SCADA and CIP Security in a Post-Stuxnet World

The Future of Critical Infrastructure Security

Eric Byres, P.Eng.
CTO, Byres Security Inc.

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What is Stuxnet?

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The Stuxnet Worm

- **July, 2010:** Stuxnet worm was discovered attacking Siemens PCS7, S7 PLC and WIN-CC systems around the world
- Infected 100,000 computers
- Infected **at least** 22 manufacturing sites
- Appears to have impacted its possible target, Iran's nuclear enrichment program

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Great - We Weren't the Target…

- Stuxnet infected a large US manufacturing plant
  - Started with two USB keys
  - Spread over the network to 100 WinCC HMIs communicating with about 60 OPs and about 45 S7 PLCs
  - Virus would modify project communication configuration for the PLC's Ethernet ports
- Impact:
  - Major resource drain to disinfect project files
  - Plant continued to experience symptoms on PLCs one month later

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How Stuxnet Spreads

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Isn’t a Nuclear Materials System Air-Gapped?

- How could Stuxnet migrate from the Internet to an isolated industrial control system?
- Could the next worm do the same to a different victim?

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A Trivial Scenario

- **Scenario**:
  1. Joe finds a USB flash drive in the parking lot and brings it into the control room
  2. Joe plugs it into the PLC programming station
  3. PLC programming station infects PLCs
- **Solution**:
  1. Ban all USB flash drives in the control room

NOT Realistic!

Gap Analysis Methodology

- **Goal:** Understanding the routes that a directed worm takes as it targets an ICS
- **Premise:** Start with an industrial site that exactly follows the security best practices defined in vendor documents
- **Model:** Map ways that Stuxnet could make its way through the defenses to cause physical damage

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Core SIMATIC PCS 7 Control System Components

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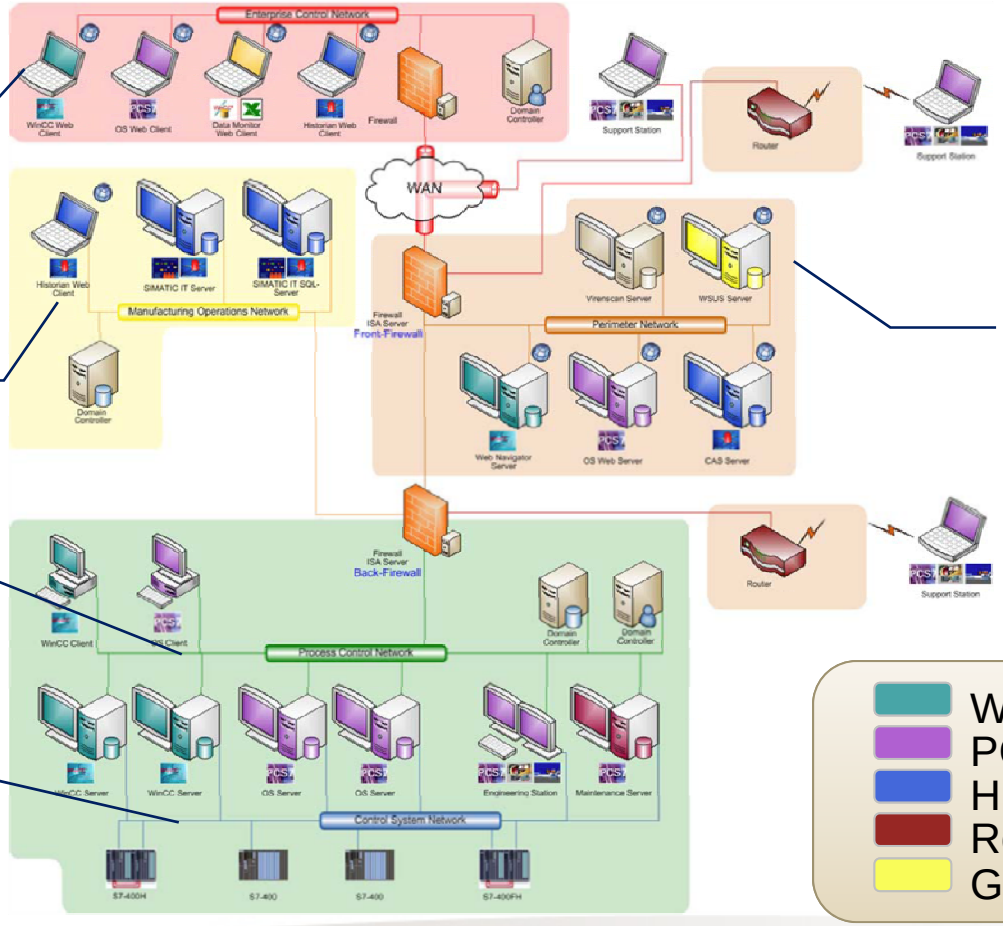
PCS 7 High Security Architecture

Enterprise Control Network

Manufacturing Operations Network

Process Control Network

Control System Network



Perimeter Control Network

WinCC
PCS7
Historian
Remote Access
General Purpose

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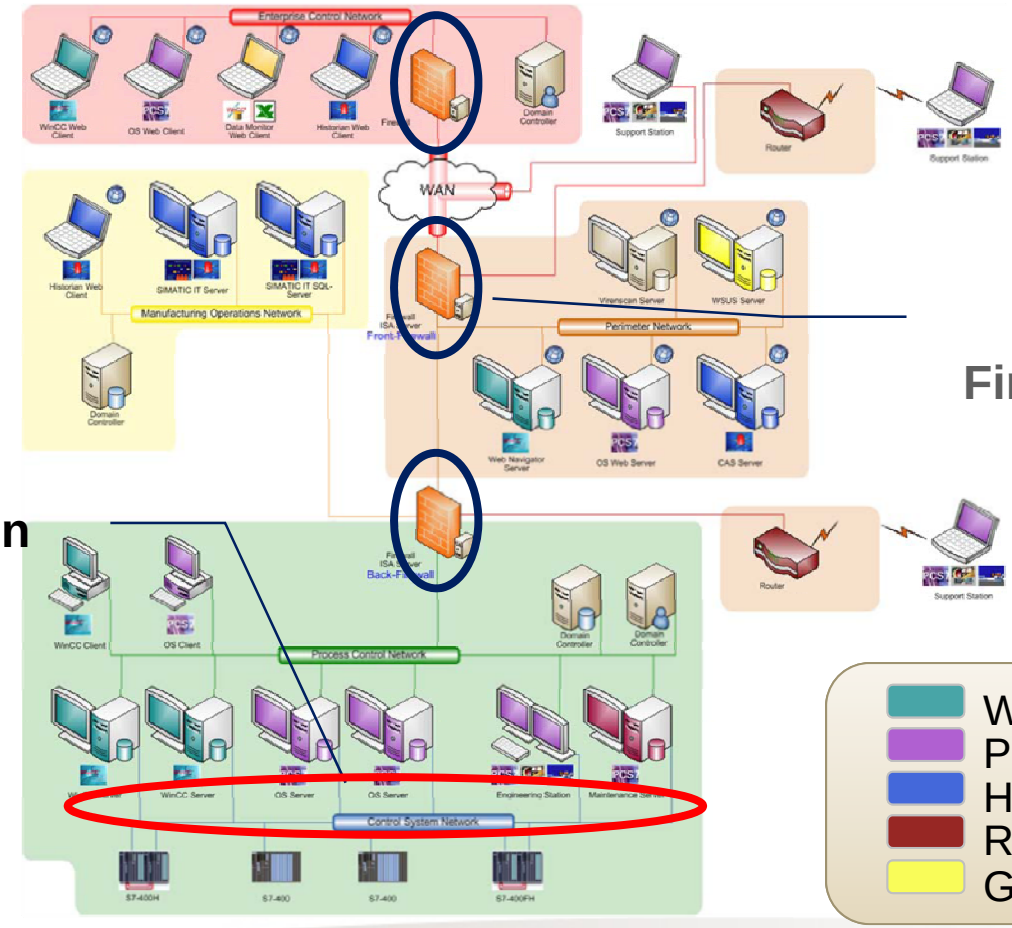
PCS 7 High Security Architecture



