Tightening side channel protections with Intel SGX AEX-Notify

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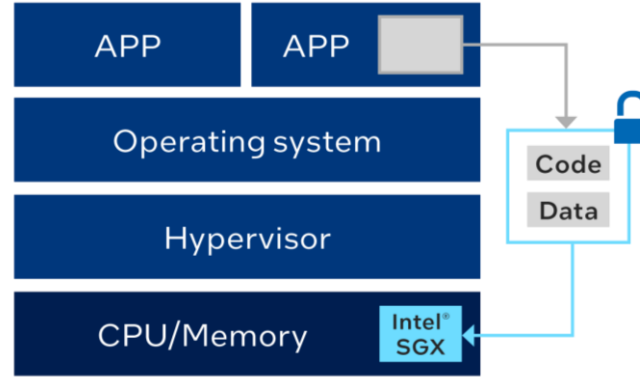
Intel® Software Guard Extensions

- Intel® SGX is the **most deployed**, **researched**, and **updated** Confidential Computing technology in data centers today
- Delivers the **smallest potential attack surface** of any TEE available for the data center



Intel SGX for the Datacenter

2018: Intel SGX **first offered for the data center** with Intel Xeon-E processors

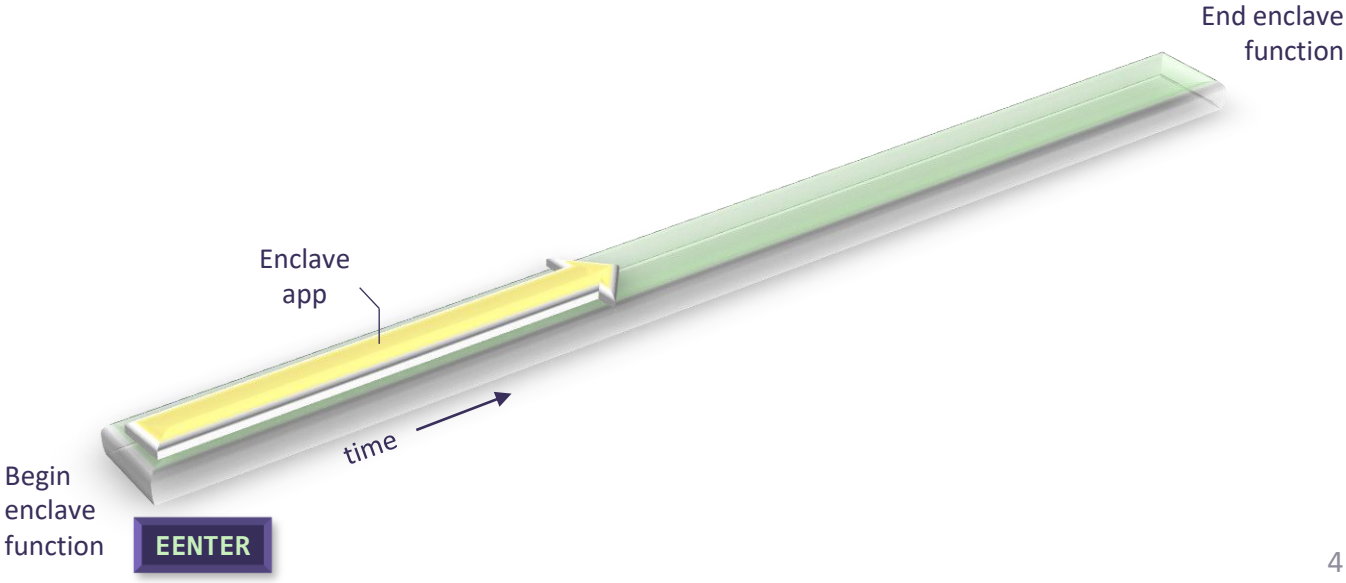
2021: Intel SGX offered on Intel 3rd Gen Xeon Scalable Processors (codenamed Ice Lake)

