
# The Remote Butler Did It!

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Microsoft

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# Speaker Info – Tal Be'ery

- Sr. Security Research Manager @Microsoft
- Developing MicrosoftATA (Advanced Threat Analytics)
- Former VP for Research @Aorato (Acquired by Microsoft)
- 15 years of security research
- Author of the TIME attack on SSL
- Regular speaker in top conventions
- Named a "Facebook Whitehat"
- Twitter: @TalBeerySec

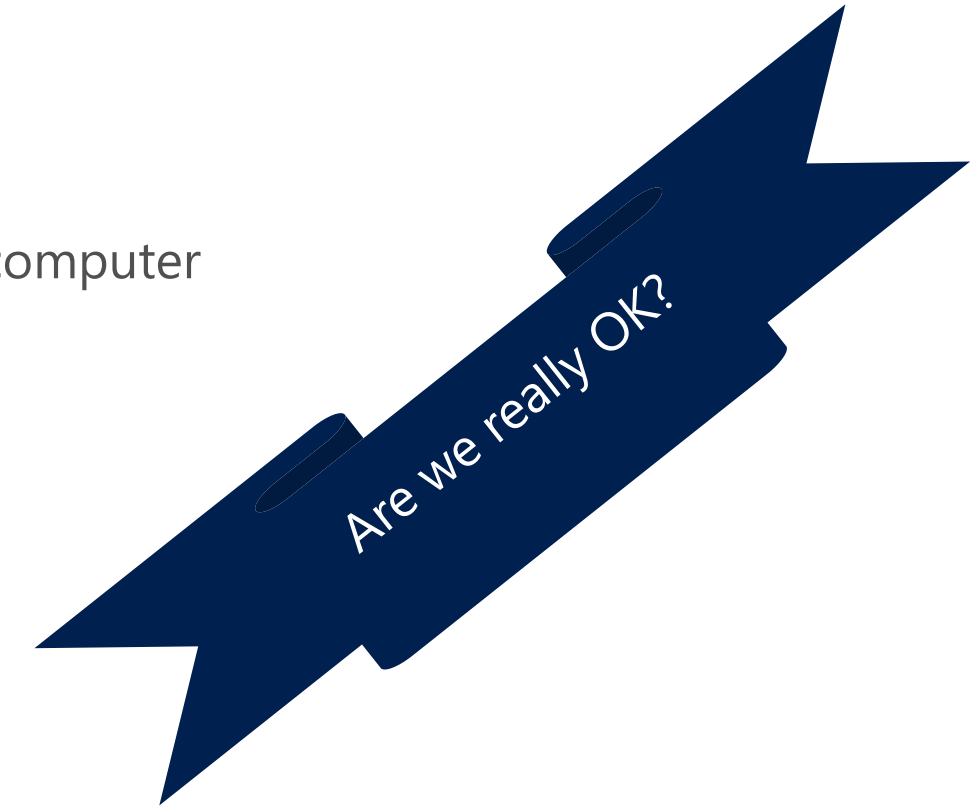
# Speaker Info – Chaim Hoch

- Security Researcher @Microsoft
- Developing MicrosoftATA (Advanced Threat Analytics)
- 8 years of signal analysis and information security research
- Starting M.Sc. in Computer Science
- Twitter : @chaimh90

# What's Missing in this Painting?

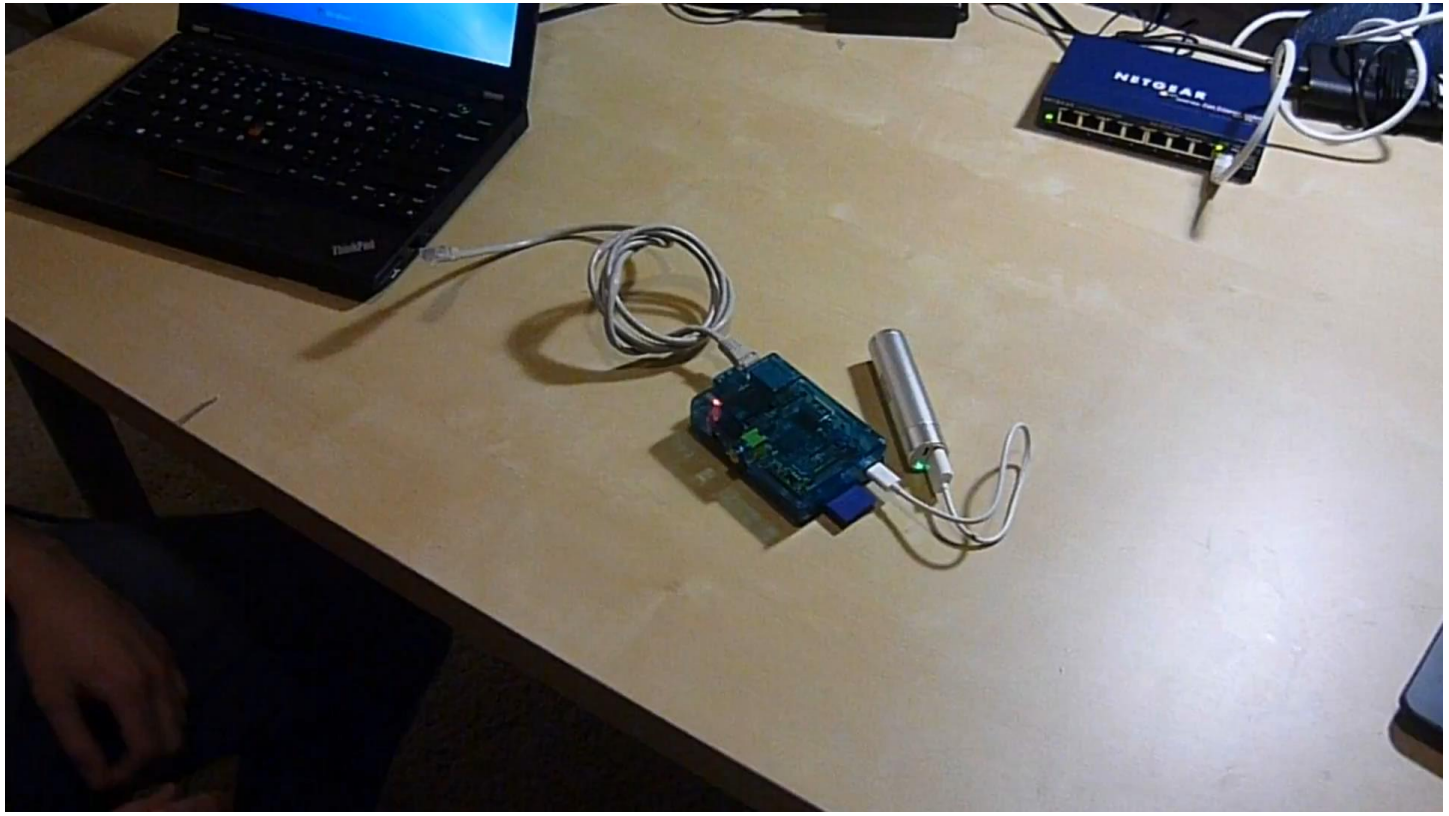
# They didn’t take their Laptops for Breakfast!

- Someone might hack their unattended laptops
- But… all doors to the data are locked!
  - Main door (Logon) is locked:
    - The computer is password locked (trivial ☺)
  - Back door (Hard-Drive) is locked:
    - The computer’s Hard-Drive (HD) is encrypted
    - Otherwise attacker can just mount it in another computer
- So we are OK!



# The “Evil Maid” Attack

- Source: Ian Haken’s YouTube Channel




https://www.youtube.com/watch?v=LT0Z9asOedM

# Agenda

- "Evil Maid" Attack
  - Ian Haken's local attack
  - Logon Mechanics: Kerberos, Cached Credentials, Change password
- "Remote Malicious Butler" attack
  - Attackers' Motivation: Gaps in the Cyber Kill Chain
  - Migrating "Evil maid" to "Remote Butler"
- Solutions
  - Patching, Hardening, Defense in Depth!

# “Evil Maid”

# The “Evil Maid” attack

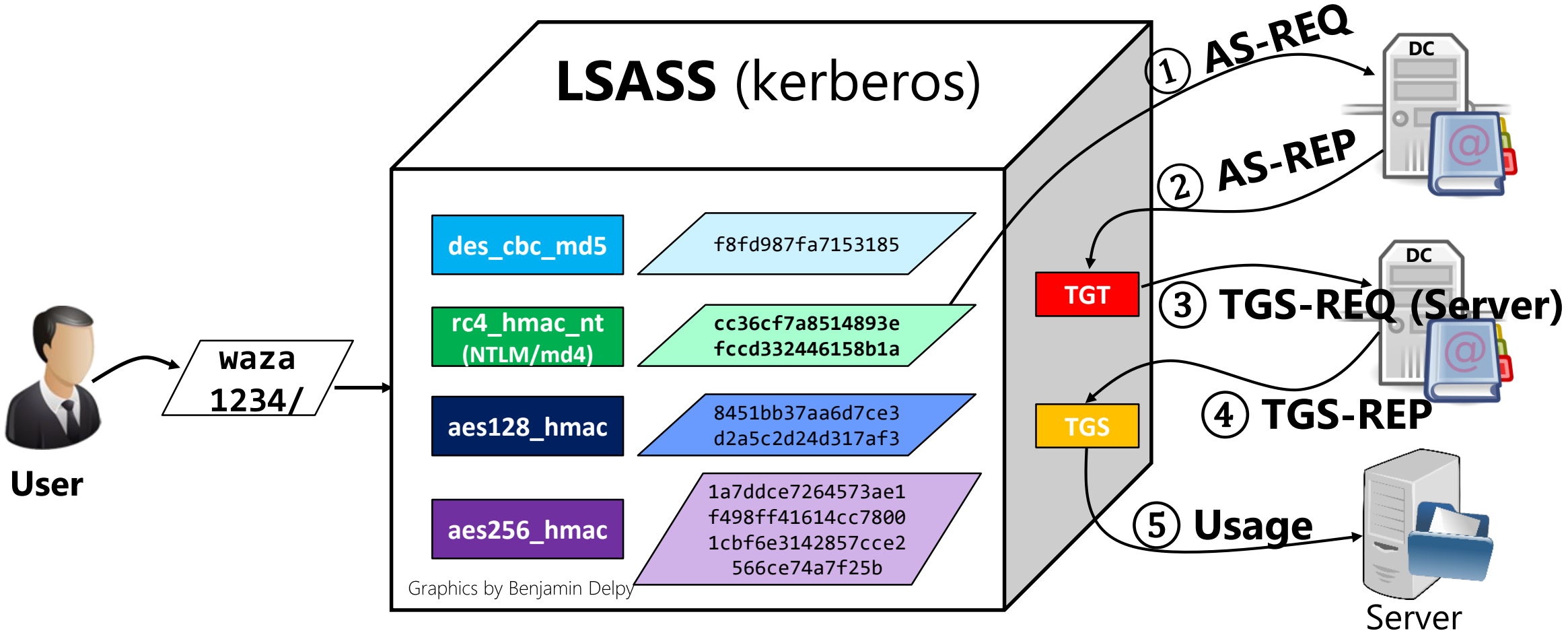
- Coined by Joanna Rutkowska ,2009
- Physical access scenario
  - "You leave your laptop in a hotel room and go down for a breakfast… Meanwhile an Evil Maid enters your room.“
- All doors to the data are locked:
  - Main door (Logon) is locked:
    - The computer is password locked (trivial ☺)
  - Back door (Hard-Drive) is locked:
    - The computer’s Hard-Drive (HD) is encrypted
    - Otherwise attacker can just mount it in another computer
- Original Attack: Attacking the back door
  - “Evil Maid” boots computer from an Evil USB stick
  - The Evil Boot sniffs HD encryption keys and wins

