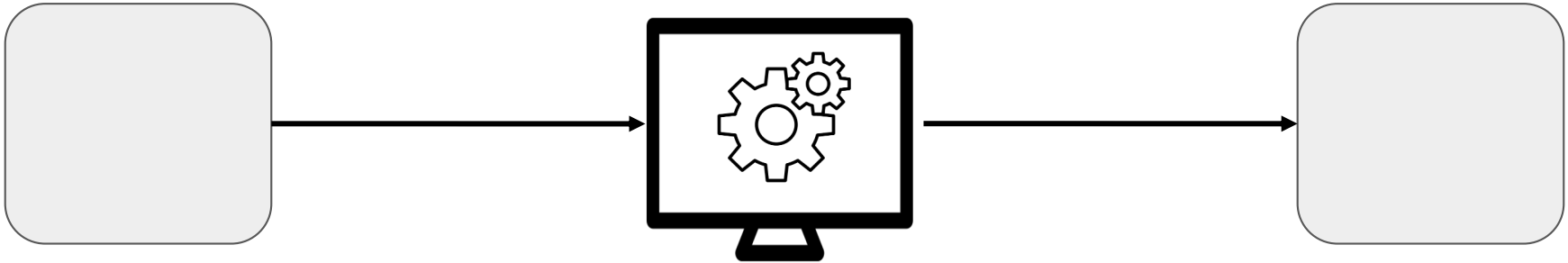
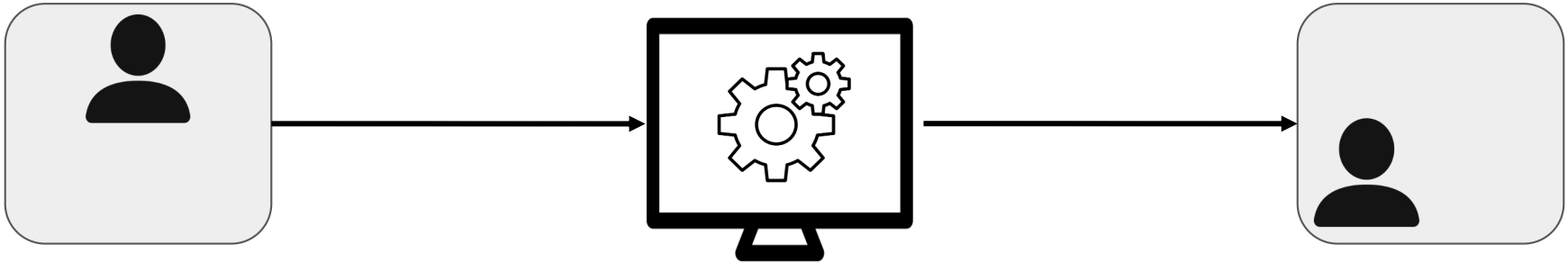
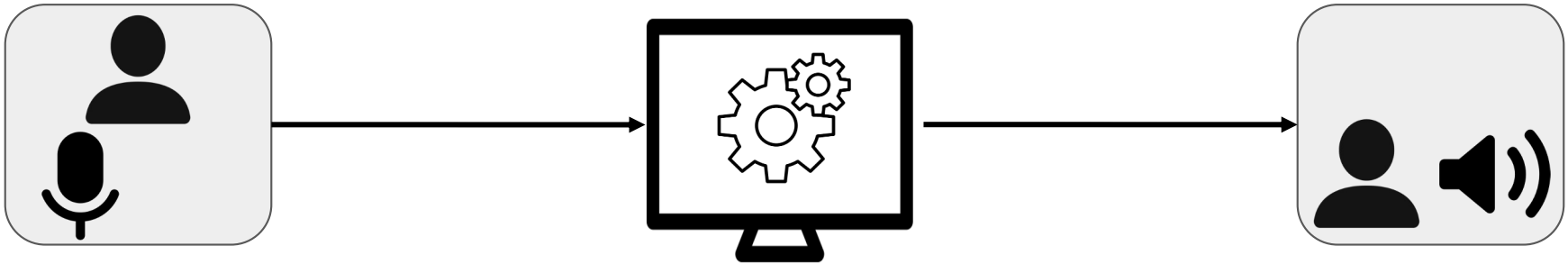
Information Flow–Based Vulnerability Modeling

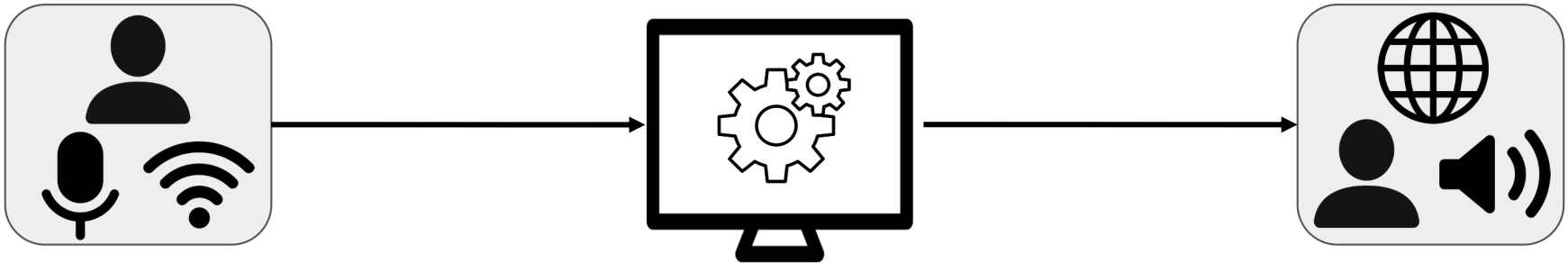
Brian Johannesmeyer

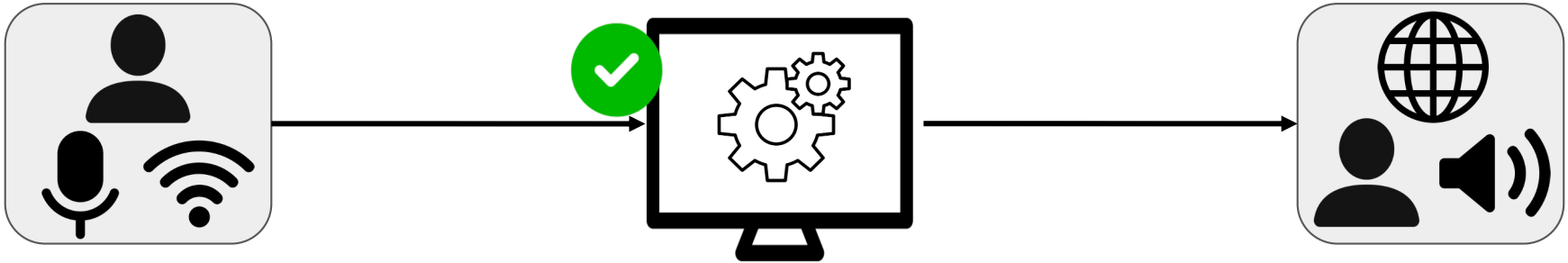
VU VRIJE UNIVERSITEIT AMSTERDAM

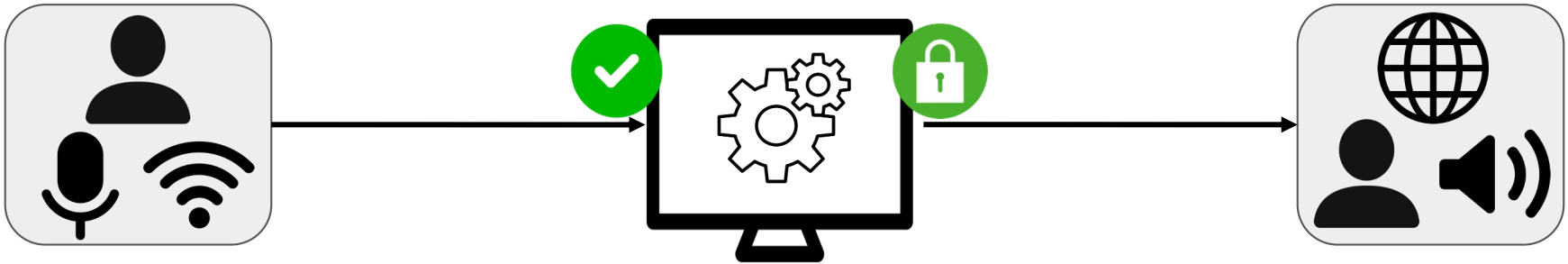


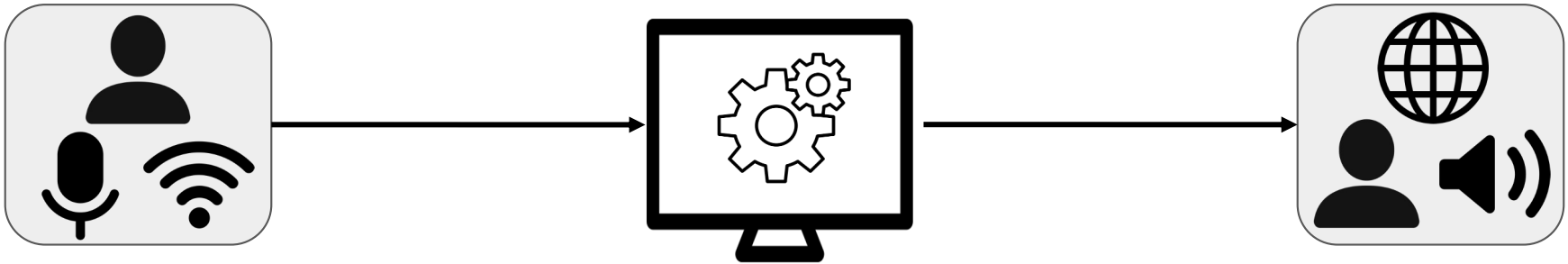


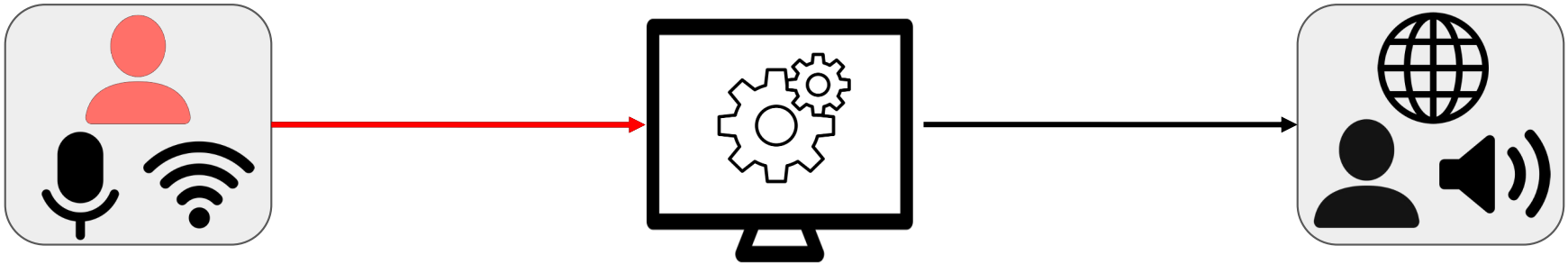


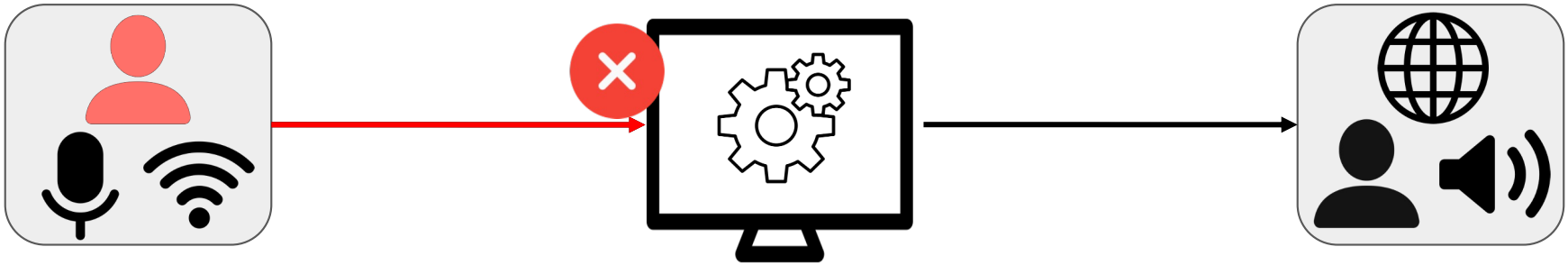


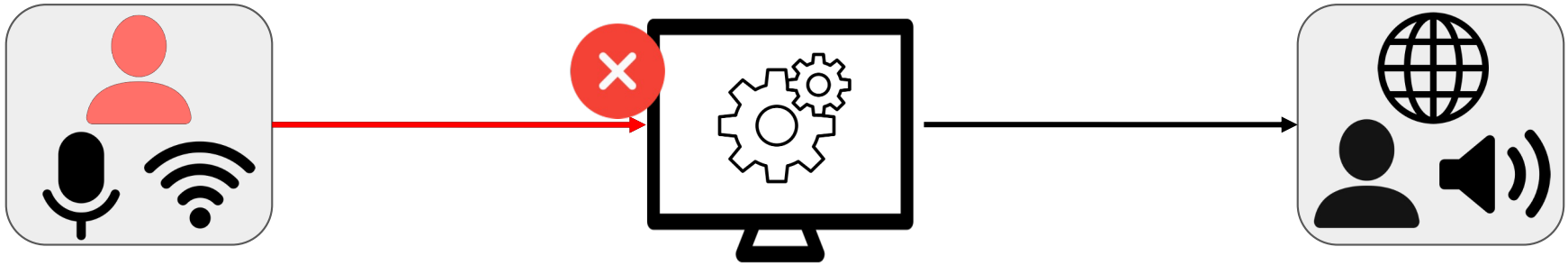










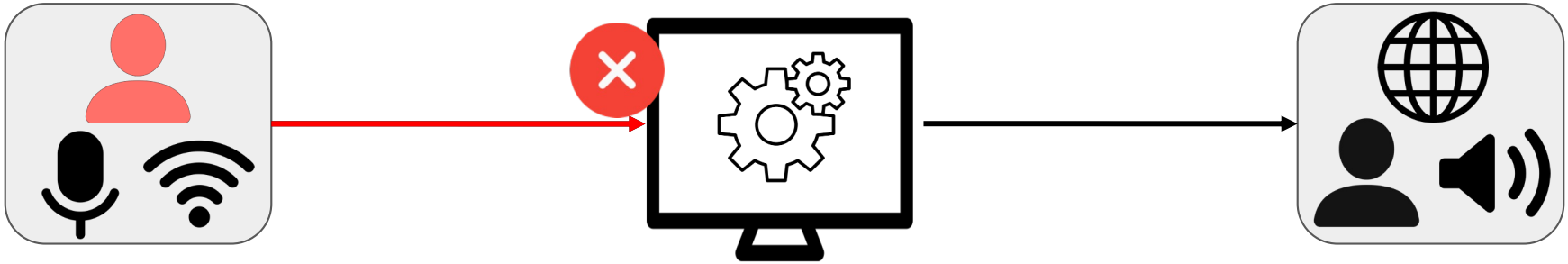


KIM ZETTER SECURITY NOV 3. 2014 6:30 AM

An Unprecedented Look at Stuxnet, the World's First Digital Weapon

In an excerpt from her new book, "Countdown to Zero Day," WIRED's Kim Zetter describes the dark path the world's first digital weapon took to reach its target in Iran.

This recent undated satellite image provided by Space Imaging/Inta SpaceTurk shows the once-secret Natanz nuclear complex in Natanz, Iran, about 150 miles south of Tehran. AP PHOTO/SPACE IMAGING/INTA SPACETURK, HO



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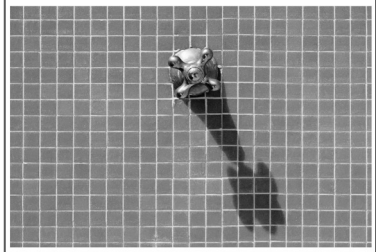
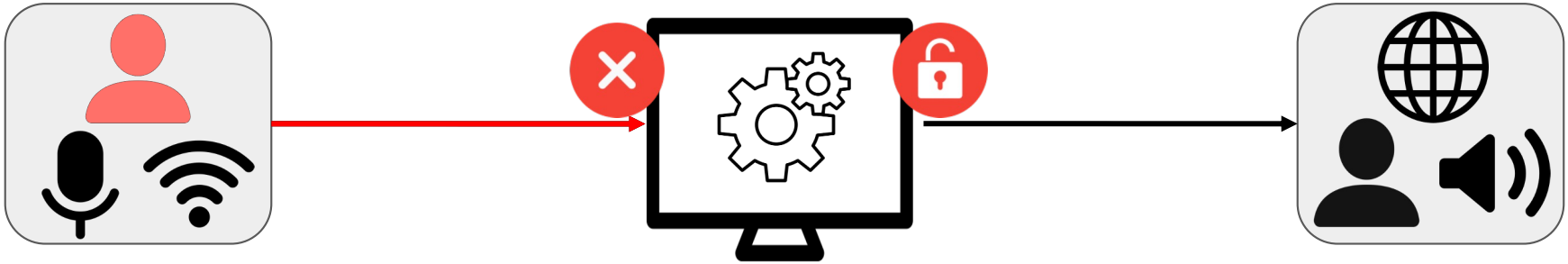
ANDY GREENBERG SECURITY FEB 8. 2021 6:54 PM

A Hacker Tried to Poison a Florida City's Water Supply, Officials Say

The attacker upped sodium hydroxide levels in the Oldsmar, Florida, water supply to extremely dangerous levels.



The cursor began clicking through the water treatment plant's controls. Within seconds, the intruder was attempting to change the water supply's levels of sodium hydroxide. PHOTOGRAPH: GETTY IMAGES



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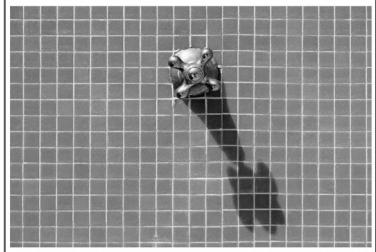

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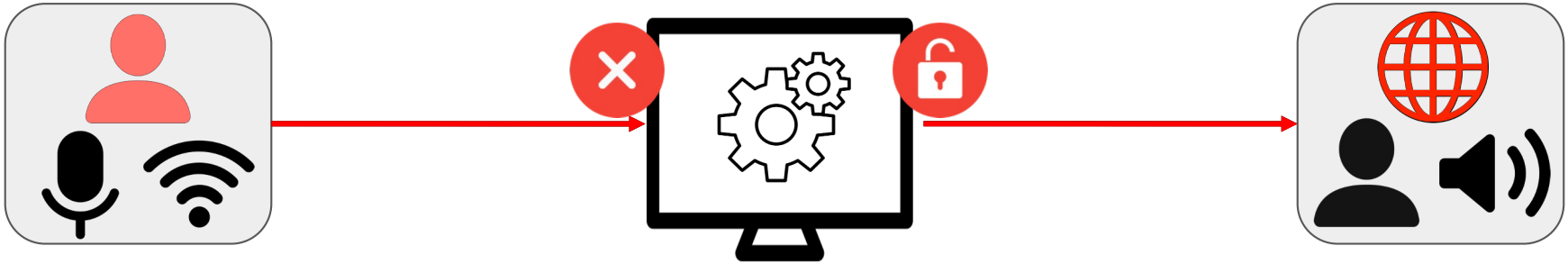

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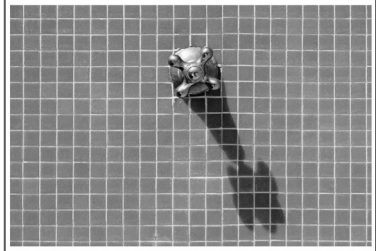

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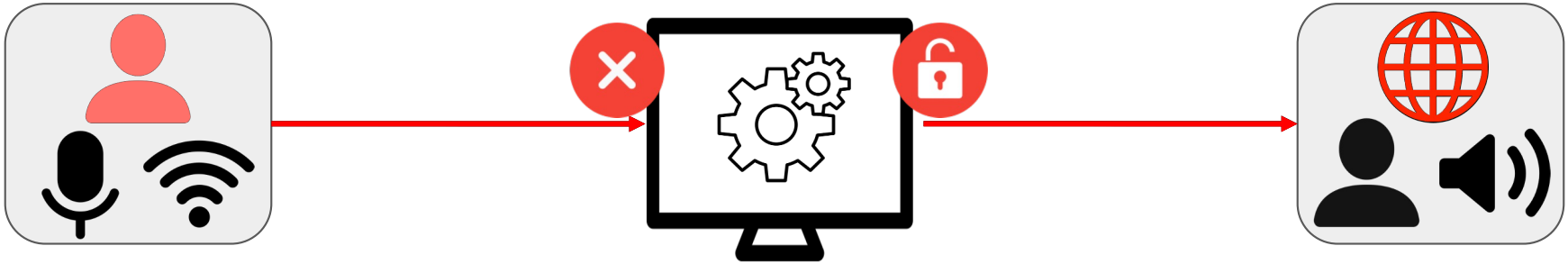

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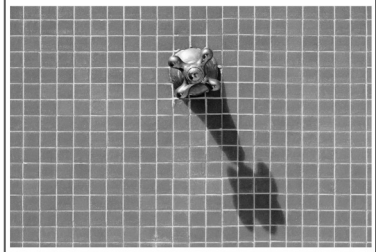

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KIM ZETTER SECURITY APR 11. 2014 4:57 PM

Report: NSA Exploited Heartbleed to Siphon Passwords for Two Years

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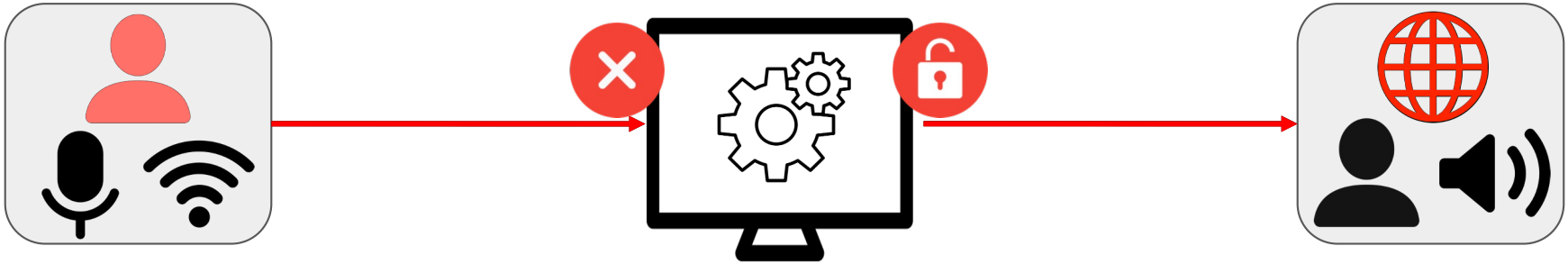

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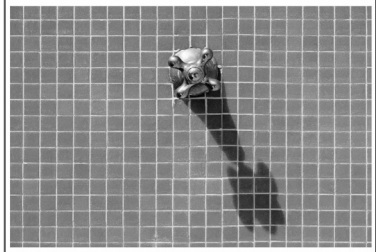

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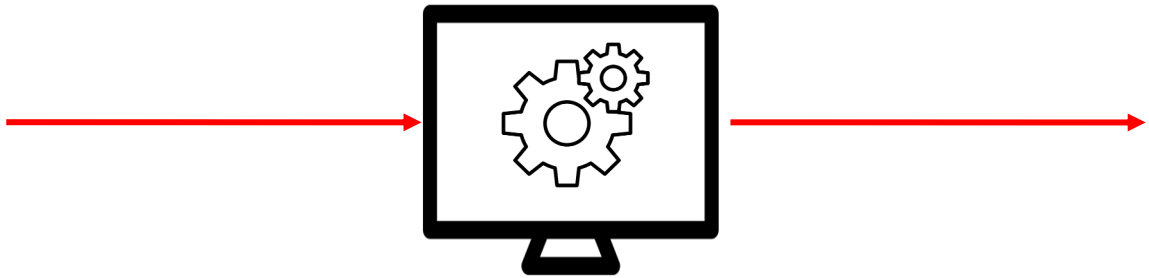
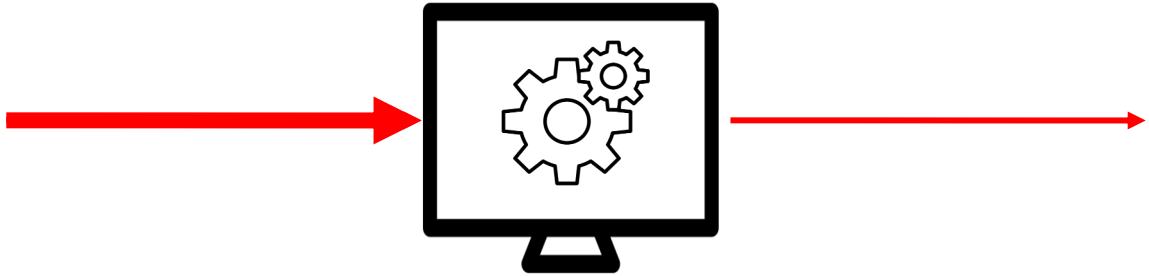
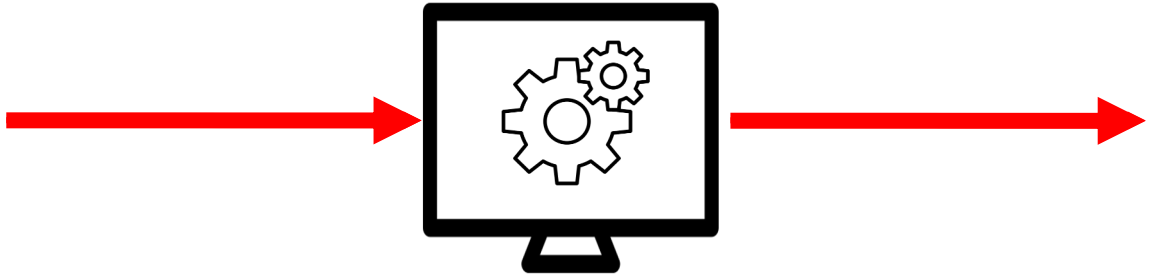
BRIAN BARRETT SECURITY DEC 19. 2020 9:00 AM

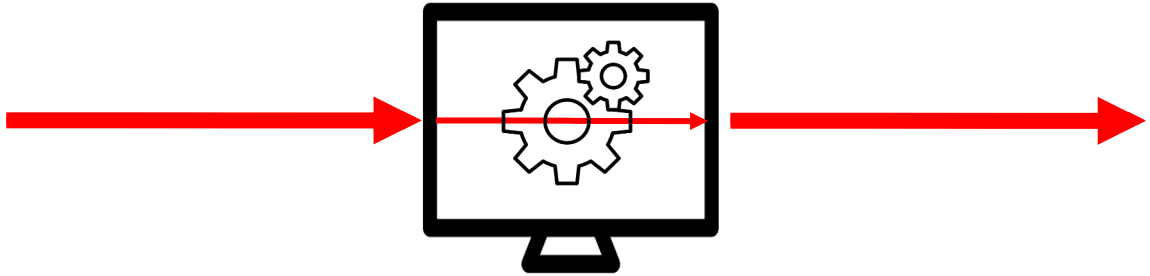
Security News This Week: Russia's SolarWinds Hack Is a Historic Mess

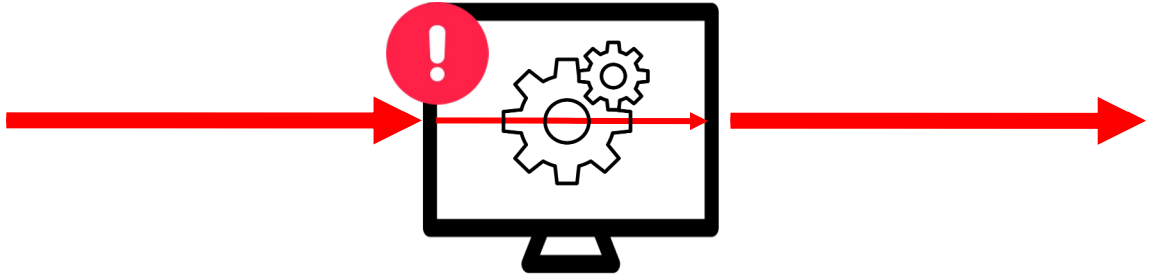
All the most important stories about the biggest hack in years.

