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Simulating cold boot attacks in the gem5 simulator

Loïc FRANCE

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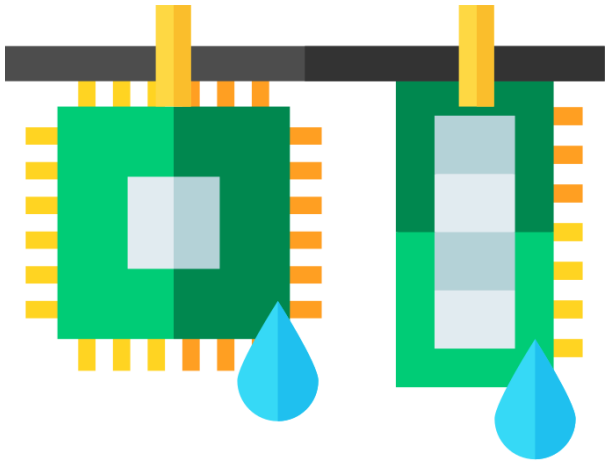
The ARCHISEC project



ARCHI-SEC

micro-ARCHItectural SECurity

<u>Goal:</u>

Simulate microarchitecture to find weaknesses and develop appropriate protections.

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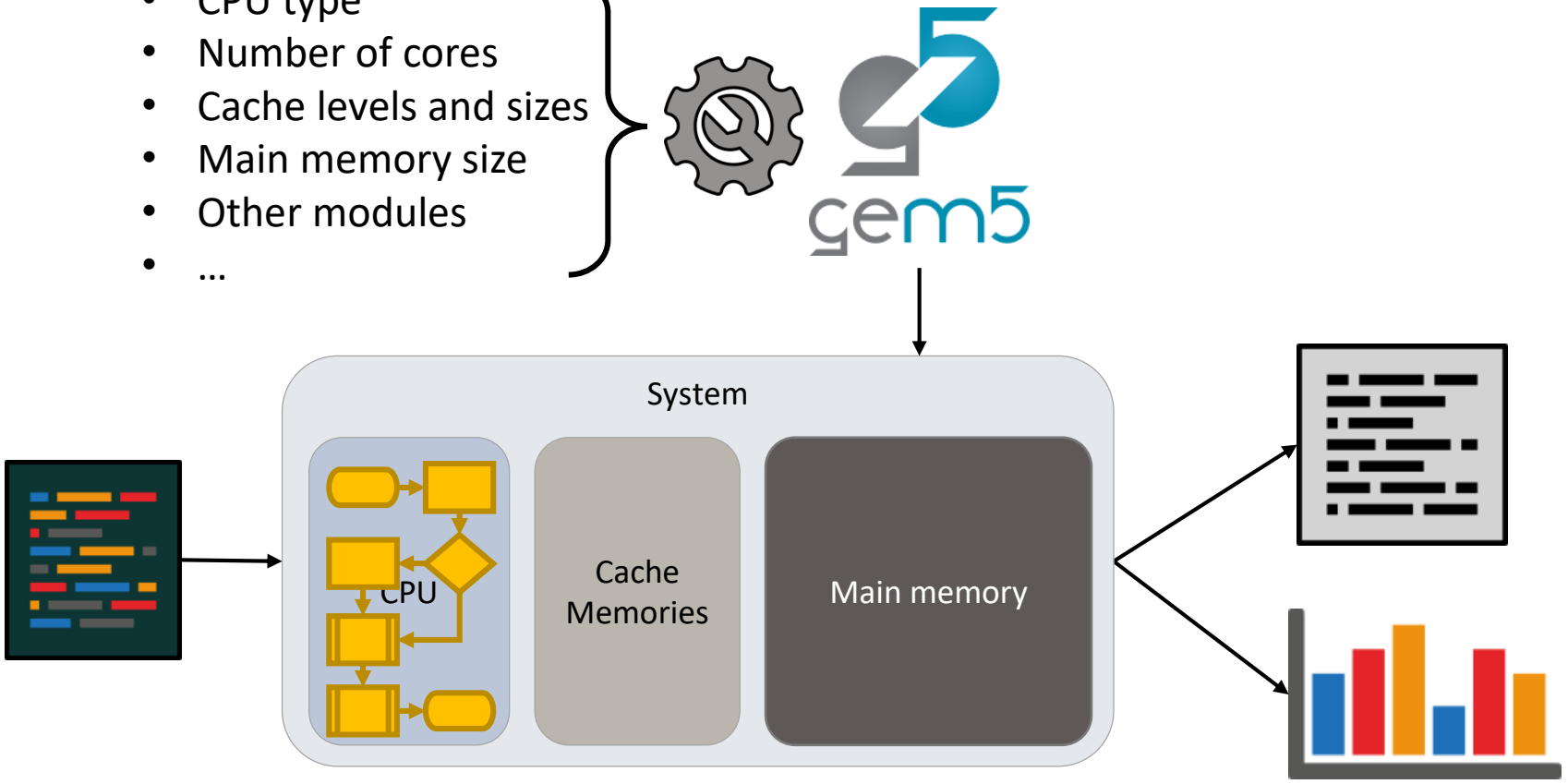
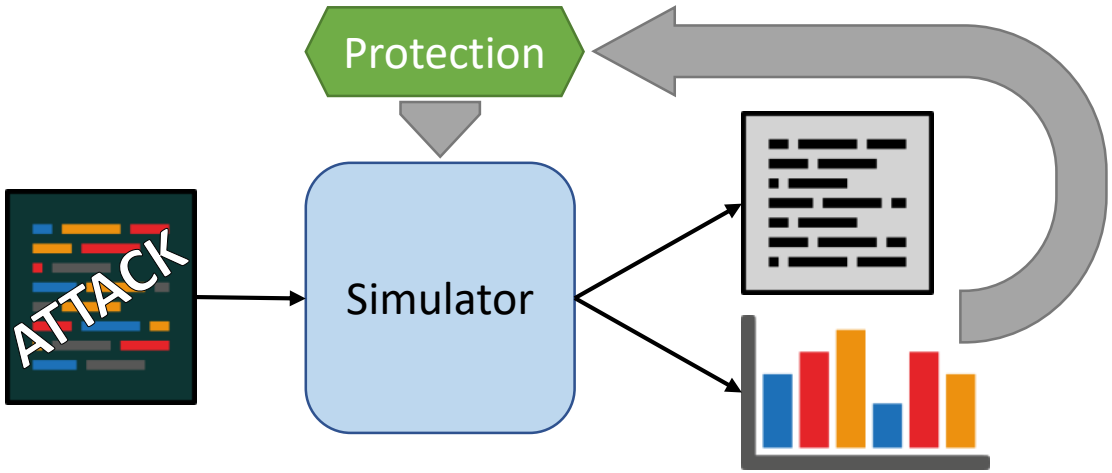
gem5: Architecture simulator