# Ian Haken's "Evil Maid" attack

- Presented by Ian Haken @BlackHat Europe 2015
- Attacking through the main door: "Bypassing Local Windows Authentication to Defeat Full Disk Encryption"

# Domain Logon: Kerberos

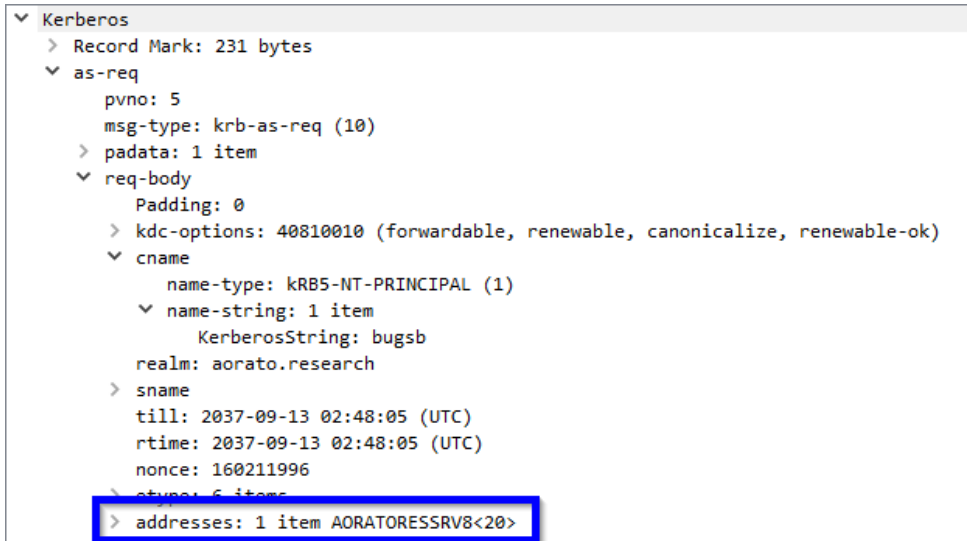
- The Domain Controller (DC) validates the passwords, via the Kerberos protocol

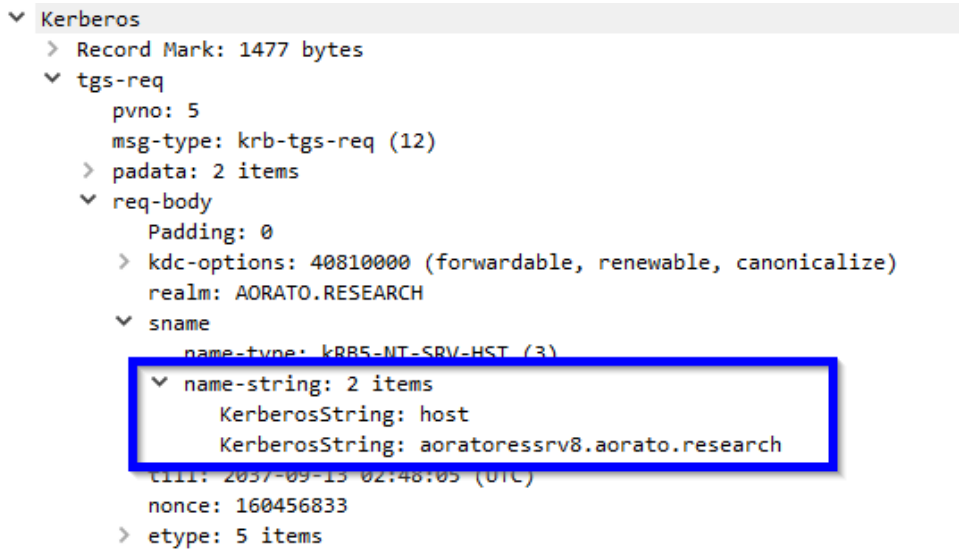


# Domain Logon: Over the Wire

- Logon is a special case of resource access
  - The resource is the target computer
  - The ticket is for Host/<Machine name>
- Encrypted with the computer's password
  - Yes, computer got ~~feelings~~ passwords too!
- Creates "Domain Trust Relationship"

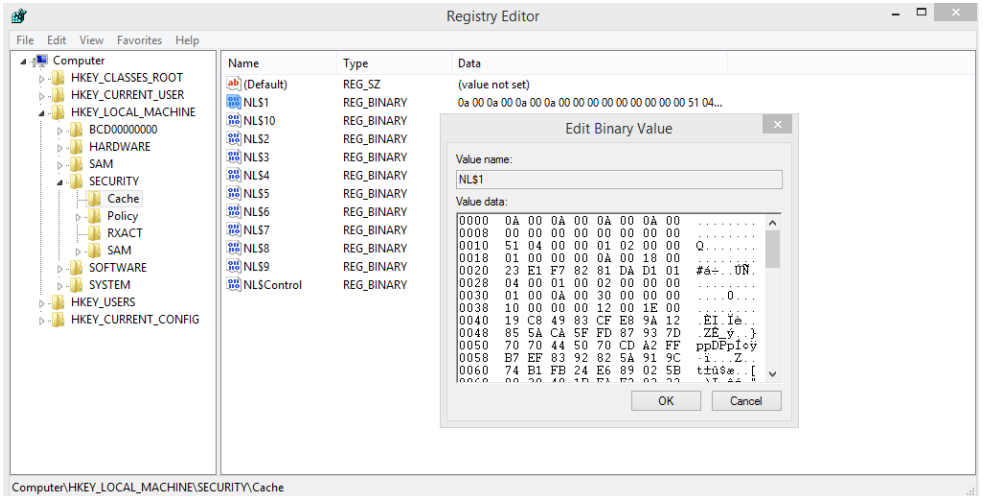
| Info | KerberosString |
|---|---|
| AS-REQ | bugsb,krbtgt,aorato.research |
| KRB Error: KRB5KDC_ERR_PREAUTH_REQUIRED | krbtgt,aorato.research |
| AS-REQ | bugsb,krbtgt,aorato.research |
| AS-REP | bugsb,krbtgt,AORATO.RESEARCH |
| TGS-REQ | krbtgt,AORATO.RESEARCH,host,aoratoressrv8.aorato.research |
| TGS-REP | bugsb,host,aoratoressrv8.aorato.research |



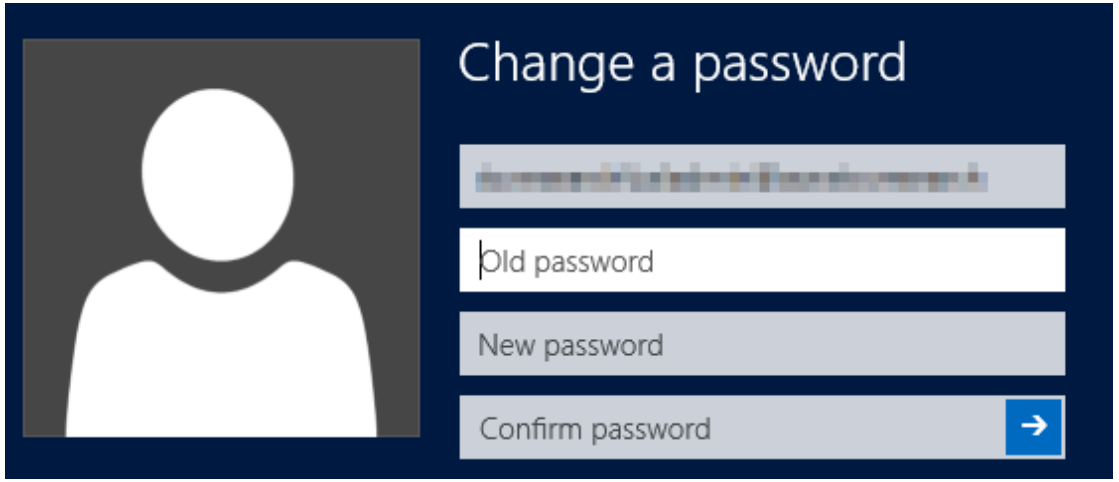
# Local Authentication: Cached Credentials

- Used for logon when DC is not available
- Password hashes of previously logged on users, are:
  - Stored on the Registry (HD)
  - Algorithm is MS-Cache2 (Vista and onwards):
    - PBKDF2_SHA(MD4 (MD4(password)+lowercase(user), iterations )
- Cached credentials hashes:
  - Hard to crack (PBKDF2 + Salt)
  - Not reusable: No “Pass-the-Cached-Credentials” attack



# Expired Password Change

- DC alerts user that password had changed via Kerberos Error message
- Triggers the normal password change procedure:
  - Old password is used to access the password change service
  - The new password is sent to DC in an encrypted message
- New password is updated in Cached Credentials

