Data is Flowing in the Wind: A Review of Data-Flow Integrity Methods to Overcome Non-Control-Data Attacks

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Rationale

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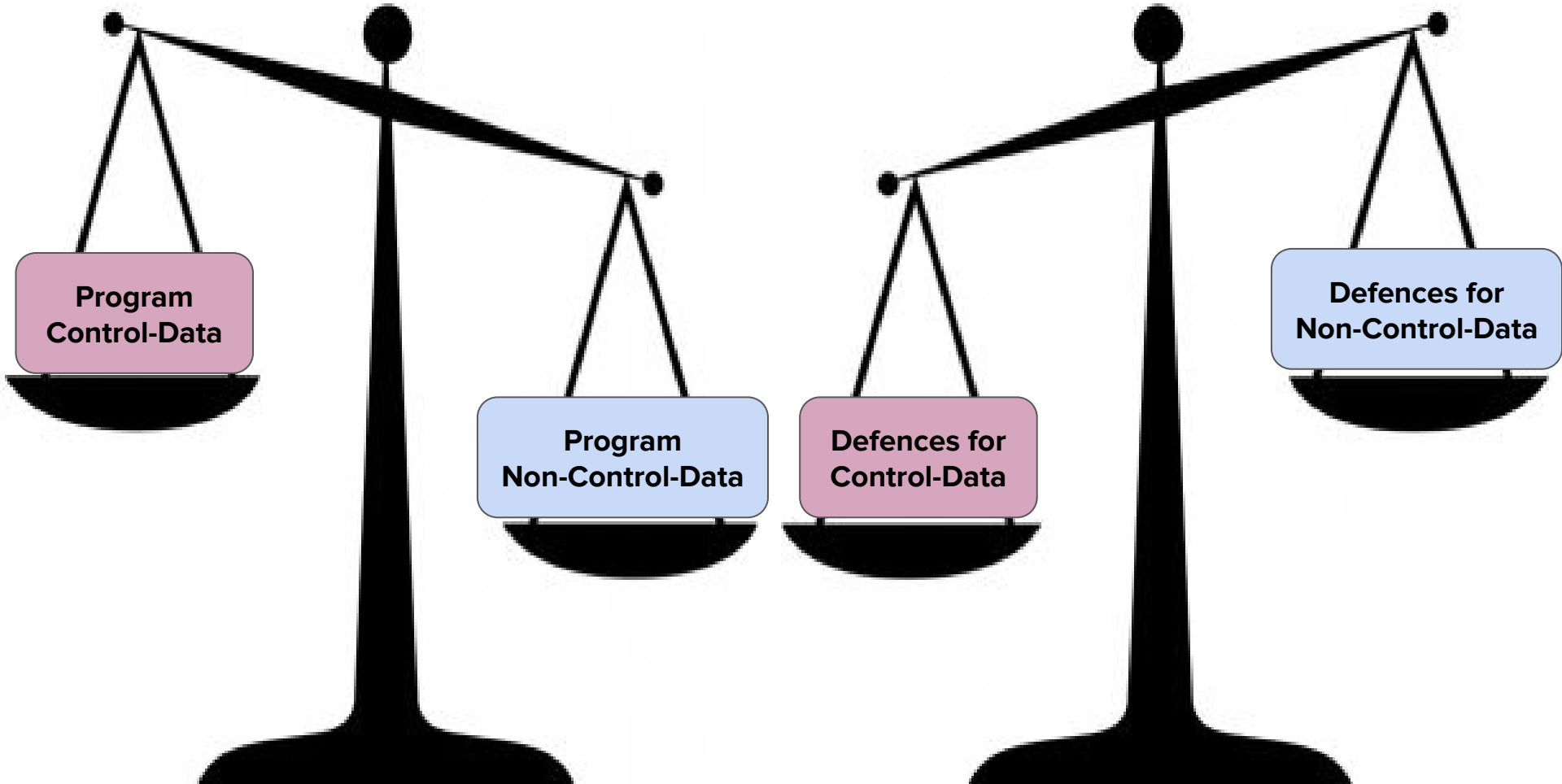
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Control-Data
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Non-Control-Data
Defences for
Control-Data
Defences for
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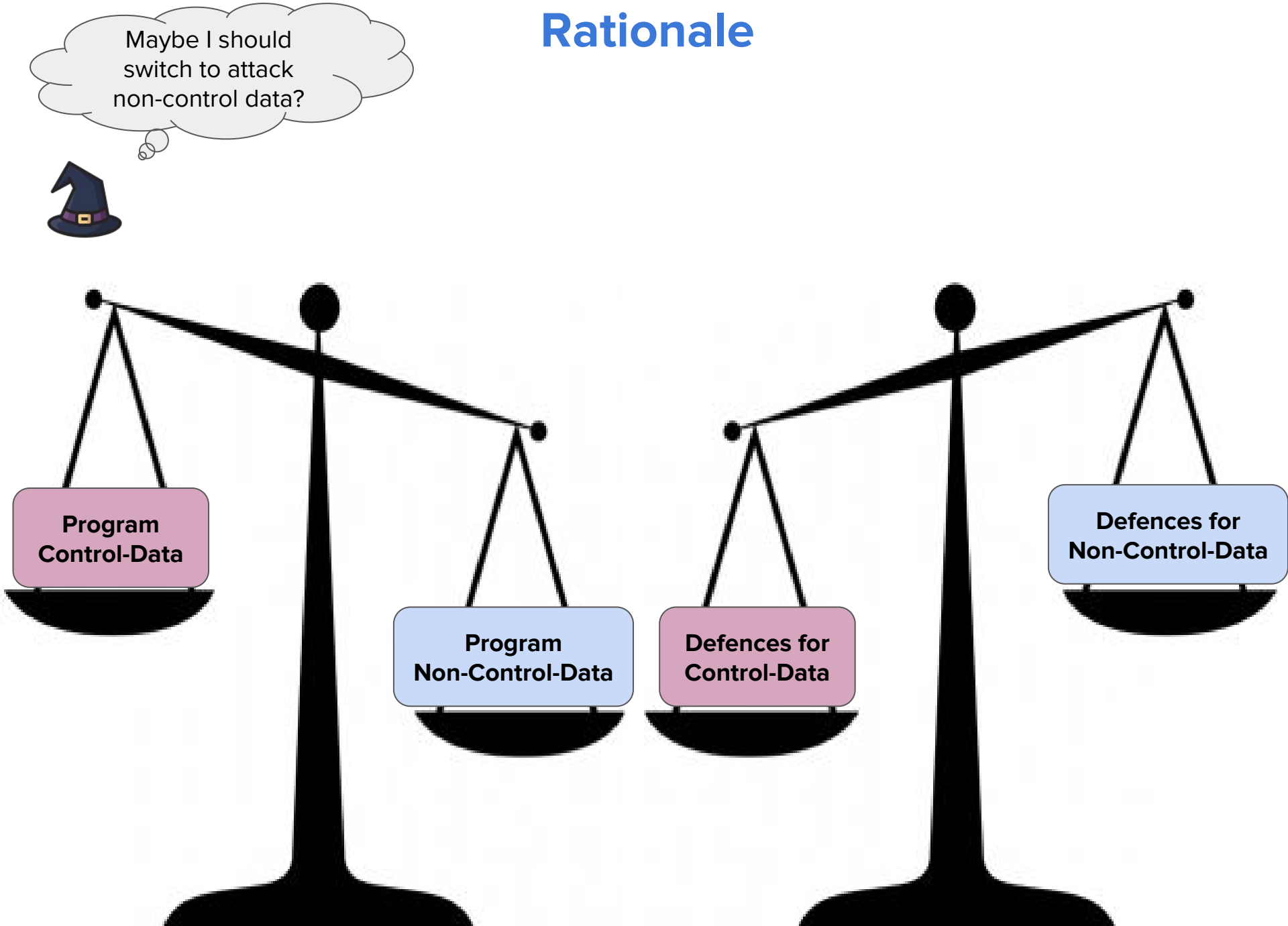
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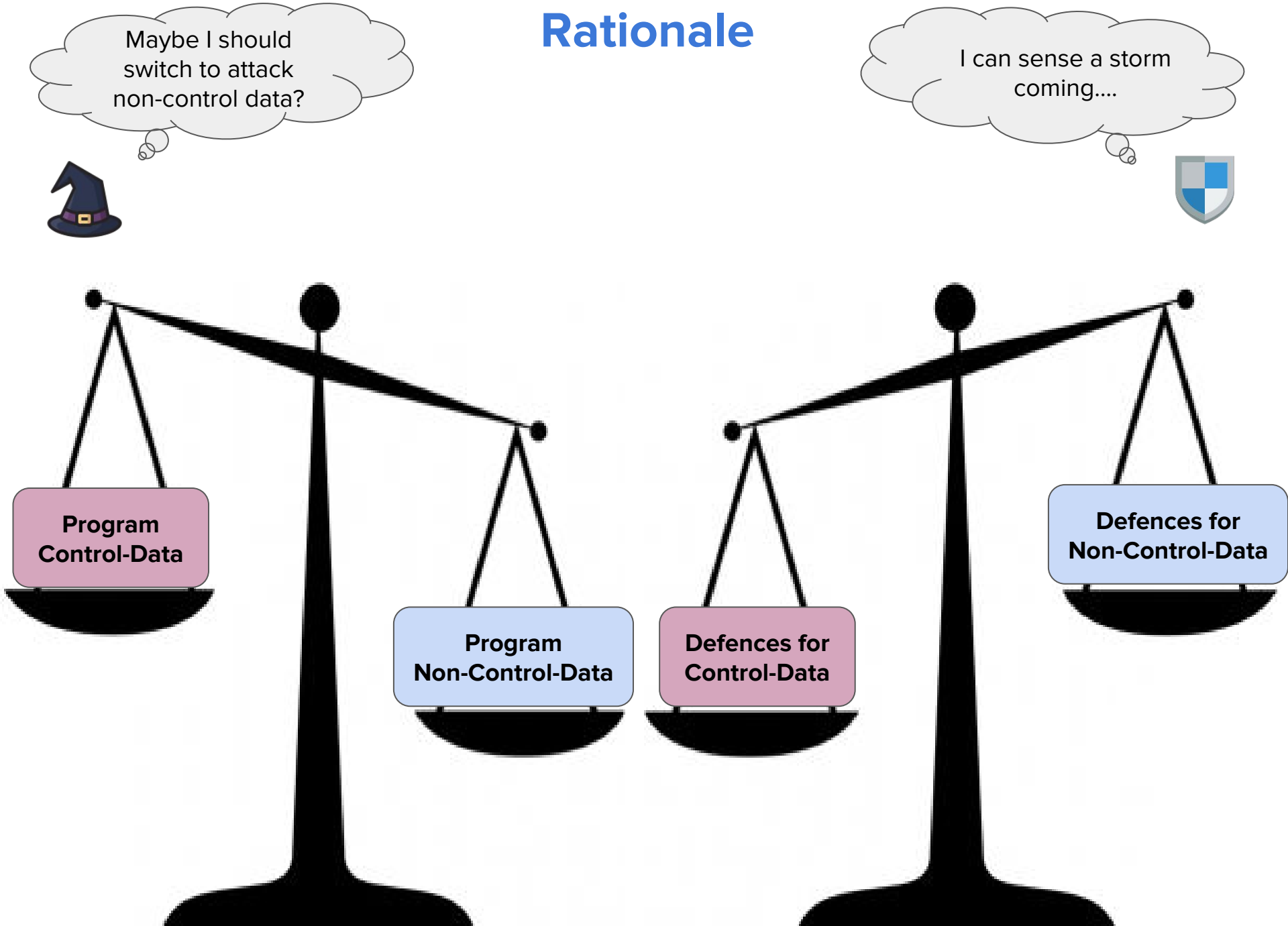
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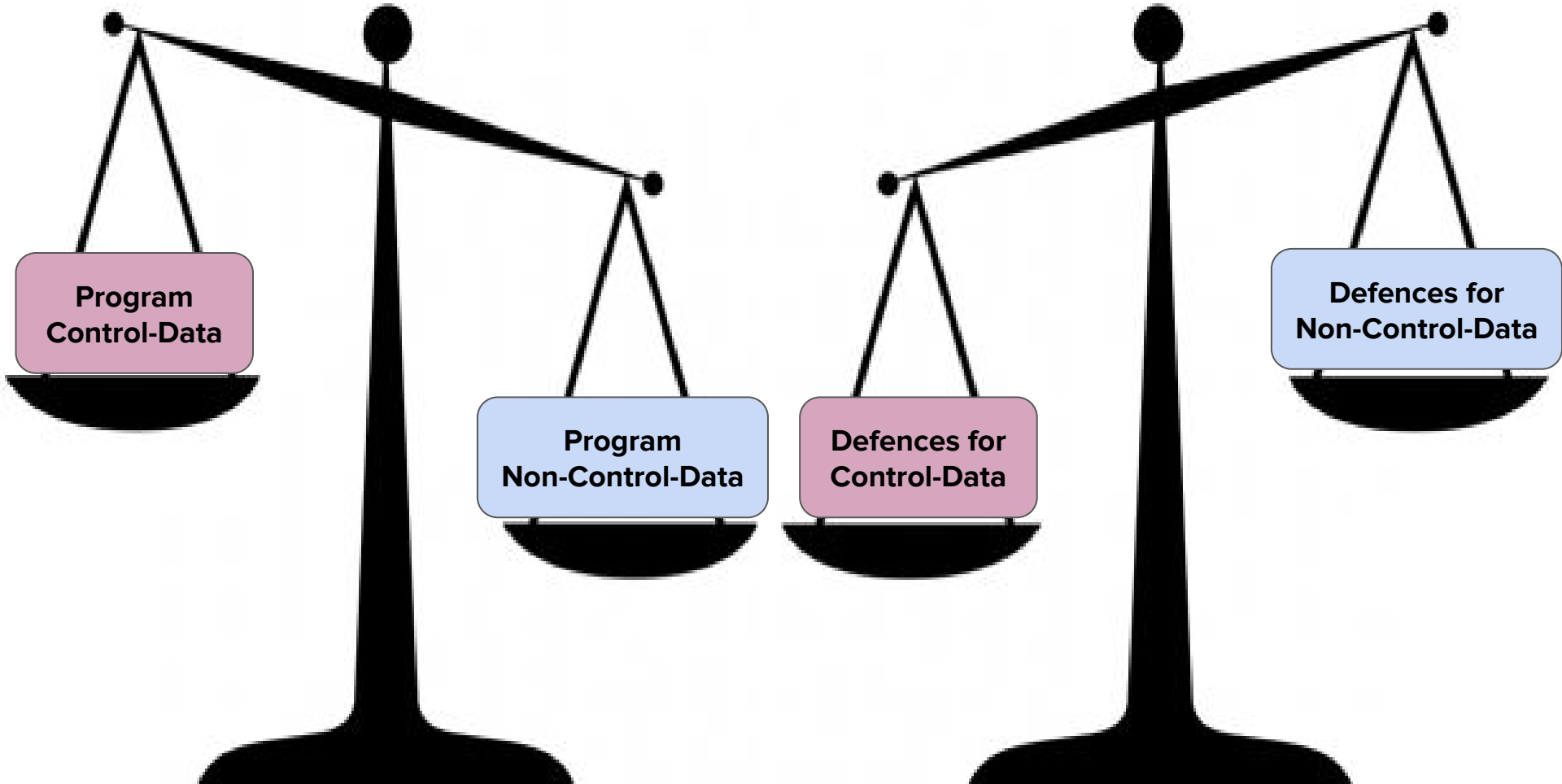
Non-Control-Data Attacks Are Realistic Threats. Chen et al. Usenix Sec'05