- CPU type
- Number of cores
- Cache levels and sizes
- Main memory size
- Other modules
- …

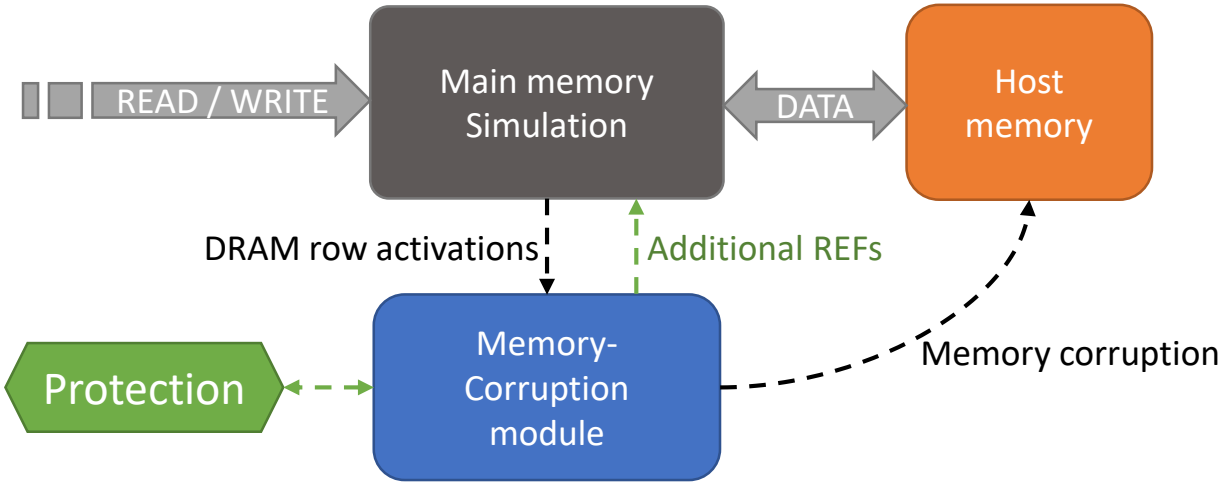


Use simulators to create protections

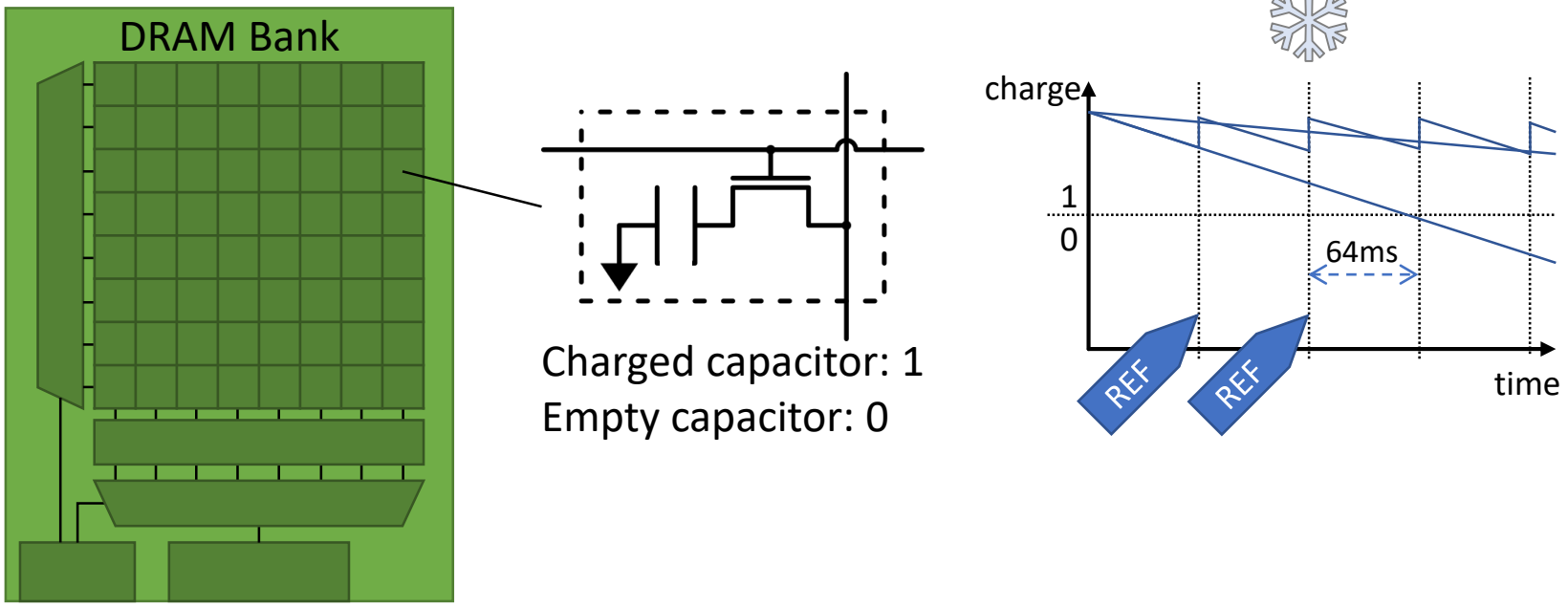


Previous work: Rowhammer

Integration of memory corruption from **Rowhammer** attacks (corruption of the memory induced by memory accesses)



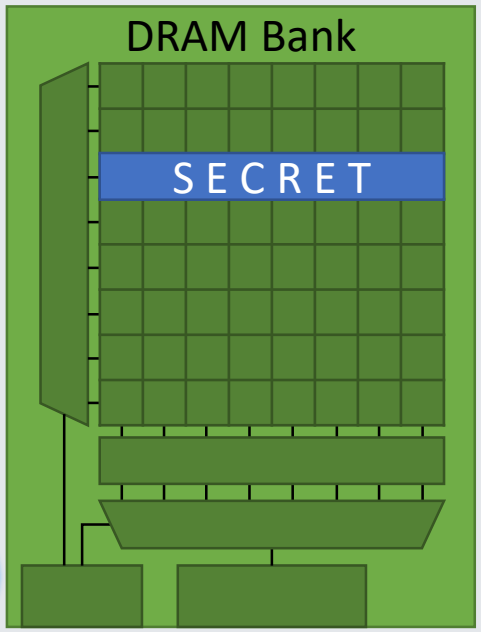
DRAM data persistance



Cold-Boot attack

Principle: recover persistent information from the memory after turning off the victim system

