VULNERABILITY IS A LUCKY BUG

BY ARTEM SHISHKIN

DISCLAIMER

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WHOAMI

- Security researcher at Intel Corporation
- Intel STORM team member
- Windows kernel enthusiast

SPOT THE POTENTIAL BUG

```
int CaptureInput(PINPUT_TYPE pInputStruct)
{
    if (pInputStruct->OptionalDataSize > MAX_OPTIONAL_DATA_SIZE)
        return -EINVAL;
    memcpy(pTarget, pInputStruct->OptionalData,
        pInputStruct->OptionalDataSize);

    return 0;
}
```

HERE IT IS

```
int CaptureInput(PINPUT_TYPE pInputStruct)
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```

HOW LUCKY THIS BUG IS SUPPOSED TO BE TO BECOME A SECURITY ISSUE?

SINGLE THREADED ENVIRONMENT

- Not exploitable
  - Well, who is going to attack the value otherwise?

SINGLE THREADED ENVIRONMENT

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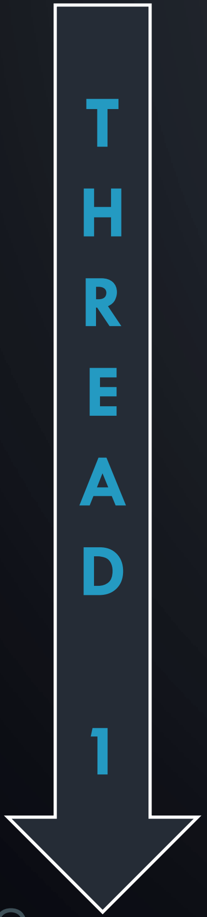

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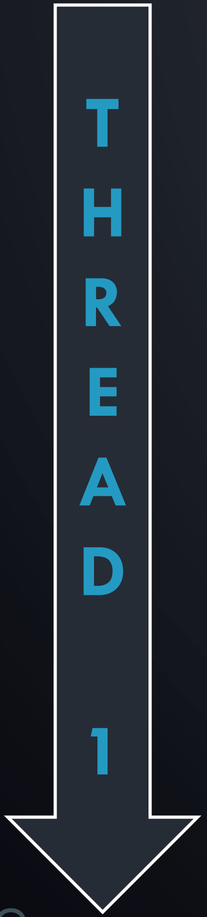

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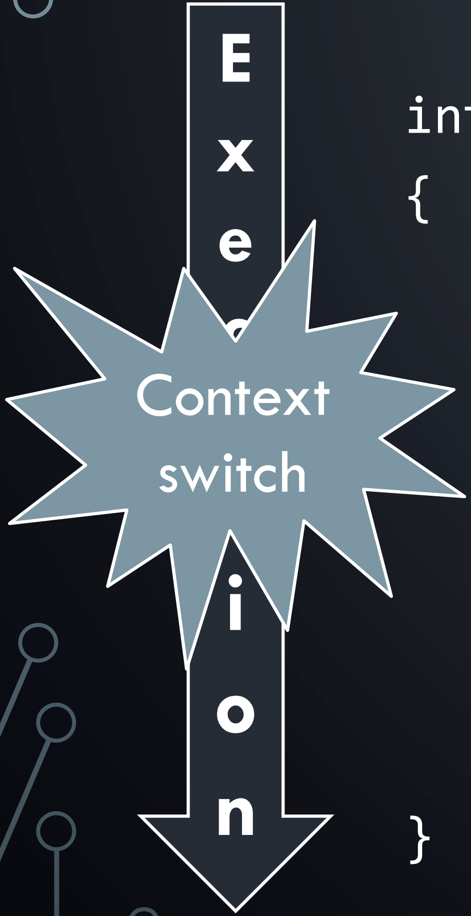
MULTITHREADED ENVIRONMENT

- Code is executed within the threads
- Thread is a basic scheduling unit on Windows
- Thread quantum is large (measured in milliseconds)
  - The race window is too small compared to the quantum duration
- Not exploitable in this case
