Bypassing Local Windows Authentication to Defeat Full Disk Encryption

black hat®
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Who Am I?

- Currently a security researcher at Synopsys, working on application security tools and Coverity’s static analysis product.
- Previously received my Ph.D. in mathematics from UC Berkeley.
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Full Disk Encryption

- A scheme for protecting data at rest. Encrypts an entire disk or volume.
- Mitigates the impact of a threat with physical access; generally does *not* provide protection against remote adversaries.
- Encrypts everything, often including the OS.

Microsoft BitLocker

- BitLocker is Microsoft's proprietary full-disk encryption feature.
- Built into all professional/enterprise versions of Windows since Vista.
- Uses the system's Trusted Platform Module (TPM) to store the master encryption key.

What is a TPM?

- A TPM is a hardware module responsible for performing cryptographic operations, performing attestation, and storing secrets.
- It has fairly general APIs, so how it is used is mostly up to applications.
- Example applications include remote attestation, and storing encryption keys.

Storing Secrets on a TPM

- A TPM contains several Platform Configuration Registers (PCRs).
- Starting with the BIOS (which is assumed to be trusted), the next part of the boot process (e.g. the MBR) is hashed and this value is stored in the a PCR.
- Each stage of the boot process is responsible for hashing the next and storing it in a PCR.

Storing Secrets on a TPM

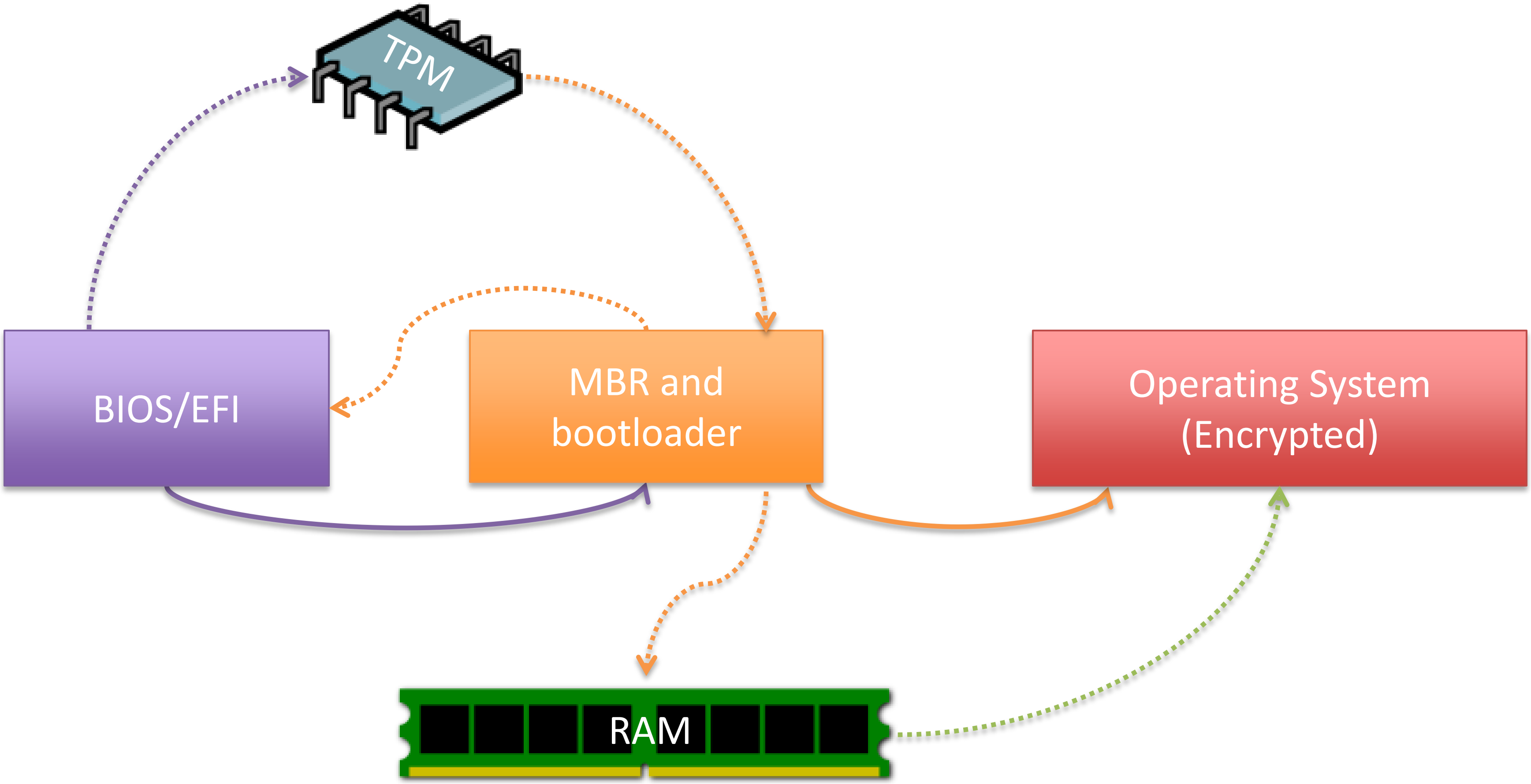
- A boot, the TPM has a zero in all PCR registers.
- Whenever the TPM is told to update a register *r* with a value *v*, it always sets: *r* = HASH (*r* | *v*)
- So PCR values can never get set directly, only appended to. Arbitrary PCR values cannot be spoofed.
- This means a set of values in the PCRs can only be replicated by having that same boot chain.