Control Data VS Non-Control-Data Attacks

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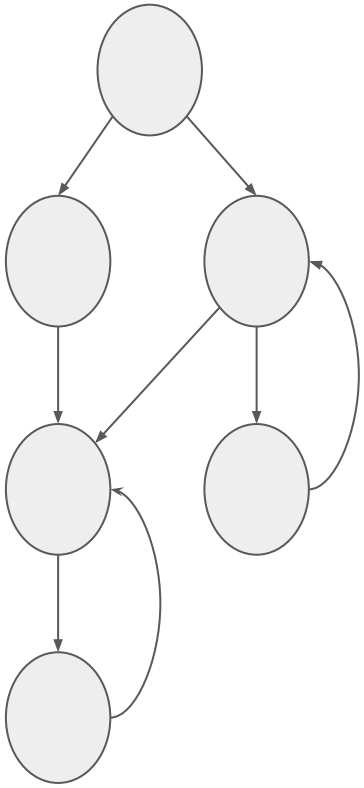
Control-Data Attacks

Modify the control-flow of a program

Control Data VS Non-Control-Data Attacks



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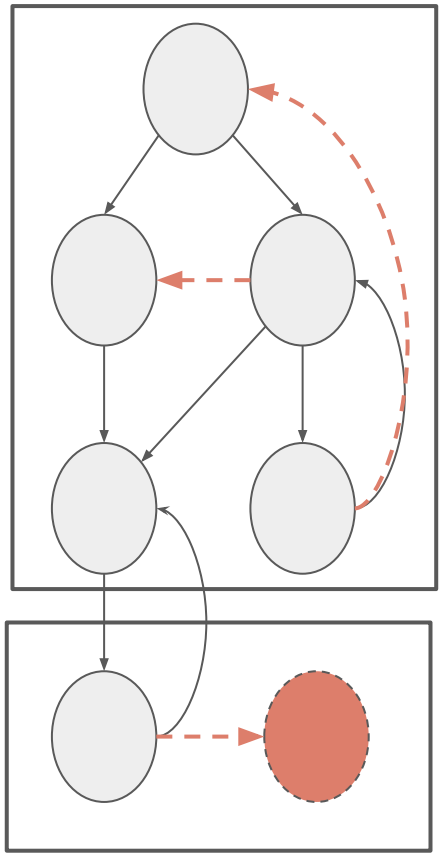

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Code injection

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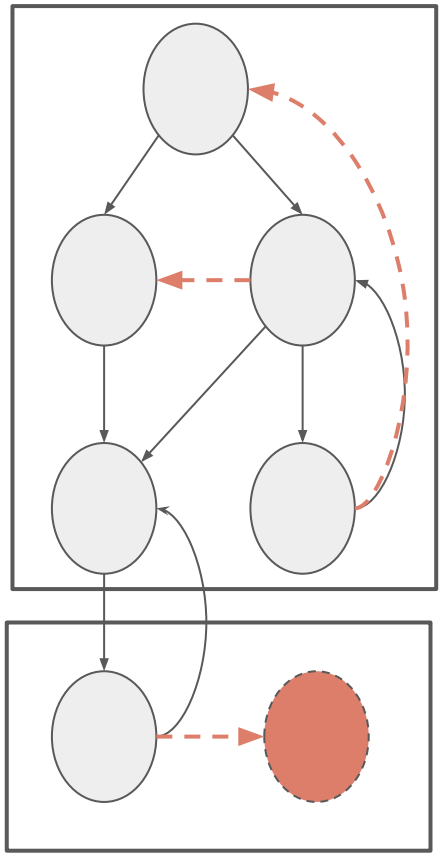

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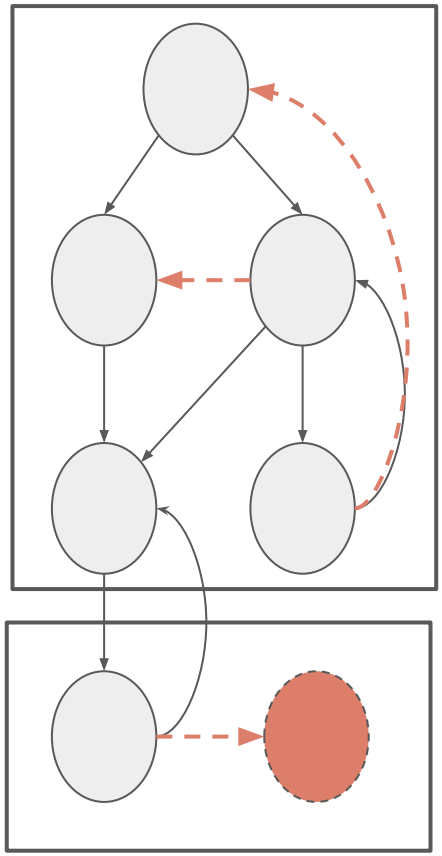

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Do not affect the control-flow of a program

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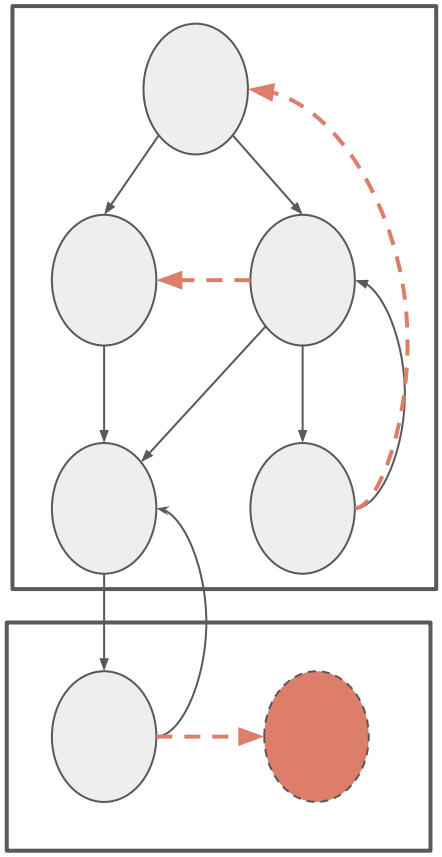

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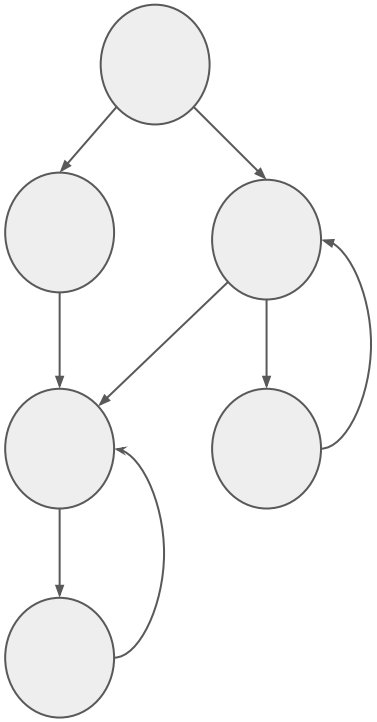

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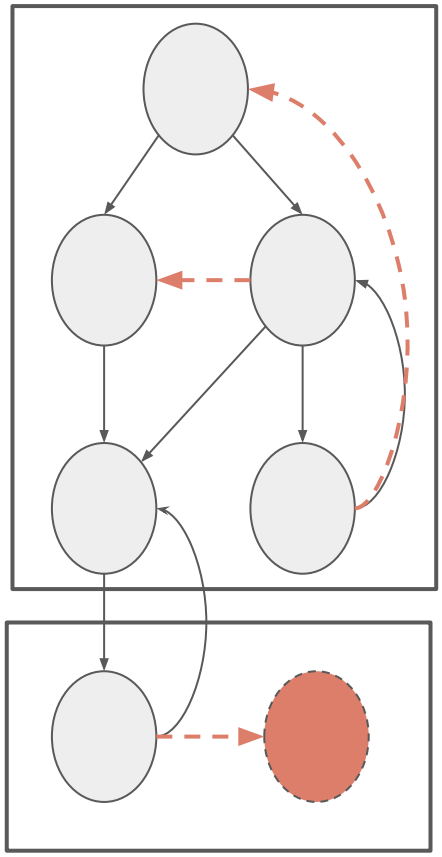

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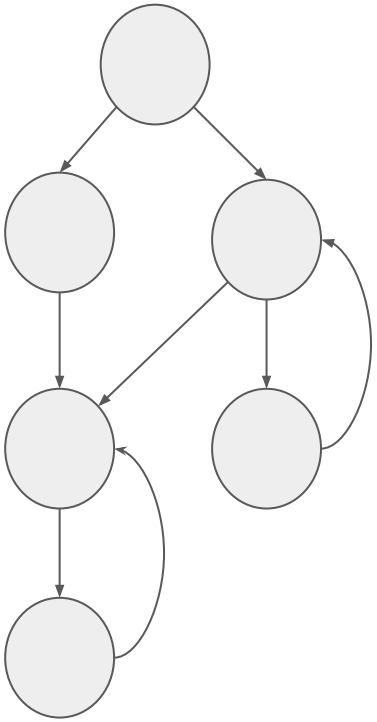

Remain invisible to techniques which only focus on control-data

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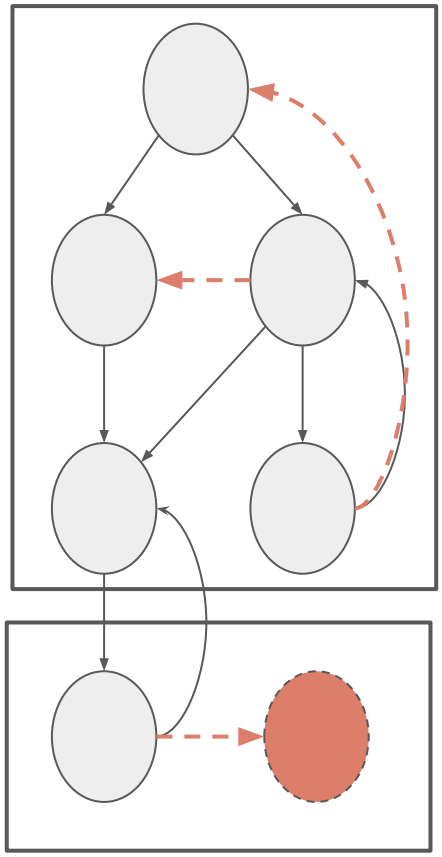

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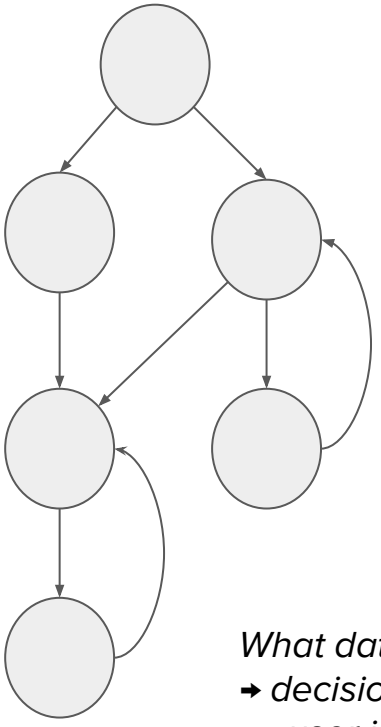

Remain invisible to techniques which only focus on control-data

What data do they target?
➔ *decision making data, user input etc.*

Control-Data Attacks

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Do not affect the control-flow of a program

Security-Critical Non-Control Data

Chen et al. Usenix Sec'05
Hu et al. Usenix Sec'15

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Configuration data

User identity data

Decision-making data

User input data

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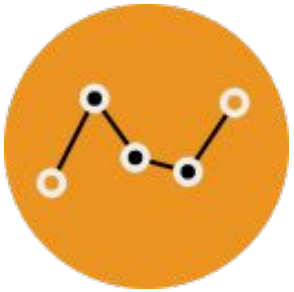

Decision-making data

User input data

Passwords & private keys

System call parameters

Randomised values

A sample non-control-data attack

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  uid_t pw_uid;
  ...
} *pw;
...
int uid = getuid();
pw->pq_uid = uid; // save current uid
// [ format string vulnerability ]
...
void passive(void)
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  seteuid(pw->pw_uid); // drop root priv
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From wu-ftpd web server.
Hu et al. Usenix Sec'15

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// [ exploit it to overwrite 'uid'  ]
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Circumvents Control Flow Integrity?