- Up to **1TB protected enclaves** for code and data
- Protected offload from enclaves to **HW accelerators**
- Achieved **broad software ecosystem support**

2023: Asynchronous Enclave Exit Notify (**AEX-Notify**) introduced on Intel 5th Gen Xeon Scalable Processors (codenamed Emerald Rapids)

- AEX-Notify is also **backportable to older server processors** via a microcode update

Entering and Exiting an Intel SGX Enclave



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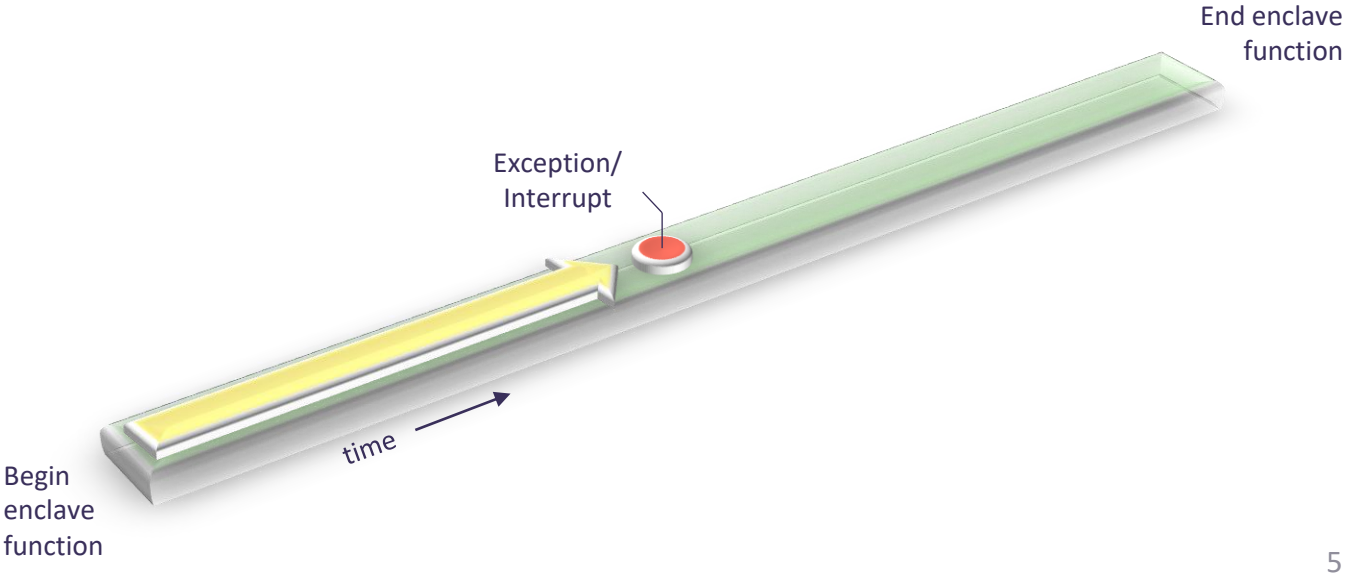

