Every Cloud has a Silver Lining

Industry Standards, Best Practices, and Recommendations for Embedded System Security

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GRAND IDEA STUDIO

Every Cloud has a Silver Lining

- Embedded Security Concepts
- Standards / Guidelines
- Best Practices
- Product / Vendor Resources

Embedded Security Concepts

Security Overview

- Security is a process
  - Constantly changing to reflect "state of the art"
  - The attacker usually has the advantage
  - Treat security as an integral part of system design, continue to evaluate during development and revisions
- Given enough time, resources, & motivation, an attacker can break any system
  - Reduce risk to an acceptable level
  - Costs of a successful attack should outweigh potential rewards

Threat Model / Risk Analysis

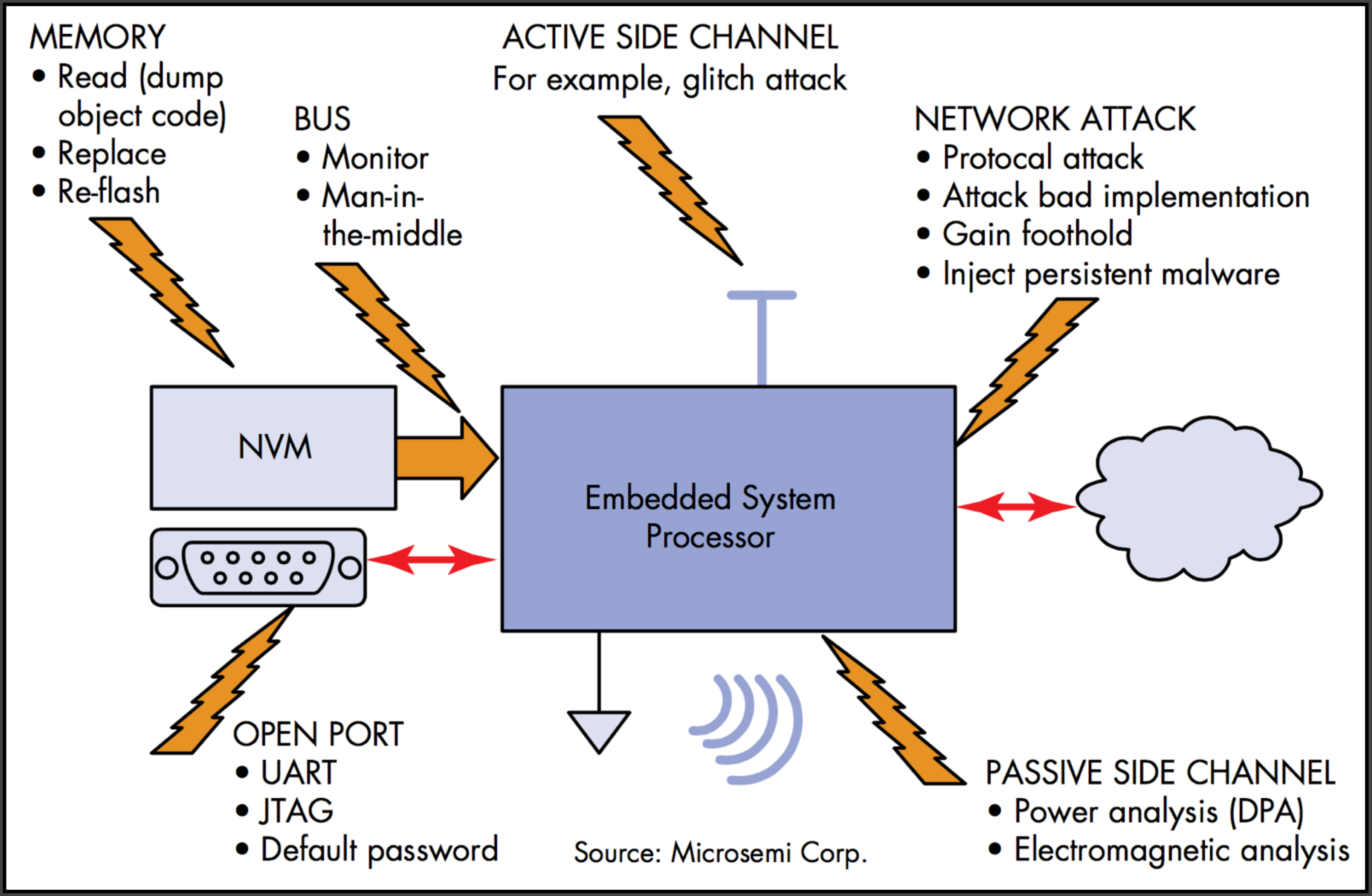
- You must understand your risk before you can protect yourself
  - What needs to be protected
  - Why it is being protected
  - Who you are protecting against (define your adversary)
- What features are absolutely necessary for system functionality?
  - Each new feature increases attack landscape
- Identify single points of failure across the lifecycle
  - Design, fabrication, integration/assembly, distribution, in-the-field