Storing Secrets on a TPM

- When the TPM stores a secret key, that key can be *sealed*. When a key is sealed, the TPM references the current value of the PCRs.
- An API call to unseal that key will fail unless the current PCR values match the original values from when the key was sealed.
- So effectively, only the original boot process will be able to retrieve that secret key.

Transparent BitLocker

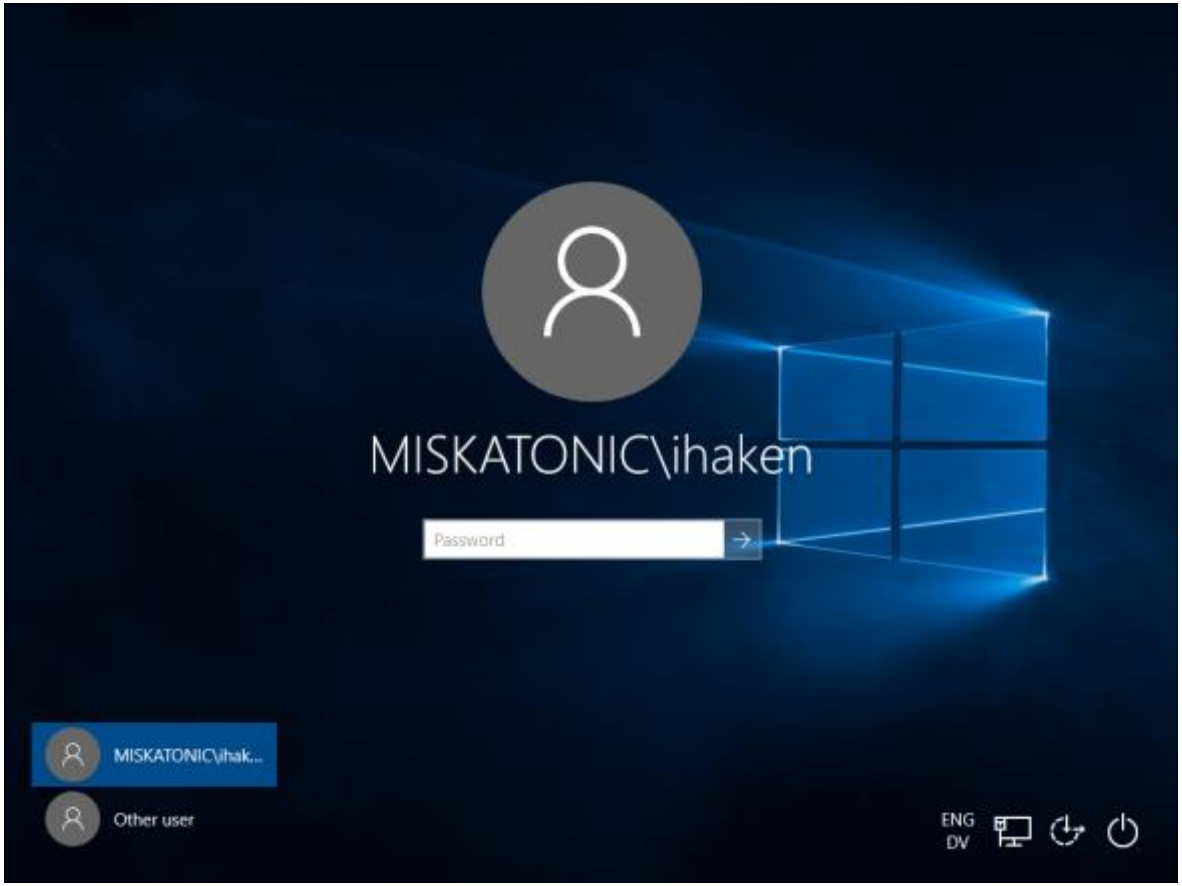
- BitLocker, in addition to the TPM, can optionally require a PIN or a key saved on a USB drive.
- However, it's recommended configuration works transparently. It seals the secret key in the TPM and only BitLocker can retrieve it.
- Your computer boots up to a login screen as usual, with no indication that FDE is enabled.


