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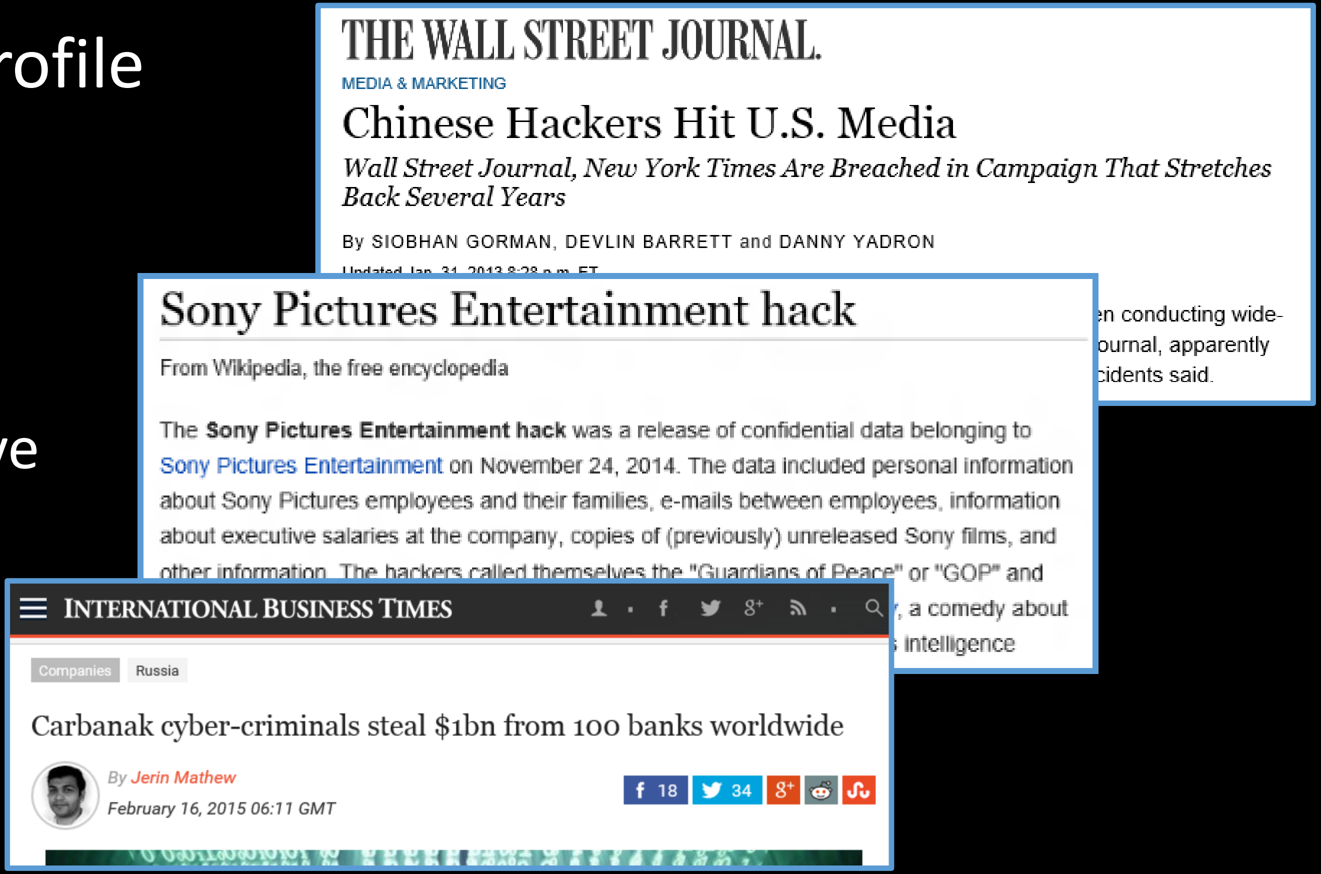
UBM
Tech

Defeating Pass-the-Hash

Separation of Powers

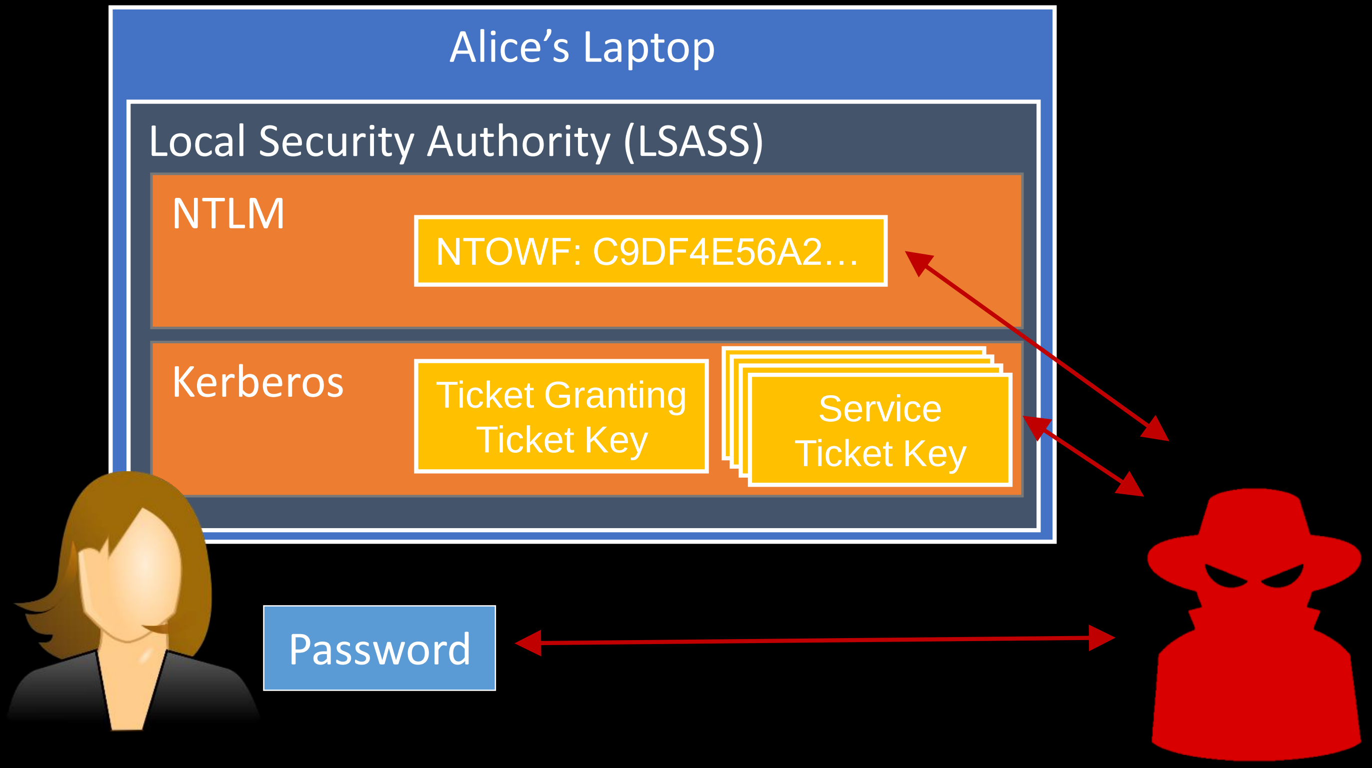
Credential Theft

- At the heart of many high-profile attacks.
- Fueled by Single Sign-On
  - A feature nobody wants to live without.