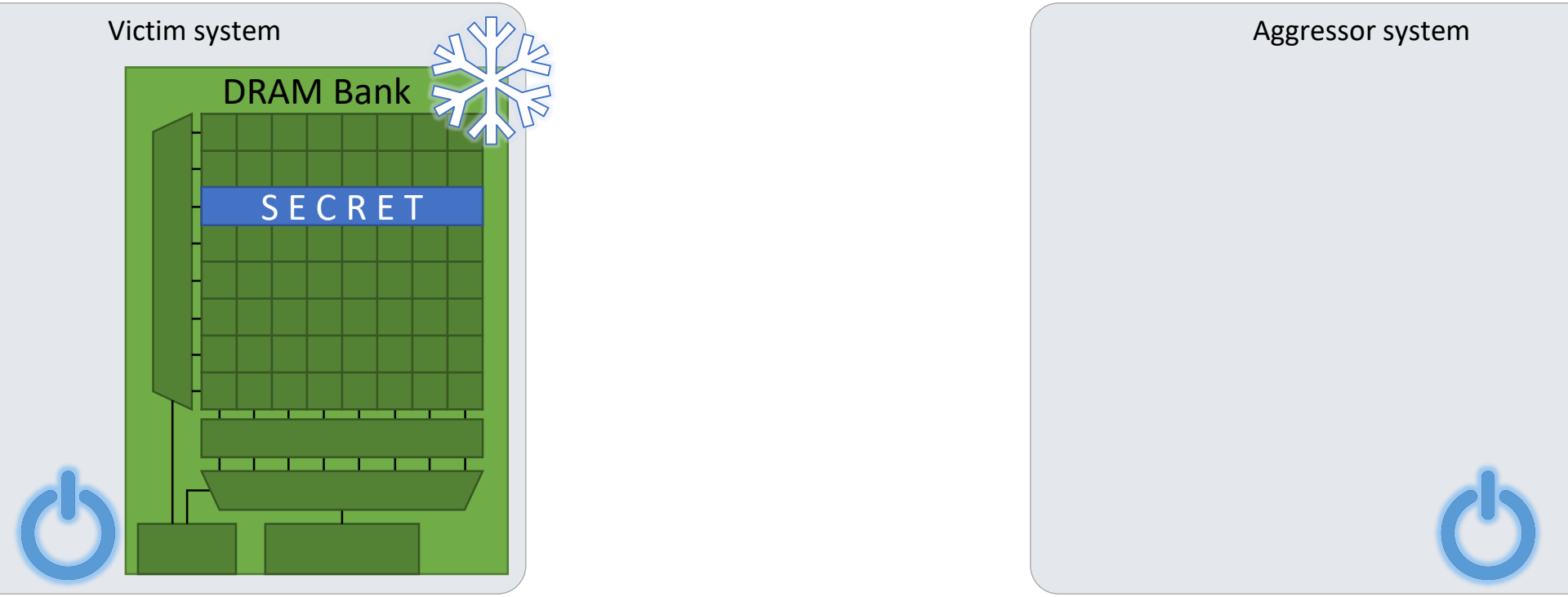
Victim system



Aggressor system

Cold-Boot attack

Principle: recover persistent information from the memory after turning off the victim system



Cold-Boot protections

- Detect temperature changes and wipe memory

P. McGregor et al., "Braving the cold: New methods for preventing cold boot attacks on encryption keys," Black Hat Security Conference, 2008

→ Not always possible

- Store sensitive data outside RAM → Usually only for encryption keys

T. Müller et al., "TRESOR Runs Encryption Securely Outside RAM," USENIX Security 2011.

- Gluing the memory on the motherboard → Can boot aggressor OS on victim device

J. A. Halderman et al., "Lest we remember: cold-boot attacks on encryption keys," ACM SS 2008

- Full-memory encryption → Performance loss

J. Götzfried et al., "RamCrypt: Kernel-based Address Space Encryption for User-mode Processes," ASIA CCS 2016

- Memory Scrambling

S.F. Yitbarek et al., "Cold Boot Attacks are Still Hot: Security Analysis of Memory Scramblers in Modern Processors," HPCA 2017