TPM
BIOS/EFI
MBR and bootloader
Operating System (Encrypted)
RAM

Attacks Given Physical Access

- Known Hardware Attacks
  - Attack the TPM (grounding control pins)
  - Do a cold-boot attack to get the key from RAM
- Attack an early part of the boot chain
  - Flash the BIOS/EFI with a custom image
  - Look for a defect in the BIOS, MBR, or boot loader
- Or see we can attack the OS itself and see if Windows will give us the key...

Booting Up With BitLocker



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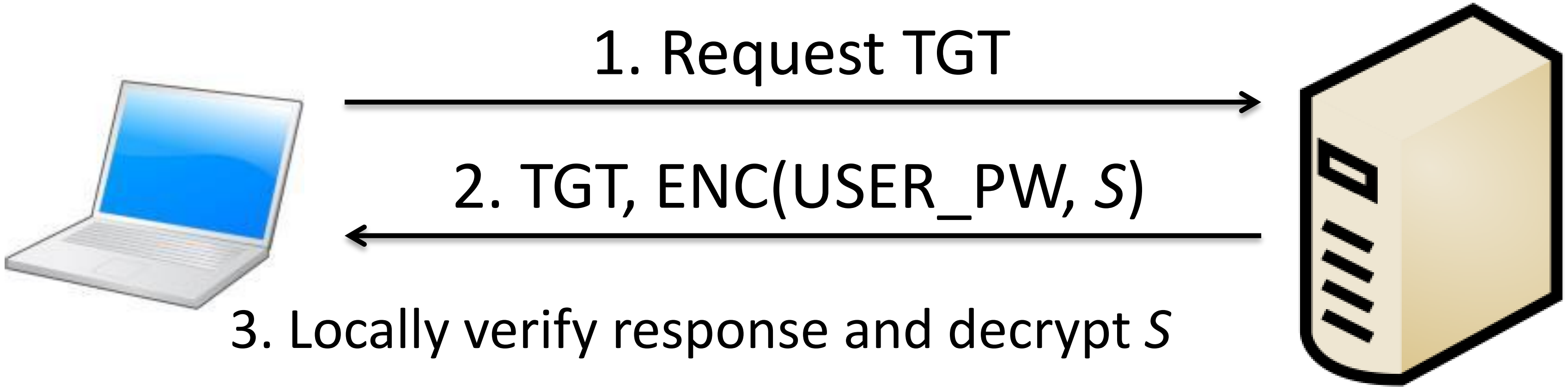
Local Windows Authentication

- The Local Security Authority (LSA) manages authentication, usually using a Security Subsystem Provider (SSP).
- For a client-domain authentication, the Kerberos SSP exchanges messages with the Domain Controller (DC).
  - When attacking FDE, we have physical access. So we control the network and can run a “mock” DC.

Windows Domain Authentication

- Requests a session ticket (TGT) from the DC.
  - The TGT includes a secret key *S*, encrypted by the DC with the saved user password. Login screen decrypts *S* using the typed password.