  - Could be in a case with scheduling interruption in the race window

MULTITHREADED ENVIRONMENT



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int CaptureInput(PINPUT_TYPE pInputStruct)
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    if (pInputStruct->OptionalDataSize > MAX_OPTIONAL_DATA_SIZE)
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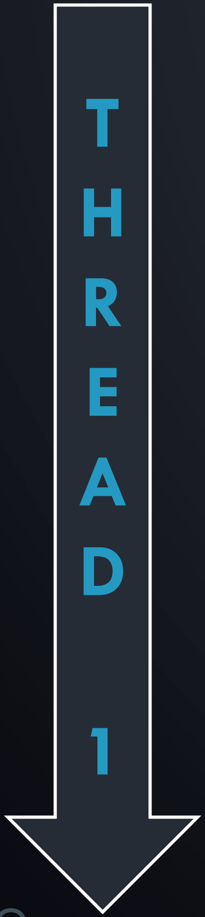

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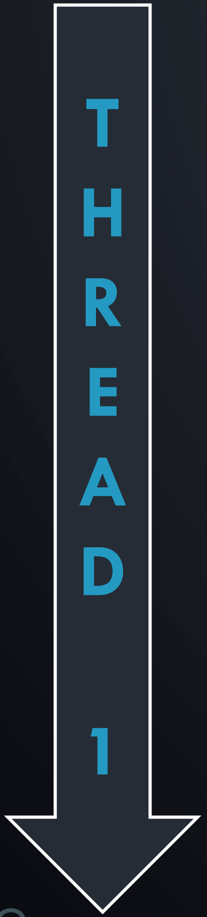

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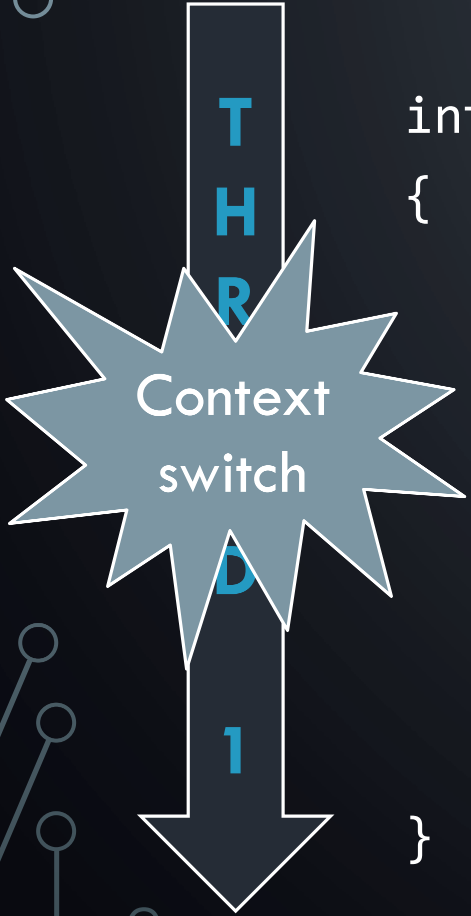

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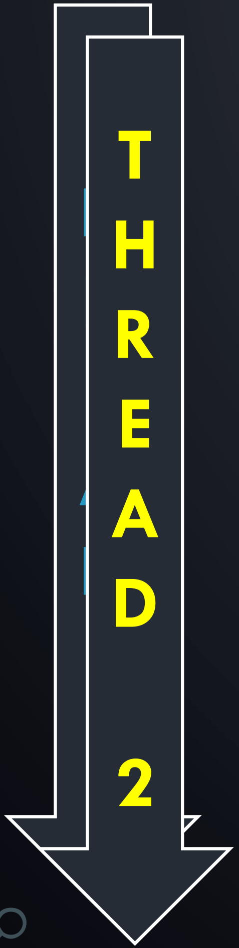

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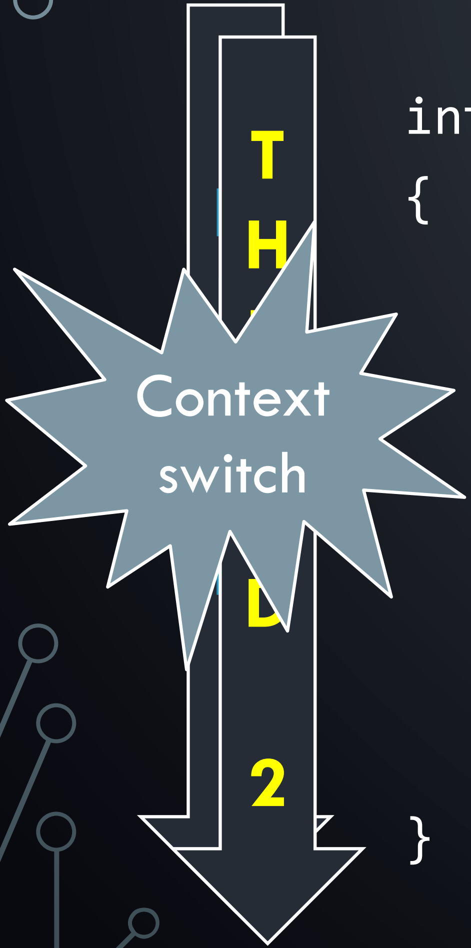

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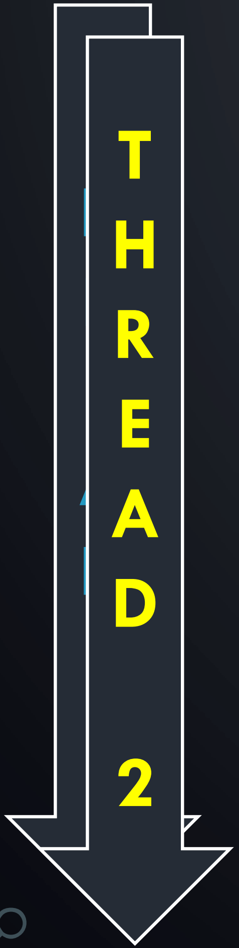

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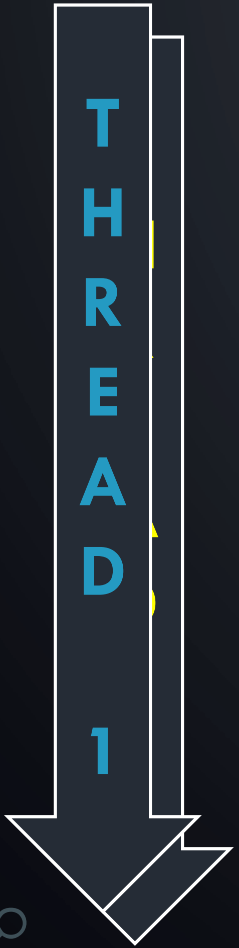

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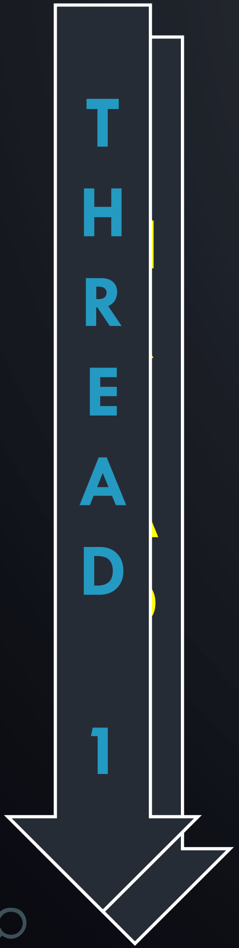

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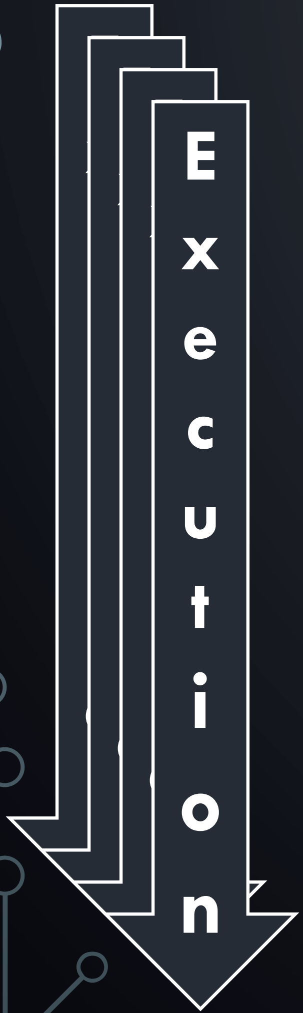
MULTITHREADED MULTICORE ENVIRONMENT

- CPU cores execute code simultaneously
- So we can schedule thread execution on different CPU cores
- So, exploitable?