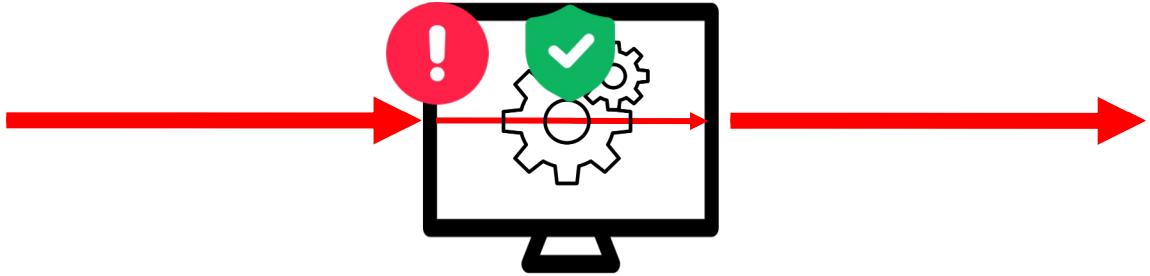


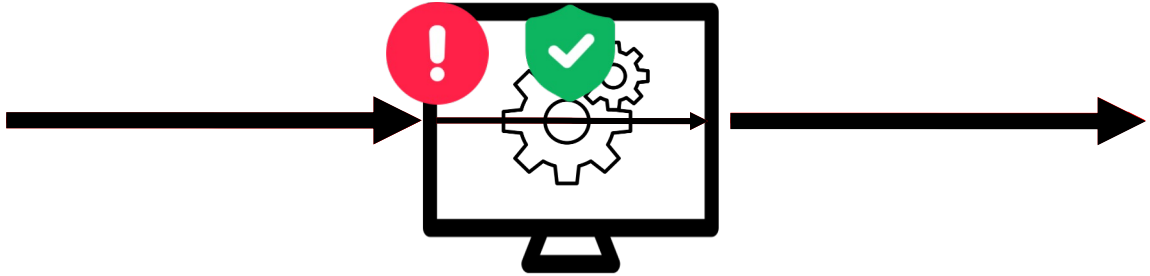


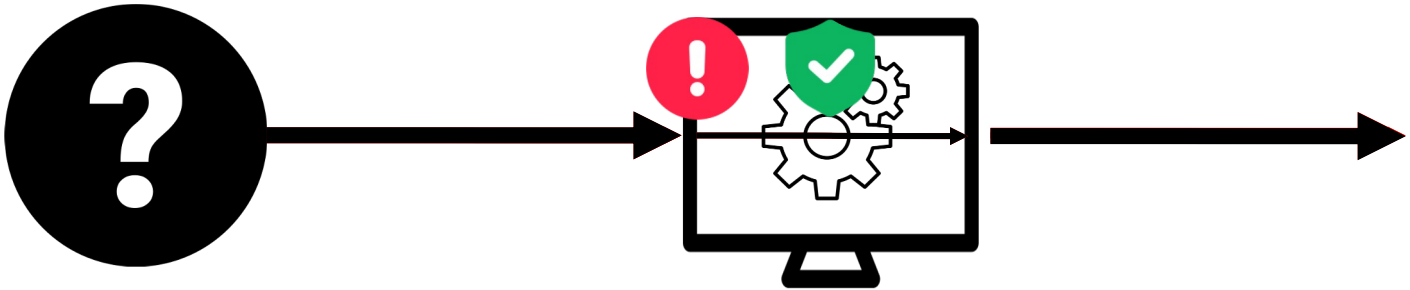


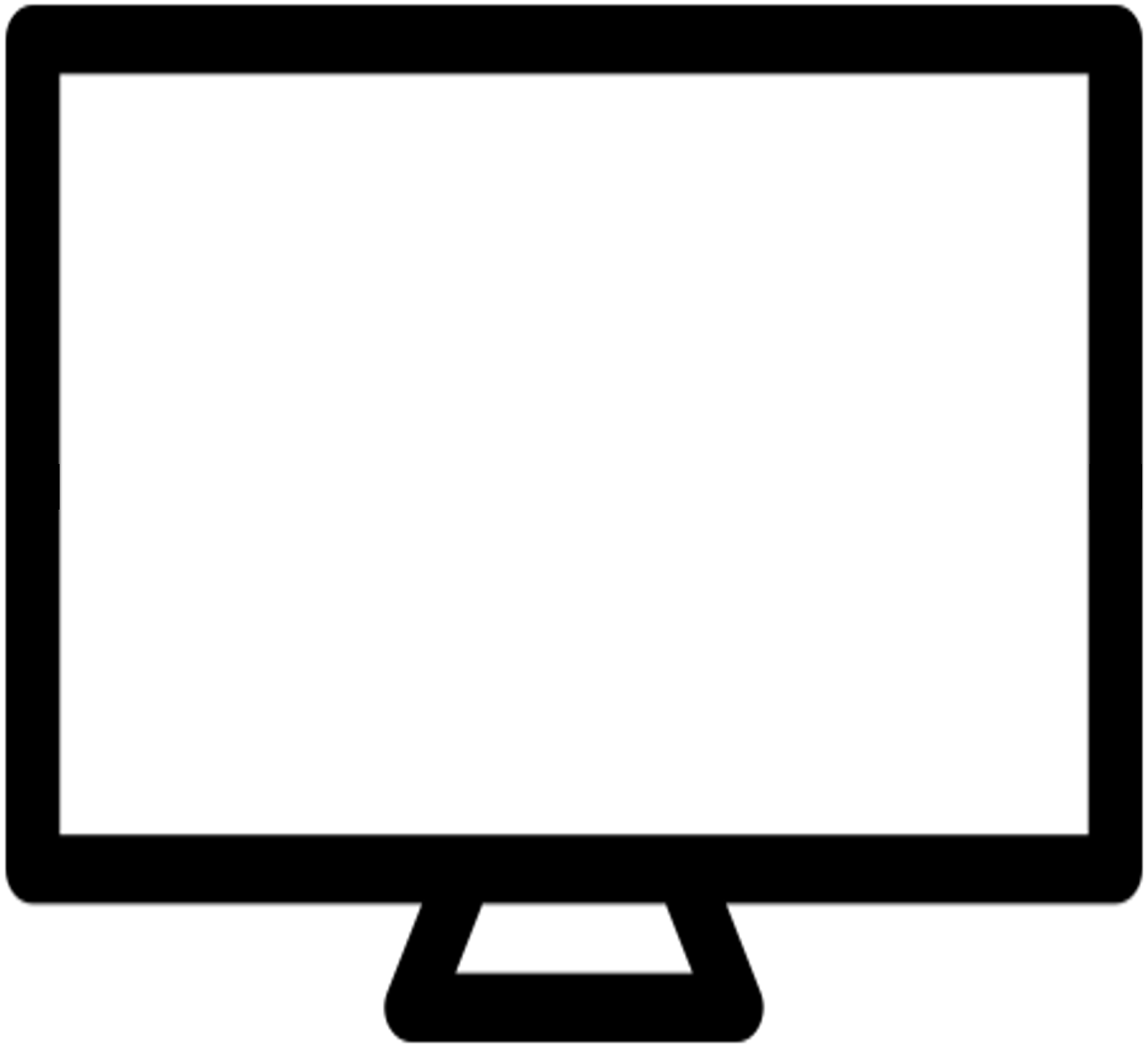


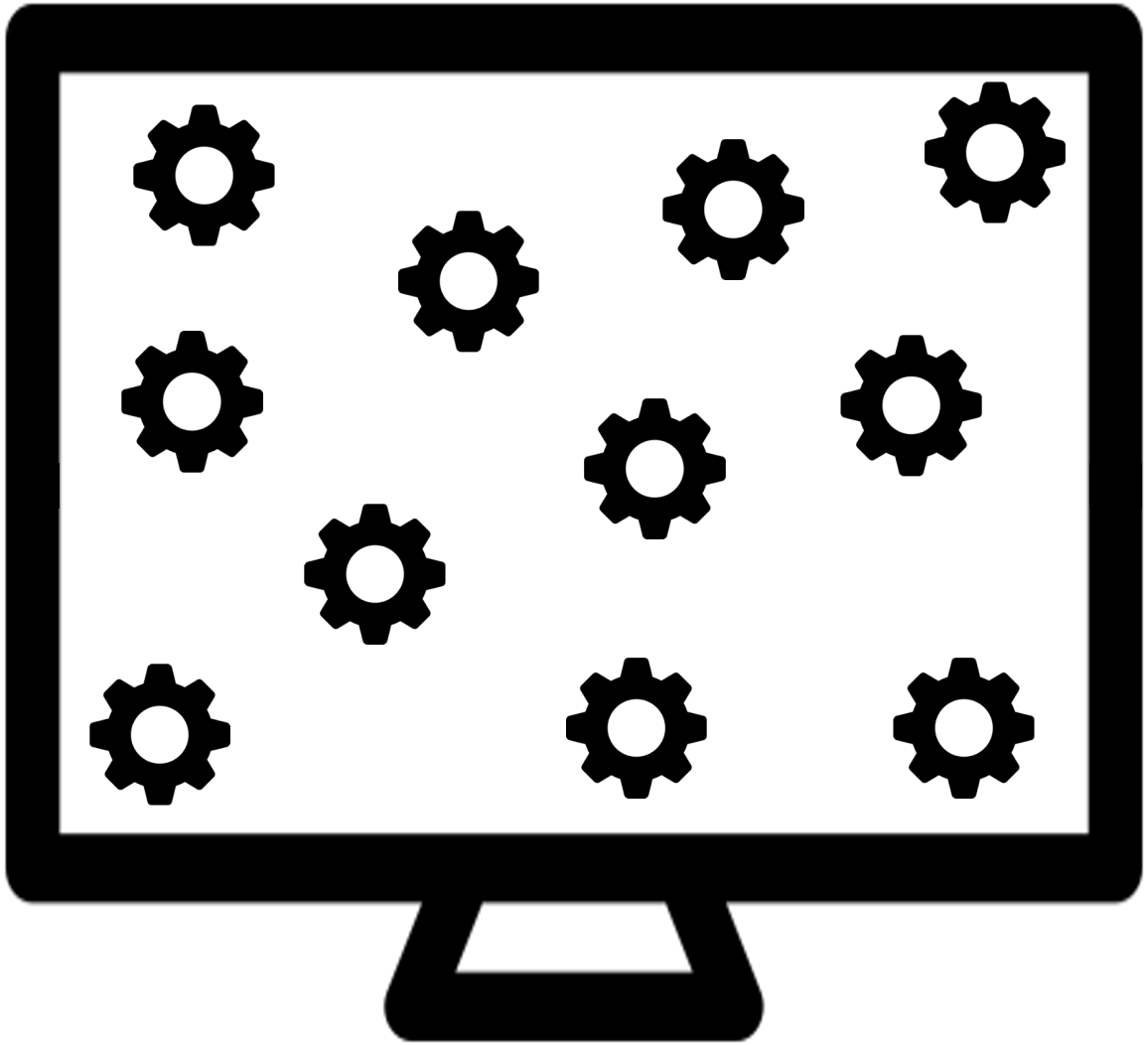


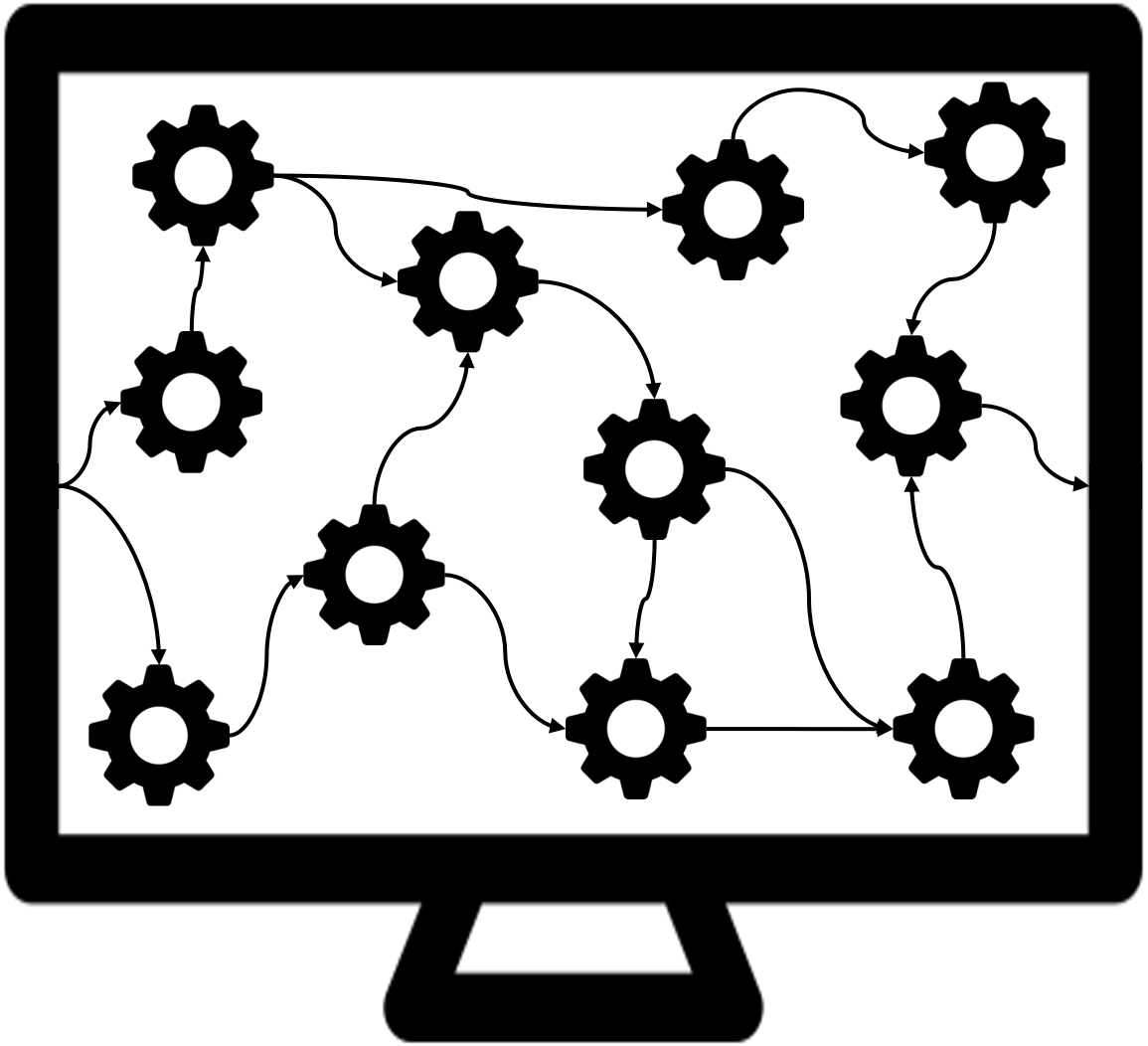


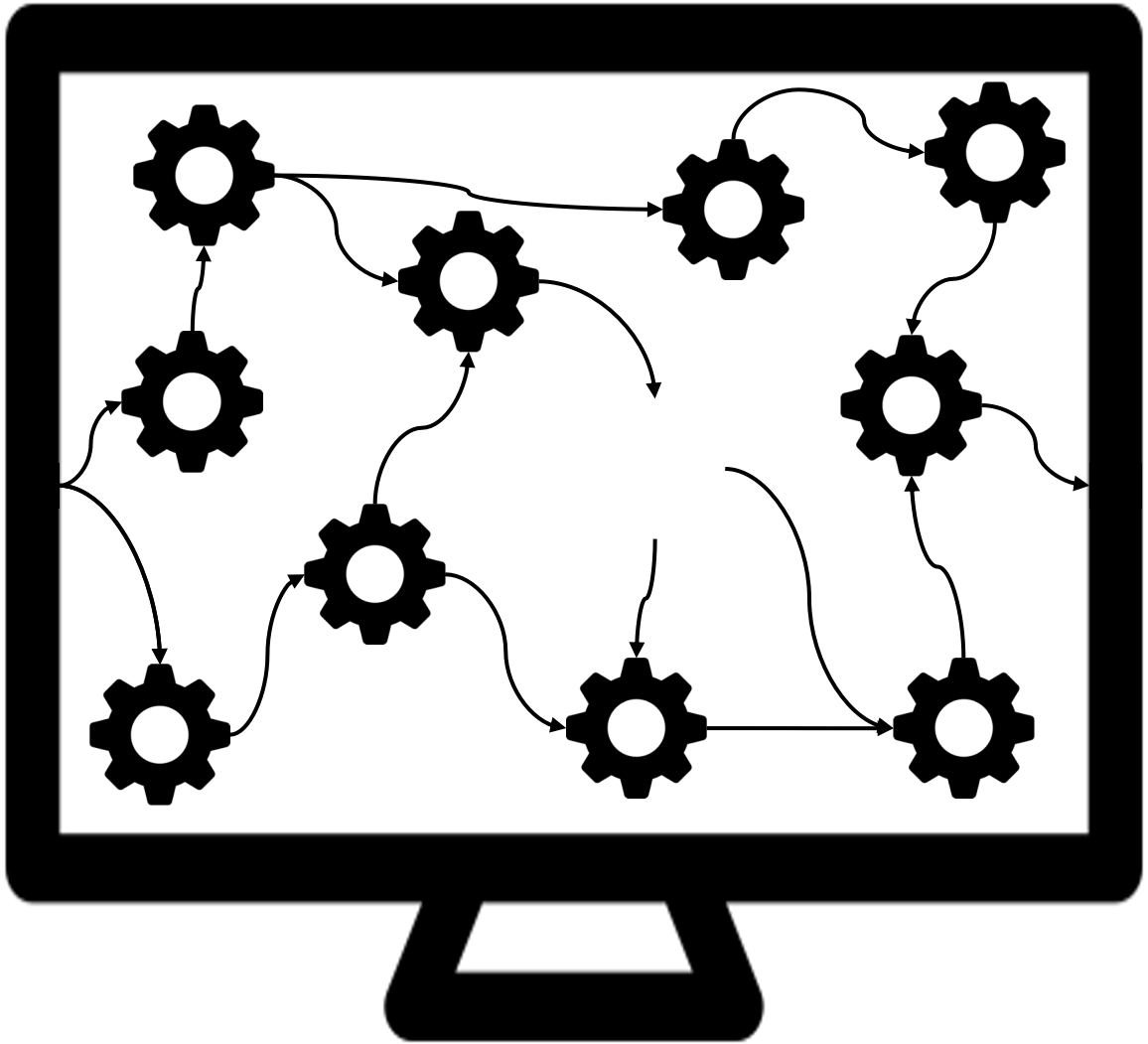


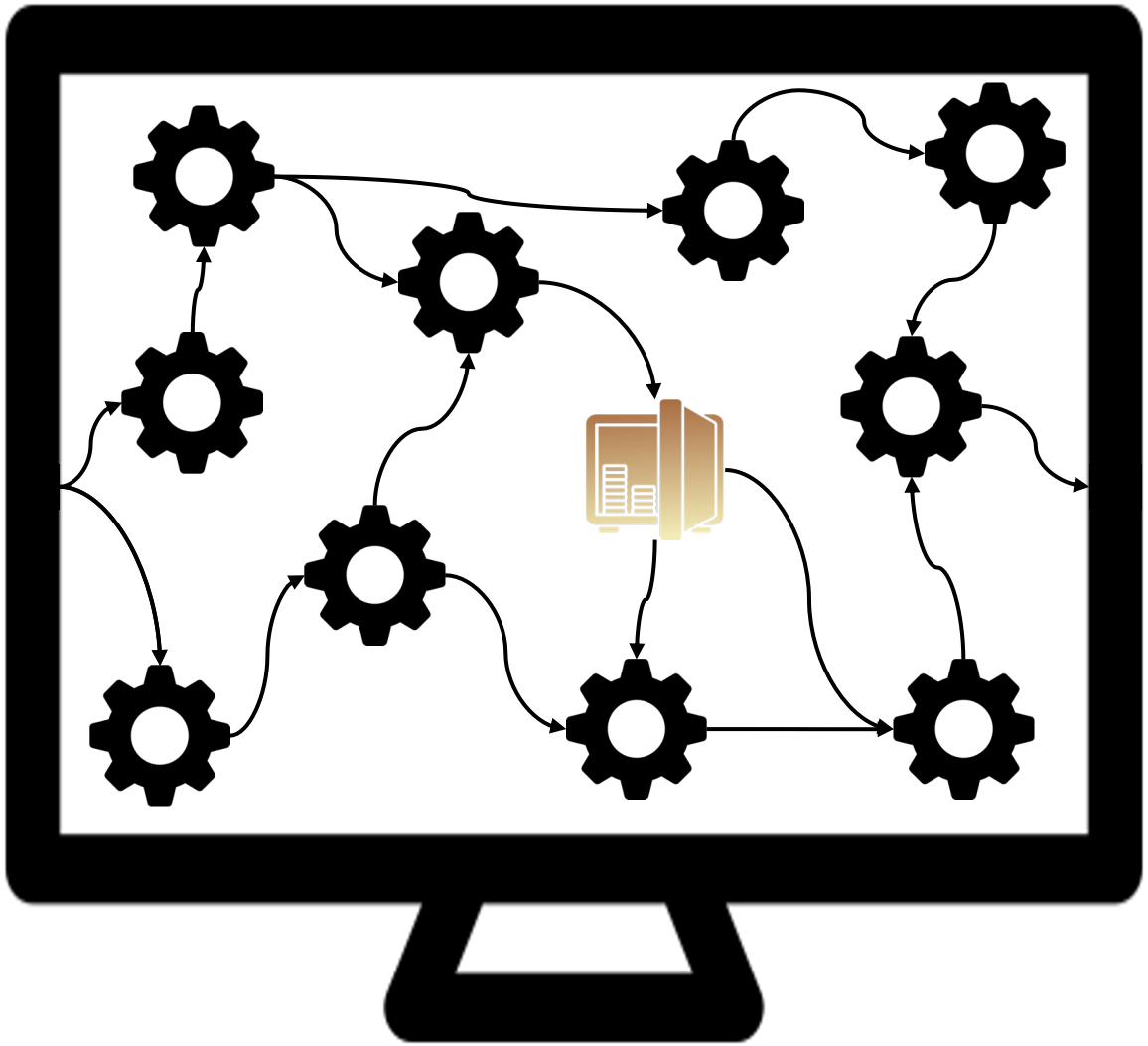












Policy

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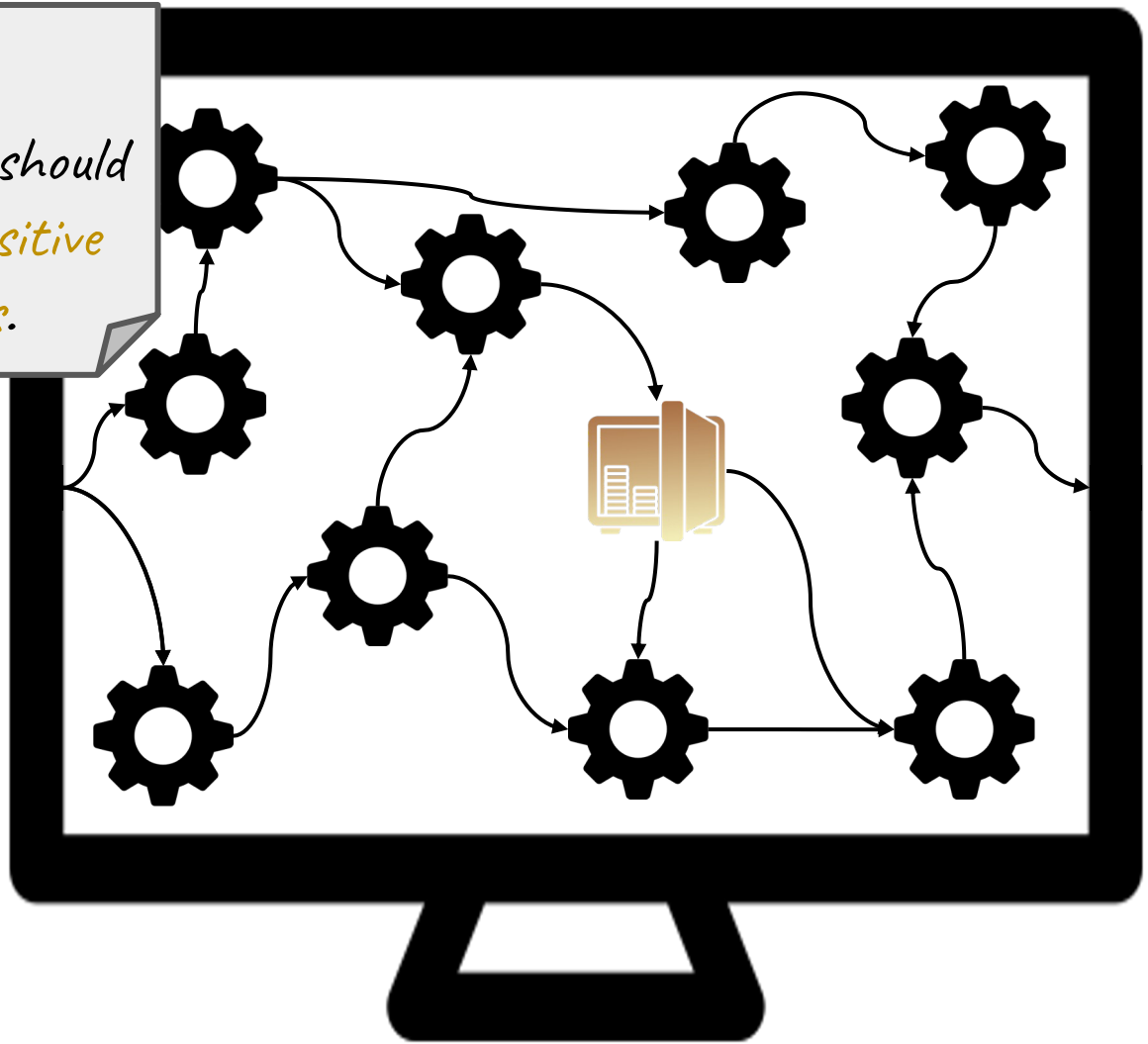

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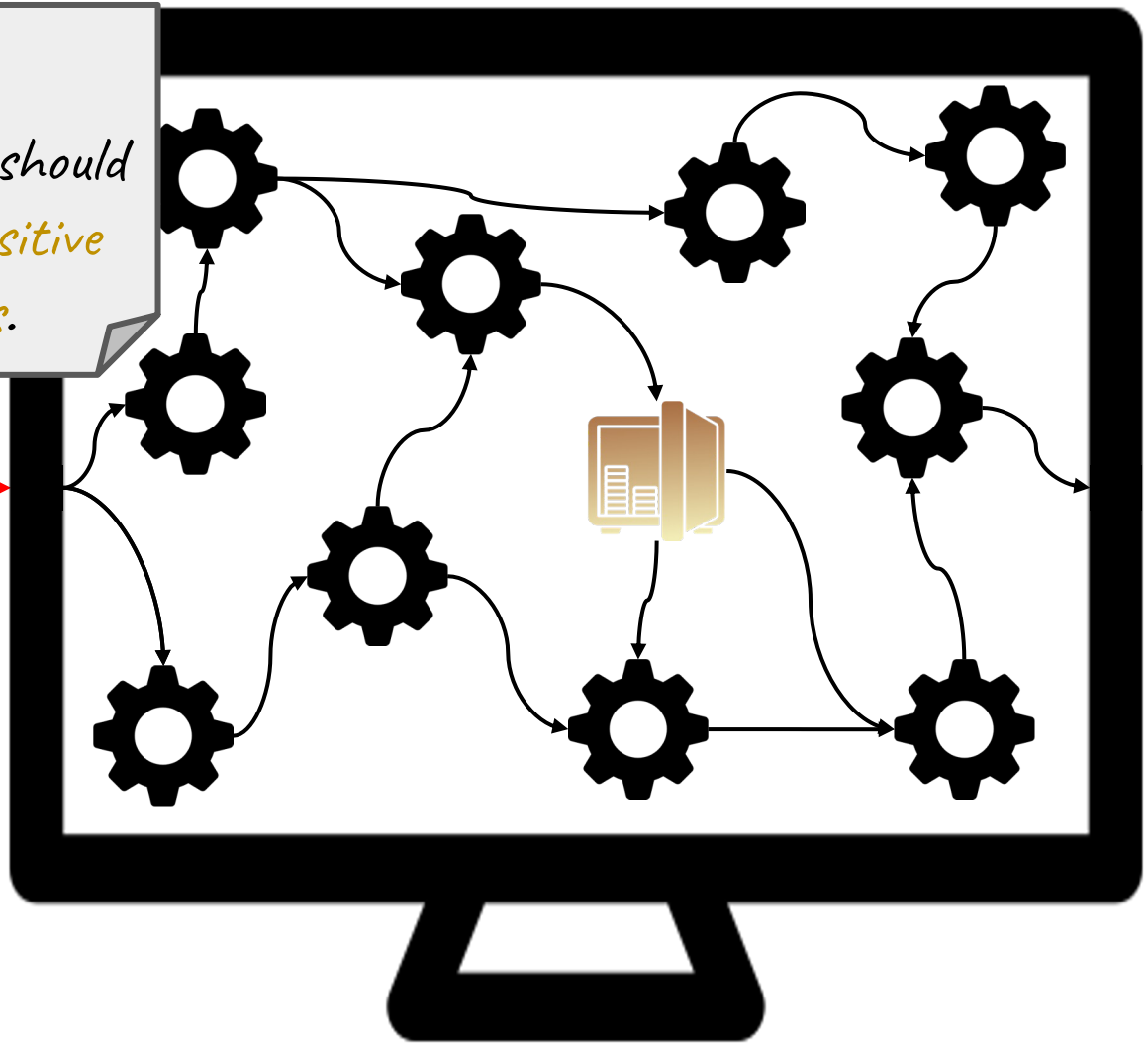

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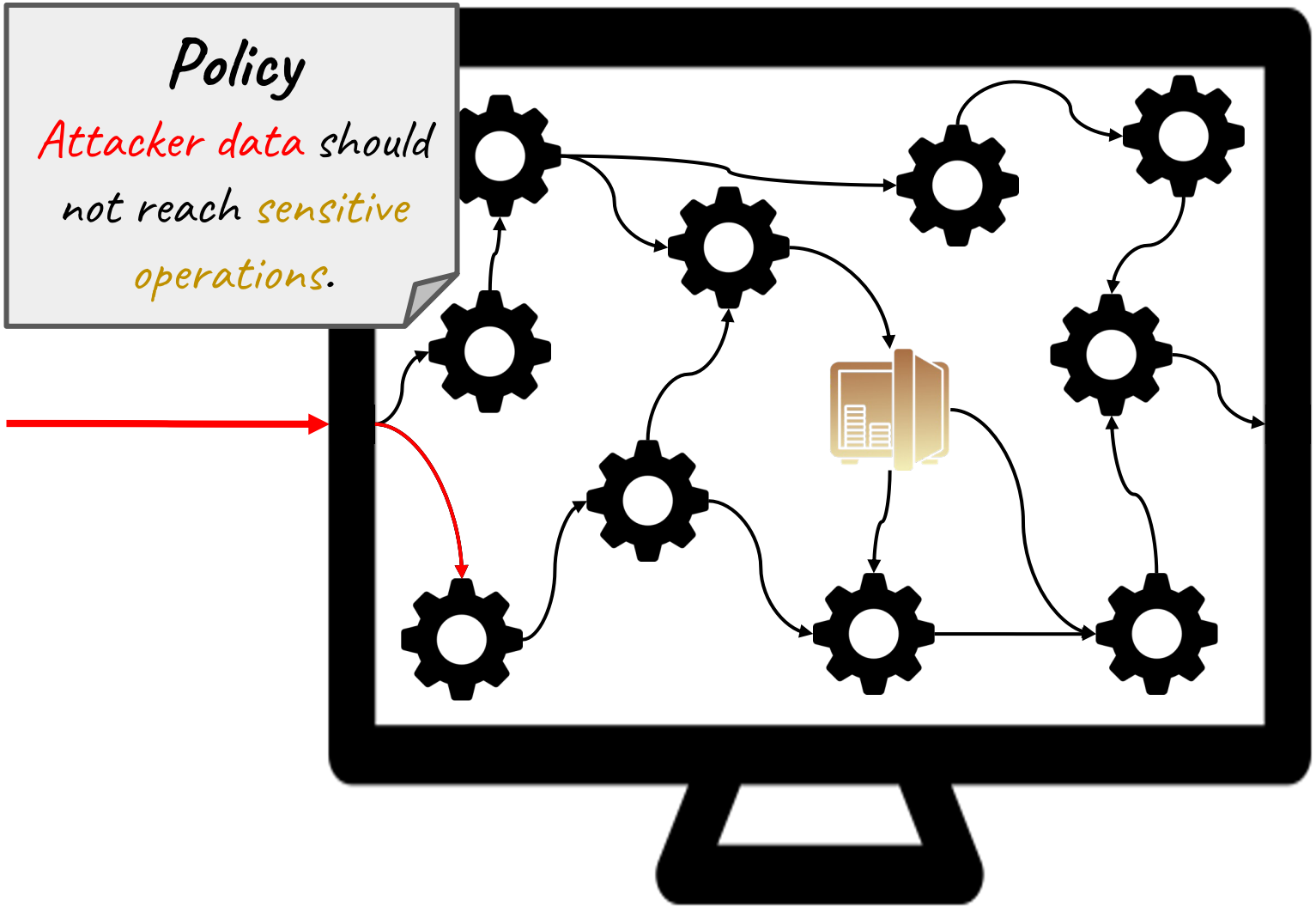

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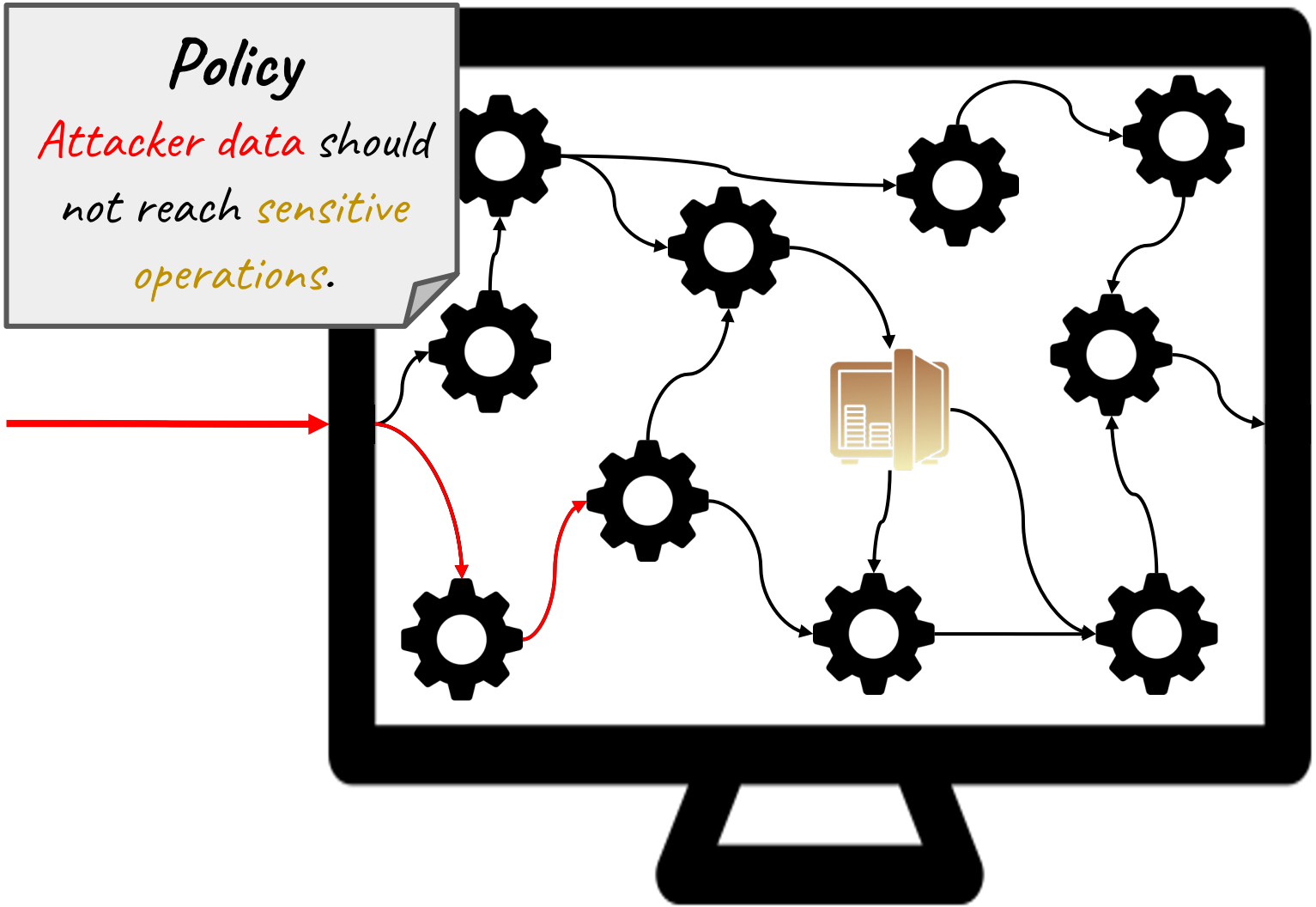

