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Towards Effective Cybersecurity for Modular, Open Architecture Satellite Systems

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Small Satellite Cybersecurity Challenges

Competing Forces

- Need for rapid system development and fielding
- Desire to leverage low cost technology solutions
- Requirement for information assurance and security

Unique Cybersecurity Challenges

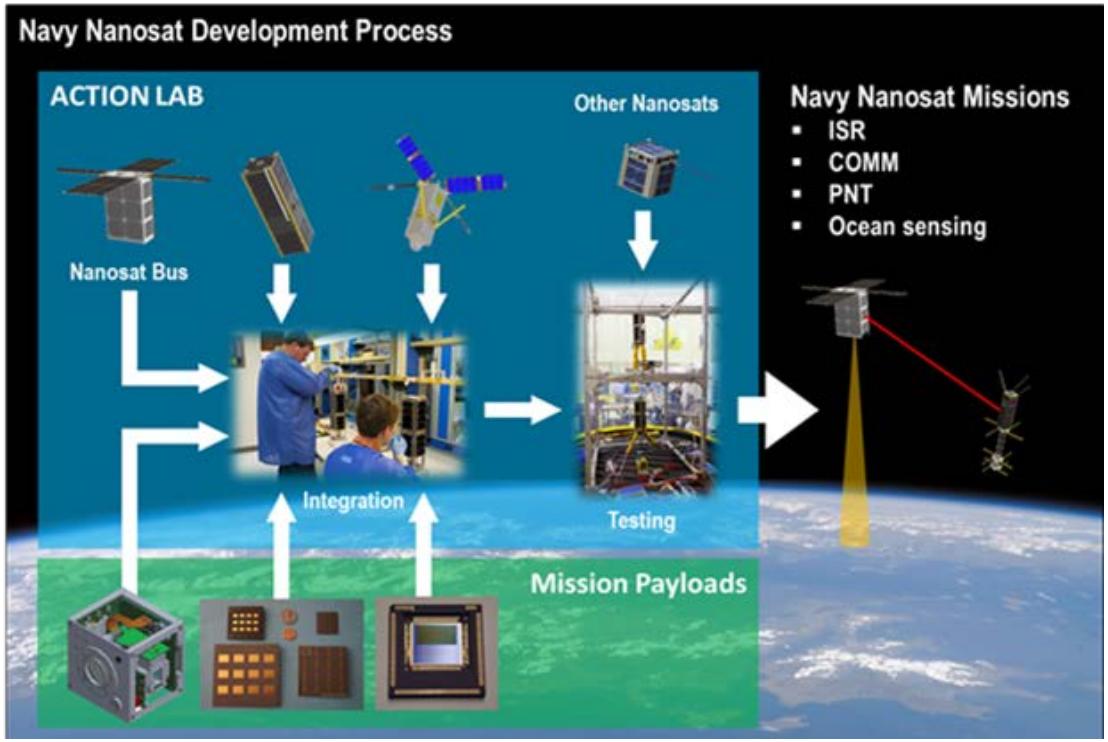
- Inherent risks within low-cost, components-off-the-shelf (COTS)-heavy supply chain
- Modular, net-centric architectures and technologies
- Open-source software products and libraries
- Ground and on-orbit automation
- Time and cost of current space system accreditation processes

Life-cycle Cybersecurity is at Odds with COTS-heavy Plug-N-Play

SSC Pacific Small Satellite Vision

- Government small satellite integration facility
- Rapid prototyping and fielding of responsive space capabilities
- Life-cycle integration and test environment
- Integrate small satellite busses with specialized payloads for military applications
- Infuse cybersecurity into every life-cycle phase
- Leverage specialized resources of government and industry partners
- Break-through traditional space system cost drivers!!

ACCELERATED CAPABILITY FOR TESTING INTEGRATION AND OPERATION OF NANOSATELLITES



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Small Satellite Lifecycle Cyber Overlay

Typical Small Satellite Lifecycle	Cybersecurity Overlay
Concept Development & Design	Assess vulnerabilities Plan security controls
Payload & Subsystem Development	Incorporate security controls Greybox and blackbox testing of interfaces
Bus, Payload, & Ground Subsystem Acceptance	Static and dynamic analysis Reverse engineering
System-level Integration and Testing	Dynamic analysis and testing of vulnerability to signal interference, interception, and injection
Launch, On-orbit Operations, and Maintenance	Monitor and defend network & components

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Cybersecurity Lab Objectives

- "Test like you Fly" cybersecurity
- Defense-in-depth approach
- Assess security at each layer from the hardware to the network
- Investigate mitigations at each layer
- Penetration testing
  - Dynamic, static & concolic binary analysis
  - Reverse engineering
  - Blackhat techniques to uncover hidden vulnerabilities
- Report on state-of-the-art options for small satellite security
- Recommendations for improving cybersecurity posture