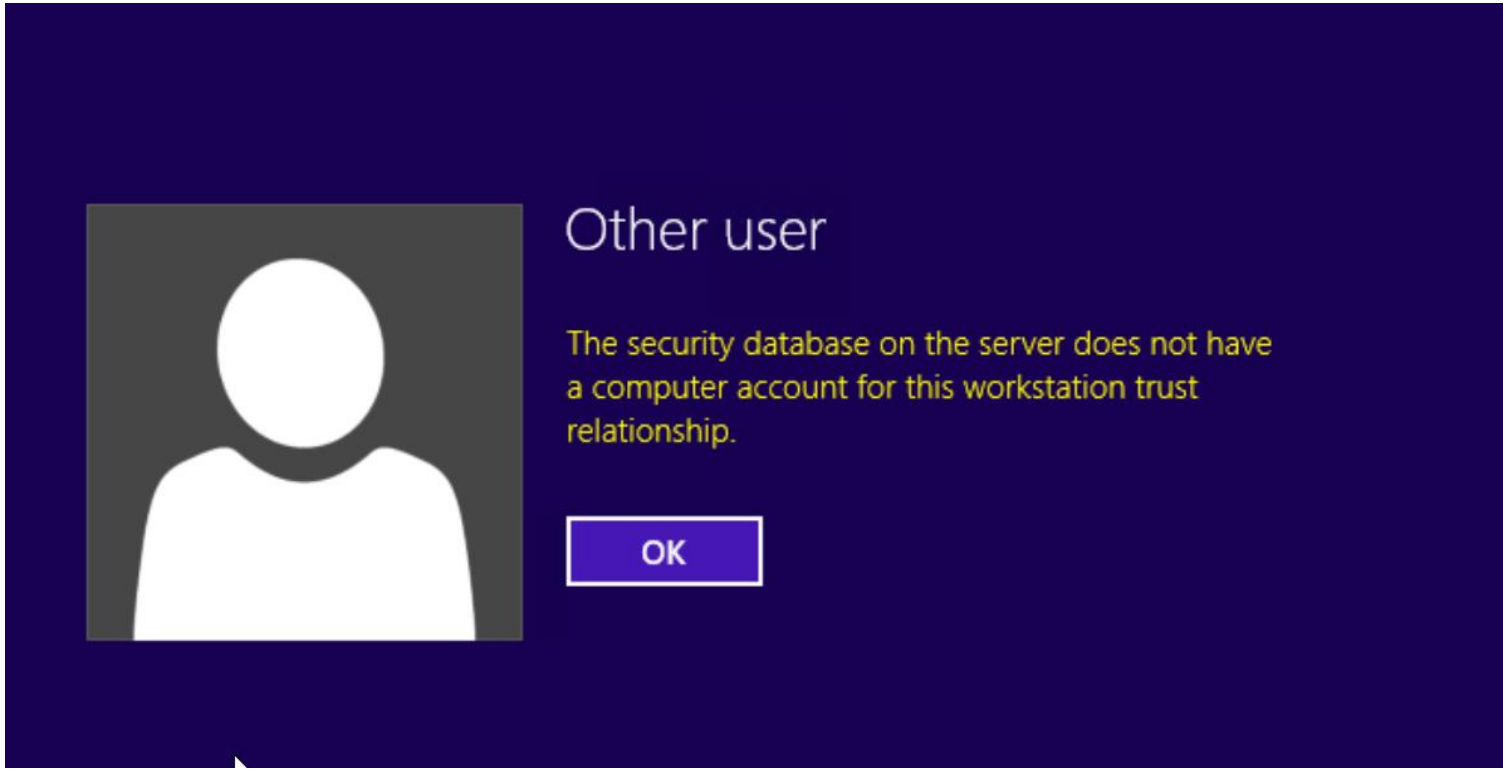



| Source | Destination | Protocol | Info |
|---|---|---|---|
| 192.168.0.17 | 192.168.0.2 | KRB5 | AS-REQ |
| 192.168.0.2 | 192.168.0.17 | KRB5 | KRB Error: KRB5KDC_ERR_PREAUTH_REQUIRED |
| 192.168.0.17 | 192.168.0.2 | KRB5 | AS-REQ |
| 192.168.0.2 | 192.168.0.17 | KRB5 | KRB Error: KRB5KDC_ERR_KEY_EXP NT Status: STATUS_PASSWORD_MUST_CHANGE |
| 192.168.0.17 | 192.168.0.2 | KRB5 | AS-REQ |
| 192.168.0.2 | 192.168.0.17 | KRB5 | KRB Error: KRB5KDC_ERR_PREAUTH_REQUIRED |
| 192.168.0.17 | 192.168.0.2 | KRB5 | AS-REQ |
| 192.168.0.2 | 192.168.0.17 | KRB5 | AS-REP |
| 192.168.0.17 | 192.168.0.2 | KPASSWD | Reply |
| 192.168.0.2 | 192.168.0.17 | KPASSWD | Reply |

# Attackers' Steps: Naïve attack

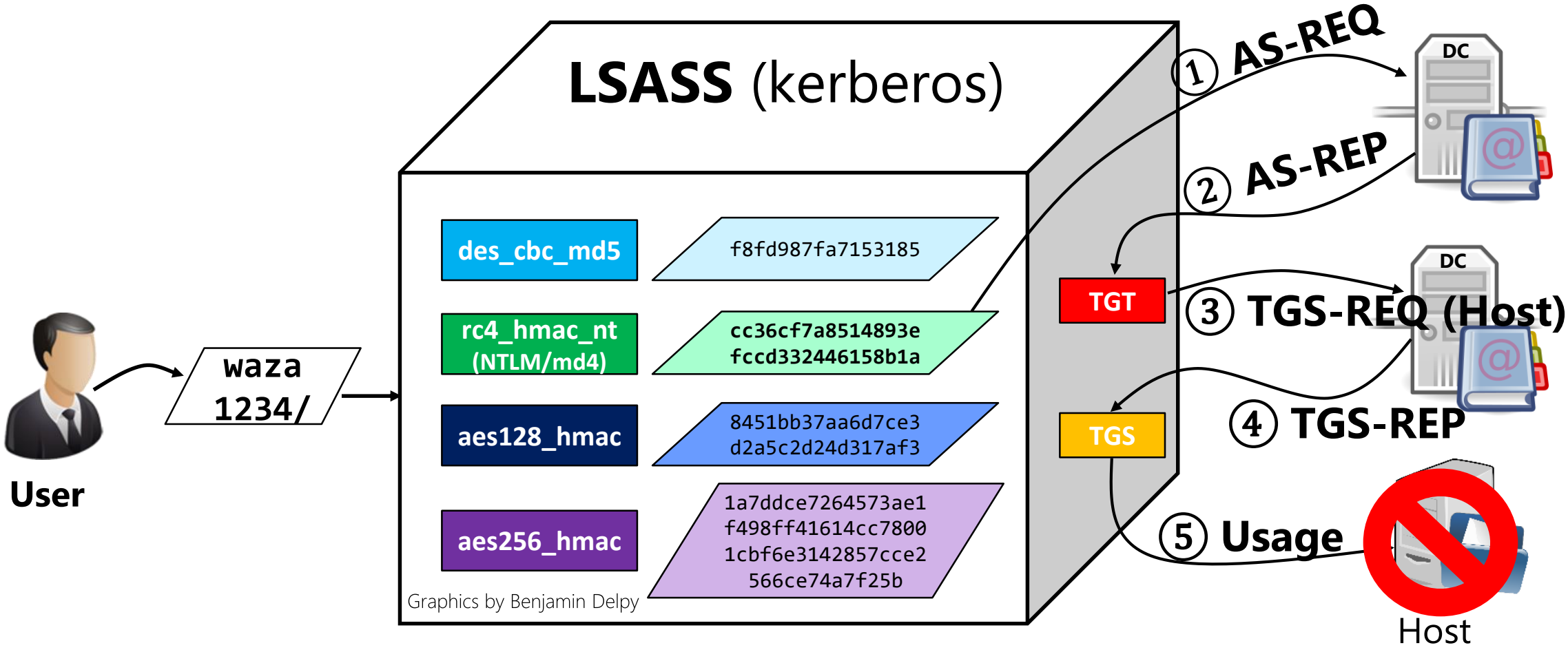
- Attackers set up a new rogue DC with the same domain name
  - the name can be easily found by looking at the UI
- On the rogue DC, attackers create a user account
  - The password is chosen by the attacker
- Attackers physically connects the machine to the Rogue DC.
- Attackers login with the rogue password to the victim machine
- AND…

# Fail!


Other user
The security database on the server does not have a computer account for this workstation trust relationship.
OK

# Kerberos Authentication Against the Rogue DC

Attackers don't know the Host's password!

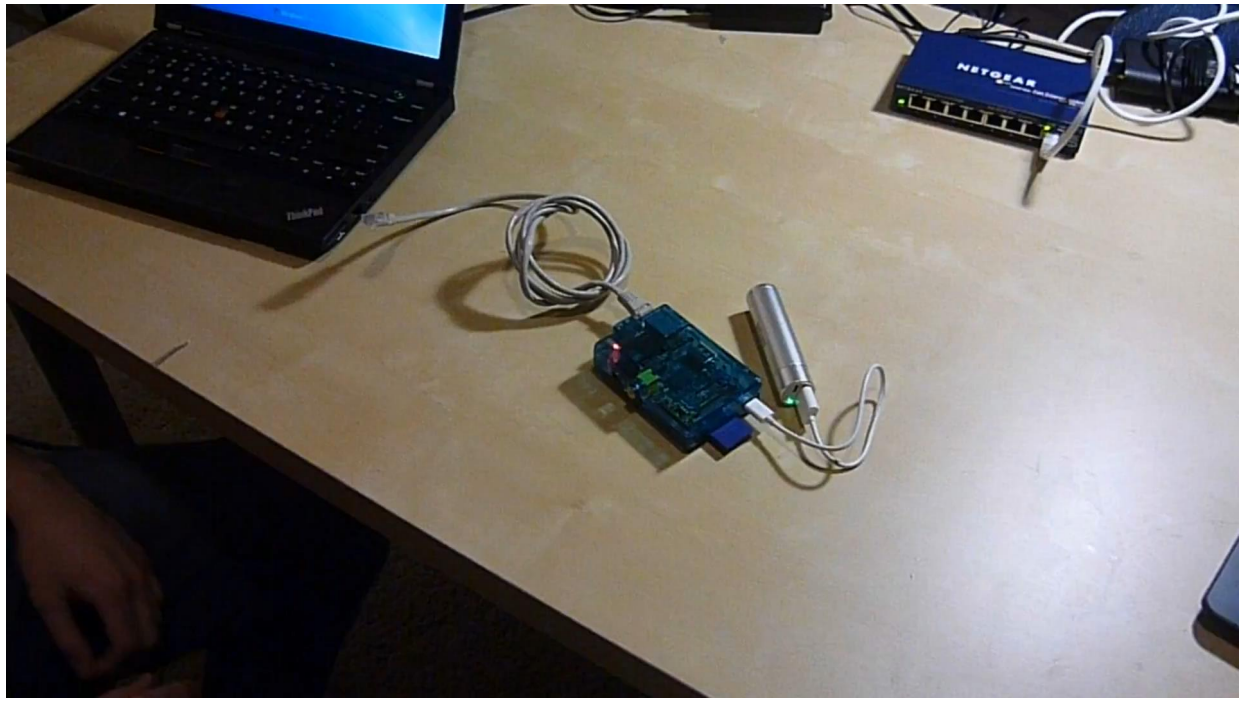


# Attackers' Steps: Revised

- On the rogue DC, attackers create a user account with the same name as the attacked user:
  - The password is chosen by the attacker
  - The password is marked as expired
- Attackers login with the rogue (expired) password to the victim machine and is prompted to change the password
- Attackers change password → The Cached Credentials entry gets poisoned with the new password!
- Attackers stop answering from Rogue DC → login is successfully preformed against the cached credentials with the new password
- Attackers take over; install a RAT