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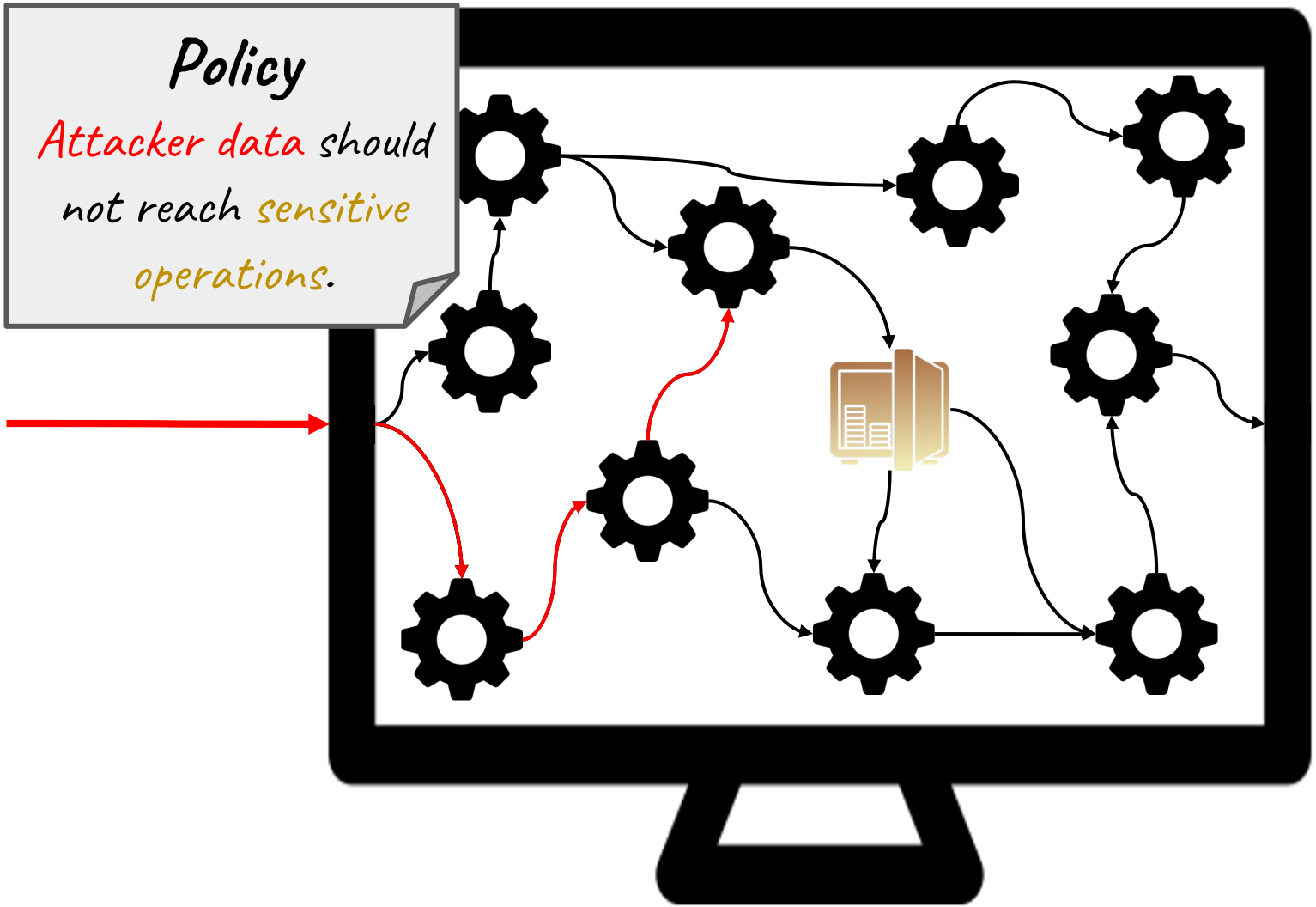

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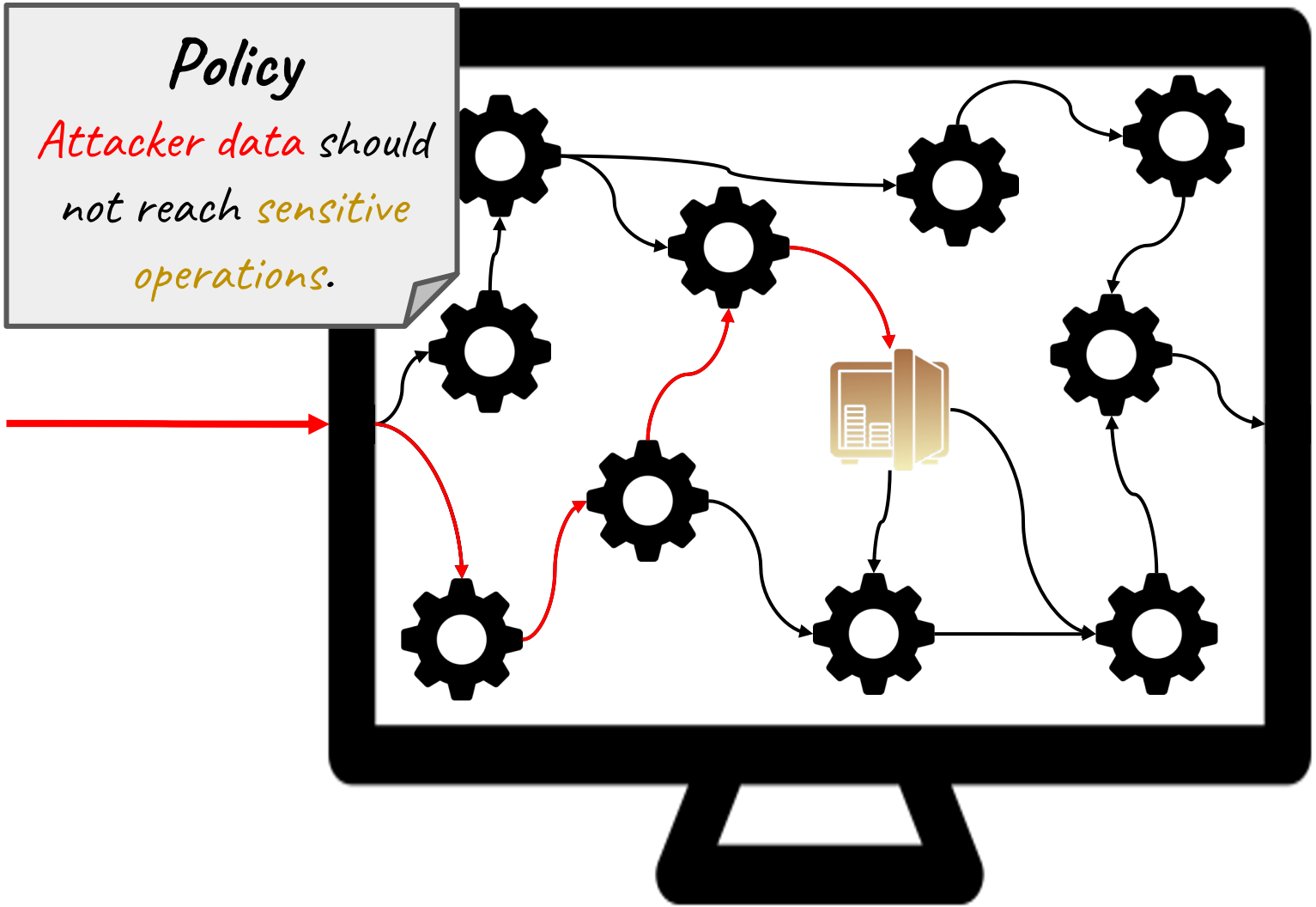

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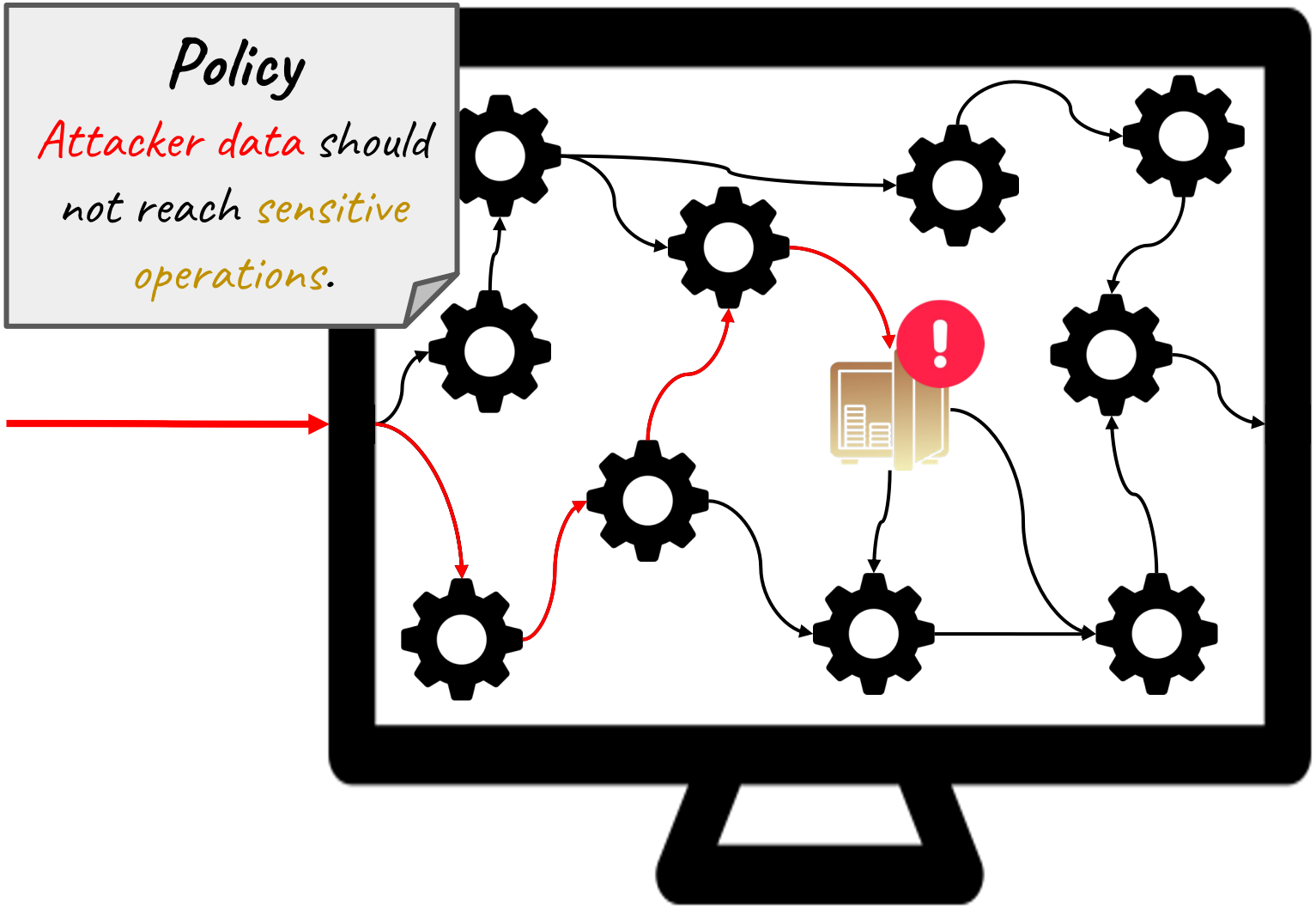

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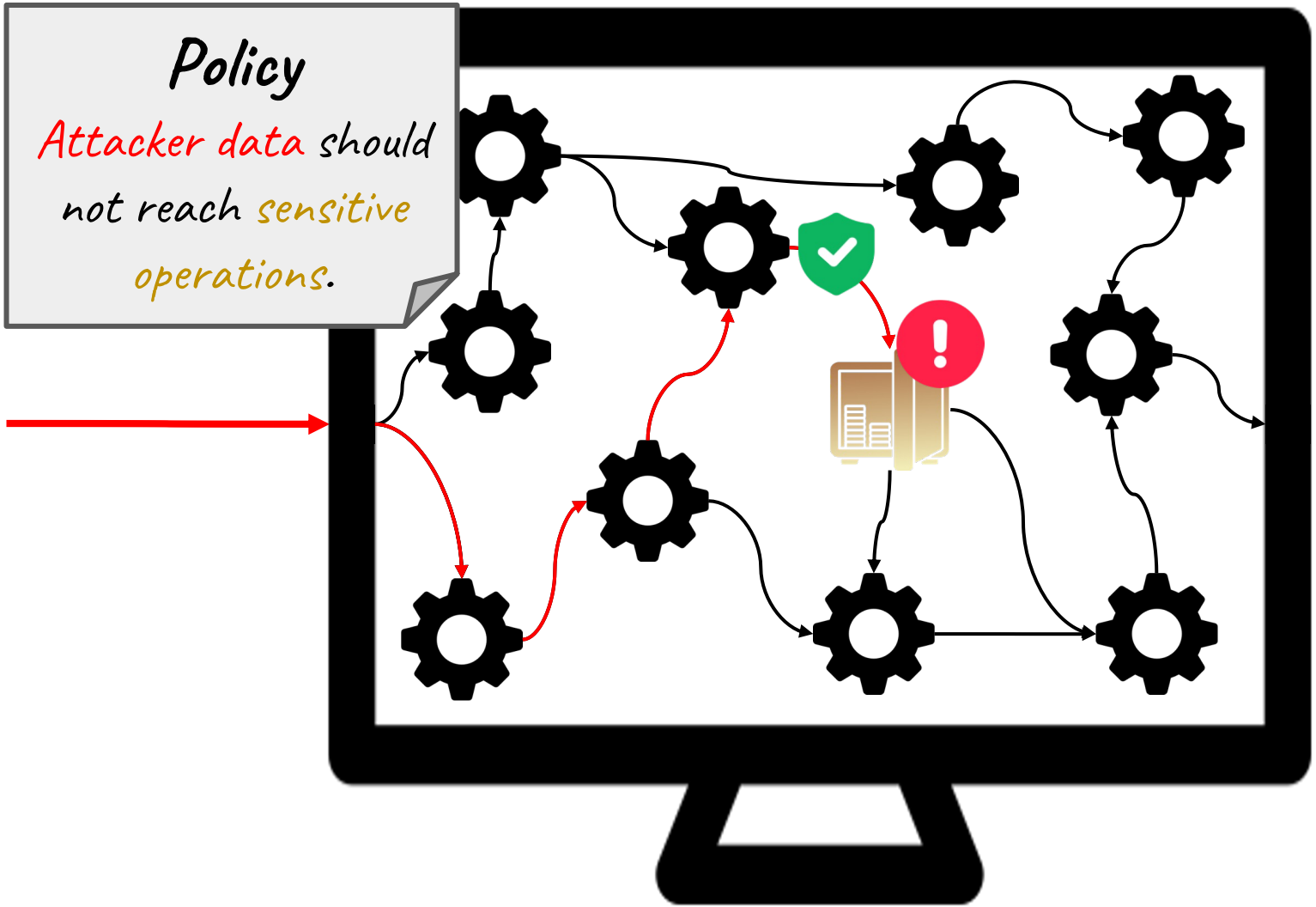

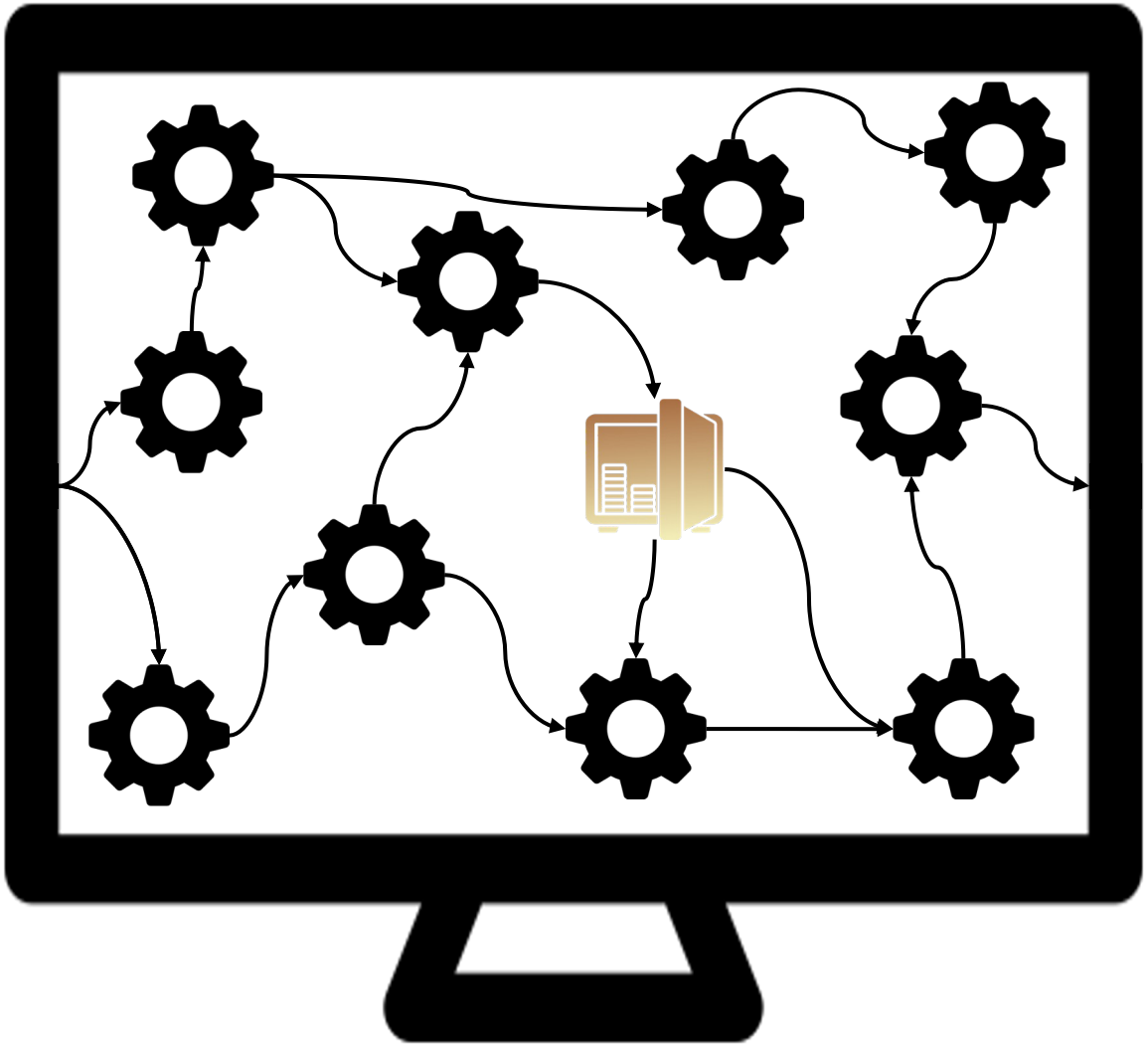

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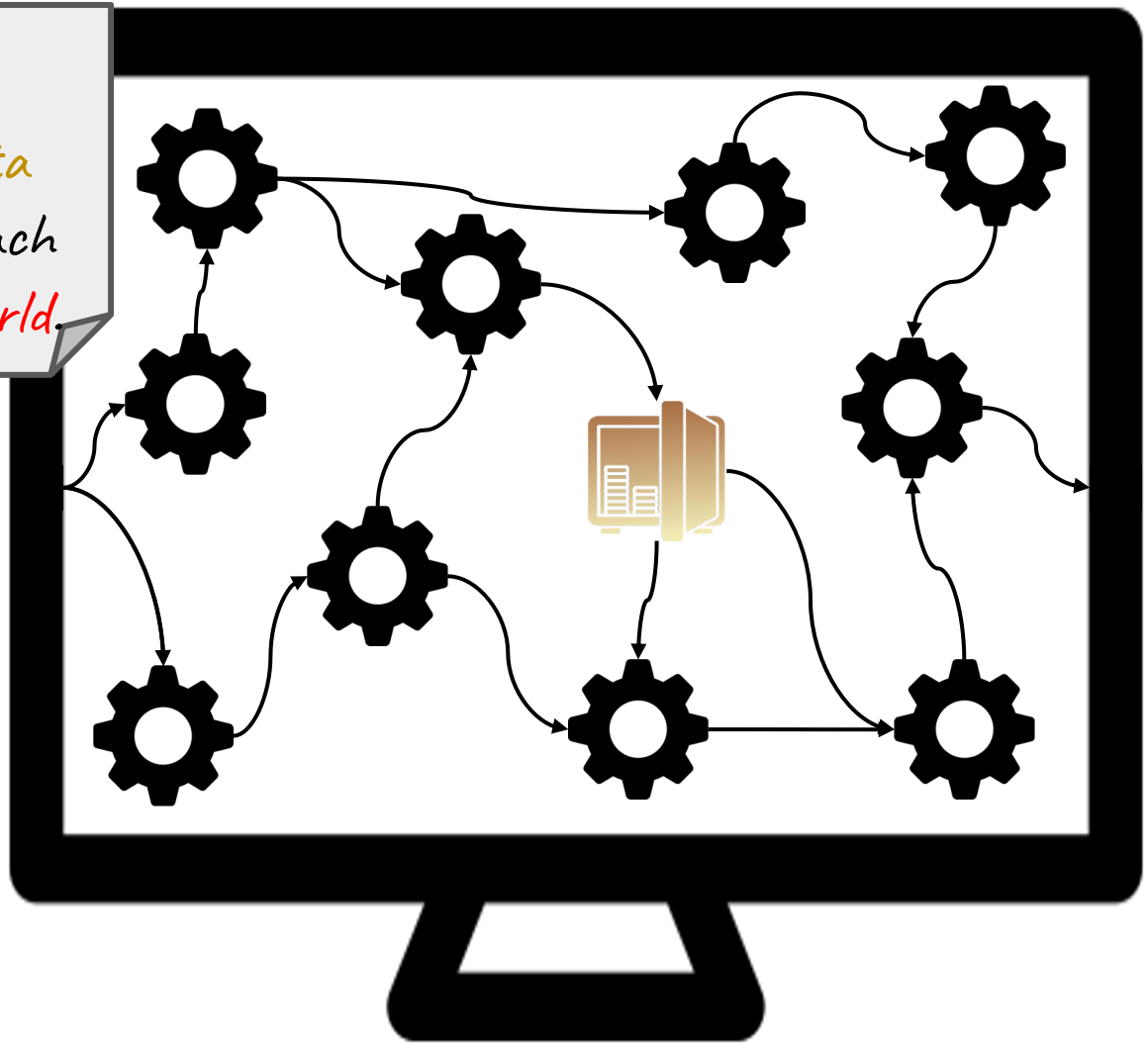

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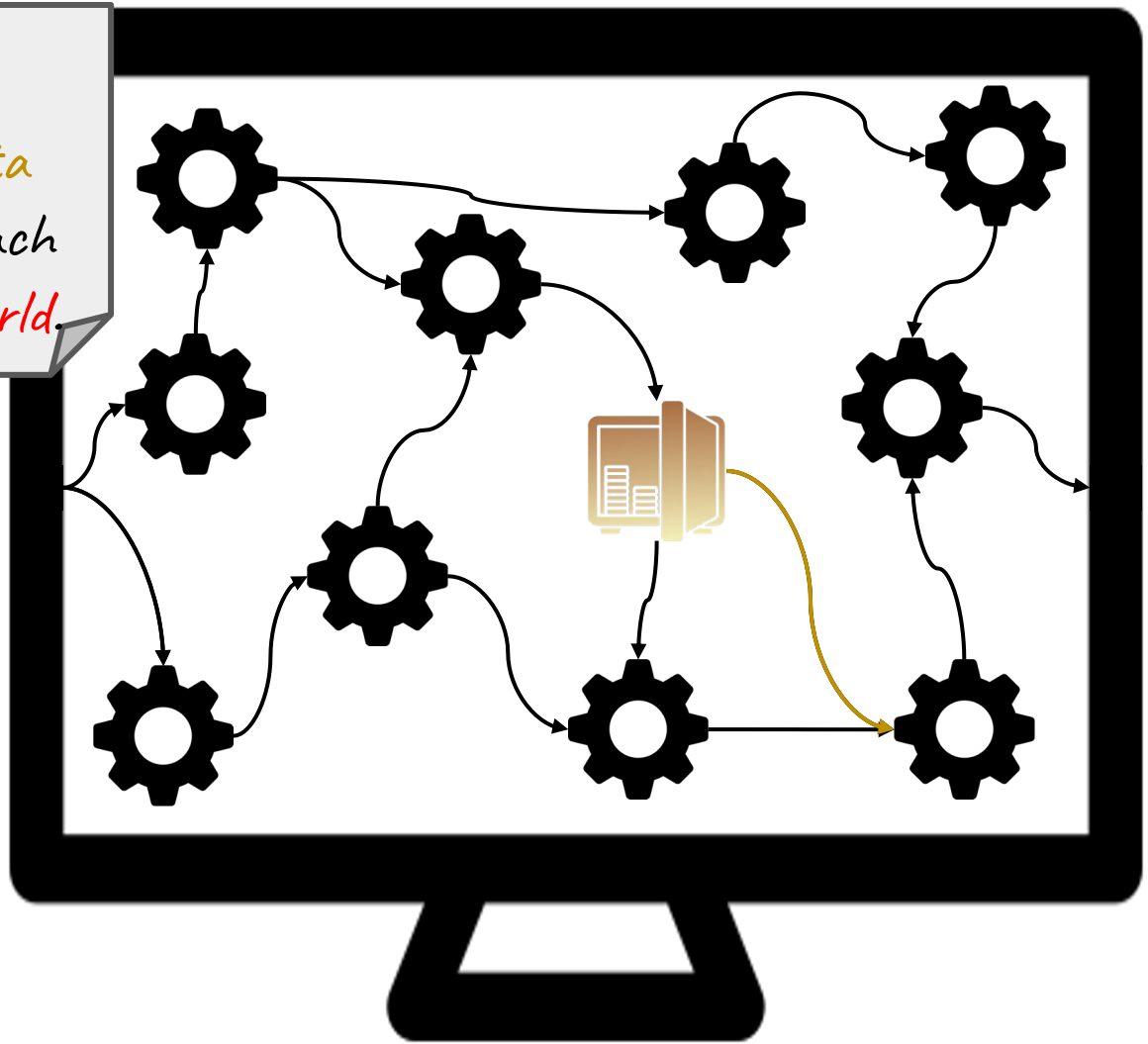

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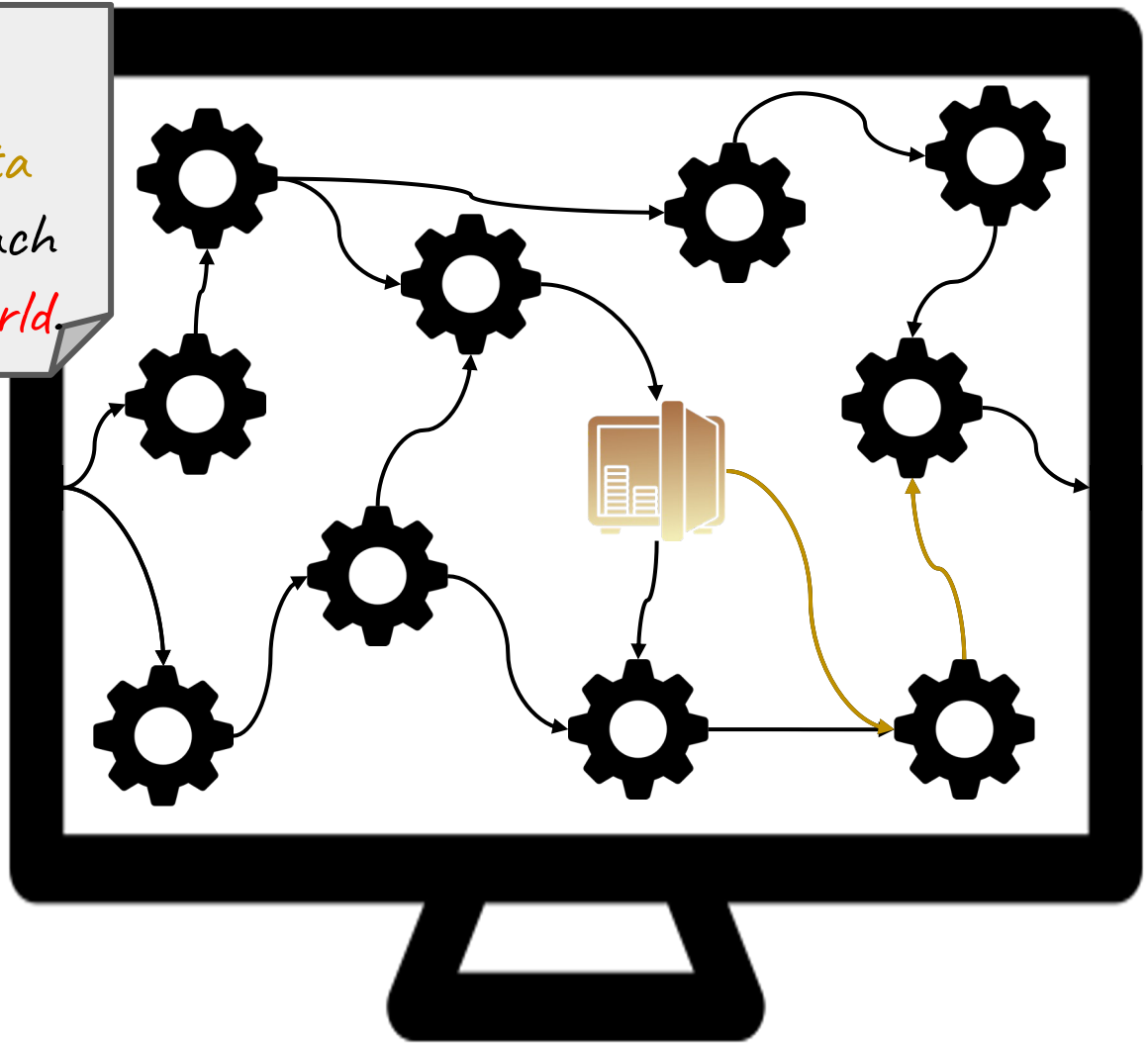

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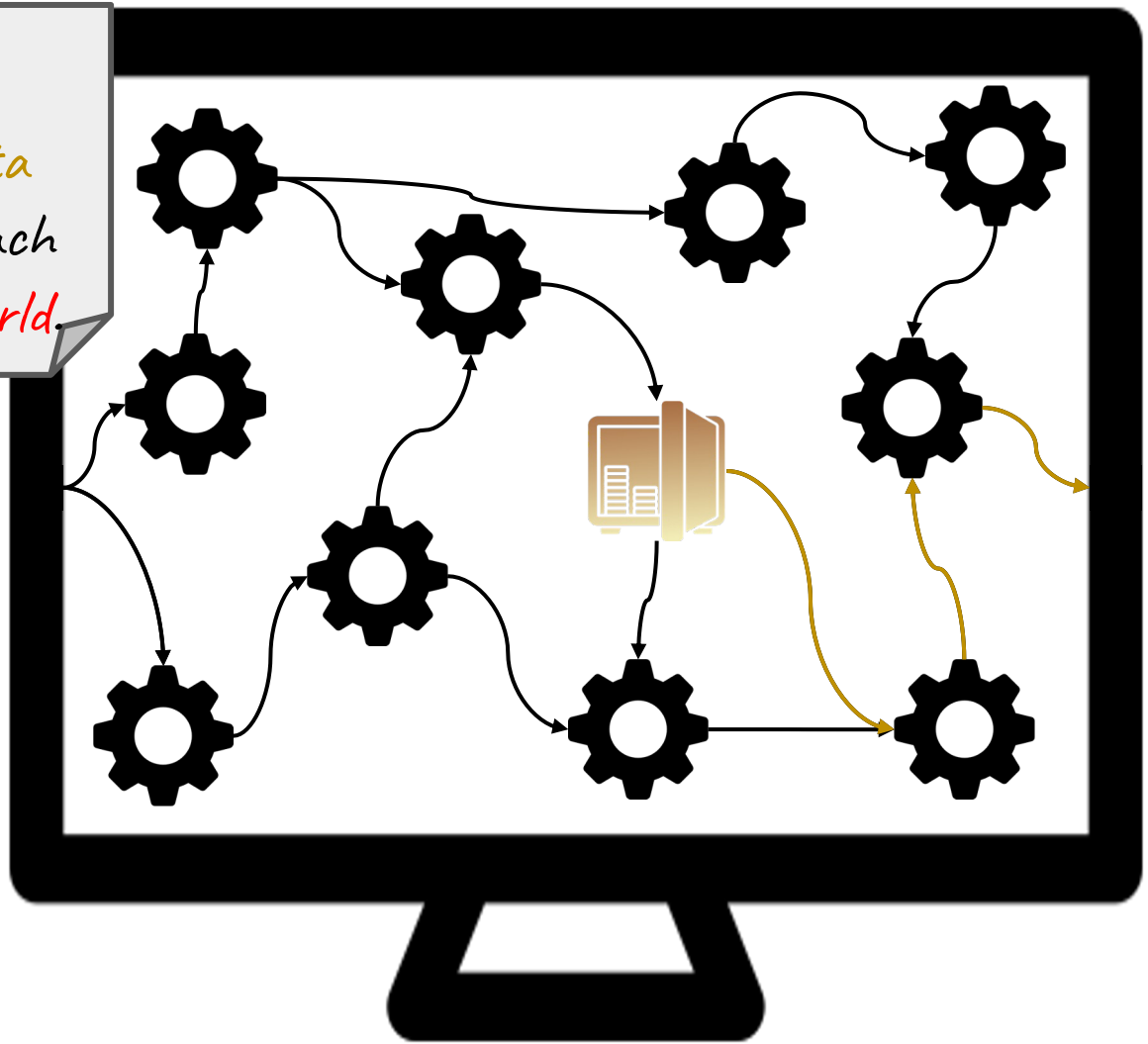