MULTITHREADED MULTICORE ENVIRONMENT



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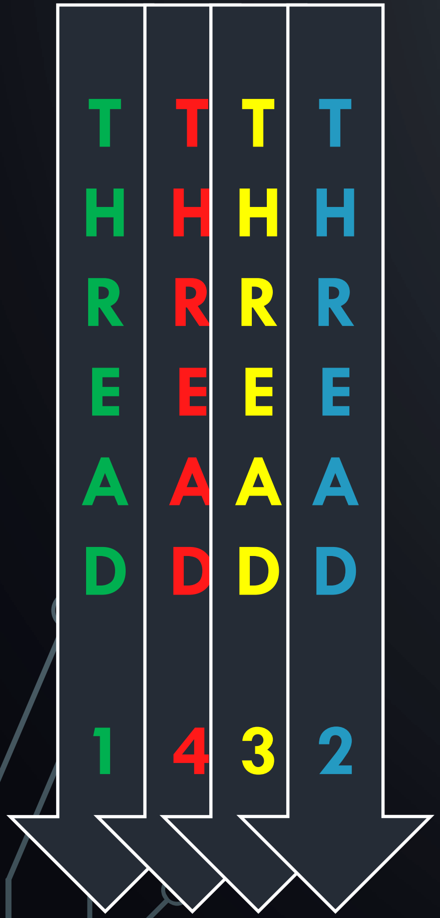

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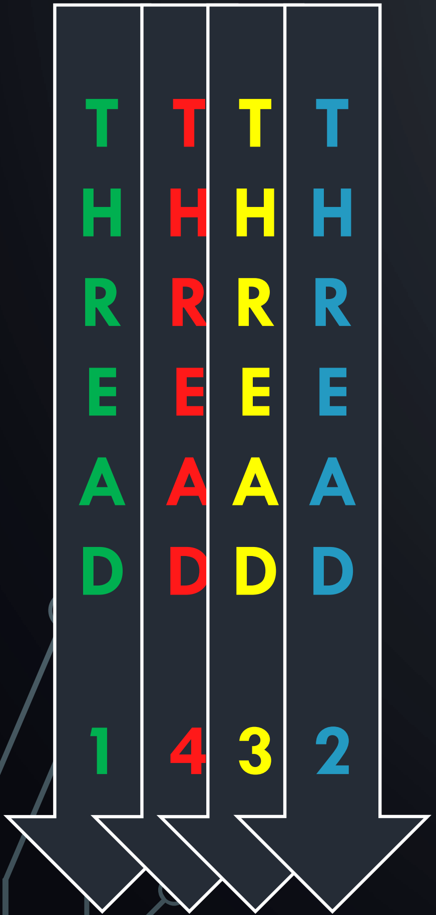

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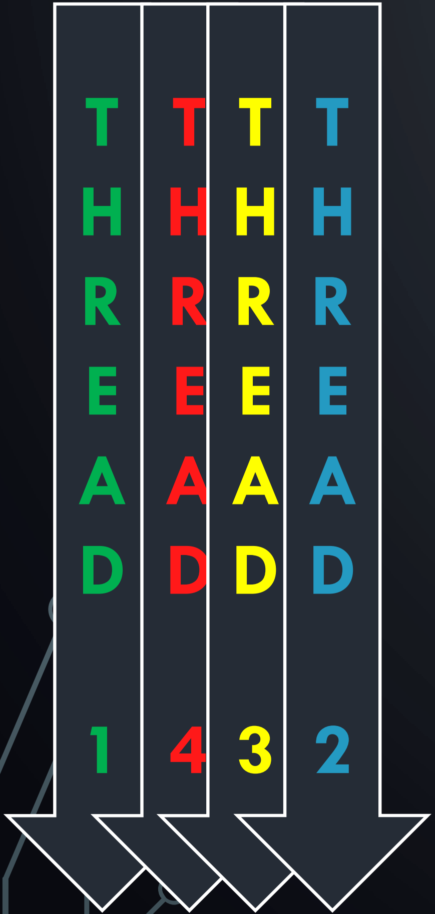

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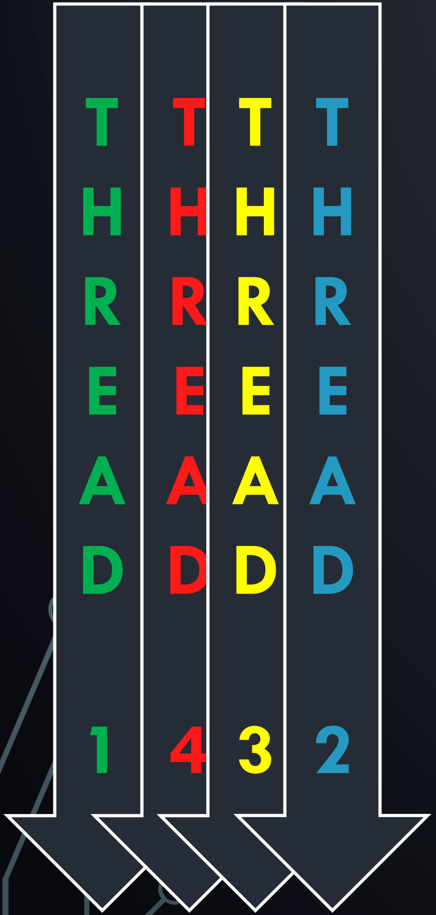

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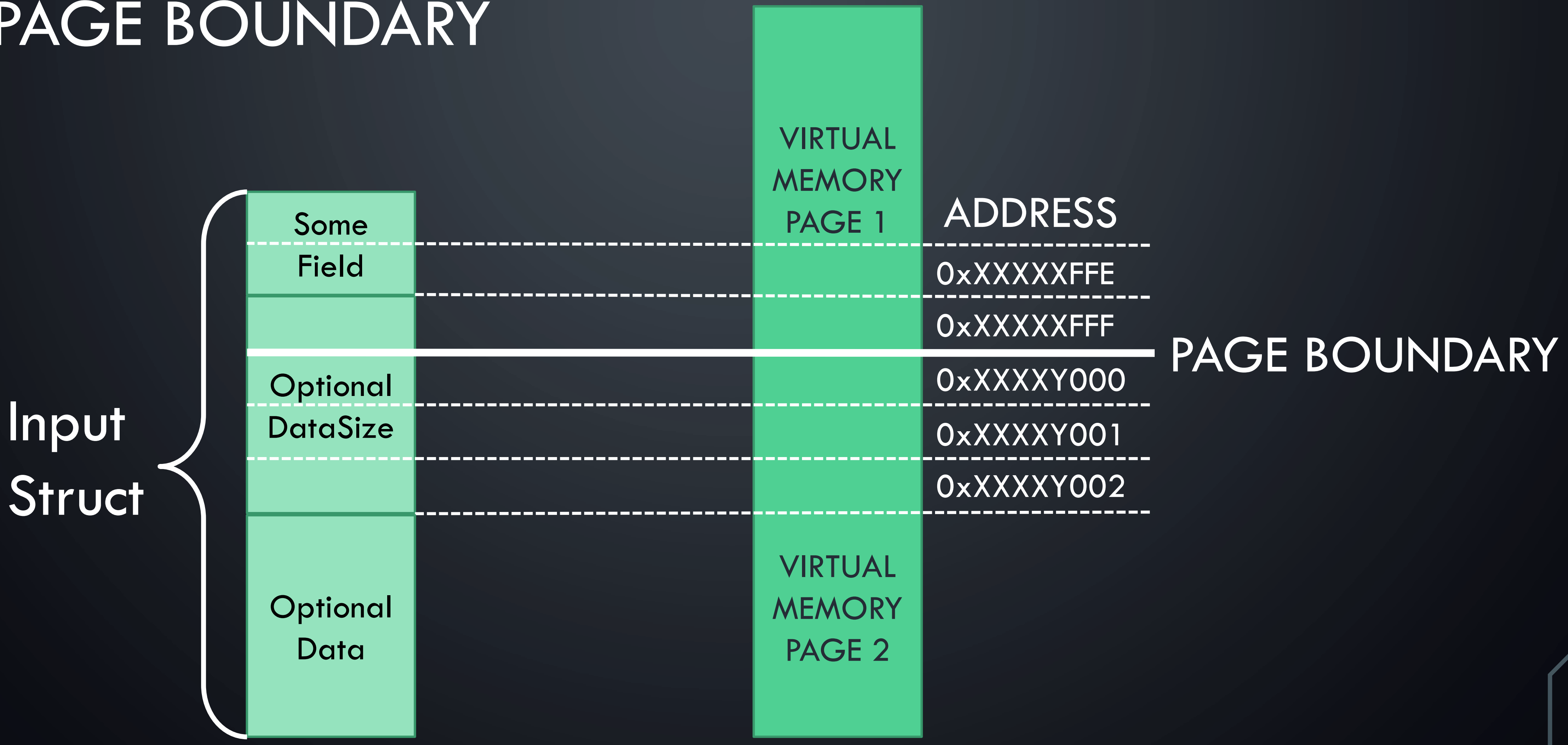
RACE COMPETITION

- Thread 1 executes the vulnerable code
