CMPSC 447
Anatomy of an Attack

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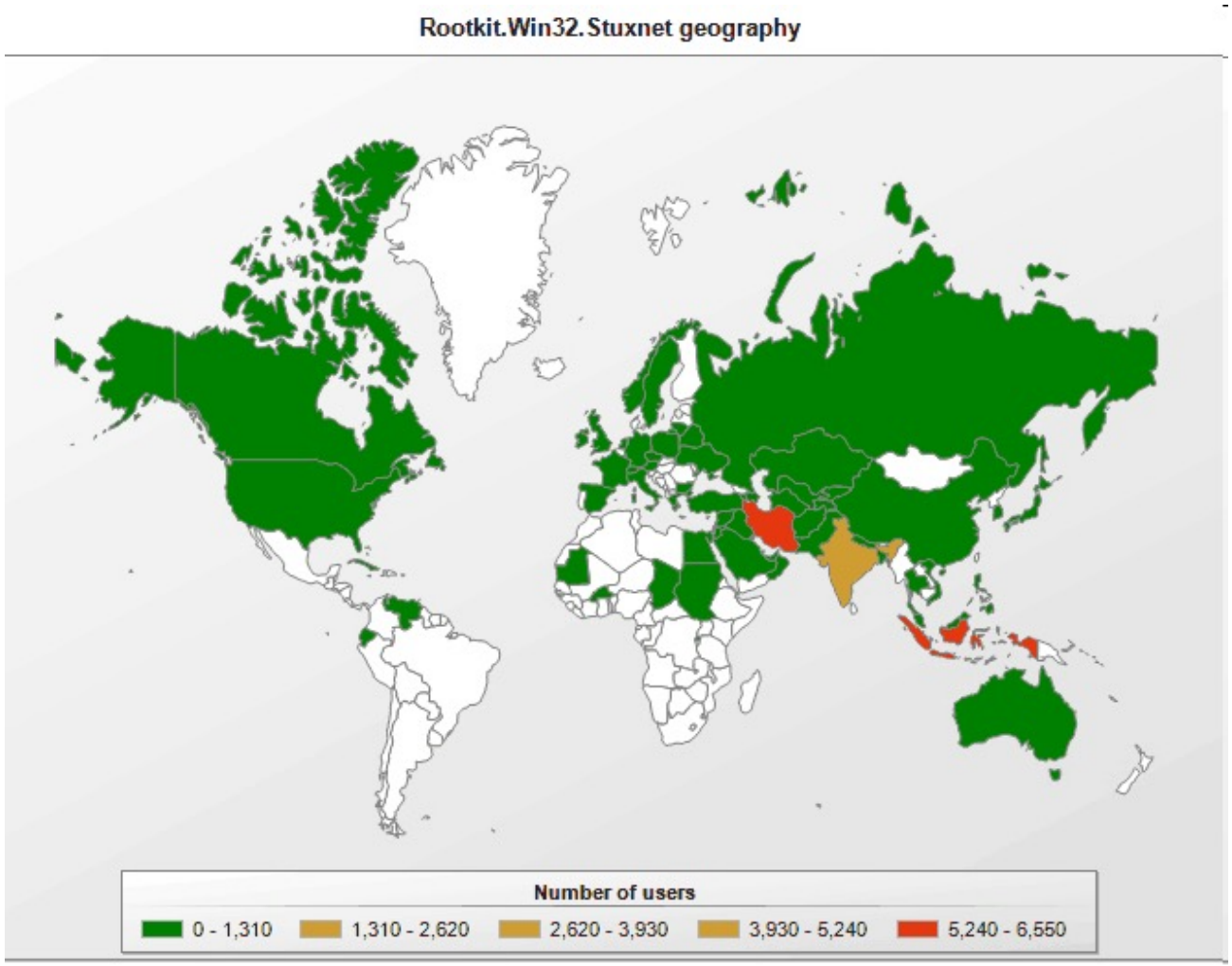
Adversarial Operations