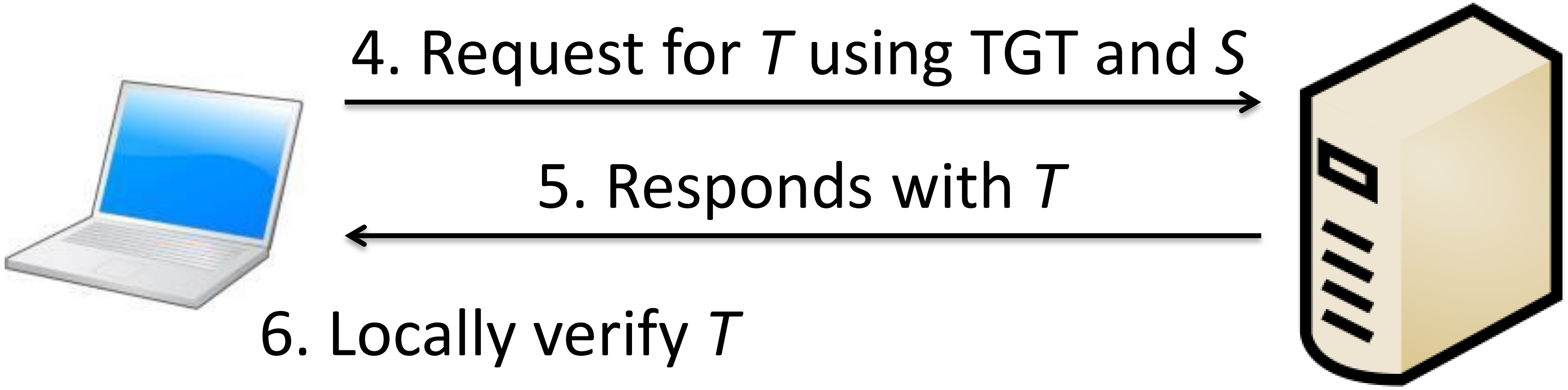
1. Request TGT

2. TGT, ENC(USER_PW, *S*)

3. Locally verify response and decrypt *S*

Windows Domain Authentication

- TGT and *S* are used to request a service ticket *T* from the DC for the target service (in this case, the local workstation).
  - The local workstation verifies *T*.



