Risks in the Software Supply Chain

Software Engineering Institute
Carnegie Mellon University
Pittsburgh, PA 15213

Mark Sherman, Ph.D.
Technical Director, CERT

May 2, 2019

This material is based upon work funded and supported by the Department of Defense under Contract No. FA8702-15-D-0002 with Carnegie Mellon University for the operation of the Software Engineering Institute, a federally funded research and development center.

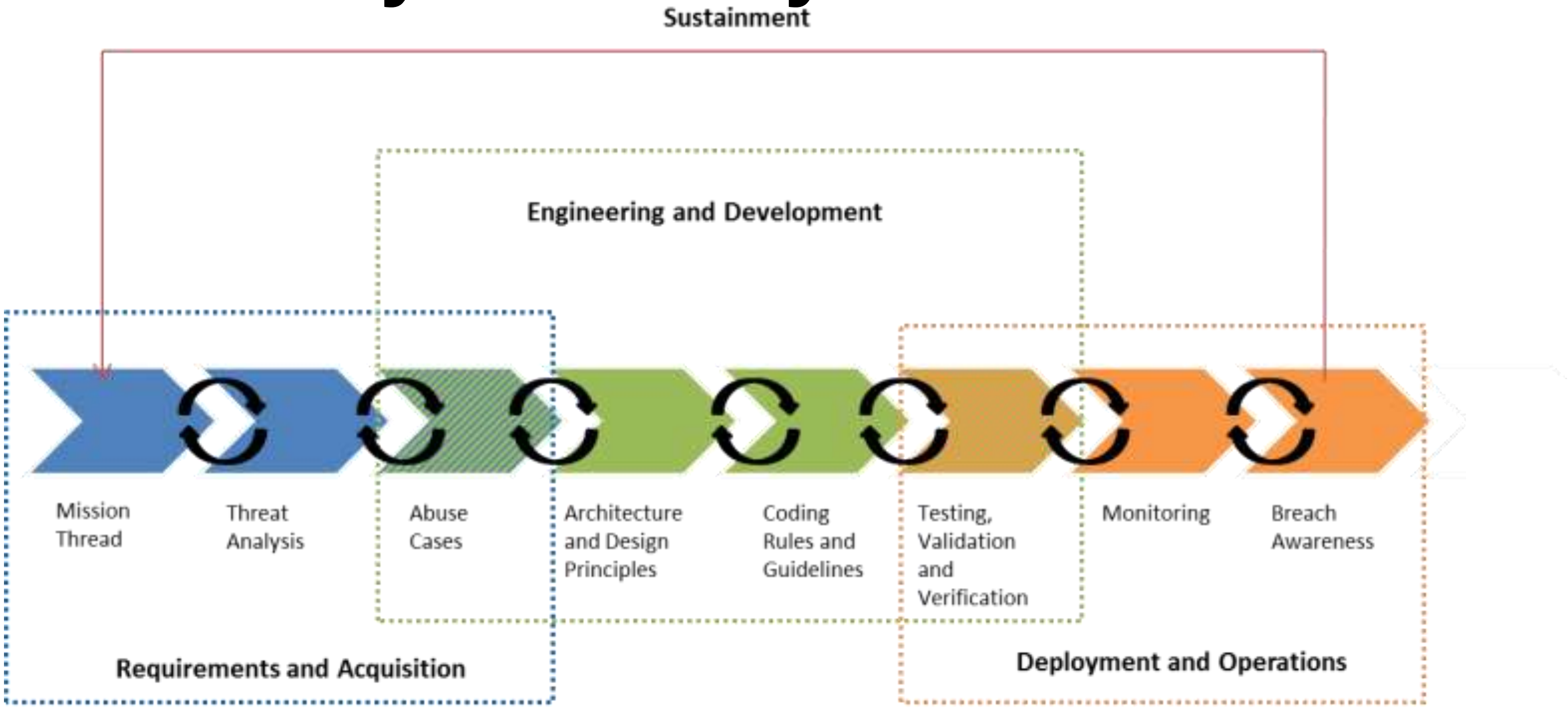
The view, opinions, and/or findings contained in this material are those of the author(s) and should not be construed as an official Government position, policy, or decision, unless designated by other documentation.

References herein to any specific commercial product, process, or service by trade name, trade mark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by Carnegie Mellon University or its Software Engineering Institute.

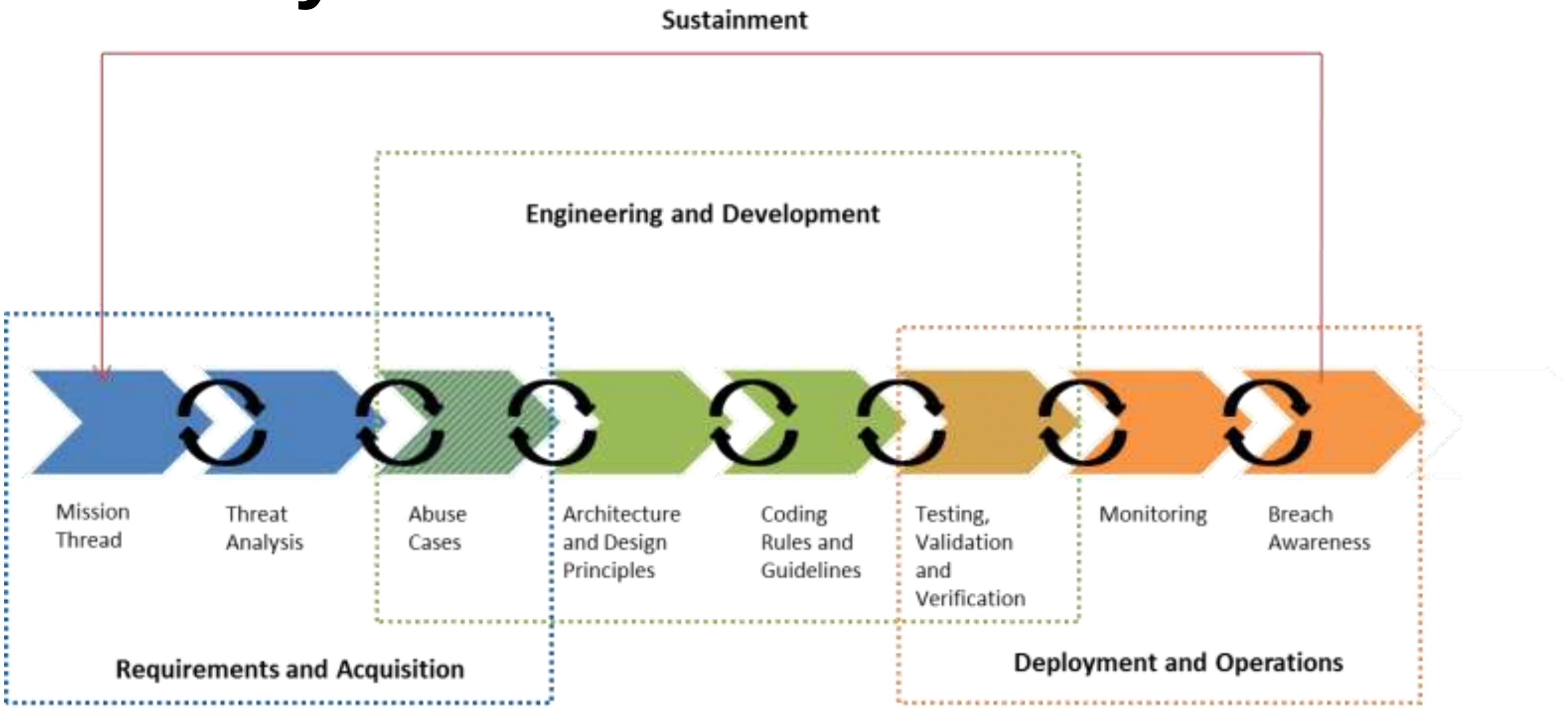
NO WARRANTY. THIS CARNEGIE MELLON UNIVERSITY AND SOFTWARE ENGINEERING INSTITUTE MATERIAL IS FURNISHED ON AN "AS-IS" BASIS. CARNEGIE MELLON UNIVERSITY MAKES NO WARRANTIES OF ANY KIND, EITHER EXPRESSED OR IMPLIED, AS TO ANY MATTER INCLUDING, BUT NOT LIMITED TO, WARRANTY OF FITNESS FOR PURPOSE OR MERCHANTABILITY, EXCLUSIVITY, OR RESULTS OBTAINED FROM USE OF THE MATERIAL. CARNEGIE MELLON UNIVERSITY DOES NOT MAKE ANY WARRANTY OF ANY KIND WITH RESPECT TO FREEDOM FROM PATENT, TRADEMARK, OR COPYRIGHT INFRINGEMENT.