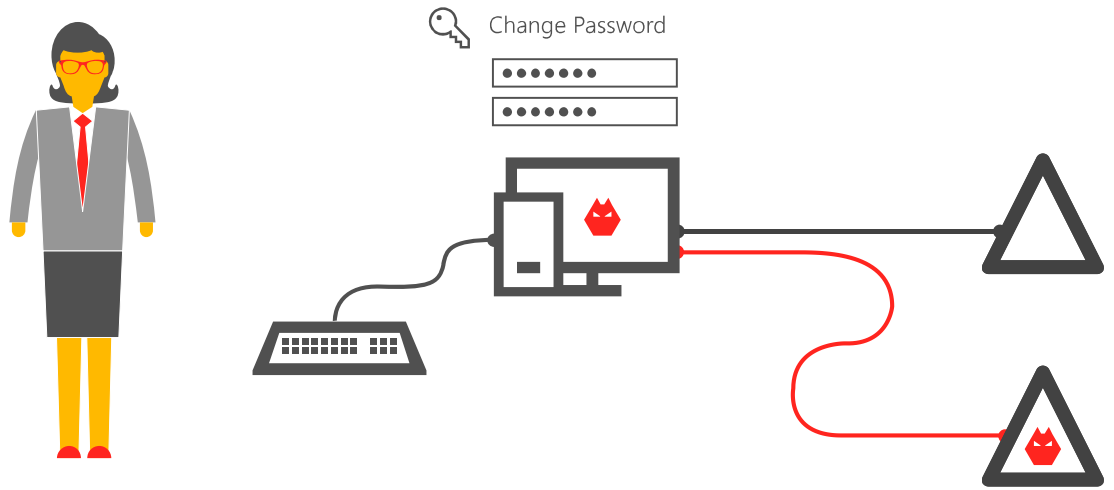
# The “Evil Maid” Attack

- Source: Ian Haken’s YouTube Channel
- Source code: https://github.com/JackOfMostTrades/bluebox




https://www.youtube.com/watch?v=LT0Z9asOedM

# Evil Maid

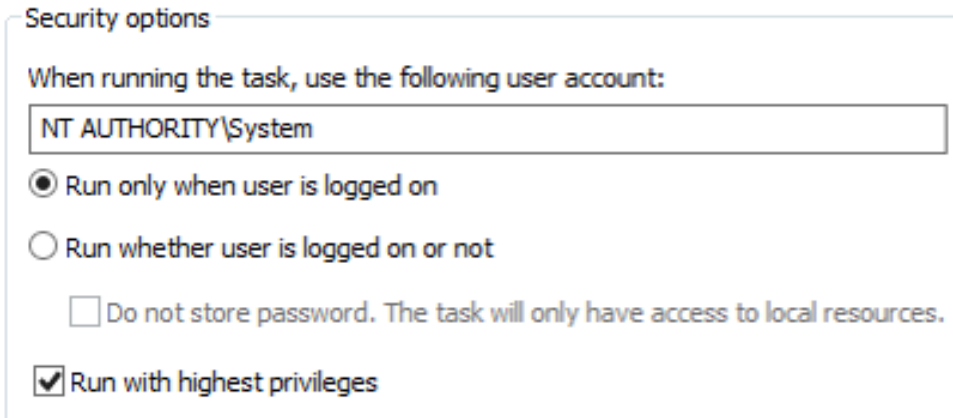


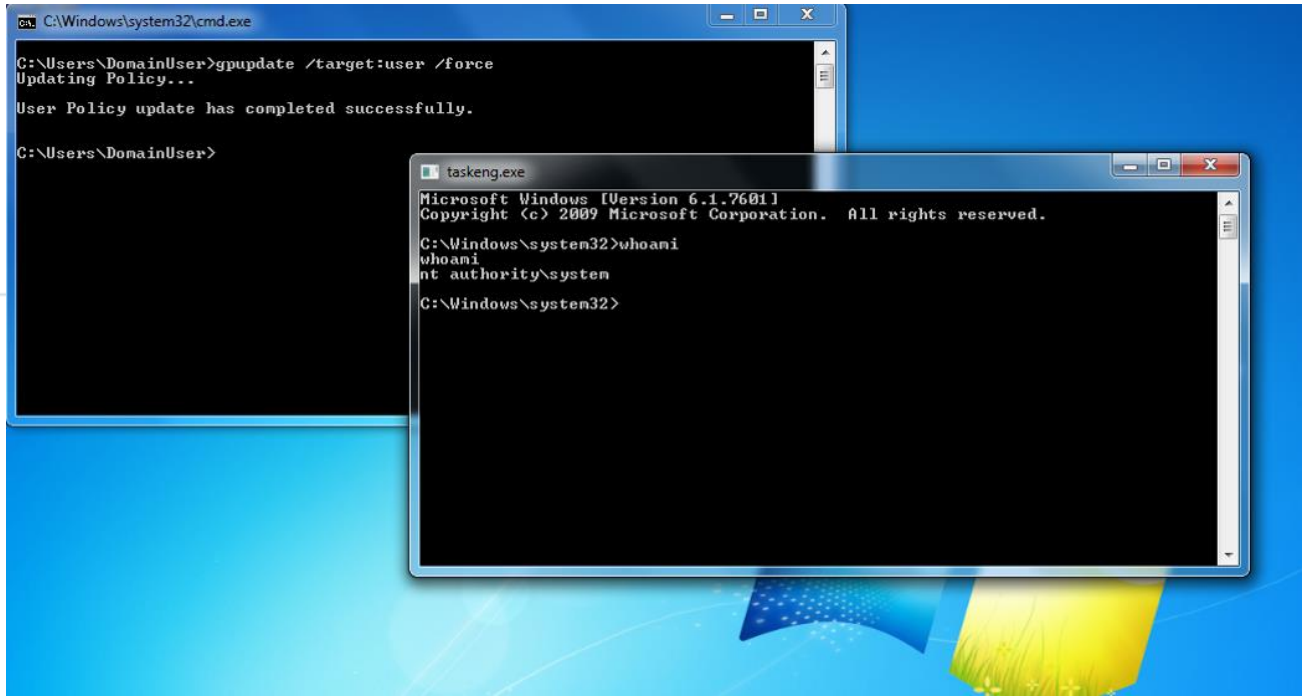
# “Evil Maid”: The Fix

- MS15-122 (+ MS16-014)
- Prevents the Cached Credentials poisoning
- Cached Credentials entry is only updated if Trust is validated == Host’s ticket is validated
  - **MS16-014 actually validates the trust**
  - **Vulnerability discovered by Nabeel Ahmed & Tom Gilis**
- Since the attacker does not know the Host’s password, the attack is thwarted

# Privilege Escalation

- "From zero to system: on full disk encrypted windows system"
  - **Nabeel Ahmed & Tom Gilis, late June 2016**
- Group Policy (GP) updates does not validate the computer Trust
- Attackers can:
  - Reconnect rogue DC
  - Fetch user's GP