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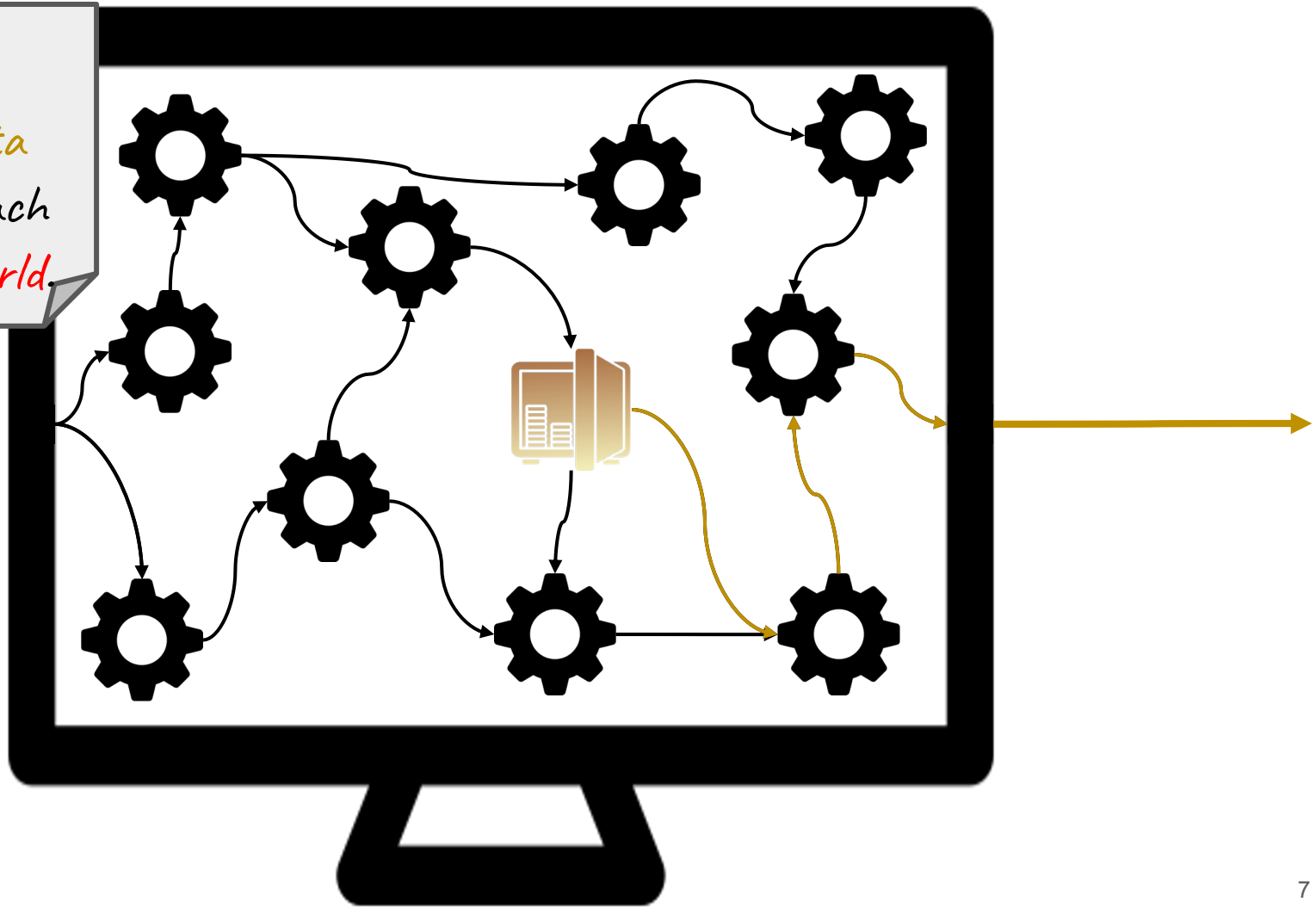

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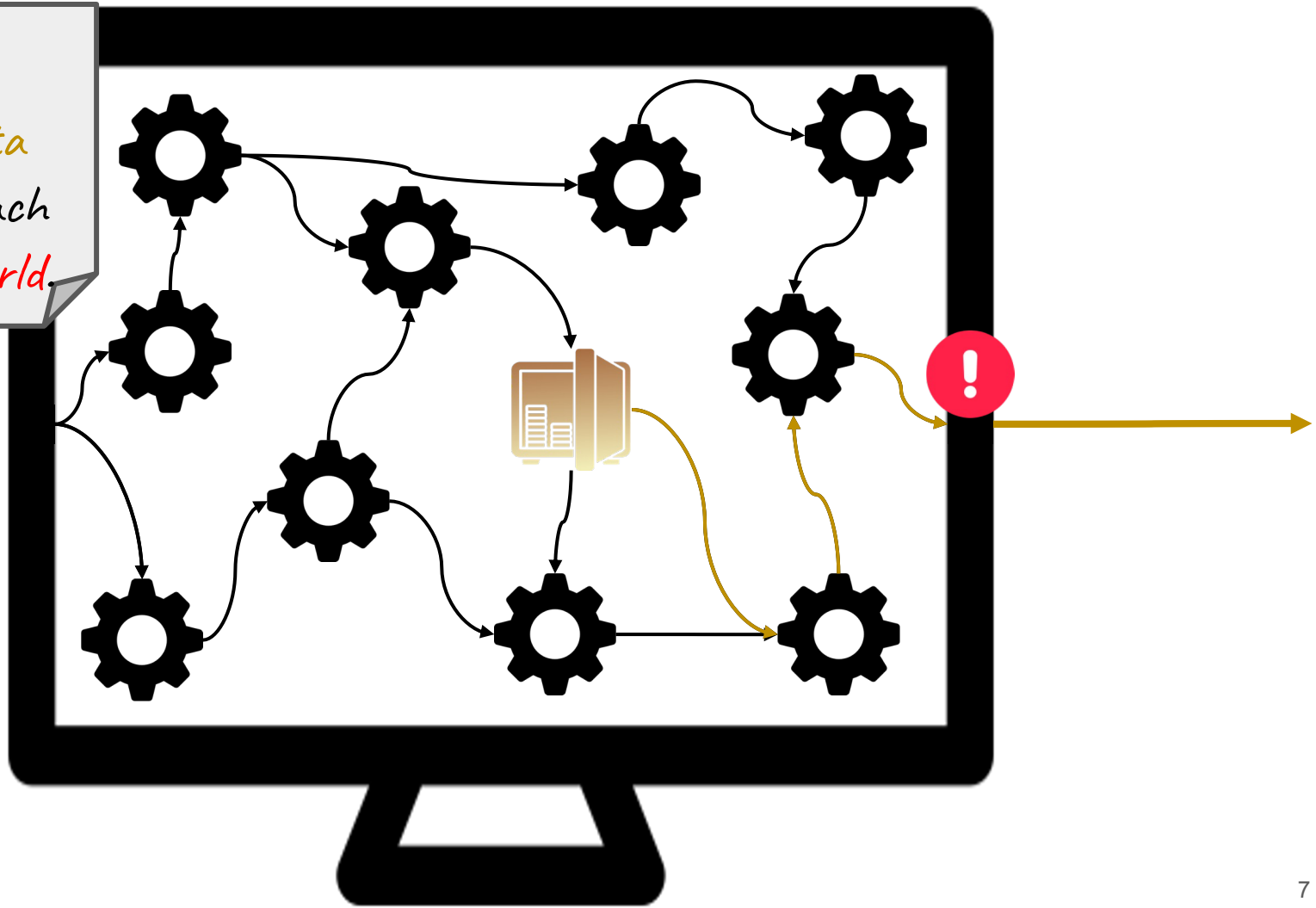

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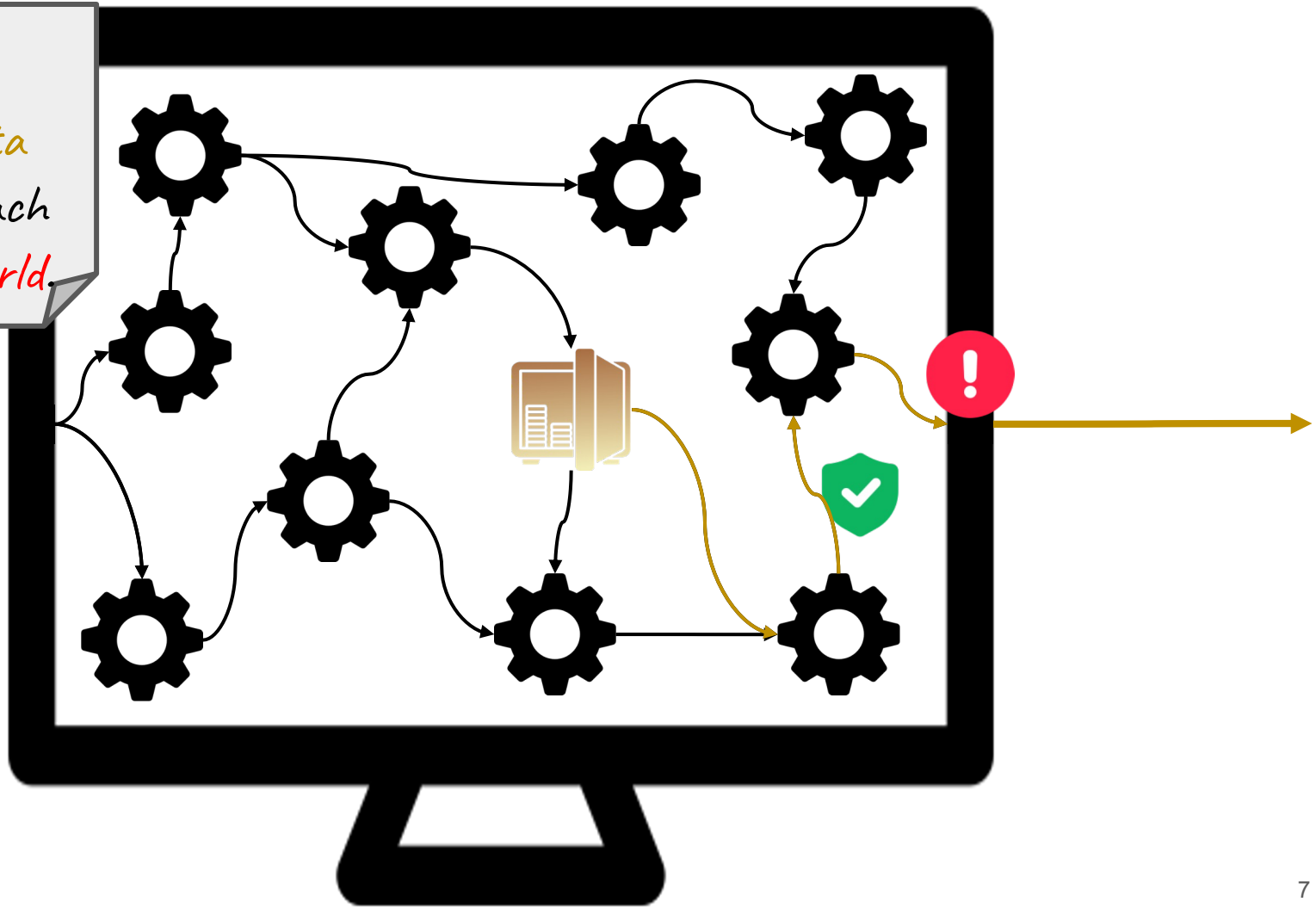
Sensitive data should not reach the outside world.



Policy (NDSS 2005)

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Policy (FSE 2006)

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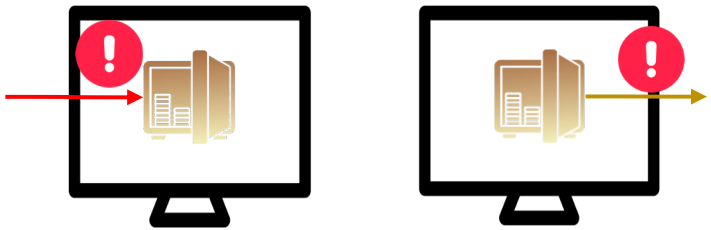

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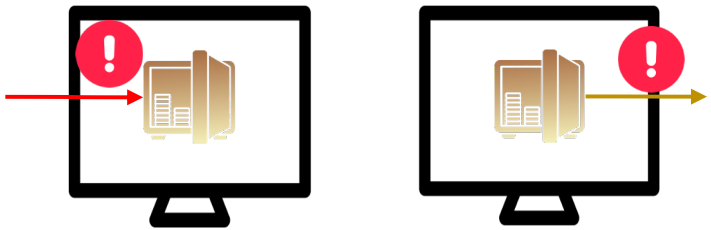

Policy (OSDI 2010)
Smartphone sensor data should not reach third-party applications.

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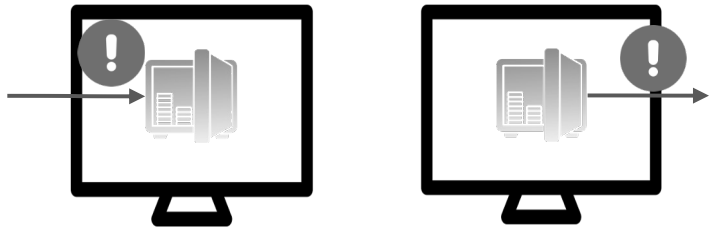
Policy (FSE 2006)
Network data should not reach a



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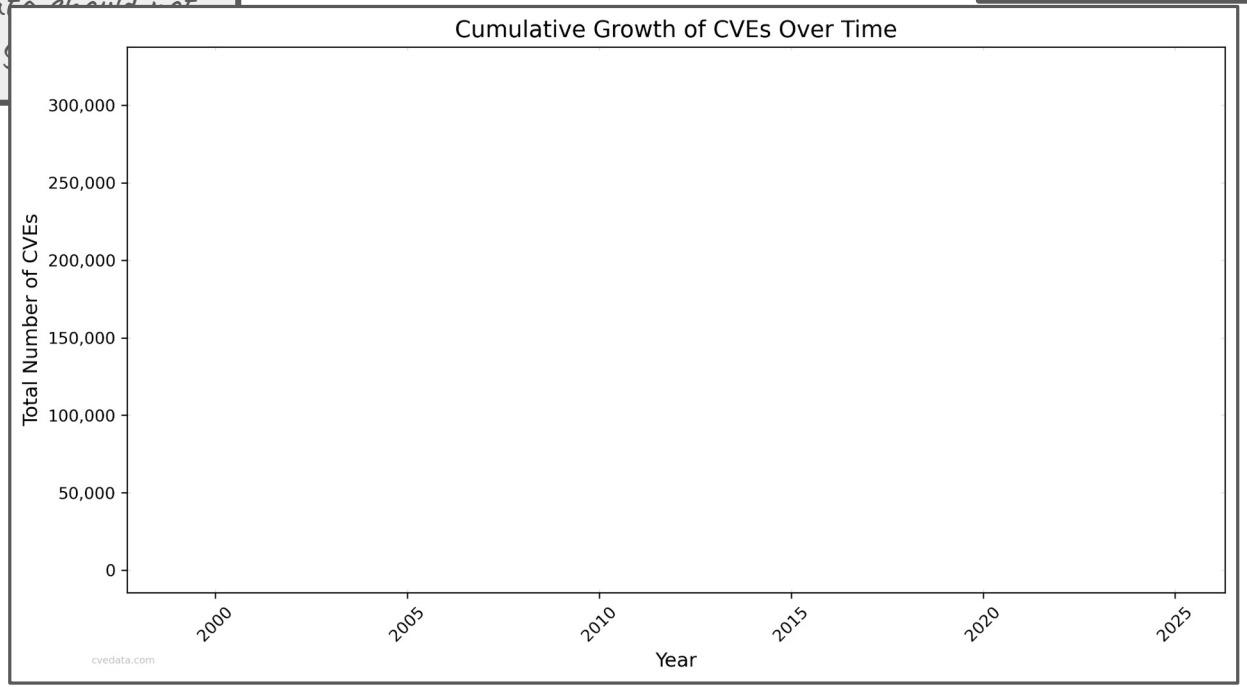

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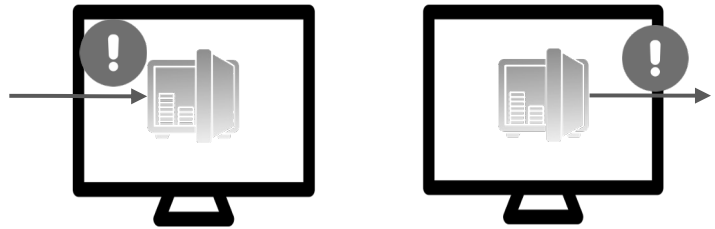

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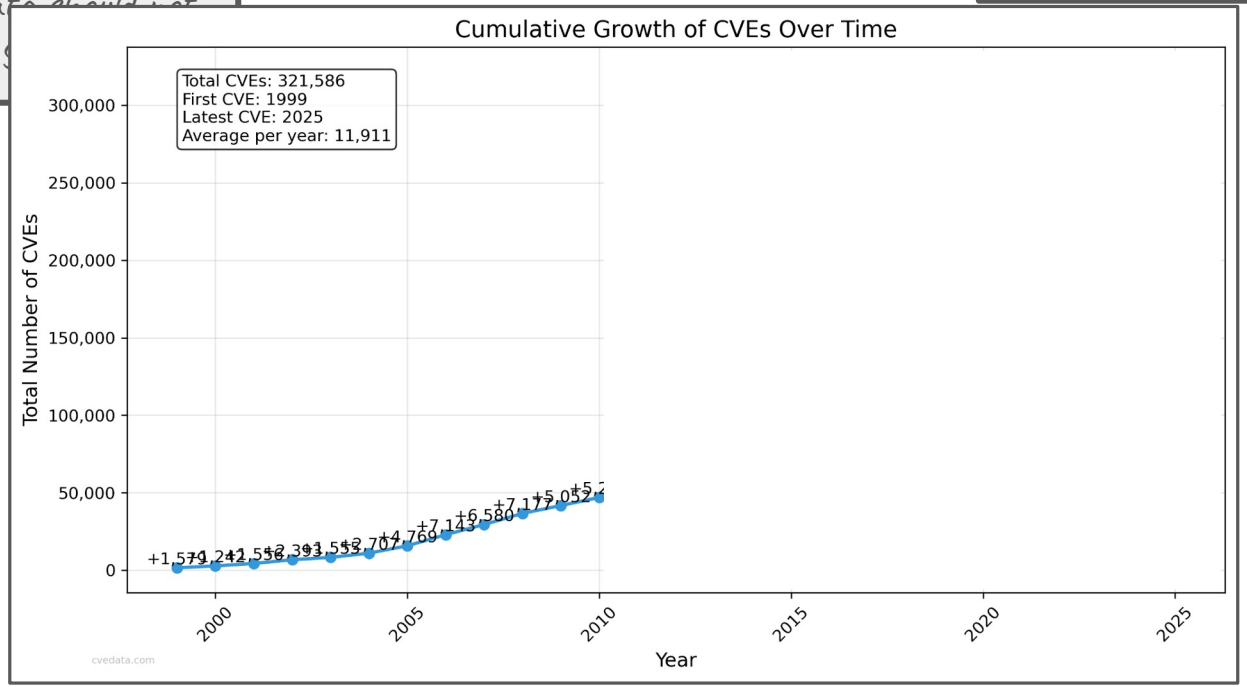

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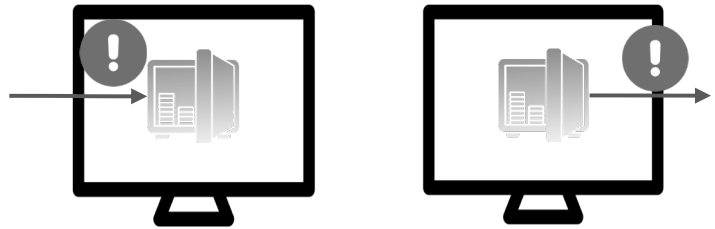

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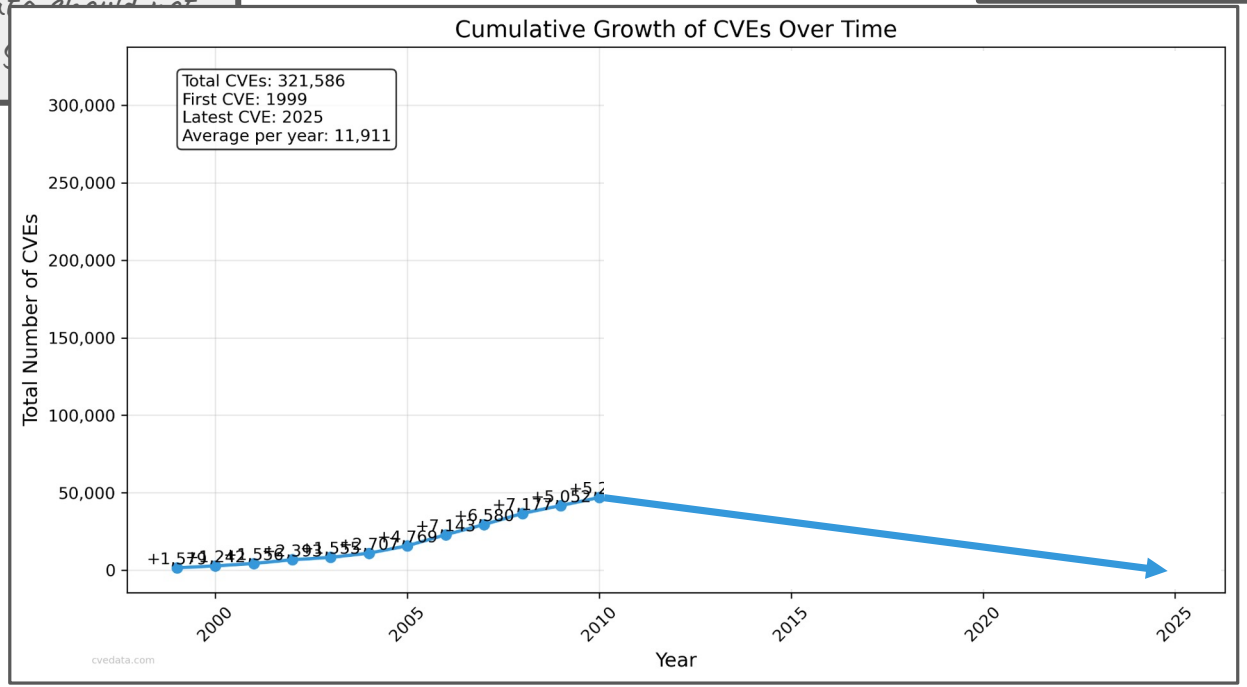

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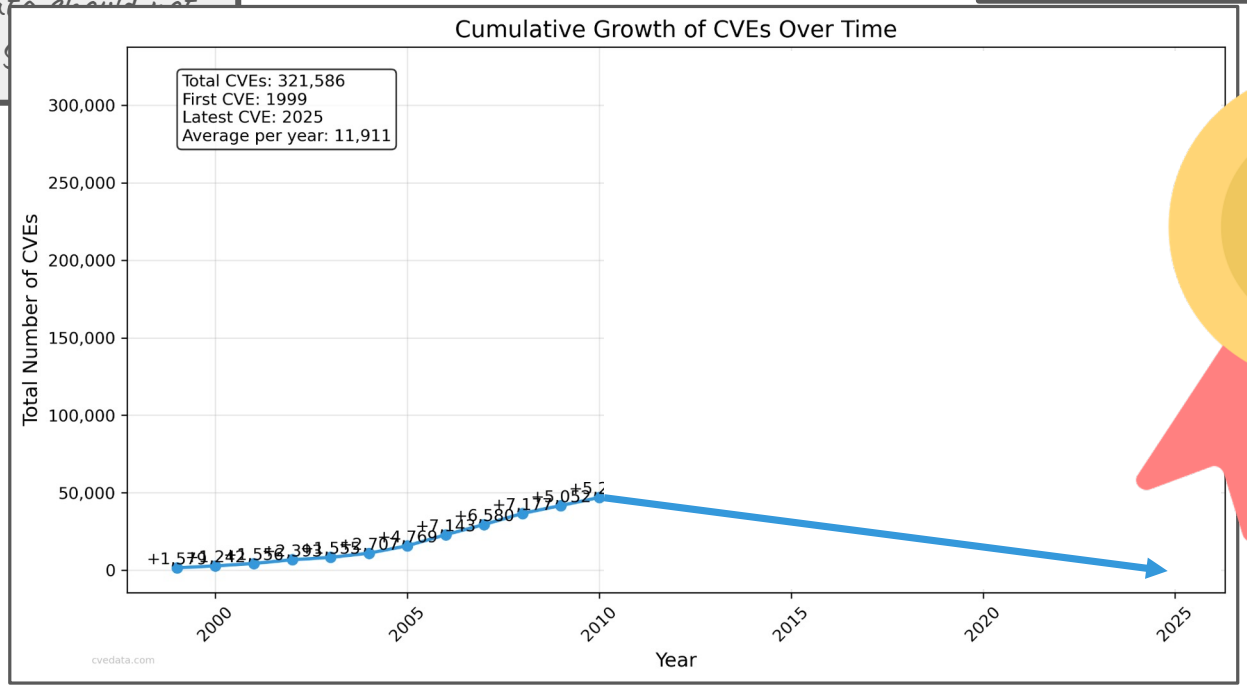

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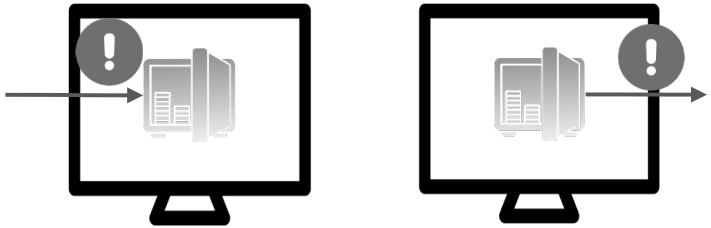

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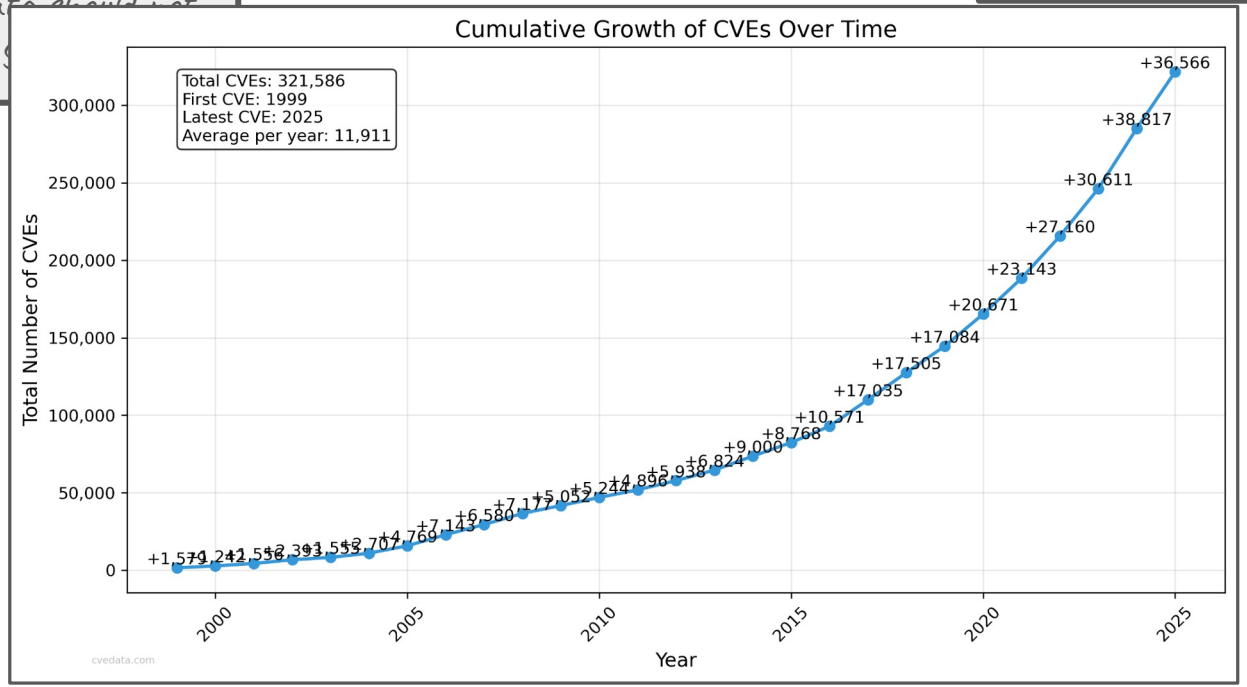

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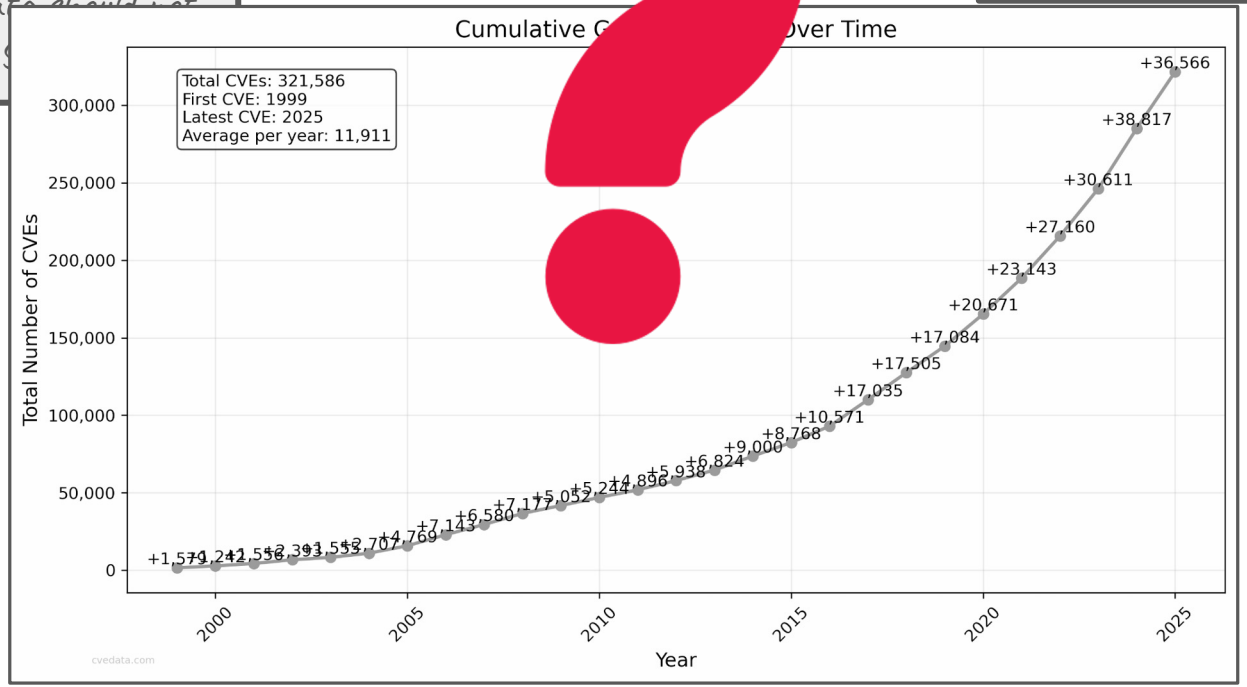

*Previous approaches: Modeled specific **exploit techniques**.*

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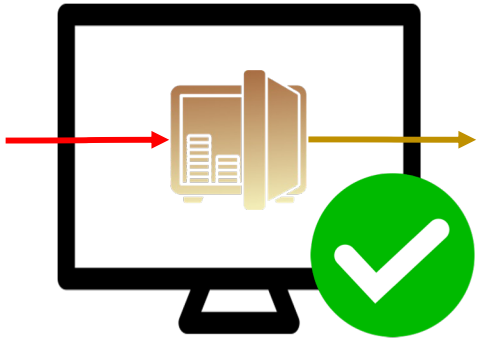

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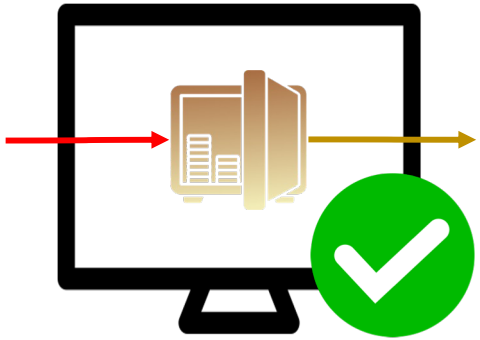

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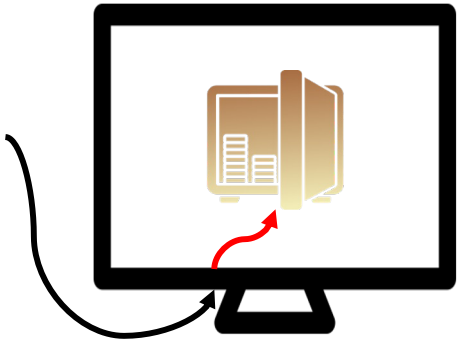

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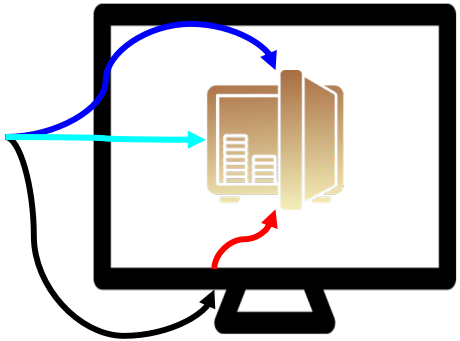

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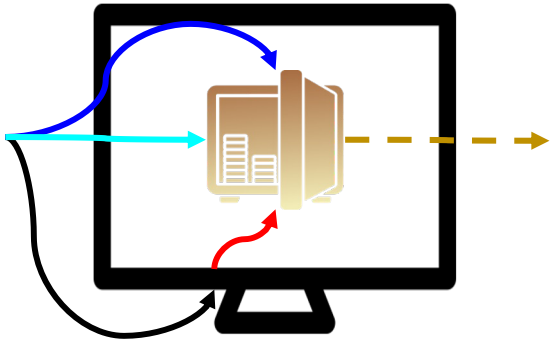