- We have examined a variety of attack types
  - Question: How do adversaries really use such attacks in practice to execute attacks
- Today, we examine one of the more elaborate attacks executed
  - Where we have a good idea how it performed
- Then, we will examine the what defenders think about how attacks proceed
  - MITRE ATT&CK

Real World Example: Stuxnet Worm



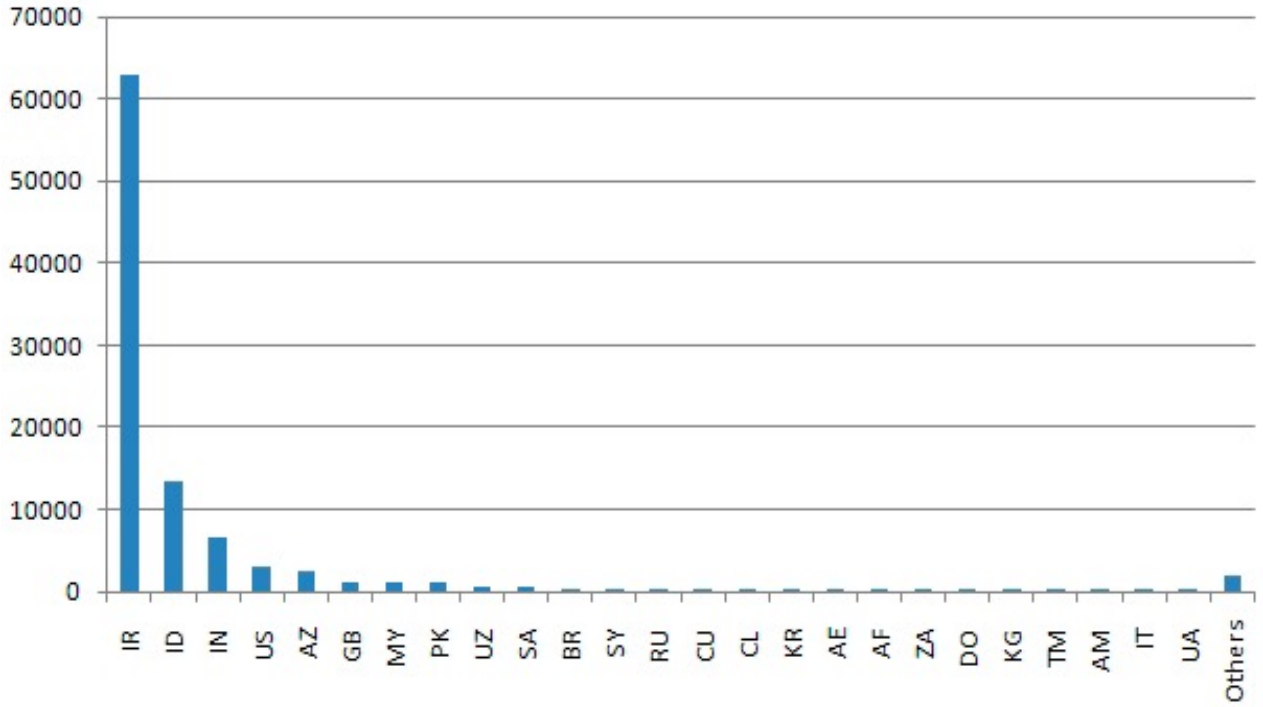
Slides by pmateti@wright.edu from many sources

Stuxnet: Overview

- June 2010: A worm targeting Siemens WinCC industrial control system.
- Targets high speed variable-frequency programmable logic motor controllers from just two vendors: Vacon (Finland) and Fararo Paya (Iran)
- Only when the controllers are running at 807Hz to 1210Hz. Makes the frequency of those controllers vary from 1410Hz to 2Hz to 1064Hz.
- http://en.wikipedia.org/wiki/Stuxnet

Stuxnet Infection Statistics

- 29 September 2010, From Symantec
- Infected Hosts



Industrial Control Systems (ICS)

- ICS are operated by a specialized, assembly-like code on programmable logic controllers (PLCs).
- The PLCs are programmed typically from Windows computers (PCs).
- The ICS are not connected to the Internet – even the PCs used.
- ICS usually consider availability and ease of maintenance first and security last.
- ICS consider the "airgap" as sufficient security.