→ Only slows down attacks

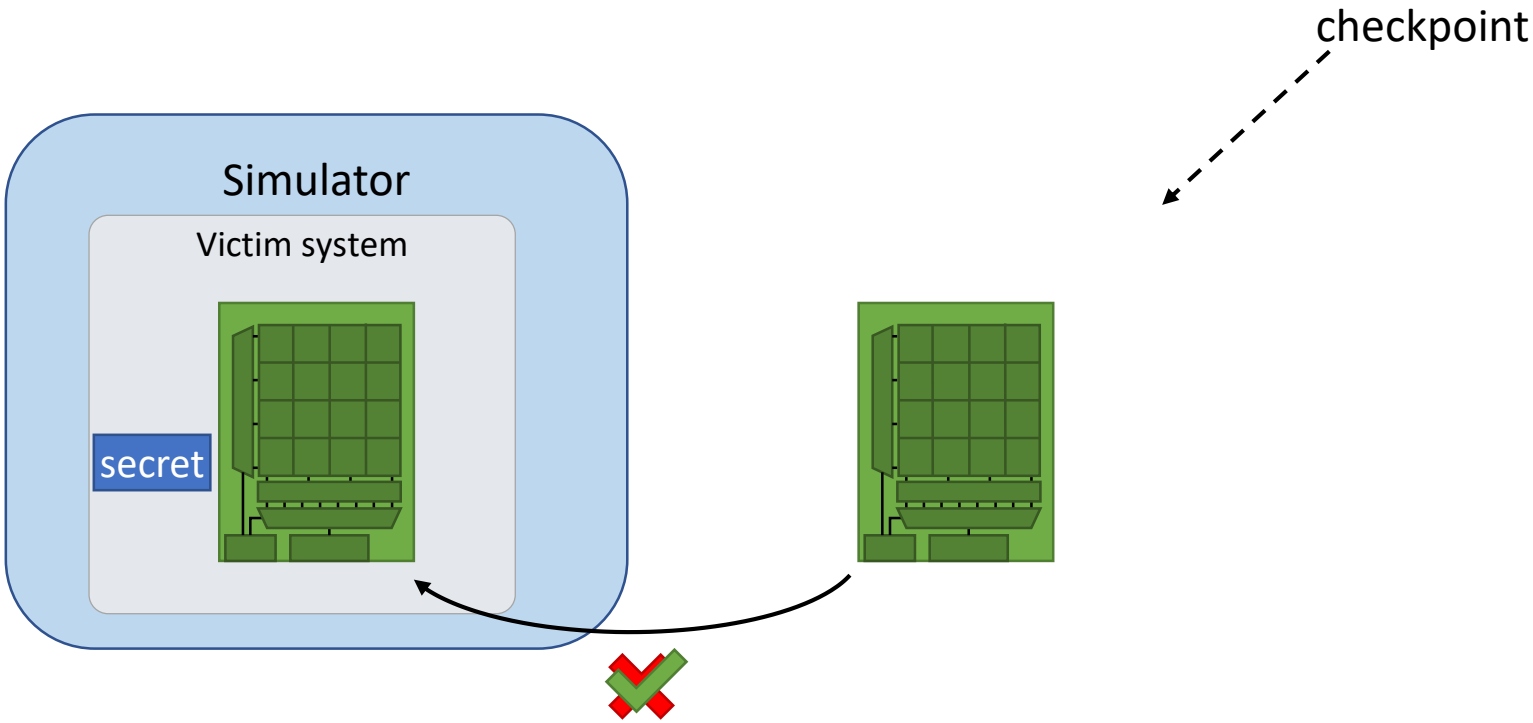
Cold-Boot attacks on NV RAM

Non-volatile → does not need cooling, data persist for a very long time after shut down

$\Longrightarrow$ **make attacks easier to execute**

X. Pan et al., "NVCool: When Non-Volatile Caches Meet Cold Boot Attacks," IEEE ICCD 2018.

Cold-Boot simulation



Demo

checkpoint

RAM

```
int main() {
  char buffer[] = "secret: cryptarchi2023";
  // ...
  return 0;
}
```

```
$>gem5.opt […]
  --kernel=victim.elf
  --checkpoint-at-end
```