Data-Flow Stitching

Hu et al. Usenix Sec'15

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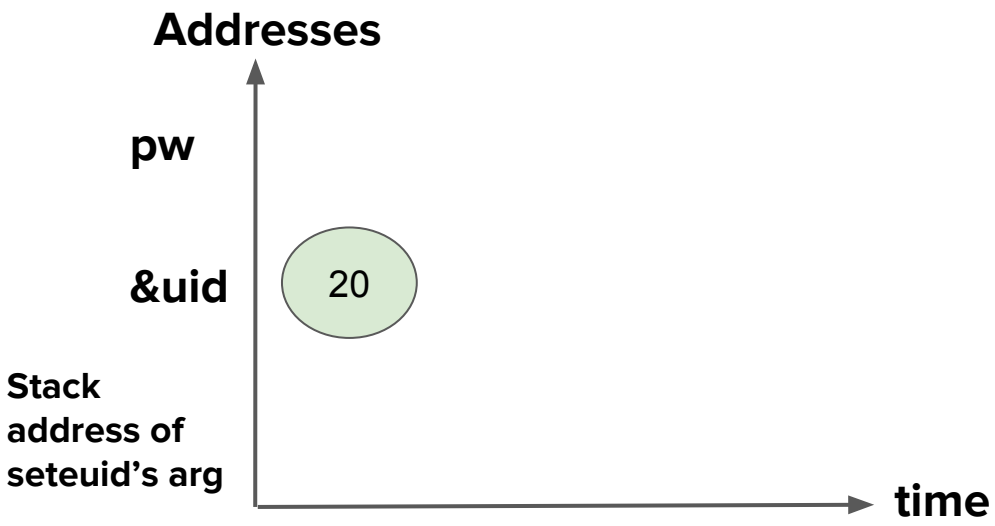

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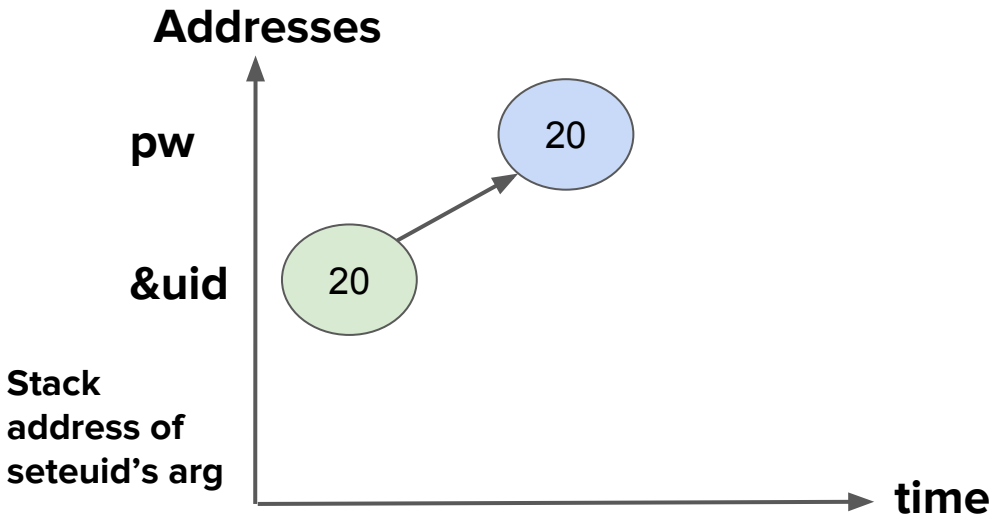

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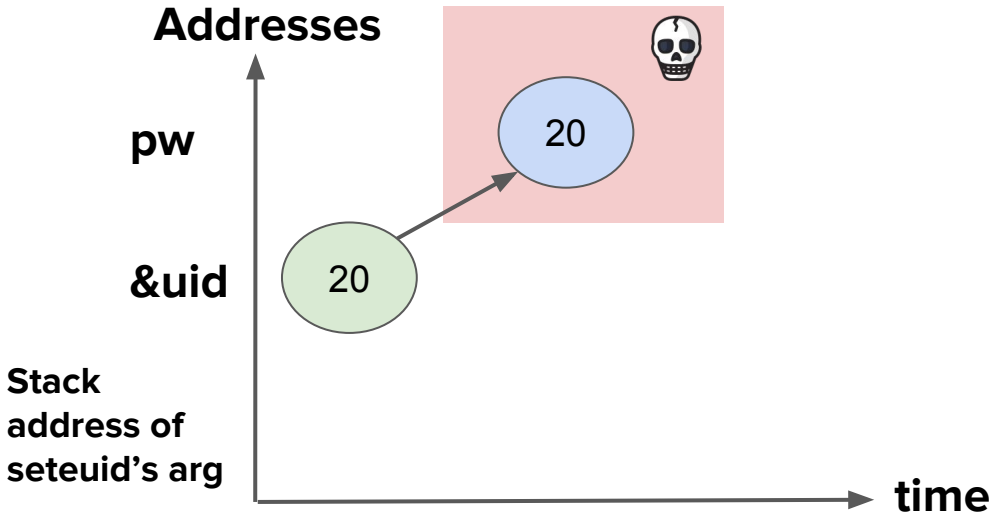

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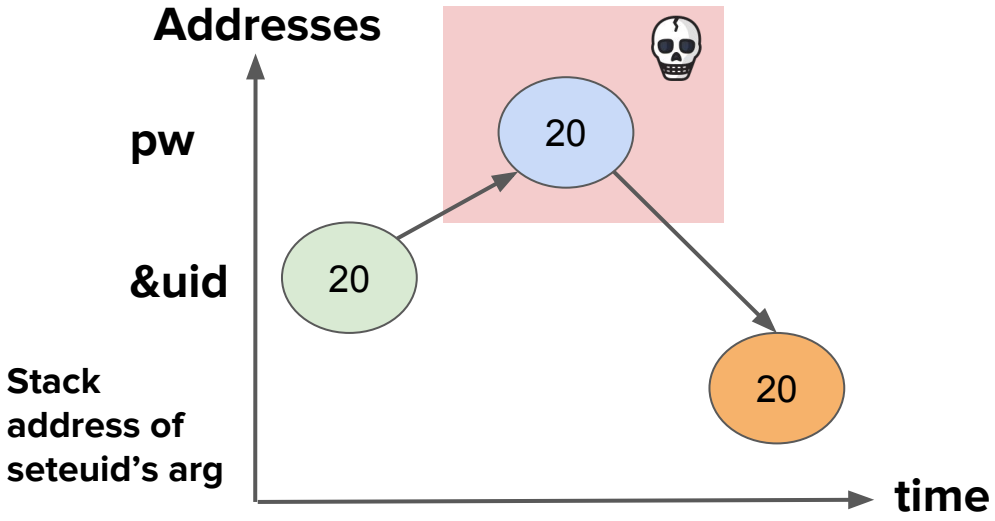

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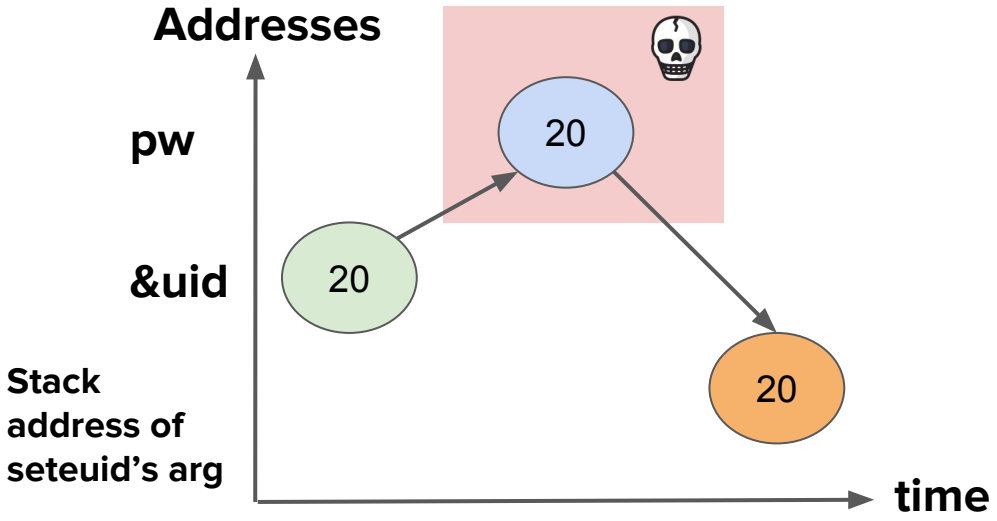

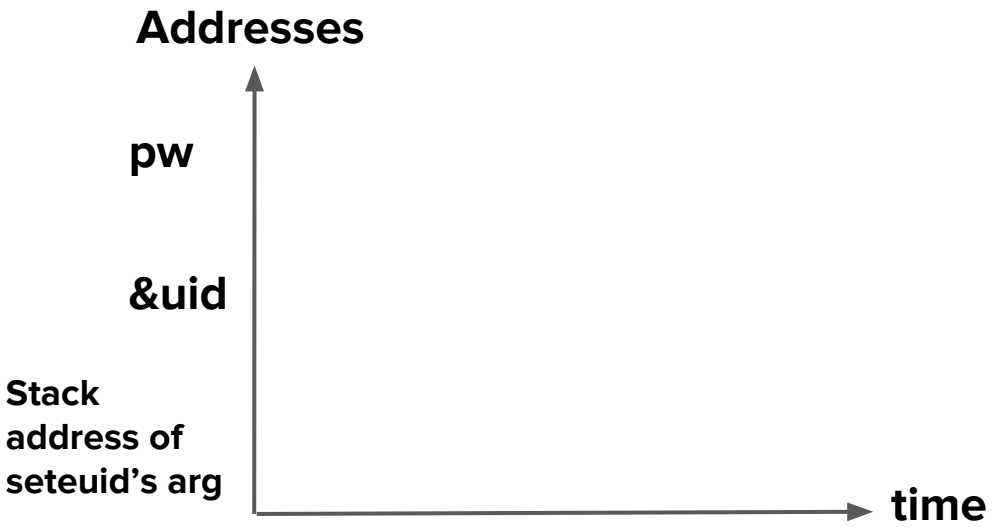

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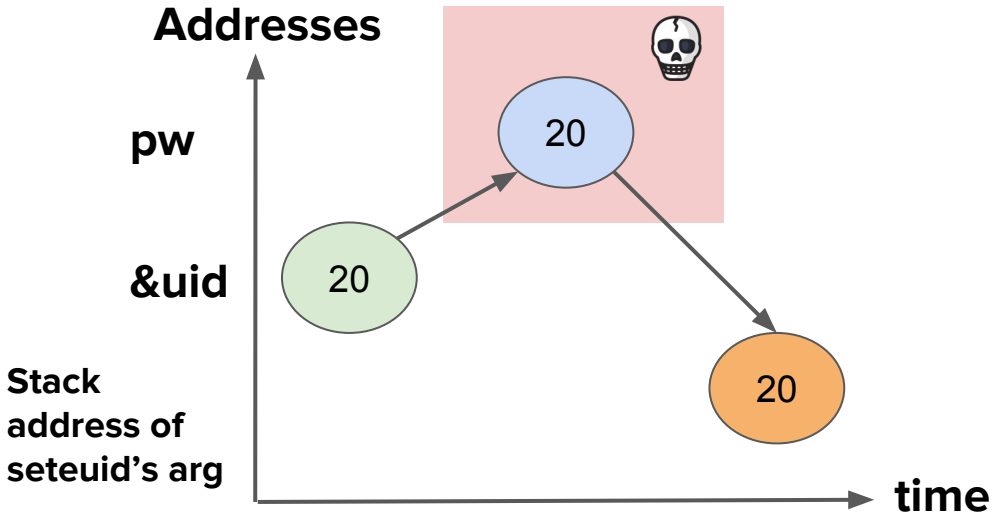

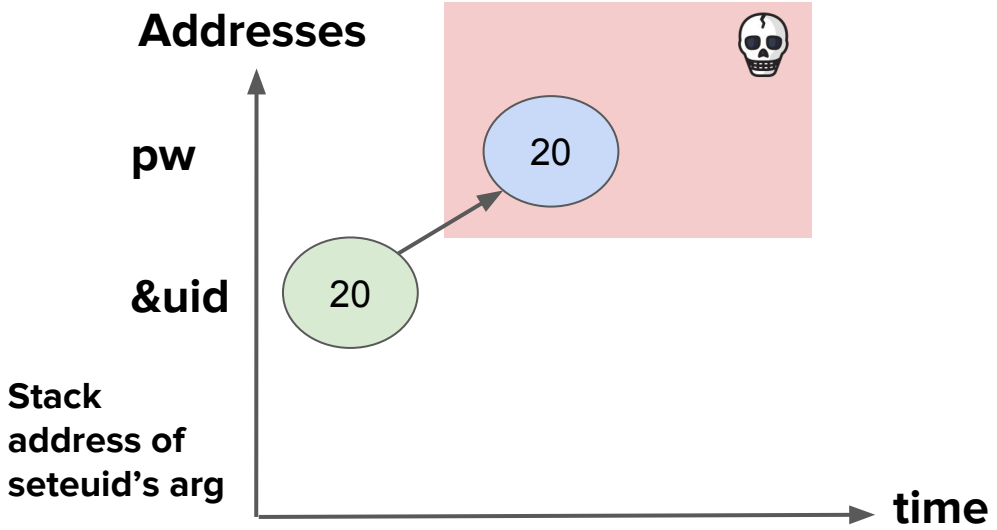

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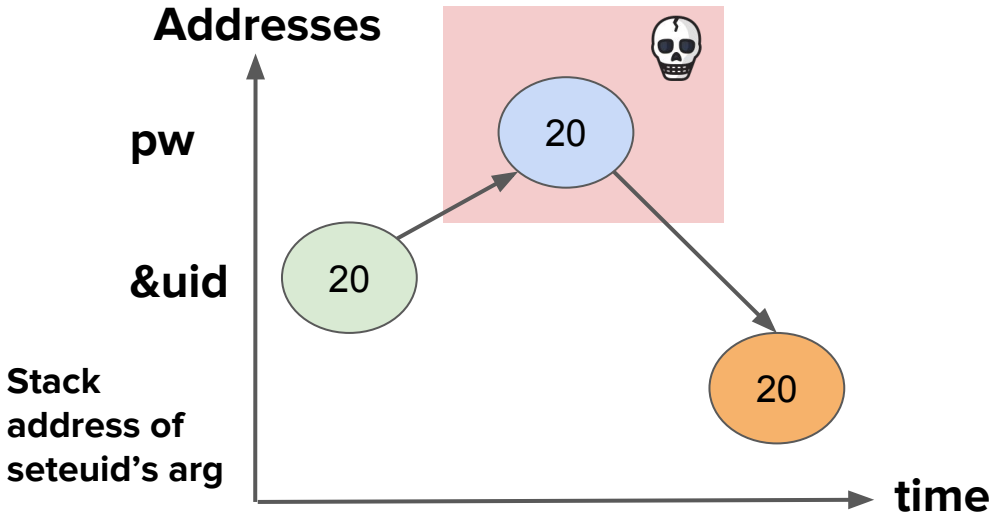