Seimens SIMATIC PLCs

Nuclear Centrifuges

- Uranium-235 separation efficiency is critically dependent on the centrifuges' speed of rotation
- Separation is theoretically proportional to the peripheral speed raised to the 4th power. So any increase in peripheral speed is helpful.
- That implies you need strong tubes, but brute strength isn't enough: centrifuge designs also run into problems with "shaking" as they pass through naturally resonant frequencies
  - "shaking" at high speed can cause catastrophic failures to occur.
  - www.fas.org/programs/ssp/nukes/fuelcycle/centrifuges/engineering.html

Timeline

- 2009 June: Earliest Stuxnet seen
  - Does not have signed drivers
- 2010 Jan: Stuxnet driver signed
  - With a valid certificate belonging to Realtek Semiconductors

- 2010 June: Virusblokada reports W32.Stuxnet
  - Verisign revokes Realtek certificate
- 2010 July: Anti-virus vendor Eset identifies new Stuxnet driver
  - With a valid certificate belonging to JMicron Technology Corp
- 2010 July: Siemens report they are investigating malware SCADA systems
  - Verisign revokes JMicron certificate

Stuxnet: Tech Overview

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- Components used
  - Zero-day exploits
  - Windows rootkit
  - PLC rootkit (first ever)
  - Antivirus evasion
  - Peer-to-Peer updates
  - Signed driver with a valid certificate
- Command and control interface
- Stuxnet consists of a large .dll file
- Designed to sabotage industrial processes controlled by Siemens SIMATIC WinCC and PCS 7 systems.

Stuxnet: Steps

- What do we need to know to launch an attack?
- What do we need to do to initiate an attack?
- How do we get the malware onto a disconnected host?
- How to we change the operation of the PLC?
- Without being detected?

Attack Scenario (Conjecture)

- Reconnaissance
  - Each PLC is configured in a unique manner
  - Targeted ICS's schematics needed
  - Design docs stolen by an insider?
  - Retrieved by an early version of Stuxnet
  - Stuxnet developed with the goal of sabotaging a specific set of ICS.
- Development
  - Mirrored development environment needed
    - ICS Hardware
    - PLC modules
    - PLC development software
  - Estimation
    - 6+ man-years by an experienced and well-funded development team

Attack Scenario (2)

- The malicious binaries need to be signed to avoid suspicion
  - Two digital certificates were compromised.
  - High probability that the digital certificates/keys were stolen from the companies' premises.
  - Realtek and JMicron are in close proximity.
- Initial Infection
  - Stuxnet needed to be introduced to the targeted environment
    - Insider
    - Third party, such as a contractor
  - Delivery method
    - USB drive
    - Windows Maintenance Laptop
    - Targeted email attack

Attack Scenario (3)

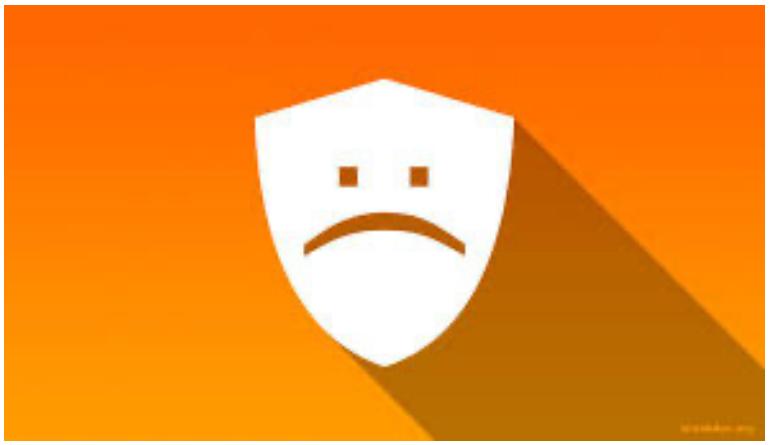
- Infection Spread
  - Look for Windows computer used to program the PLC's
    - The Field PG are typically not connected to network
    - Spread the Infection on computers on the local LAN
      - Zero-day vulnerabilities
      - Two-year old vulnerability
      - Spread to all available USB drives
  - When a USB drive is connected to the Field PG, the Infection jumps to the Field PG
    - The "airgap" is thus breached