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Small Satellite Cybersecurity Hurdles:
Similarities to Industrial Control Systems (ICS)

- CIA vs AIC
  - (C)onfidentiality, (I)ntegrity, and (A)vailability
- Reliance on proprietary protocols and proprietary software for critical operations
- Hardware often constrained in terms of memory & CPU
- Sub-systems often lack proper security testing, thus easily compromised due to large attack surface
- Software updates and patching can be difficult, and slow in implementation
- Lack of manpower that understands both the technology and the cybersecurity

ICS Cybersecurity Methodology for Small Satellites

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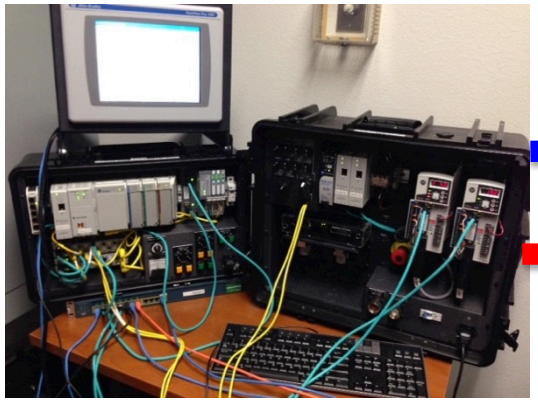


Vulnerability Scanner

CAULDRON

SCADA Vulnerability Visualization

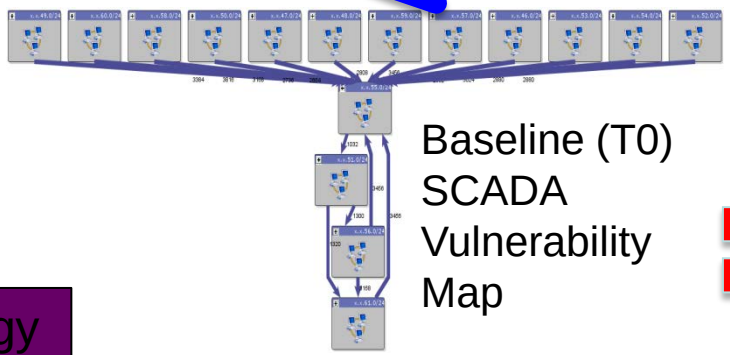
SCADA Data Generation

Rockwell Automation + SIEMENS

Technology X

Technology Y

Technology Z



Baseline (T0) SCADA Vulnerability Map

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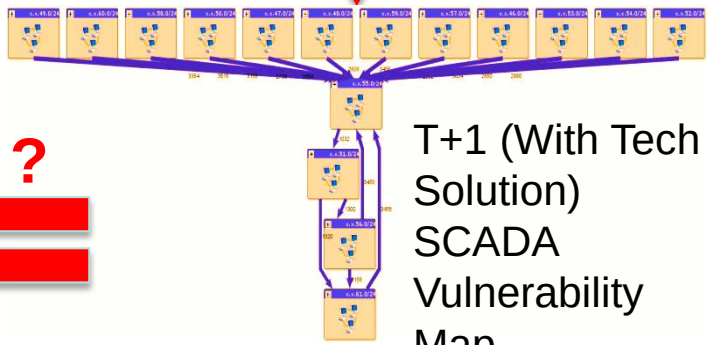

T+1 (With Tech Solution) SCADA Vulnerability Map

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ICS Cybersecurity Methodology for Small Satellites

- Layered security assessments
  - Hardware -> firmware -> operating system -> user space applications -> network
  - Security controls & mitigations at each layer
- Tools
  - Vulnerability scanners
    - ACAS/OpenVas/nmap
  - Security Assessment
    - Kali Linux / Metasploit
    - Scripting languages – python/ruby/bash
  - Binary Analysis
    - Dynamic, static & concolic analysis (maximize coverage)
    - IDA Pro (Disassemblers for reverse engineering)
  - Continuous security monitoring
    - Sophia (investigating ICS security monitoring tool)

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Case Study: Beagle Bone Black

- Network-based vulnerability assessment
  - Limited reconnaissance information gleaned from initial scan
  - Particular test article implemented hardened external interface
- Operating system assessment
  - Linux-based
  - Standard kernel implemented
  - Loadable kernel modules(LKM)
  - Common single-layer defensive approach
  - Lack of OS level hardening
  - No Kernel customization
  - Development tools
- Next Steps
  - User-space application assessments in progress
  - Firmware and hardware assessments in the near future

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