4. Request for *T* using TGT and *S*

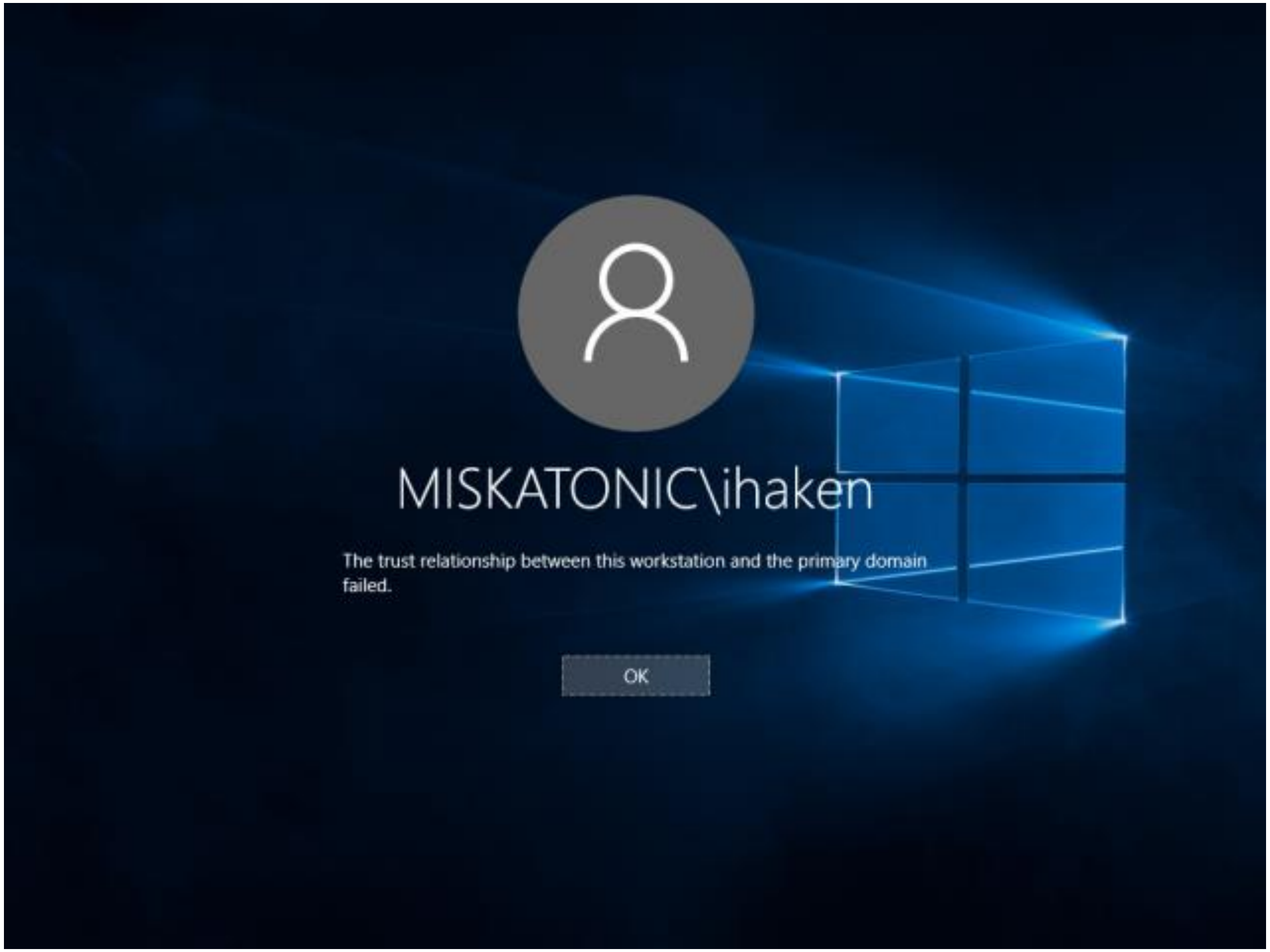
5. Responds with *T*

6. Locally verify *T*

Machine Passwords

- When a workstation first joins a domain...
  - A secret key is generated, called the machine password.
  - This password is sent to the DC, so they have a shared secret for future communication.
- To grant access to the workstation, the login process must present a valid service ticket *T*.
  - This ticket is signed using the machine password.
  - Which we don't have...

If the DC uses the wrong machine password



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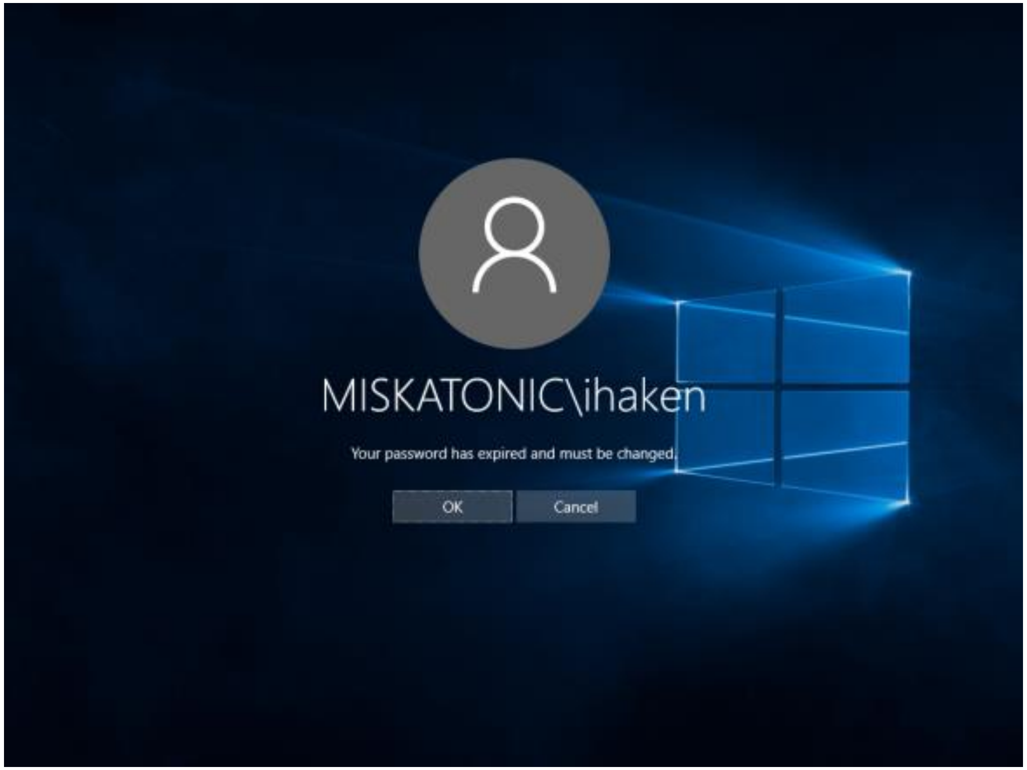
The trust relationship between this workstation and the primary domain failed.