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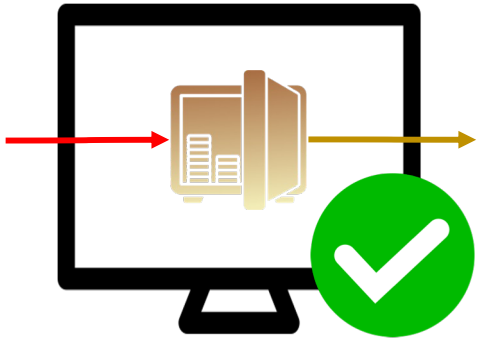

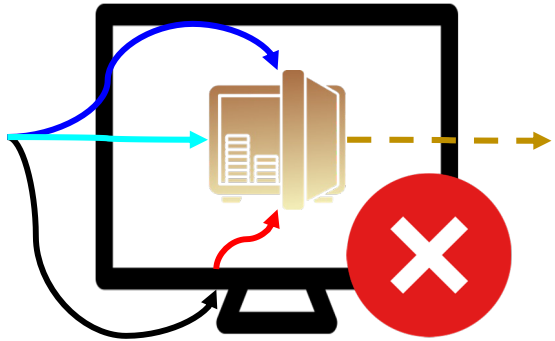

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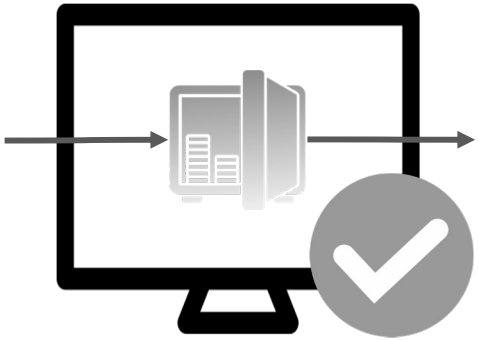

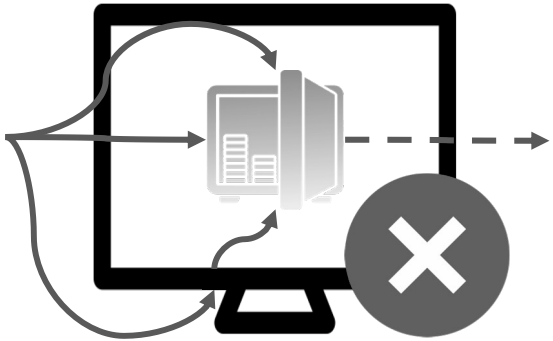

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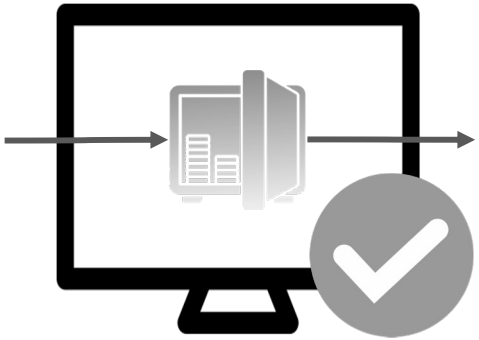

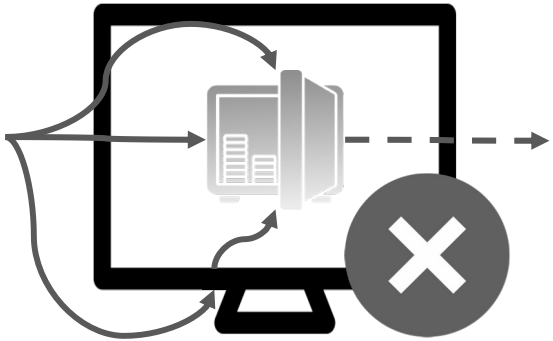

*Our approach: Model the **essential steps of a vulnerability**.*

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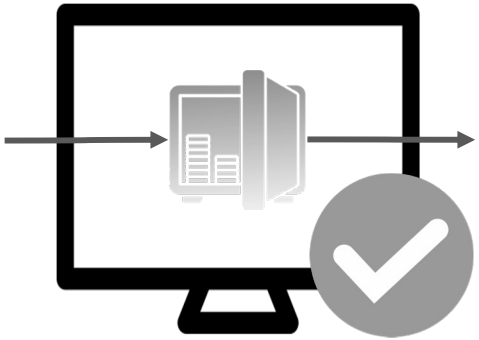

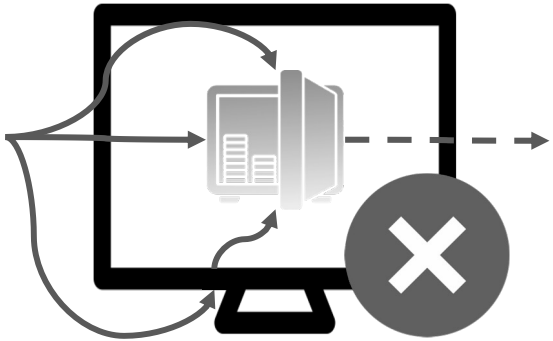

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- *Identifies modern vulnerabilities*

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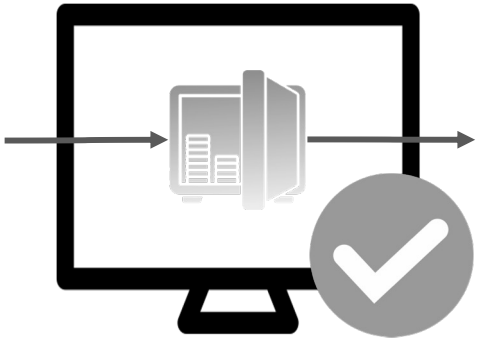

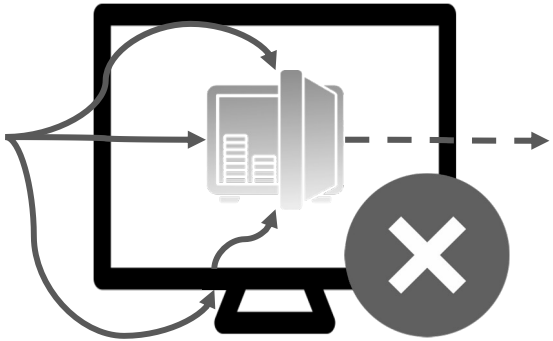

*Our approach: Model the **essential steps of a vulnerability**.*

- *Identifies modern vulnerabilities*
- *Reduce false alarms.*

Explicit vulnerability modeling: ***Case studies***

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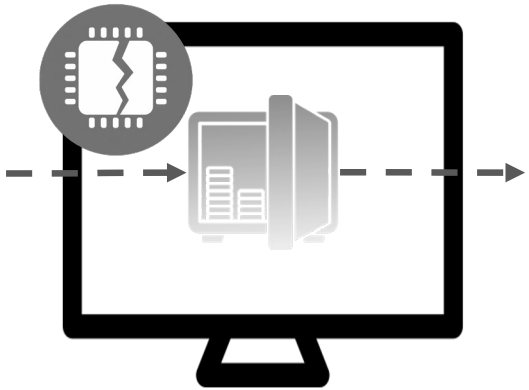
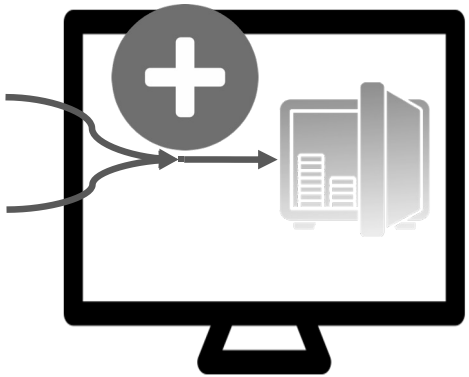


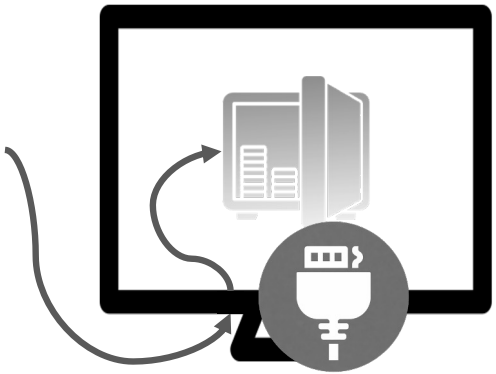
Kasper

(NDSS 2022)



Einstein

(USENIX Sec. 2024)



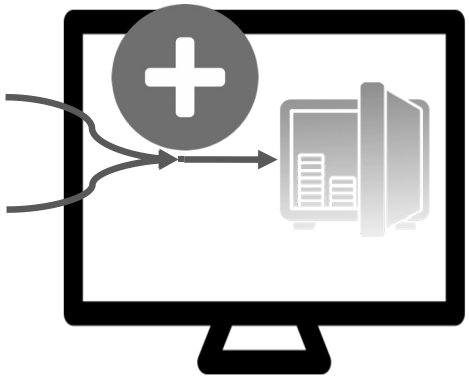
DMARacer

(CCS 2025)

Explicit vulnerability modeling: ***Case studies***

Kasper

(NDSS 2022)



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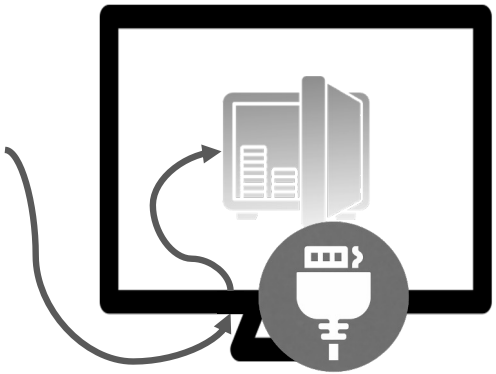

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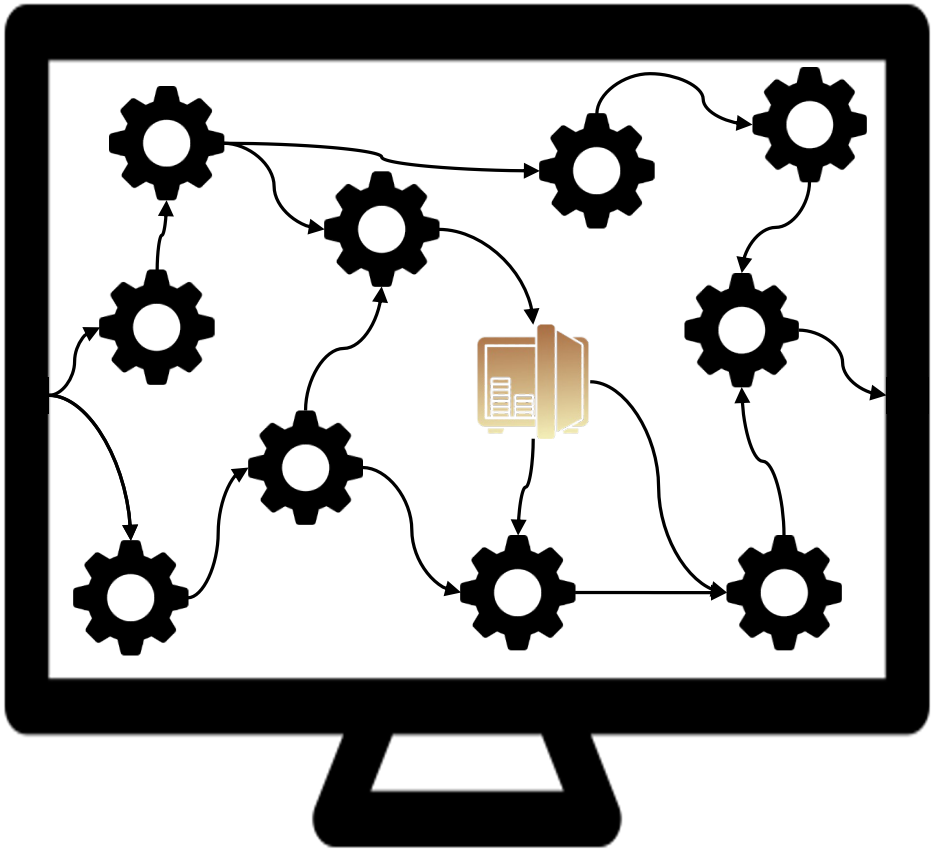
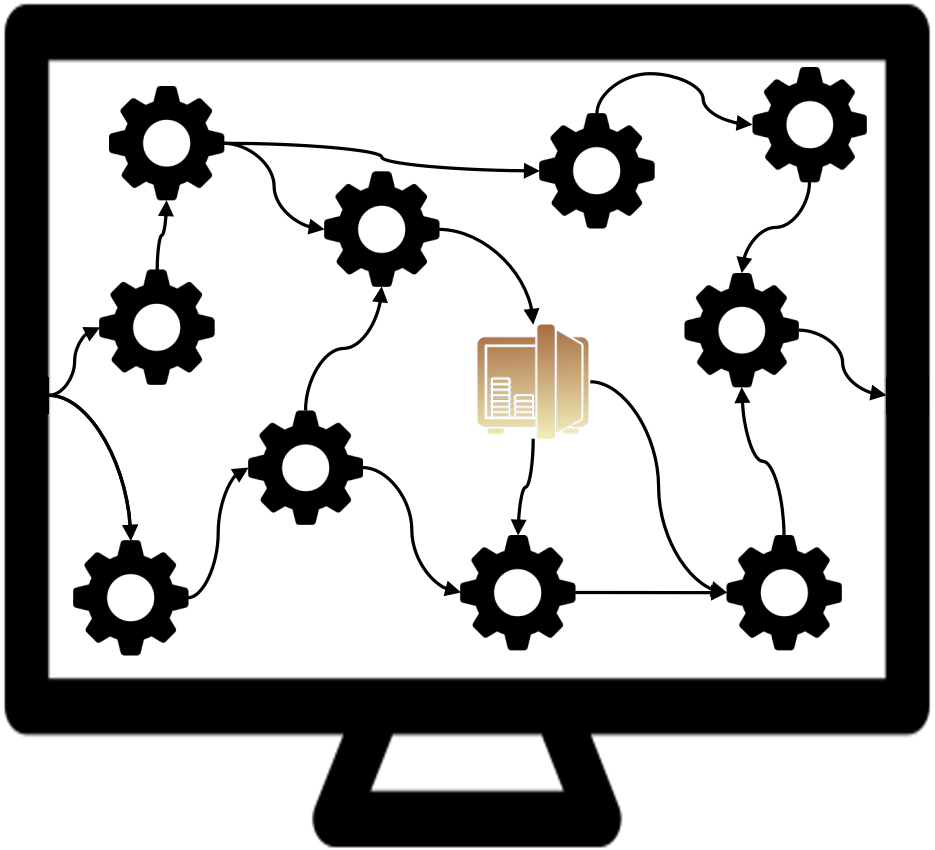


Kasper

Branch Misprediction

Divert conditional branches.



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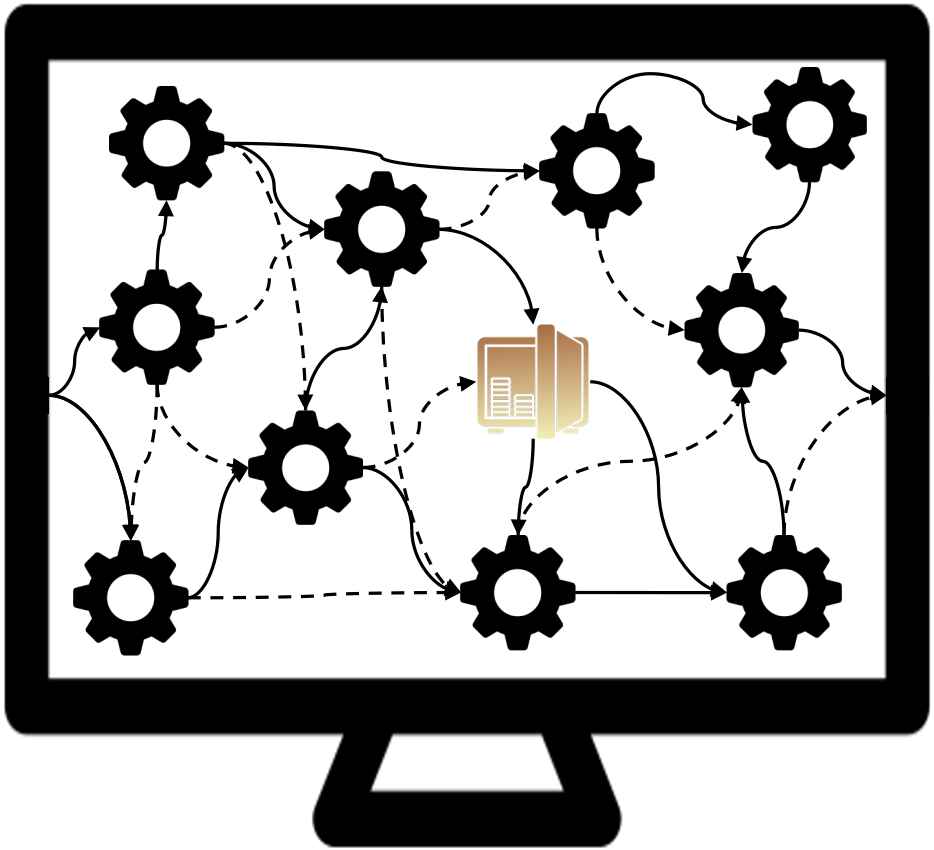

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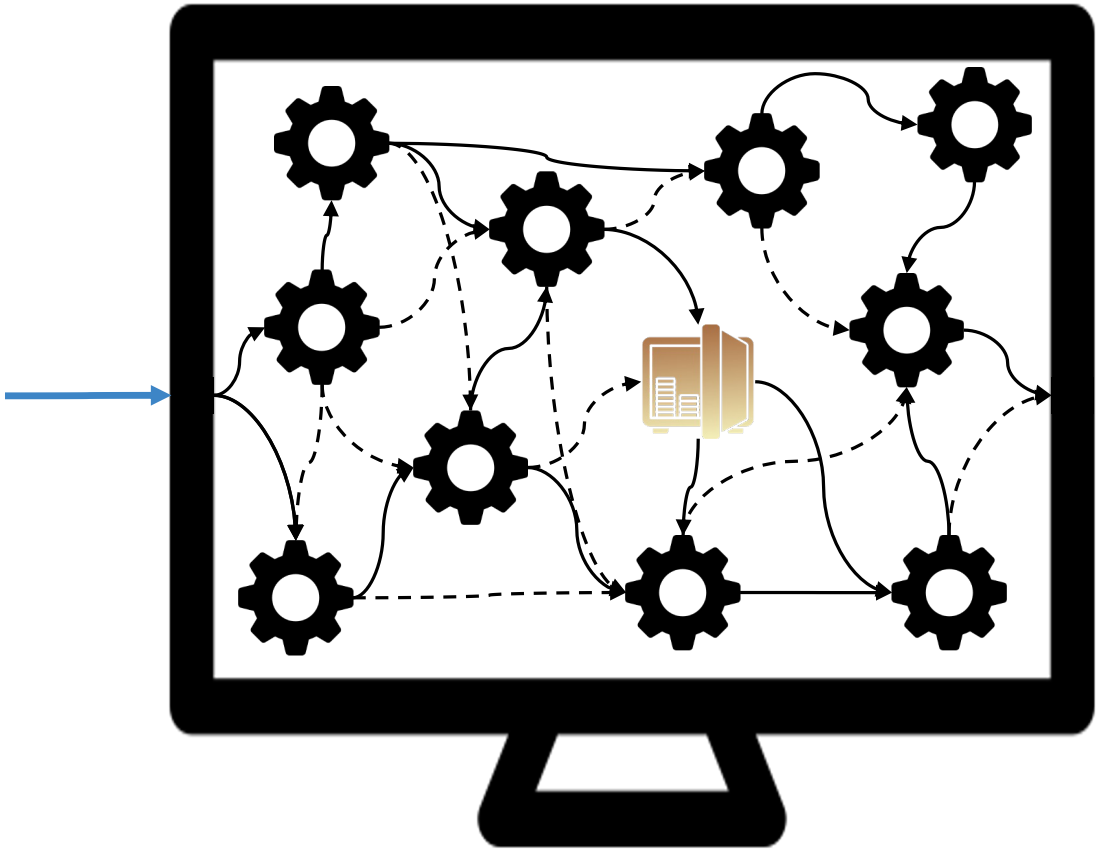

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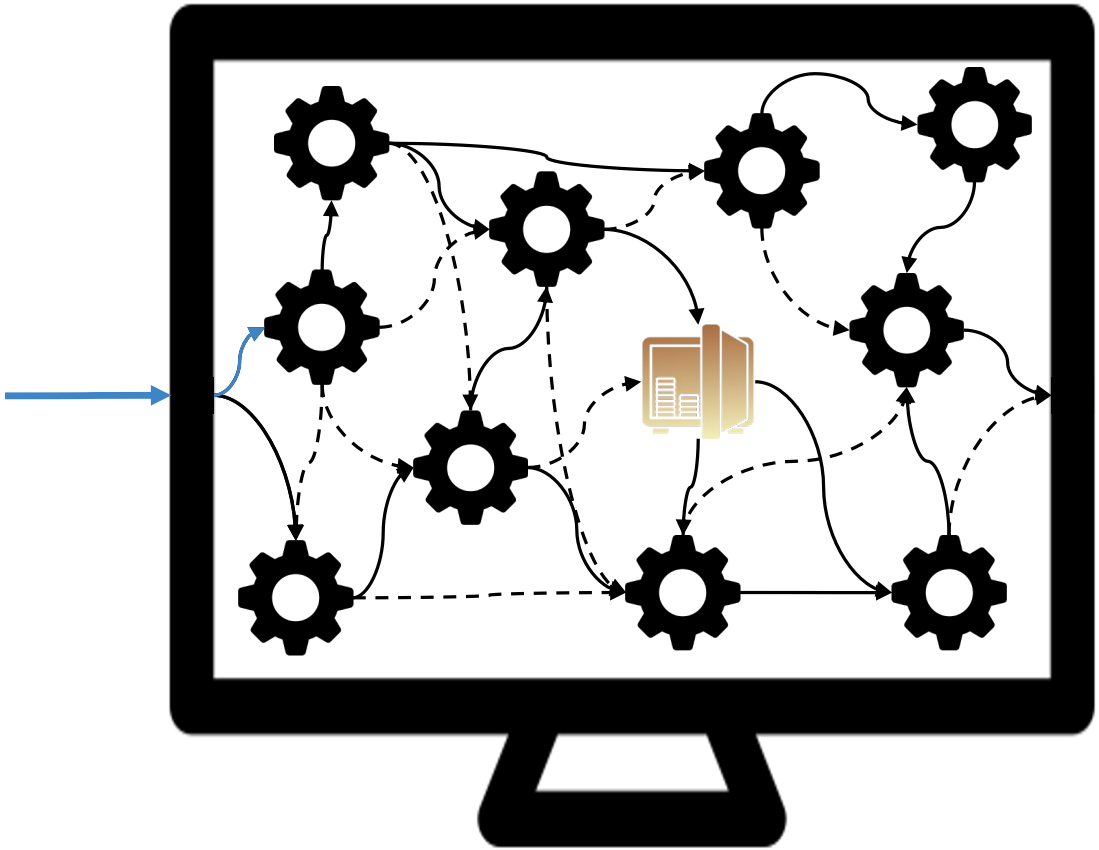

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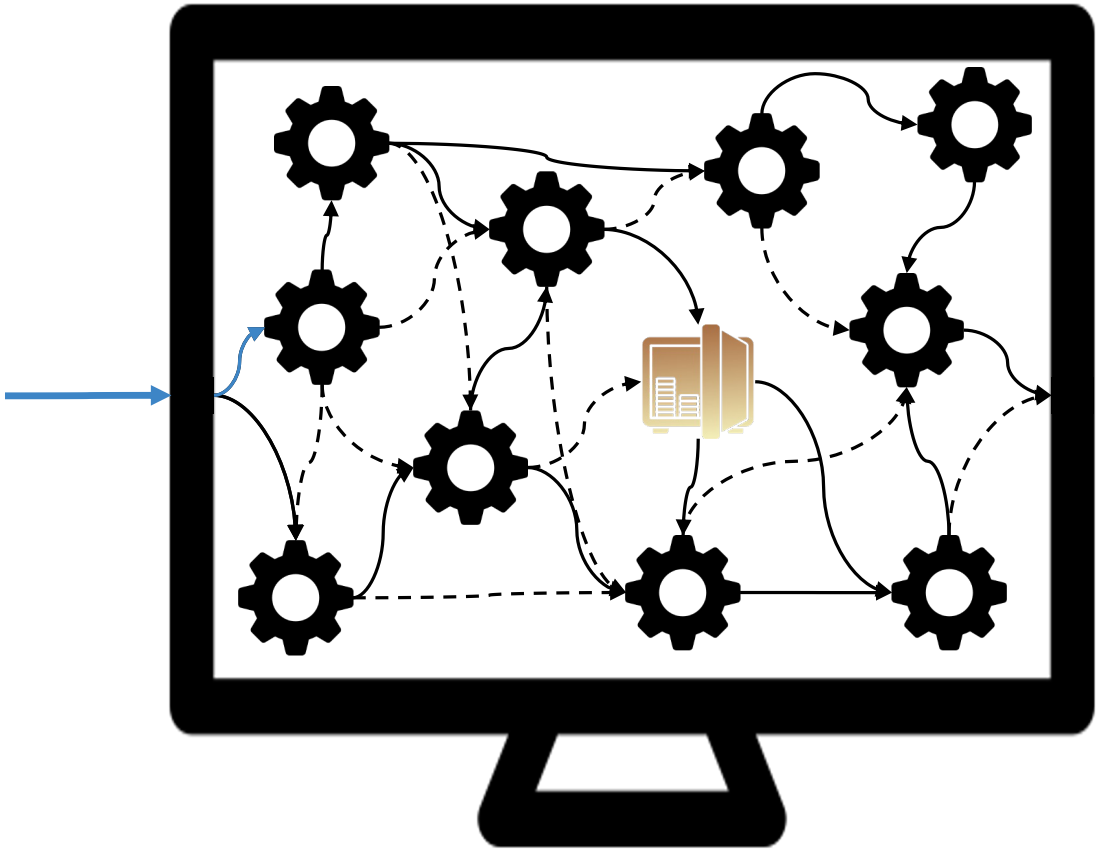
LVI

Invalid transient loads inject attacker data.



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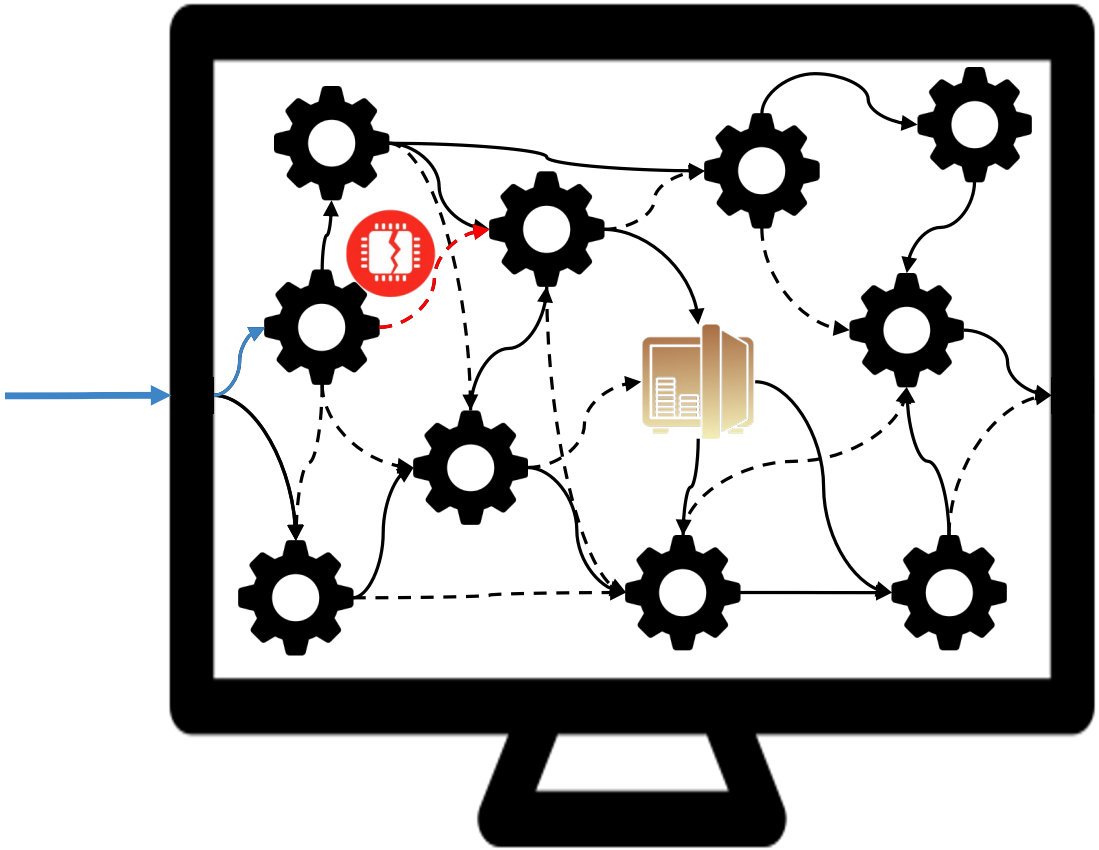

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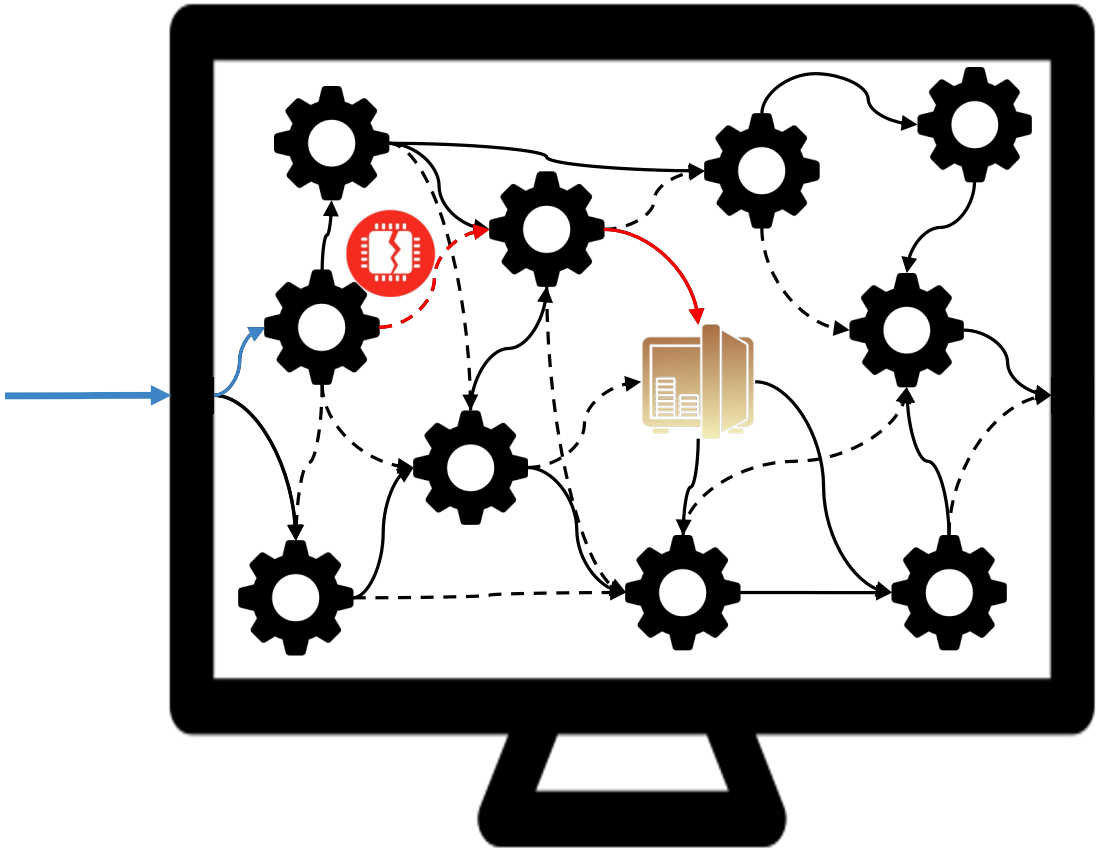

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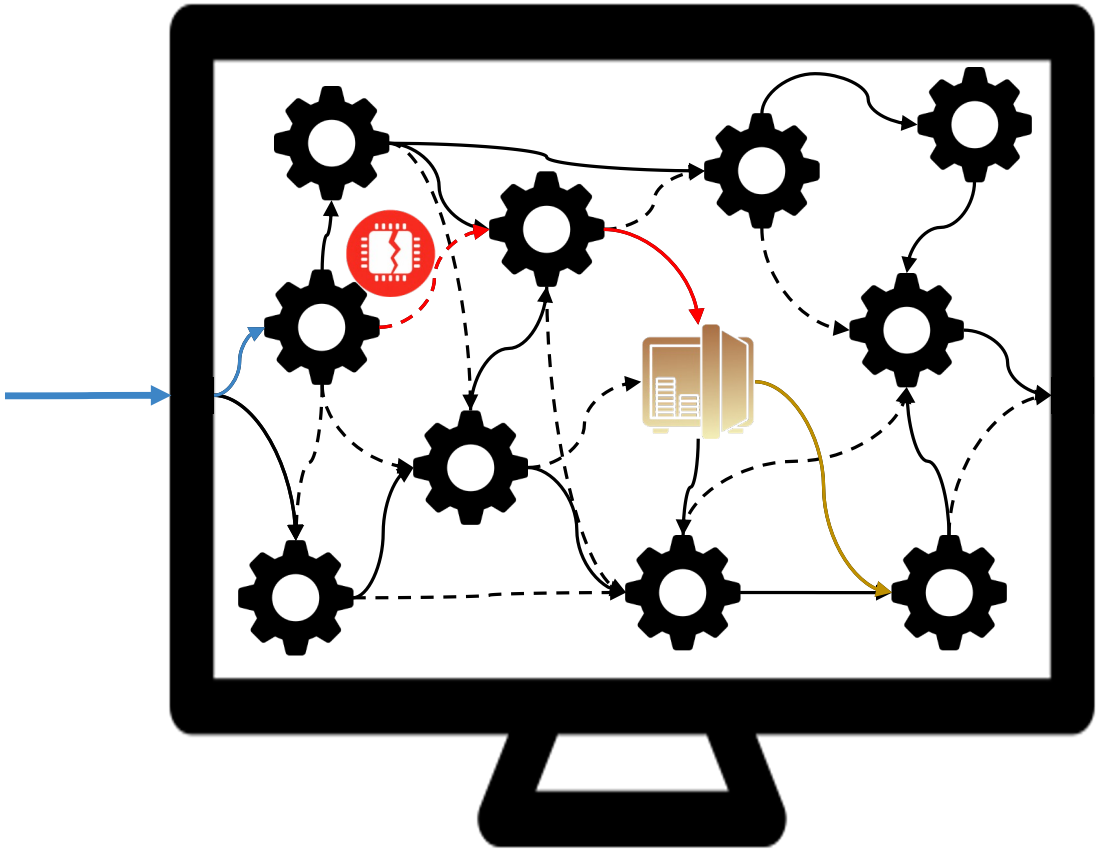

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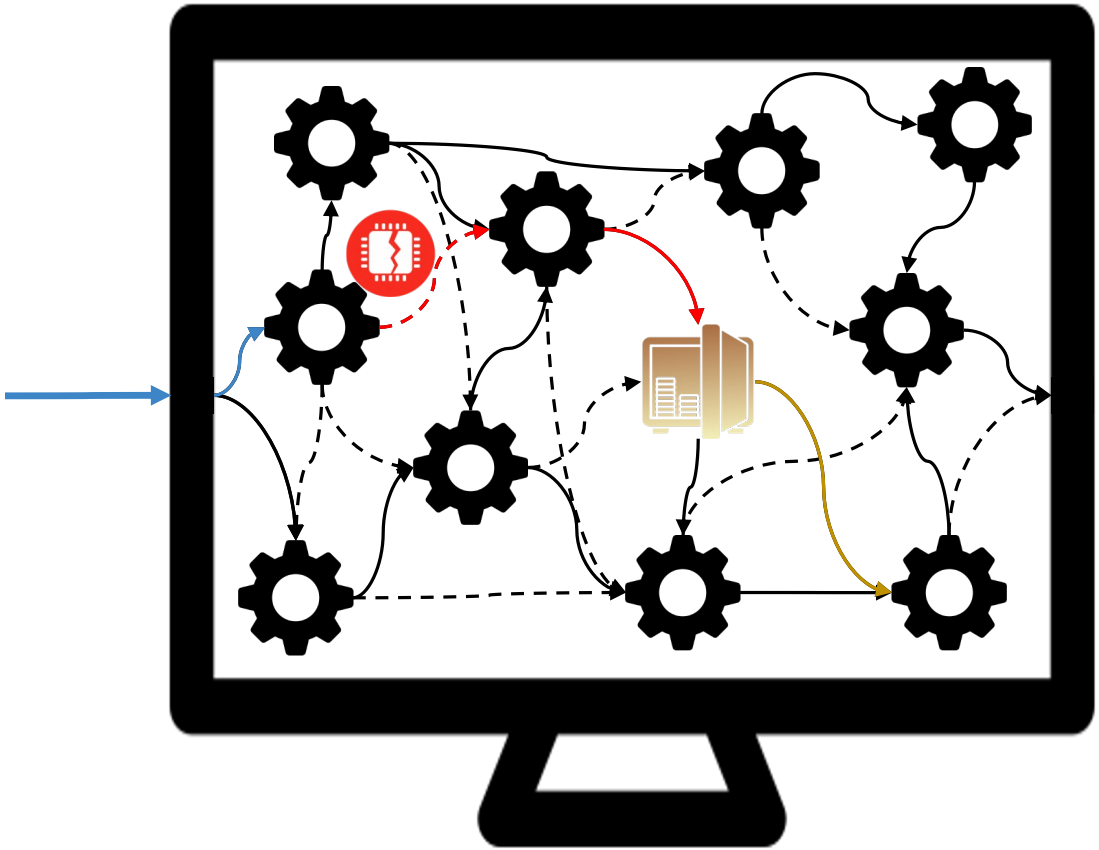
Invalid transient loads inject attacker data.