DM19-0427

Cybersecurity is a lifecycle issue


Sustainment
Engineering and Development
Mission Thread
Threat Analysis
Abuse Cases
Architecture and Design Principles
Coding Rules and Guidelines
Testing, Validation and Verification
Monitoring
Breach Awareness
Requirements and Acquisition
Deployment and Operations

Cross lifecycle issues

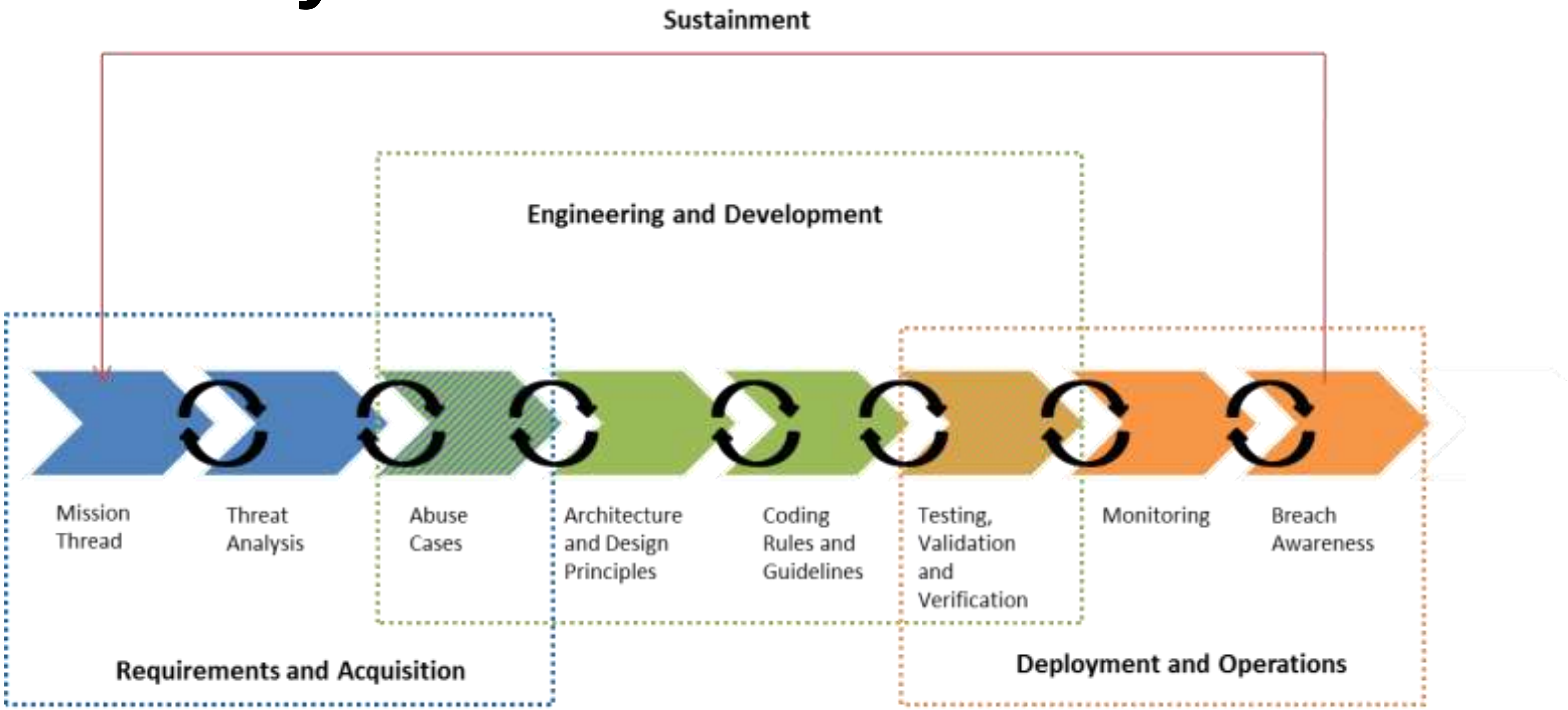

Sustainment
Engineering and Development
Mission Thread
Threat Analysis
Abuse Cases
Architecture and Design Principles
Coding Rules and Guidelines
Testing, Validation and Verification
Monitoring
Breach Awareness
Requirements and Acquisition
Deployment and Operations

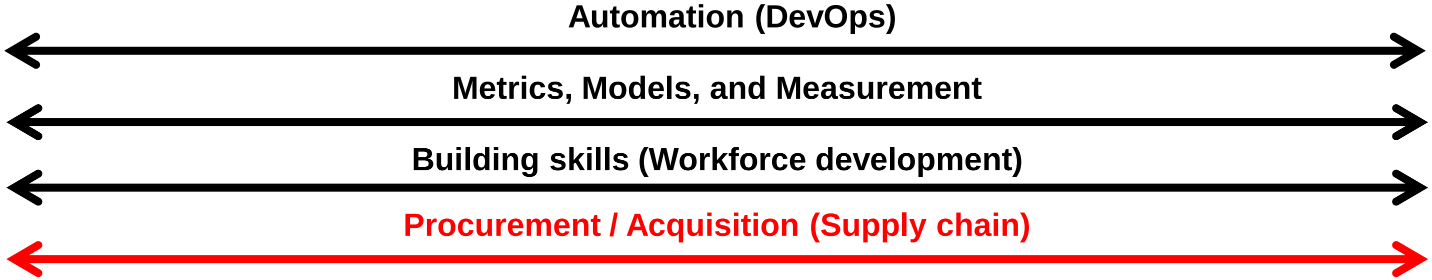
Automation (DevOps)

Metrics, Models, and Measurement

Building skills (Workforce development)

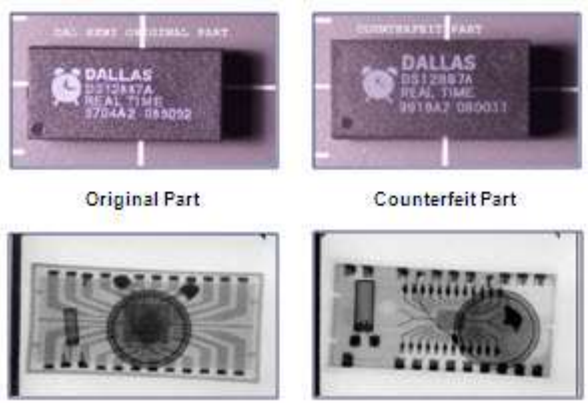
Cross lifecycle issues


Sustainment
Engineering and Development
Mission Thread
Threat Analysis
Abuse Cases
Architecture and Design Principles
Coding Rules and Guidelines
Testing, Validation and Verification
Monitoring
Breach Awareness
Requirements and Acquisition
Deployment and Operations


Automation (DevOps)
Metrics, Models, and Measurement
Building skills (Workforce development)
Procurement / Acquisition (Supply chain)

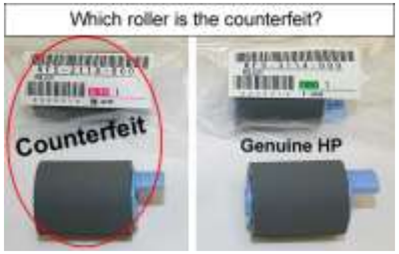
[Distribution Statement A] This material has been approved for public release and unlimited distribution.