Types of Hackers / Attackers

Resource	Curious Hacker	Academic	Organized Crime	Government
Time	Limited	Moderate	Large	Large
Budget ($)	< $1000	$10k - $100k	> $100k	Unknown
Creativity	Varies	High	Varies	Varies
Detectability	High	High	Low	Low
Target/Goal	Challenge	Publicity	Money	Varies
Number	Many	Moderate	Few	Unknown
Organized?	No	No	Yes	Yes
Release info?	Yes	Yes	Varies	No

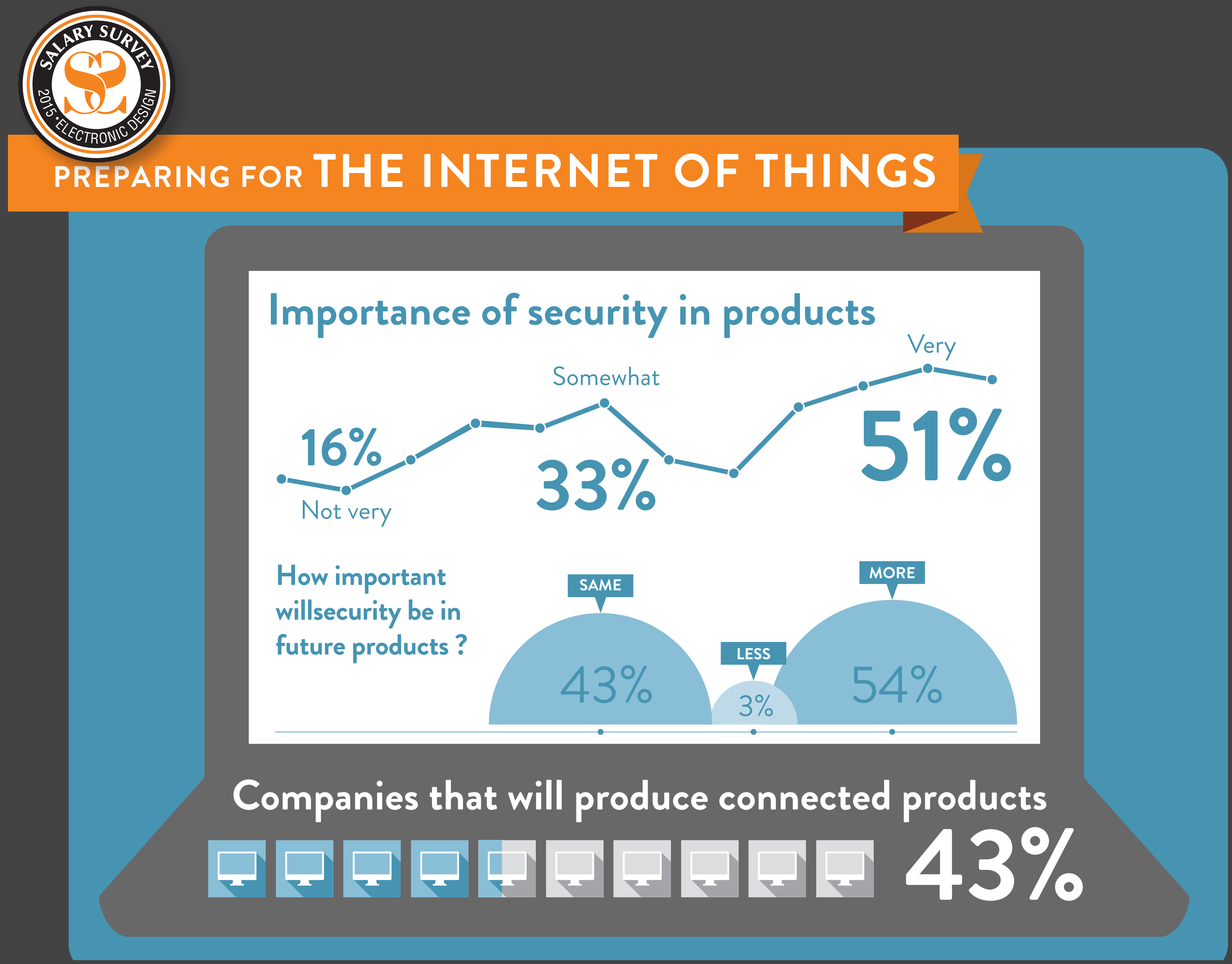
P. Kocher, Crypto Due Diligence, RSA Conference 2002