Attack Scenario (4)

- Target Infection of Field PG
  - Look for Specific PC
    - Running Step 7 Operating System
  - Change PLC code
    - Sabotage system
    - Hide modifications
  - Command and Control may not be possible
    - Due to the “airgap”
    - Functionality already embedded

Bypassing Intrusion Detection

- Antivirus software monitors library calls
  - Especially for loads of new libraries
  - How evade that? And stay away from detection?



Bypassing Intrusion Detection

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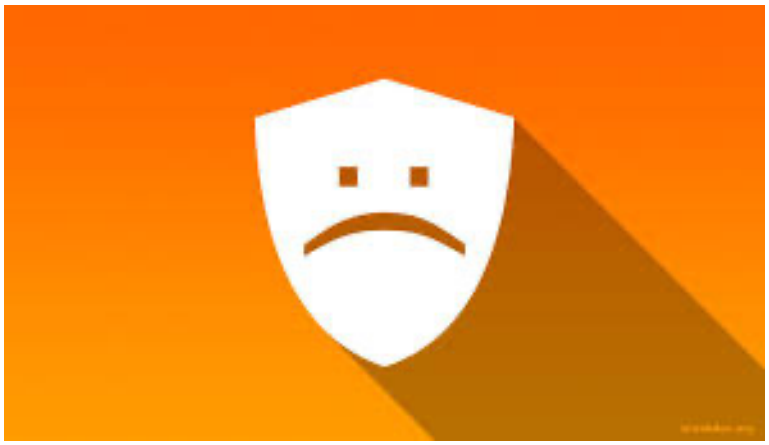
- Stuxnet calls LoadLibrary
  - With a specially crafted file name that does not exist
  - Which causes LoadLibrary to fail.
- However, W32.Stuxnet has hooked Ntdll.dll
  - To monitor specially crafted file names.
  - Mapped to a location specified by W32.Stuxnet.
  - Where a .dll file was stored by the Stuxnet previously.

Code Injection

- Stuxnet accounted for trusted Windows processes or security products
  - Lsass.exe, Winlogin.exe, Svchost.exe
  - Kaspersky KAV (avp.exe), Mcafee (Mcshield.exe), AntiVir (avguard.exe)
  - BitDefender (bdagent.exe), Etrust (UmxCfg.exe), F-Secure (fsdfwd.exe)
  - Symantec (rtvscan.exe), Symantec Common Client (ccSvcHst.exe)
  - Eset NOD32 (ekrn.exe), Trend Pc-Cillin (tmpproxy.exe)
- Stuxnet detects the version of the security product and based on the version number adapts its injection process