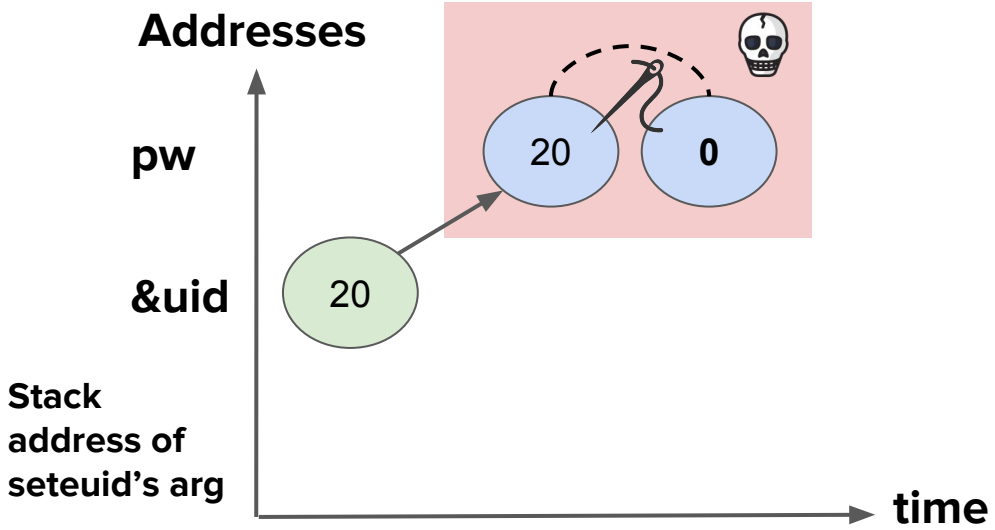

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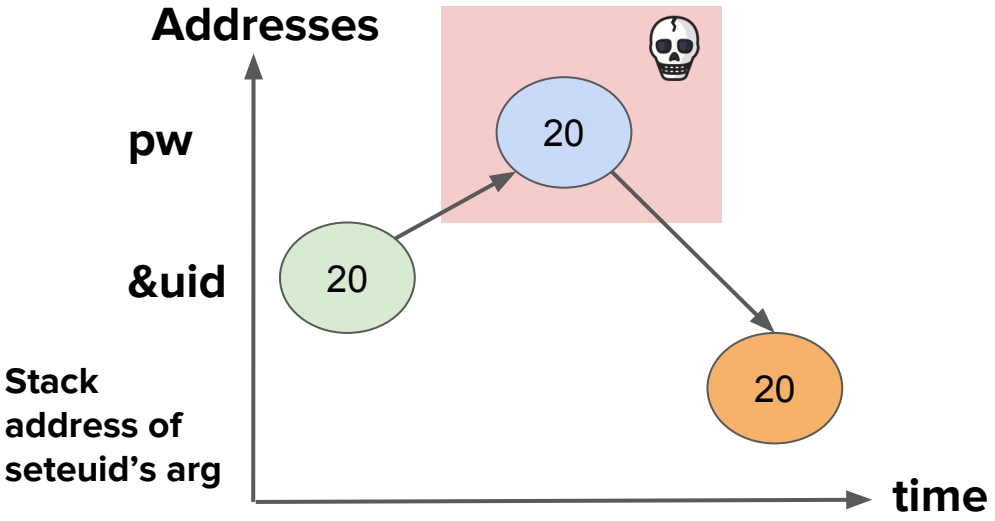

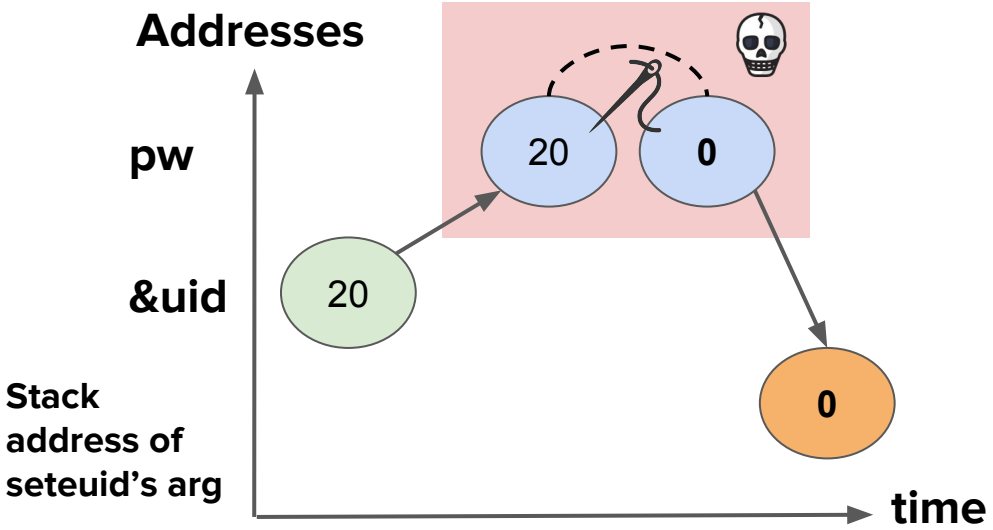

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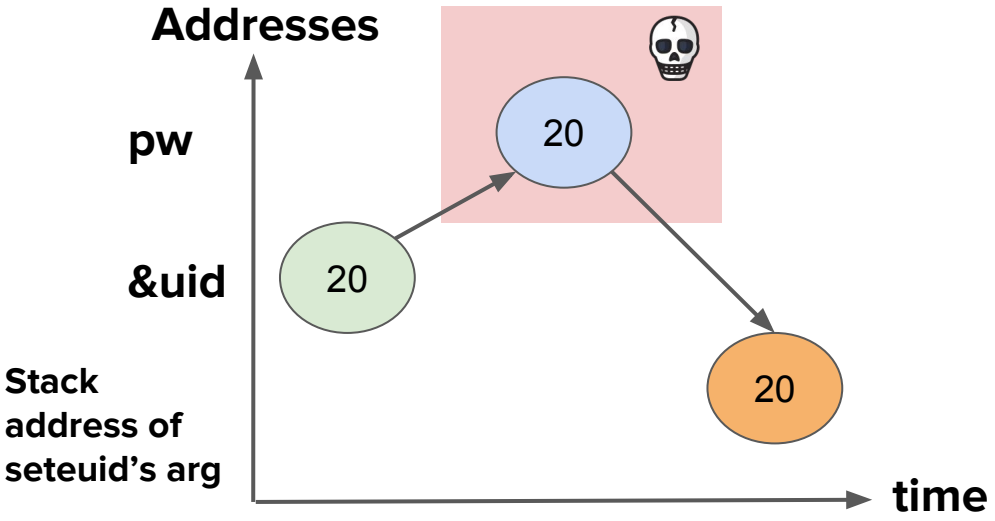

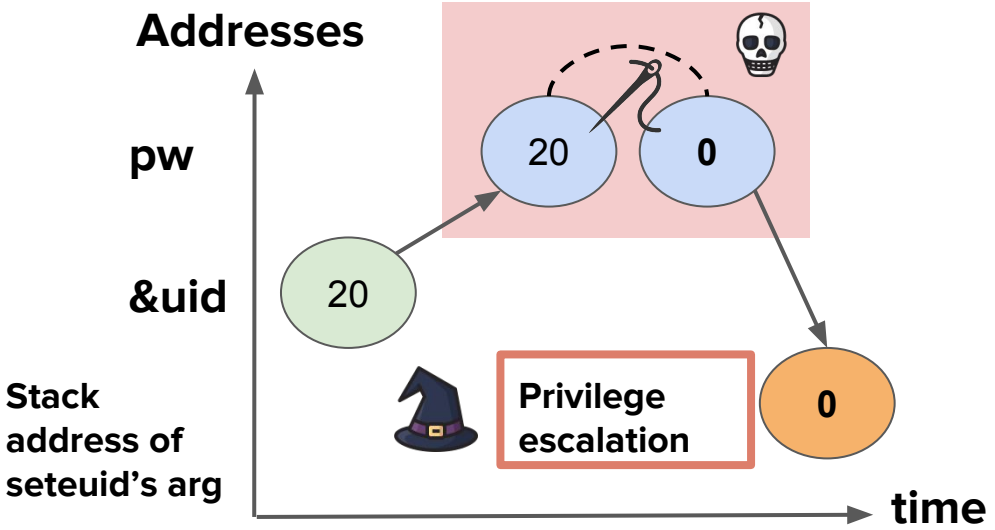

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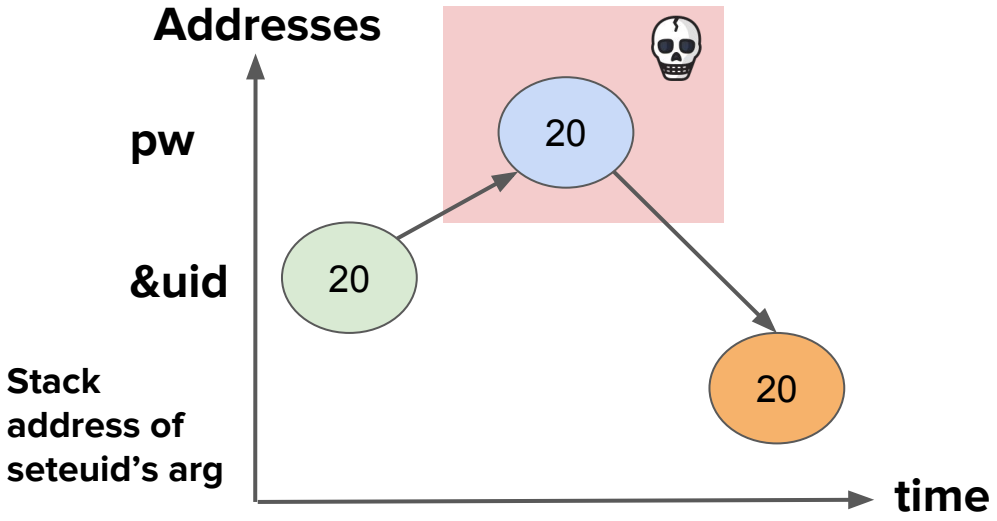

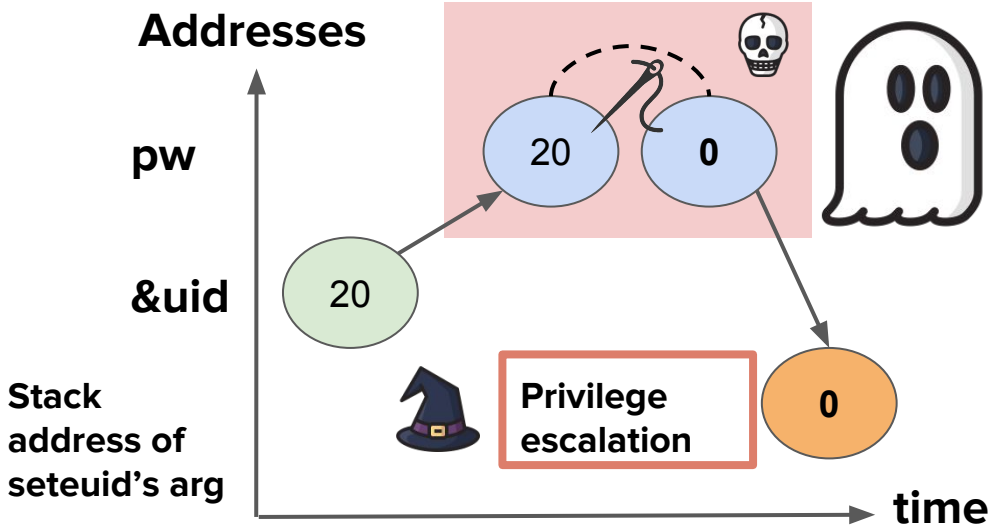

Data-Oriented Programming (DOP)

Hu et al. Oakland'16

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Code-reuse attacks with Control-Data

ROP, JOP, SROP

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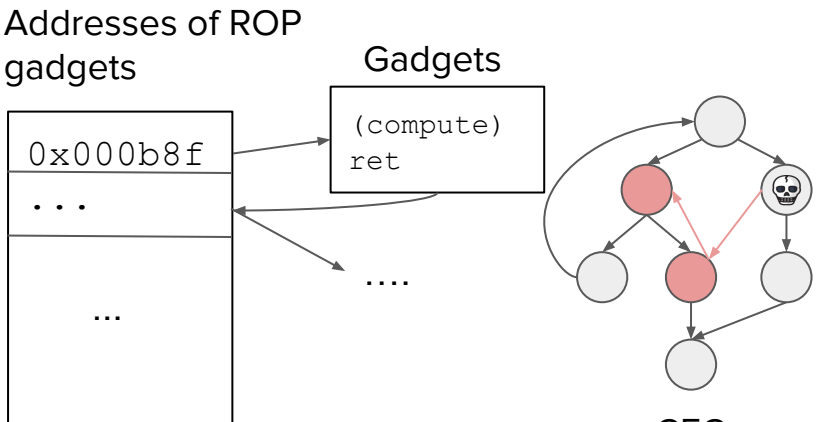