Pass-the-Hash: A Windows Primer

- LSASS on Alice's laptop hosts the authentication protocols
- Administrator-level attackers may access:
    - NTLM Hash
    - Kerberos Keys
    - Alice's password
- Attackers steal and replay these legacy protocol artifacts



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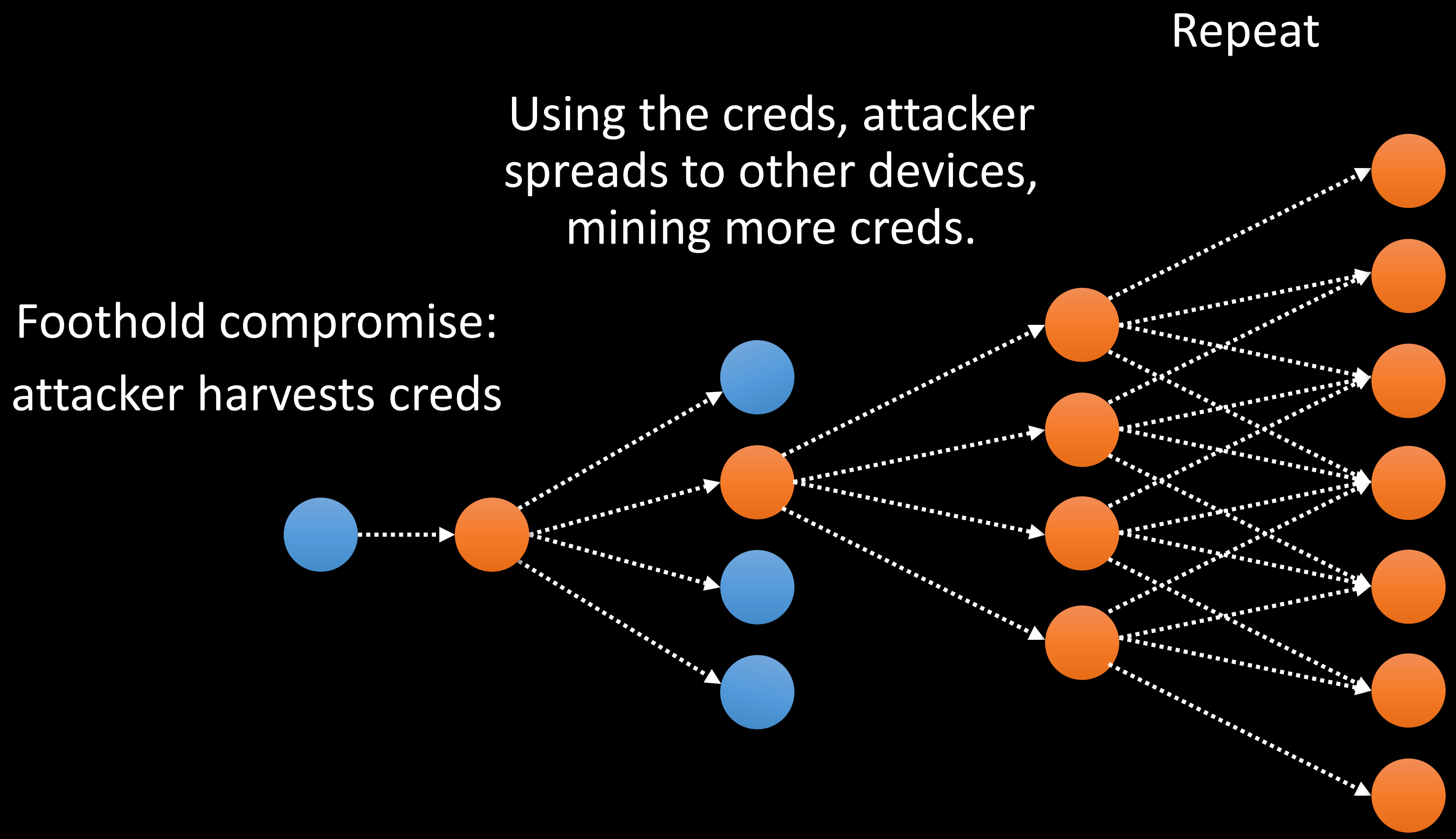
The Chain Reaction



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We Have the Technology

- Multi-Factor Authentication
  - Stealing one credential isn't enough.
- Strong Credentials
  - Smart cards, FIDO key, etc
- Token Binding
  - Make stolen tokens useless.

Businesses Like Making Money

- Legacy components keep working
  - “My printer works with NTLM.”
  - NAS, Printers, Software, etc.
  - Business depends on these

- Legacy protocols include replayable artifacts

How to keep a secret?

Separation of Powers

- Balance of powers prevents abuse
- Ensures accountability

- Legislation passes the laws.
- Executive branch carries out the tasks.
- Judicial system make sure everyone is playing by the rules.

- OS and real governments aren't that different.
- **Administrators** → The Legislative Power
- **Kernel / System Services / Drivers** → Executive Power
- **Trusted Computing Base (TCB)** → Judicial Power
(makes sure everyone obeys the constitution)

Admin == Kernel == TCB: Risky business

- ***Admins are human, humans err***
  - Data shows: > 90% (!!) of Windows users run as some sort of administrator
  - Total loss of system when a malicious attachment is run
- What if the ***administrator is malicious***?
  - Admins should not have total control on the machine
  - E.g. games, multi-tenant scenarios
- We can't simply trust the kernel, either.
  - Attack surface too big: Thousands of system calls, IOCTLs
  - Diverse ecosystem: Many 3rd party drivers with different quality assurance standards

This is not a new problem…

- Authenticode / Kernel Mode Code Signing
  - Principle: Putting reputation of an authenticated identity on the line
  - Cost + traceability negatively impacts exploit economics
  - Problem: Strong verification of publishers by CAs is questionable at best and recalls are hard and slow.
- Protected Process – PP / Protected Process Light – PPL
  - Principle: Isolate sensitive processes from others by preventing injection of threads, memory access, etc.
  - Problem: Not enough, still vulnerable to kernel mode, which is not TCB.
- Patch-guard
  - Principle: Limit what code in kernel mode can do
  - Problem: Heuristic based, not failsafe
- **They are all software based…**
- **Can the security be rooted on something.. harder?**

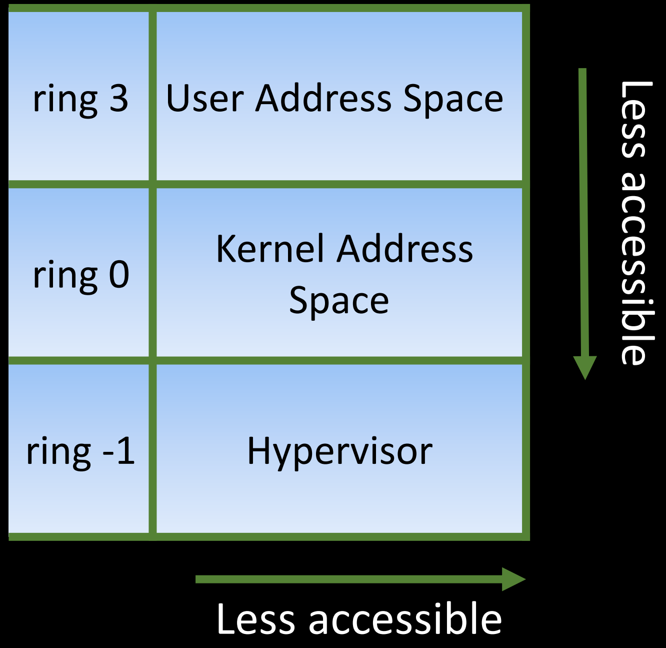
Layers of protection via Hardware

- X86/X64 systems have had a single physical address space in kernel
  - Ring 0 could access any physical memory address.
  - Ring 0 → God Mode
- "Hypervisor" provided another abstraction layer
  - AKA Ring (-1)
  - Roots its promises on HW
    - Just like rings…
    - But hypervisor is small.. very small. Easier to verify, easier to secure.
  - Hypervisor is the true TCB
- We need hypervisor kind of isolation without cluttering hypervisor.

