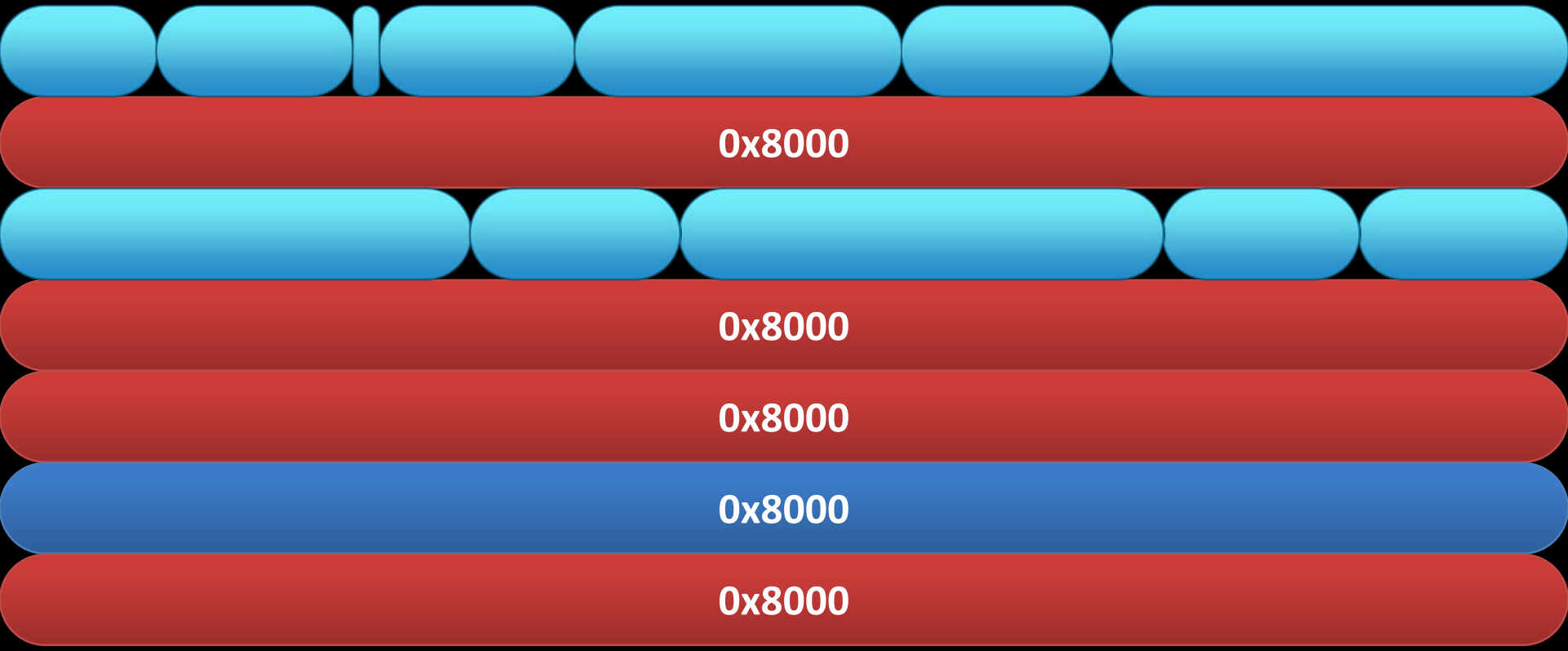


Taken

Noise

Free

0x02: Freeing

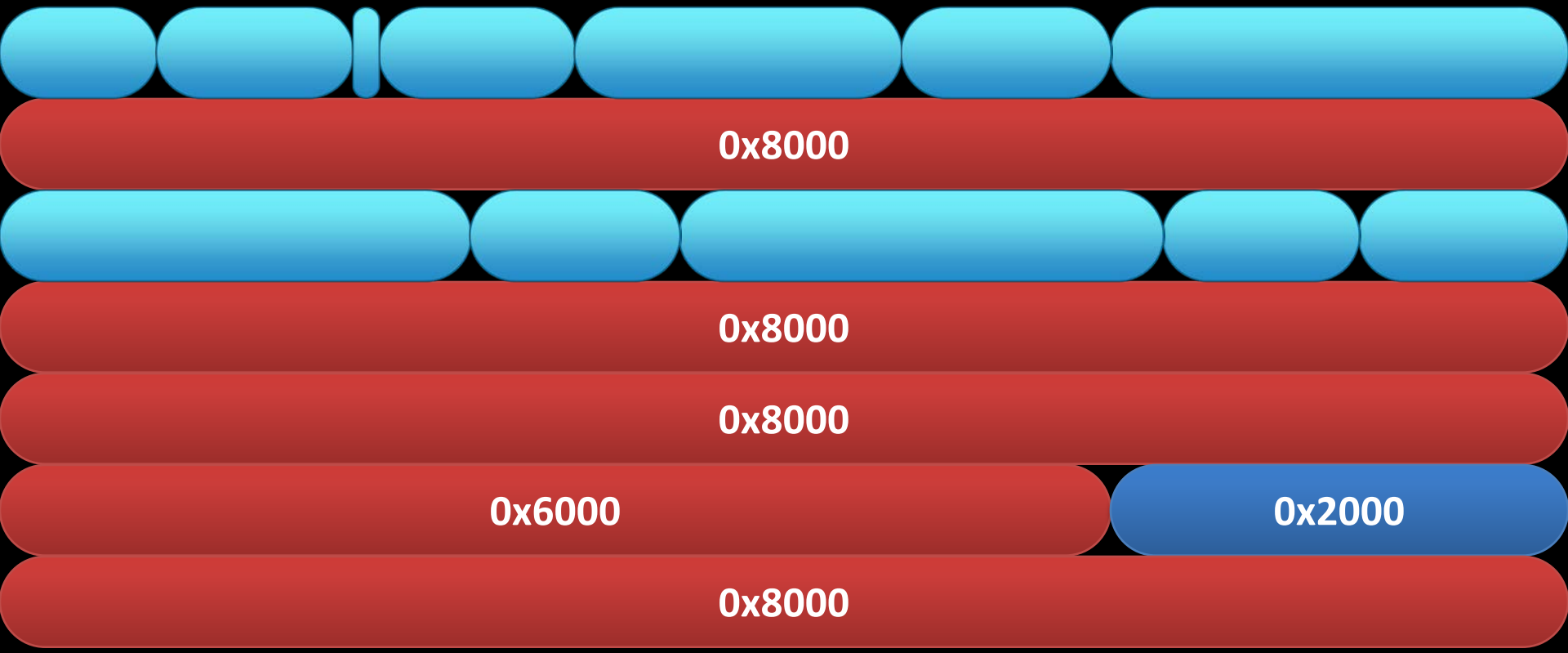


Taken

Noise

Free

0x03: Alloc 0x6000 block and make 0x2000 hole

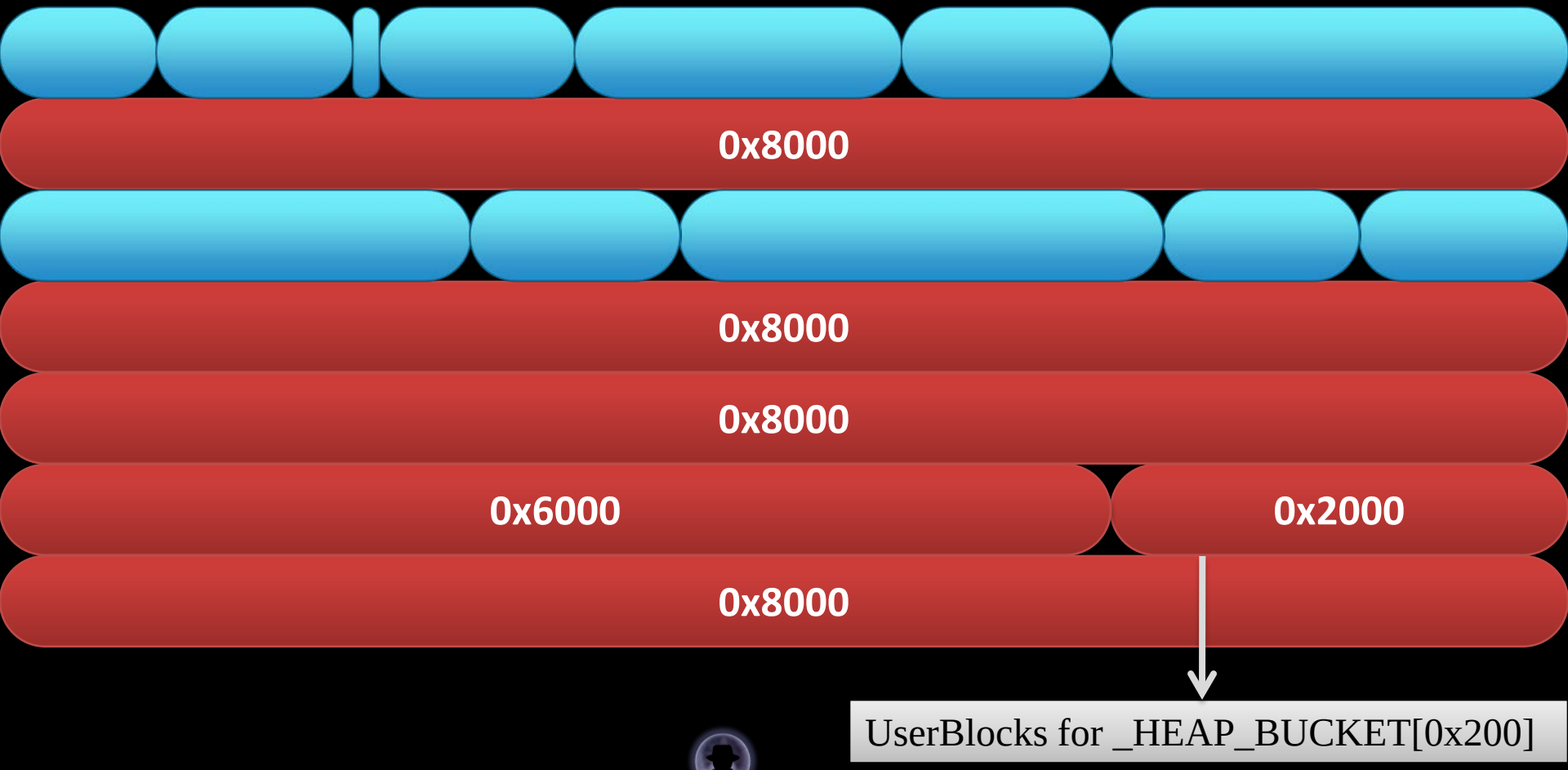


Taken

Noise

Free

0x04: Trigger LFH (0x200)



0x6000

_HEAP_USERDATA_HEADER	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY
_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY
_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY

UserBlocks for _HEAP_BUCKET[0x200]

0x6000

_HEAP_USERDATA_HEADER	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY
_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY
_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY

0x6000 – 0x300

0x300

_HEAP_USERDATA_HEADER	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY
_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY
_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY