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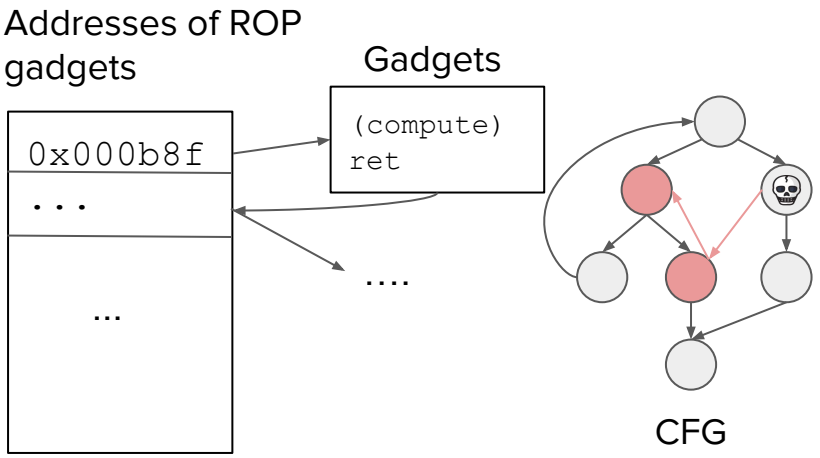
1. Classic gadgets
2. The gadgets must be chained



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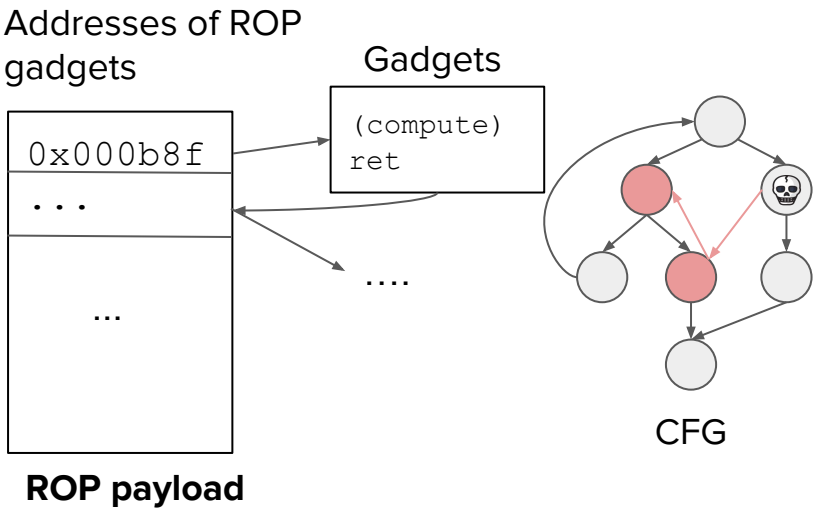

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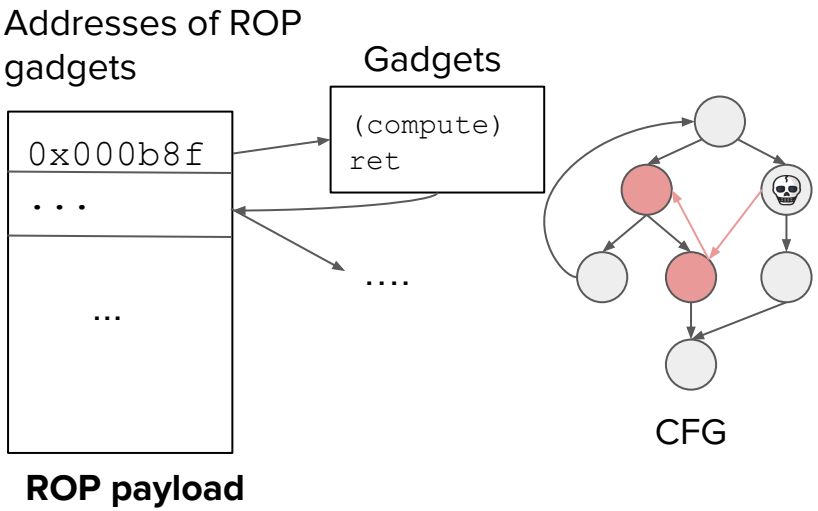

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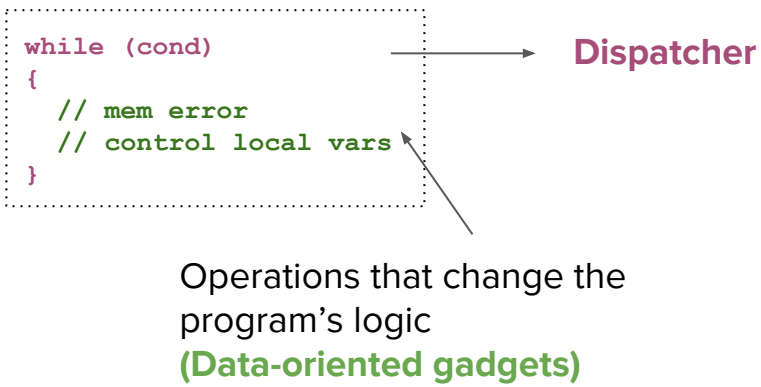

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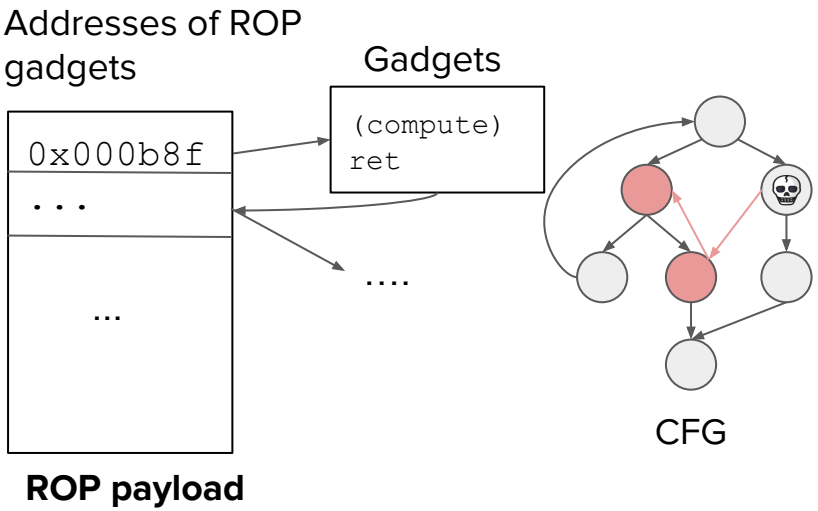
Requirements:

1. Classic gadgets
2. The gadgets must be chained

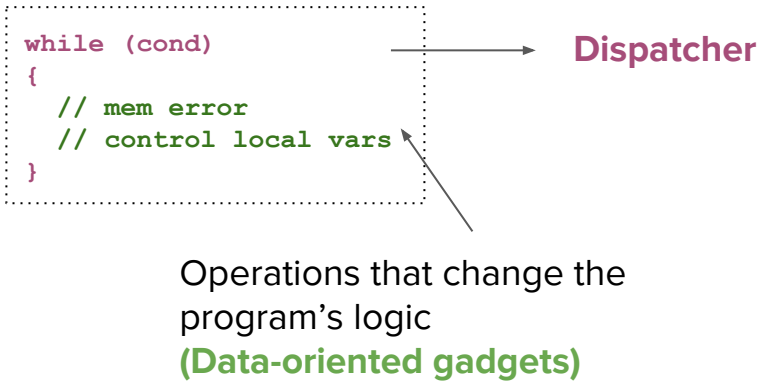


Code-reuse attacks with Non-Control-Data

DOP

Requirements:

1. Data-oriented gadgets
2. Gadget dispatcher



Data-Oriented Programming (DOP)

Hu et al. Oakland'16

Code-reuse attacks with Control-Data

ROP, JOP, SROP

Requirements:

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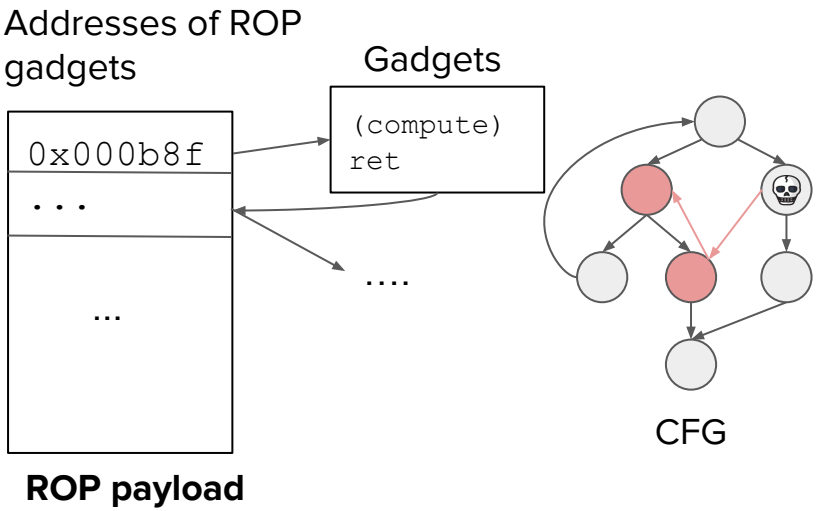
2. The gadgets must be chained

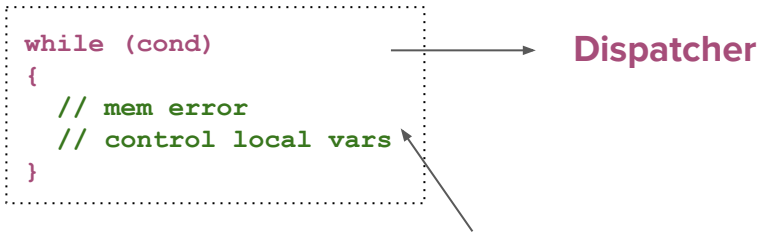


Code-reuse attacks with Non-Control-Data

DOP

Requirements:

1. Data-oriented gadgets
2. Gadget dispatcher
3. **Must follow the legitimate execution path**



Operations that change the program's logic
(Data-oriented gadgets)

Data-Flow Integrity (DFI)

Castro et al. OSDI'06

Data-Flow Integrity (DFI)

Castro et al. OSDI'06

1 - Offline: DFG computation

Data-Flow Integrity (DFI)

Castro et al. OSDI'06

```
x = 100;
a = 0;
if (...)
{
    x = 0;
    // mem. error
}
y = x * 2;
```

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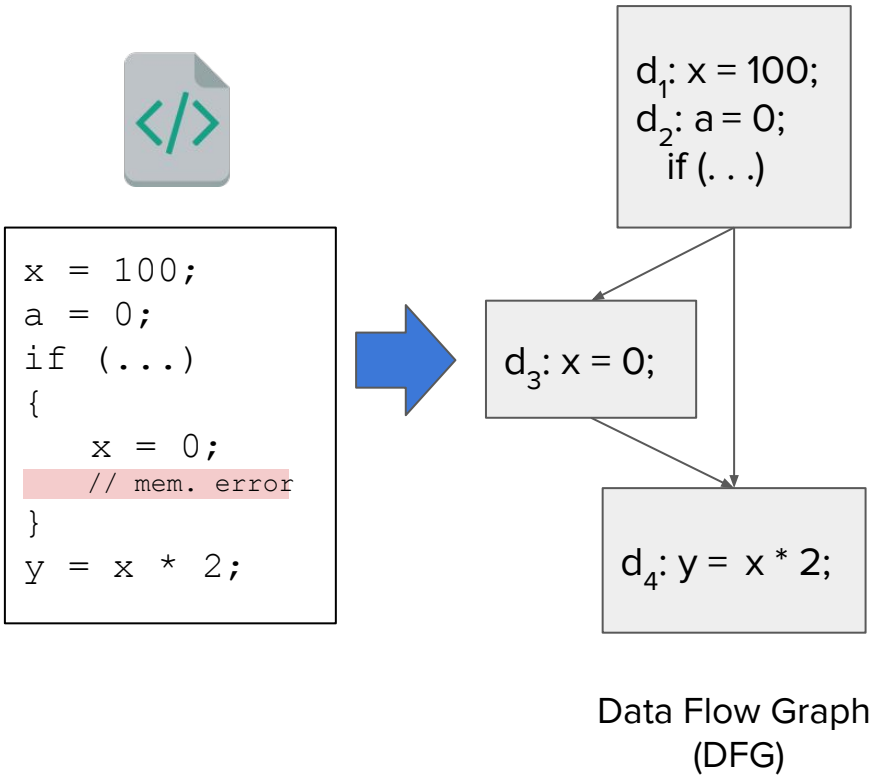
Data-Flow Integrity (DFI)

Castro et al. OSDI'06



Data Flow Graph
(DFG)