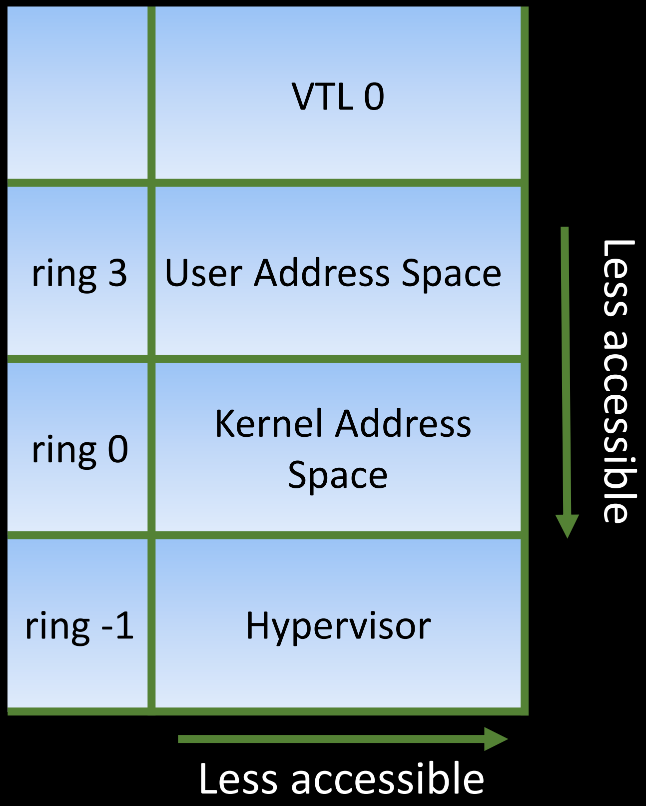
Introducing Virtual Trust Levels - VTL

- Using virtualization technologies and Second Level Address Translation (SLAT), sections of memory can be access-protected in a cascading fashion
- Guest virtual → Guest physical → System physical

Introducing
Virtual Trust Levels - VTL

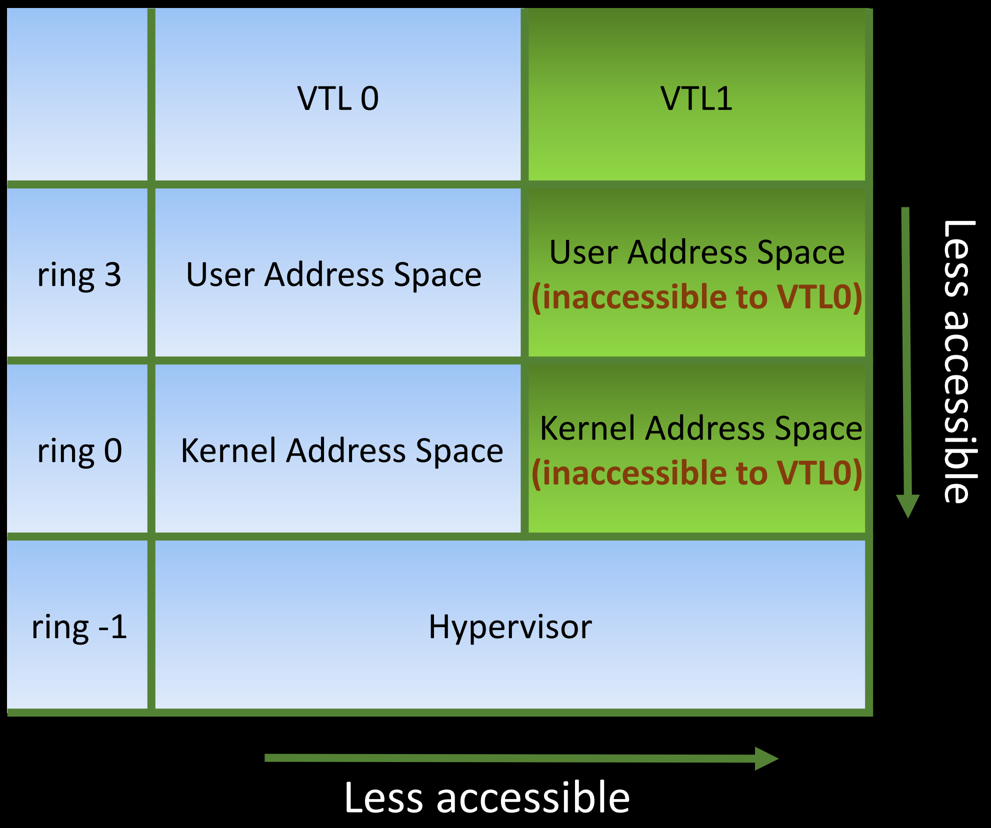


Introducing
Virtual Trust Levels - VTL



VTLs bring a new **dimension** with new properties

Introducing
Virtual Trust Levels - VTL



- Regular Windows, “Normal world”, runs in VTL0
- “Secure world”, new in Windows 10 is **selectively inaccessible** to normal world, even normal NTOS.
    - Code can be safely shared / reused
    - Data can be shared so that VTL0 / 1 can pass data back and forth as needed

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Introducing
Virtual Trust Levels - VTL

