Constant-Time Foundations for the New Spectre Era

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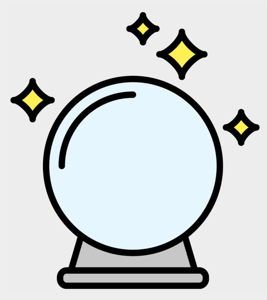
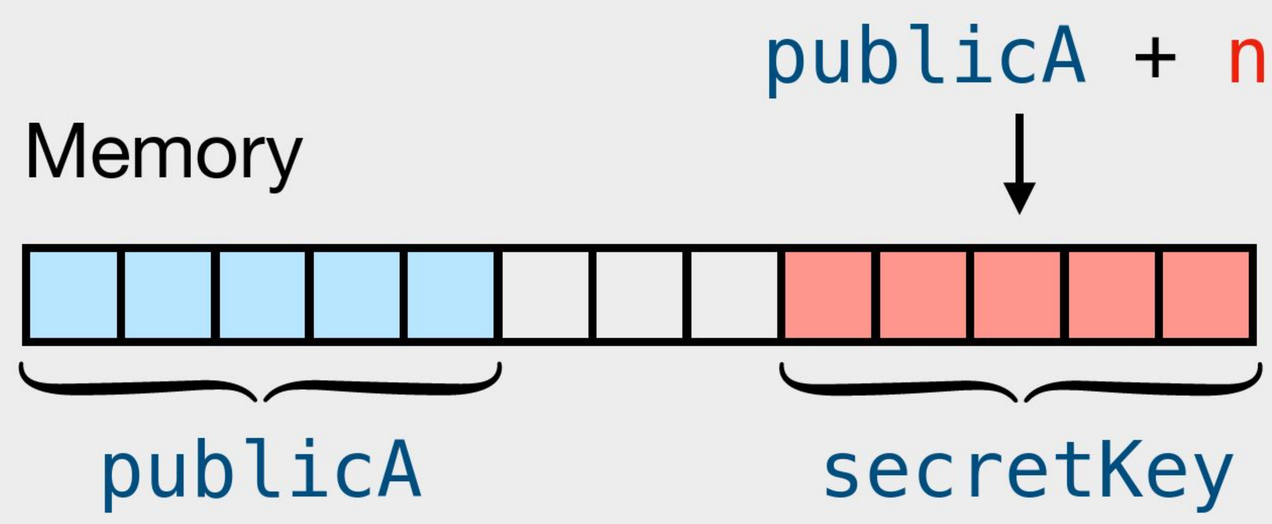


```
if (n < publicLen) {
  x = publicA[n]; // n is normally safe, but is OoB when misspeculated!
  y = publicB[x]; → Secret memory access!
}
```



Spectre attacks can **break secure code.**

The only robust way to prevent leaking secrets in cryptographic code is to use *constant-time programming*.

Unfortunately, Spectre attacks reveal that even *securely written* cryptographic code may unintentionally leak secret information as a result of *misspeculation* in the processor.

The example on the left is constant-time. But if the processor *misspeculates* into the branch, it can still leak bytes of `secretKey` via the cache!

Existing Spectre defenses are **ad hoc** and **miss attacks.**

Existing defenses are generally unsound (Microsoft's `/Qspectre` compiler flag) or far too heavy-handed (Intel's SSBD feature) — **we need defenses rooted in formal methods**. To that end, we define **Speculative Constant-Time** (SCT), the *first formal notion of security for cryptographic code*. Code that is SCT is secure even when the attacker has *complete control* over the branch predictor or other hardware features!