- Thread 2 is trying to modify the controlled data in the structure
- Slow down the first thread
  - Place the data on a page boundary for the first thread
  - Keep flipping the attacked value in the second thread
  - Flip only the part that is spread on a single page

PAGE BOUNDARY

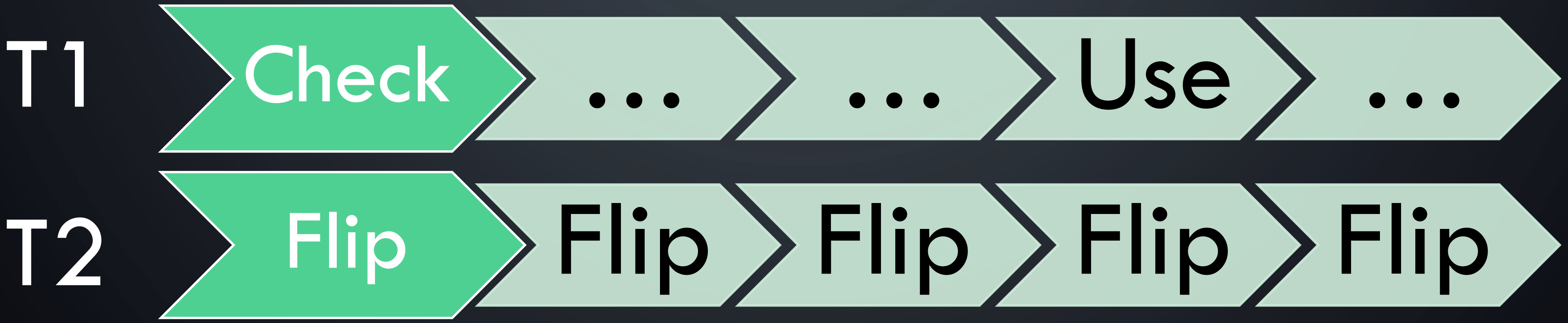


MEMORY LAYOUT

```
0: kd> dt someapp!_INPUT_TYPE 0x00000207`f0590ffb
   +0x000 SomeField              : 2
   +0x004 OptionalDataSize   : 4
   +0x008 OptionalData         : [1]  "A“

0: kd> db 0x00000207`f0590ff0
00000207`f0590ff0   00 00 00 00 00 00 00 00-00 00 00 02 00 00 00 04  ........