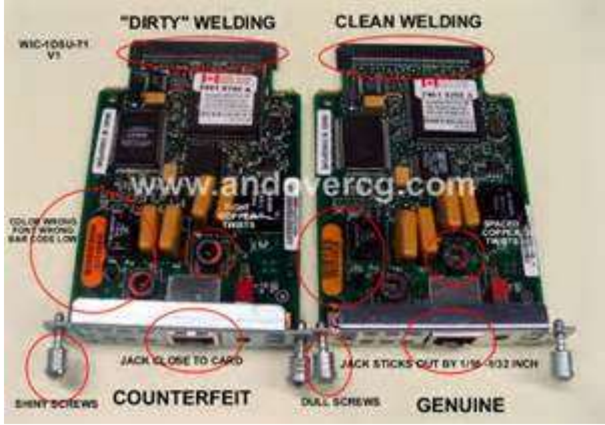
Conventional view of supply chain risk



Original Part

Counterfeit Part





Sources: http://www.nytix.com/NewYorkCity/articles/handbags.html; http://www.laserwisetech.co.nz/secret.php; http://www.muscatdaily.com/Archive/Oman/Fake-car-parts-contribute-to-rise-in-road-accidents-Experts; http://www.andovercg.com/services/cisco-counterfeit-wic-1dsu-t1.shtml; http://unites-systems.com/l.php?id=191

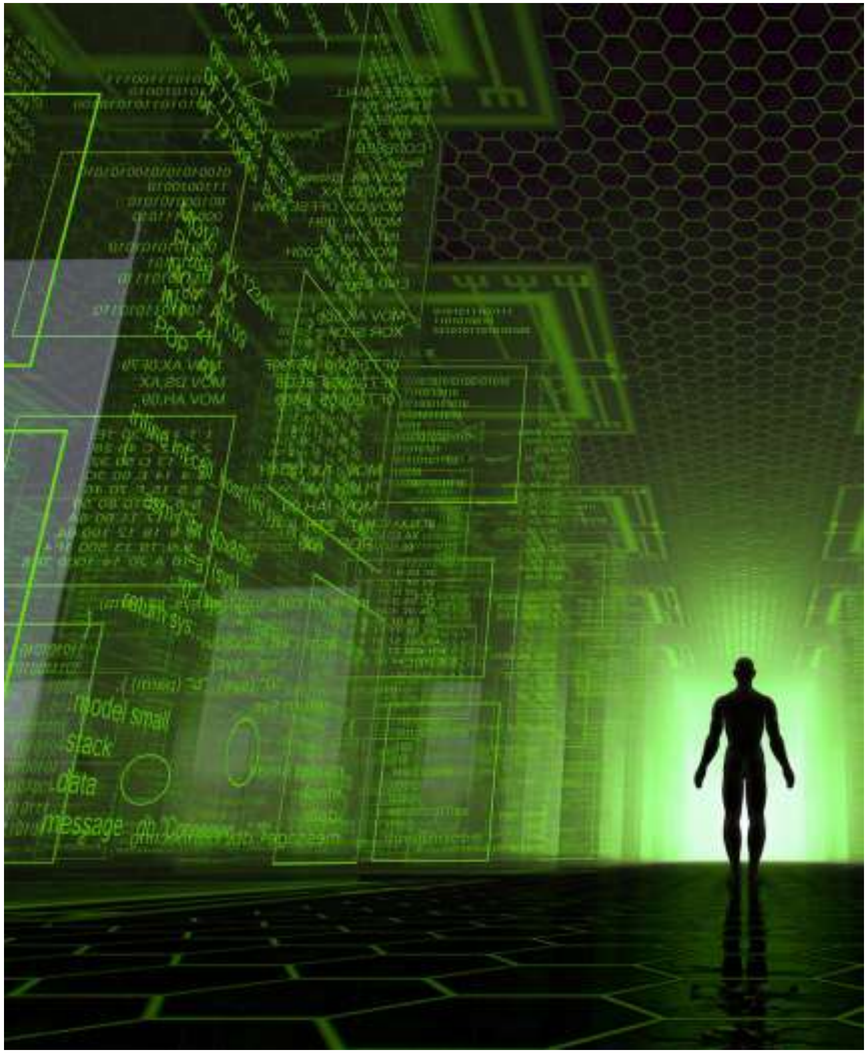
Supply chains also maintain product properties

Cold Chain

A cold chain is a temperature-controlled supply chain. An unbroken cold chain is an uninterrupted series of storage and distribution activities which maintain a given temperature range.

Source: Wikipedia, https://en.wikipedia.org/wiki/Cold_chain

Software is the new hardware – IT

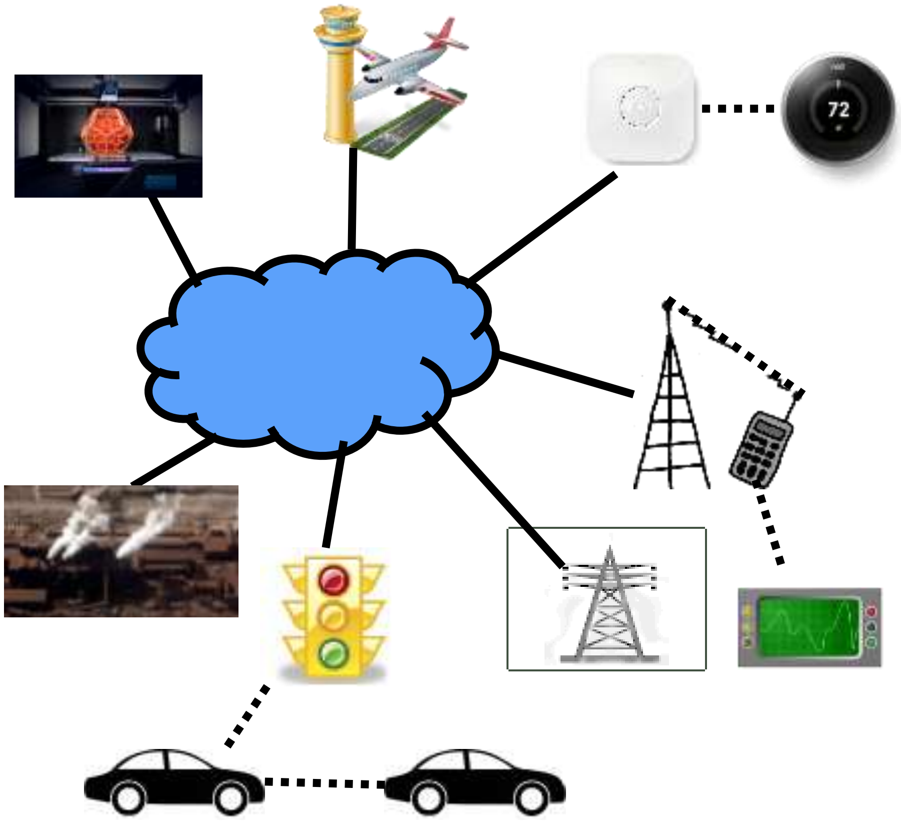


IT moving from specialized hardware to software, virtualized as

- Servers: virtual CPUs
- Storage: SANs
- Switches: Soft switches
- Networks: Software defined networks
- Communications: Software defined radios

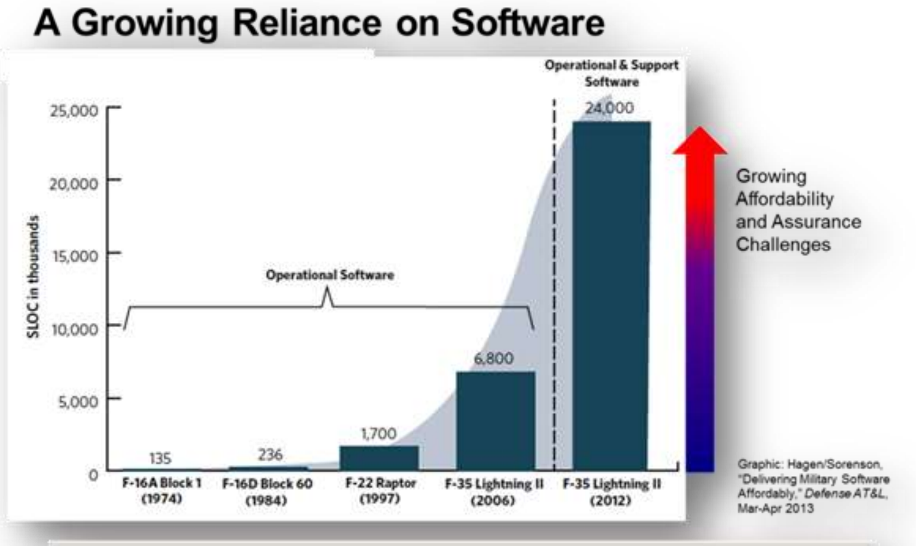
[Distribution Statement A] This material has been approved for public release and unlimited distribution.