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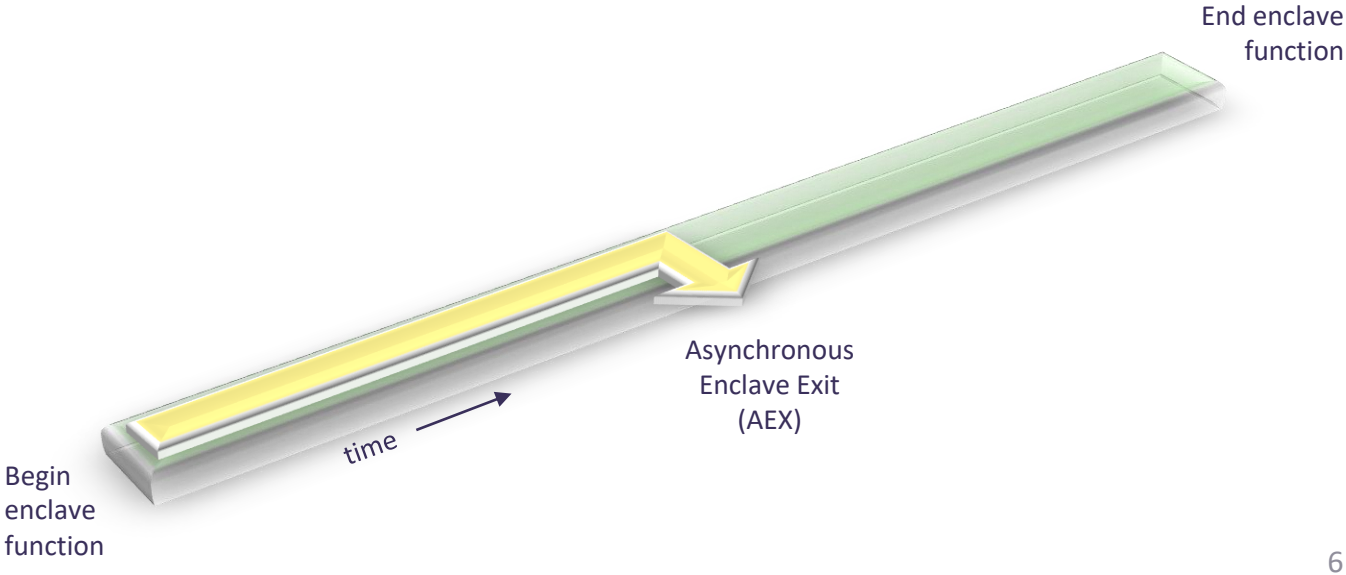

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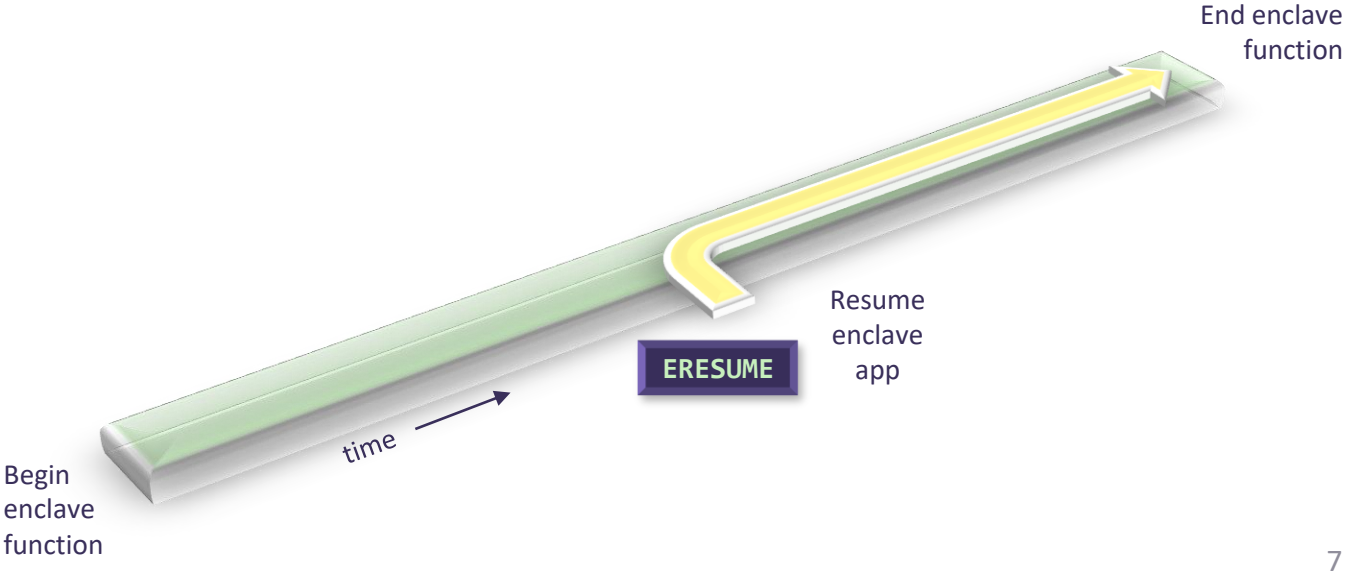

