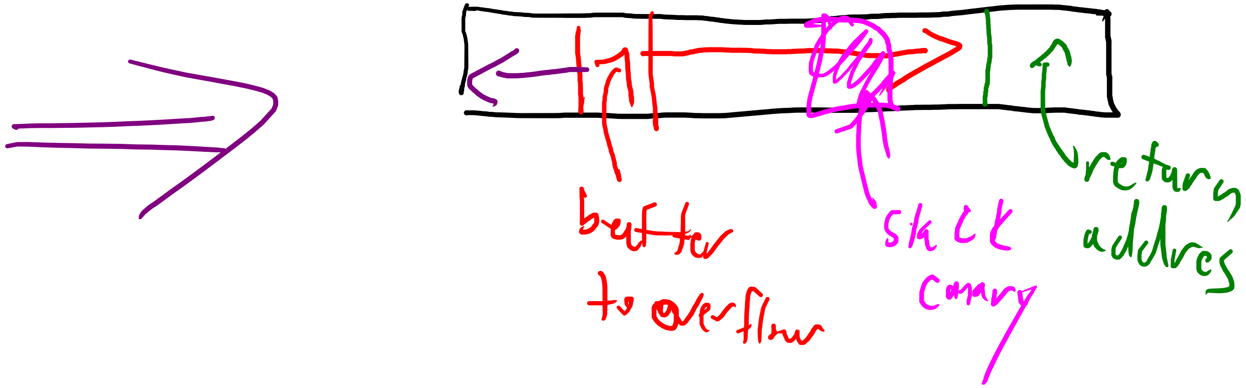
EXERCISE #17

MEMORY ATTACK REVIEW

Write your name and answer the following on a piece of paper

Describe how a stack canary protects against return-oriented programming



ADMINISTRIVIA AND ANNOUNCEMENTS

Second reading assigned

- The original paper on CFI

Basically halfway through the semester

- Time to check in on how things are going

CONTROL-FLOW INTEGRITY

EECS 677: Software Security Evaluation

Drew Davidson

TOPIC CONTEXT

CONTEMPLATED A FORM OF ATTACK,
LEFT WITH A HINT OF DEFENSES

LAST TIME: MEMORY ATTACKS

REVIEW: LAST LECTURE

Buffer Overflows

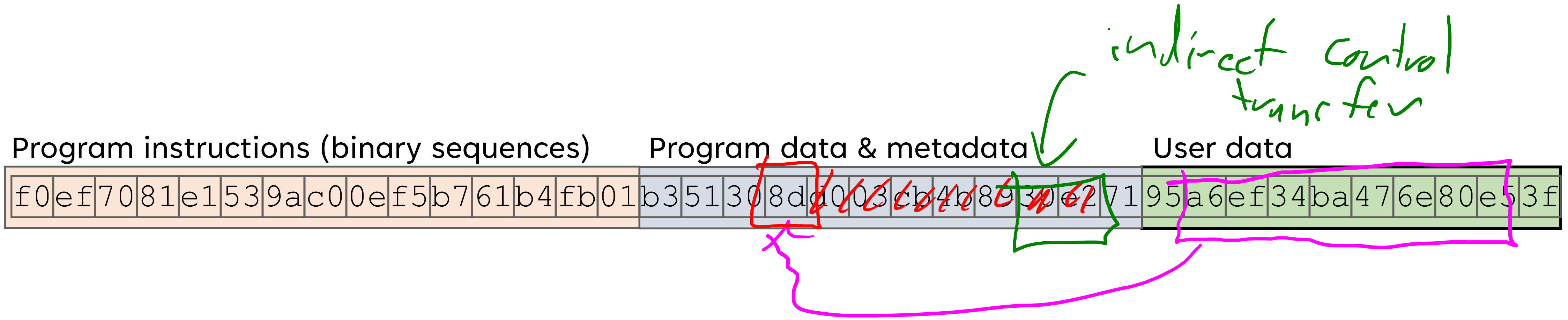
Exceed the boundary of a region of memory, start overwriting other program (meta)data