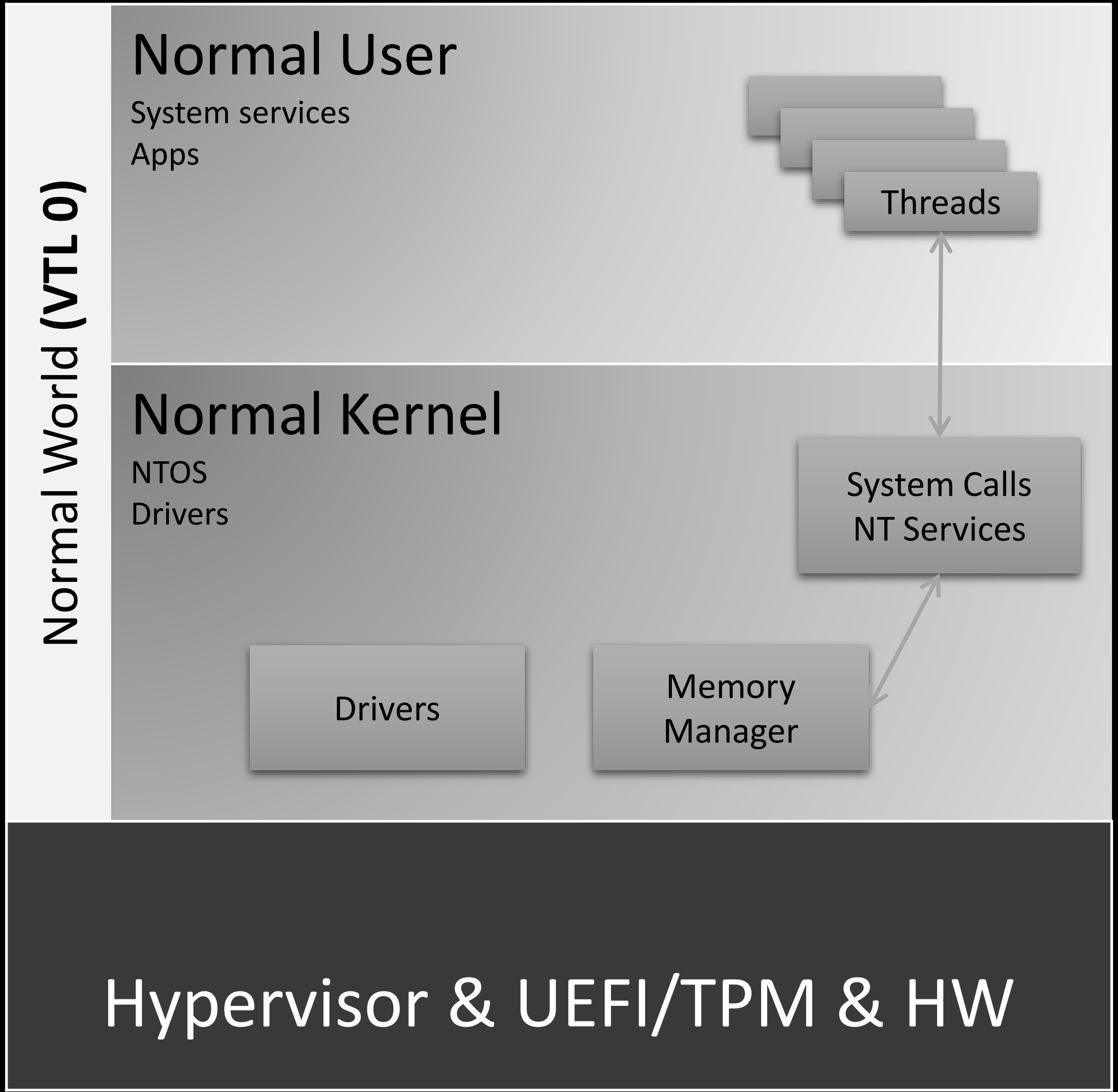
	VTL 0	VTL1	VTL (N)
ring 3	User Address Space	User Address Space **(inaccessible to VTL0)**	**TBD**
ring 0	Kernel Address Space	Kernel Address Space **(inaccessible to VTL0)**	**TBD**
ring -1	Hypervisor		