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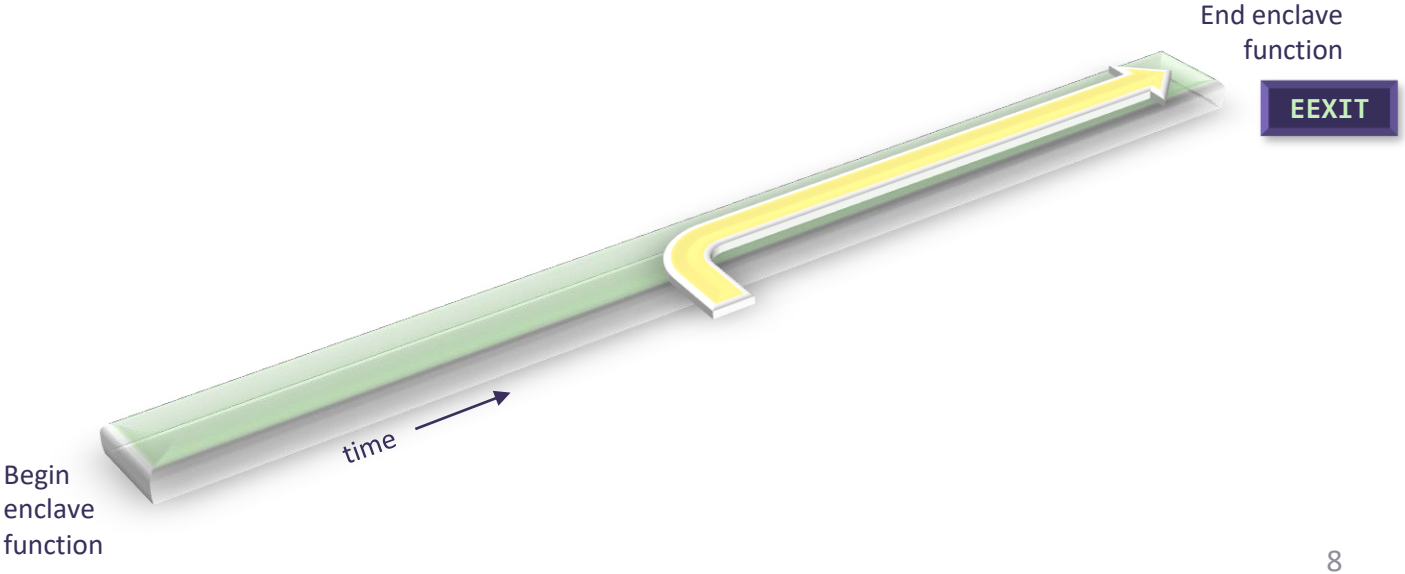
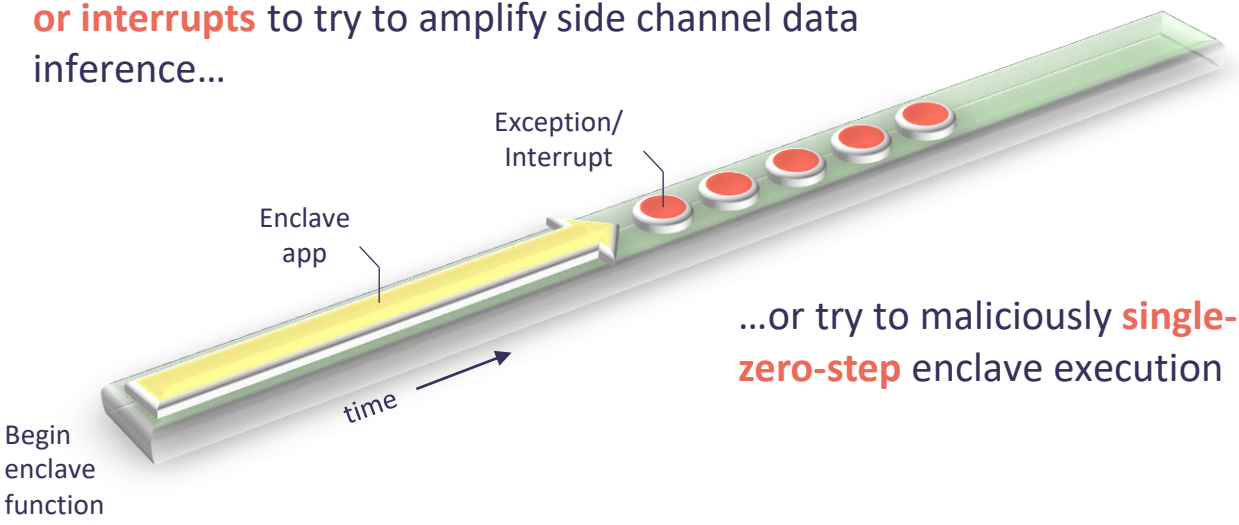