Cache Contention

Dereferencing an secret pointer leaks it.



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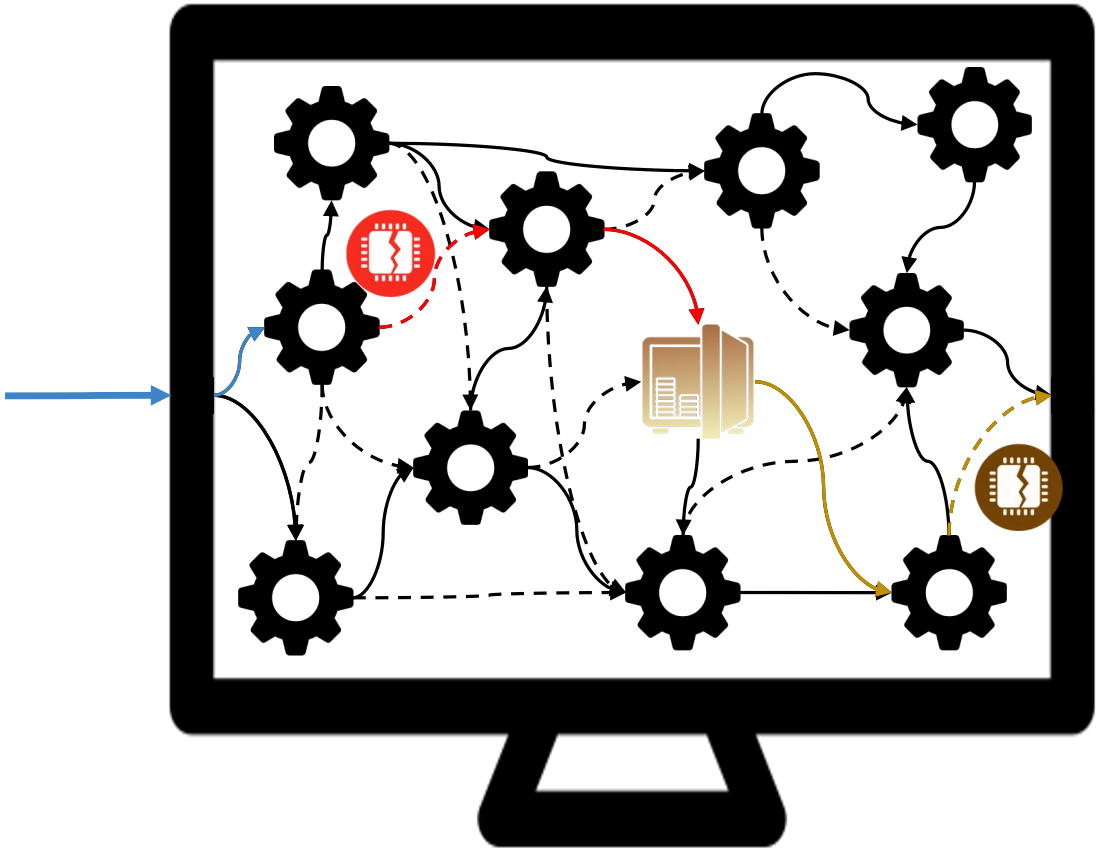

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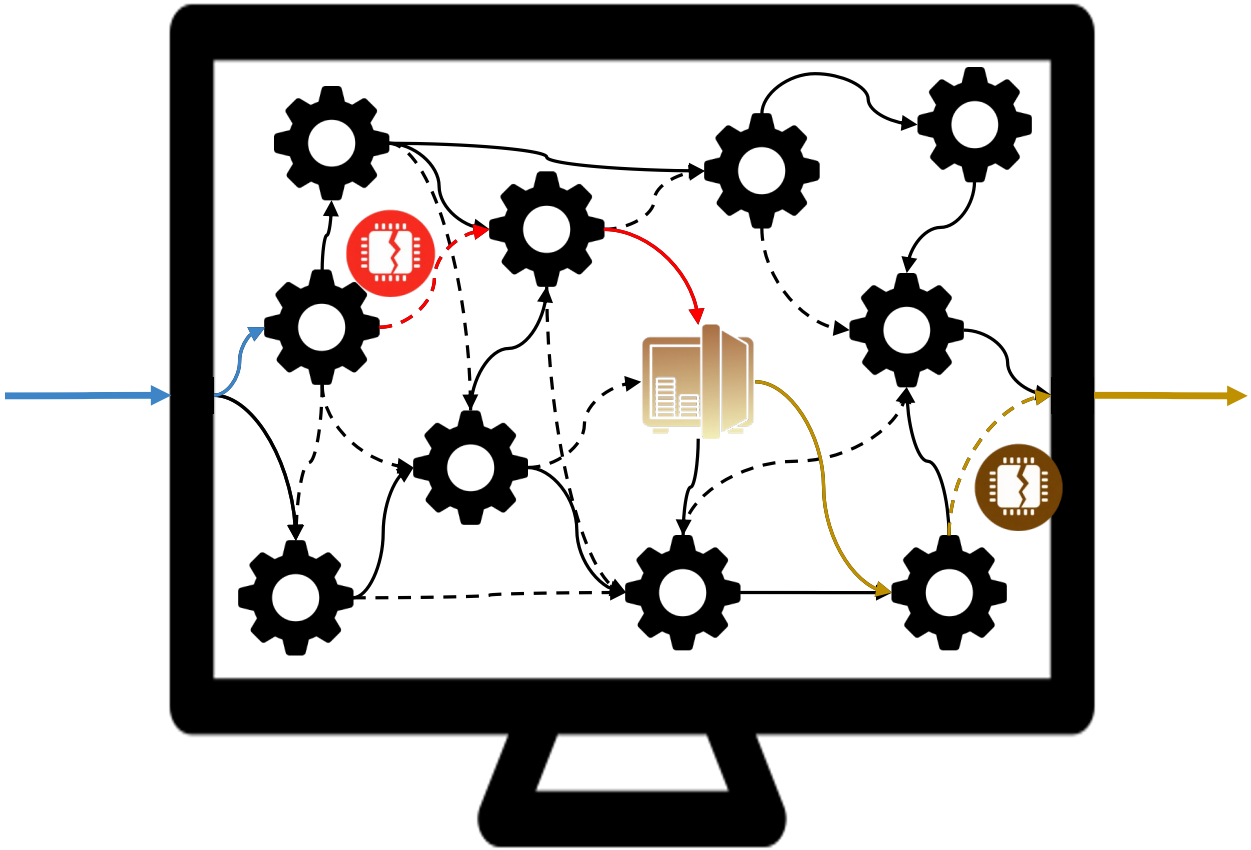

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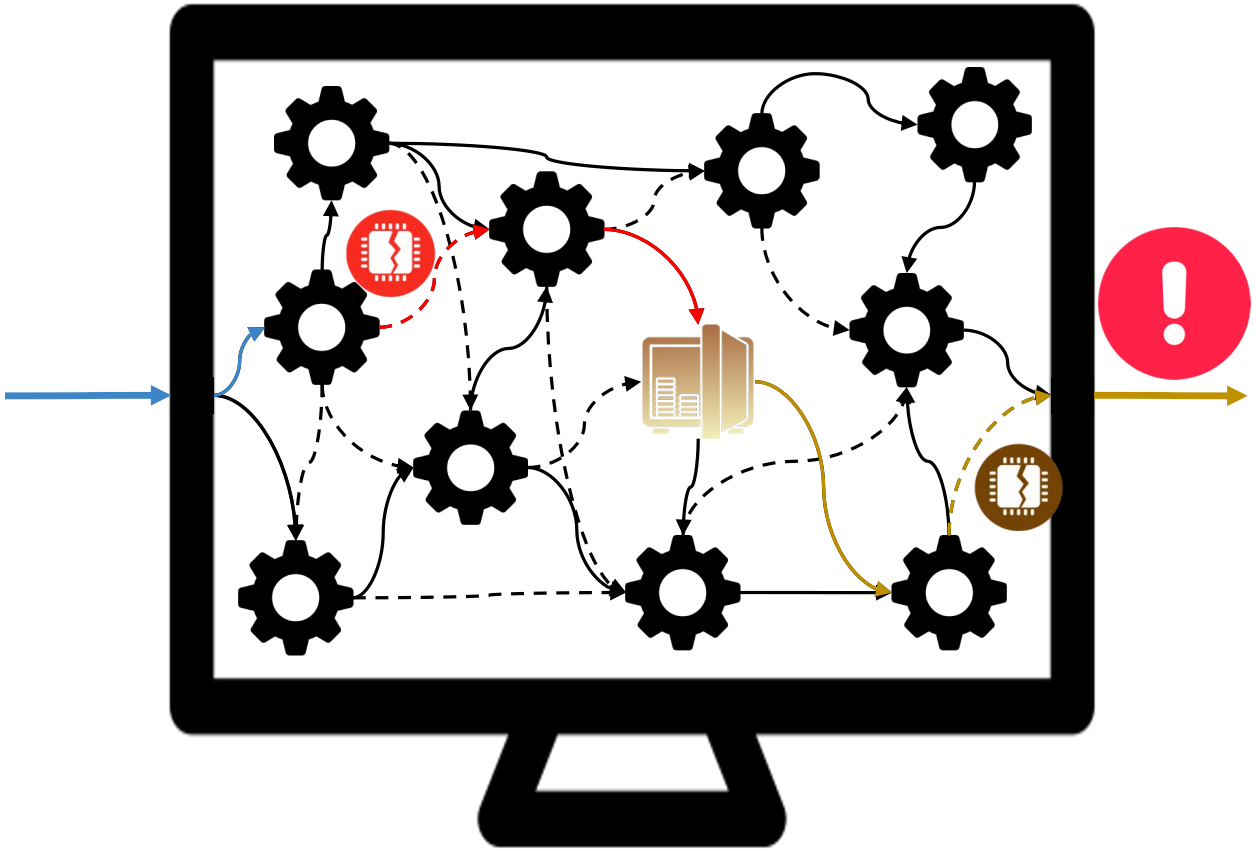


Kasper

Branch Misprediction
Divert conditional branches.

Memory Massaging
Unsafe transient

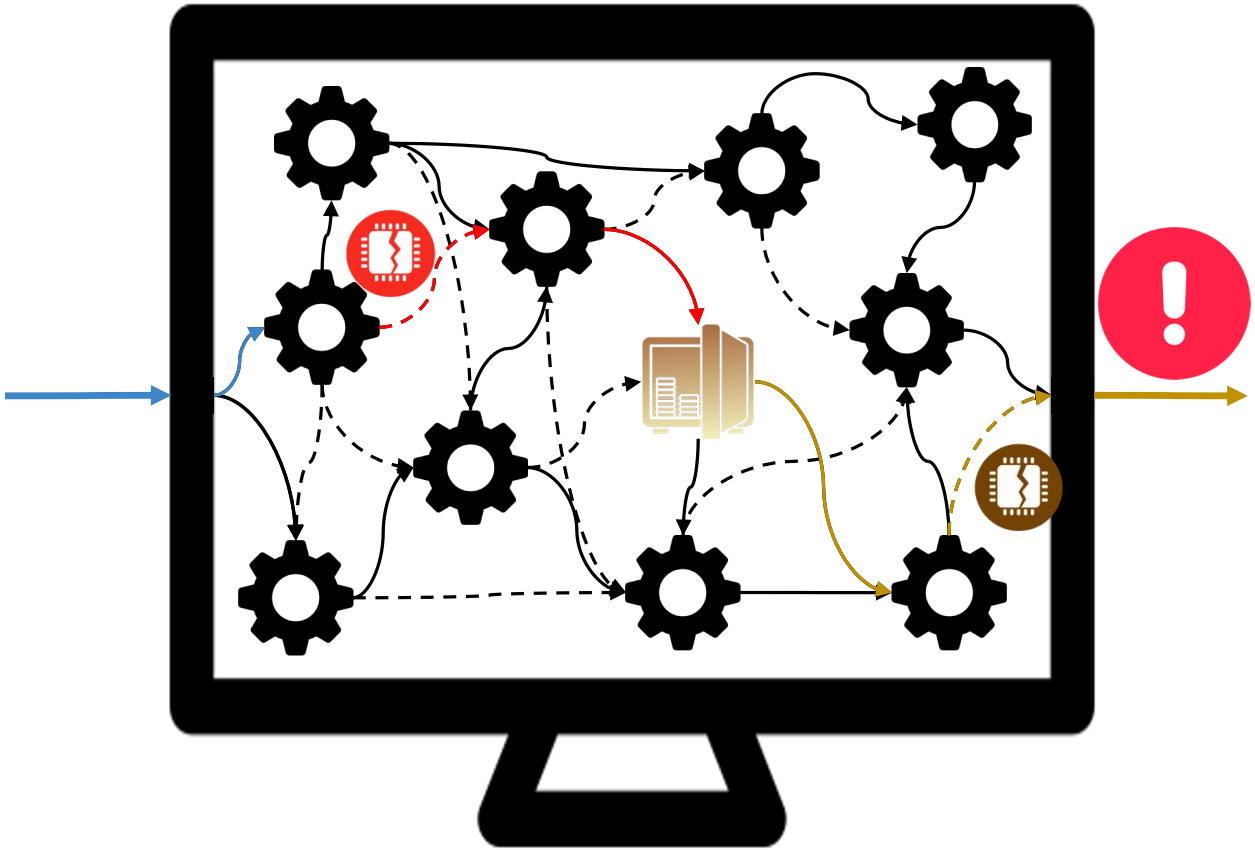
LVI
Invalid transient loads inject attacker data.

User Data
Syscall arguments and
cercopies inject attacker data.

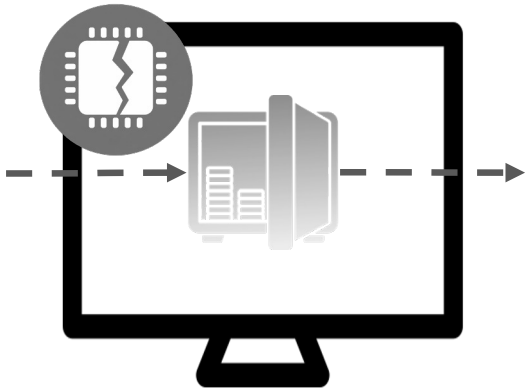
Port Contention
Branching on a
leak

MDS
acker
et it

Cache Contention
Dereferencing an secret pointer leaks it.



Explicit vulnerability modeling: ***Case studies***



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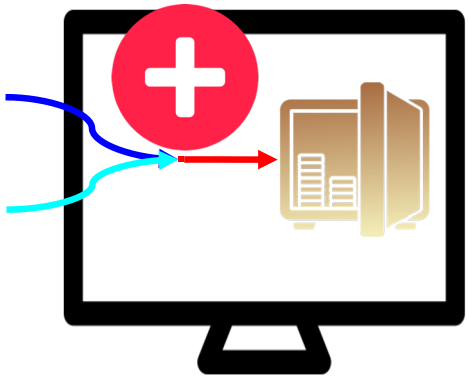
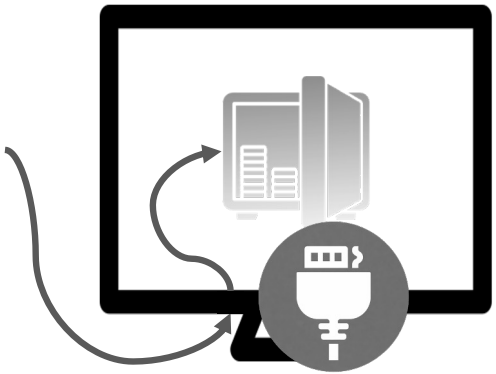
(NDSS 2022)



Einstein

(USENIX Sec. 2024)



DMARacer

(CCS 2025)

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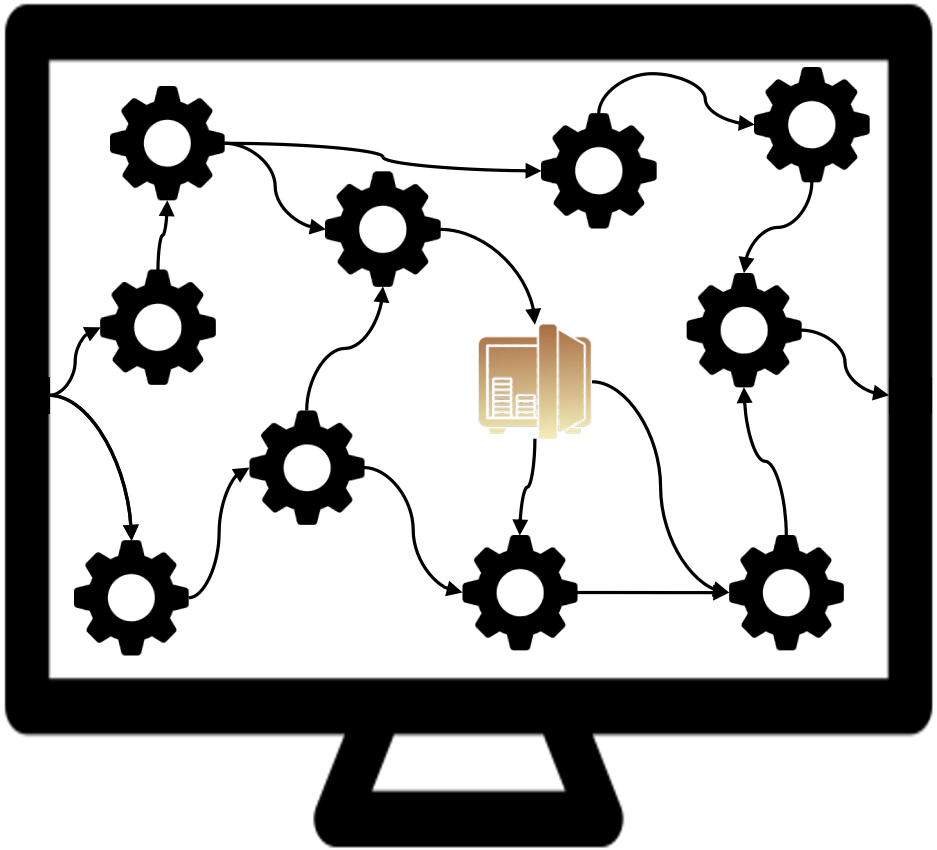

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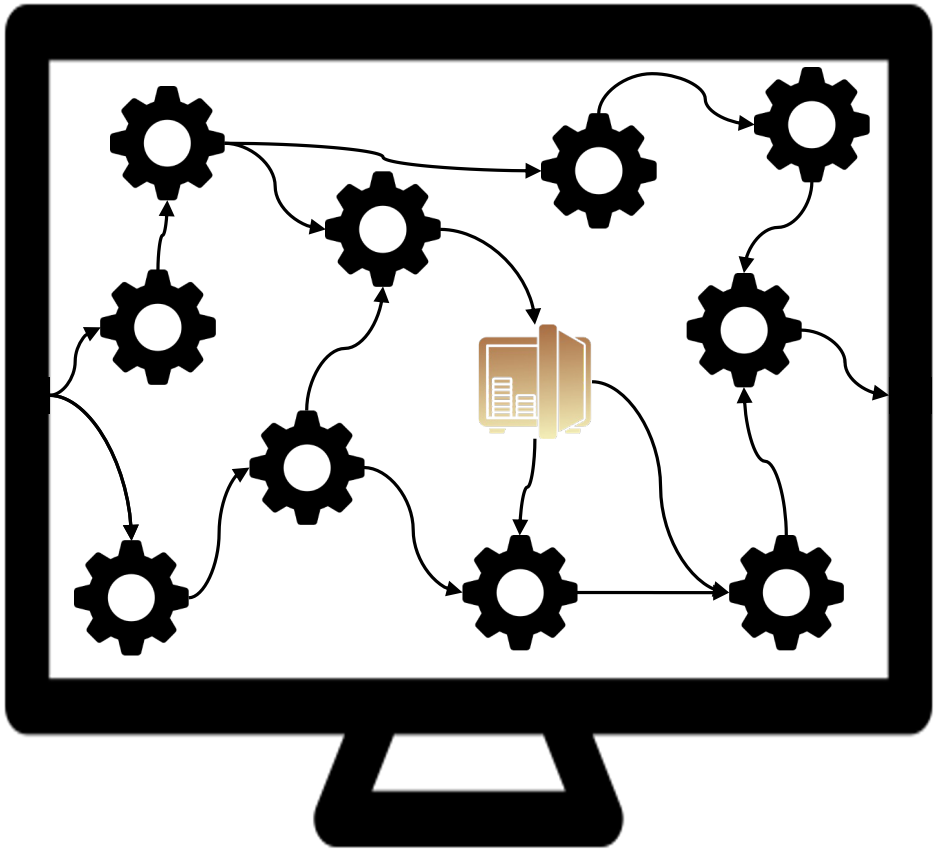

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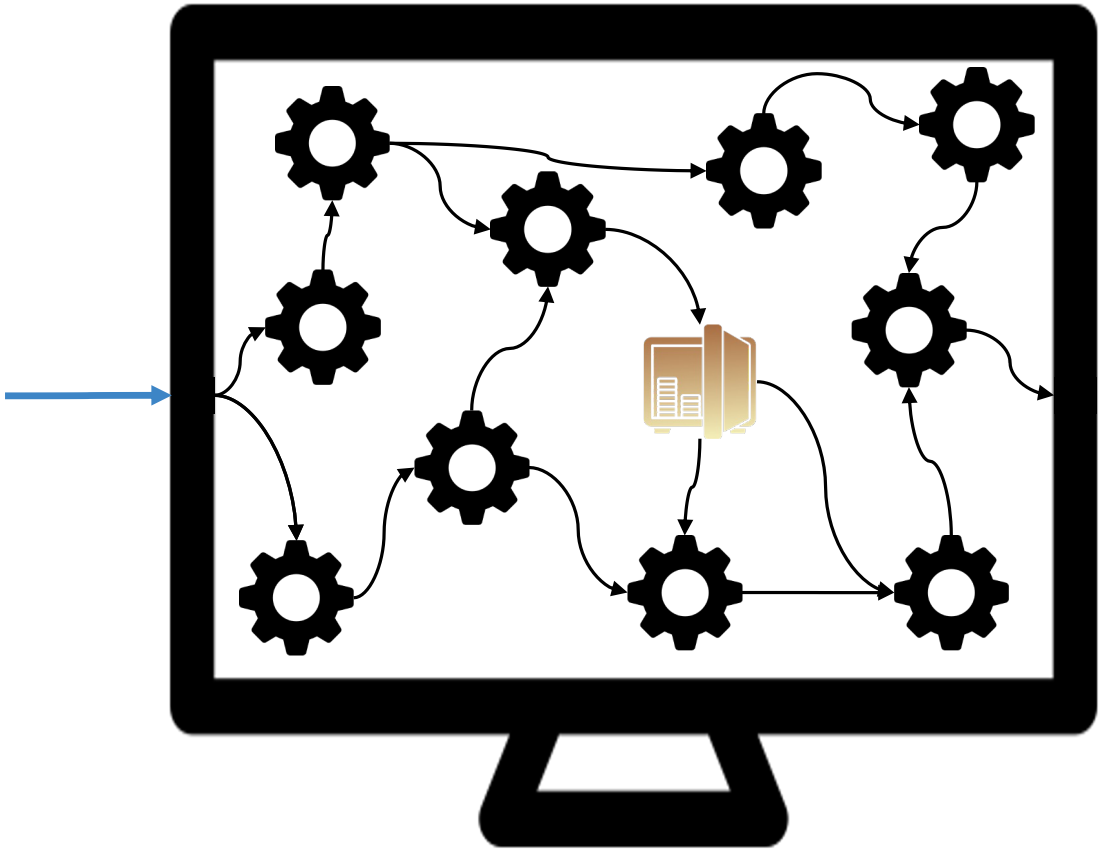

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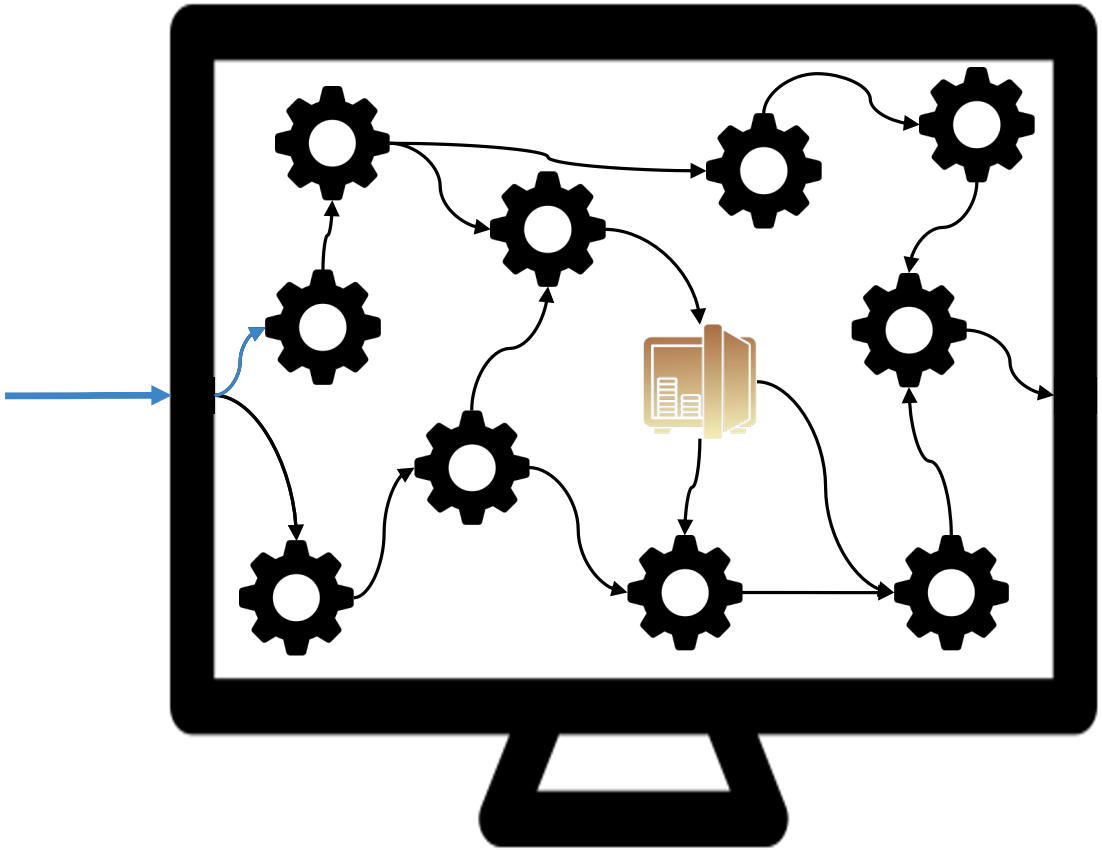

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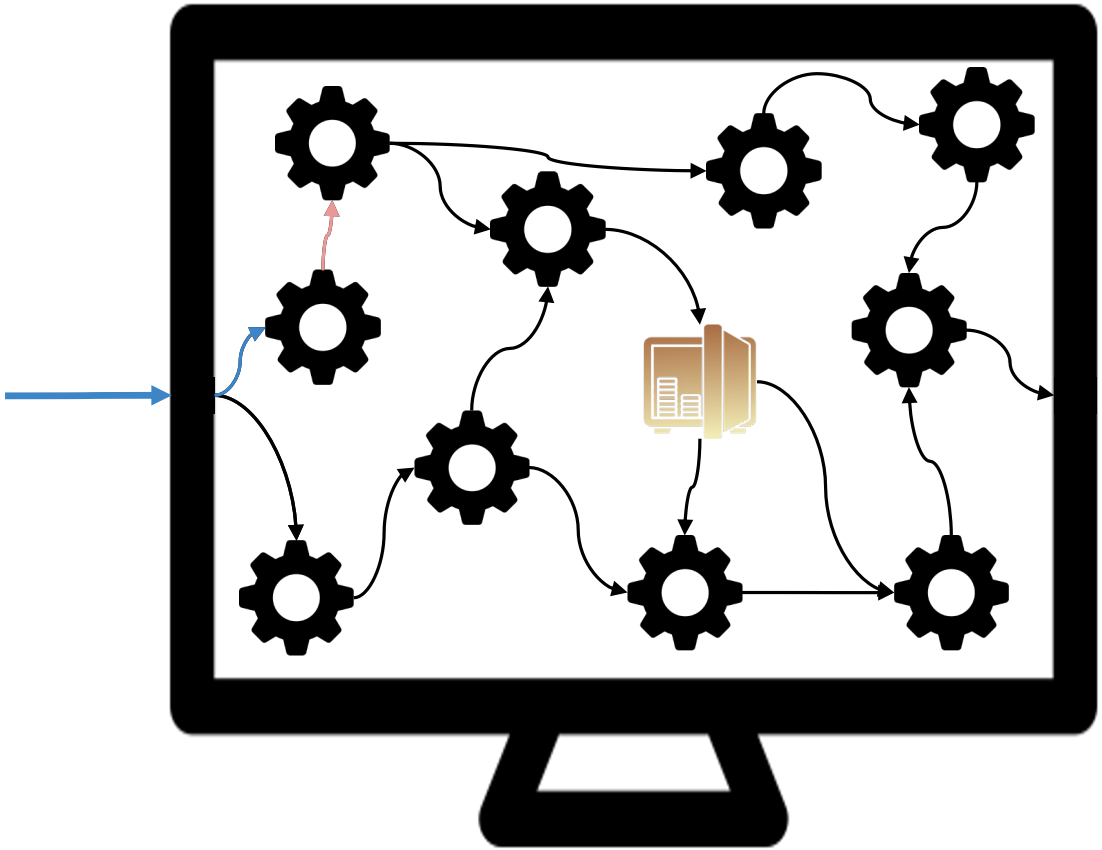