Less accessible

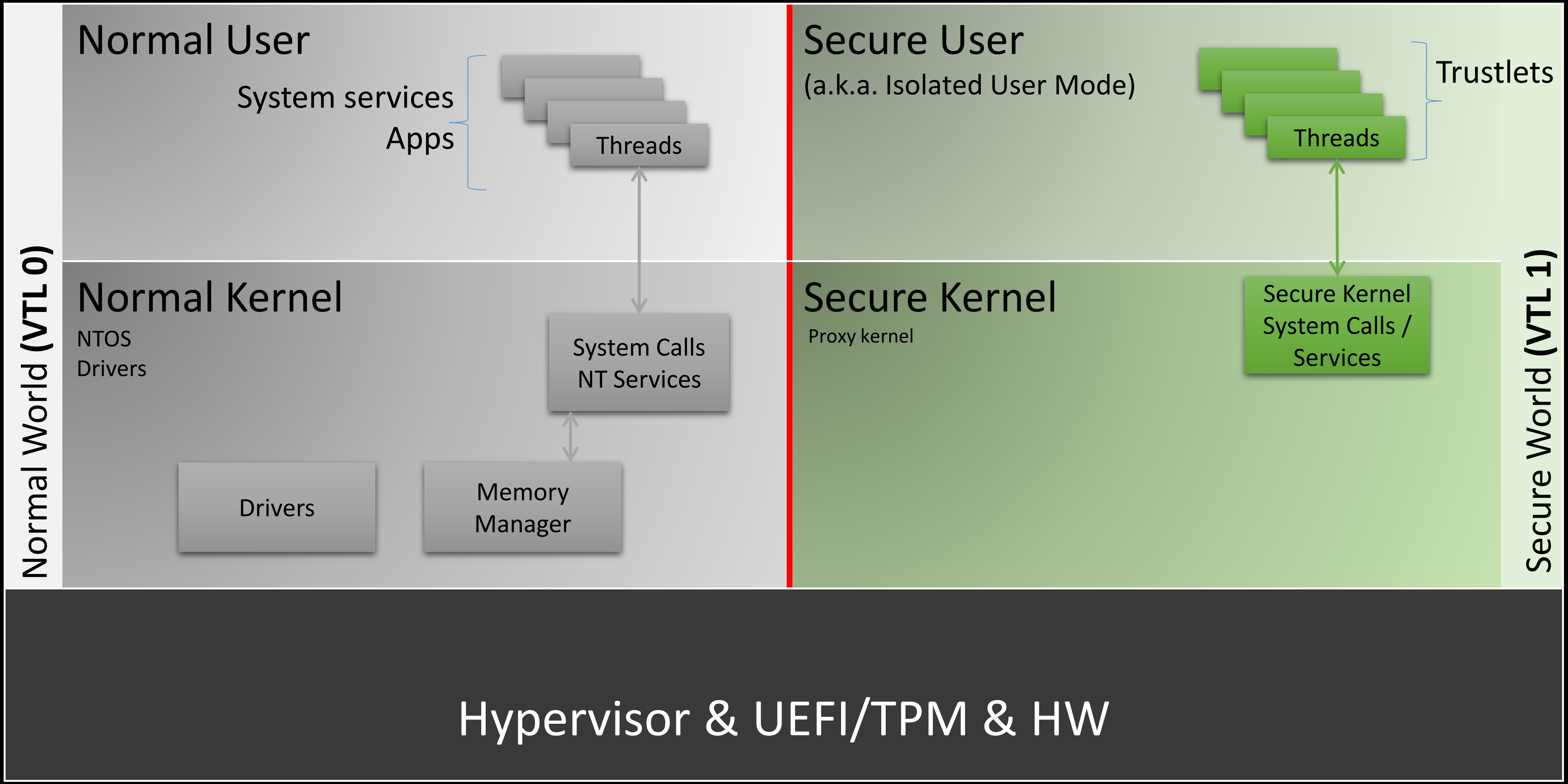
Less accessible

- Unlike rings, VTLs are extensible

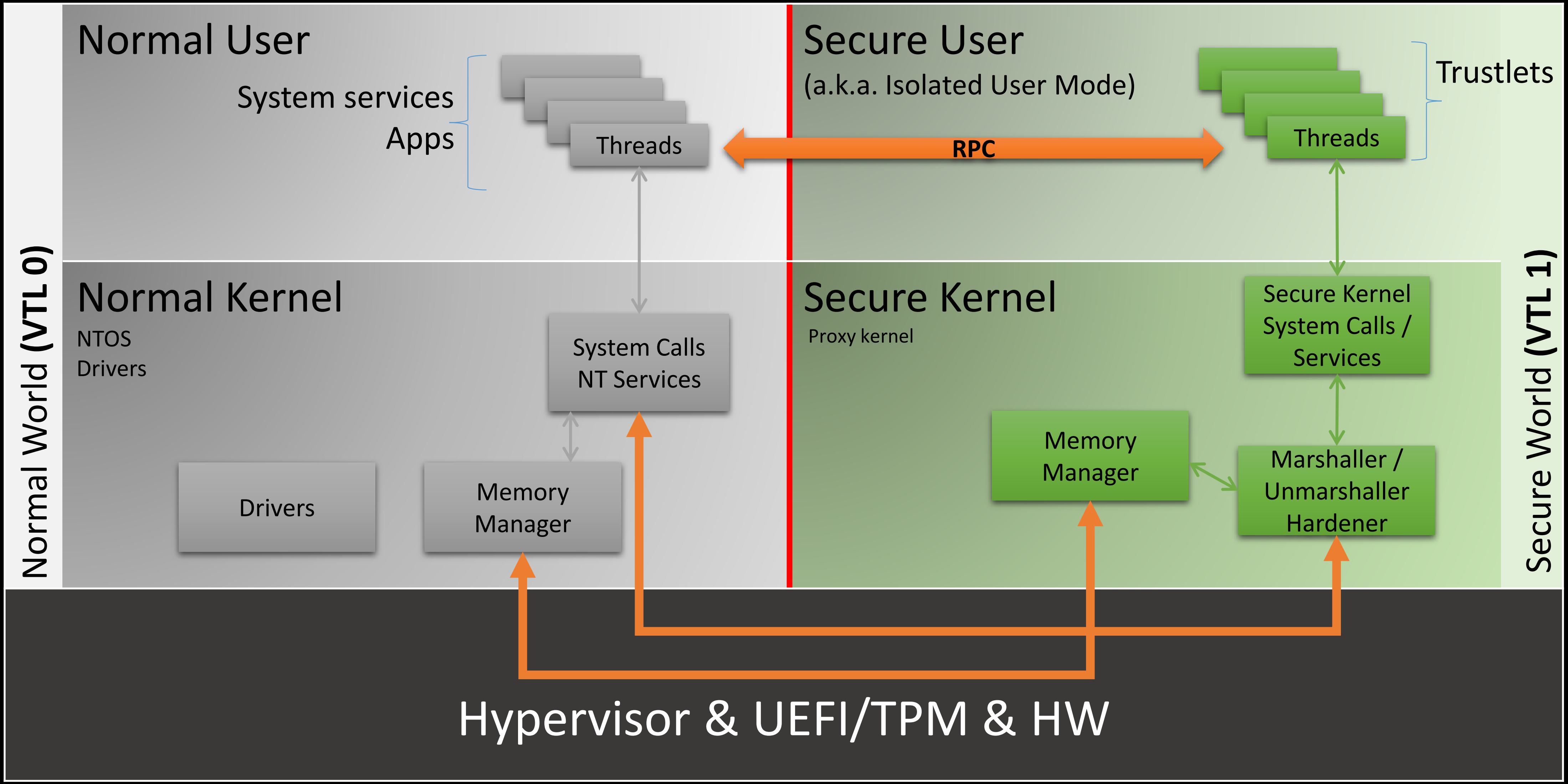
Normal World – Pretty much as always



Introducing Secure World



Introducing Secure World



Secure World

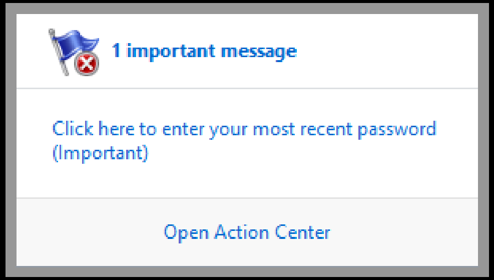
- Invisible
  - No user interaction / UI
  - Minimal impact on perf (< 5%)
- Tighter control
  - No 3rd party code in the secure kernel
  - Trustlets are isolated from each other
  - Trustlets are limited in number, purpose built - much smaller, easier to protect
- World is small.. Secure world is smaller.
  - If no secure mode, a trustlet can run as a normal mode process
  - Secure world relies on enlightened normal world / NTOS for many things *(scheduling, most of memory management, synchronization etc.)*
  - Secure kernel only does the bare minimum *(configuring SLAT as applicable, encrypting pages before paging out, etc.)*
  - *VTL0 is not trusted → Secure kernel hardens its NTOS interfaces*

Using VSM to Mitigate PtH

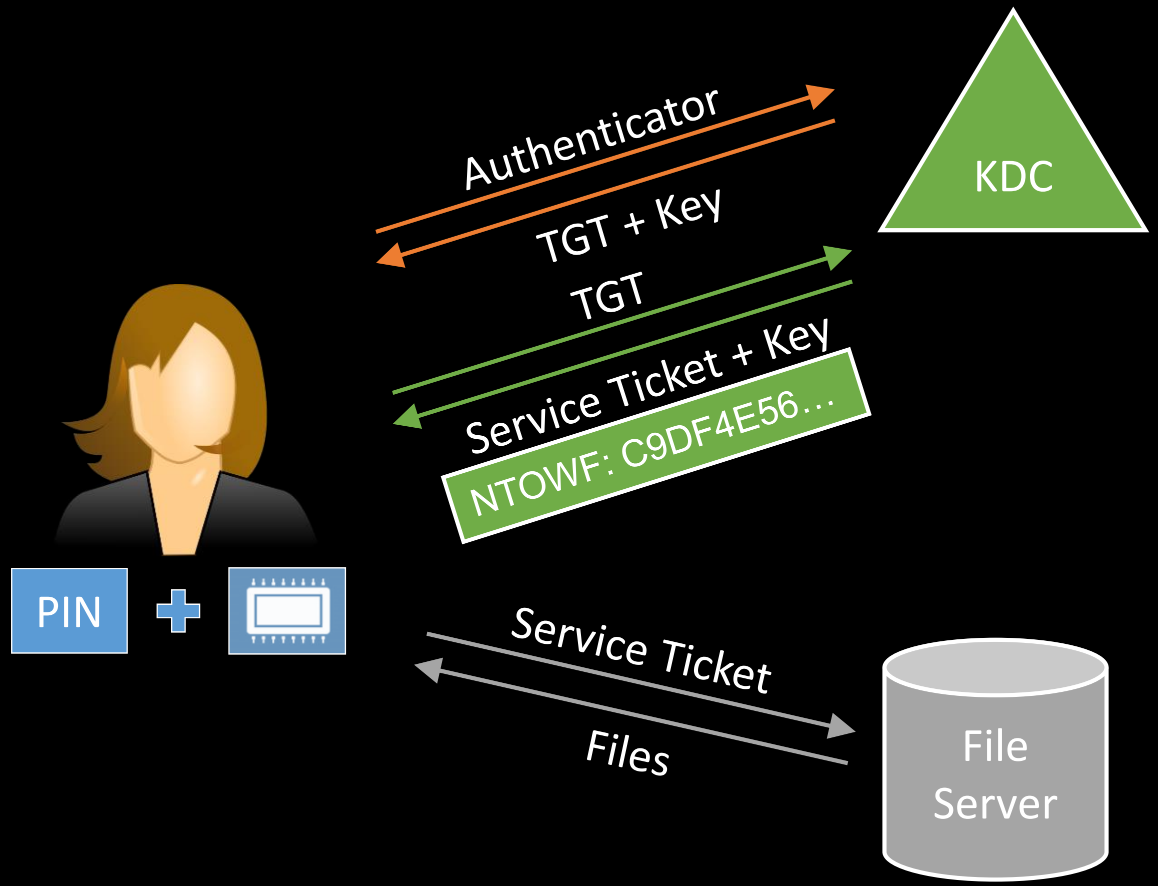
You can't pass the hash if you don't have it

Credential Strength

- Weak credentials are easily stolen by
  - Cookie Theft
  - Phishing
  - Key Logging
- Strong credentials are theft resistant
  - Smart card
  - Two factor authentication
- Users with weak credentials are vulnerable.