Software is the new hardware – cyber physical



- Cellular
  - Main processor
  - Graphics processor
  - Base band processor (SDR)
  - Secure element (SIM)
- Automotive
  - Autonomous vehicles
  - Vehicle to infrastructure (V2I)
  - Vehicle to vehicle (V2V)
- Industrial and home automation
  - 3D printing (additive manufacturing)
  - Autonomous robots
  - Interconnected SCADA
- Aviation
  - Next Gen air traffic control
  - Fly by wire
- Smart grid
  - Smart electric meters
  - Smart metering infrastructure
- Embedded medical devices

Software is advancing function in aviation



A Growing Reliance on Software

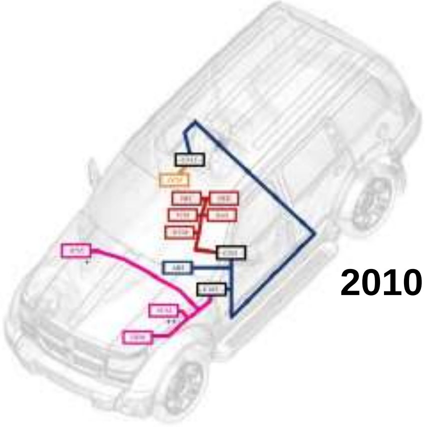
Graphic: Hagen/Sorenson, "Delivering Military Software Affordably," *Defense AT&L*, Mar-Apr 2013

Software as % of total system cost

1997: 45% ⟶ 2010: 66% ⟶ 2024: 88%

Source: U.S. Air Force Scientific Advisory Board. *Sustaining Air Force Aging Aircraft into the 21st Century* (SAB-TR-11-01). U.S. Air Force, 2011.

Vehicle technology following the same path

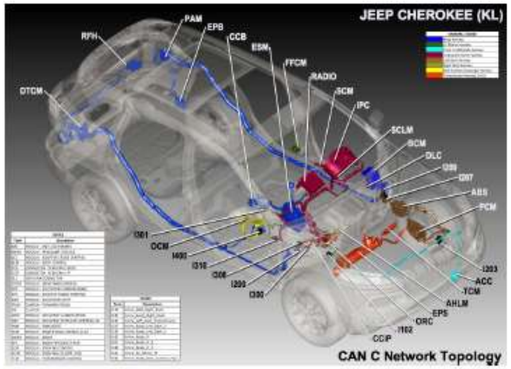


2010 Jeep Cherokee

(12 ECUs)

2014 Jeep Cherokee

(32 ECUs)



CAN-C Network – 2014 Jeep Cherokee

Common assertion that modern high end vehicles have

- Over 100M lines of code
- Over 50 antennas
- Over 100 ECUs

Sources: Miller and Valasek, A Survey of Remote Automotive Attack Surfaces, http://illmatics.com/remote%20attack%20surfaces.pdf; https://www.cst.com/webinar14-10-23~?utm_source=rfg&utm_medium=web&utm_content=mobile&utm_campaign=2014series
https://en.wikipedia.org/wiki/Electronic_control_unit

Evolution of software development

Custom development – context:

- Software was limited
  - Size
  - Function
  - Audience
- Each organization employed developers
- Each organization created their own software

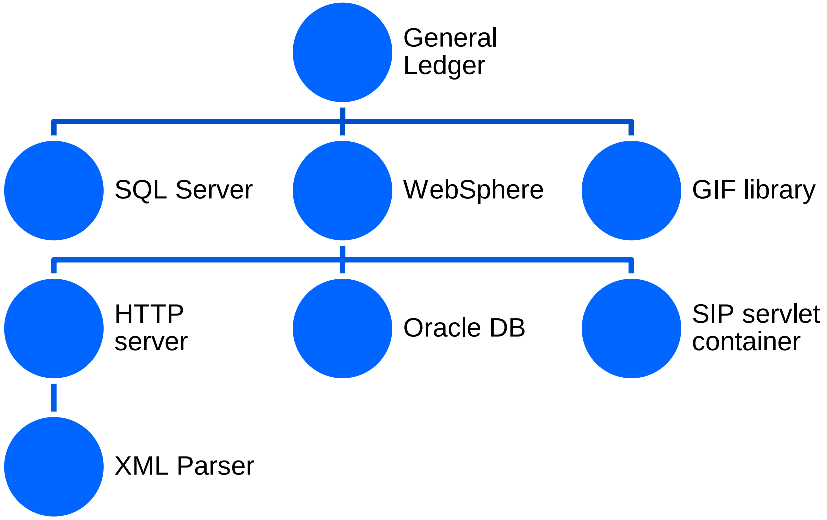
Supply chain: practically none

Shared development – ISVs (COTS) – context:

- Function largely understood
  - Automating existing processes
- Grown beyond ability for using organization to develop economically
- Outside of core competitiveness by acquirers

Supply chain: software supplier

Development is now assembly



Collective development – context:

- Too large for single organization
- Too much specialization
- Too little value in individual components

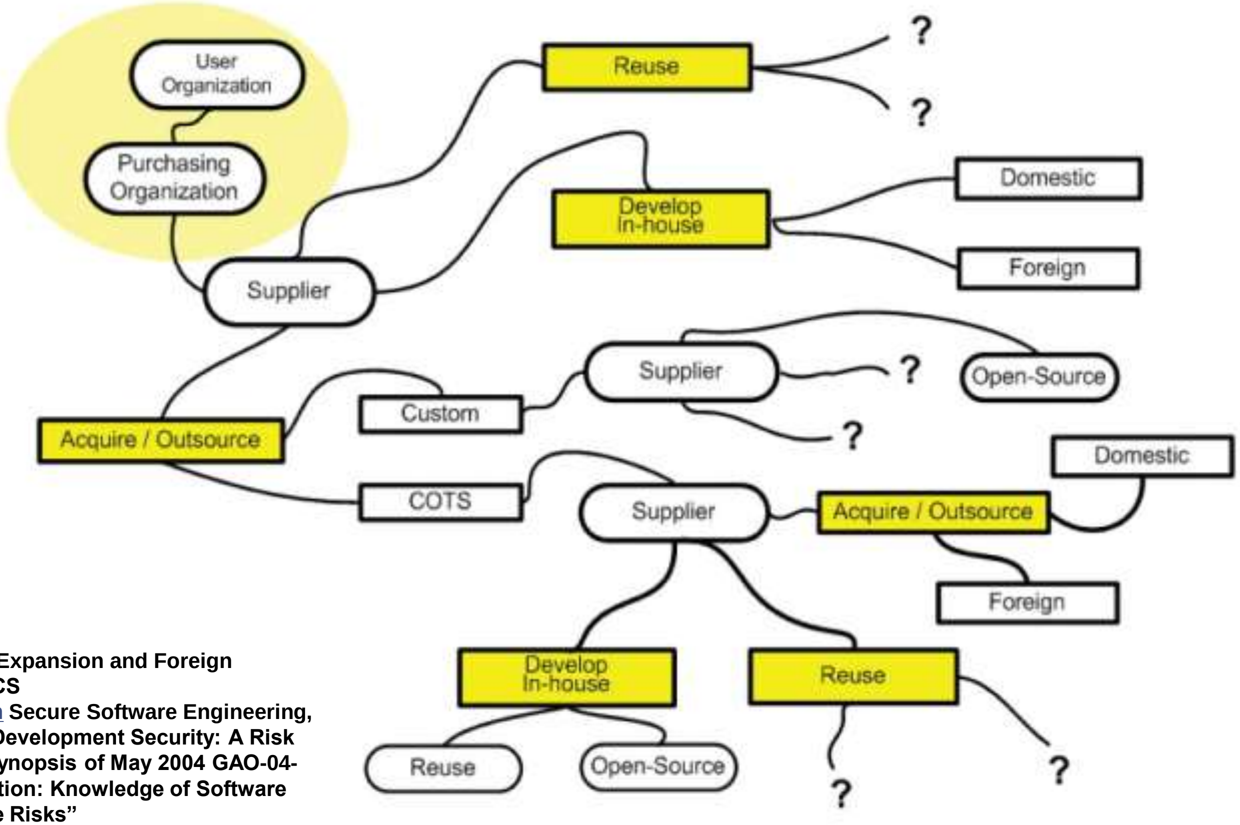
Supply chain: long

Note: hypothetical application composition

Software supply chain for assembled software

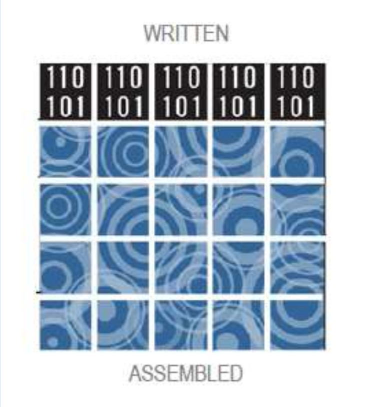
Expanding the scope and complexity of acquisition and deployment