What if the OS/VMM is malicious?

What if the OS/VMM is Malicious?

The OS/VMM might induce frequent **exceptions or interrupts** to try to amplify side channel data inference…



…or try to maliciously **single-step** or **zero-step** enclave execution

How can AEX-Notify help?

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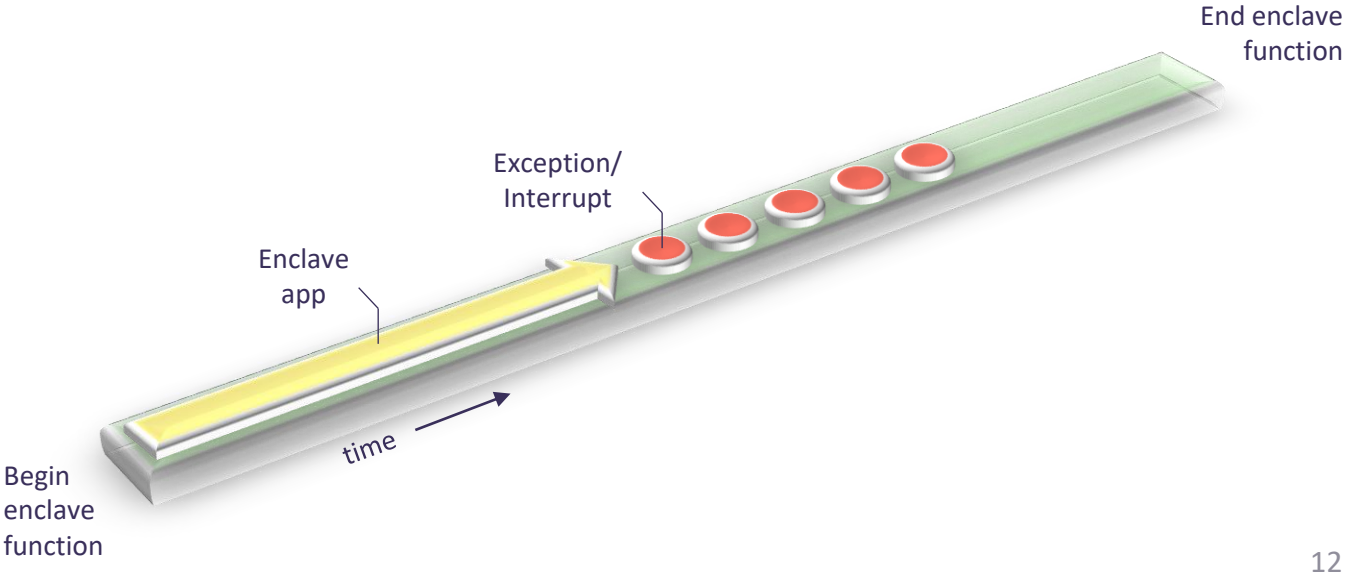