Windows Smart Card Primer



1. Prove identity and receive a Ticket Granting Ticket
2. Present TGT to gain a service ticket
3. Present service ticket to access service.

But wait! There's more…

4. The service ticket reply contains an NTOWF for NTLM compatibility

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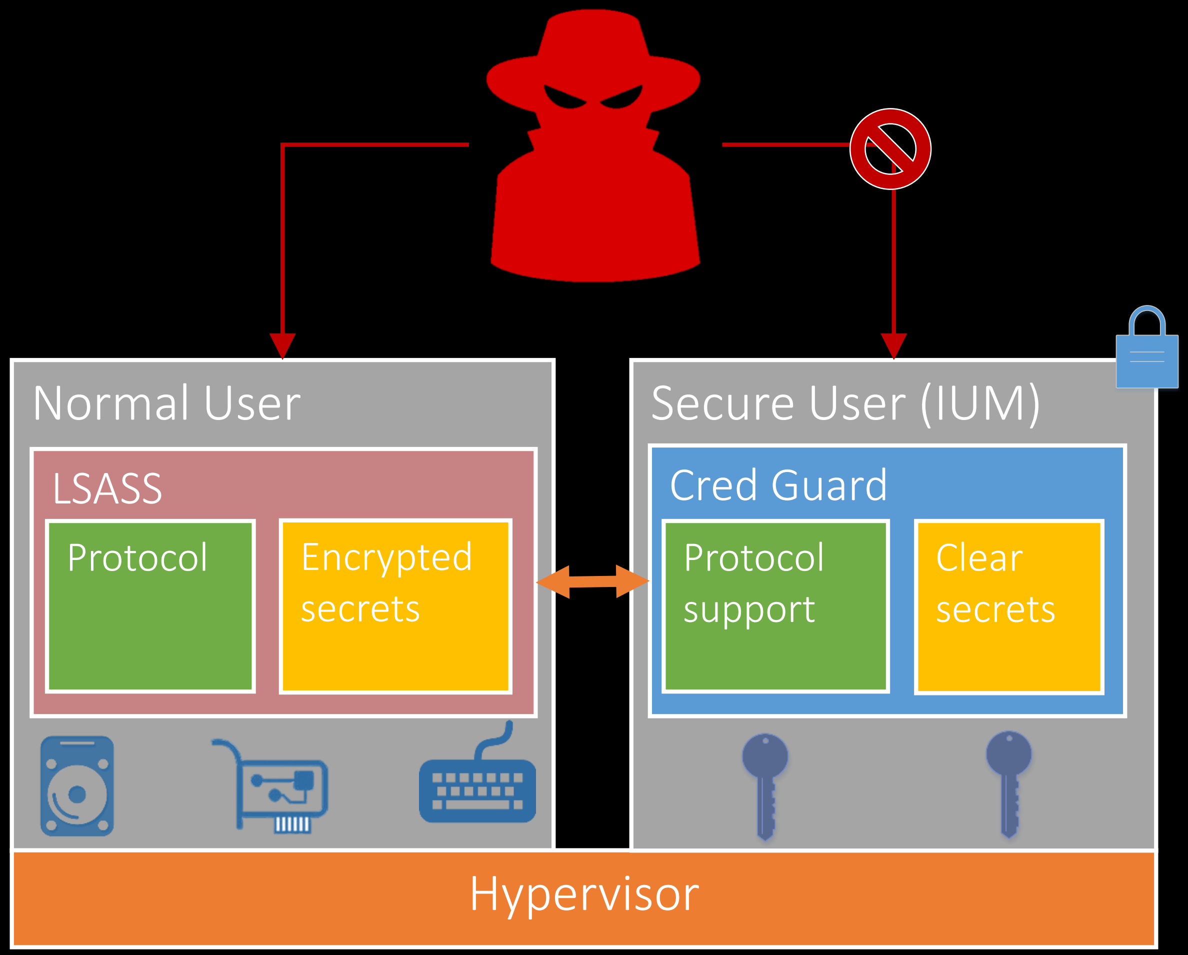
Isolation Architecture



- LSASS continues to run in normal world
  - Core protocol logic stays in LSASS
- Cred Guard provides *isolation services* to LSASS
  - All use of secrets happens here
- LSASS talks to Cred Guard over RPC
- Secure-mode keys encrypt data
  - No clear secrets in normal world

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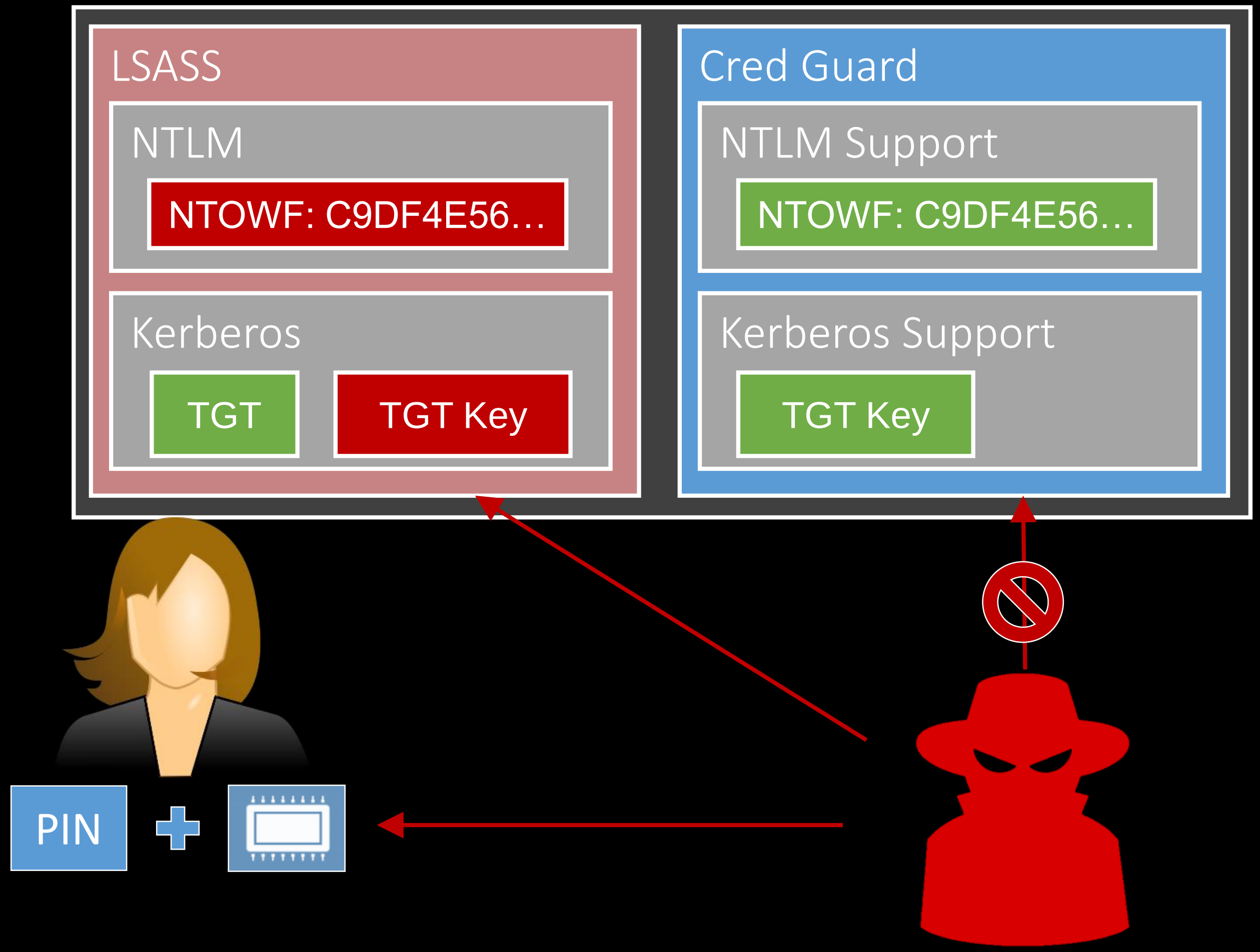
Artifact Isolation