Code Injection

Overwrite a return address and jump to your own user-written buffer

Return-oriented Programming

Overwrite a return address and jump to "gadgets" of existing code



OVERVIEW

KEEP THE CONTROL FLOW “ON RAILS”

LECTURE OUTLINE

- Motivation
- Implementation considerations
- Practical manifestations

WE KNOW THE PROBLEM

MOTIVATION

JUMPING WHERE YOU SHOULDN'T

- This certainly includes ROP
- Might also involve other attacks

```c
#include <stdio.h>
#include <string.h>

struct auth {
	char pass[4];
	void (*func)(struct auth*);
};

void success() { printf("Success!\n"); }
void failure() { printf("Failure\n");  }

void check(struct auth *a) {
	if (strcmp(a->pass, "pass") == 0)
		a->func = &success;
	else
		a->func = &failure;
}
int main(int argc, char **argv) {
	struct auth a;

	printf("Enter your password:\n");
	scanf("%s", &a.pass);

	a.func(&a);
}
```

WE KNOW THE PROBLEM

MOTIVATION

Jumping where you shouldn't

- This certainly includes ROP
- Might also involve other attacks

Look, no ret overwrite!

```
#include <stdio.h>
#include <string.h>

struct auth {
        char pass[4];
        void (*func)(struct auth*);
};

void success() { printf("Success!\n"); }
void failure() { printf("Failure\n");  }

void check(struct auth *a) {
        if (strcmp(a->pass, "pass") == 0)
                a->func = &success;
        else
                a->func = &failure;
}
int main(int argc, char **argv) {
        struct auth a;

        printf("Enter your password:\n");
        scanf("%s", &a.pass);

        a.func(&a);
}
```

We know the problem

Motivation

Jumping where you shouldn't

- This certainly includes ROP
- Might also involve other attacks

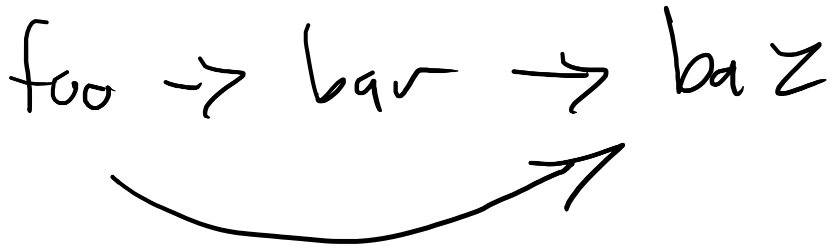
Look, no ret overwrite!

LECTURE OUTLINE

- Motivation
- Implementation considerations
- Practical manifestations

HOW TO IMPLEMENT?

IMPLEMENTATION CONSIDERATIONS



Naïve Approach:

Encode the entire CFG into the program text

CALL GRAPH ANALYSIS

IMPLEMENTATION CONSIDERATIONS

Naïve Approach:

Encode the entire CFG into the program text

HOW TO IMPLEMENT?

IMPLEMENTATION CONSIDERATIONS

Naïve Approach:

Encode the entire CFG into the program text

Issues:

Dynamic: overhead

Static: precision

HOW TO IMPLEMENT?

IMPLEMENTATION CONSIDERATIONS

Naïve Approach:

Encode the entire CFG into the program text

Issues:

Dynamic: overhead

HOW TO IMPLEMENT?

IMPLEMENTATION CONSIDERATIONS

Naïve Approach:

Encode the entire CFG into the program text

Issues:

Dynamic: overhead

Static: precision

LECTURE OUTLINE

- Motivation
- Implementation considerations
- Practical manifestations

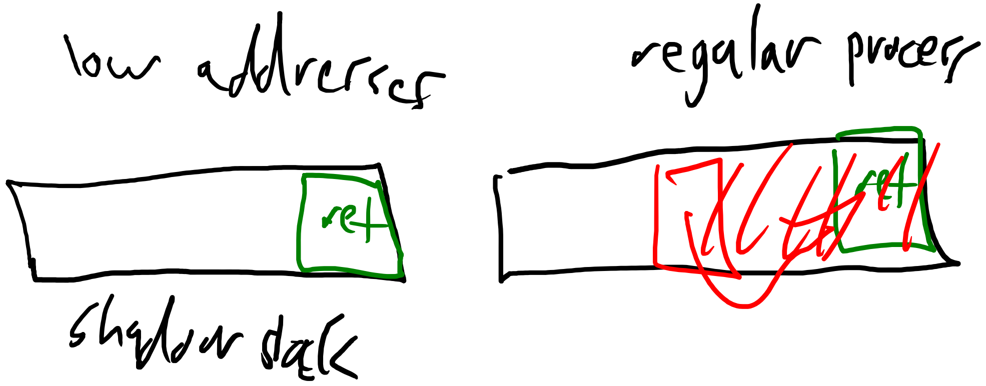
INTEL CET

PRACTICAL MANIFESTATIONS

Control-Flow Enhancement Technology

Requires recompilation of software to support

Requires hardware support (!)



Scope

1) Prevent ret overwriting with a shadow stack

INTEL CET

PRACTICAL MANIFESTATIONS

Control-Flow Enhancement Technology

Requires recompilation of software to support

Requires hardware support (!)

Scope

1) Prevent ret overwriting with a shadow stack

2) ~~Hardware modifications~~ prevent indirect jumps into gadgets

INTEL CET
PRACTICAL MANIFESTATIONS

CET HARDWARE CHANGES

Altered semantics of the CALL and JMP

Moves a processor state machine into the WAIT_FOR_ENDBRANCH state

In WAIT_FOR_ENDBRANCH, next instruction must be the ENDBRANCH instruction

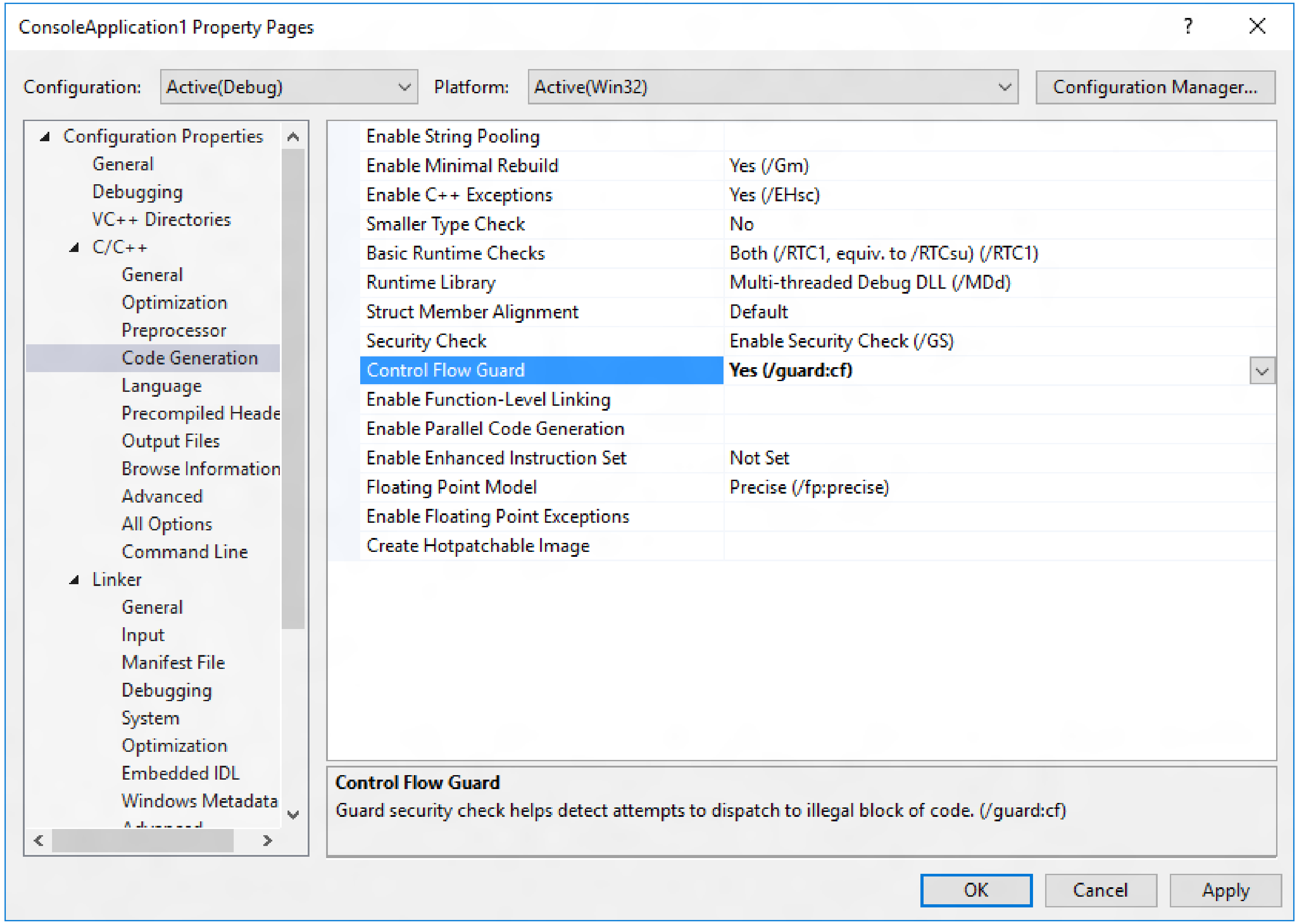
Added a new instruction at control-transfer targets