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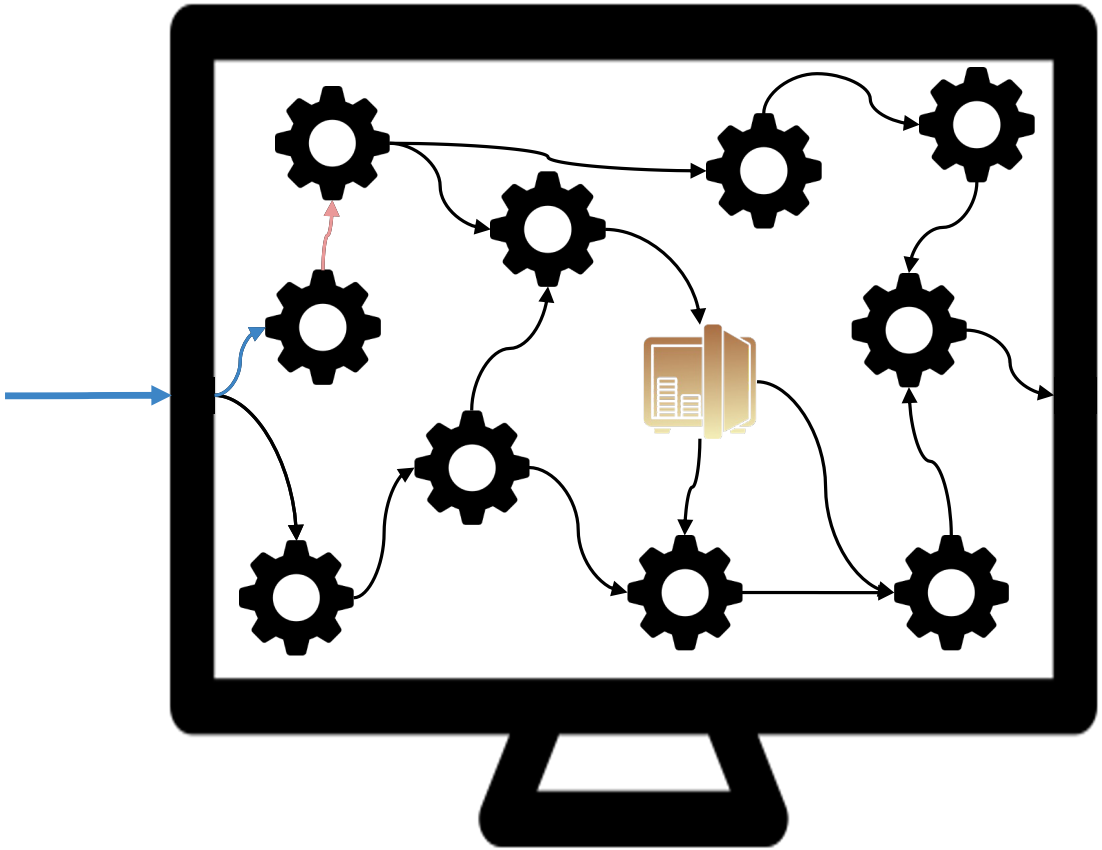

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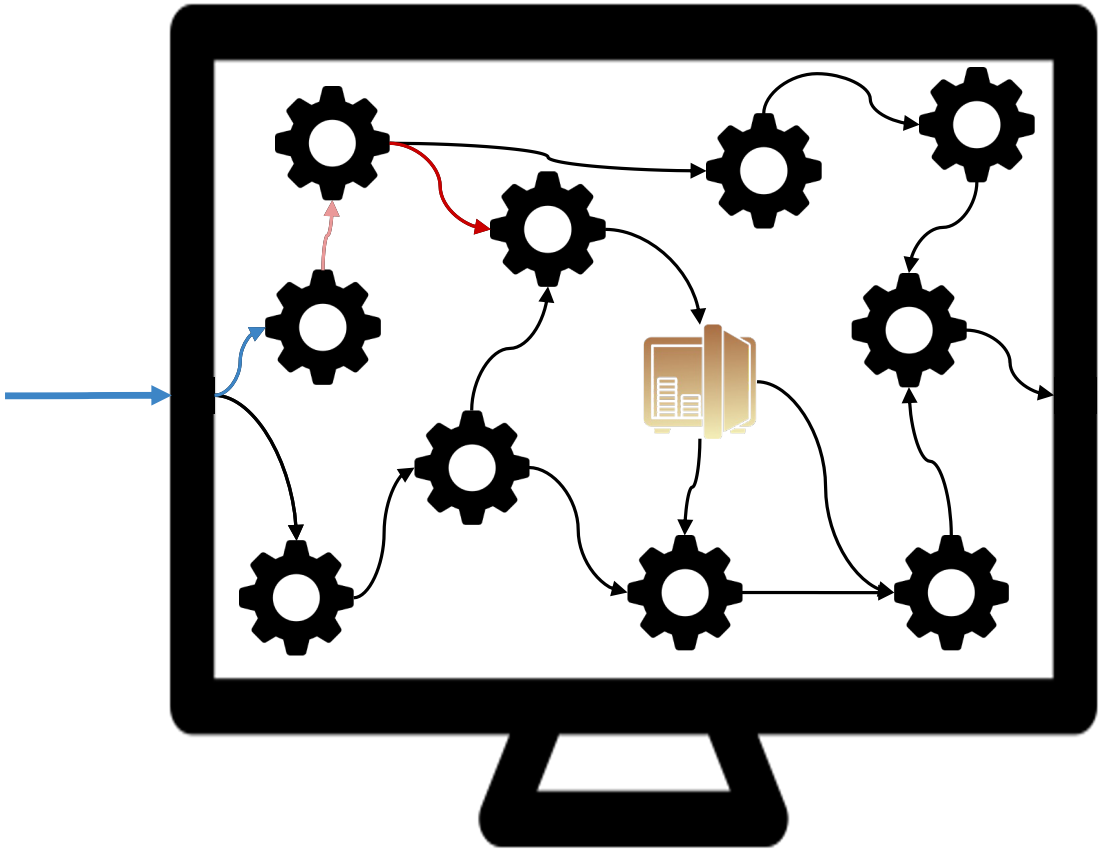

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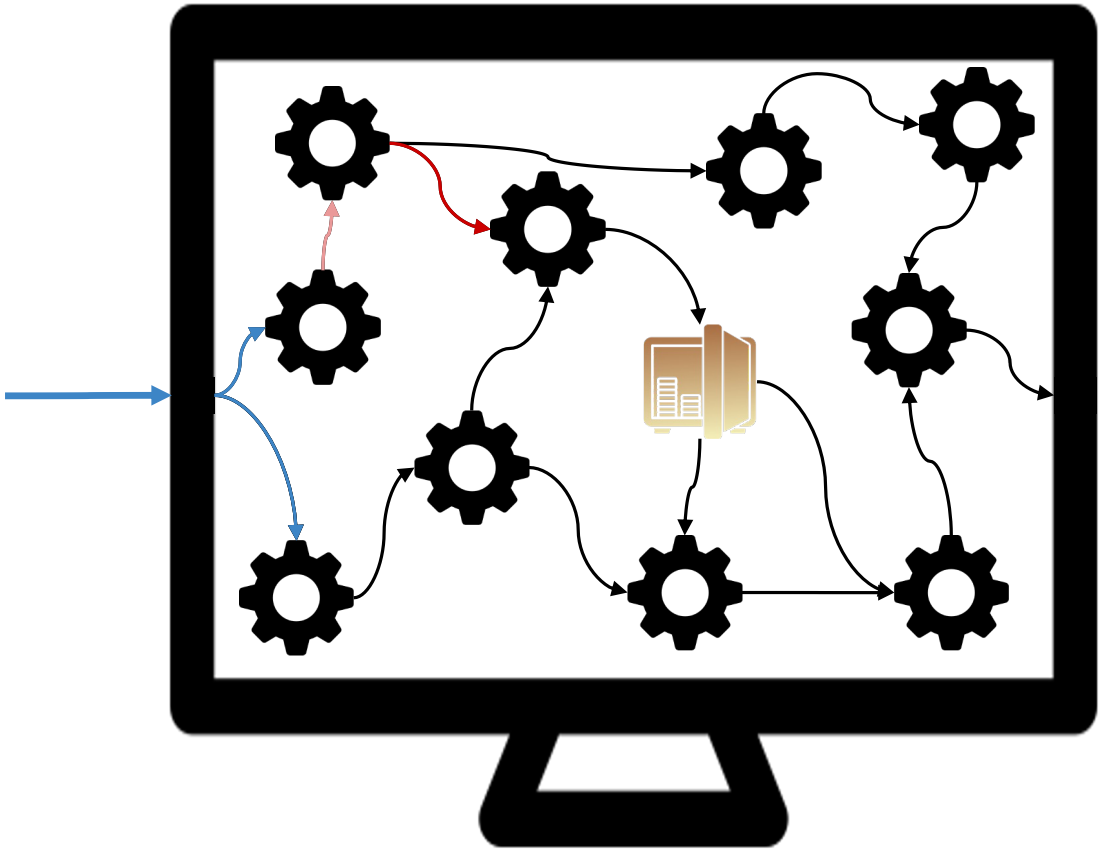

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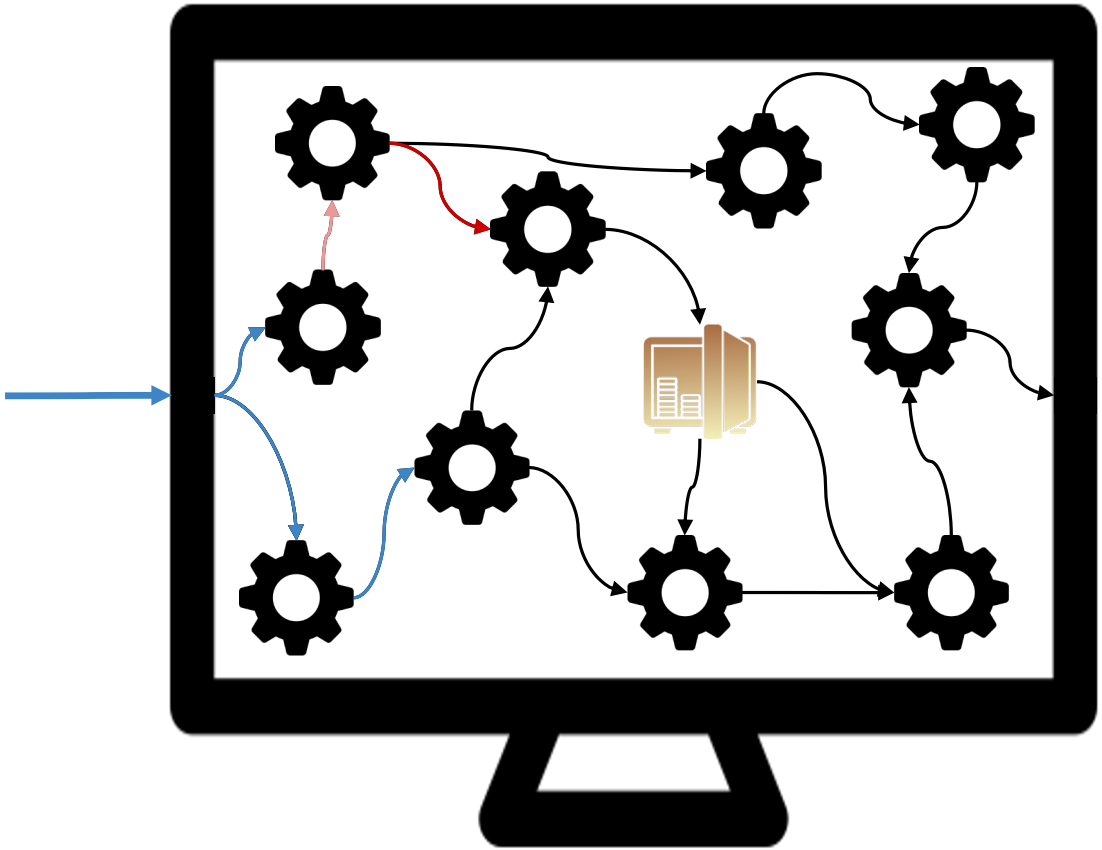

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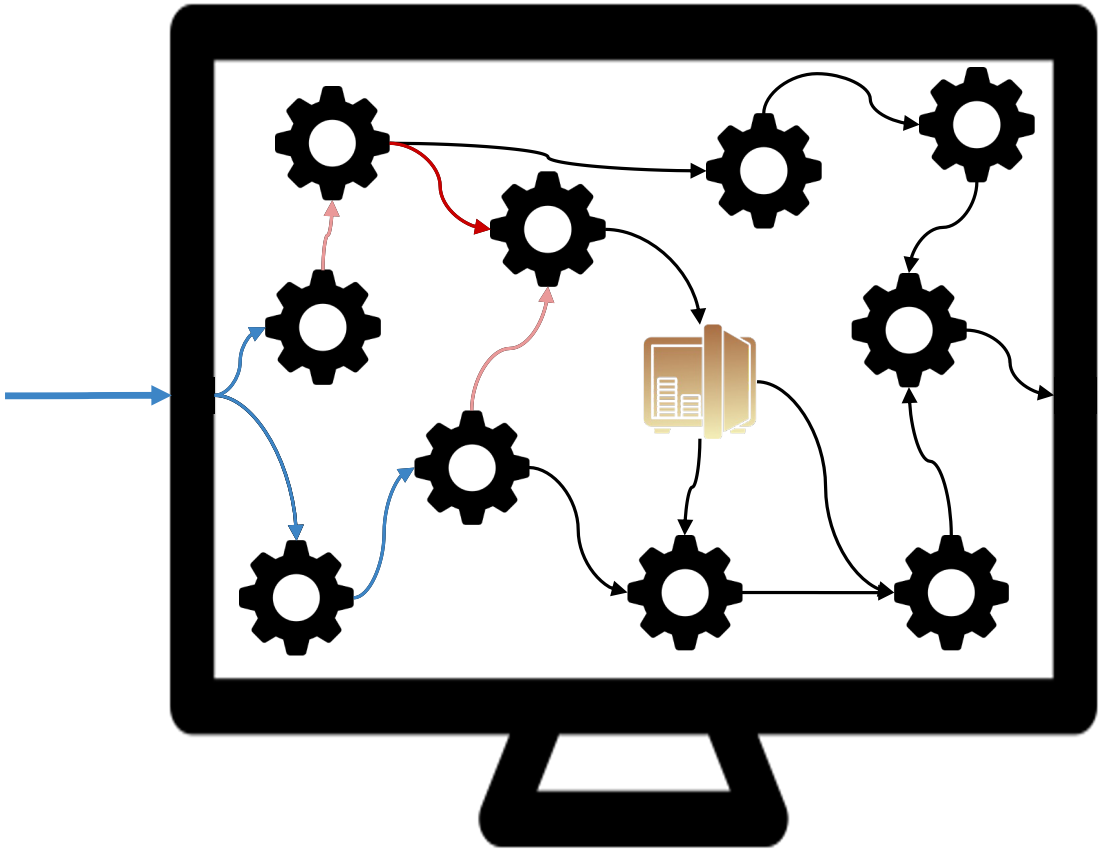

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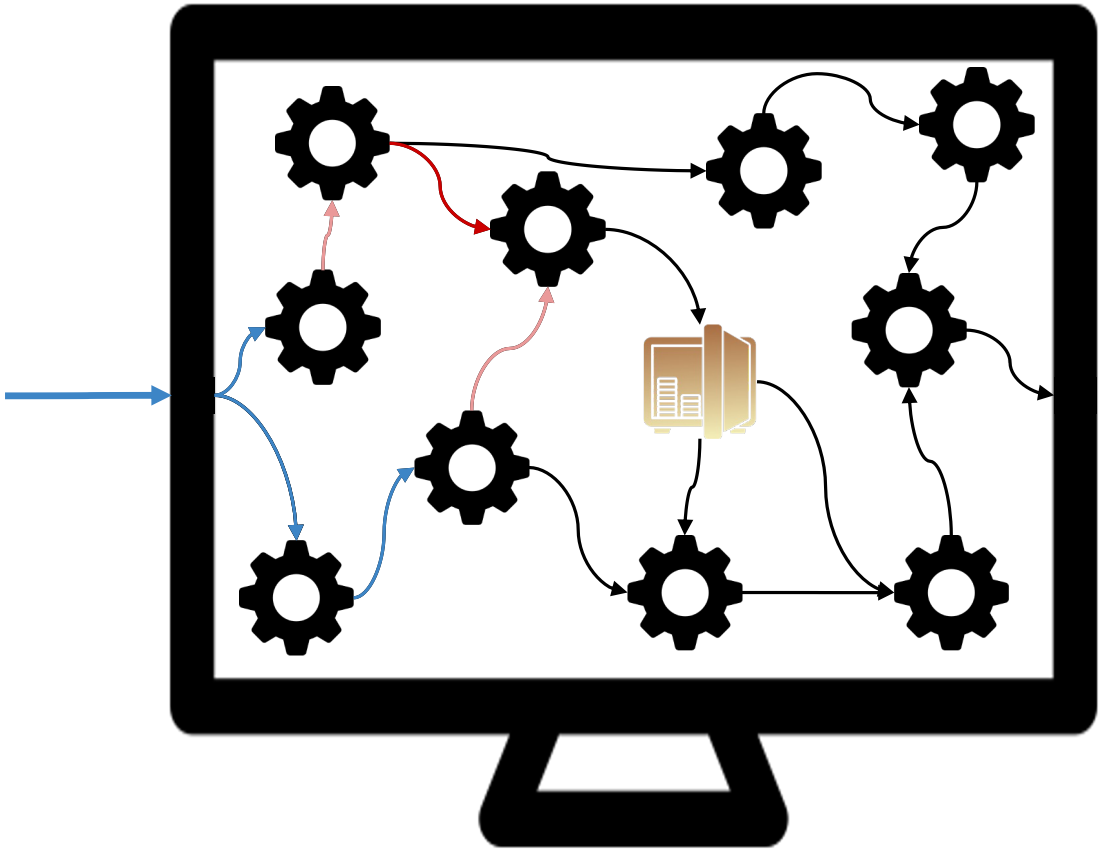

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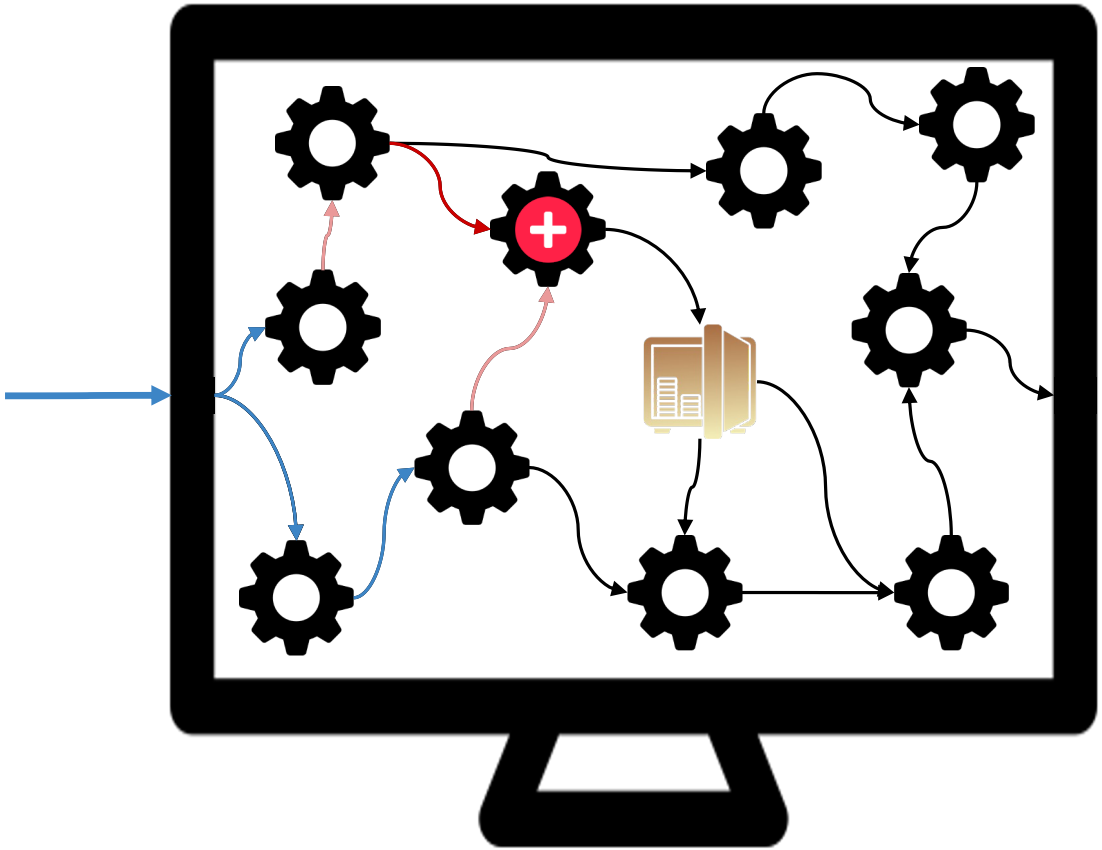

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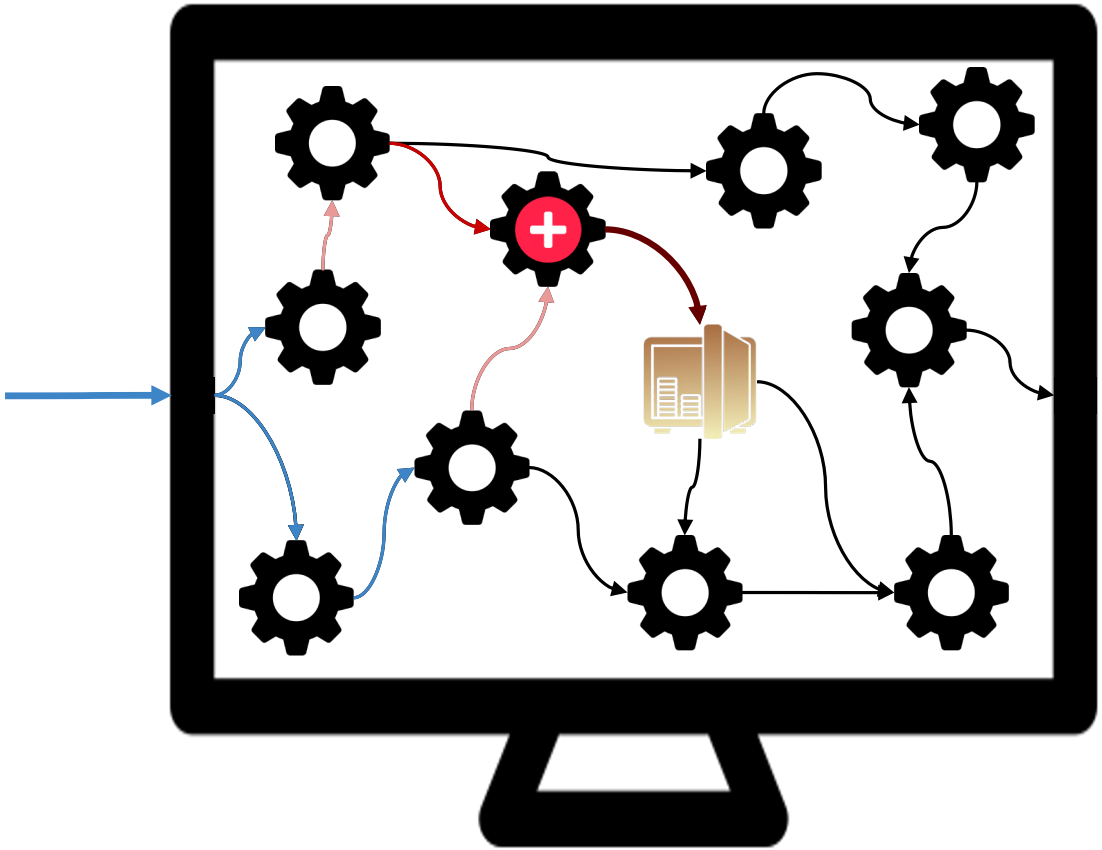

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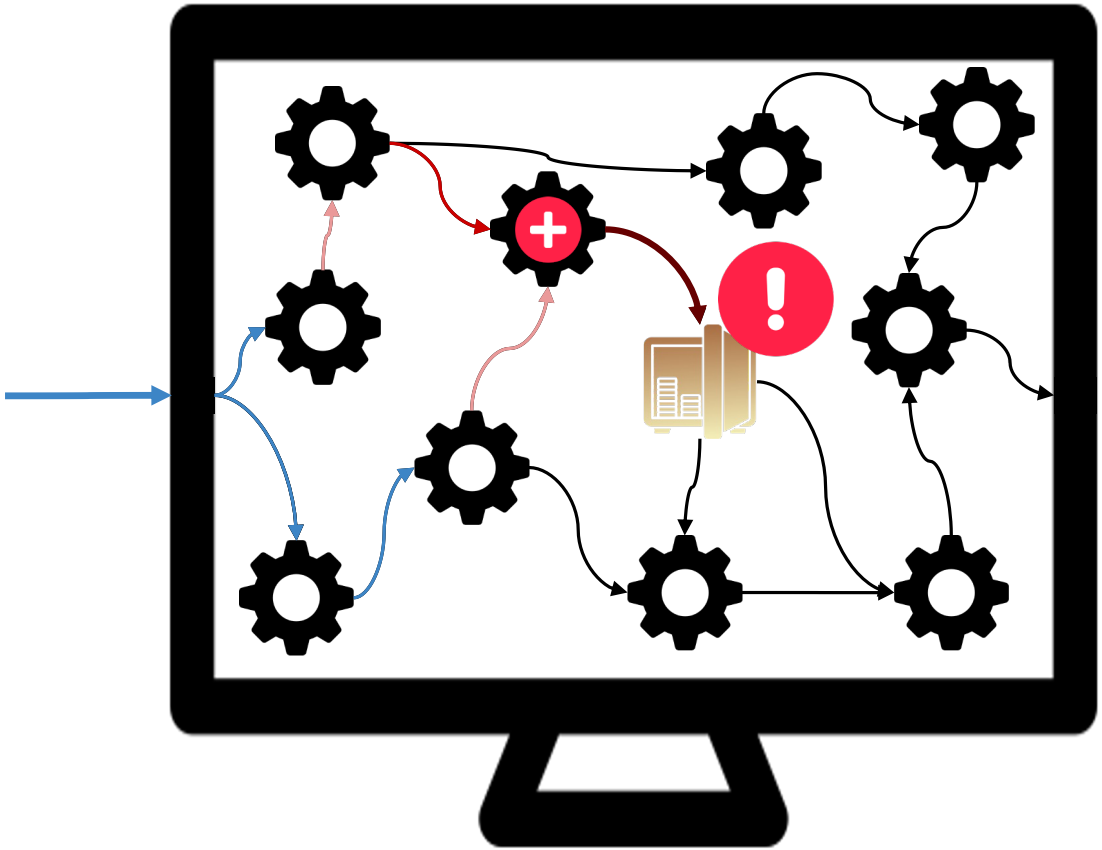

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openat

Attacker argument generates an attacker file.

connect

ttacker argument enerates an attacker socket.

execve

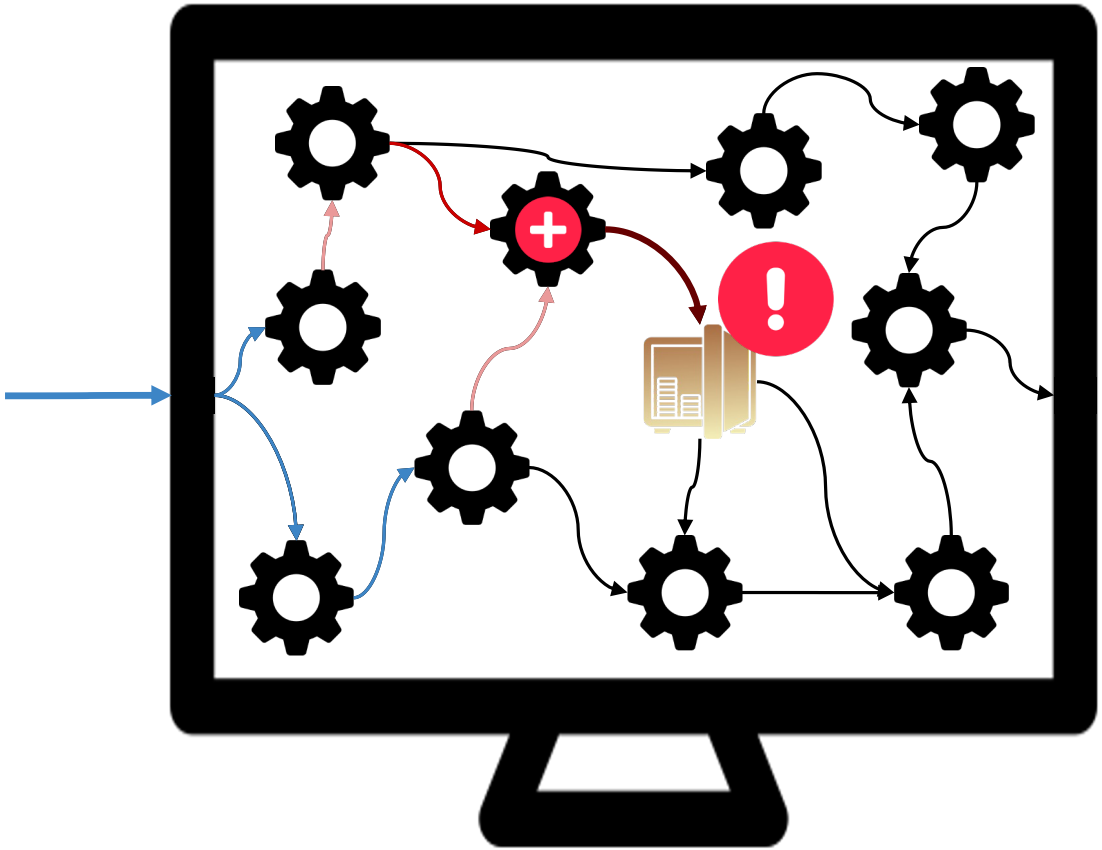
Attacker argument yields a code-execution attack.

endto

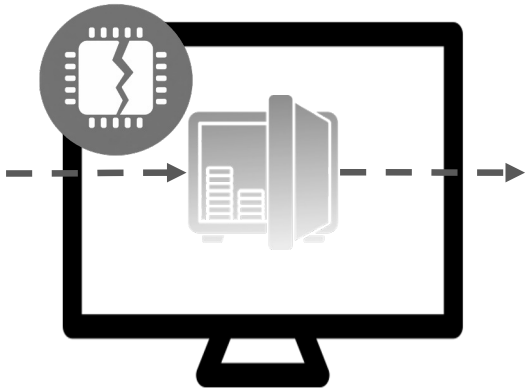
t yields a send- e attack.

write

Attacker argument yields a write-what-where attack.