Common Attack Surfaces

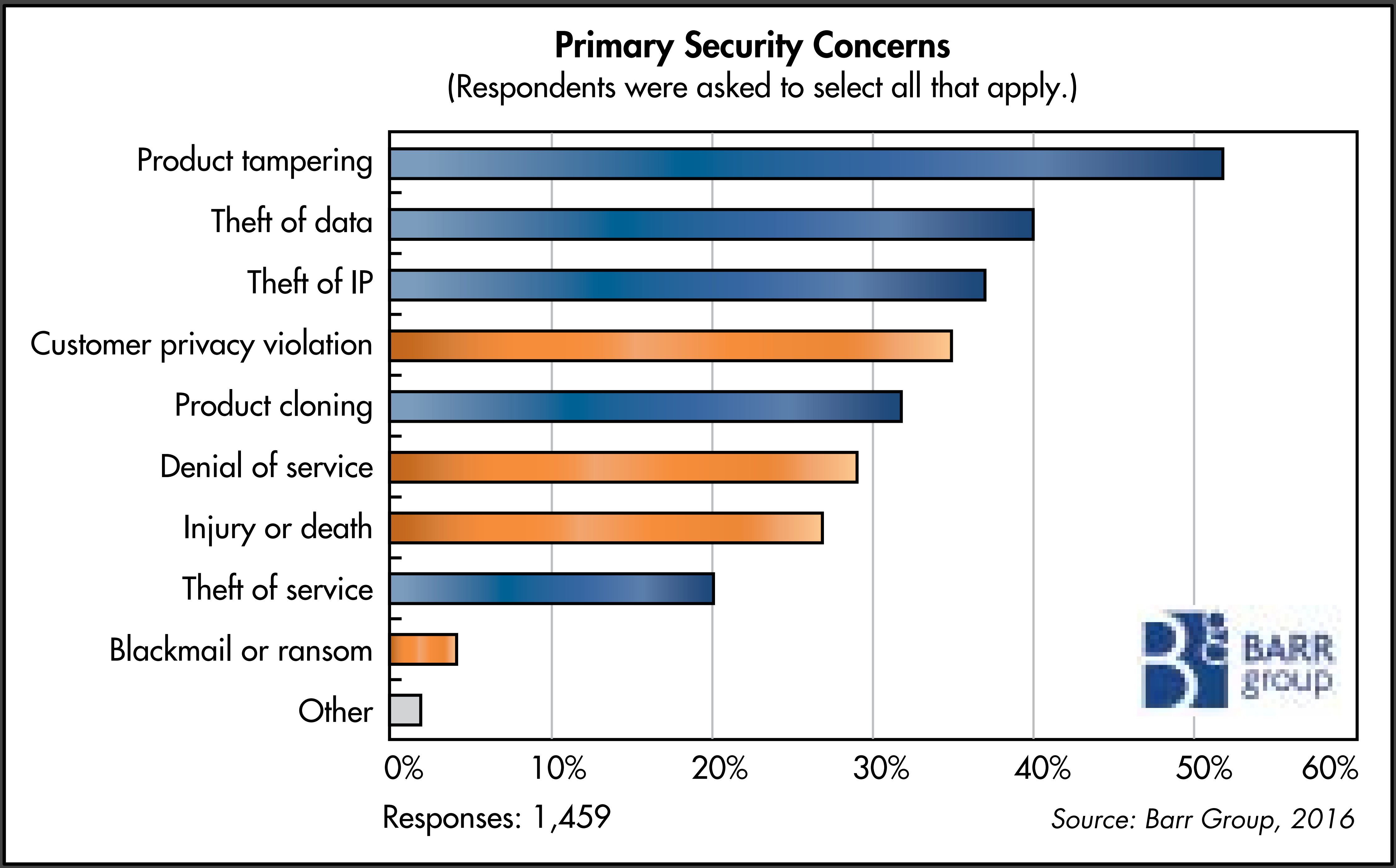


The Biggest Security Threats Facing Embedded Designers, Electronic Design, June 2016

Security Concerns



Security Concerns 2



Easier Said Than Done

- Challenge of cost v. security v. convenience
- Implementation is product specific/resource dependent
  - No one-size-fits-all solution
- However, security solutions/techniques/resources becoming more accessible
  - Still requires some level of security competency
  - Be sure to independently verify what you're implementing