Visibility and direct controls are limited (only in shaded area)



Source: "Scope of Supplier Expansion and Foreign Involvement" graphic in DACS www.softwaretechnews.com Secure Software Engineering, July 2005 article "Software Development Security: A Risk Management Perspective" synopsis of May 2004 GAO-04-678 report "Defense Acquisition: Knowledge of Software Suppliers Needed to Manage Risks"

Substantial open source contained in supply chain



- 90% of modern applications are assembled from 3rd party components
  - At least 75% of organizations rely on open source as the foundation of their applications
- Most applications are now assembled from hundreds of open source components, often reflecting as much as 90% of an application

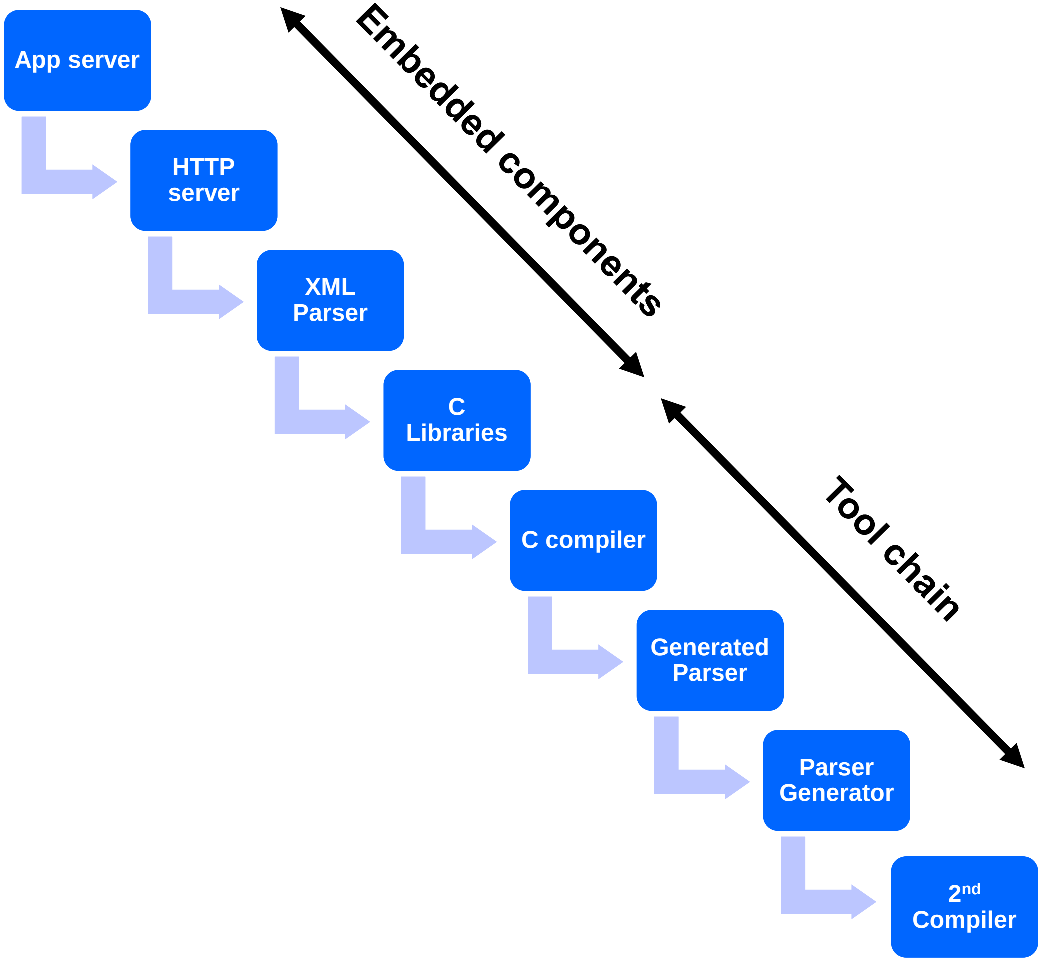
Distributed development – context:

- Amortize expense
- Outsource non-differential features
- Lower acquisition (CapEx) expense

Supply chain: opaque

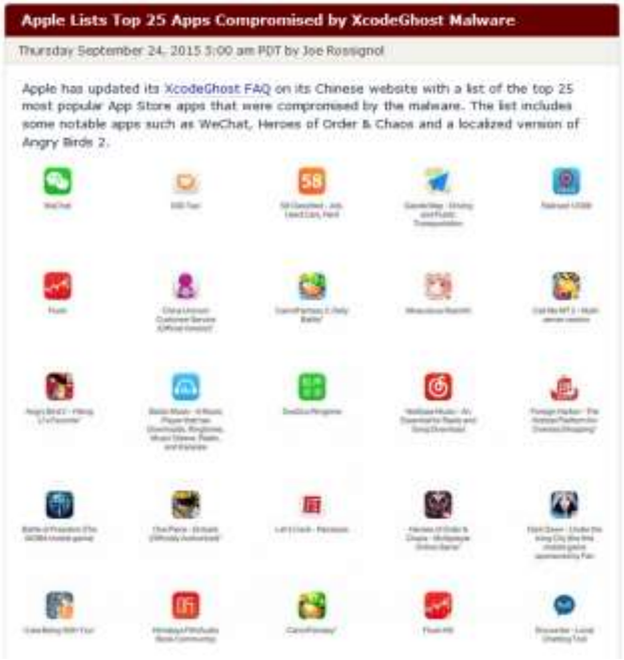
Sources: Geer and Corman, "Almost Too Big To Fail," ;login: (Usenix), Aug 2014; Sonatype, 2014 open source development and application security survey

Open source supply chain has a long path



[Distribution Statement A] This material has been approved for public release and unlimited distribution.