1 - Offline: DFG computation

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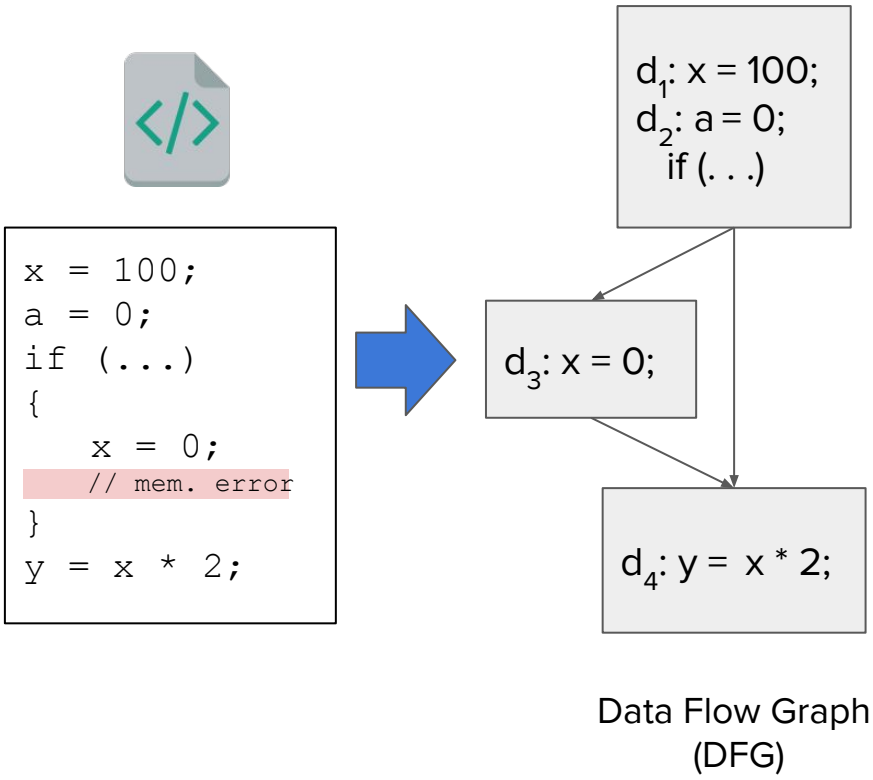
Castro et al. OSDI'06



Data Flow Graph (DFG)

1 - Offline: DFG computation

2 - Runtime: DFG enforcement

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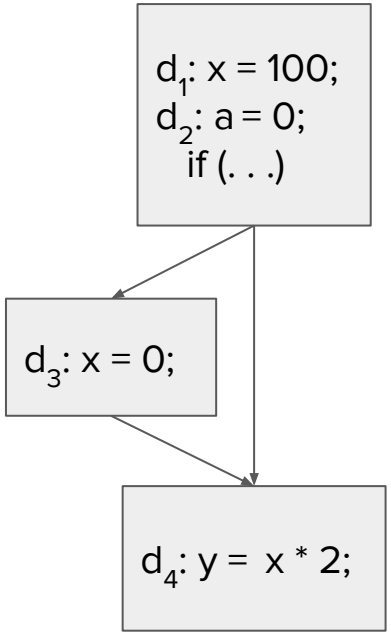


Data Flow Graph (DFG)

$x \rightarrow \{ d_1, d_3 \}$
$a \rightarrow \{ d_2 \}$
$y \rightarrow \{ d_4 \}$

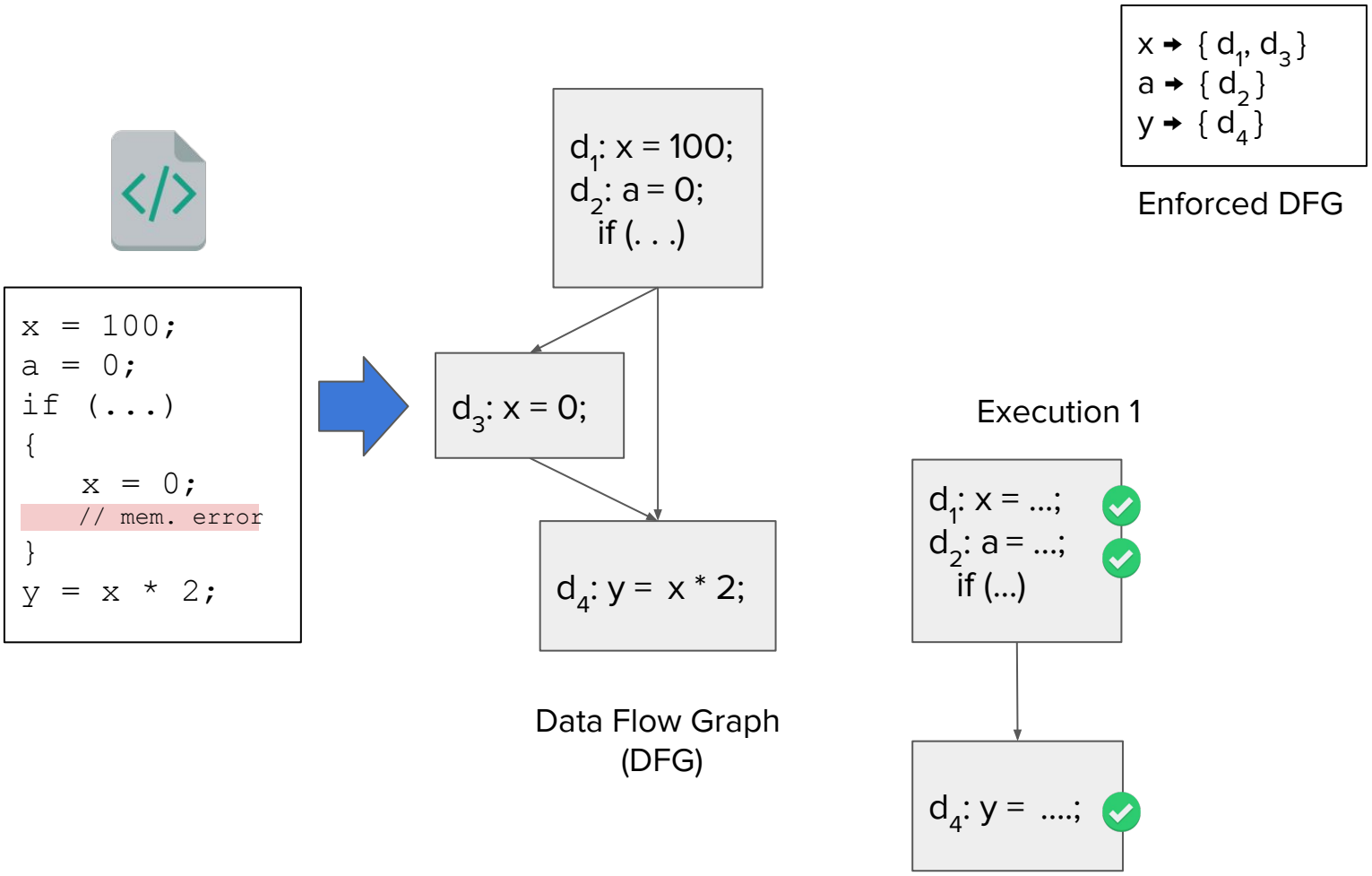
Enforced DFG

1 - Offline: DFG computation

2 - Runtime: DFG enforcement

Data-Flow Integrity (DFI)

Castro et al. OSDI'06



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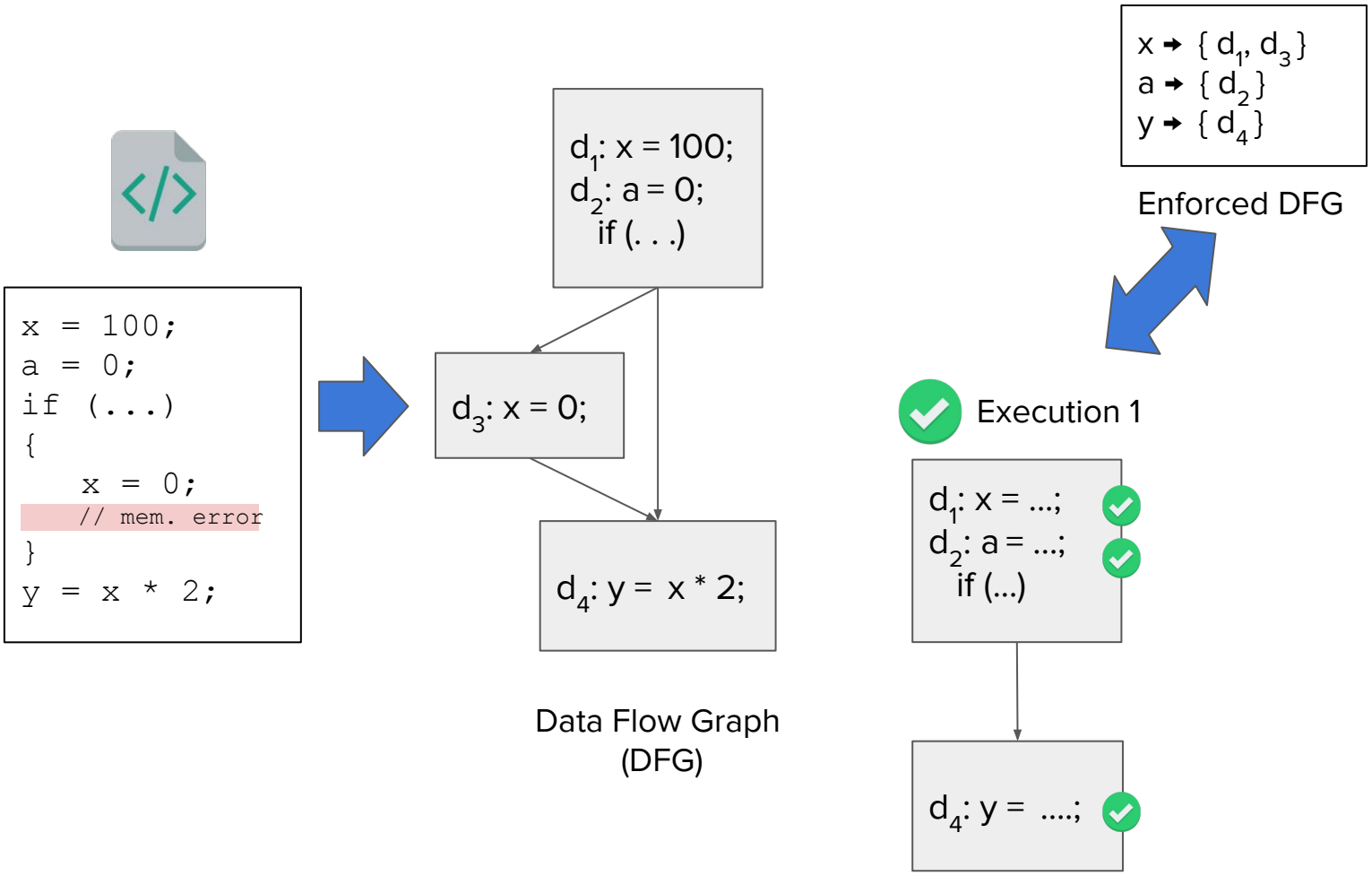

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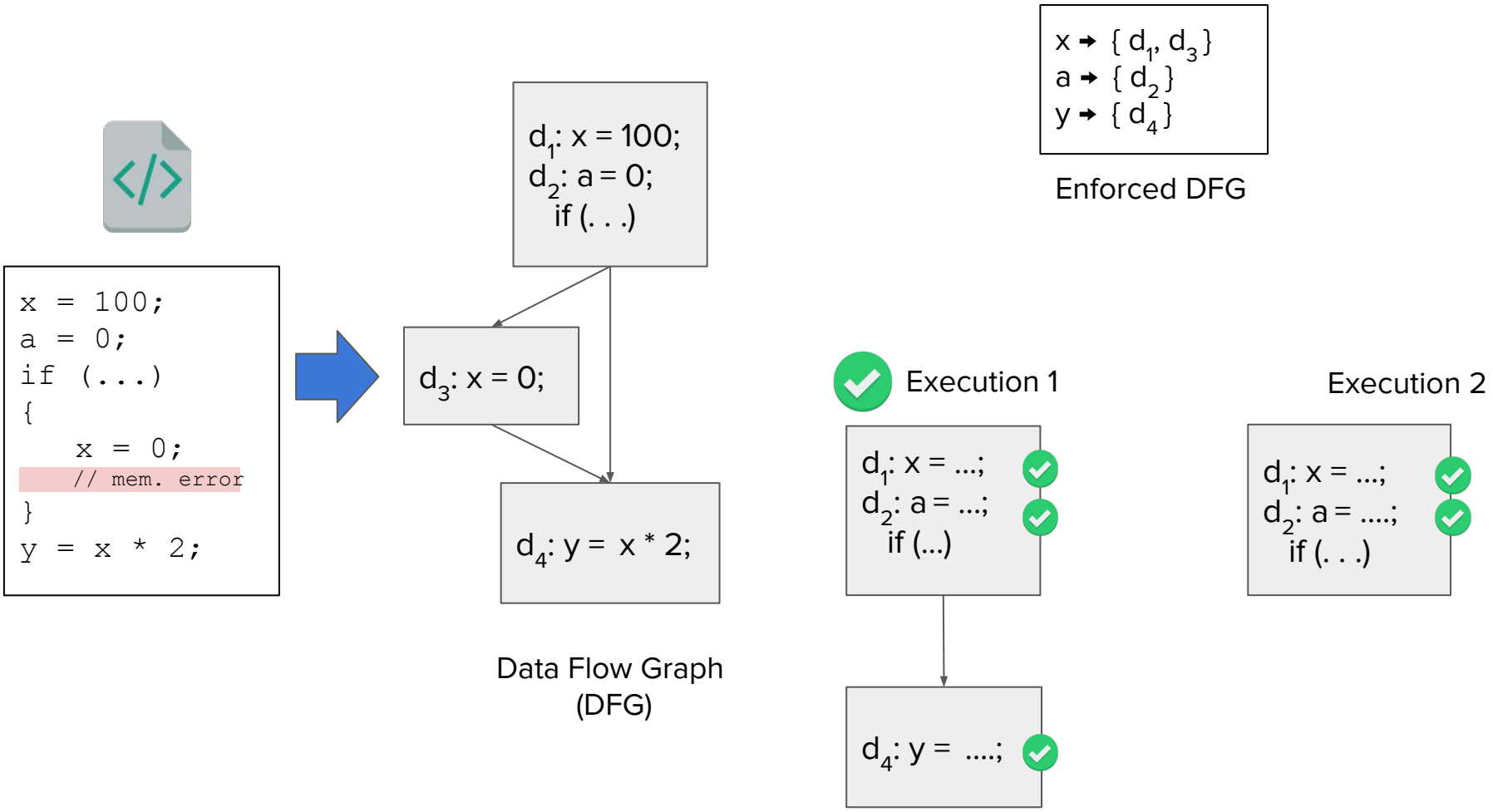