Guiding the Malware

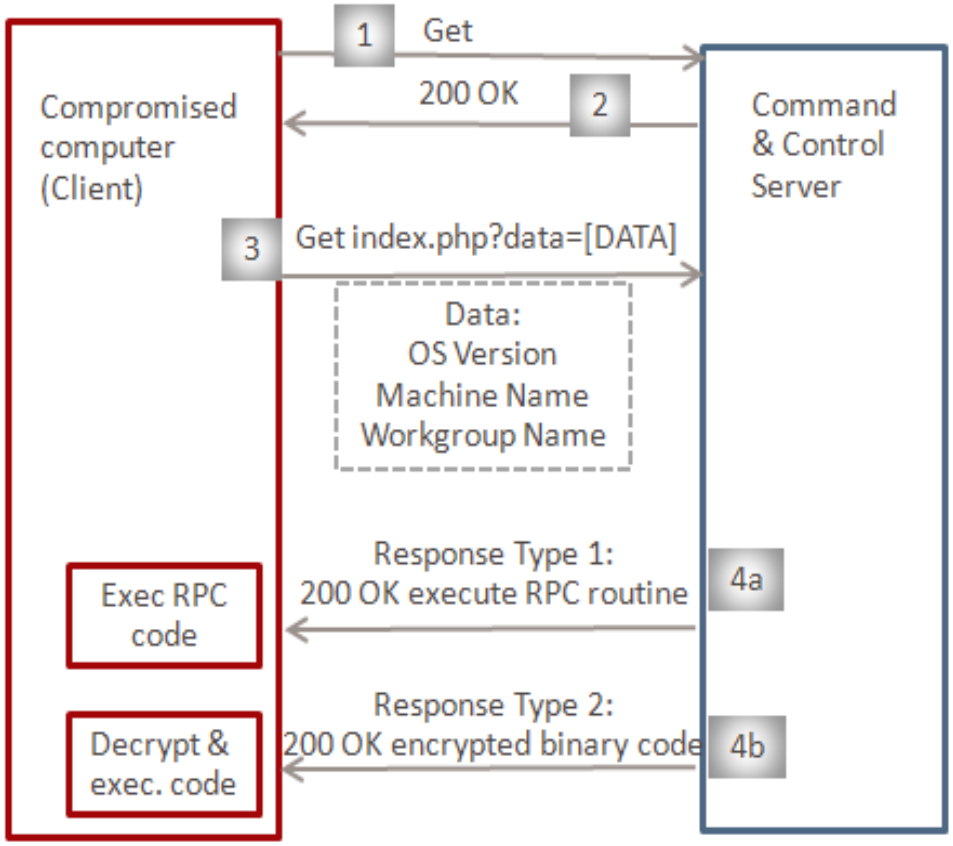
- The malware may need to reconfiguration to propagate the attack
  - How do we do that?



Command & Control

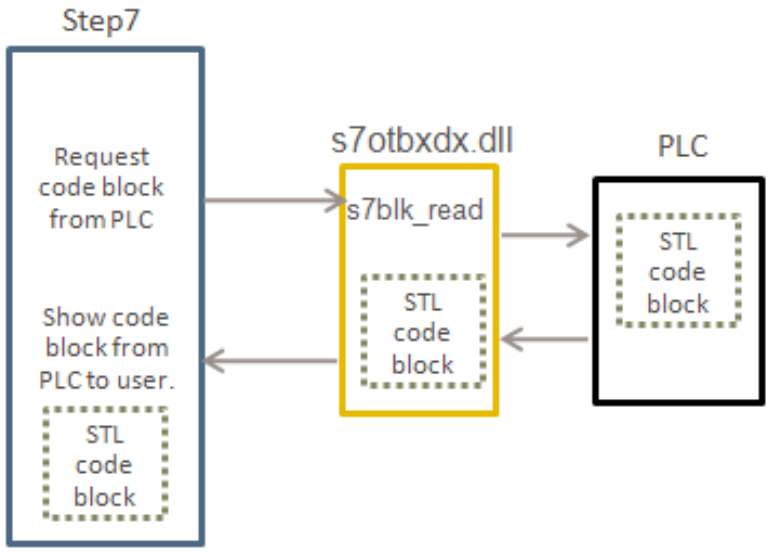
- Stuxnet tests if it can connect to
  - www.windowsupdate.com
  - www.msn.com
  - On port 80
- Contacts the command and control server
  - www.mypremierfutbol.com
  - www.todaysfutbol.com
  - The two URLs above previously pointed to servers in Malaysia and Denmark
  - Sends info about the compromised computer

Command & Control (2)



1 & 2: Check internet connectivity
3: Send system information to C&C
4a: C&C response to execute RPC routine
4b: C&C response to execute encrypted binary code