Corruption in the tool chain already exists



Apple Lists Top 25 Apps Compromised by XcodeGhost Malware

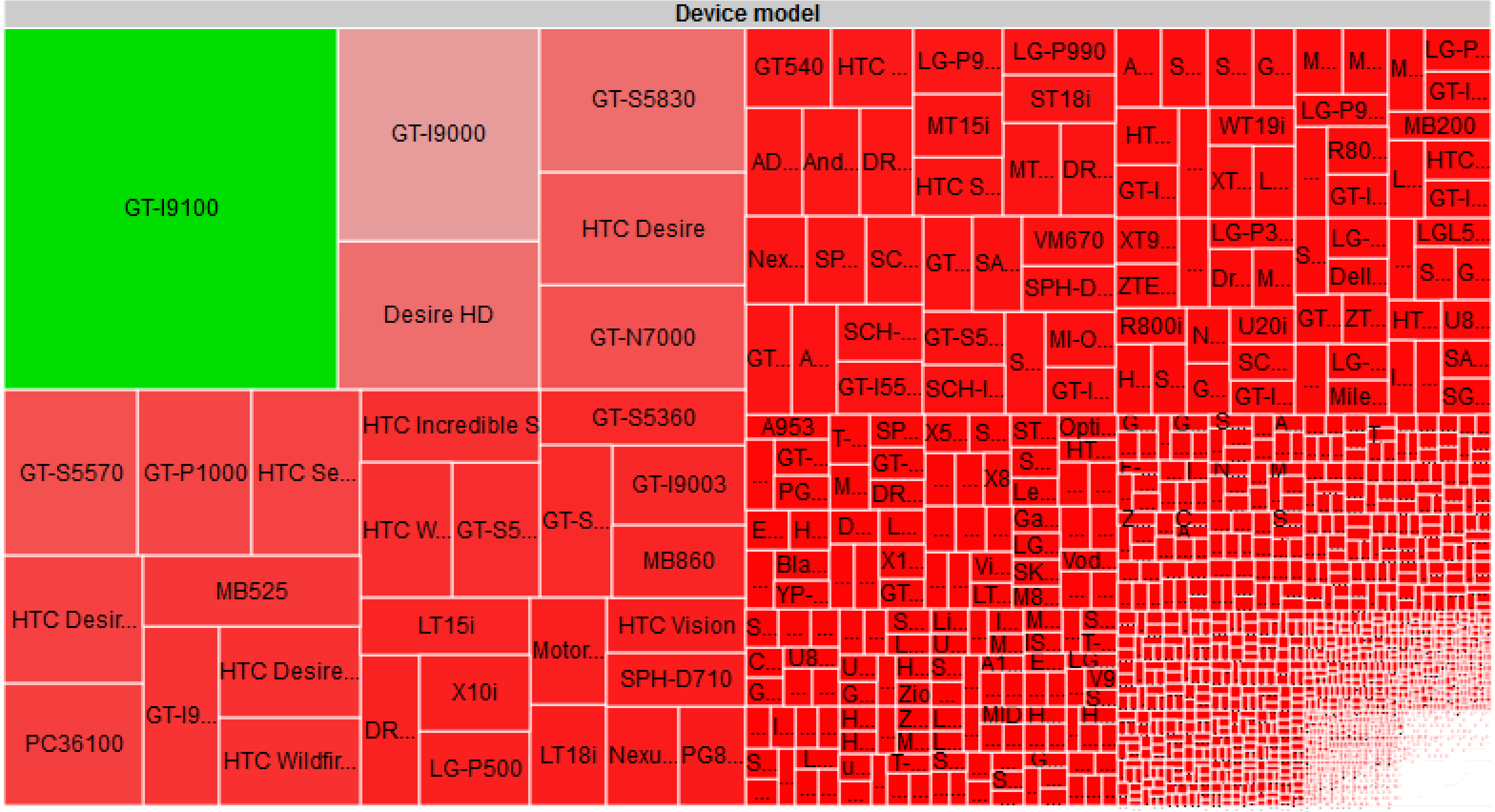
Thursday September 24, 2015 3:00 am PDT by Joe Rossignol

Apple has updated its XcodeGhost FAQ on its Chinese website with a list of the top 25 most popular App Store apps that were compromised by the malware. The list includes some notable apps such as WeChat, Heroes of Order & Chaos and a localized version of Angry Birds 2.

- XcodeGhost corrupted Apple’s development environment
- Major programs affected
  - WeChat
  - Badu Music
  - Angry Birds 2
  - Heroes of Order & Chaos
  - iOBD2
- Not alone
  - Expensive Wall (2017)
  - HackTask (2017)

Sources: http://www.macrumors.com/2015/09/24/xcodeghost-top-25-apps-apple-list/
http://www.itntoday.com/2015/09/the-85-ios-apps-affected-by-xcodeghost.html

Versions of Android illustrate open source fragmentation



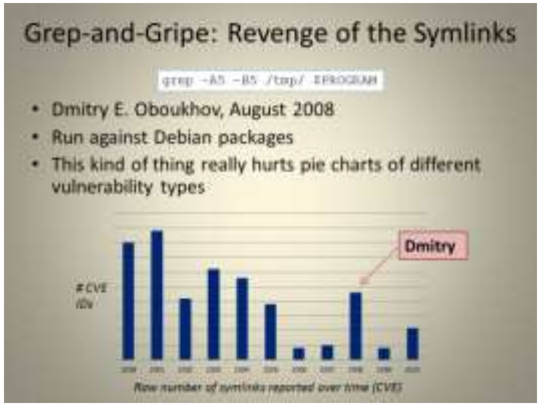
Source: http://opensignal.com/reports/fragmentation.php

.

Open source is not secure

Heartbleed and Shellshock were found by exploitation

Other open source software illustrates vulnerabilities from cursory inspection

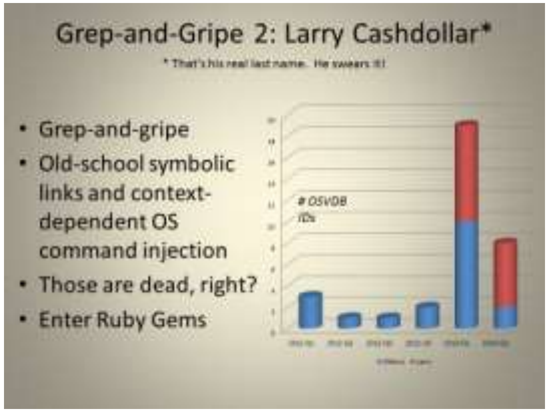


Grep-and-Gripe: Revenge of the Symlinks

```
grep -A5 -B5 /tmp/ $PROGRAM
```

- Dmitry E. Oboukhov, August 2008
- Run against Debian packages
- This kind of thing really hurts pie charts of different vulnerability types

Dmitry
# CVE IDs
Raw number of symlinks reported over time (CVE)



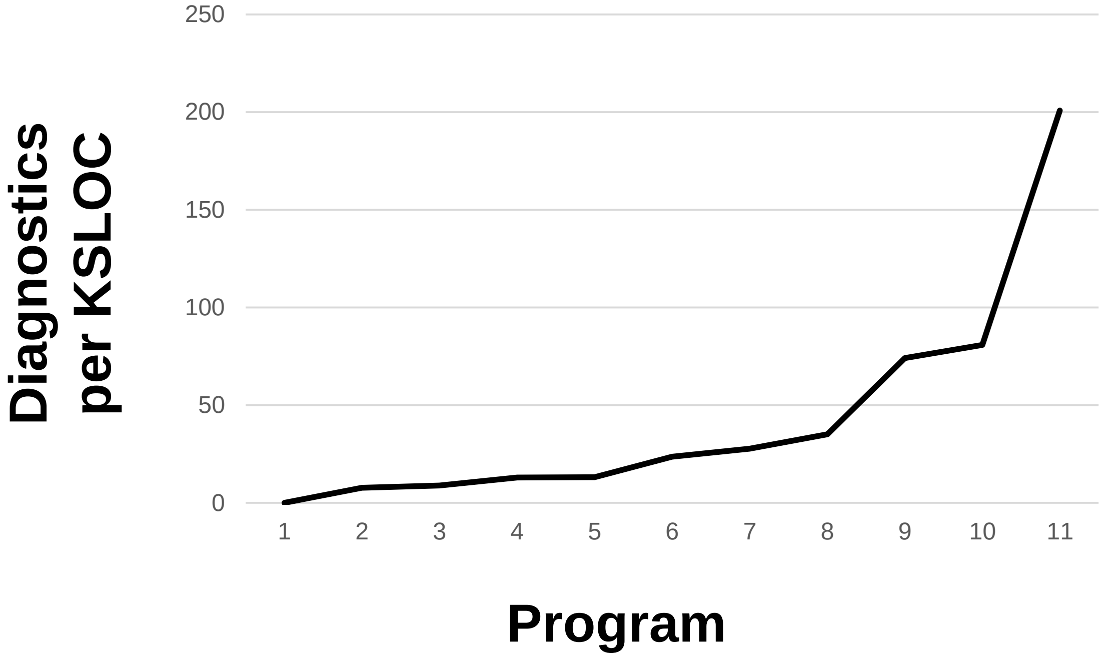
Grep-and-Gripe 2: Larry Cashdollar*

* That's his real last name. He swears it!