Identical Firewalls Here

No Firewall Between CSN and PCN

- WinCC
- PCS7
- Historian
- Remote Access
- General Purpose

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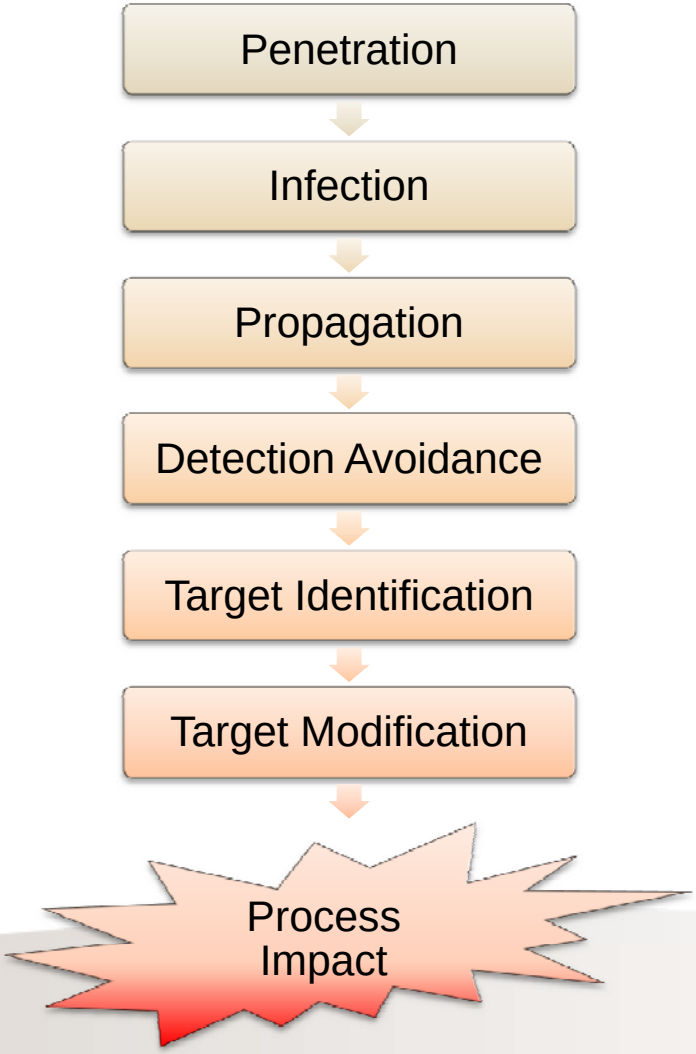
Stuxnet Phases



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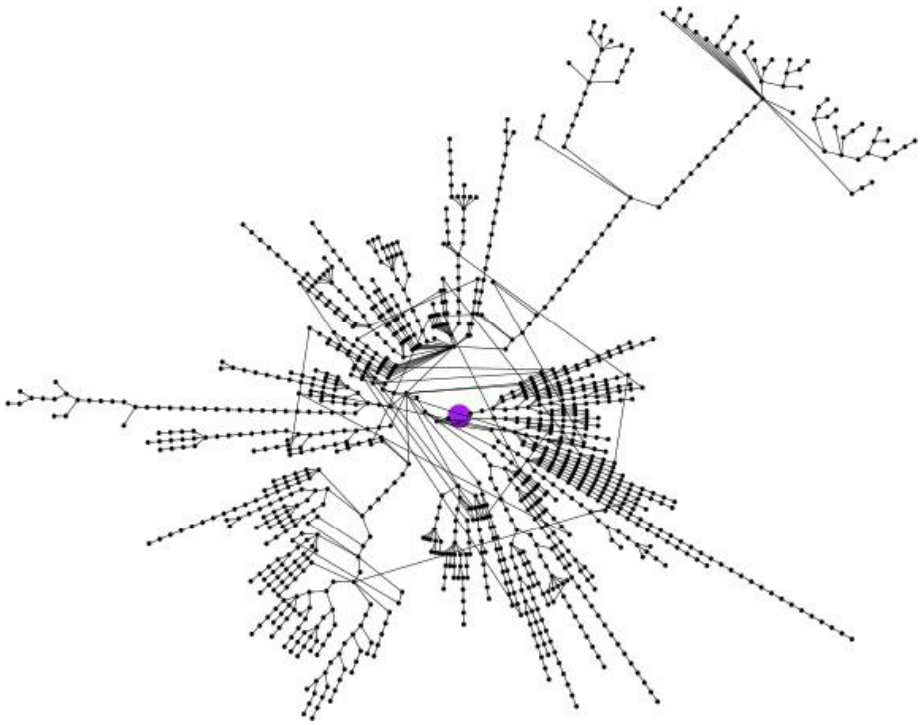
Penetration (aka Handoff to Target Organization)

- Stuxnet handoffs were highly focused
- June 2009 to May 2010 10 infiltration events
- Handoffs were made to at least five separate target organizations



Sample Graph of Infected Hosts
Domain E / Infection initiation 2010/05/11
Courtesy of Symantec Inc

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Penetration Possibilities

- Employee given infected USB flash drive
- Employee given infected project files from contractor
- Employee is transmitted email with “dropper”
- Employees laptop infected offsite

….

- Many possibilities for attackers

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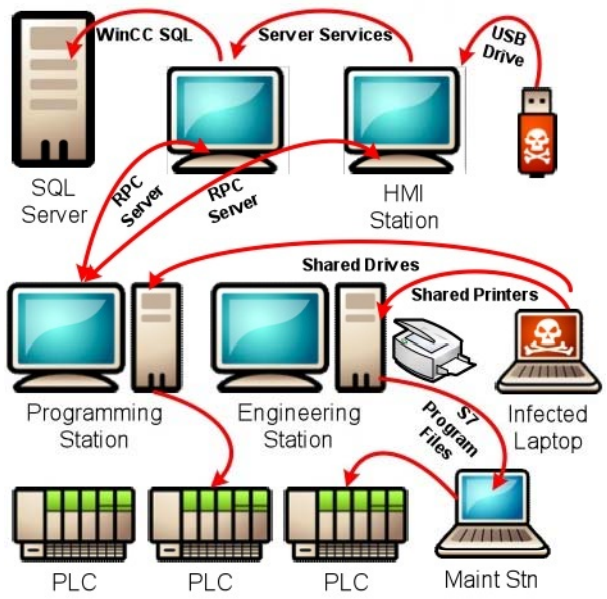
Core Propagation Methods

- Via Infected Removable Drives
  - USB flash drives
  - Portable hard disks
- Via Local Area Networks
  - Administrative and IPC Shares
  - Shared network drives
  - Print spooler services
  - SQL Connections
- Via infected Siemens project files
  - WinCC files
  - STEP 7 files



A very simplified view …

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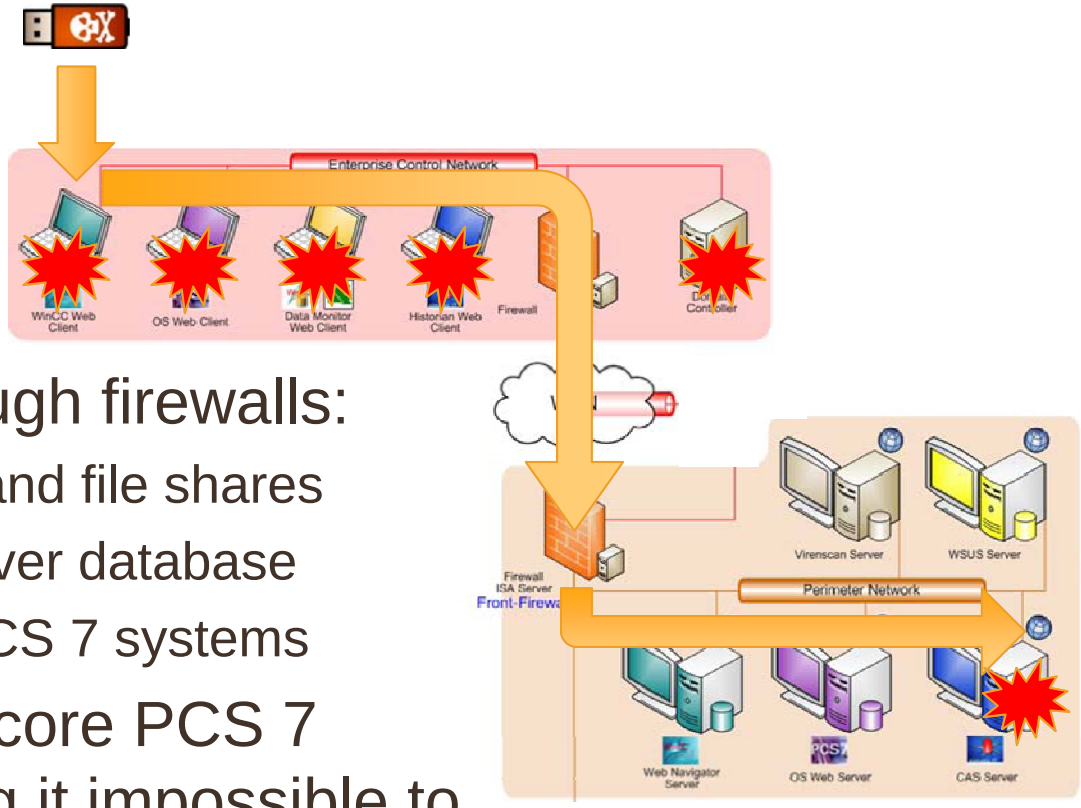
Penetrating Perimeter Network Firewalls



- Many paths through firewalls:
  - Network printer and file shares
  - WinCC SQL Server database
  - RPC between PCS 7 systems
- Piggybacked on core PCS 7 protocols, making it impossible to block at the firewall