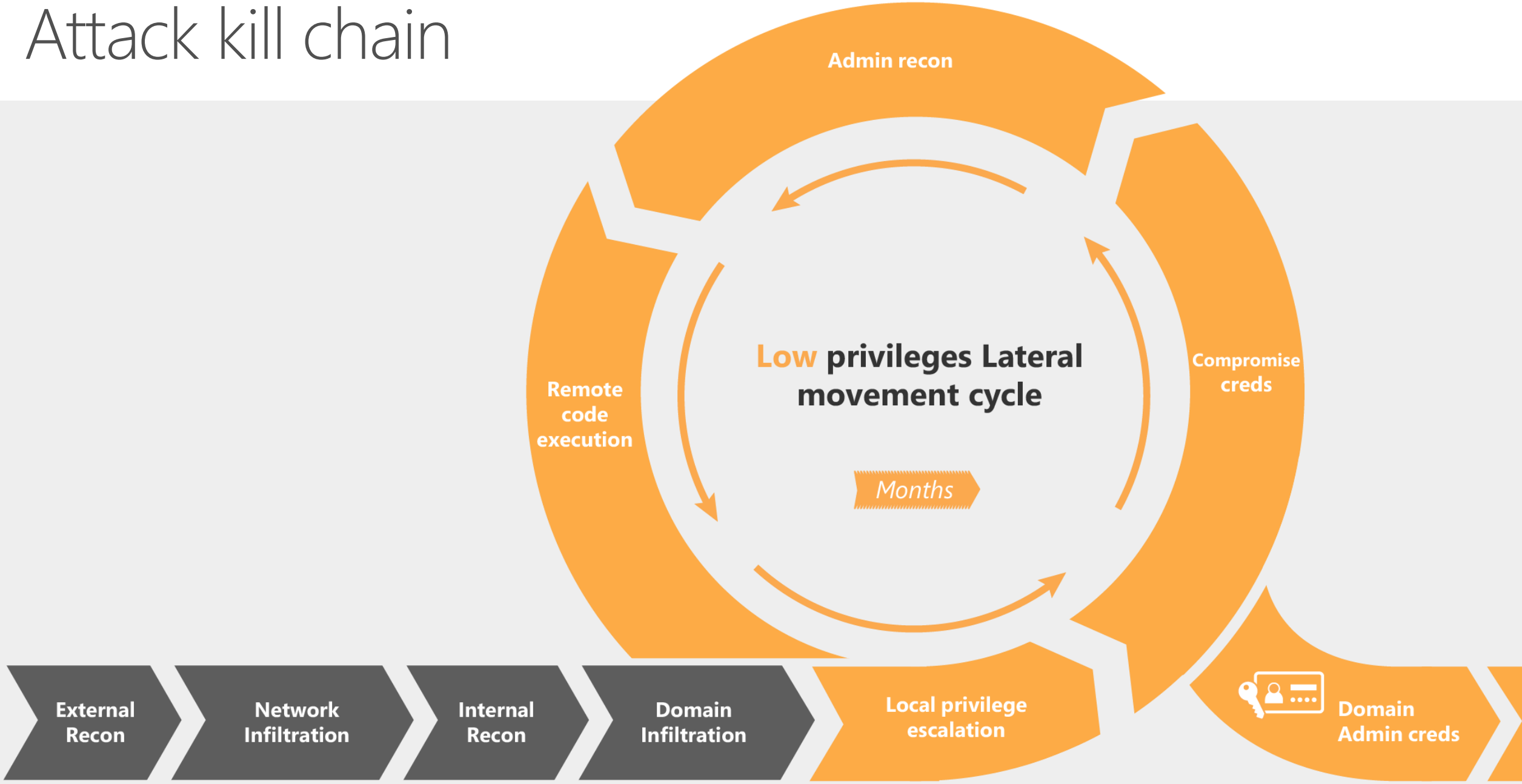
# Remote Butler

## Or “When Evil Maid met the Cyber Kill-chain”

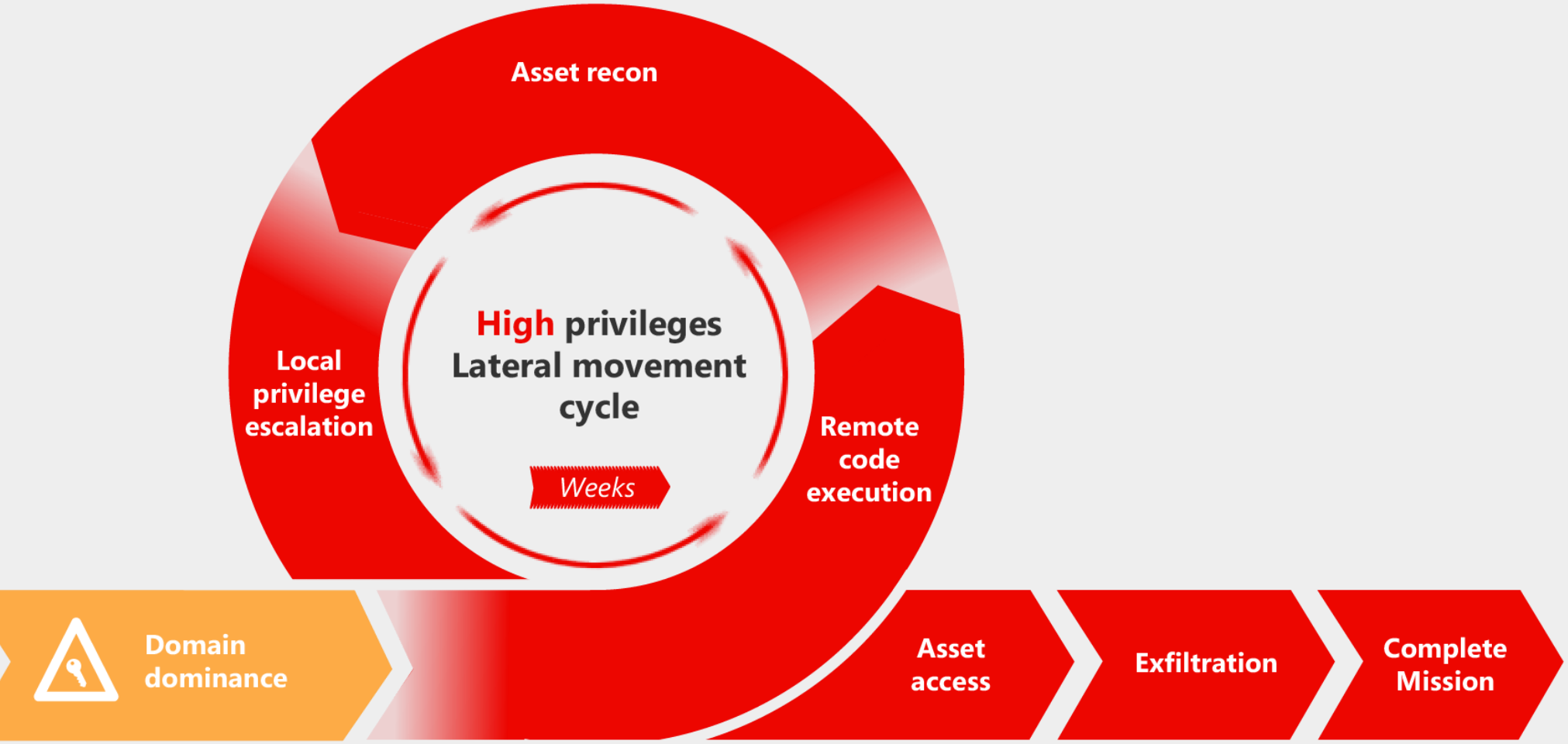
# Physical Access vs. Remote Access

- Physical access
  - Very Cool
  - But… Not the MO!
- Remote access
  - This is the MO!

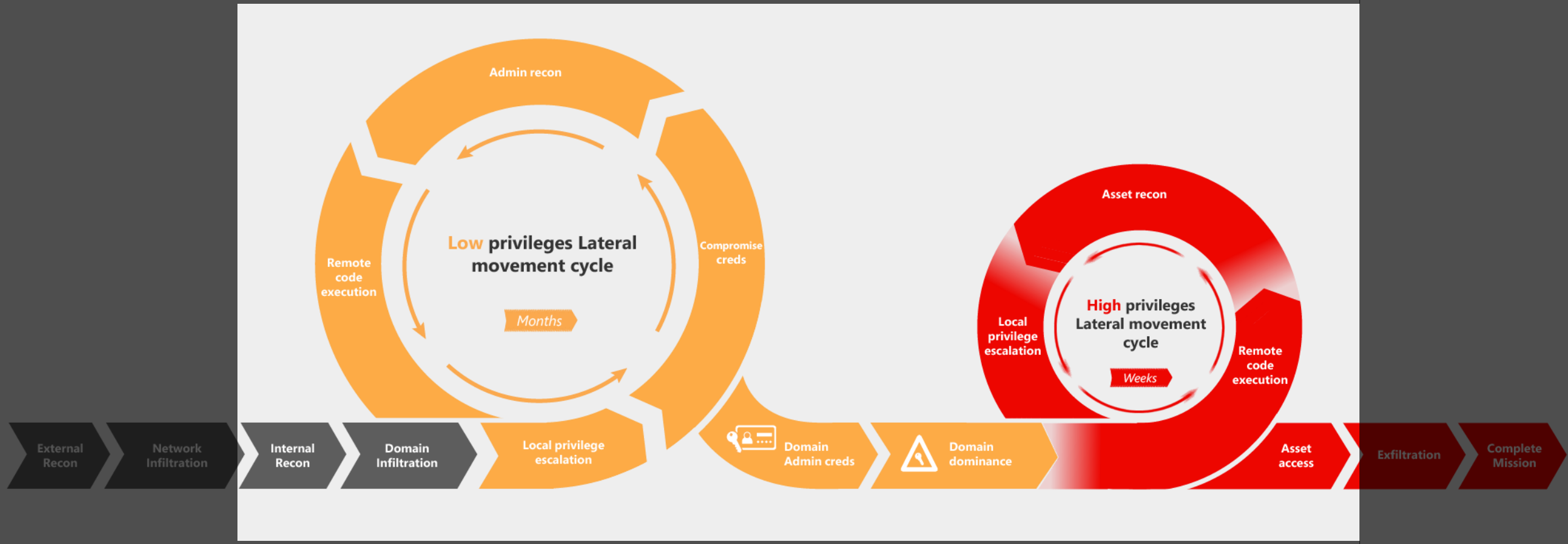
# Attack kill chain



# Attack kill chain



# Attack kill chain and ATA



# Attackers' Motivation: Network to Domain Travel


- In many attacks, attackers gain access to the network, but not yet for the domain
  - Hacked a Non-Domain joined internet facing server:
    - "Web Shell" hacked Web-Server
    - Router
    - Security device
    - IoT
  - VPN (non-Domain) credentials obtained through credentials theft/re-use

# Network to Domain Travel: HackingTeam breach

- Full attacker report: https://ghostbin.com/paste/6kho7
- Network Infiltration:
  - Vulnerable internet facing network device
  - Linux based, non-Domain joined
- Internal Recon:
  - Passive scans: Eavesdropping on adjacent computers' network traffic
    - Using Responder
  - Active scans
    - NMAP scan: Discovered NAS with no authentication required
- Domain infiltration
  - NAS contained a backup of VM
  - Attackers extracted domain credentials from VM Disk
  - Connected to the live VM using these creds

```
----[ 5.3 - Technical Exploitation ]----------------------------------------

After the Gamma Group hack, I described a process for searching for
vulnerabilities [1]. Hacking Team had one public IP range:
inetnum:        93.62.139.32 - 93.62.139.47
descr:          HT public subnet

Hacking Team had very little exposed to the internet. For example, unlike
Gamma Group, their customer support site needed a client certificate to
connect. What they had was their main website (a Joomla blog in which Joomscan
[2] didn't find anything serious), a mail server, a couple routers, two VPN
appliances, and a spam filtering appliance. So, I had three options: look for
a 0day in Joomla, look for a 0day in postfix, or look for a 0day in one of the
embedded devices. A 0day in an embedded device seemed like the easiest option,
and after two weeks of work reverse engineering, I got a remote root exploit.
```

```
--[ 7 - Watch and Listen ]---------------------------------------------------

Now inside their internal network, I wanted to take a look around and think
about my next step. I started Responder.py in analysis mode (-A to listen
without sending poisoned responses), and did a slow scan with nmap.
```

```
Nmap scan report for ht-synology.hackingteam.local (192.168.200.66)
...
3260/tcp open  iscsi?
| iscsi-info:
|   Target: iqn.2000-01.com.synology:ht-synology.name
|     Address: 192.168.200.66:3260,0
|_    Authentication: No authentication required
```

```
$ losetup /dev/loop0 Exchange.hackingteam.com-flat.vmdk
$ fdisk -l /dev/loop0
/dev/loop0p1            2048  1258287103   629142528    7  HPFS/NTFS/exFAT

so the offset is 2048 * 512 = 1048576
$ losetup -o 1048576 /dev/loop1 /dev/loop0
$ mount -o ro /dev/loop1 /mnt/exchange/
```

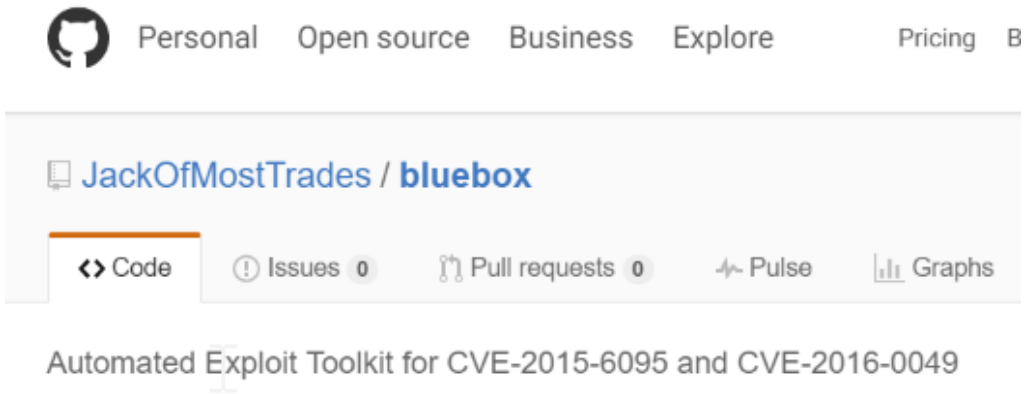
```
 SC_BlackBerry MDS Connection Service
0000   16 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00    ................
0010   62 00 65 00 73 00 33 00 32 00 36 00 37 00 38 00    b.e.s.3.2.6.7.8.
0020   21 00 21 00 21 00 00 00 00 00 00 00 00 00 00 00    !.!.!...........
```

# Translating “Evil Maid” to “Remote Butler”

- Logon UI view and access
  - Physical access → RDP access
- Rogue DC
  - Raspberry Pi → Breached machine
- Replacing original DC with a rogue DC
  - Network cable → routing manipulation
- Additional problems
  - Remote Butler is just an initial stage in the larger Cyber Kill Chain
  - It must be stealthy!