00000207`f0591000  00 00 00 41 41 41 41 41-41 41 41 41 41 41 41 41
...AAAAAAAAAAAAA
00000207`f0591010  41 41 41 41 41 41 41 41-41 41 41 41 41 41 41 41
AAAAAAAAAAAAAAAA
00000207`f0591020  41 41 41 41 41 41 41 41-41 41 41 41 41 41 41 41
AAAAAAAAAAAAAAAA
```

RACE COMPETITION



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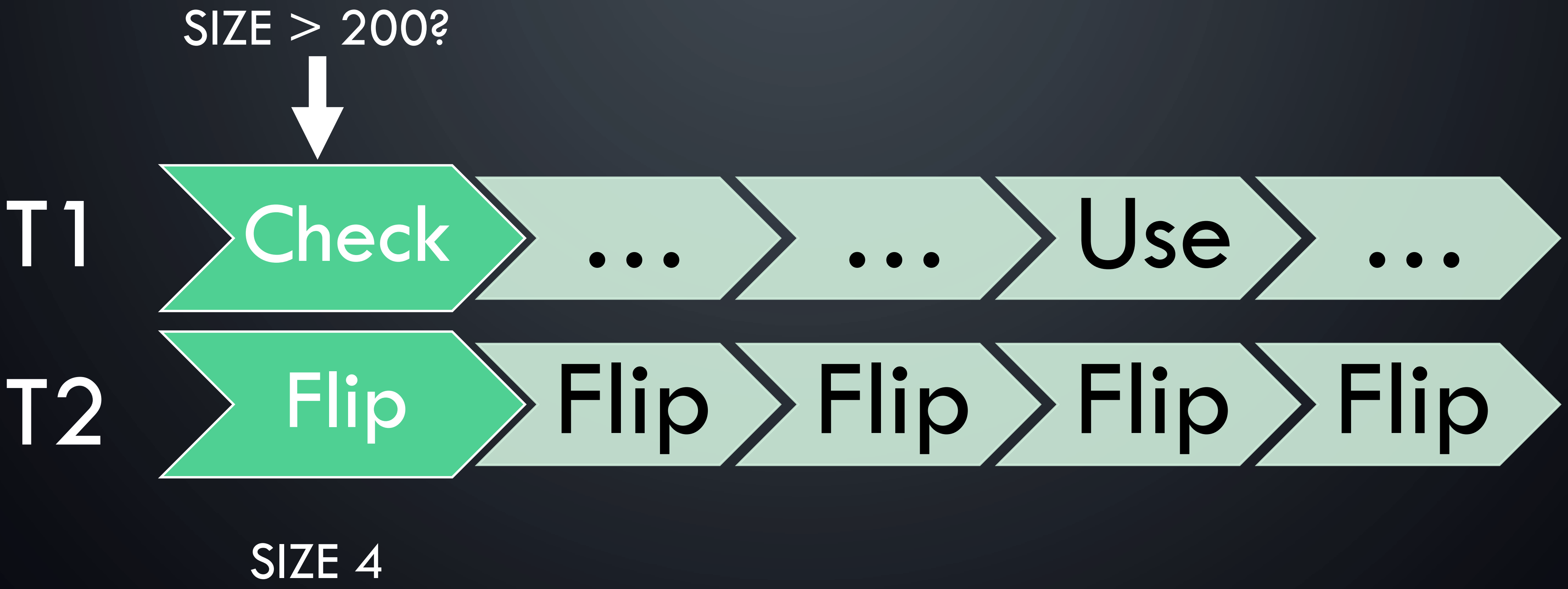

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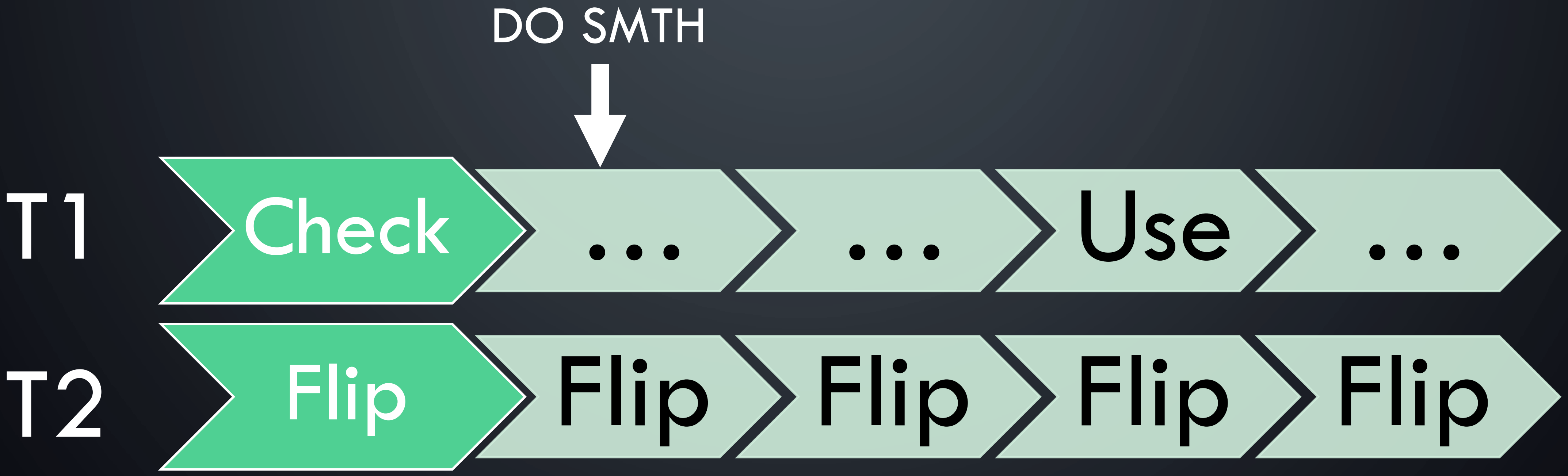