Modifying PLC code



Modifying PLC's

- The end goal of Stuxnet is to infect specific types of PLCs
- Original s7otbxdx.dll is responsible for handling exchange between the programming device and the PLC
  - By replacing this .dll file with its own, Stuxnet is able to perform the following actions:
    - Monitor PLC blocks being written to and read from the PLC
    - Infect a PLC by inserting its own blocks
    - Remove infected statements when reading from the PLC

Stuxnet Conclusion

- Stuxnet is a significant milestone in malicious code history
  - It is the first to exploit multiple zero-day vulnerabilities.
  - Used two (compromised) digital certificates.
  - Injected code into industrial control systems.
  - Hid the code from the operator for several months
- Stuxnet is of great complexity
  - Requiring significant resources to develop
- Stuxnet has highlighted that direct attacks on critical infrastructure are possible.

References

- Nicolas Falliere, Liam O Murchu, and Eric Chie, "W32.Stuxnet Dossier", February 2011, Symantec.com
- Ralph Langner, "Cracking Stuxnet, a 21st-century cyber weapon", http://www.ted.com/, Mar 31, 2011.
- Eric Byres, Andrew Ginter and Joel Langill, Stuxnet Report: A System Attack, A five part series, www.isssource.com/ stuxnet-report-a-system-attack/, March 2011
- "Cyber War, Cyber Terrorism and Cyber Espionage," http://pages.uoregon.edu/joe/cyberwar/cyberwar.ppt
- ACK: Many sources on the web. I (pmateti@wright.edu) merely assembled the slides. May 2011.

MITRE ATT&CK Framework

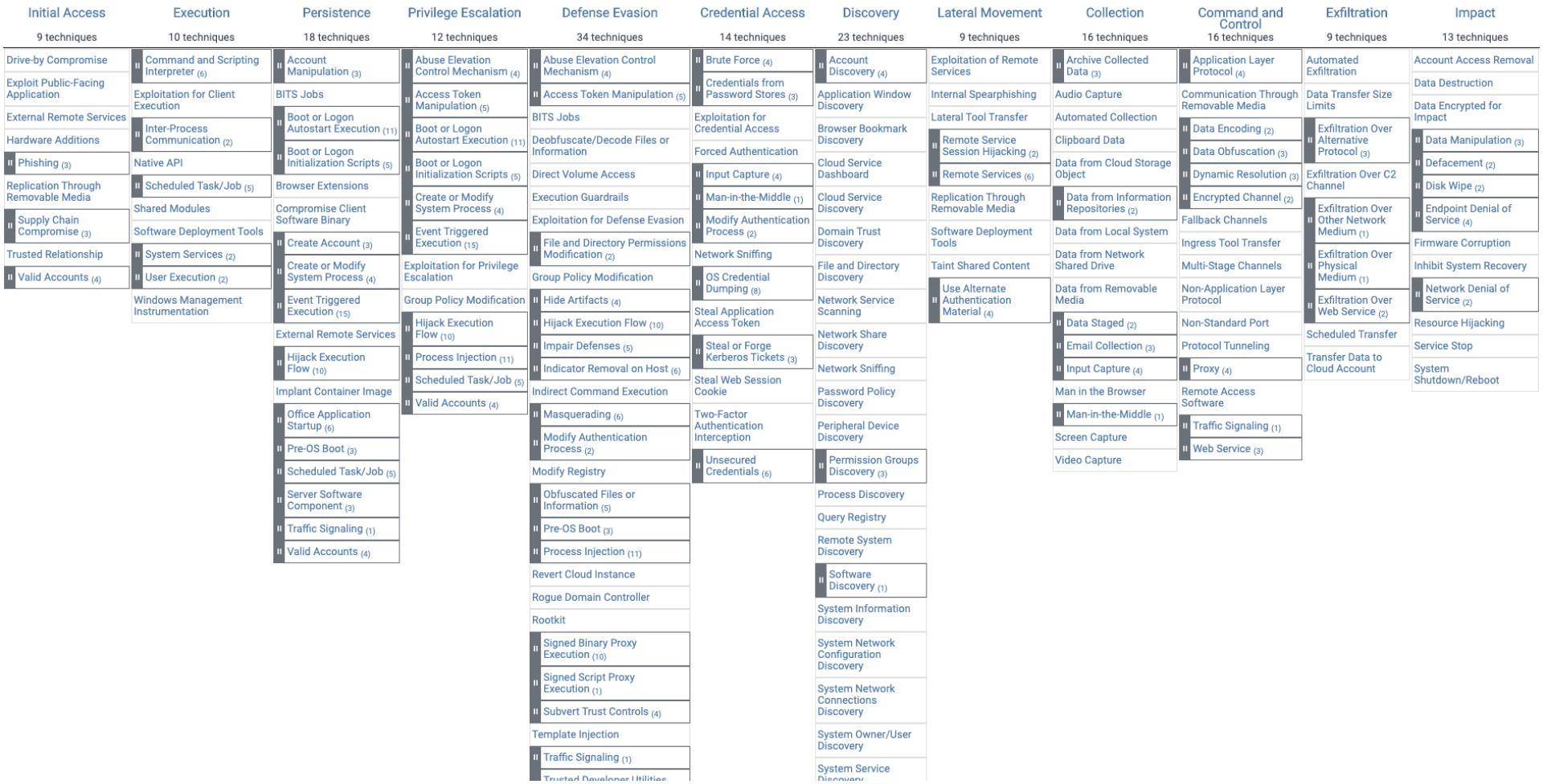
- Knowledge base of adversary tactics and techniques based on real-world observations
  - https://attack.mitre.org
- Tactics and the techniques adversaries may use to implement those tactics
  - And mitigations for those techniques
  - Hopefully, helping defenders to prevent and detect attacks