The Local Credentials Cache

- A user can login when the DC isn’t available
  - Like when you’re using your laptop at a conference during someone’s talk…
- The cache is usually updated whenever the workstation sees the credentials are changed.
  - So it's updated when you successfully login and were authenticating against the DC.
  - Also updated when you change your domain password.

Too Bad We Can't Change the Password On the Login Screen



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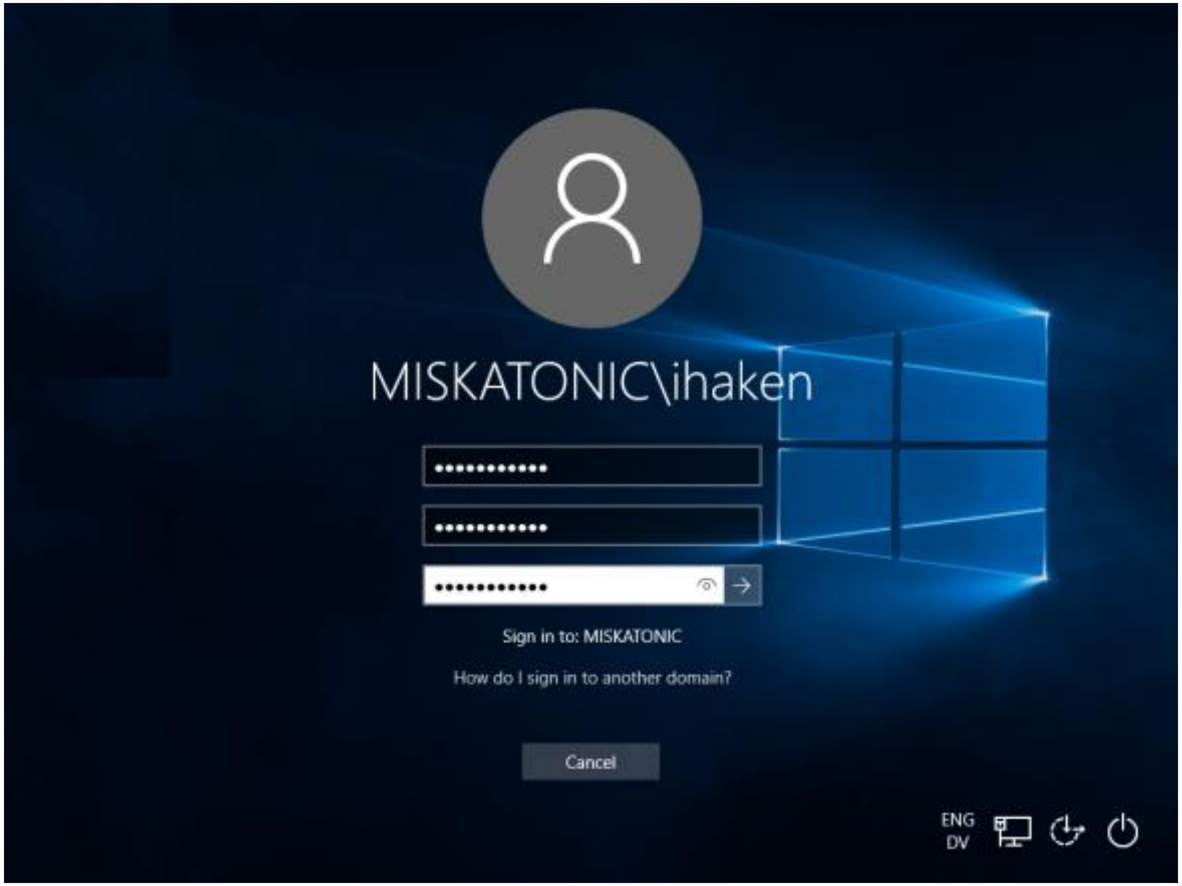
Your password has expired and must be changed.