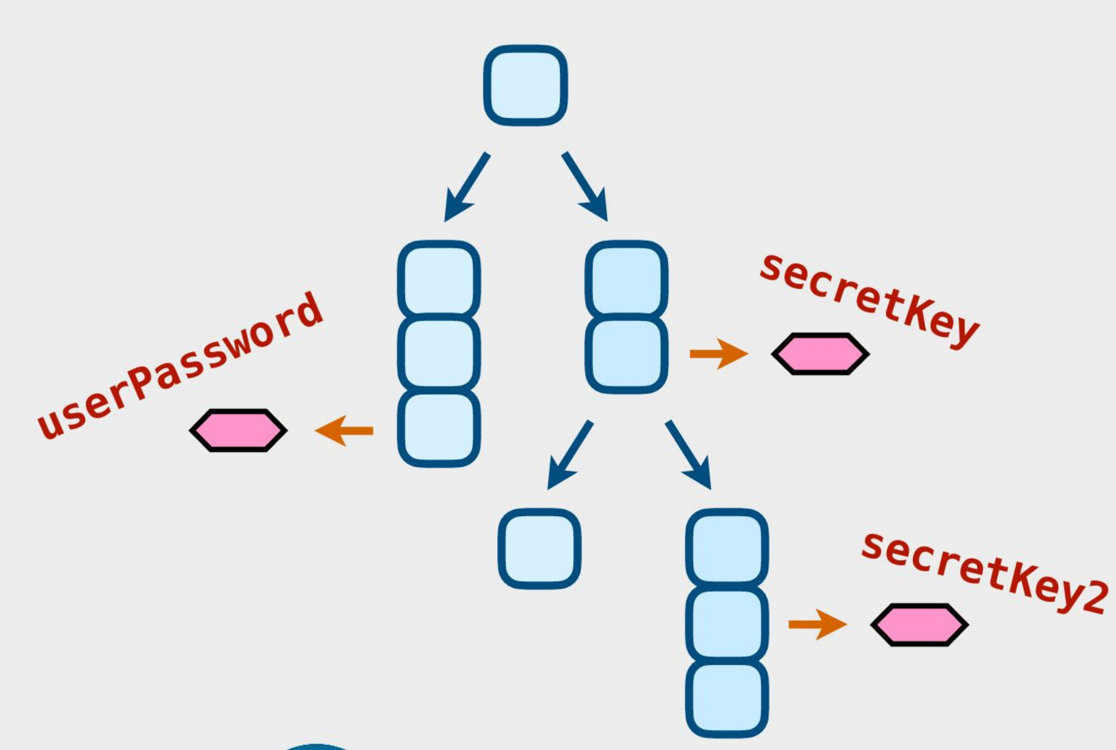
SCT is backed by our *execution semantics*, which is powerful enough to capture every known variant of Spectre, *including future ones* — we predicted and modeled the flaw in AMD's *“Predictive Store Forwarding”* feature, **which wasn't even in processors until after our paper!**

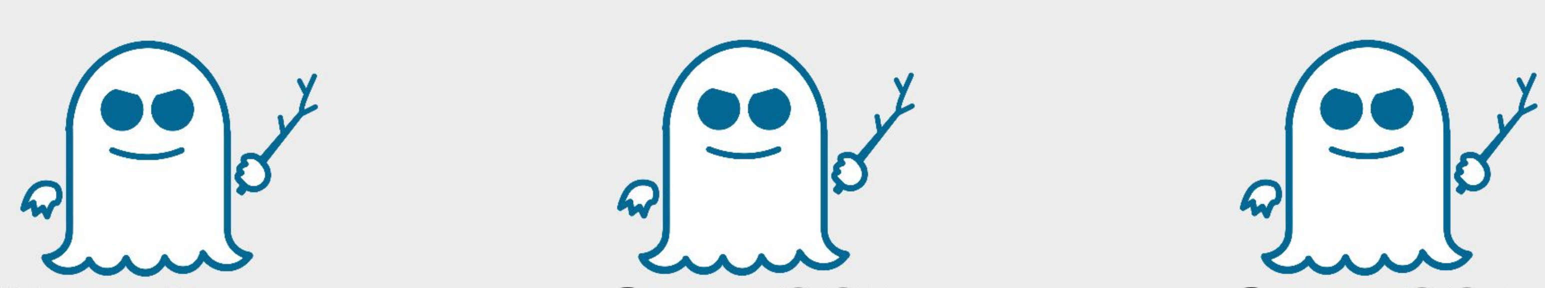
We can adapt **new hardware features** and model **future Spectre variants.**

Pitchfork reveals Spectre gadgets in **real code.**

Our semantics is also the basis for *Pitchfork*, our prototype analysis tool. Pitchfork explores every *speculative* execution path in a binary and detects whether secrets can be leaked.

We used Pitchfork to find Spectre gadgets in the libsodium and OpenSSL libraries, in code that was previously verified to be *constant-time*. In fact, we found that *compilers themselves* can insert Spectre gadgets: The vulnerable code in libsodium was part of Clang's stack-smashing defense!





libsodium secretbox

OpenSSL ssl3 validate

OpenSSL MEE-CBC

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