- Grep-and-gripe
- Old-school symbolic links and context-dependent OS command injection
- Those are dead, right?
- Enter Ruby Gems

Sources: Steve Christey (MITRE) & Brian Martin (OSF), Buying Into the Bias: Why Vulnerability Statistics Suck, https://media.blackhat.com/us-13/US-13-Martin-Buying-Into-The-Bias-Why-Vulnerability-Statistics-Suck-Slides.pdf; Sonatype, Sonatype Open Source Development and Application Security Survey; Sonatype, 2016 State of the Software Supply Chain; Aspect Software "The Unfortunate Reality of Insecure Libraries," March 2012

There is a wide range of application security quality



On average, there is ~1 vulnerability per 10KLOC

Source: CERT sample of evaluated programs

AI and Data Make Supply Chain Issues Worse

Newer, advanced software depends on these additional “supplies”

Relatively less is known about the security of these “supplies”

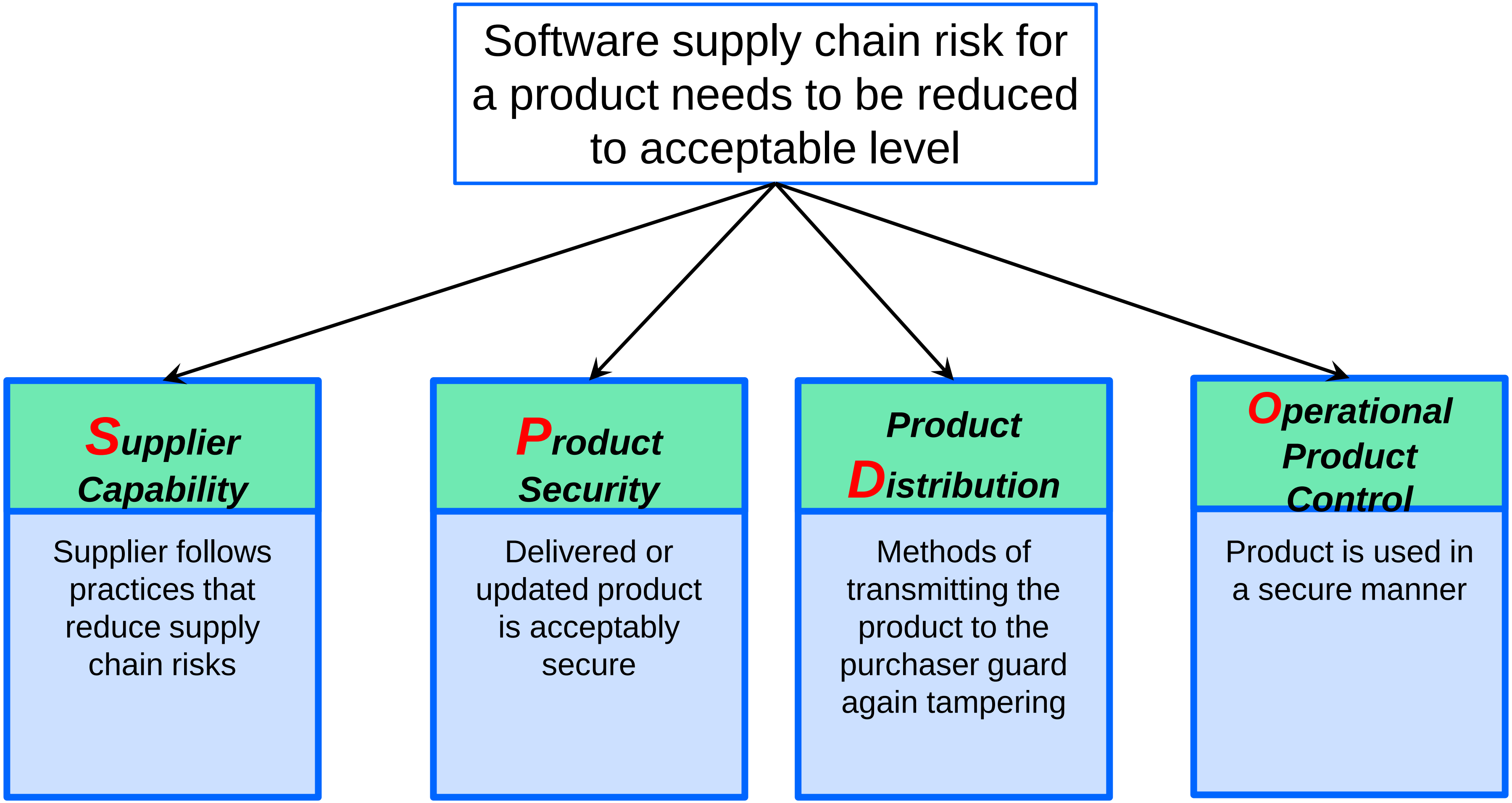
Machine Learning Frameworks

- Pandas
- Numpy
- Scikit-learn
- Matplotlib
- TensorFlow
- Keras
- Seaborn
- Pytorch & Torch

Data Sources

- Kaggle
- UCI Machine Learning Repository
- Find Datasets
- Data.gov
- xView
- ImageNet
- Google’s Open Images

Reducing software supply chain risk factors



Software supply chain risk for a product needs to be reduced to acceptable level

Supplier Capability

Supplier follows practices that reduce supply chain risks

Product Security

Delivered or updated product is acceptably secure

Product Distribution

Methods of transmitting the product to the purchaser guard again tampering

Operational Product Control

Product is used in a secure manner

Supplier security commitment evidence

Supplier employees are educated as to security engineering practices

- Documentation for each engineer of training and when trained/retrained
- Revision dates for training materials
- Lists of acceptable credentials for instructors
- Names of instructors and their credentials

Supplier follows suitable security design practices

- Documented design guidelines
- Has analyzed attack patterns appropriate to the design such as those that are included in Common Attack Pattern Enumeration and Classification (CAPEC)
- Application of code signing techniques (interest in ISO 17960 – in early draft)

Evaluate a product’s threat resistance

What product characteristics minimize opportunities to enter and change the product’s security characteristics?

- Attack surface evaluation: Exploitable features have been identified and eliminated where possible
  - Access controls
  - Input/output channels
  - Attack enabling applications – email, Web
- Design and coding weaknesses associated with exploitable features have been identified and mitigated (CWE)
- Independent validation and verification of threat resistance
- Dynamic, Static, Interactive Application Security Testing (DAST, SAST, IAST)
- Delivery in or compatibility with Runtime Application Self Protection (RASP) containers

Establishing good product distribution practices

Recognize that supply chain risks are accumulated

- Establish provenance procedures
  - Subcontractor/COTS-product supply chain risk is inherited by those that use that software, tool, system, etc.

Apply to the acquiring organizations and their suppliers

- Require good security practices by their suppliers
- Assess the security of delivered products
- Address the additional risks associated with using the product in their context

Minimize internal suppliers

- Single point of distribution to development community

Ideally open source is built with a compiler you trust

Corruption along the supply chain is easy

Unexpected or unintended behaviors in components

incibe_

OCTAVO ENCUENTRO INTERNACIONAL DE SEGURIDAD DE LA INFORMACIÓN
LA ESTRATEGIA DE CIBERSEGURIDAD NACIONAL A EXAMEN

enise

enise CIBERAMENAZAS

DEMO

CIBERAMENAZAS
Pedro Candel
CyberSOC Academy, Deloitte

Knowledgeable analysts can convert packaged binary into malware in minutes

Sources: Pedro Candel, Deloitte CyberSOC Academy , Deloitte

http://www.8enise.webcastlive.es/webcast.htm?video=08; http://www.microsoft.com/Products/Games/FSInsider/freeflight/PublishingImages/scene.jpg; https://www.withfriendship.com/user/mithunss/easter-eggs-in-microsoft-products.php

Distribution Environment Attacks

Types of supply chain attacks that leveraged compromised code and the development environment:

- Source code attacks

  Shadowpad (2017), Anti-Virus Code attack (2017)

- Download site attacks

  Havex/Dragonfly (2014), KingSlayer (2015), Fioxif/CCleaner (2017)

- Patch site attacks

  NotPetya/MeDoc (2017) paralyzed networks worldwide

Maintain operational attack resistance

Who assumes responsibility for preserving product attack resistance with product deployment?

- Maintaining inventory of components
- Patching and version upgrades (component lifecycle management)
- Expanded distribution of usage
- Expanded integration

Usage changes the attack surface and potential attacks for the product

- Change in feature usage or risks
- Are supplier risk mitigations adequate for desired usage?
- Effects of vendor upgrades/patches and local configuration changes
- Effects of integration into operations (system of systems)

[Distribution Statement A] This material has been approved for public release and unlimited distribution.

Cyber attacks on physical systems

Steelworks compromise causes massive damage to furnace.

One of the most concerning was a targeted APT attack on a German steelworks which ended in the attackers gaining access to the business systems and through them to the production network (including SCADA). The effect was that the attackers gained control of a steel furnace and this caused massive damages to the plant.