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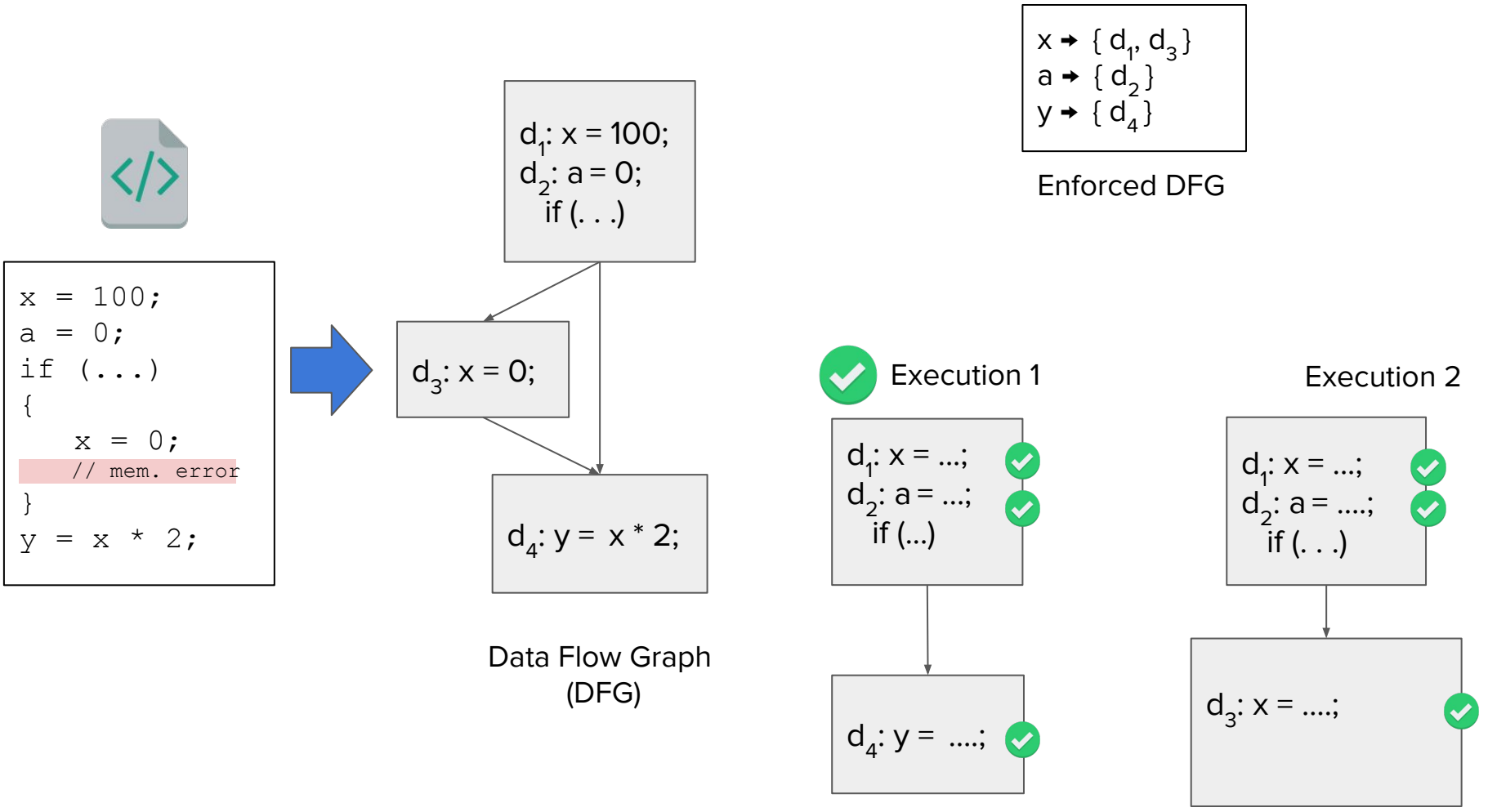

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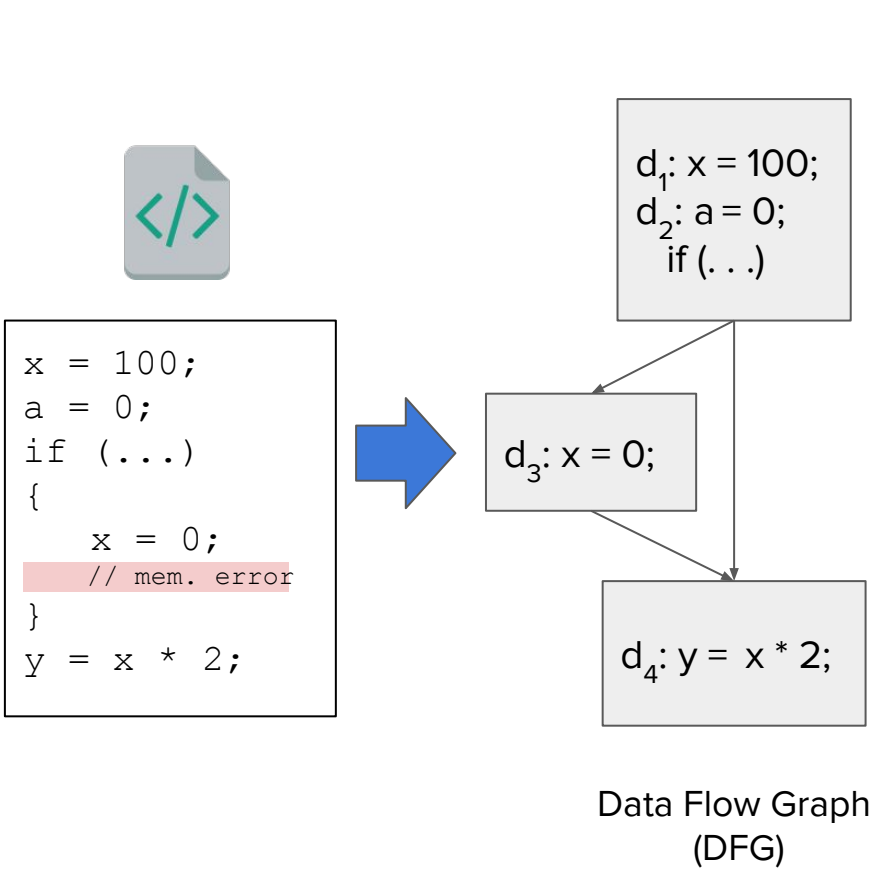

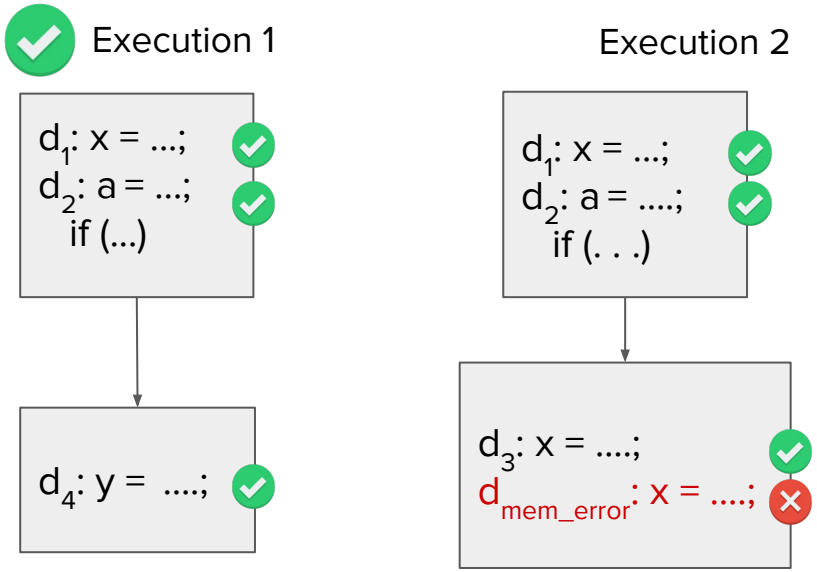

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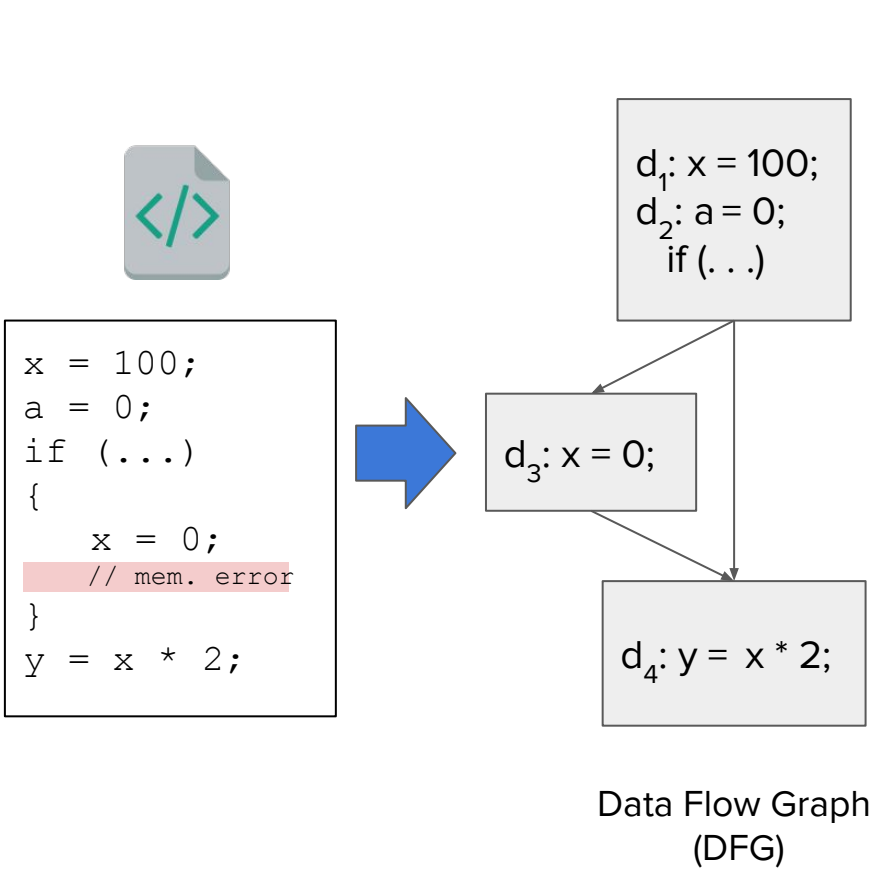

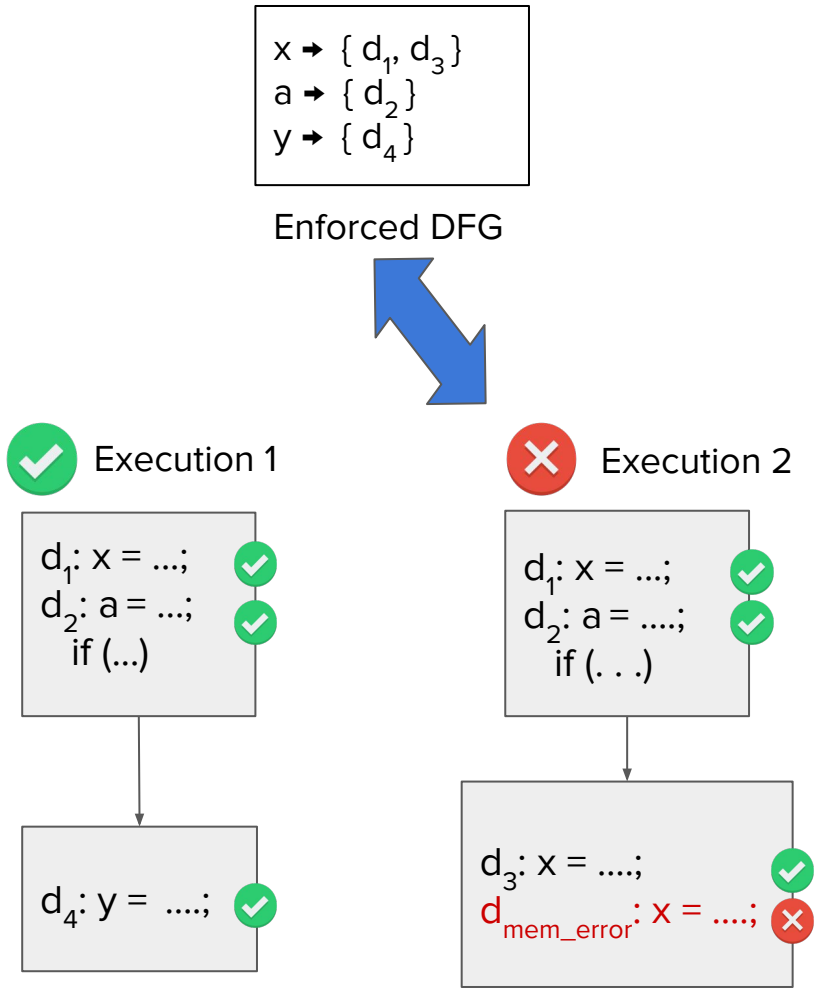

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Kernel Data-Flow Integrity

Song et al. NDSS'16

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Protect the kernel against memory-corruption-based privilege escalation attacks

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Protect the access control mechanisms

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Access control checks

Integrity of the code & data of the access controls

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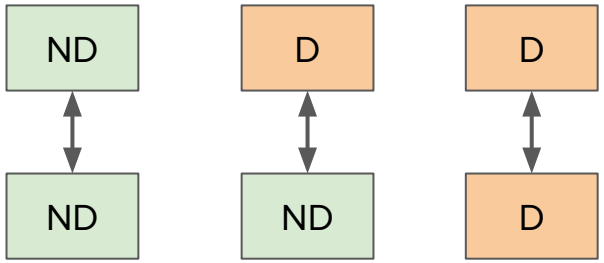