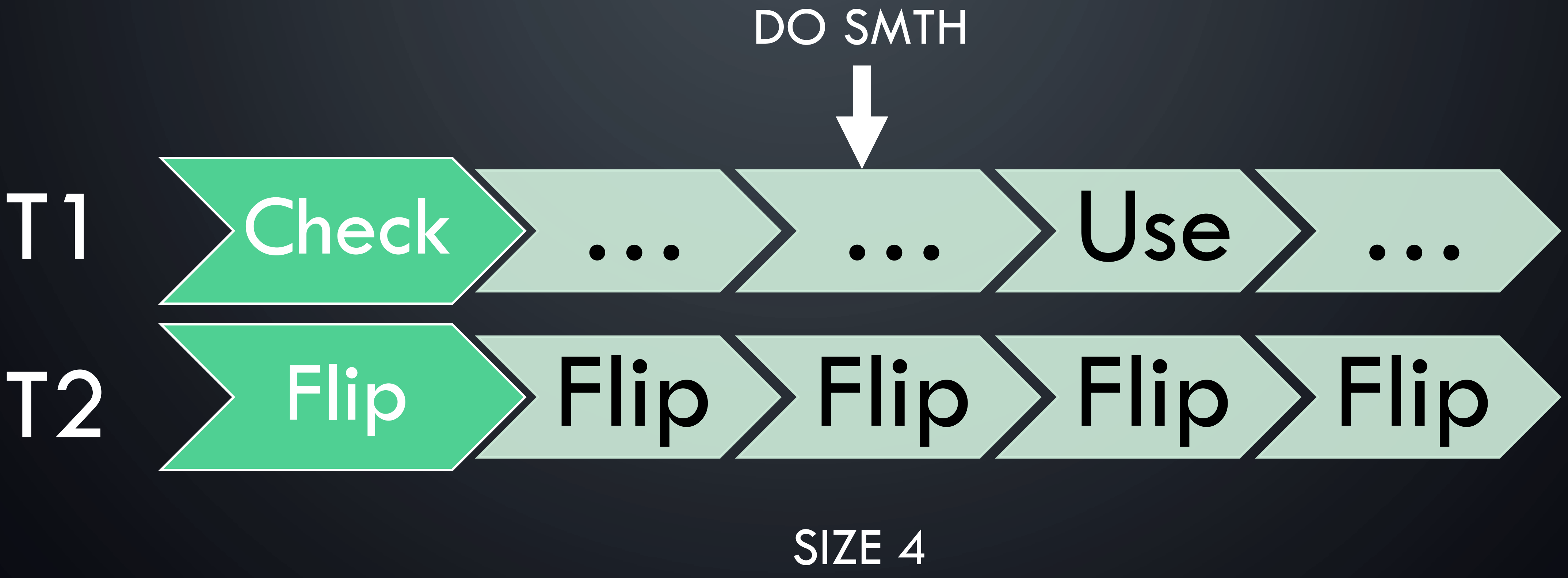


SIZE 204

RACE COMPETITION



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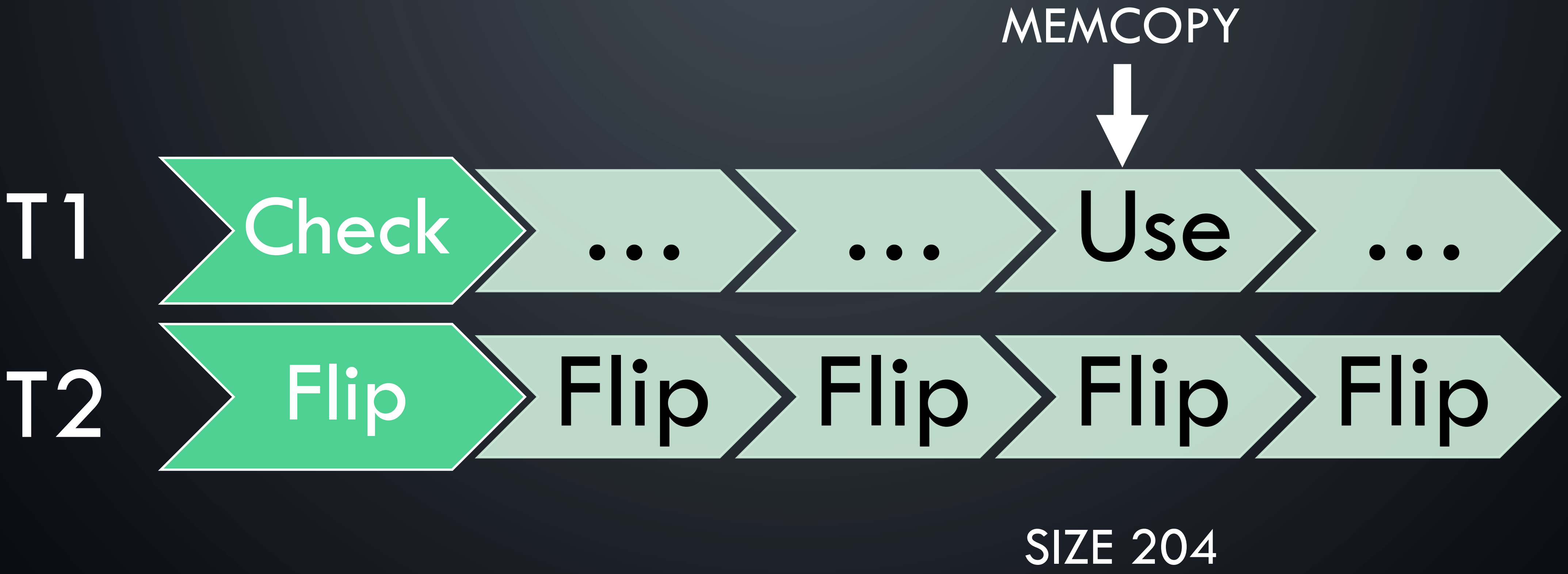

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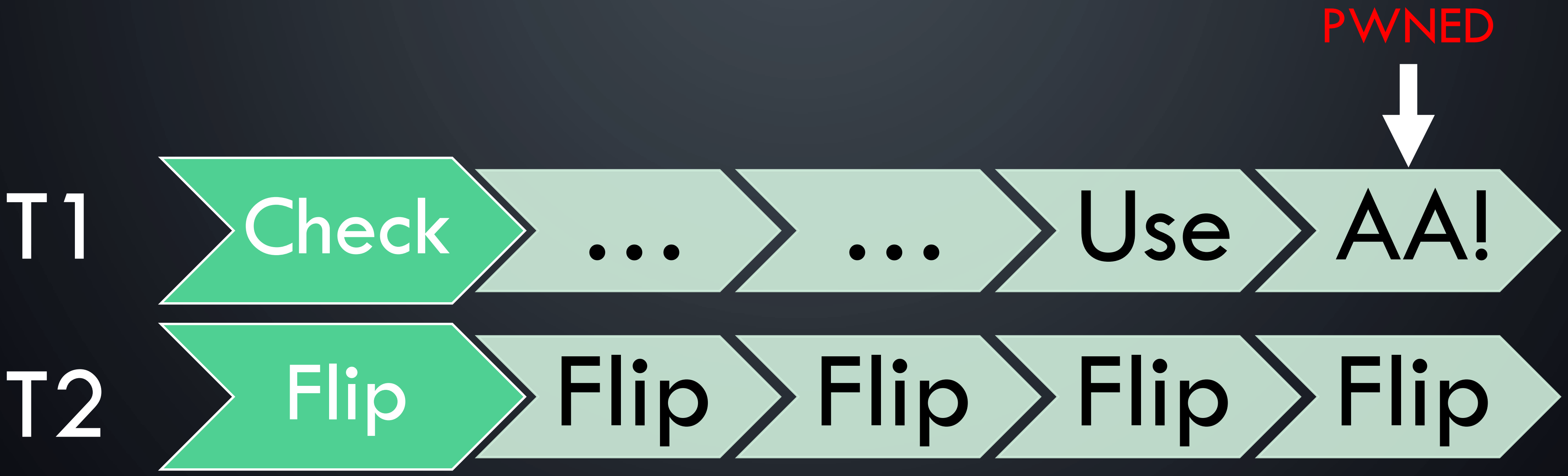
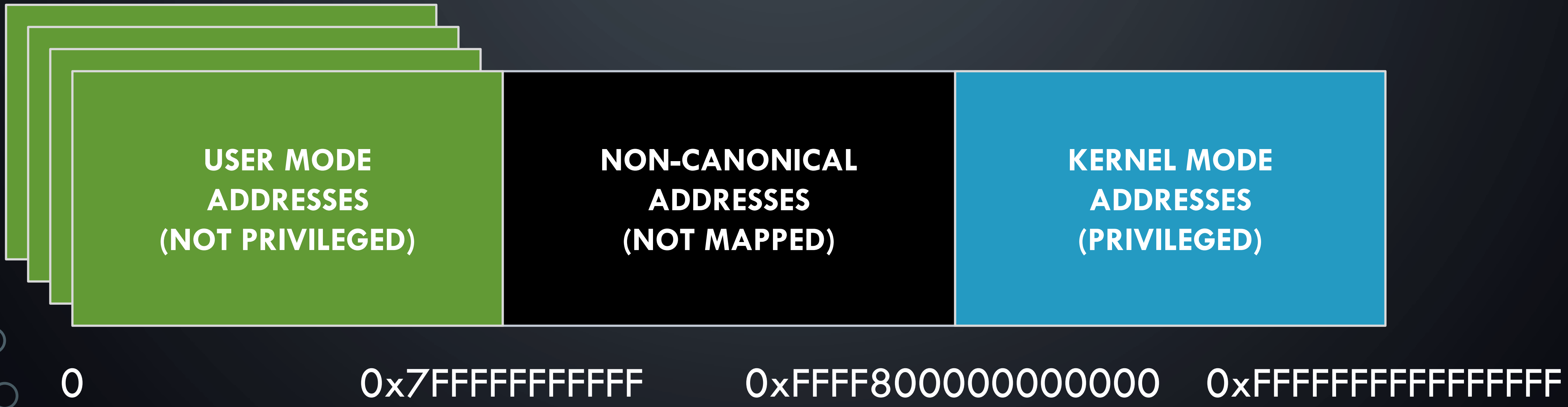


SIZE 4

WINDOWS VIRTUAL ADDRESS SPACE LAYOUT (X64)


USER MODE ADDRESSES (NOT PRIVILEGED)
NON-CANONICAL ADDRESSES (NOT MAPPED)
KERNEL MODE ADDRESSES (PRIVILEGED)
0
0x7FFFFFFFFFF
0xFFFF800000000000
0xFFFFFFFFFFFFFFFF

DEMO

LET’S WINDBG THIS

WINNER WINNER CHICKEN DINNER

- This doesn’t lead to the code execution anyway
- Chaining with some other bug needed
- Every exploitation path is unique
  - Depends on the environment
  - Depends on input limitation
  - Depends on reachability

CODE EXEC GAINED

- What’s the impact?