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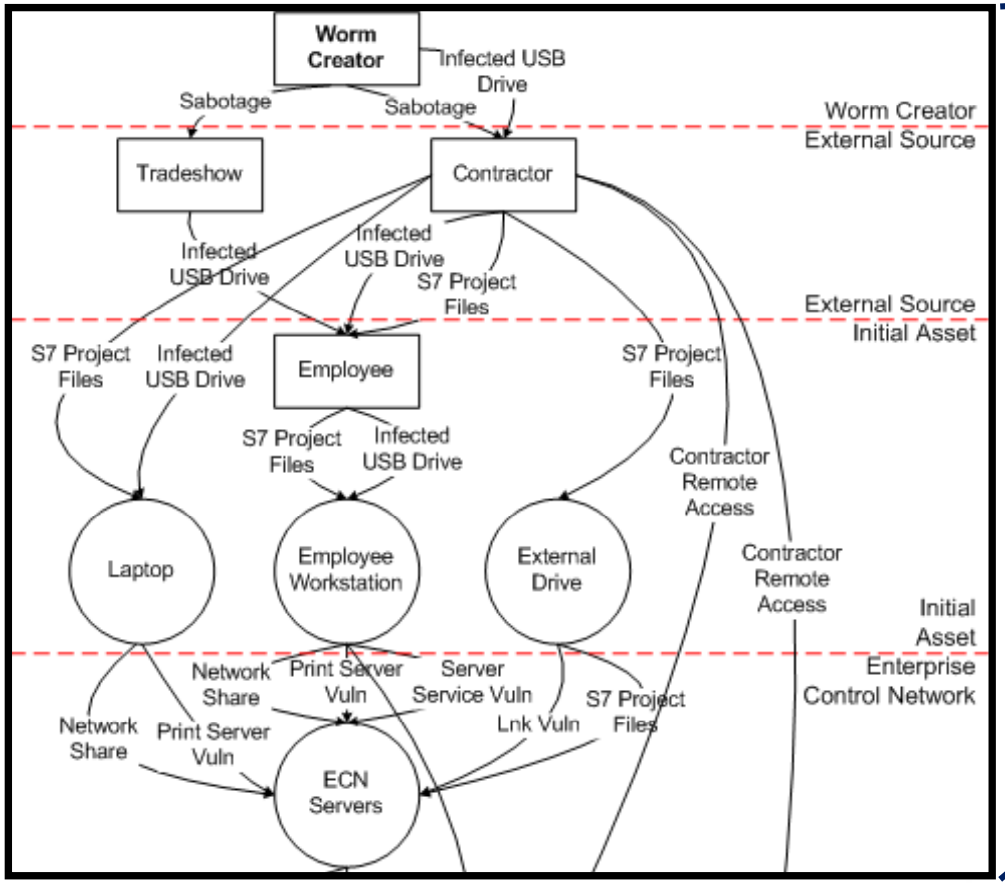
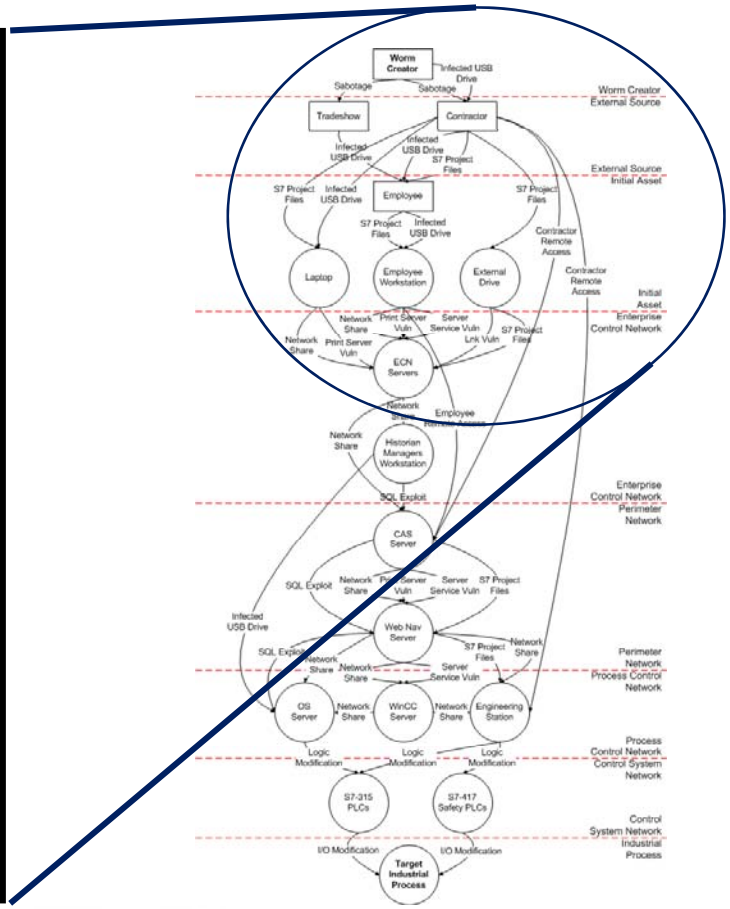
Stuxnet Had Many Paths to its Victim PLCs





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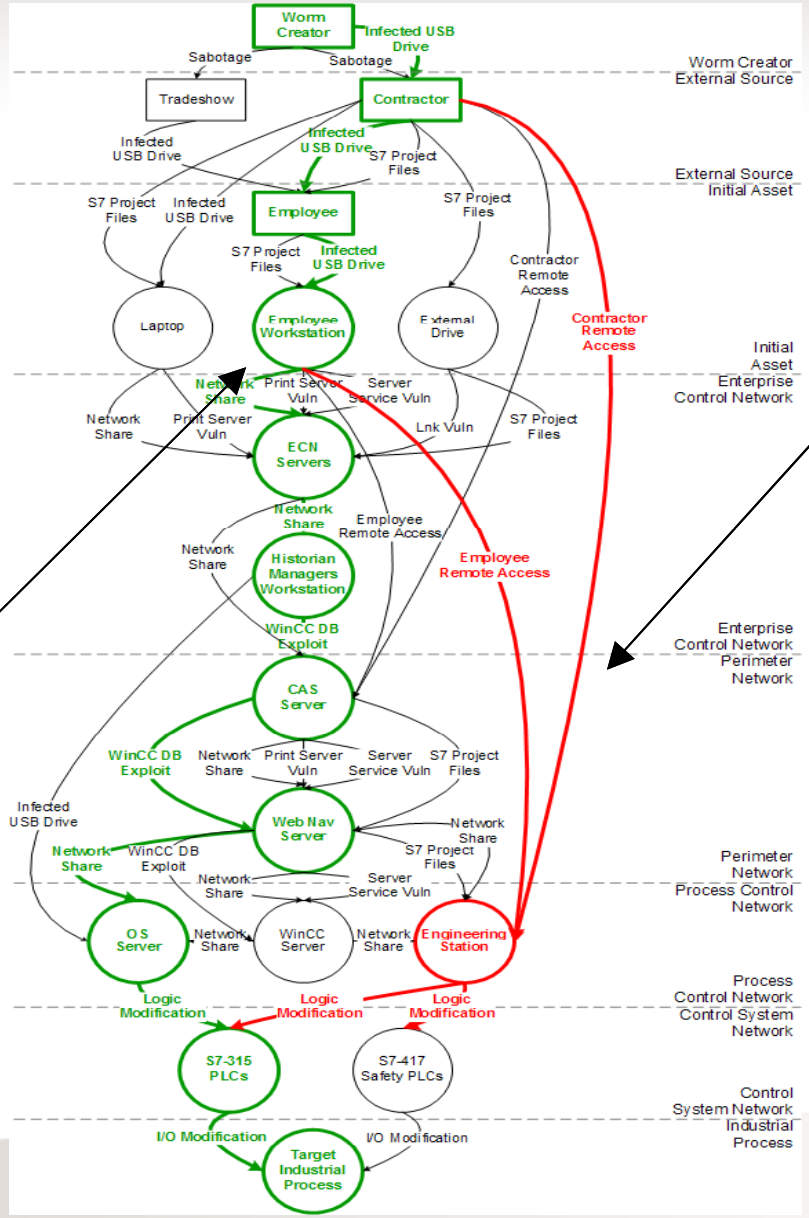
Green highlights infection path described in paper



Red highlights more direct paths which bypass existing security controls

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Some Lessons Learned

- A modern ICS or SCADA system is highly complex and interconnected
- Multiple potential pathways exist from the outside world to the process controllers
- Assuming an air-gap between ICS and corporate networks is unrealistic
- Focusing security efforts on a few obvious pathways (such as USB storage drives or the Enterprise/ICS firewall) is a flawed defense

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The Death of
“Security by Obscurity”

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A Typical Month for ICS/SCADA Vulnerabilities

- March 15 Moscow-based Gleg Ltd. released their Agora SCADA+ exploit pack for Canvas, which included 11 0-days (now at 54 exploits)
- On March 21, a security researcher from Italy "publically disclosed" 34 vulnerabilities on 4 different ICS platforms
- On March 22-23, vulnerabilities were disclosed for 2 additional ICS platforms

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Control Systems Security Program (CSSP)