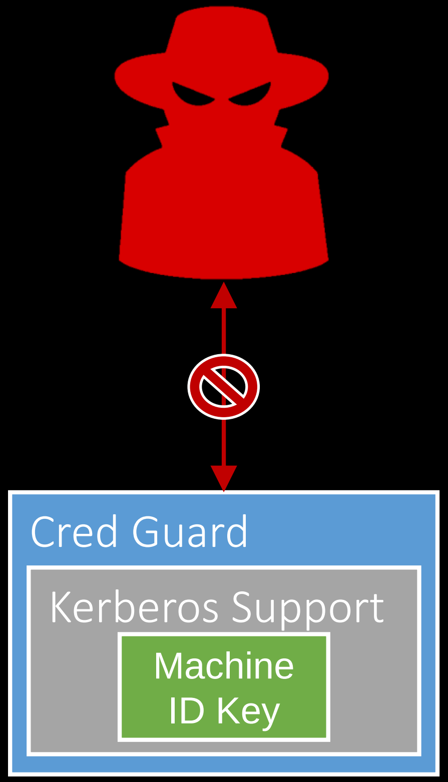
- Old: Everything in LSASS
  - Bad admin owns you
- New: All “passable” secrets protected by Cred Guard
  - Secrets are now hidden
  - Attackers cannot steal secrets from memory they cannot read.
- *However…* Attackers still have oracle access to the user’s credential.
  - We’re not there yet.

Ensuring Secrets are Isolated

- An attacker with oracle access to your cred can PtH
- Isolation is only good if we can guarantee it.
  - Client trickery is never enough.
- Solution: Kerberos FAST (RFC 6113)
  - Compound authentication: What machine is a user coming from.
  - Provides the promise of truly hidden artifacts

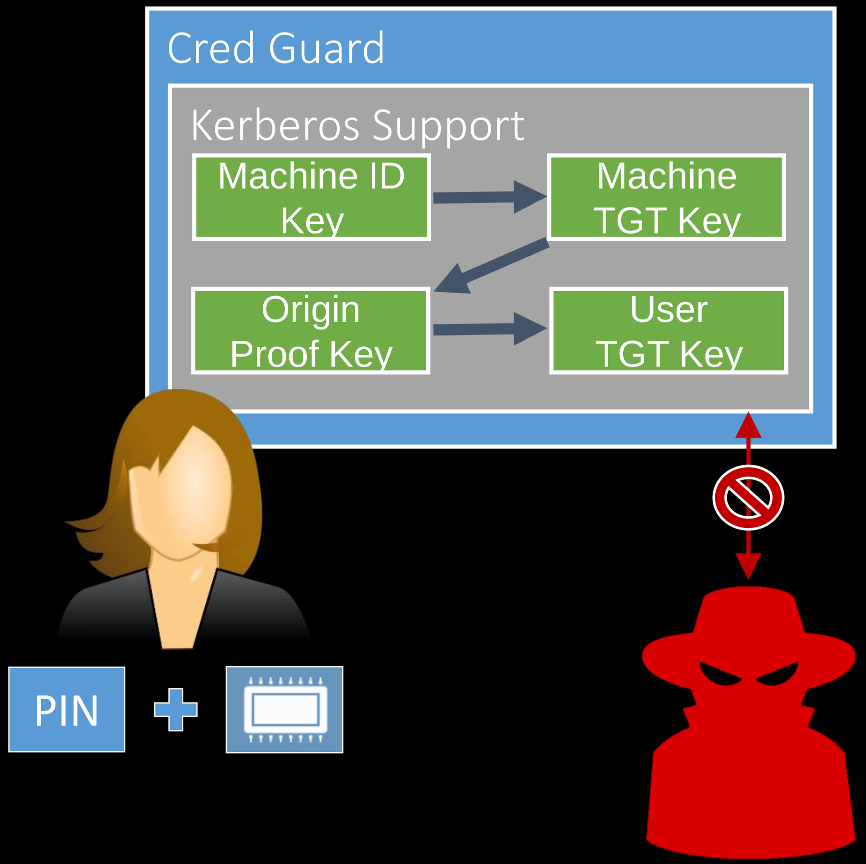
Foundation: Strong Machine Credentials

- Like users, systems have credentials.
  - Traditionally passwords
  - Key pairs are supported as of 2012 R2
- Cred Guard owns the system private key.
  - Attackers cannot access this credential.
- We combine this with compounding (FAST)
  - 2012 R2 allows binding of users to machines
    - Authentication policies