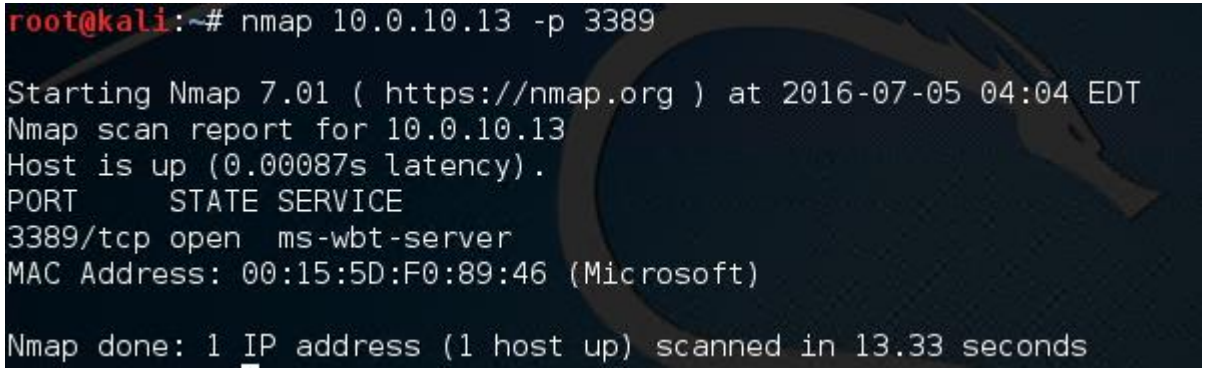
# Remote Butler: Network Infiltration

- Attackers breach a non-domain joined machine on the internal network
- Attackers install the needed rogue DC functionality on the breached machine
  - Change Password
  - Kerberos Authentication



# Remote Butler: Internal Reconnaissance

- Attackers scan for open RDP ports
- Attackers monitor adjacent Domain joined computers' traffic
- Find targets:
  - Traffic is hijackable
  - RDP is open
  - Victim user is not active (otherwise malicious RDP connection will kick him out)

# Remote Butler: Domain infiltration

- Attackers hijack the victim machine traffic to DC
  - ARP Spoofing, DNS poisoning, or just answering before original DC
- Attackers connect via RDP to victim machine
- Attackers configure the rogue DC with the victim's domain name
  - the name can be easily found by looking at the RDP UI
- Attackers perform "Evil Maid" to poison Cached Credentials
- Attackers take over
  - If needed, attackers can escalate privileges via a malicious Group Policy update (MS16-072)
  - Dump domain creds from memory (and HD)
  - Can return to the computer with the Domain compromised credentials, no RAT is needed

# Remote Butler: Domain Creds

- Attackers get the original user keys!
- This is the regular behavior of a password change, old password keys remain in LSASS memory





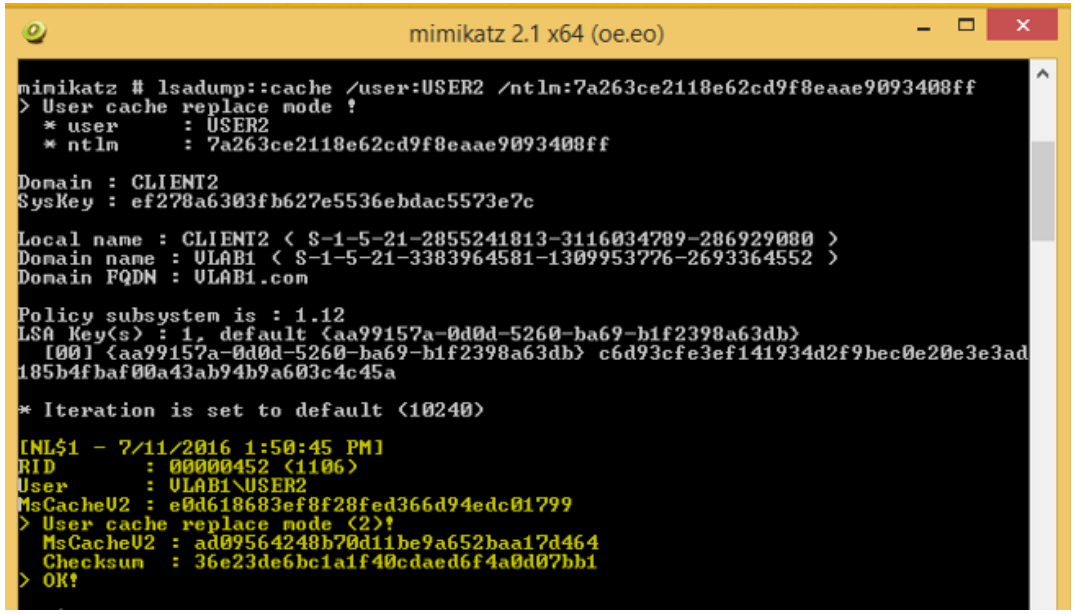
| Passwords: | NTLM Hashes: |
| --- | --- |
| abc123ABC | 7A263CE2118E62CD9F8EAAE9093408FF |
| b | A047EE4A9DB8BC8B4F3F8A03D72DEB80 |

# Remote Butler: Clean-Up

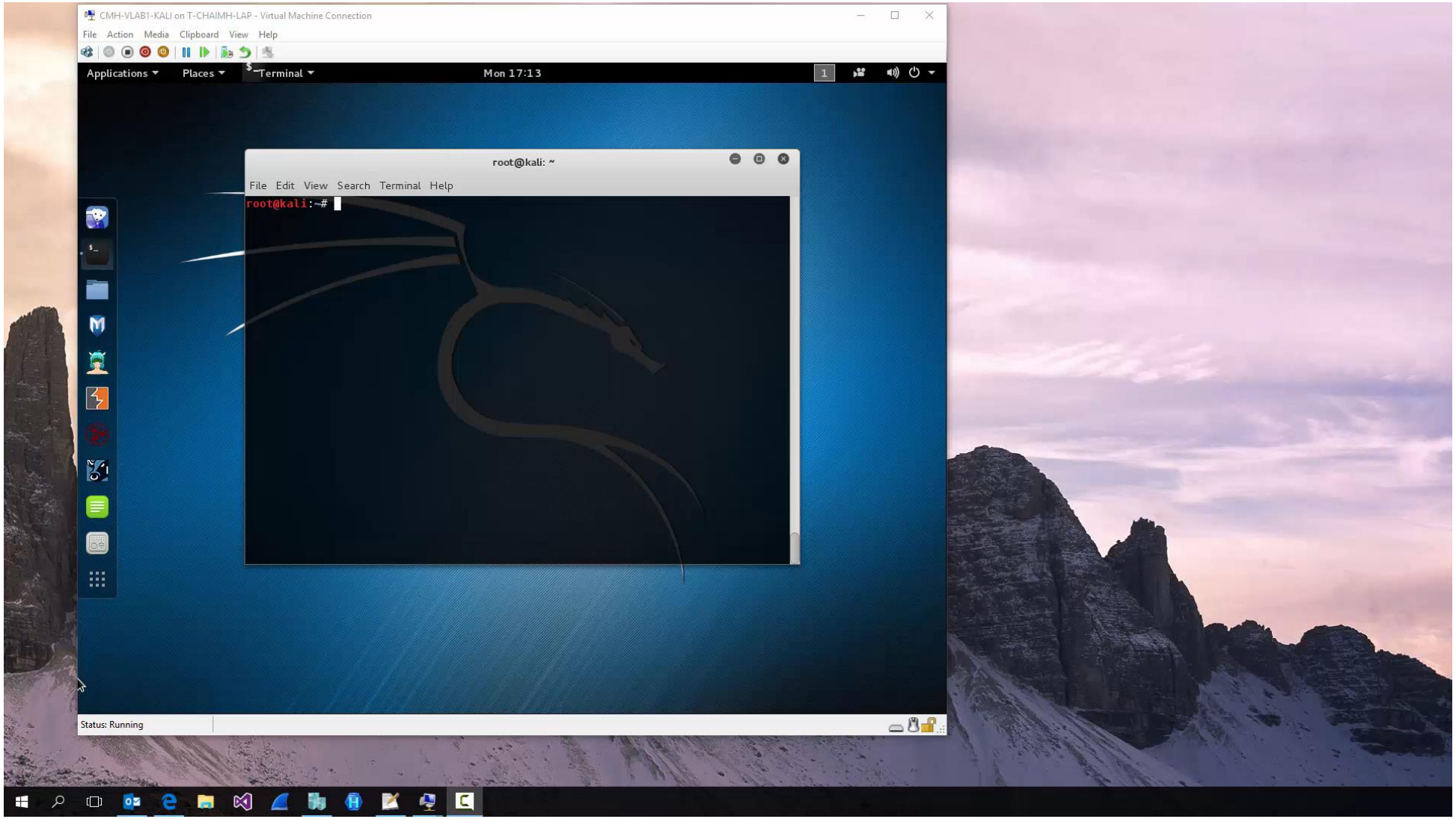
- Attackers change DC's routing back to its original state
- Original DC and Victim user are not aware that the password was changed
- When the victim user connects to victim machine using the "old" password:
  - Authentication is successful
  - Cached Credentials gets updated with the "old" password
- Nothing happened! (besides a compromised domain ☹ )
- But what if the victim user wants to logon outside of the domain?

# Remote Butler: Even Better Clean-Up

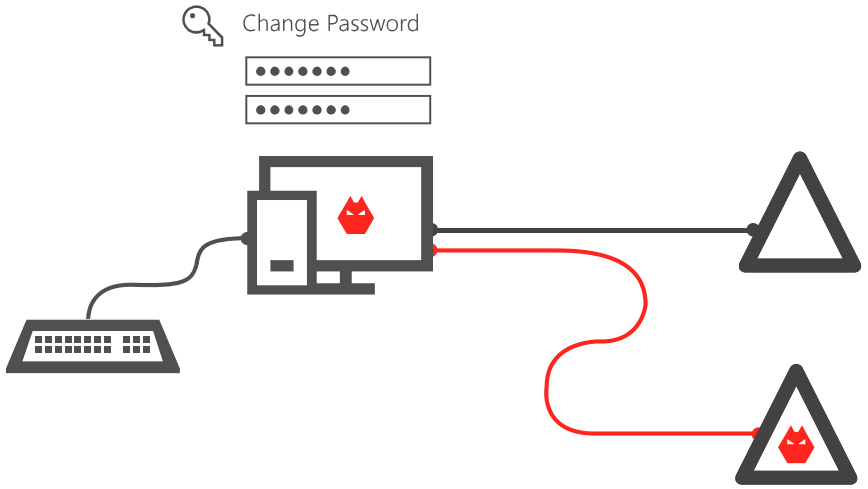
- Cached Credentials
  - PBKDF2_SHA(MD4 (MD4(password)+lowercase(user), iterations )
- Recall that NT hash = MD4(password)
- Attackers have all the ingredients!
  - They also have the tool for it: Mimikatz!
- Now, the victim user will be able to connect logon outside of the domain!



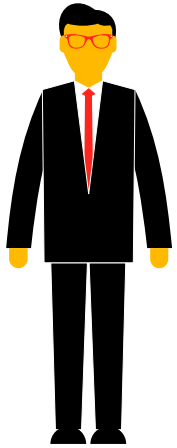
# Demo Time!