Control Systems Advisories and Reports Archive

- ICS-CERT has released an Alert titled "ICS-ALERT-11-256-01 - Multiple Vulnerabilities in Progea Movicon"
- ICS-CERT ALERT "ICS-ALERT-11-255-01- SCADATEC SCADAPhone ModbusTagServer"
- ICS-CERT Advisory "ICSA-11-216-01 - Scadatec Limited Procyon Telnet Buffer Overflow"
- ICS-CERT Advisory "ICSA-11-244-01 - Siemens WinCC flexible Runtime Heap Overflow"
- ICS-CERT Alert "ICS-ALERT-11-245-01 - Multiple ActiveX Vulnerabilities in Advantech BroadWin WebAccess"
- ICS-CERT updated Alert "ICS-ALERT-11-238-01A - Sunway ForceControl SCADA SEH"
- ICS-CERT Alert "ICS-ALERT-11-238-01 - Sunway ForceControl SCADA SEH"
- ICS-CERT Advisory "ICSA-11-173-01 - ClearSCADA Remote Authentication Bypass"
- ICS-CERT updated Advisory "ICSA-11-223-01A - (UPDATE) Siemens SIMATIC PLCs Reported Issues Summary"
- ICS-CERT Advisory "ICSA-11-231-01- Inductive Automation Ignition Information Disclosure Vulnerability"
- ICS-CERT Newsletter, the "ICS-CERT Monthly Monitor"
- ICS-CERT ALERT "ICS-ALERT-11-230-01 - AGORA SCADA+ Update 1.4"
- ICS-CERT Advisory "ICSA-11-103-01A - (UPDATE) Honeywell ScanServer ActiveX Control"
- ICS-CERT Advisory "ICSA-11-223-01 - Siemens SIMATIC PLCs Reported Issues Summary"
- ICS-CERT UPDATE ALERT "ICS-ALERT-11-204-01B - (UPDATE) S7-300 Hardcoded Credentials"
- ICS-CERT ALERT "ICS-ALERT-11-204-01A - (UPDATE) S7-300 Hardcoded Credentials"
- ICS-CERT Announcement, "Cross-Vendor Working Group"
- ICS-CERT ALERT "ICS-ALERT-11-204-01 S7-300_S7-400 Hardcoded Credentials"

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- ICS-CERT Advisory "ICSA-11-195-01 - Invensys Wonderware Information Server"
- ICS-CERT Advisory "ICSA-11-189-01 - 7-Technologies IGSS Remote Memory Corruption"
- ICS-ALERT-11-186-01 "Password Protection Vulnerability in Siemens SIMATIC Controllers S7-200, S7-300, S7-400 and S7-1200"
- ICS-CERT Advisory "ICSA-11-175-02 - Siemens WinCC Exploitable Crashes"
- ICS-CERT Advisory "ICSA-11-182-01 - ICONICS TrustedZone Vulnerability"
- ICS-CERT Advisory "ICSA-11-182-02 - ICONICS Login ActiveX Vulnerability"
- ICS-CERT Advisory "ICSA-11-122-01 - AzeoTech DAQFactory Networking Vulnerabilities"
- ICS-CERT updated Advisory "ICSA-11-168-01A - Indusoft ISSymbol ActiveX Control Buffer Overflows"
- ICS-CERT Advisory "ICSA-11-175-01 - Rockwell FactoryTalk Diag Viewer Memory"
- ICS-CERT Advisory "ICSA-11-168-01 - InduSoft ISSymbol ActiveX Control Buffer Overflows"
- ICS-CERT Advisory "ICSA-11-167-01 - Heap overflow vulnerabilities in Sunway ForceControl and pNetPower"
- ICS-CERT Newsletter, the "ICS-CERT Monthly Monitor"
- ICS-CERT has released an updated Advisory "ICSA-11-056-01A - (UPDATE) Progea Movicon TCPUploadServer"
- ICS-CERT Advisory "ICSA-11-161-01 Rockwell RSLinx Classic EDS Wizard buffer overflow"
- ICS-CERT ALERT "ICS-ALERT-11-161-01 Siemens S7-1200 PLC"
- ICS-CERT Updated Advisory "ICSA-11-069-01B - (UPDATE) Samsung Data Management Server"
- ICS-CERT Advisory "ICSA-11-132-01A - (UPDATE) 7-Technologies IGSS DoS"
- ICS-CERT updated Advisory "ICSA-11-147-01B - (UPDATE) Ecava IntegraXor DLL Hijacking"
- ICS-CERT Advisory "ICSA-11-147-02 - Ecava IntegraXor XSS"
- ICS-CERT report "Common Cybersecurity Vulnerabilities in Industrial Control Systems"
- ICS-CERT newsletter, the "ICS-CERT Monthly Monitor"
- ICS-CERT Advisory "ICSA-11-132-01 - 7-Technologies IGSS DoS"
- ICS-CERT Advisory "ICSA-11-147-01A - Ecava IntegraXor DLL Hijacking"
- ICS-CERT Advisory "ICSA-11-131-01-ICONICS GENESIS32 and BizViz ActiveX Stack Overflow"
- ICS-CERT Alert "ICS-ALERT-11-131-01 - Advantech Studio ISSymbol ActiveX Control Buffer Overflow Vulnerabilities"
- ICS-CERT Alert "ICS-ALERT-11-129-01 - Samsung Data Management Server Root Access"
- ICS-CERT Update Advisory "ICSA-11-069-01A—(UPDATED) Samsung Data Management Server"
- ICS-CERT Advisory "ICSA-11-126-01 - 7-Technologies IGSS Stack Overflows and Directory Traversal"
- OSAMA BIN LADEN – THEMED PHISHING ATTEMPTS
- ICSA-11-119-01 - 7-Technologies IGSS Remote Stack Overflow
- ICS-CERT Alert "ICS-ALERT-11-111-01 - Agora Plus Update 1.1"
- ICS-CERT Advisory "ICSA-11-110-01 - RealFlex RealWin Multiple Vulnerabilities"
- ICS-CERT Advisory "ICSA-11-108-01 - ICONICS GENESIS Multiple Vulnerabilities"

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- ICS-CERT Advisory "ICSA-11-103-01 - Honeywell ScanServer ActiveX Control"
- ICS-CERT Advisory "ICSA-11-094-01 - Wonderware InBatch Client ActiveX Buffer Overflow"
- "NCCIC Advisory Targeted Phishing Attacks"
- ICS-CERT newsletter "ICS-CERT Monthly Monitor"
- Advisory "ICSA-11-096-01 - Agora SCADA+"
- Advisory Update "ICSA-11-091-01A -(UPDATE)" Multiple Vulnerabilities in Siemens Tecnomatix FactoryLink
- Advisory "ICSA-11-094-02 - BroadWin (Advantech) WebAccess RPC"
- Advisory "ICSA-11-091-01 - Multiple Vulnerabilities in Siemens Tecnomatix FactoryLink"
- "US-CERT EWIN 11-077-01A - Malicious Indicators Update"
- Advisory "ICSA-11-084-01 - Solar Magnetic Storm Control Systems Impact"
- Advisory "ICS-Advisory -11-082-01 - Ecava IntegraXor Unauthenticated SQL vulnerability"
- Alert "ICS-ALERT-11-081-01 - BroadWin WebAccess"
- ICS-CERT Alert "ICS-ALERT-11-080-01 - Multiple Vulnerabilities in Siemens Tecnomatix FactoryLink"
- ICS-CERT Alert "ICS-ALERT-11-080-02 - Multiple Vulnerabilities in Iconics Genesis"
- ICS-CERT Alert "ICS-ALERT-11-080-03 - Multiple Vulnerabilities in 7-Technologies IGSS"
- ICS-CERT Alert "ICS-ALERT-11-080-04 - Multiple Vulnerabilities in RealFlex RealWin"
- Advisory "ICSA-11-056-01 - Progea Movicon TCPUploadServer"
- Advisory "ICSA-11-074-01 - WellinTech KingView 6.53 KVWebSvr ActiveX"
- Alert "ICS-ALERT-11-066-01 - ActiveX Vulnerability in WellinTech KingView 6.53"
- UPDATED Advisory "ICSA-10-348-01A - Wonderware InBatch Buffer Overflow"
- UPDATED Advisory "ICSA-10-314-01A - Multiple Vulnerabilities in ClearSCADA Software"
- UPDATED Advisory "ICSA-11-041-01A - McAfee Night Dragon"
- Advisory "ICSA-11-041-01 - McAfee Night Dragon"
- Advisory "ICSA-11-018-02 - IGSS 8 ODBC Server Remote Heap Corruption"
- Report "ICS-CERT 2010 Year in Review"
- Advisory "ICSA-10-314-01 - Multiple Vulnerabilities in ClearSCADA Software"
- ICSA-11-025-01 - Federal Aviation Administration GPS Testing
- Alert ICS-ALERT-11-024-01 - Federal Aviation Administration GPS Advisories
- Advisory ICSA-11-018-01–AGG SCADA Viewer OPC Buffer Overflow Vulnerability
- Advisory ICSA-10-322-02A - Automated Solutions OPC Server
- Advisory ICSA-11-017-01 - WellinTech KingView
- Advisory ICSA-11-017-02 - Sielco Sistemi Winlog Stack Overflow
- Alert ICS-Alert-11-011-01 WellinTech KingView Buffer Overflow
- Advisory ICS-CERT 10-337-01 - Advantech Studio Test Web Server Buffer Overflow
- Alert ICS-CERT ALERT-10-362-01 - Ecava IntegraXor