Password Reset



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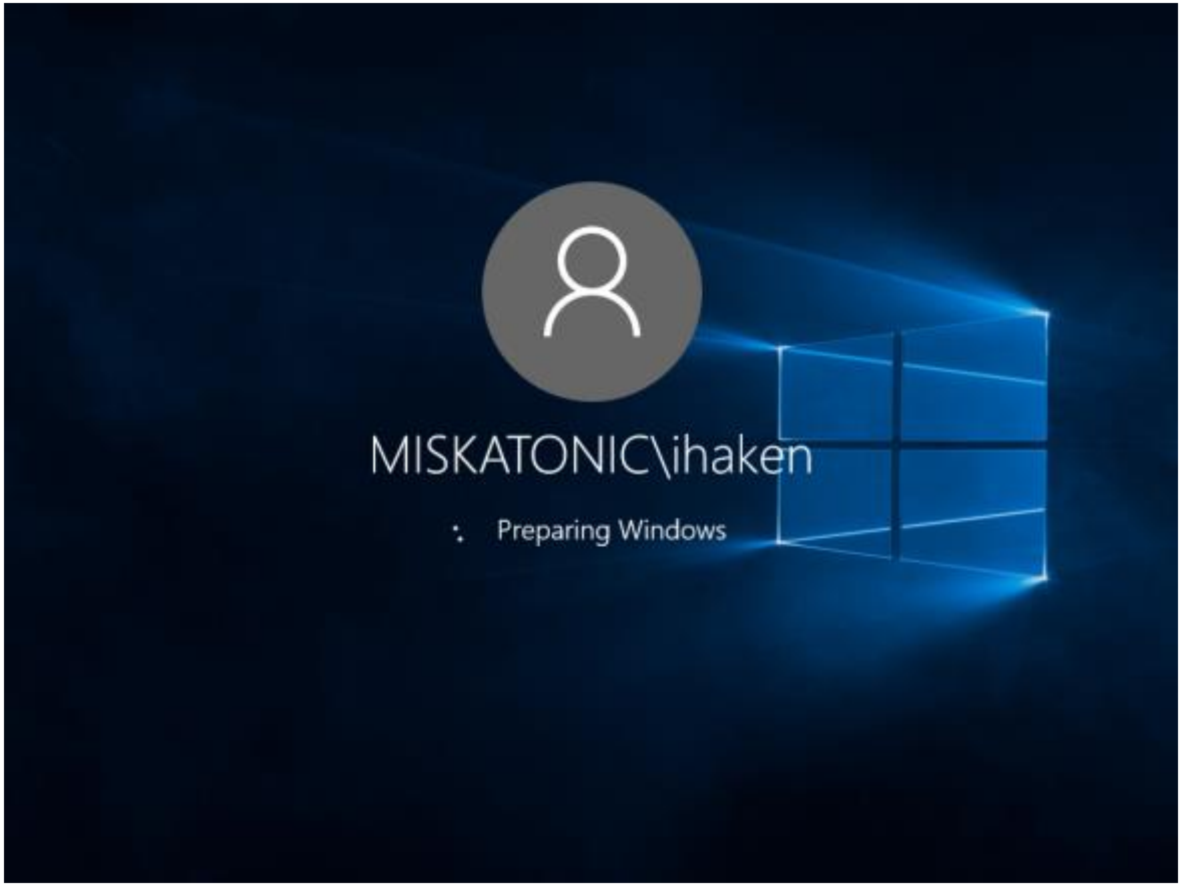
Sign in to: MISKATONIC

How do I sign in to another domain?