MITRE ATT&CK Framework

- MITRE ATT&CK Philosophy Document
  - https://attack.mitre.org/docs/ATTACK_Design_and_Philosophy_March_2020.pdf
- Originated out of a project to document and categorize post-compromise adversary tactics and techniques
  - And procedural methods to implement techniques
- Ideally, a defender would have coverage for all attack tactics and techniques (attack coverage)
  - But "is unrealistic", so monitor where use is possible

ATT&CK Matrix

- MITRE ATT&CK Matrix
  - https://attack.mitre.org/matrices/enterprise/



ATT&CK Matrix

- Organized by tactics (columns) with techniques
  - Where there are procedures to implement techniques
- Tactics
  - Adversary's tactical objective: the reason for performing an action
- Techniques
  - "how" an adversary may achieve a tactical objective
- Procedures
  - Specific implementation of a technique

ATT&CK Tactics

- Initial Access
- Execution
- Persistence
- Privilege Escalation
- Defense Evasion
- Credential Access
- Discovery
- Lateral Movement
- Collection
- Command and Control
- Exfiltration
- Impact
- Reconnaissance
- Resource Development

ATT&CK Tactics in Action

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- Initial Access, Discovery, and Credential access
  - Gain and expand access (via secrets) in an environment
  - What was that for Stuxnet?
- Execution
  - "Execution of adversary-controlled code"
  - How Stuxnet?
- Collection and Exfiltration
  - Steal data from the domain
  - Did Stuxnet do that?

ATT&CK Tactics in Action

- Persistence and Defense Evasion
  - "to persist in the target environment" "undetected"
  - How did Stuxnet do that?
- Privilege Escalation and Lateral Movement
  - Gain more permissions in the environment and control more components of same privilege
  - How for Stuxnet?
- Command and Control
  - Method to obtain commands for malware
  - Did Stuxnet do that?

ATT&CK Matrix

- Familiarize yourself with the concepts in the ATT&CK Matrix
  - And use of each type of tactics in the matrix
- I can give you attack scenarios and ask questions about how those scenarios relate to tactics, etc.

Take Away

- Today, we examined attacks "in the large"
- From the perspective of one of the more complex attack campaigns launched
  - Stuxnet
- Stuxnet demonstrates several features of an attack
  - Articulated in the MITRE ATT&CK Framework
  - Tactics, Techniques, and Procedures
- Not practical to articulate all the attack procedures or perhaps even techniques yet