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- Advisory ICS-CERT 10-362-01 - Ecava IntegraXor Directory Traversal
- Advisory ICS-CERT 10-355-01 - Ecava IntegraXor
- Advisory ICS-CERT has released Update A to ICSA-10-316-01A - Intellicom Netbiter WebSCADA Multiple Vulnerabilities
- Advisory ICS-CERT has released ICSA-10-322-01 - Ecava IntegraXor Buffer Overflow
- Advisory ICSA-10-348-01- Wonderware InBatch and I/A Series Batch Buffer Overflow
- Advisory ICSA-10-322-02 - Automated Solutions OPC Server Vulnerability
- Advisory ICSA-10-316-01 - Intellicom Netbiter WebSCADA Multiple Vulnerabilities
- Advisory ICSA-10-301-01A - MOXA Device Manager Buffer Overflow
- Advisory ICSA-10-313-01 - RealWin Buffer Overflow
- Alert ICS-Alert-10-305-01 - RealWin Buffer Overflows
- Advisory ICSA-10-301-01 - Moxa Device Manager Buffer Overflow
- Alert ICS-Alert-10-301-01 - Control System Internet Accessibility
- Alert ICS-Alert-10-293-02 - Vulnerability in Moxa Device Manager
- Alert ICS-Alert-10-293-01 - Multiple vulnerabilities in Intellicom's Netbiter® WebSCADA
- ICSA-10-272-01 - Primary Stuxnet Indicators
- ICSA-10-264-01 - Scada Engine BACnet OPC Client Buffer Overflow Vulnerability
- Alert ICS-Alert-10-260-01 - Scada Engine BACnet OPC Client Buffer Overflow Vulnerability
- Alert ICS-Alert-10-239-01 - Dynamic Library Loading Vulnerability in Microsoft-Based Applications
- ICSA-10-238-01B - Stuxnet Malware Mitigation
- ICSA-10-238-01A - Stuxnet Malware Mitigation
- ICSA-10-238-01 - Stuxnet Malware Mitigation
- ICSA-10-228-01 - Vendor Admin Accounts Warning
- ICSA-10-214-01 - Vxworks Vulnerabilities
- Alert ICS-Alert-10-211-01-Microsoft Announces Out-of-Band Update
- ICSA-10-201-01C - USB Malware Targeting Siemens Control Software
- ICSA-10-201-01B - USB Malware Targeting Siemens Control Software
- ICSA-10-201-01A - USB Malware Targeting Siemens Control Software
- ICSA-10-201-01 - USB Malware Targeting Siemens Control Software
- Alert ICS-ALERT-10-194-01 - Open UDP Port in Rockwell 1756-ENBT Inteface
- ICSA-10-147-01 - Cisco Network Building Mediator
- ICS-CERT Advisory ICSA-10-090-01 Mariposa Botnet
- ICS-CERT Advisory ICSA-10-070-02-Rockwell-PLC5
- ICS-CERT Advisory ICSA-10-070-01A-RSLinx-UPDATE
- ICS-CERT Advisory ICSA-10-070-01-RSLinx

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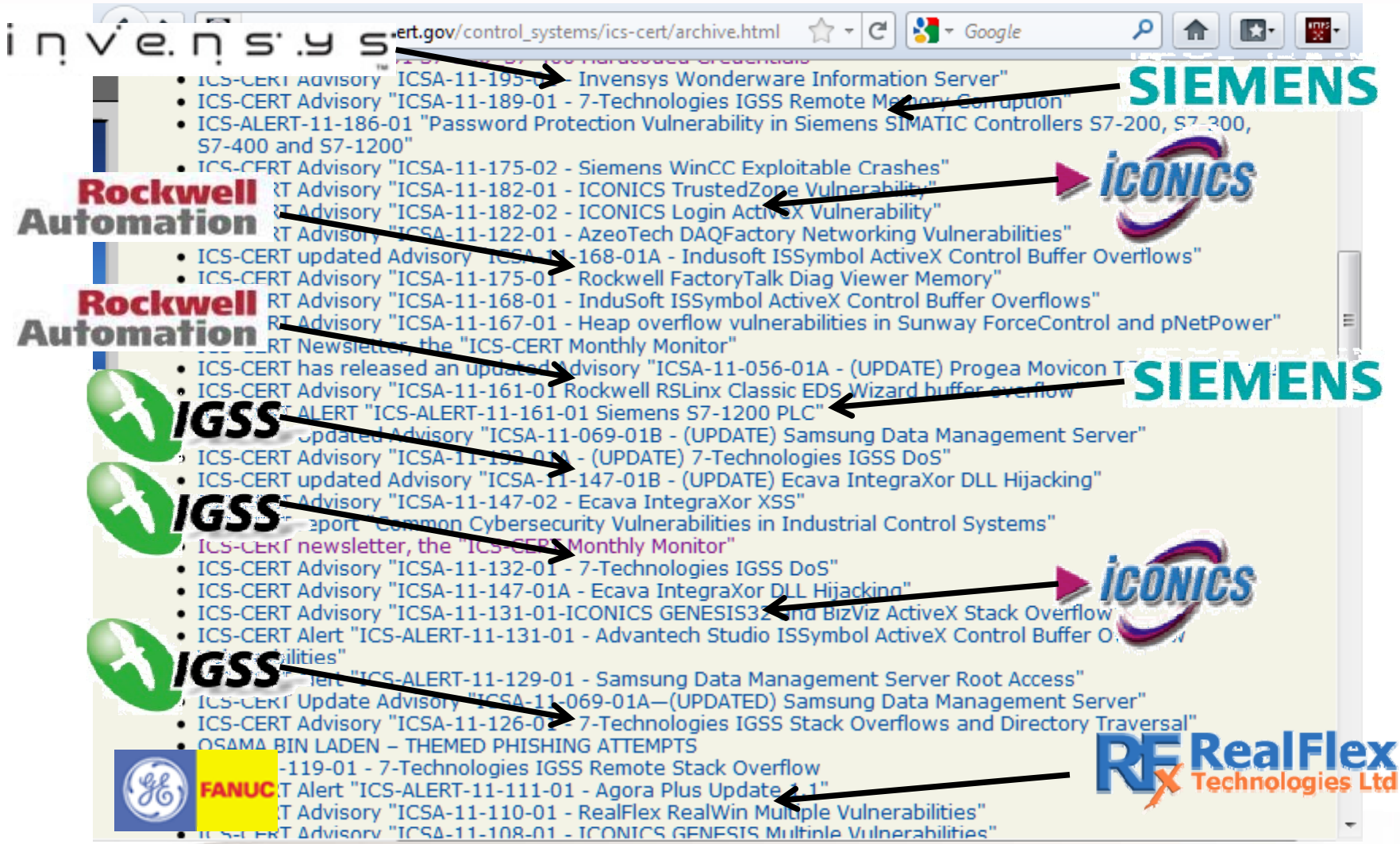

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The Life Cycle of a ICS Exploit

- ICS platforms are becoming an obvious target for attacks
- “Security Researchers” focusing on SCADA/ICS because it is easy money/fame (little malicious intent)
- Actors with intent have access to the weapons:
  - Download exploits for free (Italian list)
  - Purchase tool kits (Gleg)
  - Directed where to look for more vulnerabilities

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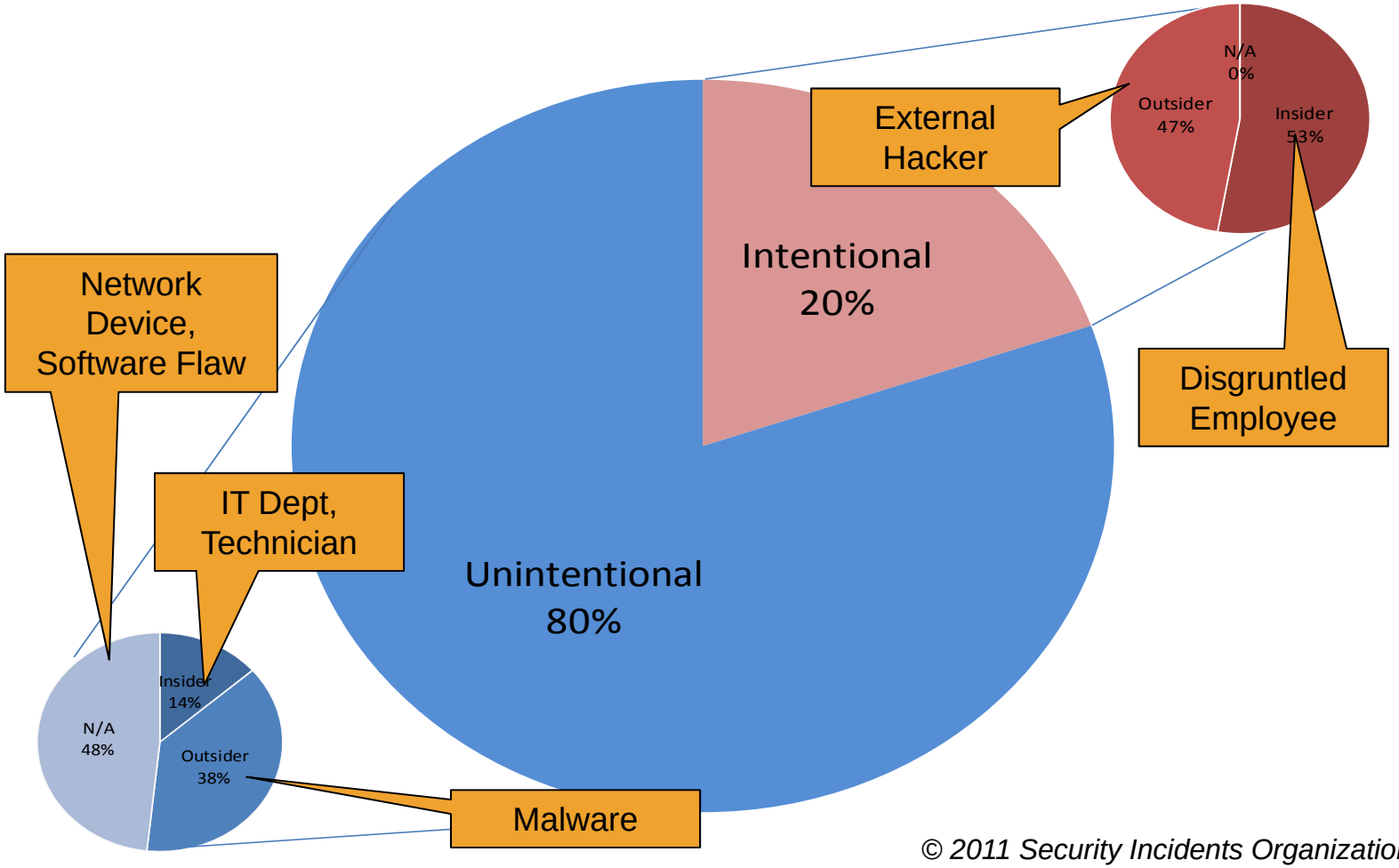
Incident Types from RISI Database