  - Privilege escalation
    - Remote code execution
    - Guest to admin
    - User to kernel
  - Trust boundary violation
    - Sensitive data leak
  - Media impact

BUT IT HAS TO BE FOUND FIRST

DETECTION PRINCIPLES

- Detect consecutive memory accesses
- Static
  - Lack of runtime info
- Dynamic
  - Coverage issues

DYNAMIC DETECTION APPROACH

- This is an example for Windows kernel vulnerabilities
- Using the full system emulation
  - Bochs (bochspwn)
  - Simics
- Using the live system
  - SMAPwn

BOCHSPWN

- By Mateusz "j00ru" Jurczyk and Gynvael Coldwind
  - https://research.google.com/pubs/archive/42189.pdf
- Slow but reliable
- Open source
  - https://github.com/googleprojectzero/bochspwn
- Can also try info leaks

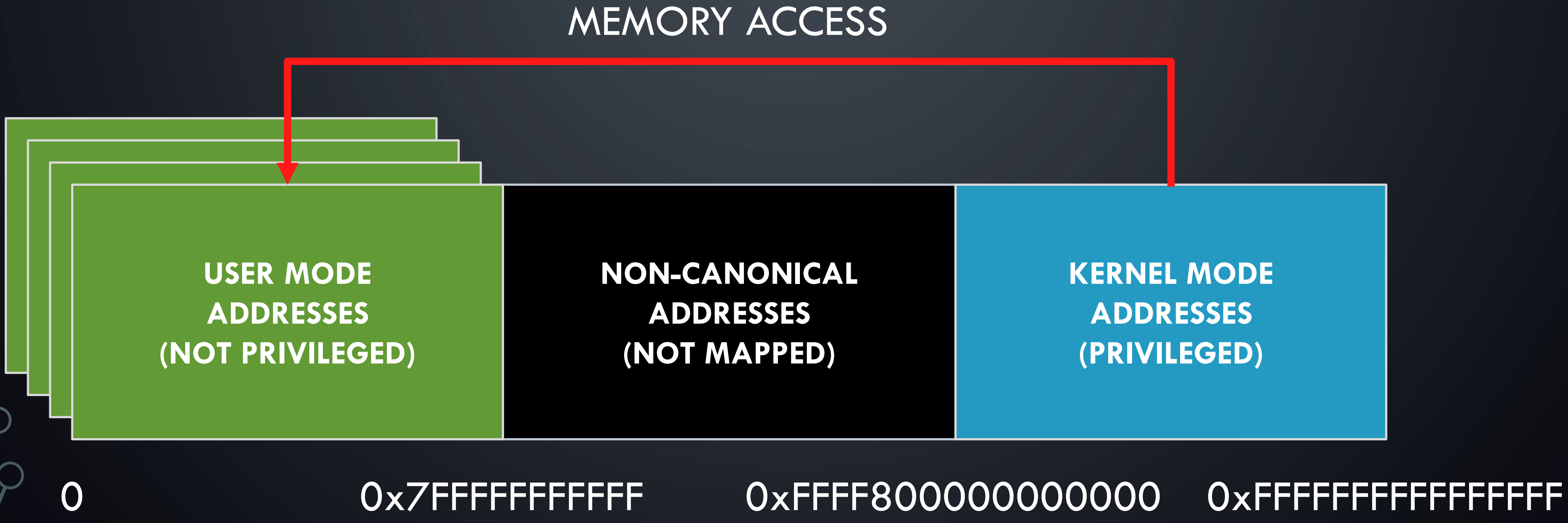
SIMICS BASED TRACKER

- BSDaemon and NadavCh did that using Simics
  - https://github.com/rrbranco/poc_gtfo/blob/master/pocorgtfo15.pdf
- Simics is not a public tool

SMAPWN WINDBG PLUGIN

- By me
- Thoroughly described at H2HC 2018
  - https://github.com/h2hconference/2018
- The plugin is still not released
  - But can be easily reproduced

SUPERVISOR MODE ACCESS PREVENTION OFF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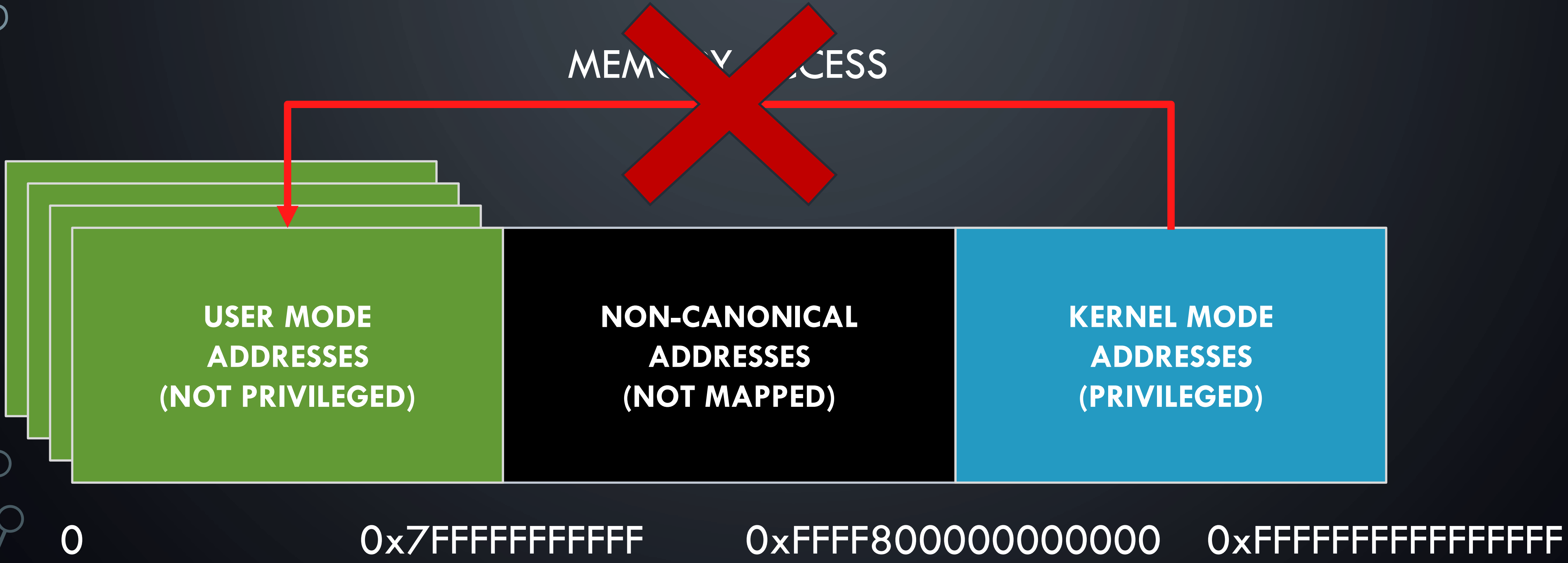
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WINDBG AGAIN

SUMMARY

- The bug has to be found
- The bug has to be reachable
- The bug has to be controlled
- The environment has to be aligned
- Security premise must be broken
- Someone must care about it

THE FIX

```
int CaptureInput(PINPUT_TYPE pInputStruct)
{
    int OptionalSize = pInputStruct->OptionalDataSize;
    if (OptionalSize > MAX_OPTIONAL_DATA_SIZE)
        return -EINVAL;
    memcpy(pTarget, pInputStruct->OptionalData, OptionalSize);

    return 0;
}
```

THANKS AND HAPPY FISHING!