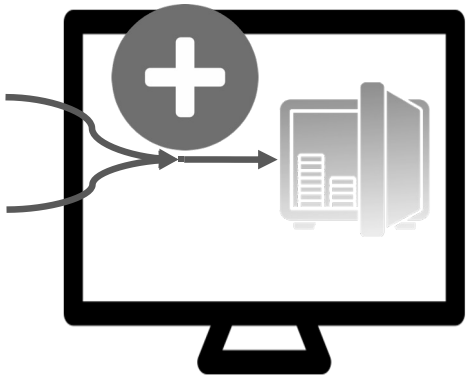


Explicit vulnerability modeling: ***Case studies***



Kasper

(NDSS 2022)



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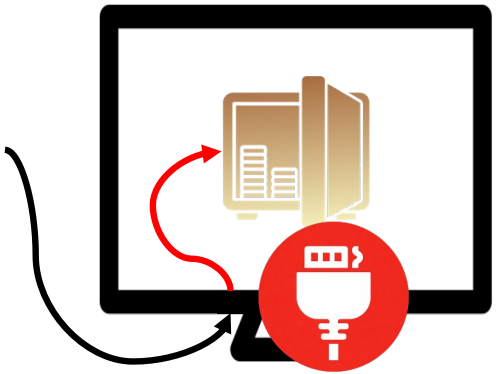
(USENIX Sec. 2024)



DMARacer

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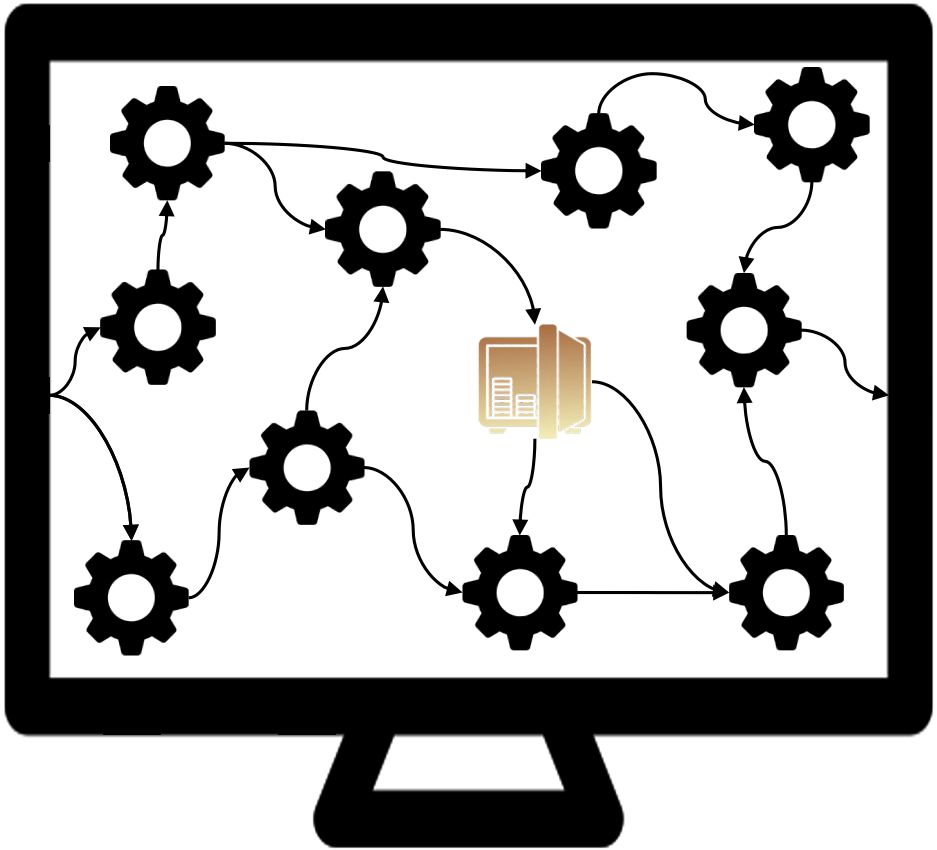

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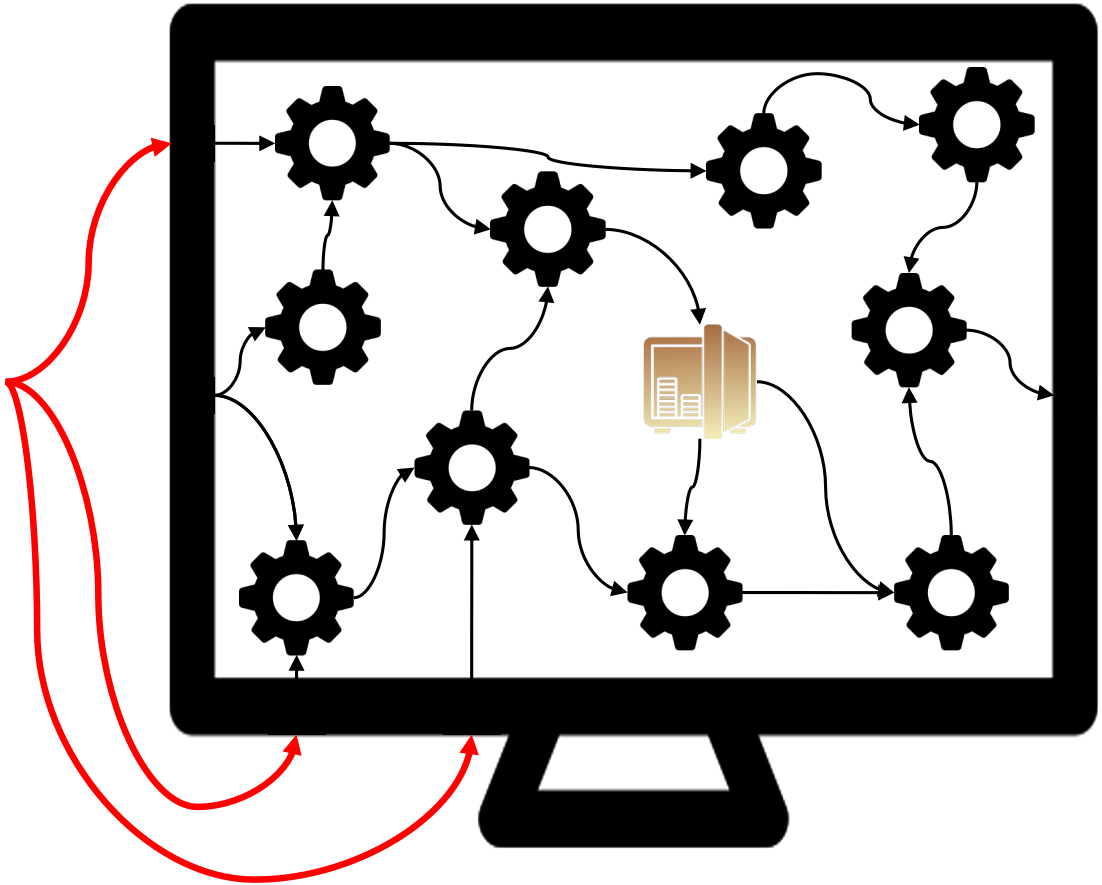
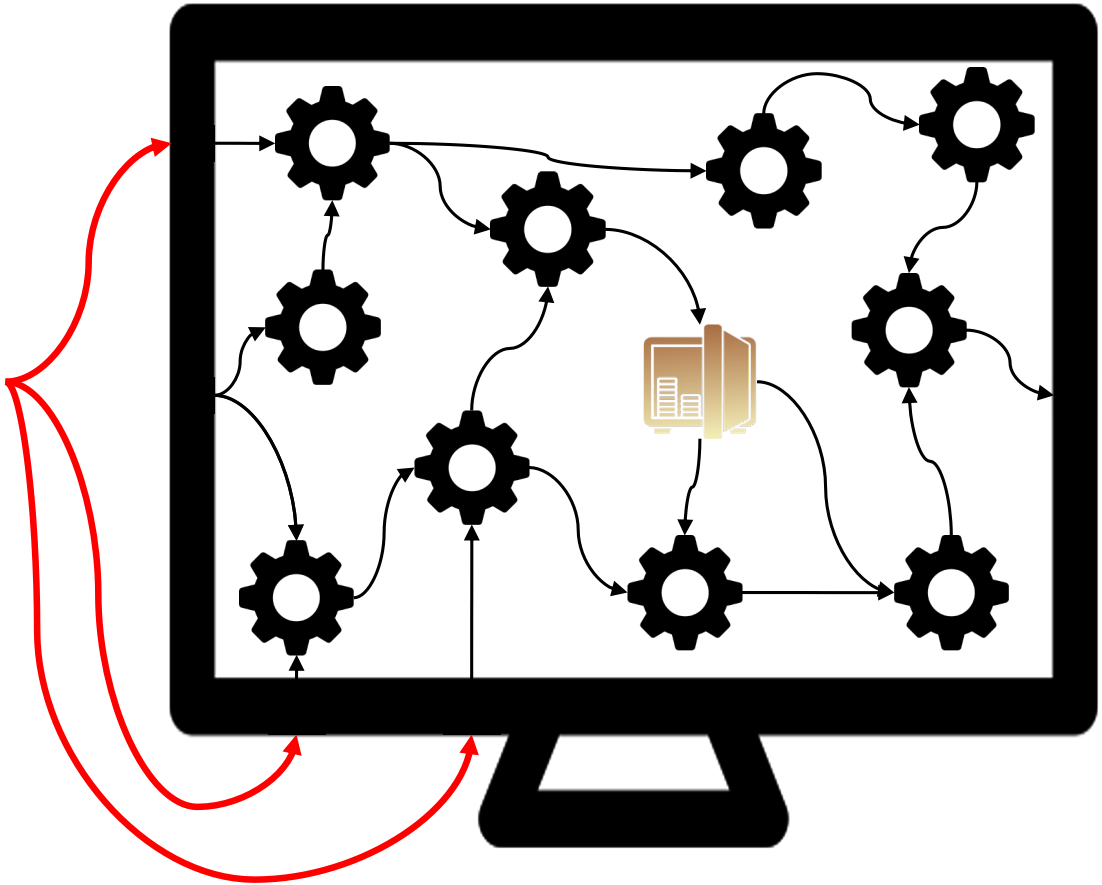


DMARacer

Time-of-Check to Time-of-Use

Multiple DMA loads generate attacker data.



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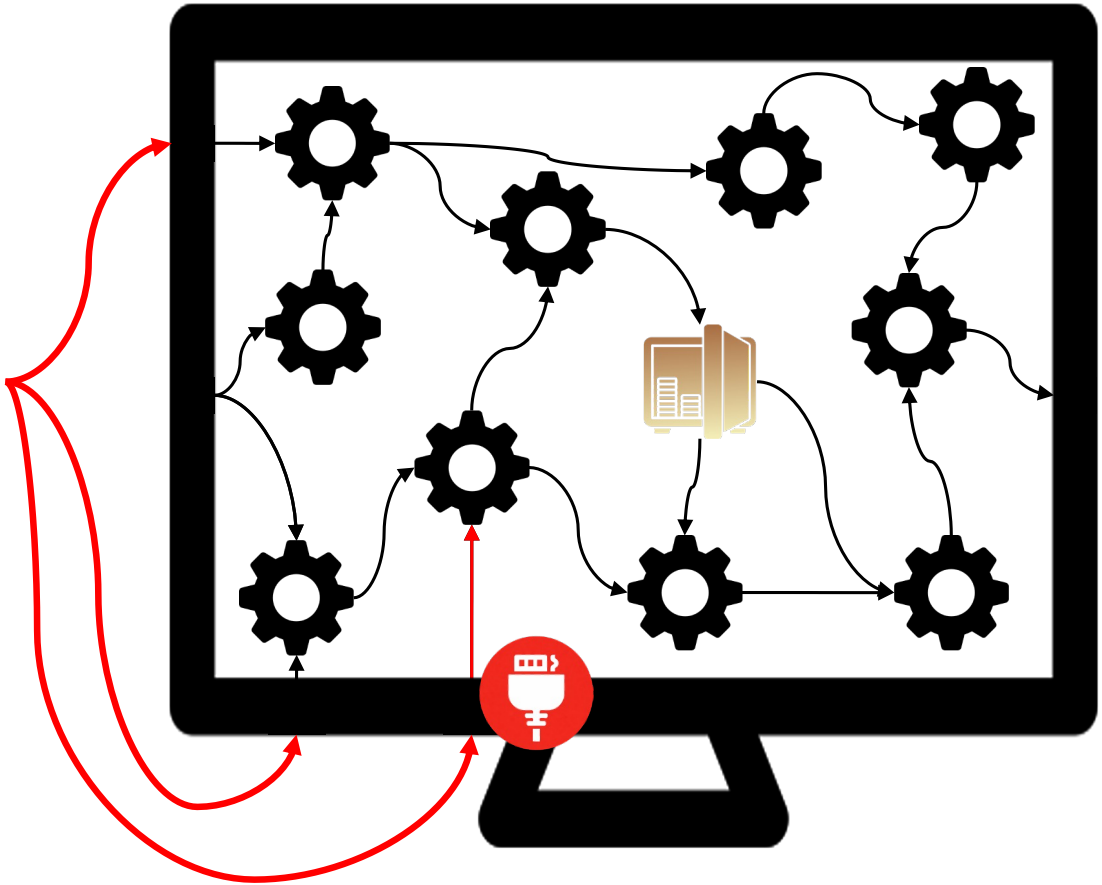

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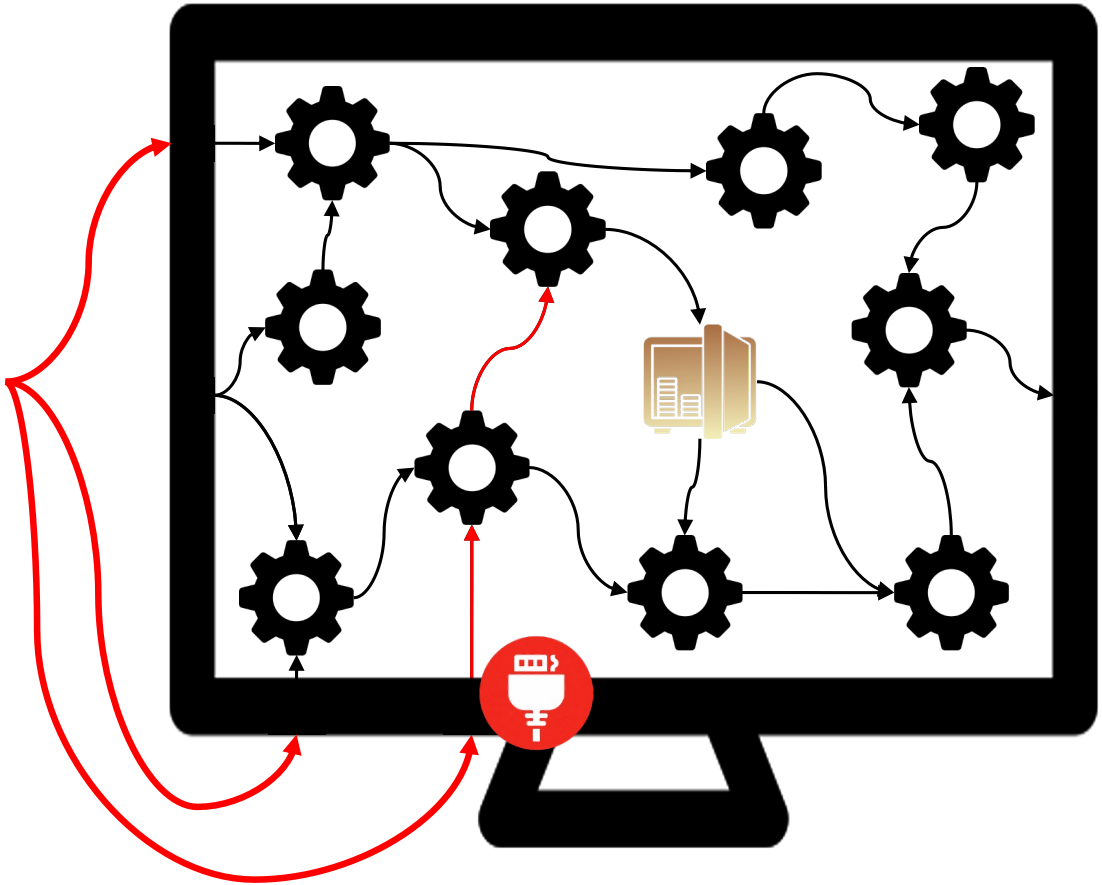

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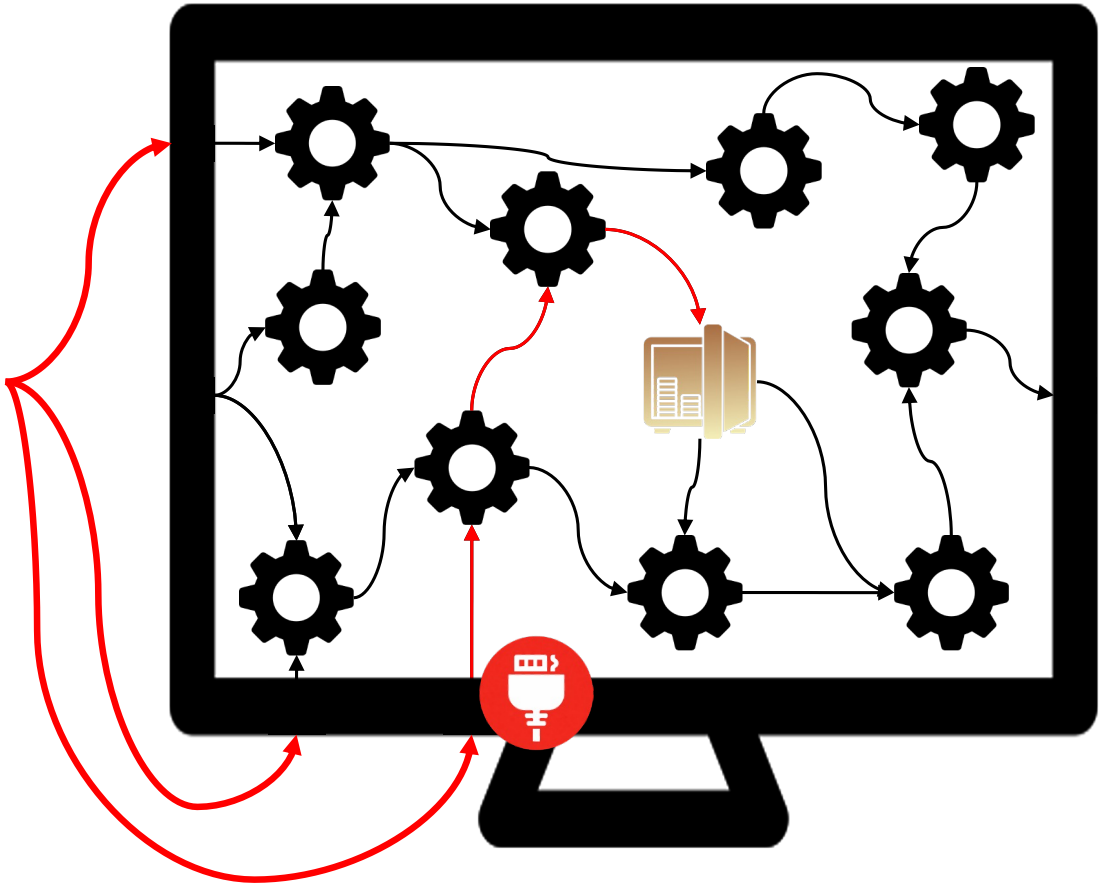


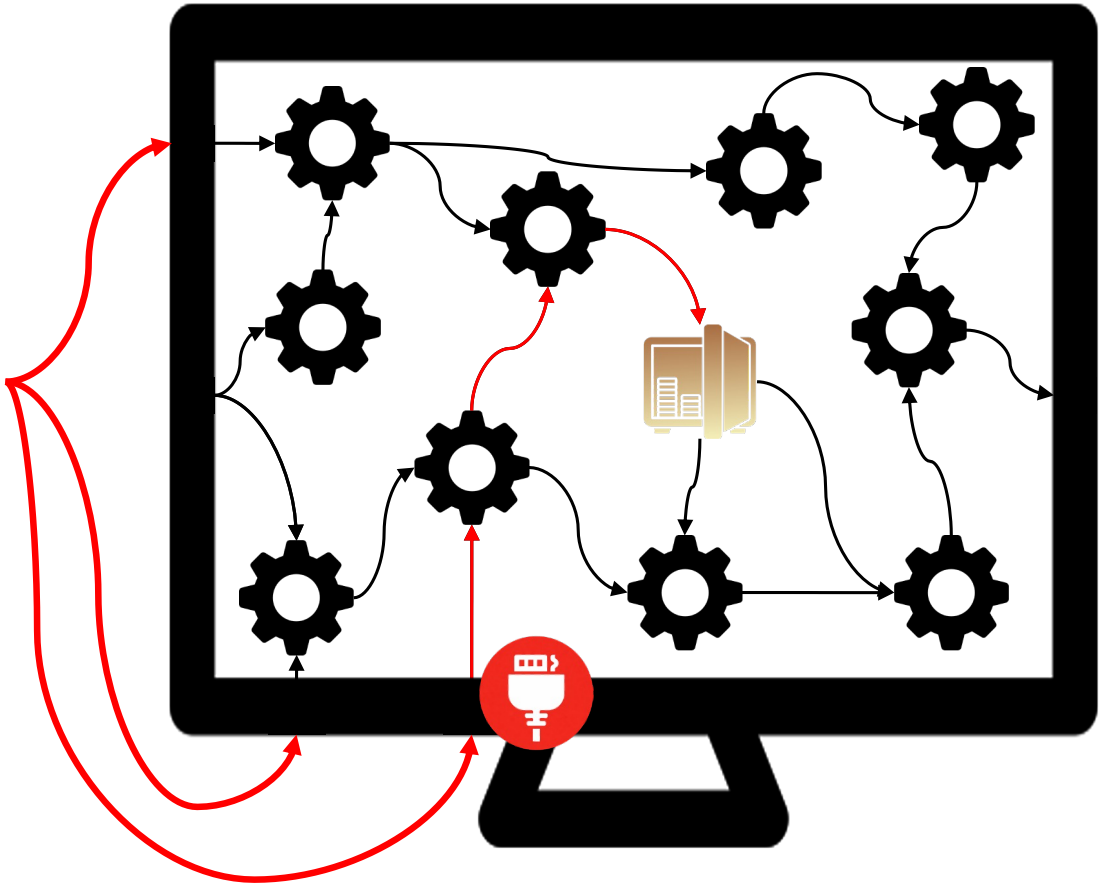
DMARacer

Time-of-Check to Time-of-Use

Multiple DMA loads generate attacker data.

Denial of Service

Asserting an attacker condition yields a DoS attack.



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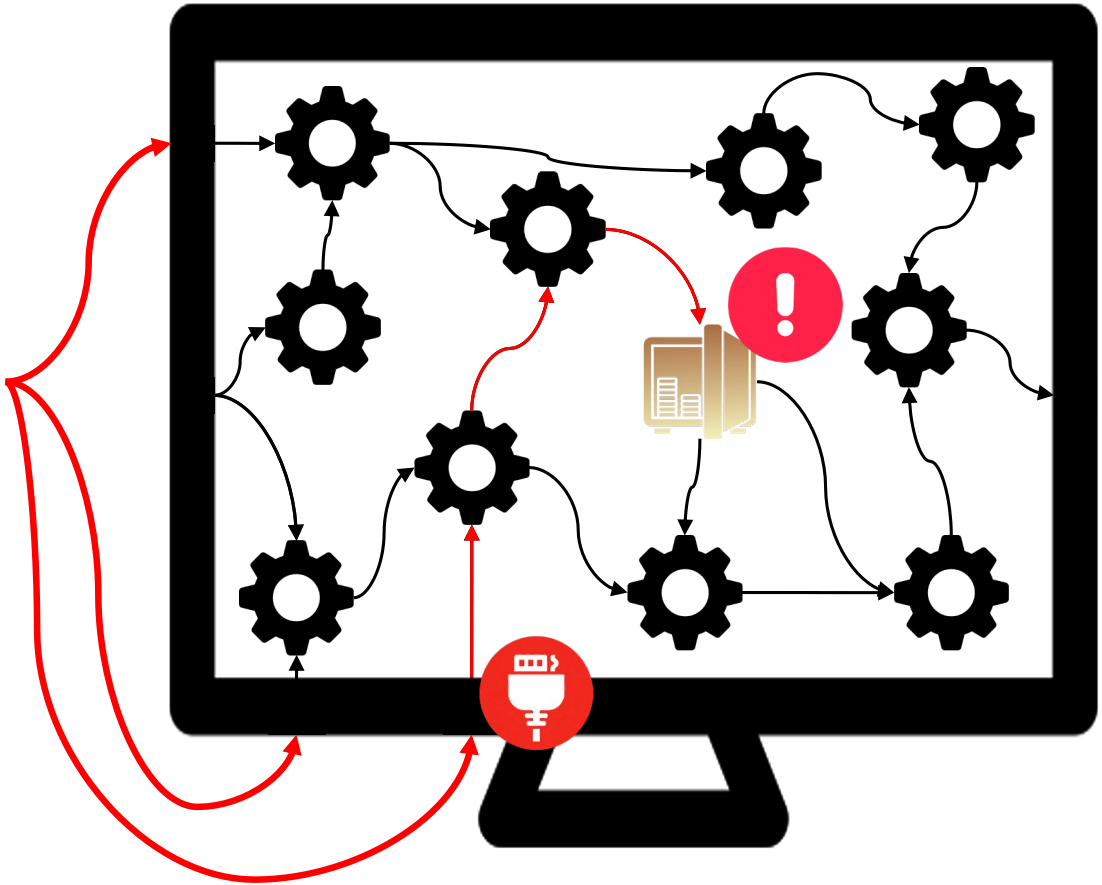

DMARacer

Time-of-Check to Time-of-Use
Multiple DMA loads generate attacker data.

Inconsiste
Unsynchronized stre
generates in

Time-of-Initialization to Time-of-Use
DMA load following a store generates attacker data.

Memory Corruption
g an attacker pointer yields
ory corruption attack.

Denial of Service
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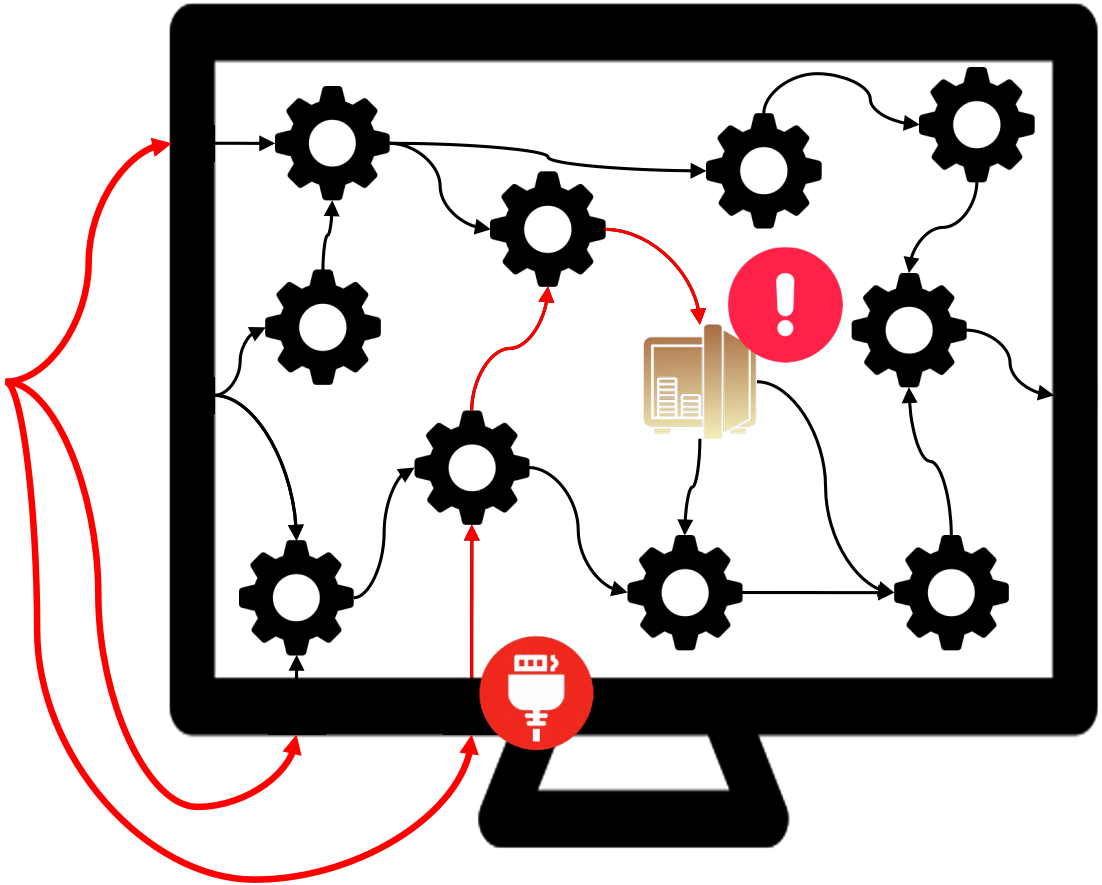

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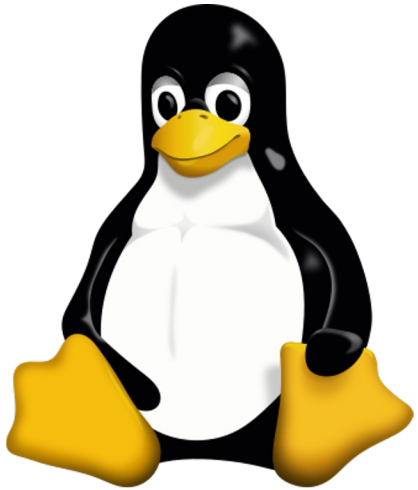

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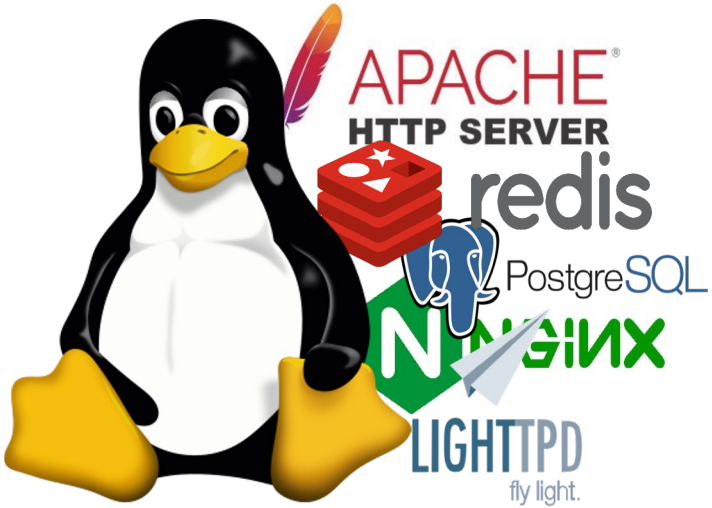

Explicit vulnerability modeling: ***Results***

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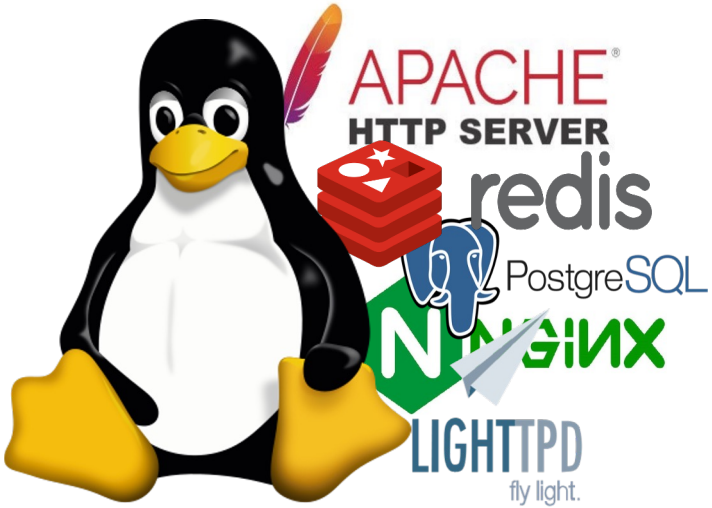

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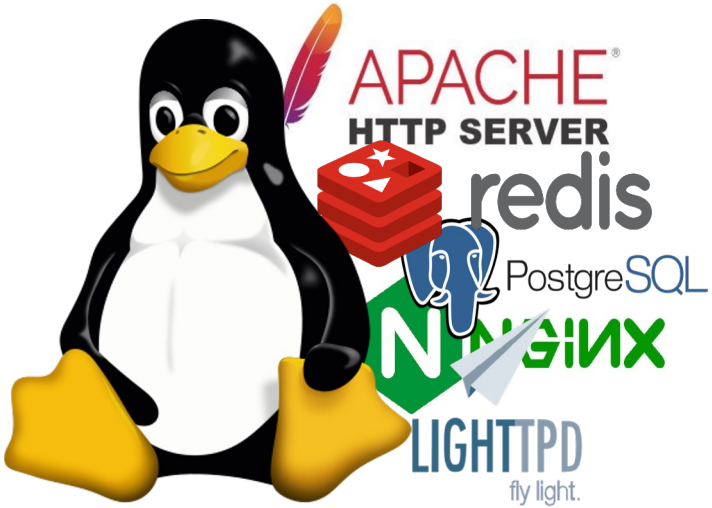

Explicit vulnerability modeling: ***Results***

- *Found vulnerabilities*
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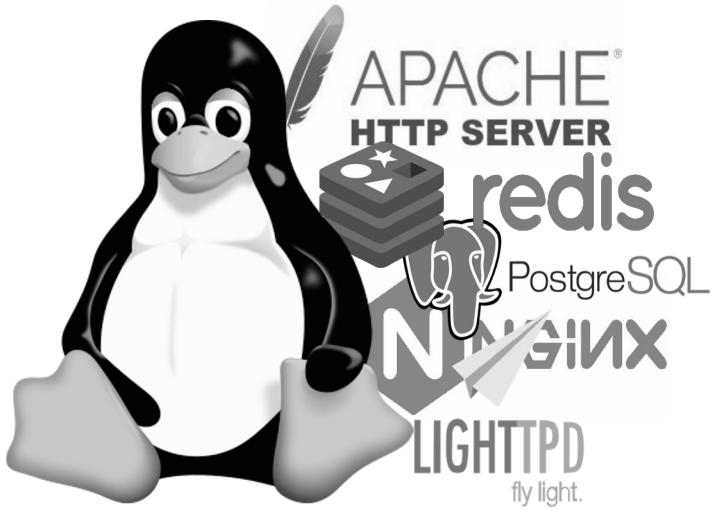
- ***Applied fixes***



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