Dragonfly attacks a dozen companies

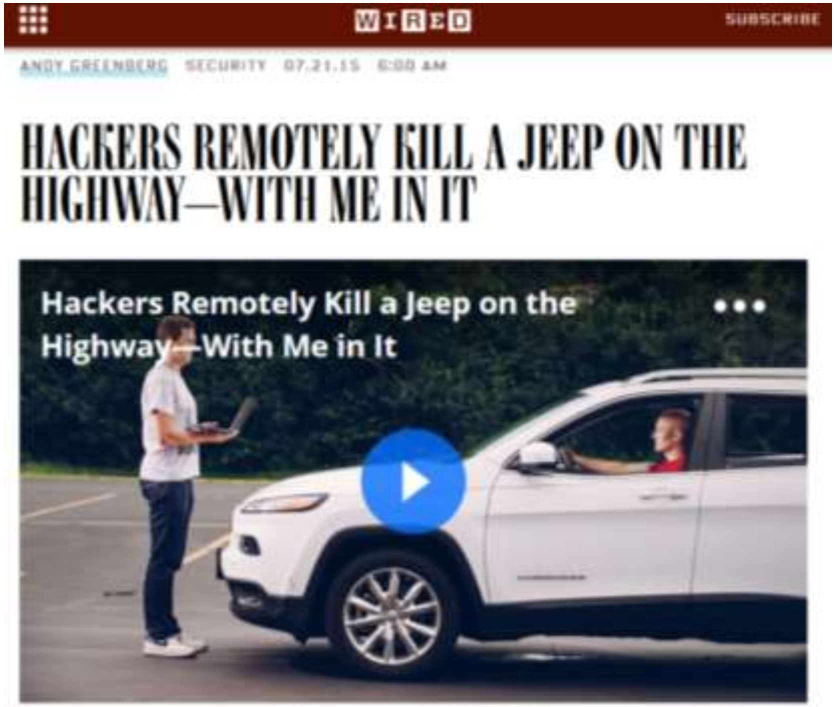
The Dragonfly hacker group attacked a number of companies' SCADA systems and installed the malware 'Havex'. This was used to gather information about the systems. No damage was done, because the compromise was detected and removed before the hackers had completed the observation and intelligence gathering phase.

Die Lage der IT-Sicherheit in Deutschland 2014

Sources: https://www.bsi.bund.de/SharedDocs/Downloads/DE/BSI/Publikationen/Lageberichte/Lagebericht2014.pdf?__blob=publicationFile;

http://www.resilienceoutcomes.com/state-ict-security/

Connecting automotive systems to internet opens system to attack



ANDY GREENBERG SECURITY 07.21.15 6:00 AM

HACKERS REMOTELY KILL A JEEP ON THE HIGHWAY—WITH ME IN IT

Hackers Remotely Kill a Jeep on the Highway—With Me in It

Extending systems opens vulnerabilities not anticipated

- Optimizations performed assuming one attack method
- Assumptions no longer hold with additional integrations

Source: http://www.wired.com/2015/07/hackers-remotely-kill-jeep-highway/

Vulnerabilities emerge in existing code

Defects in functionality found early and in new code

Vulnerabilities found in legacy code and late (“honeymoon effect”)

New operating environments are a major cause of vulnerabilities

Clark, Frei, Blaze, Smith, “Familiarity Breeds Contempt: The Honeymoon Effect and the Role of Legacy Code in Zero-Day Vulnerabilities,” ACSAC ’10 Dec. 6-10, 2010, p. 251-260.”

What about open source?

Establish a supplier for open source

- Self
- 3rd party focusing on open source

Subject to same evaluation

- Supplier capability
- Product security
- Product distribution
- Operational product control

Source: http://opensource.org/

Business decisions are about risk

There are many risks to a business process or mission thread

- Within a system
- Collection of systems

Supply chain is one of many risk components

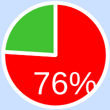
Evaluate software supply chain risk in the larger context of

- Supply chain risk
- System risk
- System of systems risk

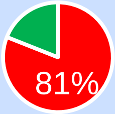
SERA: Security Engineering Risk Analysis

Where to start

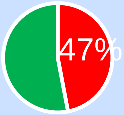
Anywhere



No meaningful controls over what components are applications



No coordination of security practices in various stages of the development life cycle



No acceptance tests for third-party code

Plenty of models to choose from

BSIMM: Building Security in Maturity Model

CMMI: Capability Maturity Model Integration for Acquisitions

PRM: SwA Forum Processes and Practices Group Process Reference Model

RMM: CERT Resilience Management Model

SAMM: OWASP Open Software Assurance Maturity Model

O-TTPS: Open Group Open Trusted Technology Provider™ Standard, Version 1.1

ASF: Acquisition Security Framework

Sources: Sonatype, 2014 Sonatype Open Source Development and Application Security Survey; Forrester Consulting, “State of Application Security,” January 2011

Further reading

Alberts, Christopher, et al., “Introduction to the Security Engineering Risk Analysis (SERA) Fraemwork,” Software Engineering Institute, Nov 2014, http://resources.sei.cmu.edu/asset_files/TechnicalNote/2014_004_001_427329.pdf

Christopher Alberts, John Haller, Charles M. Wallen and Carol Woody, “Assessing DoD System Acquisition Supply Chain Risk Management,” CrosssTalk - The Journal of Defense Software Engineering, May/June 2017, http://www.crosstalkonline.org/storage/issue-archives/2017/201705/201705-albert.pdf

Axelrod, C. Warren, “Mitigating Software Supply Chain Risk,” ISCA Journal Online, Vol 4., 2013, http://www.isaca.org/Journal/Past-Issues/2013/Volume-4/Pages/JOnline-Mitigating-Software-Supply-Chain-Risk.aspx

Axelrod, C. Warren, “Malware, Weakware and the Security of Software Supply Chains,” Cross-Talk, March/April 2014, p. 20, http://www.crosstalkonline.org/storage/issue-archives/2014/201403/201403-Axelrod.pdf

Ellison, Robert, et al, “Software Supply Chain Risk Management: From Products to Systems of Systems,” Software Engineering Institute, Dec 2010, https://resources.sei.cmu.edu/asset_files/technicalnote/2010_004_001_15194.pdf

Ellison, Robert, et al. “Evaluating and Mitigating Software Supply Chain Security Risks,” Software Engineering Institute, May 2010, http://resources.sei.cmu.edu/asset_files/technicalnote/2010_004_001_15176.pdf

Ellison, Robert and Woody, Carol, “Supply-Chain Risk Management: Incorporating Security into Software Development,” Proceedings of the 43rd Hawaii International Conference on System Sciences, 2010, http://resources.sei.cmu.edu/asset_files/WhitePaper/2013_019_001_297341.pdf

Jarzombek, Joe, “Collaboratively Advancing Strategies to Mitigate Software Supply Chain Risks,” July 30, 2009, http://csrc.nist.gov/groups/SMA/ispab/documents/minutes/2009-07/ispab_july09-jarzombek_swa-supply-chain.pdf

Software Assurance Forum, Processes and Practices Working Group, “Software Assurance Checklist for Software Supply Chain Risk Management,” https://buildsecurityin.us-cert.gov/sites/default/files/20101208-SwAChecklist.pdf

“Software Supply Chain Risk Management & Due-Diligence,” Software Assurance Pocket Guide Series: Acquisition & Outsourcing, Vol II, Version 1.2, June 16, 2009, https://buildsecurityin.us-cert.gov/sites/default/files/DueDiligenceMWV12_01AM090909.pdf

Third Party Software Security Working Group, “Appropriate Software Security Control Types for Third Party Service and Product Providers,” Financial Services Information Sharing and Analysis Center, 2013 http://docs.ismgcorp.com/files/external/WP_FSISAC_Third_Party_Software_Security_Working_Group.pdf

Contact Information

Mark Sherman

Technical Director

Cyber Security Foundations

Telephone: +1 412-268-9223

Email: mssherman@sei.cmu.edu

Web

www.sei.cmu.edu

www.sei.cmu.edu/contact.cfm

U.S. Mail

Software Engineering Institute
Customer Relations
4500 Fifth Avenue
Pittsburgh, PA 15213-2612
USA

Customer Relations

Email: info@sei.cmu.edu

Telephone:	+1 412-268-5800
SEI Phone:	+1 412-268-5800
SEI Fax:	+1 412-268-6257