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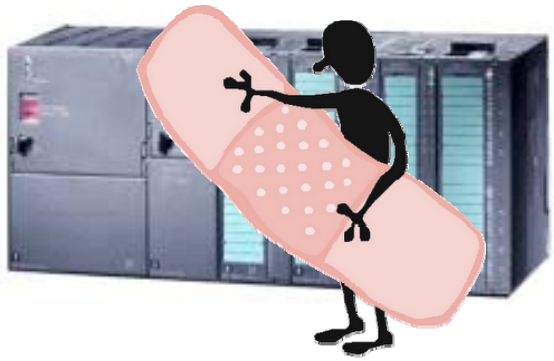
Stuxnet's Legacy

- Model for simple, destructive SCADA worms
- Exploits inherent PLC design issues
- Applicable to almost all industrial controllers
- There are no possible "patches" to the PLC



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Some Lessons Learned

- SCADA and ICS are now targets of interest
- Most systems have many exploit opportunities
- Patching is an issue for many companies
  - Patch deployment requires plant downtime
  - Vendor only patches most current version
  - Patch releases are slow
  - Upgrading to latest version may not be an option

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Protecting Against the Son-of-Stuxnet

- The Good and The Ugly
- Models for Effective CIP Security

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The Ugly:
The US Electrical Industry Security Model

- NERC CIP 002 - 009 defines security compliance requirements for organizations who are involved with the bulk electrical network in North America
- Industry has focused on **compliance** rather than **security**
- The standard focus on **boundary protection**, not **defense in depth**.
- Yet in 2009 NERC listed their #2 vulnerability in control systems as:

  "Inadequately designed control system networks that lack sufficient defense-in-depth mechanisms"

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The Bastion Model of Security

- Installing a single firewall between business and the control system is known as the ***Bastion Model*** since it depends on a single point of security
- Other examples of the bastion model:
  - The Great Wall of China
  - The Maginot Line

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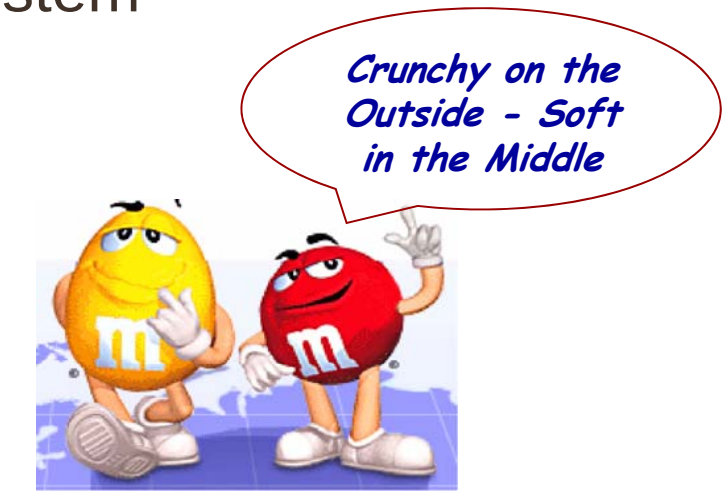
A Perimeter Defense is Not Enough

- We can't just install a boundary firewall and forget about security
  - The bad guys will eventually get in
  - Many problems originate inside the control network
- We must harden the ENTIRE system
- We need Defense in Depth



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ANSI/ISA-99: Dividing Up The Control System

- A core concept in the ANSI/ISA-99 (now IEC 62443.02.01) security standard is “Zones and Conduits”
- Offers a level of segmentation and traffic control inside the control system.
- Control networks divided into layers or zones based on control function
- Multiple separated zones manage that “***defense in depth***” strategy

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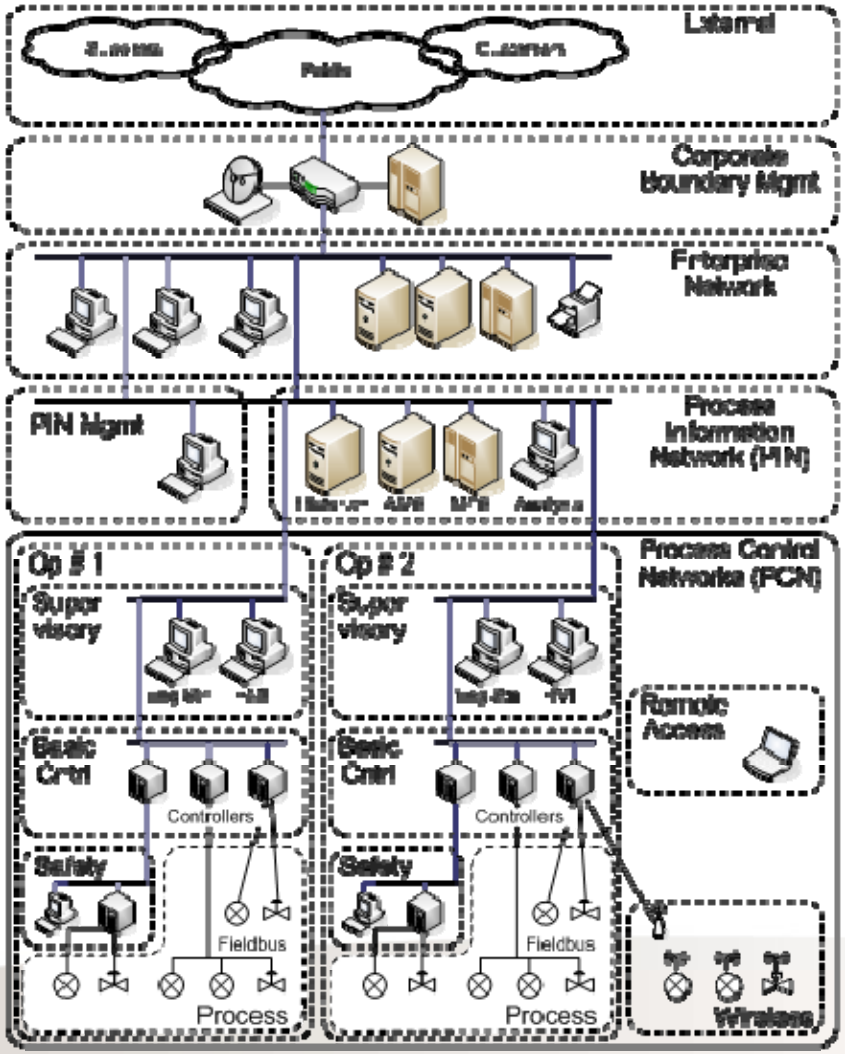
Using Zones: An Example Oil Refinery



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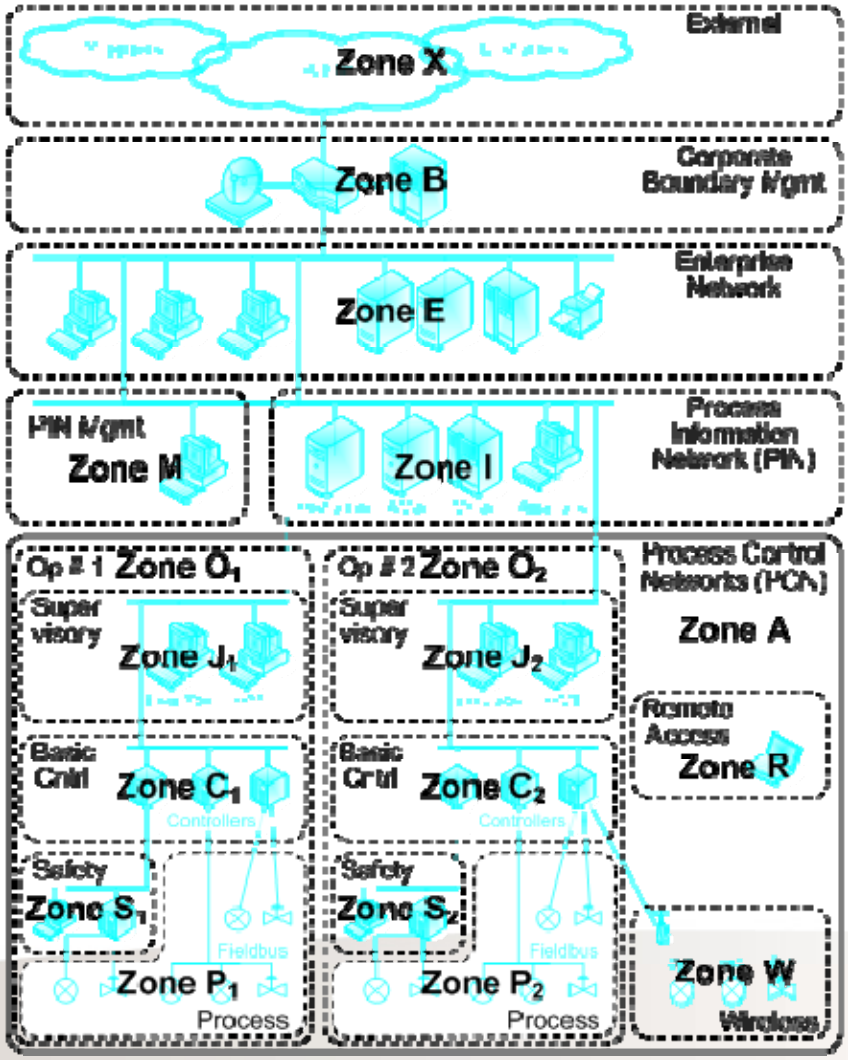
Specifying the Zones