The new ENDBRANCH instruction

Backwards compatible

MICROSOFT CONTROL FLOW GUARD

PRACTICAL MANIFESTATIONS



HISTORICAL DETOUR

PRACTICAL MANIFESTATIONS: MS CONTROL-FLOW GUARD

HISTORICAL DETOUR

PRACTICAL MANIFESTATIONS: MS CONTROL-FLOW GUARD

RECALL FROM LAST TIME…

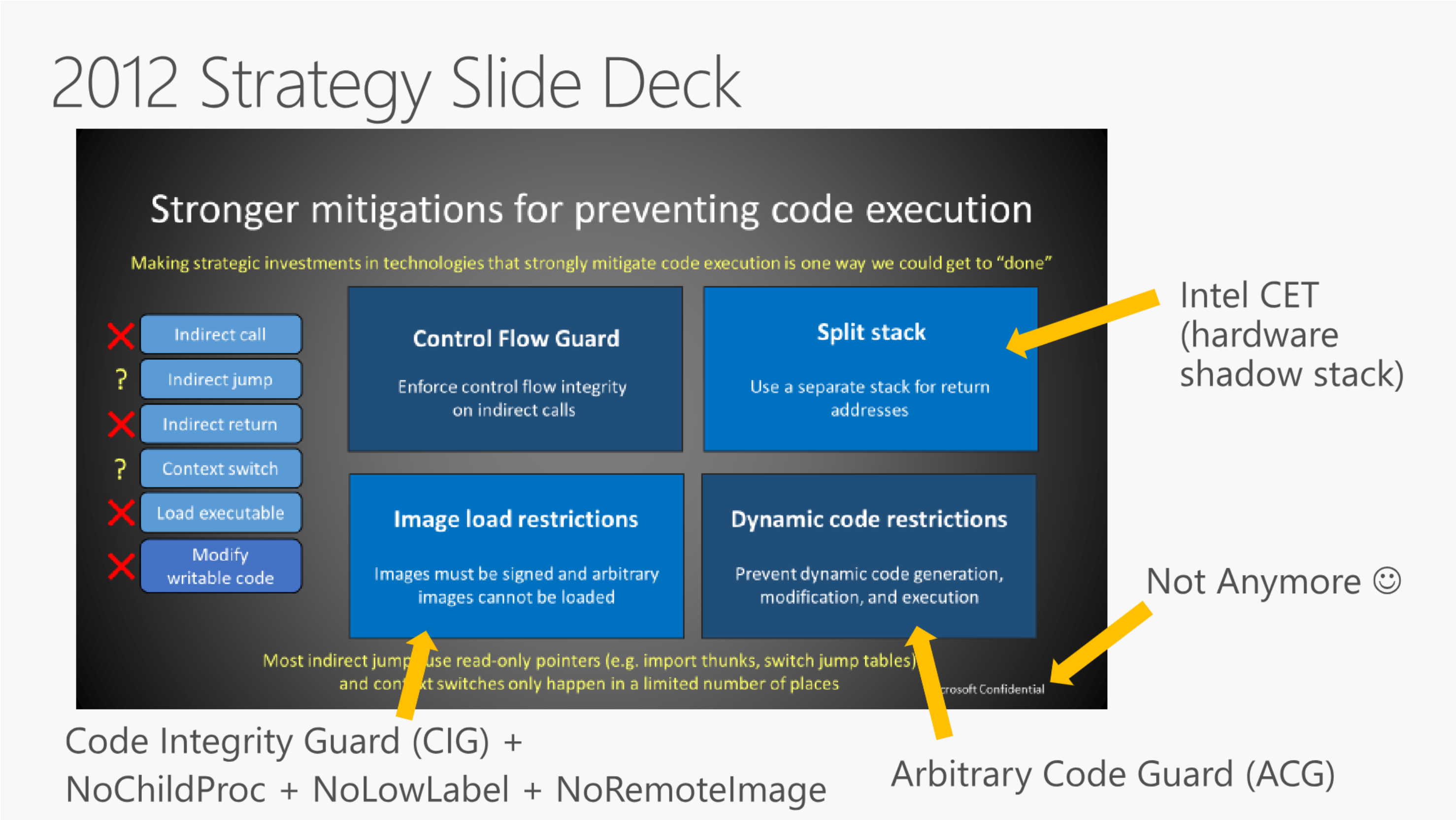
ROP attacks considered harmful

HOW INDUSTRY RESPONDED

MS CFG as a case study in a lot of interesting aspects of software security

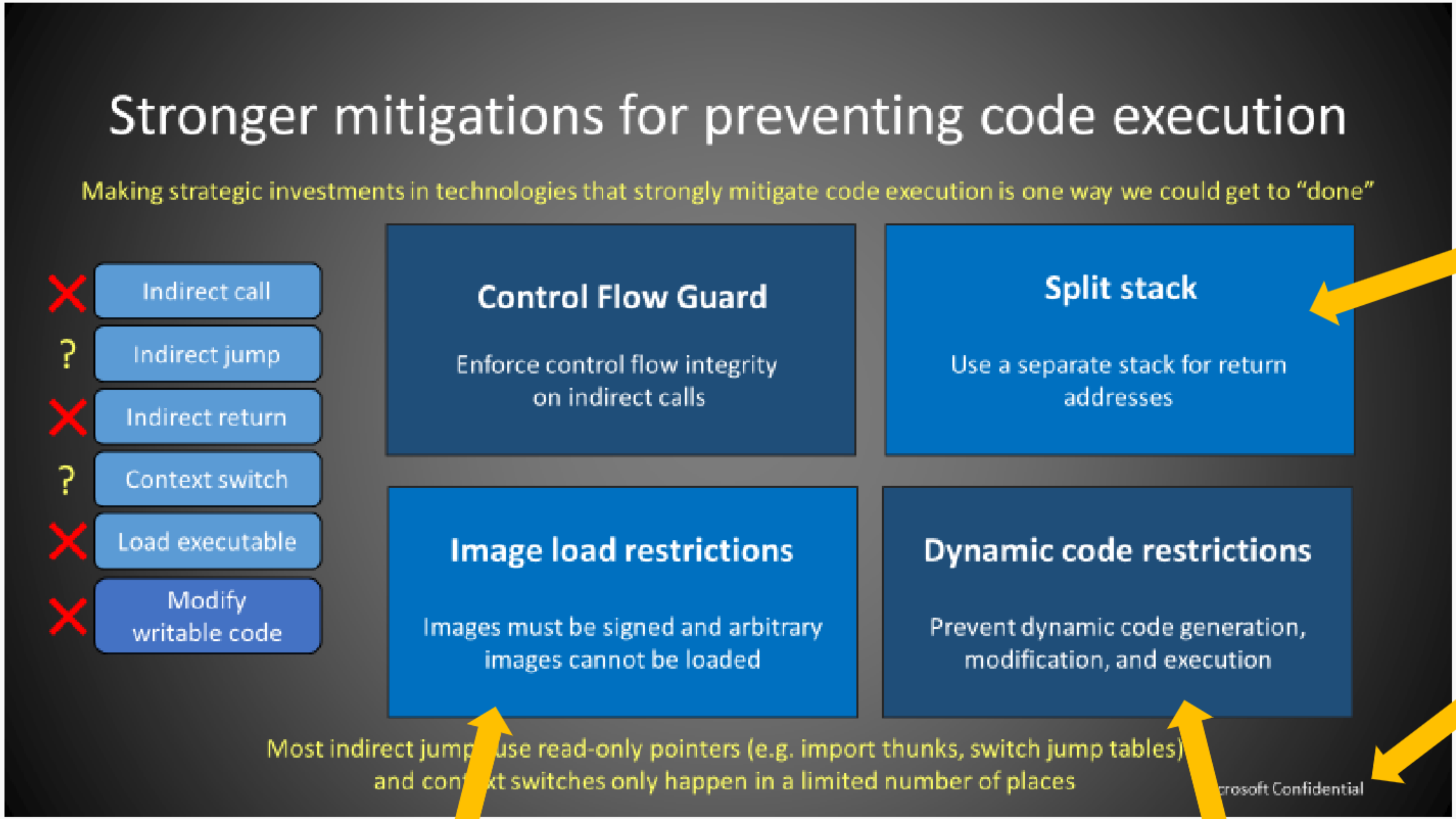
HISTORICAL DETOUR

PRACTICAL MANIFESTATIONS: MS CONTROL-FLOW GUARD



Source: https://github.com/Microsoft/MSRC-Security-Research/blob/master/presentations/2018_02_OffensiveCon/The%20Evolution%20of%20CFI%20Attacks%20and%20Defenses.pdf

2012 Strategy Slide Deck



Intel CET (hardware shadow stack)

Not Anymore ☺

Code Integrity Guard (CIG) + NoChildProc + NoLowLabel + NoRemoteImage

Arbitrary Code Guard (ACG)