Standards / Guidelines

Standards / Guidelines

- Can be used as a checklist/starting point
  - Usually consists of *what* to do, not *how* to do it
- Some markets require full compliance to specific standards
  - Arguably a detriment to security if standard is too strict (e.g., only allow a specific process or encryption algorithm)
- Just because a device conforms doesn't make it impenetrable

Thinking inside the box: system-level failures of tamper proofing, UCAM-CL-TR-711, Feb. 2008

Standards / Guidelines 2

- International Telecommunication Union (ITU) X.800
  - Security architecture for Open Systems Interconnection for CCITT applications
  - Guidelines/definitions of security-related architectural elements needed for communication between open systems
  - www.itu.int/rec/T-REC-X.800-199103-I/en

Standards / Guidelines 3

- National Institute of Standards and Technology (NIST) Computer Security Resource Center
  - Guidelines/recommendations/references for many aspects of secure systems
  - SP 800: Computer Security
  - SP 1800: Cybersecurity Practice Guides
  - SP 500: Computer Systems Technology
  - http://csrc.nist.gov/publications/PubsSPs.html

Standards / Guidelines 4

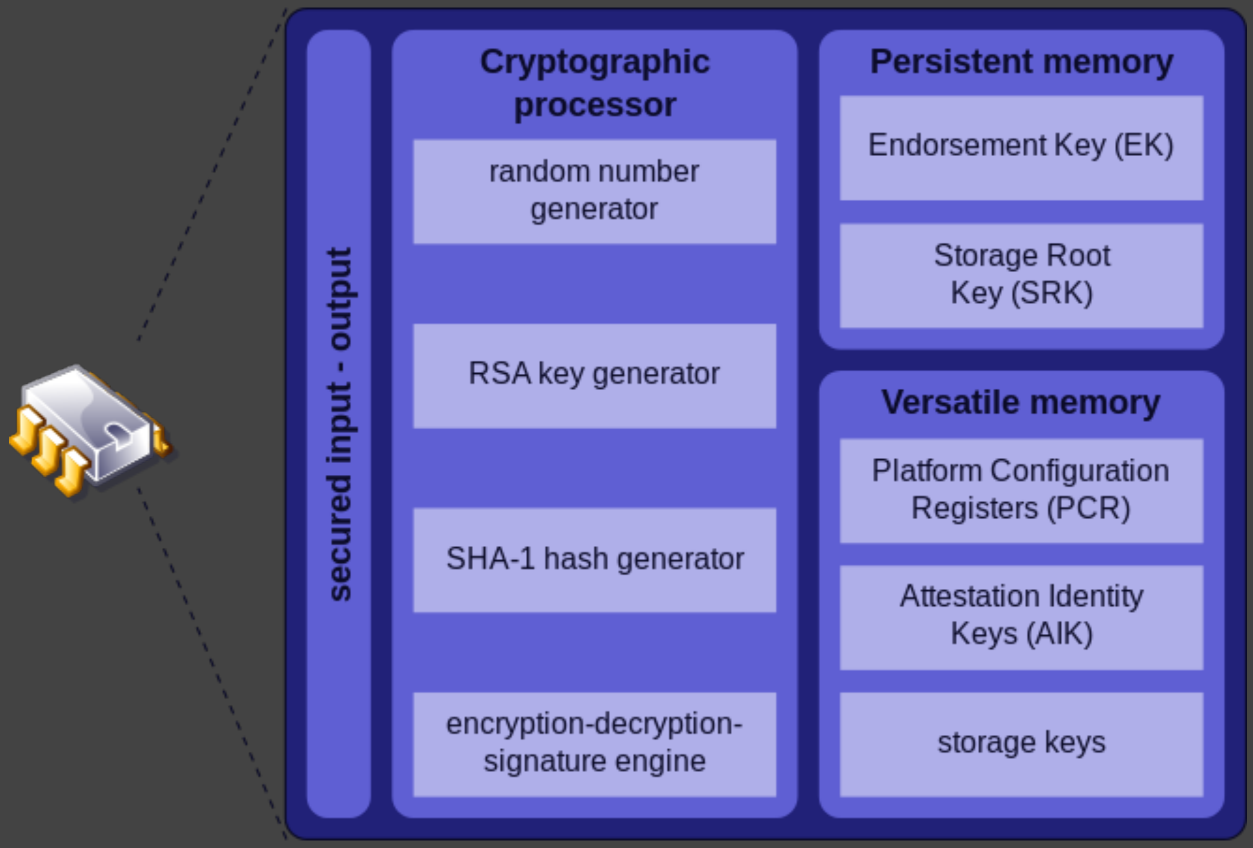
- Underwriters Laboratories Cybersecurity Assurance Program
  - UL 2900 Outline of Investigation for Software Cybersecurity for Network-Connectable Products
    - Part 1: General Requirements
    - Part 2-1: Healthcare Systems
    - Part 2-2: Industrial Control Systems
  - Standards only available for purchase
  - http://industries.ul.com/cybersecurity
  - https://standardscatalog.ul.com/standards/en/outline_2900-1_2