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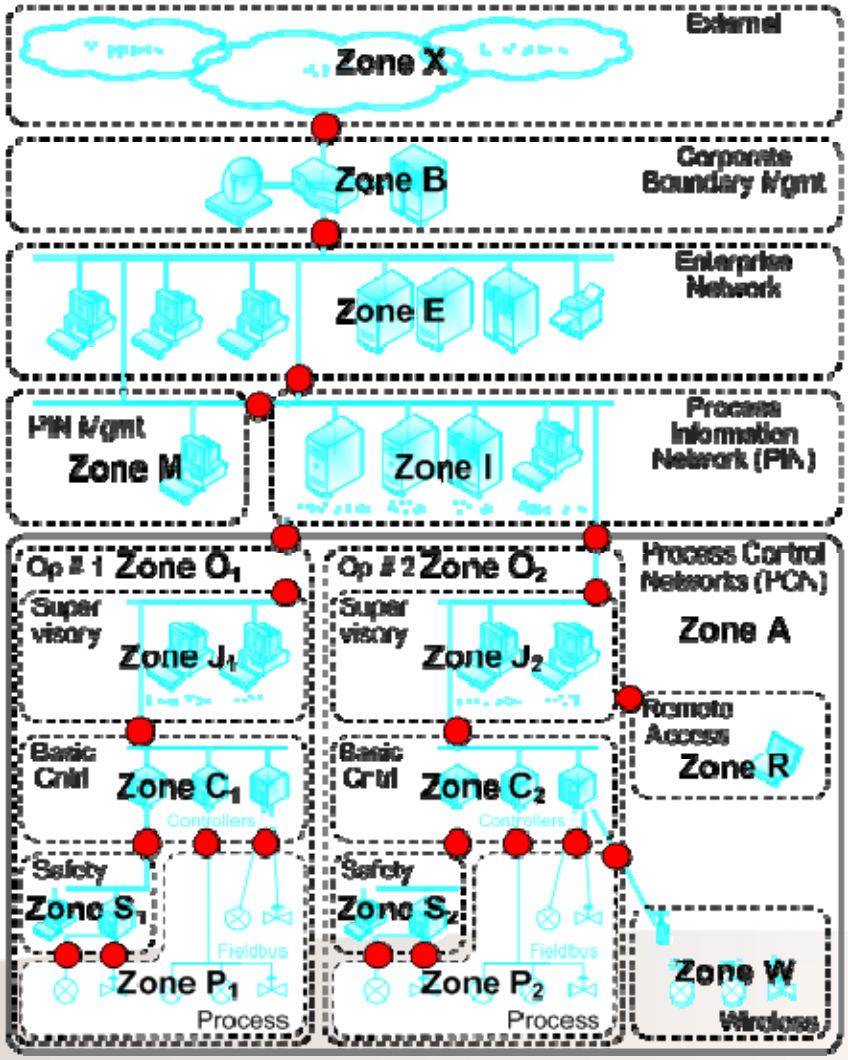
Defining the Conduits



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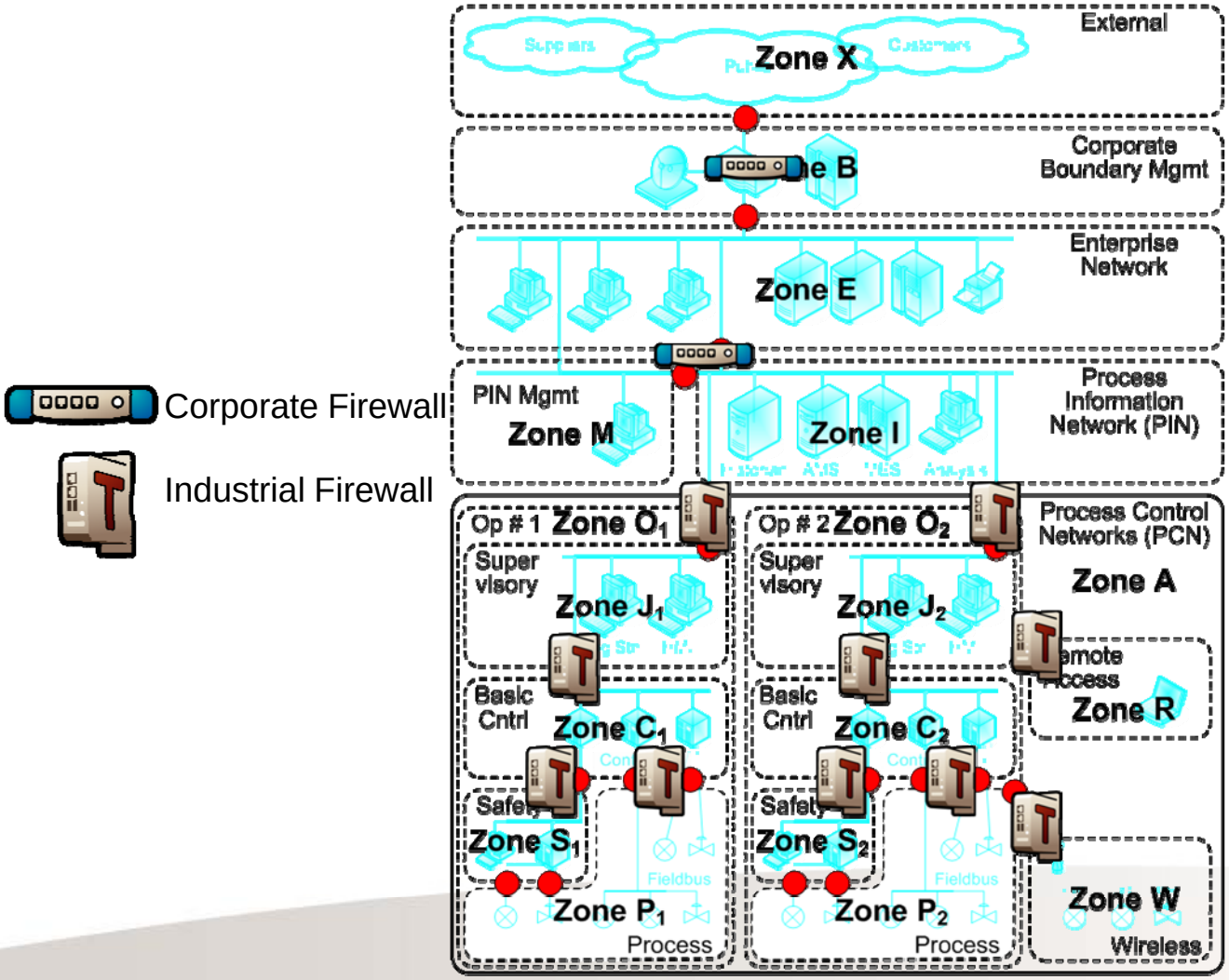
Protecting the Conduits with Firewalls



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Look At All Possible Pathways

- Don’t focus on a single pathway such as USB keys
- Consider all possible infection pathways:
  - Removable Media (CDs, DVDs, USB Drives)
  - File Transfer (Database, PDFs, PLC Project Files)
  - Portable Equipment (Laptops, Storage Units, Config Tools)
  - Internal Network Connections (Business, Lab, QA, Support)
  - External Connections (Support, Contractor, Customer)
  - Wireless (802.11, 802.15, Licensed-band, Cellular, Wireless HART, ISA-100a, Bluetooth, USB tethering)
  - Other Interfaces (Serial, Data Highways)
- Have strategies for discovering/mitigating ALL pathways