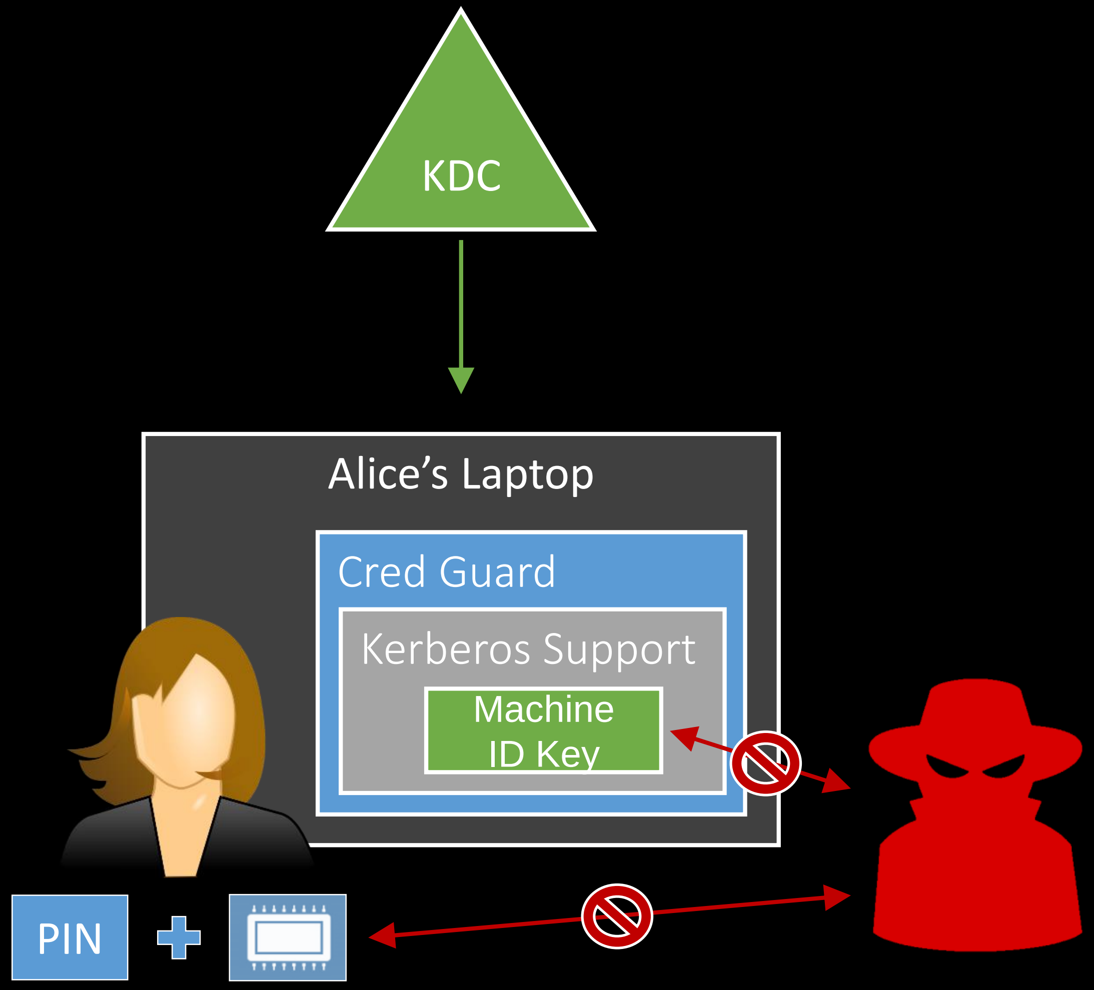
Compound Authentication

- Machine authentication uses an Cred Guard-protected ID Key.
  - The machine uses this to get a TGT
- A derived, armor key is created.
  - Alice combines her credential with the proof.
  - The KDC checks the proof and grants a TGT.
- Attackers have *zero* access to the machine ID key, preventing illicit authentication attempts.



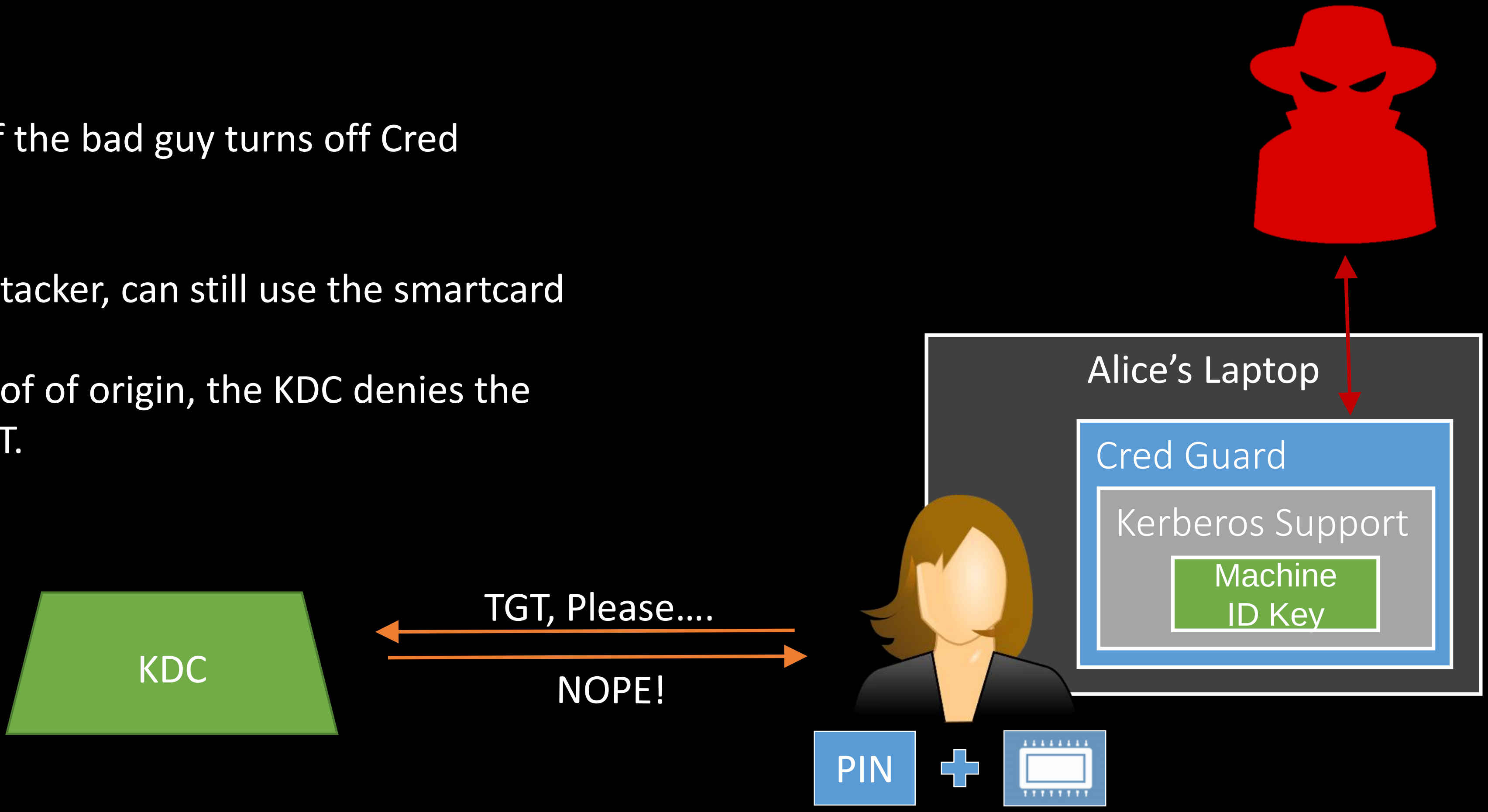
The Path to Secure Users

- Secured users *only* use strong authenticators
  - Attackers cannot steal this authenticator.
- Secured systems authenticate with an ID key
  - Attackers have zero access to the machine ID key
- Secured users may authenticate only from designated systems
  - This policy is validated at the KDC.



What if I Turn it Off?

- What happens if the bad guy turns off Cred Guard?
- Alice, and the attacker, can still use the smartcard
- Without the proof of origin, the KDC denies the request for a TGT.



Demo Time

Steps to Mitigating PtH

- Eliminate weak protocols – MSCHAPv2, NTLMv1
- Migrate users to strong credentials
- Update hardware refresh specs to IUM-compatible devices
- Enable Win10 IUM support
- Get educated on other Credential Theft mitigations
  - http://www.microsoft.com/pth

BACKUP

VSM platform requirements

- Virtualization Extensions (Intel VT-x)
- Second Level Address Translation, SLAT
  (Intel Extended Page Tables, EPT)
- IOMMU (Intel VT-d)
- UEFI 2.3.1
- TPM 2.0
- Optional Performance Enhancement - Mode Based Execution Control (MBEC)
  - Optimal performance for CI enforcement
  - Fall-back to S/W based implementation