D: distinguishing, **ND**:non-distinguishing

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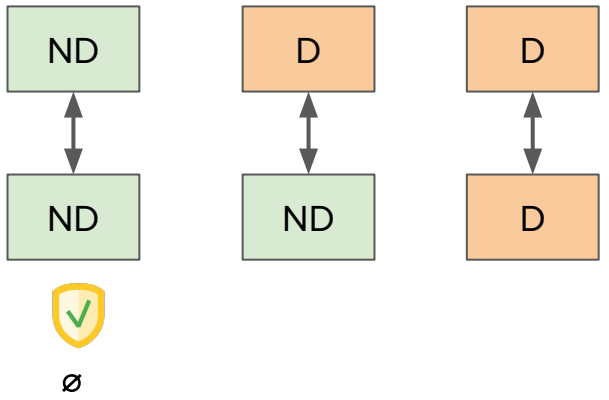

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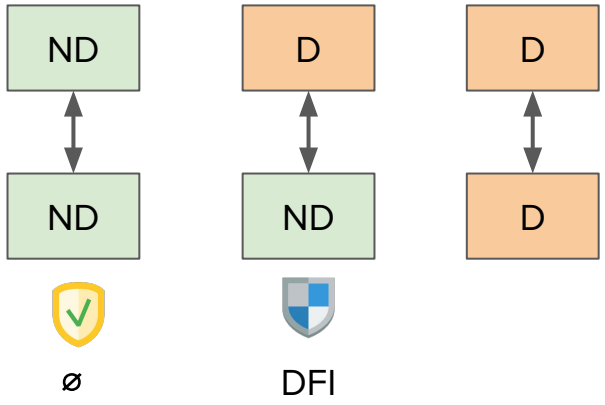

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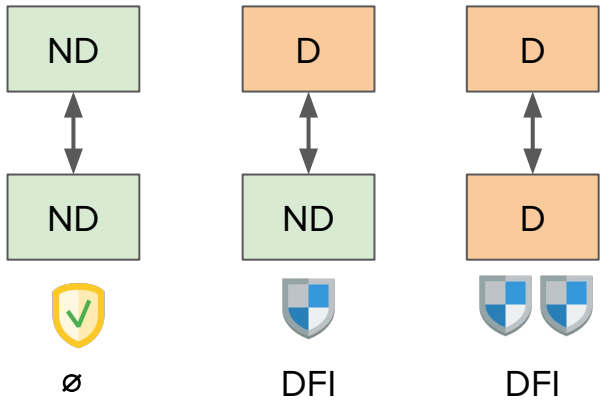

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Closing remarks

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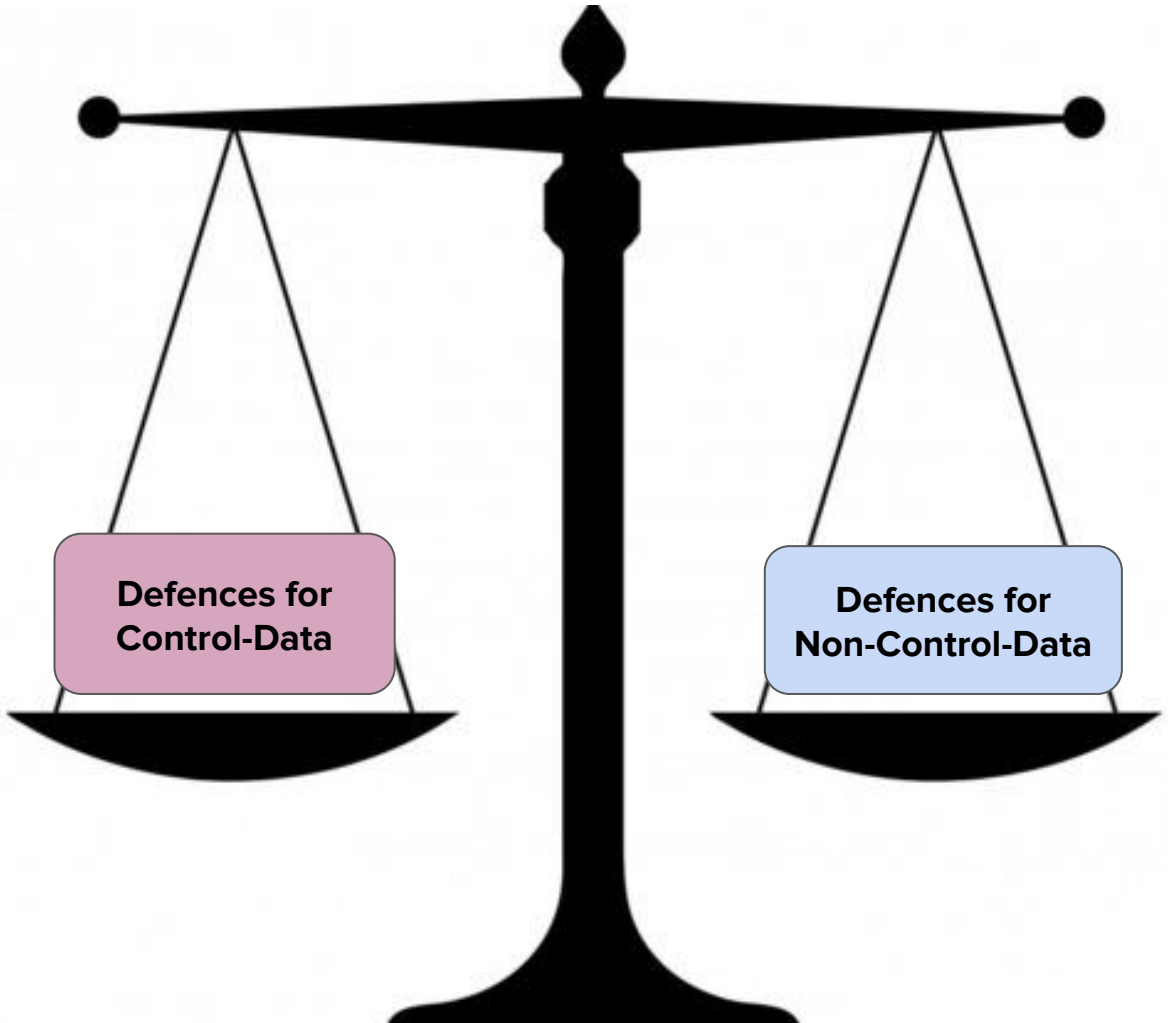
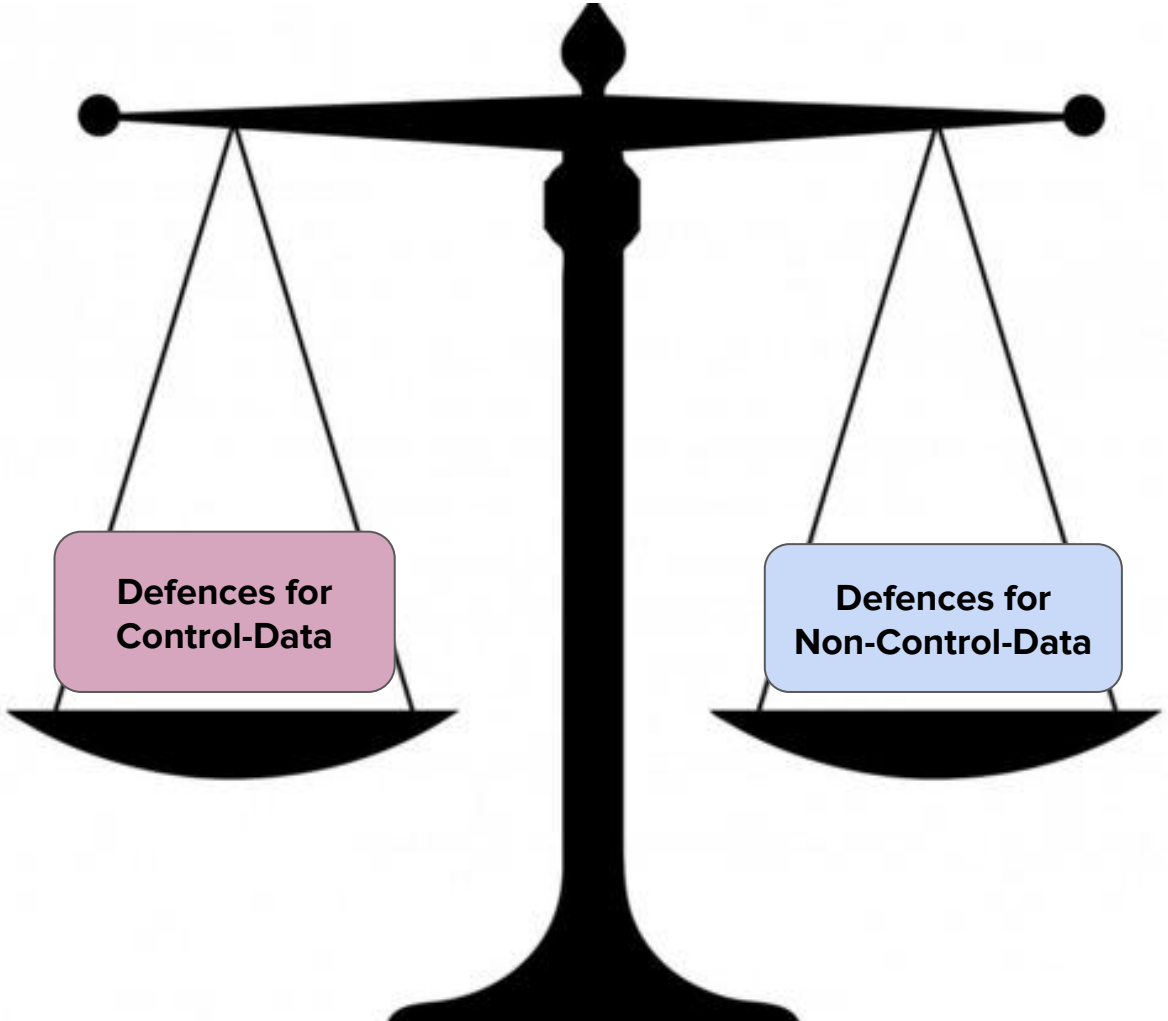


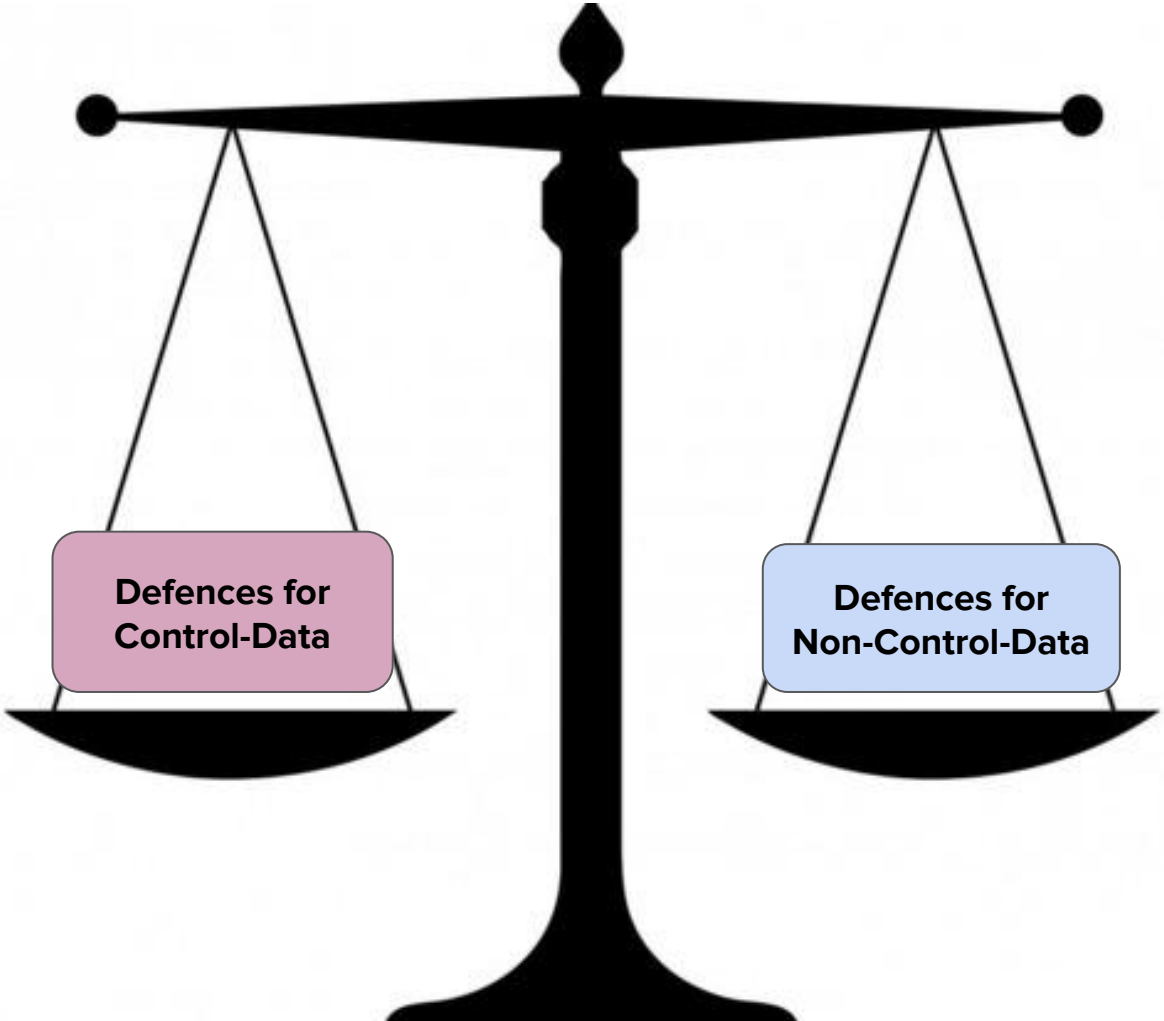
Closing remarks



Closing remarks

Why are they constantly making my life harder?

Haters gonna hate



Data is Flowing in the Wind: A Review of Data-Flow Integrity Methods to Overcome Non-Control-Data Attacks

Irene Díez-Franco, Igor Santos
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irene.diez@deusto.es isantos@deusto.es