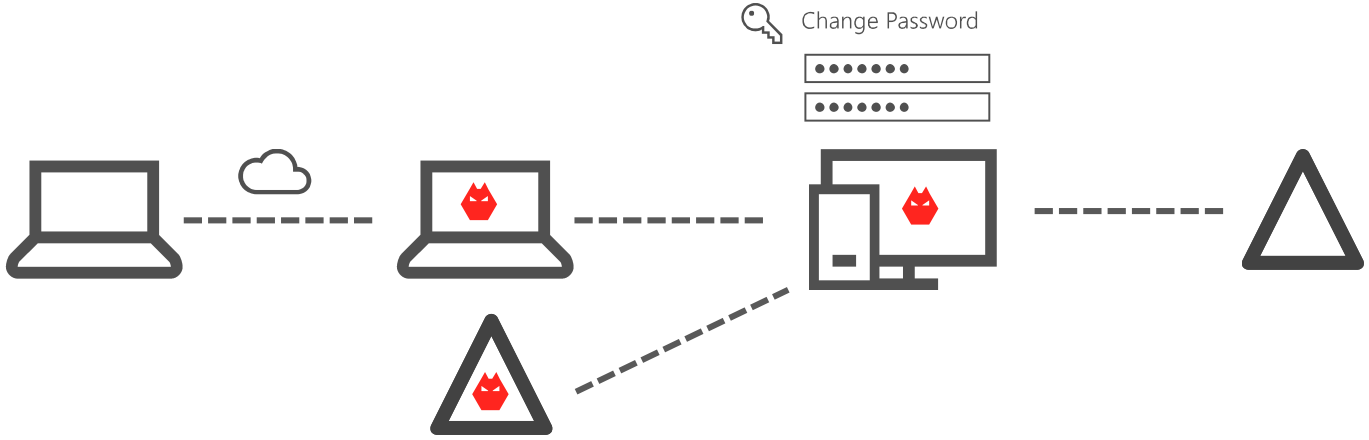

CMH-VLAB1-KALI on T-CHAIMH-LAP - Virtual Machine Connection
File Action Media Clipboard View Help
Applications Places Terminal Mon 17:13
root@kali: ~
File Edit View Search Terminal Help
root@kali:~#
Status: Running

Evil
Maid



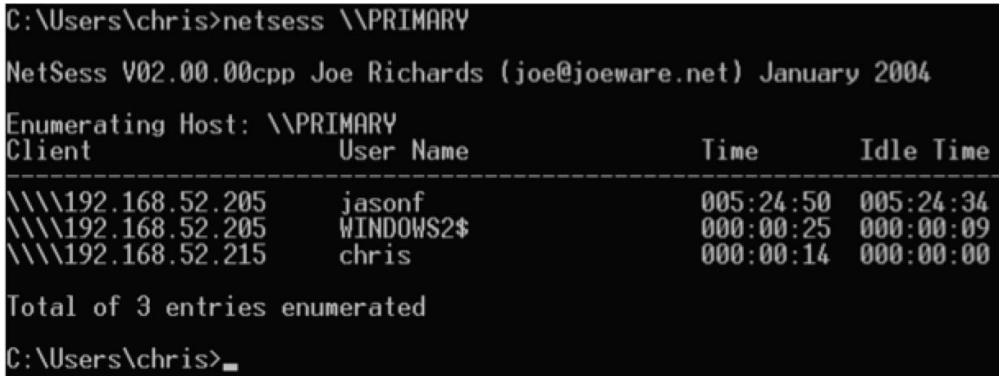

Evil
Butler

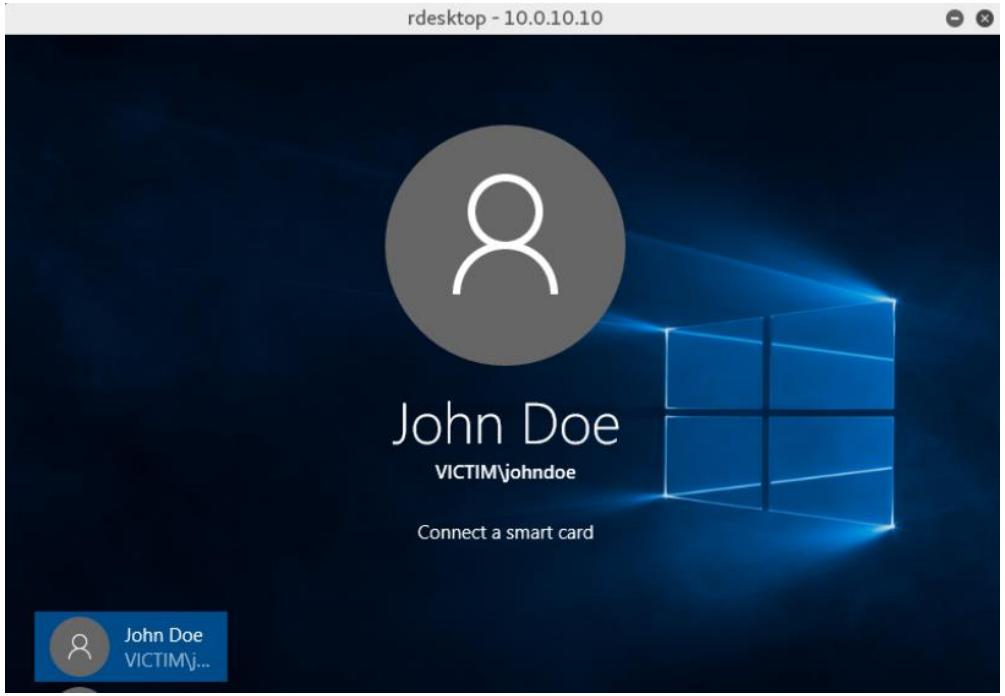




# Attackers' Motivation: Domain to Admin

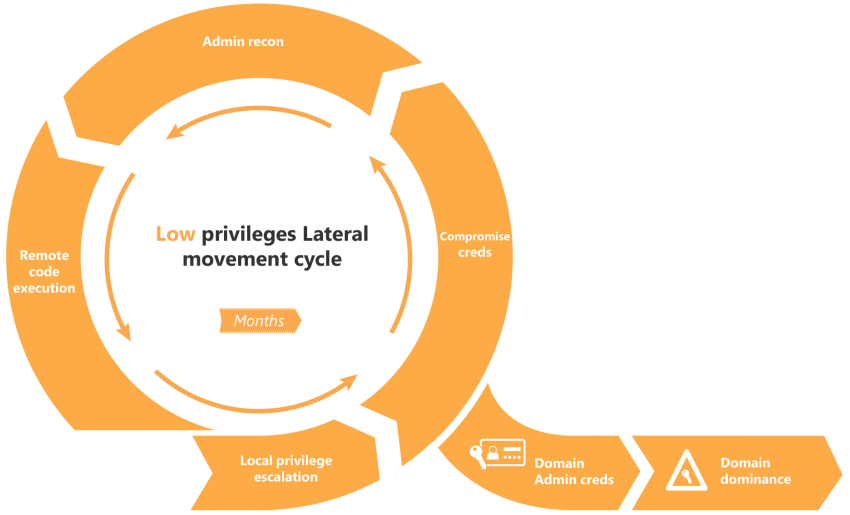
- Admin reconnaissance
- Domain user/computer/group enumeration:
  - "Net user /domain"
  - "Net group /domain"
  - "Net group "domain admins" /domain"
- User to machine mapping:
  - SMB session enumeration to DC ("Netsess")
  - RDP logon user UI!
- Attackers search for computers in which interesting users logged-on
- Attackers try to move to these machines using stolen credentials or "Remote Butler"



# Remote Butler for Lateral Movement

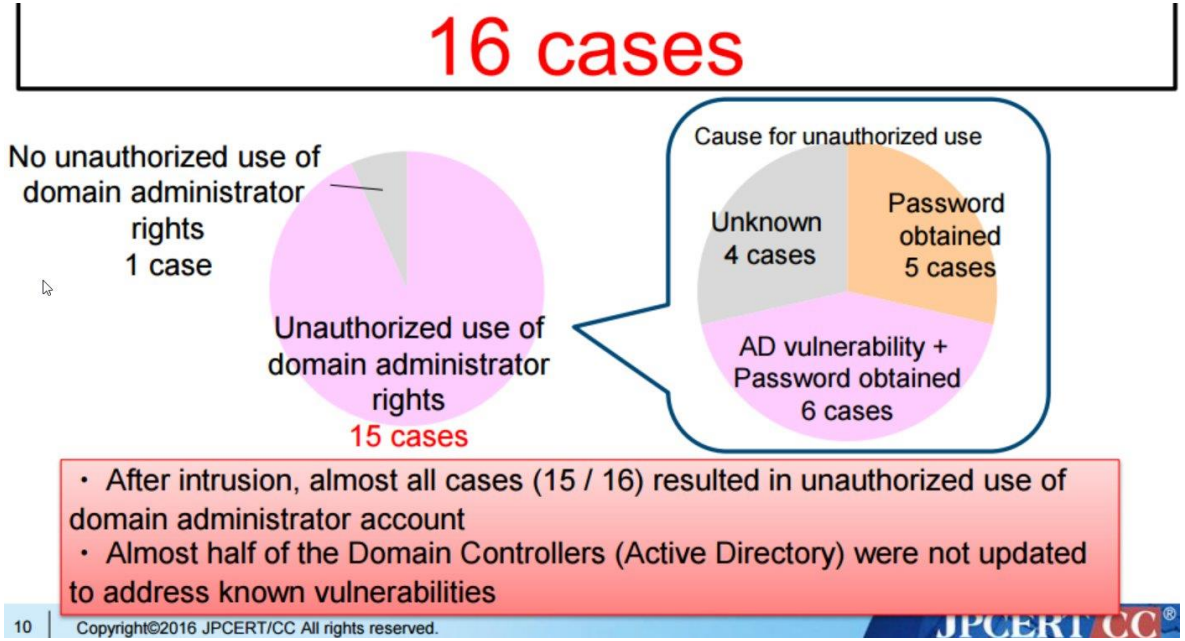
- Hijack adjacent nodes' traffic to DC to move from one Domain Joined Machine to another
  - Admin Recon: RDP Recon
  - Remote Code Execution: Remote Butler
  - Local Privilege Escalation: Rogue Group Policy
  - Compromised Creds: Extract from memory / disk (Mimikatz)



# Defending

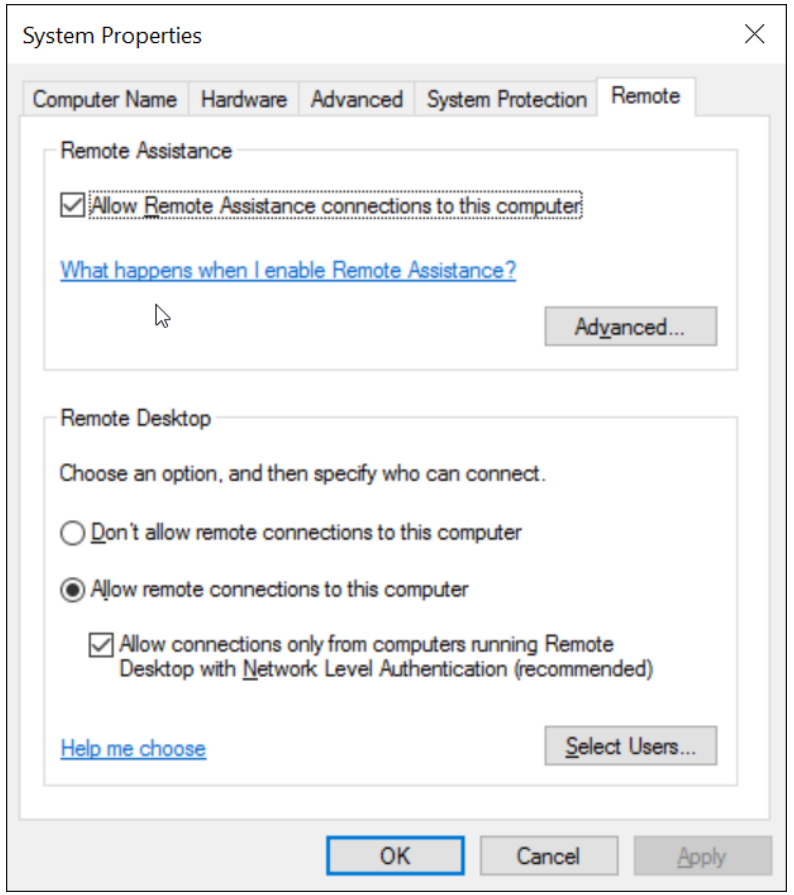
# Install updates!