HISTORICAL DETOUR

PRACTICAL MANIFESTATIONS: MS CONTROL-FLOW GUARD

This is an interesting talk!

I'd recommend you watch it: https://www.youtube.com/watch?v=oOqpl-2rMTw

It comes with the historical burden of Control Flow guard

Widely-publicized issue that allowed it to be avoided

Theory

DETOUR

Microsoft's overarching goal is to make exploitation financially infeasible or impossible

All RCE memory corruption exploits found in-the-wild hijack control flow

Attackers often follow "path of least resistance", breaking them means increasing cost of exploitation

→

Constraining control flow to "legitimate" paths breaks all of these exploits as-written

After some formal thought, we believe CFI will robustly mitigate against stronger primitives

→

Security teams are well positioned to drive these changes

CFG had no formal threat model during very early development. Thought of as a way to kill ROP.

Hindsight is 20/20, but we did have formal thought around future exploit trends. See [1]

HISTORICAL DETOUR

PRACTICAL MANIFESTATIONS: MS CONTROL-FLOW GUARD

CONTROL FLOW GUARD HAS A HISTORICAL BURDEN

Widely-publicized issue that allowed it to be avoided

We’ll get to the actual workaround, but let’s talk about its impact

HISTORICAL DETOUR

PRACTICAL MANIFESTATIONS: MS CONTROL-FLOW GUARD

CONTROL FLOW GUARD

PRACTICAL MANIFESTATIONS

DETAILS

Precision: call needs to be a valid function entry point

Enforcement: OS verifies indirect control transfer destinations via a table in protected memory

PROTECTIONS

Protected destinations page in read-only memory

Read-only memory bit can be turned off by attacker ☹

CLANG'S CFI

PRACTICAL MANIFESTATIONS

DETAILS

Precision: call needs to match type signature

Enforcement: compiler-inserted checks

WRAP-UP