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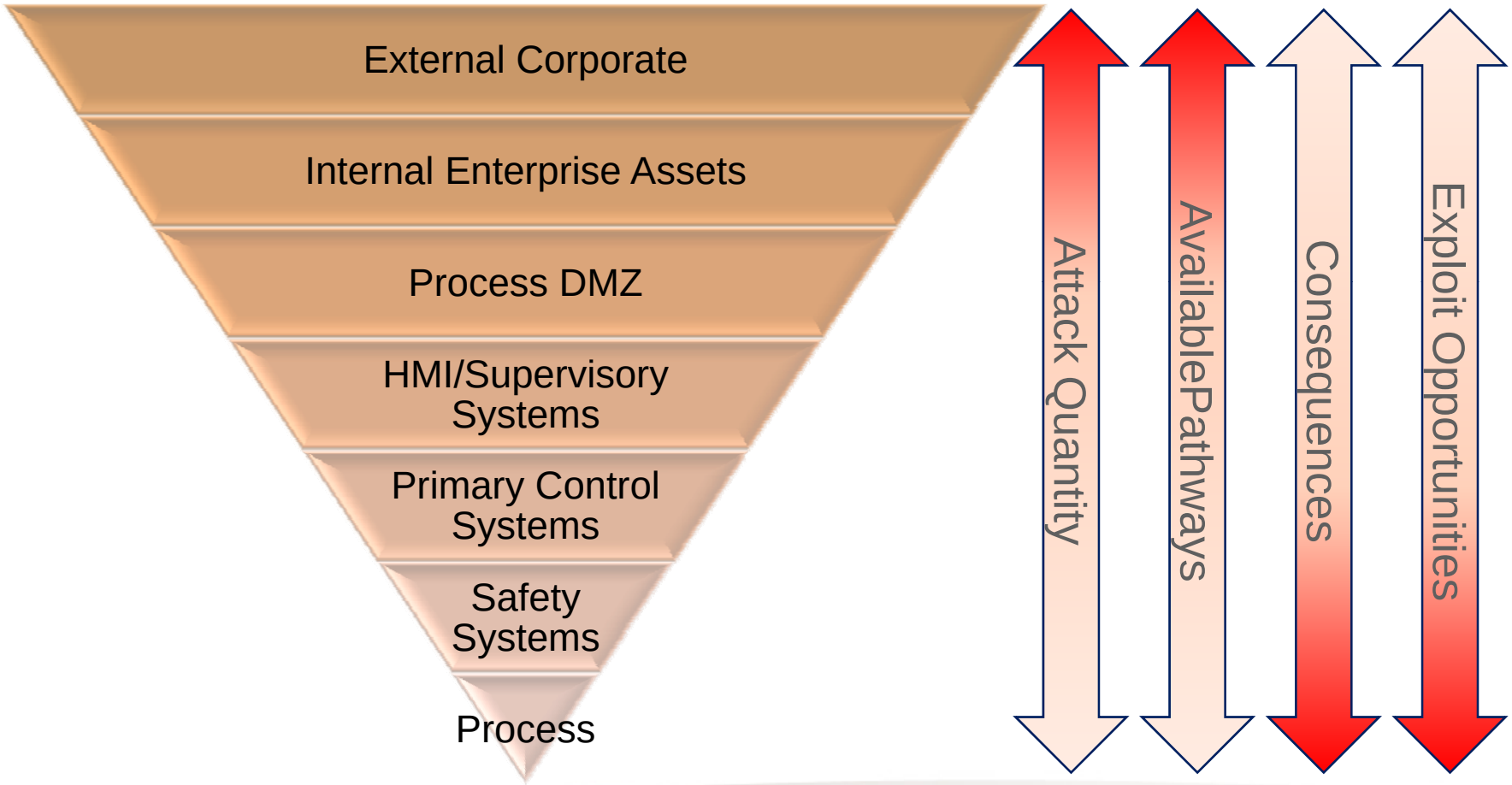
The Attack/ Consequence Funnel



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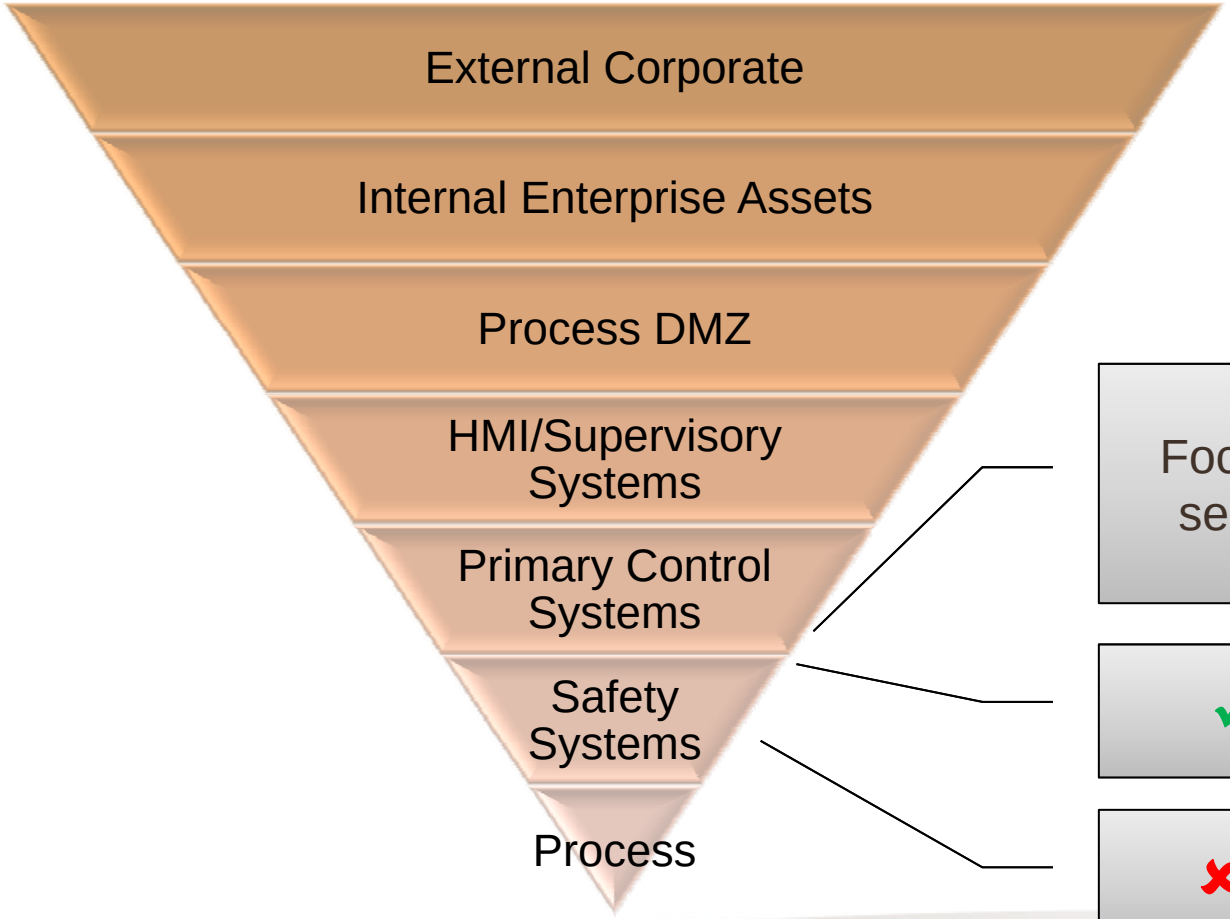
Securing Last-line-of-Defense CIP Systems



Focus on monitoring and securing SIS Boundary

✓ Limited Pathways

✘ High Consequence

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SCADA/ICS-Appropriate Technologies

- Need ICS-appropriate detection technologies to raise an alarm when equipment is compromised or at risk of compromise
- Deploy ICS-appropriate security technologies
- Look beyond traditional network layer firewalls, towards firewalls that are capable of deep packet inspection of key SCADA and ICS protocols

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Example:
Honeywell Safety System Firewall

- Honeywell needed a firewall to protect critical their safety instrumented systems (SIS)
- Wanted NO user configuration
- Security Requirements:
  - Allow data to be read from system but not written (Read-only Firewall)
  - Must provide “sanity check” SCADA application protocols
- Configuration is locked to SIS- appropriate rule set

Honeywell Modbus Read-only Firewall for SIS

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Making Security Simple

- *"Certainly controls engineers and operators need to be security aware, but they should not all need to be security experts."*
- *"We have to make this [security] something a plant superintendent, engineer, or senior operator can do in their spare time, or it will flop."*

Two Major End Users to ISA99 Committee

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Some Closing Thoughts…

- Stuxnet has changed the threat landscape
- ICS/SCADA is the target of sophisticated attacks
- ICS/SCADA is the focus for vulnerability discovery
- Industry must accept that the complete prevention of ICS infection is impossible
- Improved defense-in-depth strategies for industrial control systems are needed urgently
- Waiting for the next worm may be too late

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References

Siemens Automation

- Security concept PCS 7 and WinCC - Basic document
  http://support.automation.siemens.com/ww/view/en/26462131/

Tofino Security White Papers and Application Notes

- http://www.tofinosecurity.com/stuxnet-central
- Analysis of the Siemens PCS7 “Stuxnet” Malware for Industrial Control System Professionals:
  http://www.tofinosecurity.com/professional/siemens-pcs7-wincc-malware
- Using Tofino to Control the Spread of the Stuxnet Malware - Application Note:
  http://www.tofinosecurity.com/professional/using-tofino-control-stuxnet
- Stuxnet Mitigation Matrix - Application Note:
  http://www.tofinosecurity.com/professional/stuxnet-mitigation-matrix

Other White Papers and Documents

- http://www.langner.com/en/
- http://www.symantec.com/content/en/us/enterprise/media/security_response/whitepapers/w32_stuxnet_dossier.pdf

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