0x6000 – 0x300

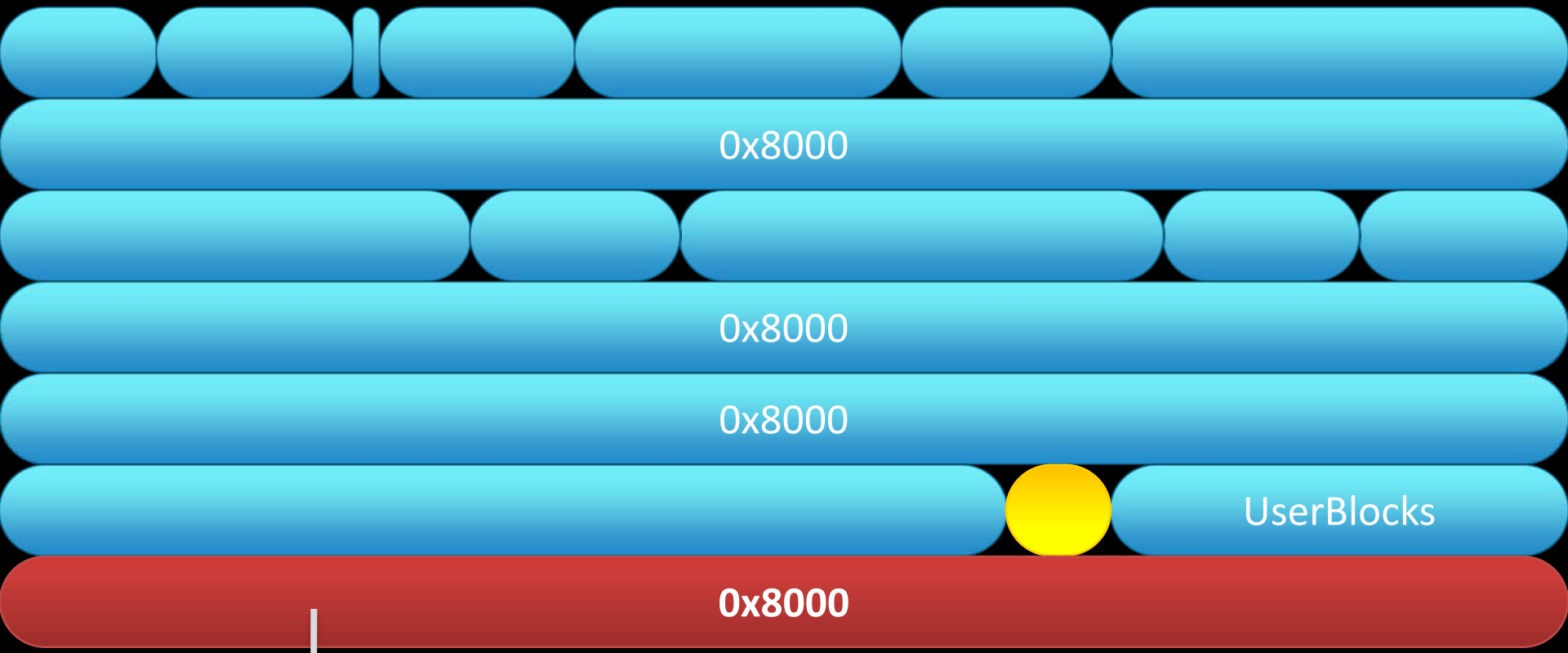
0x300

_HEAP_USERDATA_HEADER	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY
_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY
_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY	_HEAP_ENTRY

Vul buffer

Controlled

Future allocation will get controlled after overflow



Future allocation s will fall into this controlled area.

Applicable circumstance (Prerequisites)

- The LFH of the certain bin size has not been activated by the time of allocation.

(no 16 consecutive allocations of the vulnerable buffer's size)

- Allocate Buffer of Arbitrary Size w/ Arbitrary Content

- Free Buffer of Arbitrary Size

- Programmatic Control of Allocations and Frees

The exploitation process:

Step 0: Figure out the vulnerability
Step 1: Heap Feng Shui.
Step 2: Trigger the overflow, modify "FirstAllocationOffset”
Step 3: Allocate new objects with proper size.
Step 4: Modify new object’s content.
Step 5: Control the EIP.

3.02:
Practical Heap Determining in IE 10

Conclusion

Questions?