Aggressor system

RAM1 RAM2

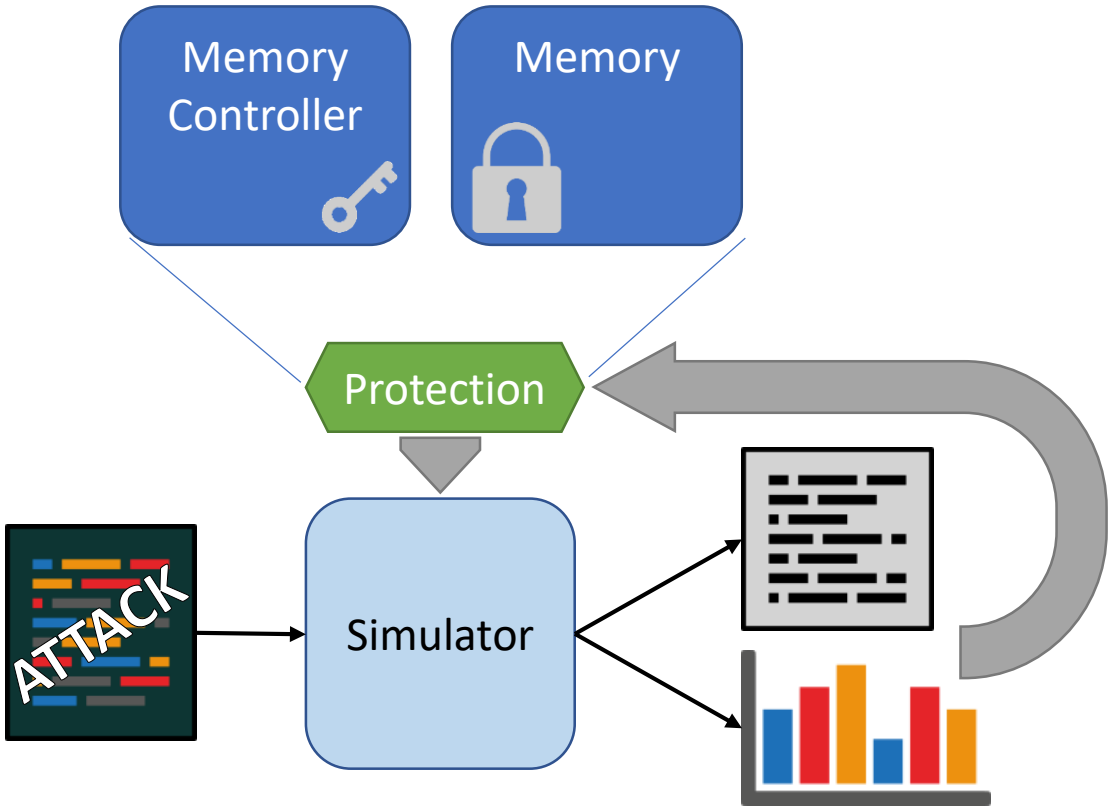
```
int main() {
  int index = find(RAM2, "secret", RAM2_SIZE);
  if (index >= 0) {
    printf("found @ 0x%x\n", index);
    dump(&(RAM2[index-64]), 128);
  }
  else {
    puts("not found\n");
  }
  return 0;
}
```

RAM2

```
$>gem5.opt […]
  --kernel=aggressor.elf
  --memory-init-storeids=8
  --memory-init-pmems=cpt/system.physmem.store7.pmem
```

```
found @ 0x000004FF
78,CD,67,E3,54,69,C4,F0,41,33,7A,1F,F2,D8,DA,41,1C,C7,5C,38,05,0B,0F,51,AD,0B,48,18,97,B9,9B,F0,    x.g.Ti..A3z....A..\8...Q..H.....
FC,A1,A1,E0,74,05,C9,3A,19,B5,39,AD,EB,49,96,08,2E,73,03,43,5A,4E,4A,06,36,5A,6A,F9,61,34,12,56,    ....t..:..9..I...s.CZNJ.6Zj.a4.V
73,65,63,72,65,74,3A,20,63,72,79,70,74,61,72,63,68,69,32,30,32,33,C3,18,8A,ED,09,8E,7B,B8,04,0C,    secret: cryptarchi2023......{...
EB,C4,76,AA,A6,24,23,C4,E4,4F,86,81,B0,0D,F2,CE,CC,92,3D,D7,62,91,10,DC,22,2A,BF,4D,9B,41,83,D8,    ..v..$#..O........=.b..."*.M.A..
```

Developing countermeasures



Thank you! Questions?

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