- DC MITM patches since 2015 (partial list)
  - JASBUG: MS15-011 & MS15-014
  - “Evil Maid”: MS15-122 & MS16-014 & MS16-072
  - Badlock: MS16-047



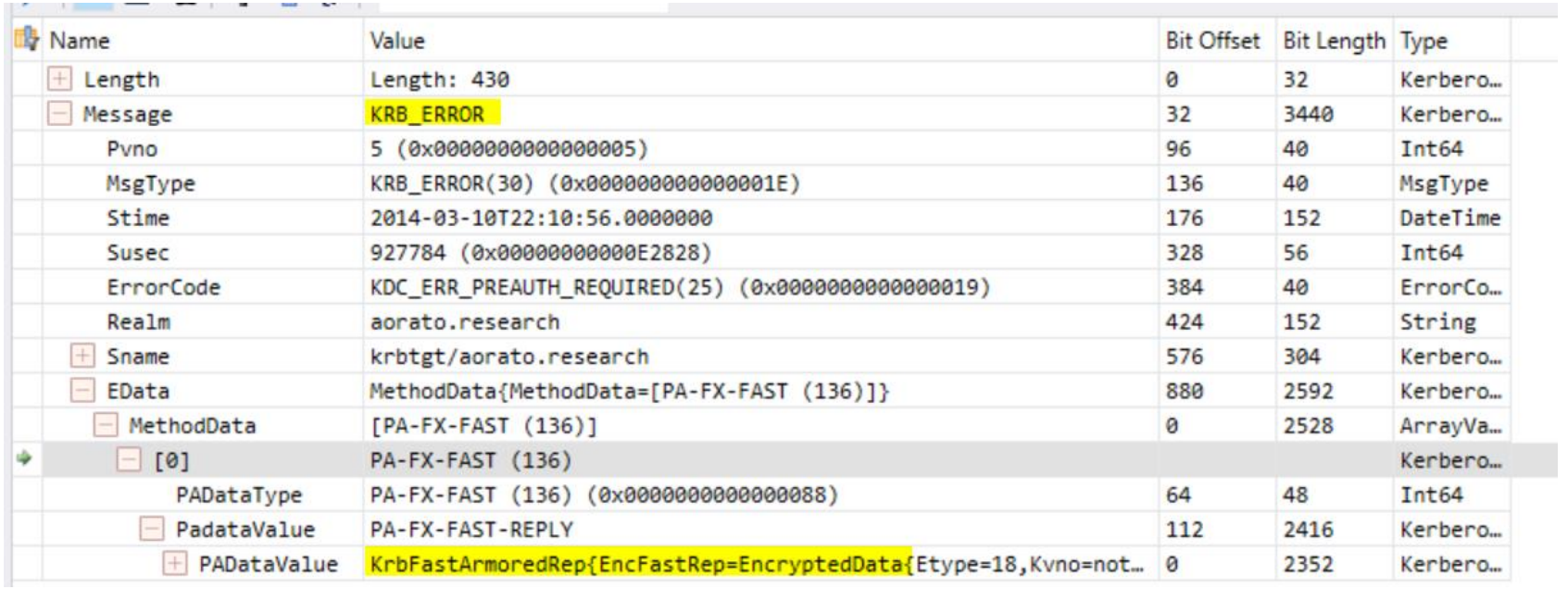
# Hardening: RDP

- RDP hardening with NLA (Network Level Authentication)
- Remote user must Authenticate and get Authorization **before** an RDP session established
- Prevents Network to Domain escalation



# Hardening: Kerberos Armoring

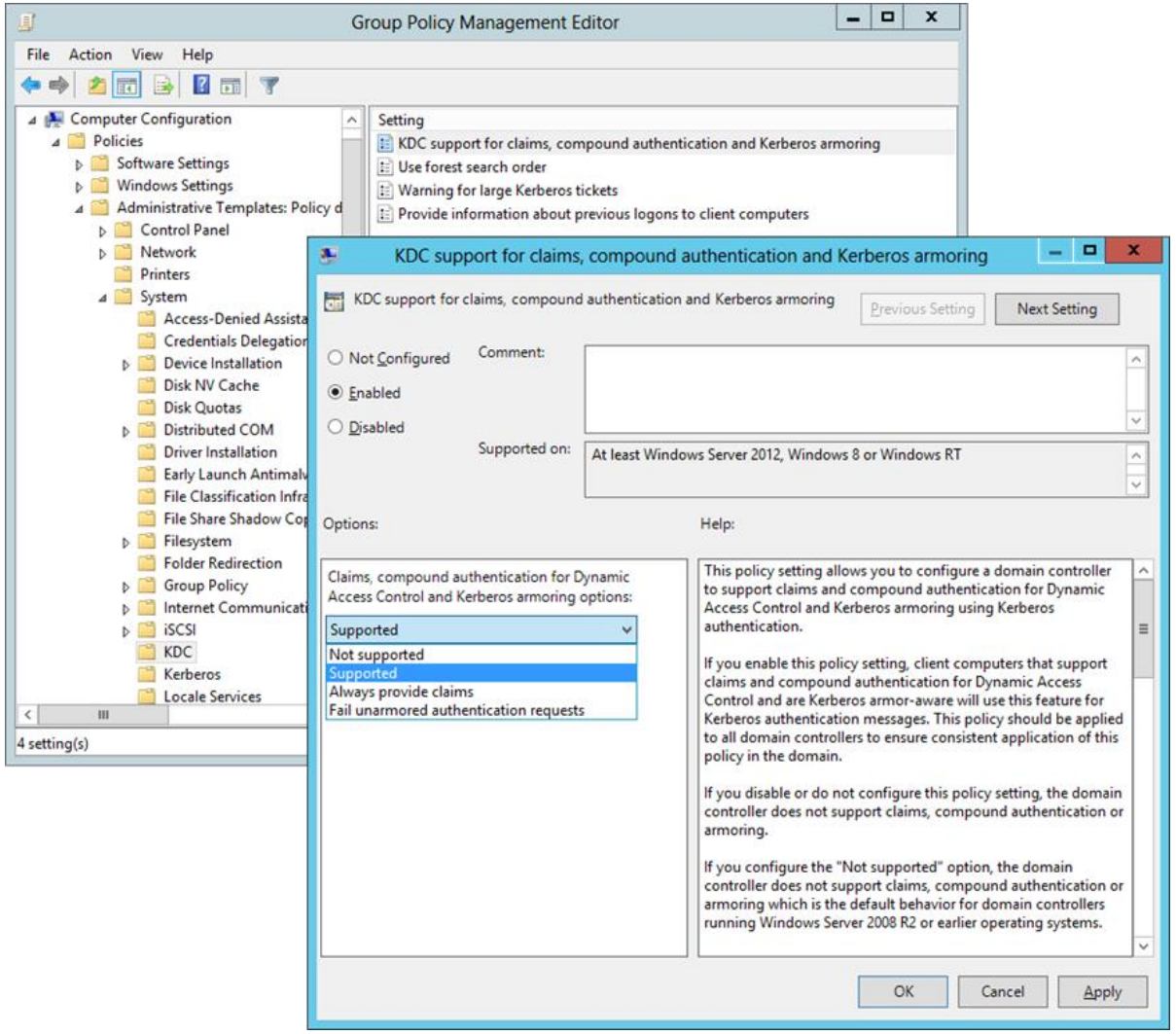
- The computer's Kerberos session key protects the user's Kerberos messages
  - Kerberos errors gets signed with the computer's session key
  - User authentication is encrypted with computer's session key
- Each prevents "Evil Maid"/"Remote Butler", as attackers don't have the computer's credentials / keys



| Name | Value | Bit Offset | Bit Length | Type |
|---|---|---|---|---|
| Length | Length: 430 | 0 | 32 | Kerbero… |
| Message | KRB_ERROR | 32 | 3440 | Kerbero… |
| Pvno | 5 (0x0000000000000005) | 96 | 40 | Int64 |
| MsgType | KRB_ERROR(30) (0x000000000000001E) | 136 | 40 | MsgType |
| Stime | 2014-03-10T22:10:56.0000000 | 176 | 152 | DateTime |
| Susec | 927784 (0x00000000000E2828) | 328 | 56 | Int64 |
| ErrorCode | KDC_ERR_PREAUTH_REQUIRED(25) (0x0000000000000019) | 384 | 40 | ErrorCo… |
| Realm | aorato.research | 424 | 152 | String |
| Sname | krbtgt/aorato.research | 576 | 304 | Kerbero… |
| EData | MethodData{MethodData=[PA-FX-FAST (136)]} | 880 | 2592 | Kerbero… |
| MethodData | [PA-FX-FAST (136)] | 0 | 2528 | ArrayVa… |
| [0] | PA-FX-FAST (136) | | | Kerbero… |
| PADataType | PA-FX-FAST (136) (0x0000000000000088) | 64 | 48 | Int64 |
| PadataValue | PA-FX-FAST-REPLY | 112 | 2416 | Kerbero… |
| PADataValue | KrbFastArmoredRep{EncFastRep=EncryptedData{Etype=18,Kvno=not… | 0 | 2352 | Kerbero… |

# Hardening: Kerberos Armoring (Cont.)

- Available since Windows 8, Server 2012



# Defense in Depth

- Remember: each step in a targeted attack is just a link in the Cyber attack Kill-chain
- Defenders can break the chain, by breaking ANY of the links
- Even if Defenders miss a step
  - For example, Remote Butler attack to escalate Network Infiltration to Domain Infiltration
- They can still catch the next step

# Parting Thoughts

# New Contributions

- Remote Butler: Extended the “Evil Maid” exploit to fit advanced attacks’ scenarios, by addressing:
  - Access over RDP
  - Rogue DC as a malware’s payload
  - Rogue DC connection with routing manipulations
  - Domain compromised credentials
  - Stealthy cleanup
- Additional contributions
  - RDP reconnaissance attack vector
- Defense
  - Applying Kerberos Armoring defeats Rogue DC “Evil Maid” attacks

# Conclusions

- Local “Evil Maid” is very cool…
- …But Remote Butler is also very practical
  - **Part of the Cyber attack Kill-chain**
- Rogue DC attacks are vast and relevant
- Solutions:
  - **Patching!**
  - **Hardening!**
  - **Defense in Depth!**

# Credits and Thanks

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  - Tom Gillis @tgilis
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# Questions?