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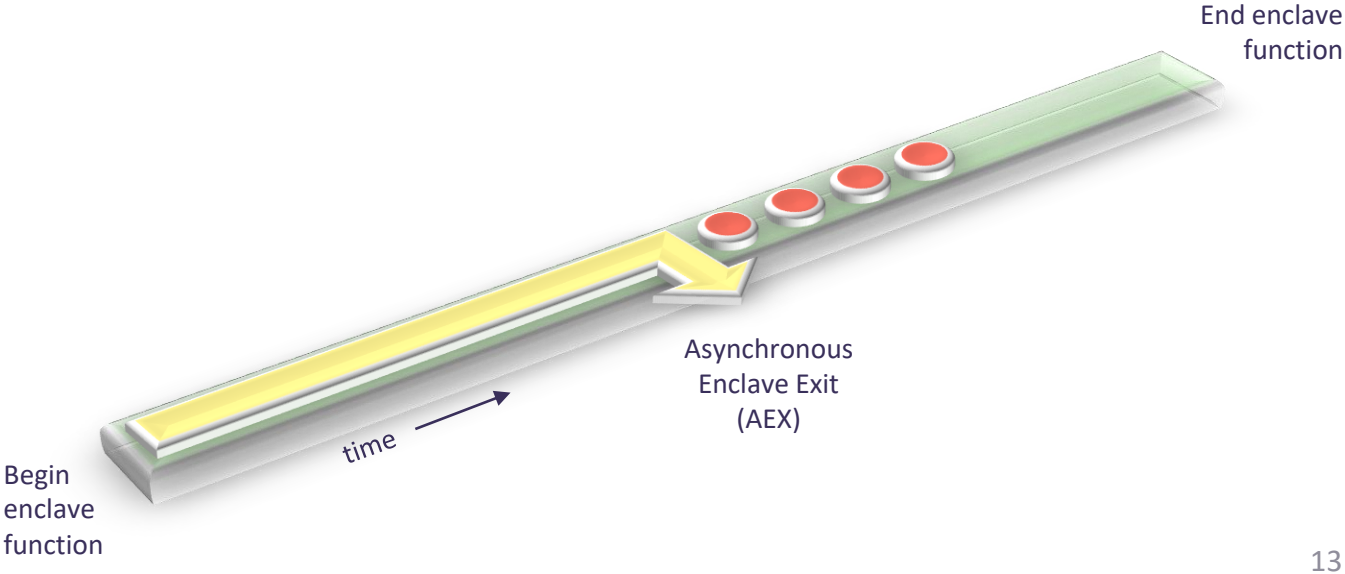
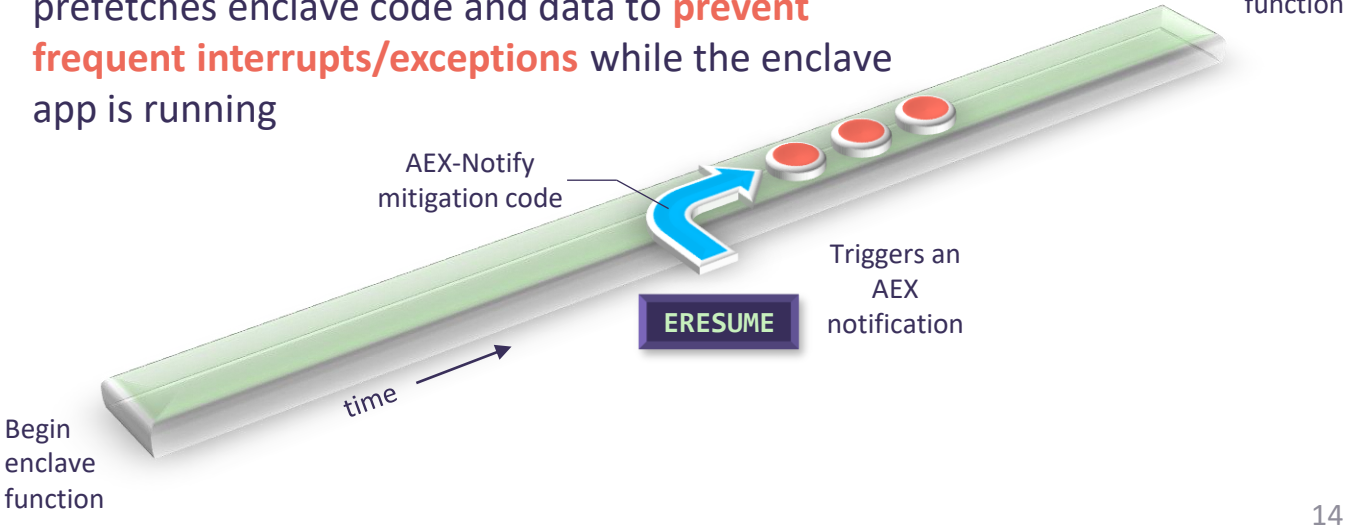