Poisoned Credentials Cache



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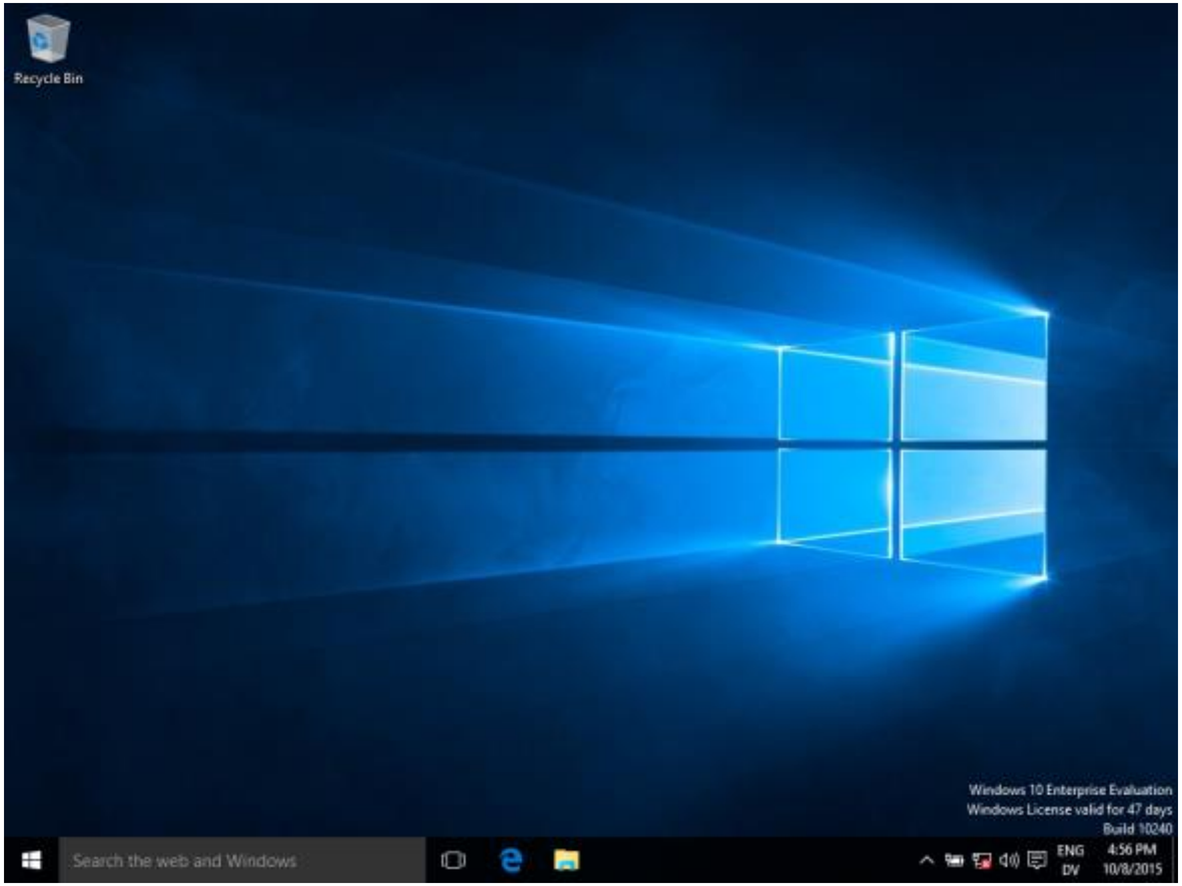
Preparing Windows

Poisoned Credentials Cache



Windows 10 Enterprise Evaluation
Windows License valid for 47 days
Build 10240

What Now?

- Dump the BitLocker key from kernel memory
  - As long as the domain account is a local admin
  - Although at this point you already have access to all the local user files, so it's pretty moot.
- Just dig through personal data
  - Saved passwords, Outlook emails, source code…
  - Drop in a trojan / backdoor, or whatever other malware you like.

Demo

System Configurations Effected

- Applies to any computer with:
  - BitLocker without pre-boot authentication
  - Attached to a domain
  - With a least one person having logged in with a domain account.
- Tested on Windows Vista, Windows 7, and Windows 8.1, Windows 10.
  - (Also Windows XP and Windows 2000)

How Else Does This Attack Apply?

- This isn't really BitLocker specific. More generally, this is an authentication bypass for domain accounts.
- If someone is logged in, locks their screen, and steps away, you could use this to unlock the PC.
  - Someone on their laptop at a coffee shop.
  - A computer in an office.

Impact and Mitigation

- This is 100% reliable attack, software-only, low sophistication, and takes a matter of seconds.
- You could use BitLocker with pre-boot authentication (i.e. using a PIN or USB key)
- You could use a BIOS password on boot
- Microsoft is releasing an update to address the issue. Expected release is November 10.
  - ACK to the Microsoft Security Response Center

Reflections: Why Does This Work?

- The protocol for password changes was written in RFC 3244 for Windows 2000, publish in 2002.
- At that point, local access was total access. Local access wasn't a valid threat model during protocol design.
- But local access is precisely the threat model under which FDE is applicable.

Black Hat Sound Bytes

- A defect in Windows domain authentication means BitLocker Full Disk Encryption can be bypassed; the attack is fast and non-technical.
- Microsoft is releasing a patch for the issue (expected November 10). *Make sure all your workstations are up-to-date!*
- Threat models change; when they do, you need to re-evaluate previous security choices.