How can AEX-Notify Help?

AEX-Notify preemptively triggers exceptions and prefetches enclave code and data to **prevent frequent interrupts/exceptions** while the enclave app is running



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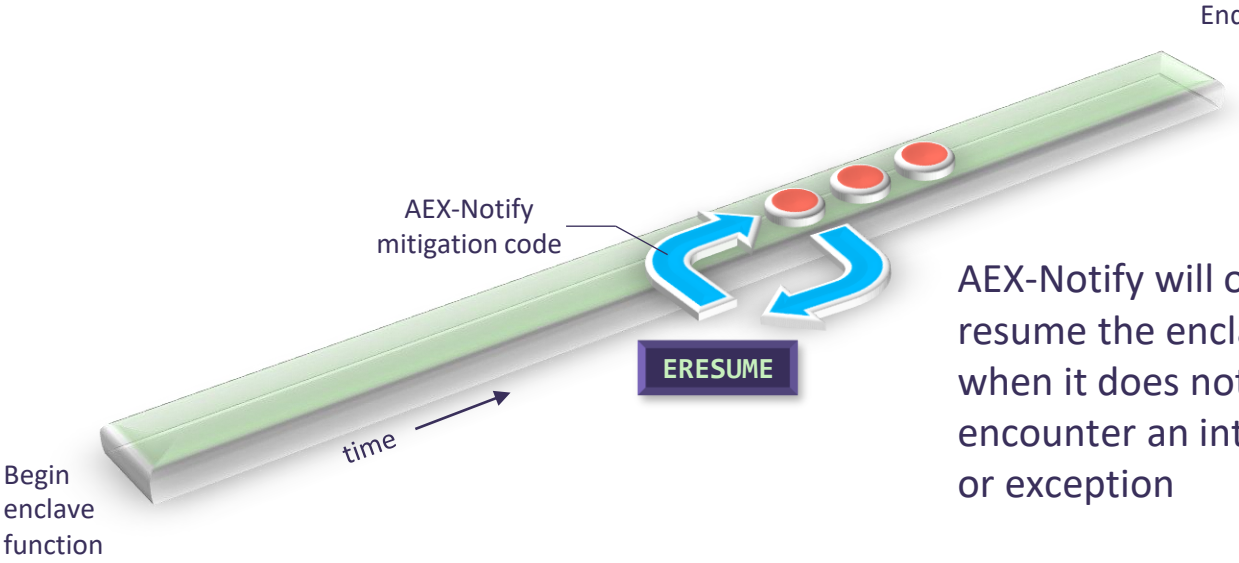
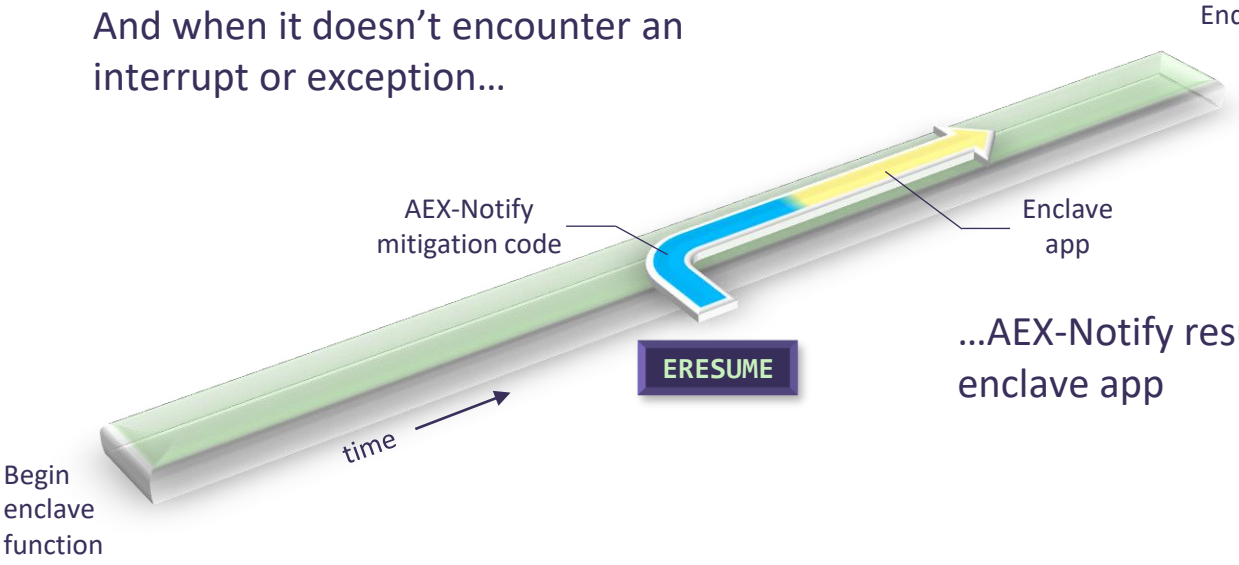


AEX-Notify will only resume the enclave app when it does not encounter an interrupt or exception

How can AEX-Notify Help?

And when it doesn't encounter an interrupt or exception…



…AEX-Notify resumes the enclave app

What products support AEX-Notify?

AEX-Notify Availability

Currently available hardware:

- 5th Gen Xeon Scalable Processors (codenamed Emerald Rapids)
- These receive AEX-Notify via microcode update:
  - 3rd and 4th Gen Xeon Scalable Processors
  - All Xeon-E processors that support Intel SGX

Software support introduced in:

- Linux kernel, version 6.2+
- Intel SGX SDK for Linux, version 2.20+
- Gramine support coming soon

Summary and Additional Information

- AEX-Notify is a new Intel SGX feature that is used by the Intel SGX SDK to mitigate malicious single-/zero-stepping
- The single-/zero-stepping mitigation is implemented in software, and can be customized for other application-specific use cases
- AEX-Notify is available on all server processors that support Intel SGX
- AEX-Notify is an attestable enclave feature
- The single-/zero-stepping mitigation does not require additional enabling in software
    - For example, this mitigation can be enabled in the enclave manifest file

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