Standards / Guidelines 5

- Federal Information Processing Standards (FIPS)
  - FIPS 140-2 Security Requirements for Cryptographic Modules
  - http://csrc.nist.gov/groups/STM/cmvp/standards.html
- Common Criteria
  - International standard for computer security certification (ISO/IEC 15408)
  - Verified by independent testing laboratories
  - www.commoncriteriaportal.org

Standards / Guidelines 6

- Trusted Platform Module (TPM 1.2/2.0)
  - Standard/specification for secure cryptographic coprocessor
  - On-chip encryption/decryption/signing/key storage/RNG
  - https://en.wikipedia.org/wiki/Trusted_Platform_Module
  - www.trustedcomputinggroup.org/tpm-main-specification/



Standards / Guidelines 7

- Avoiding the Top 10 Security Flaws
  - https://cybersecurity.ieee.org/blog/2015/11/13/avoiding-the-top-10-security-flaws/
- U.S. Dept. of Homeland Security (DHS) Strategic Principles for Securing the IoT
  - High-level guidelines/recommendations
  - www.dhs.gov/securingtheIoT
- Online Trust Alliance (OTA) IoT Trust Framework
  - Guidelines/recommendations for user privacy/security
  - https://otalliance.org/initiatives/internet-things

Standards / Guidelines 8

- Global System for Mobile Communications Association (GSMA) IoT Security Guidelines
  - Guidelines/recommendations for endpoint devices/service providers/network operators
  - www.gsma.com/connectedliving/gsma-iot-security-guidelines-complete-document-set/
- Industrial Internet Security Framework (IISF)
  - www.iiconsortium.org/IISF.htm

Standards / Guidelines 9

- FDA Cybersecurity
  - Principles/considerations for managing security in medical devices
  - Also involved in assessing security threats in released products
  - www.fda.gov/MedicalDevices/DigitalHealth/ucm373213.htm
- National Highway Traffic Safety Administration (NHTSA) Cybersecurity Best Practices for Modern Vehicles
  - Guidelines/recommendations for managing security in automotive electronic systems/communication networks/control algorithms
  - www.nhtsa.gov/Research/Crash-Avoidance/Automotive-Cybersecurity

Best Practices

Best Practices

- Proper design principles can go a long way
  - If implemented correctly...
- Remove the low-hanging fruit
  - Increase difficulty of attack
- Strive for simplicity
  - Each security feature should support a defined goal

Best Practices 2

- Compartmentalization
  - Distribute design documentation on a need-to-know basis
  - Be aware of where/how documentation appears online (firmware update packages)
- Board-Level
  - Remove all non-necessary information
  - PCB silkscreen (designators, fab markings, logos)
  - Component/IC markings (part numbers, logos)
  - Hide critical signals on inner layers, use buried vias
  - Only obfuscation, but increases reverse engineering time

Best Practices 3

- Security Fuses
  - Prevents full read-out or access to a specific memory area
  - Most commonly used on MCU internal memory
  - Easy to enable during code compilation or device programming
  - May still be exploited via brute force, glitch, die attack, off-shore services
- On-Chip Debug/Program/Diagnostic Interfaces
  - Disable or remove completely for production units
  - Implement password/authentication mechanism (may not be part of standard interface)
  - Possibly inconvenient for legitimate personnel (manufacturing, service/repair)

Best Practices 4

- Coding
  - Take care to handle undefined behavior, memory leaks, buffer overflows/bounds checking, invalid data structures, off-by-one, etc.
  - Remove debug symbols/tables, enable optimization
  - Mechanism to update/patch vulnerable code/OS (if needed)
  - Couple w/ source code review, static analysis
- Network Configuration
  - Don't use default login credentials (username/password)
  - Don't add backdoors for future use
  - Close unused ports/daemons/configuration/management interfaces
  - Learn about common network/OS exploits

Best Practices 5

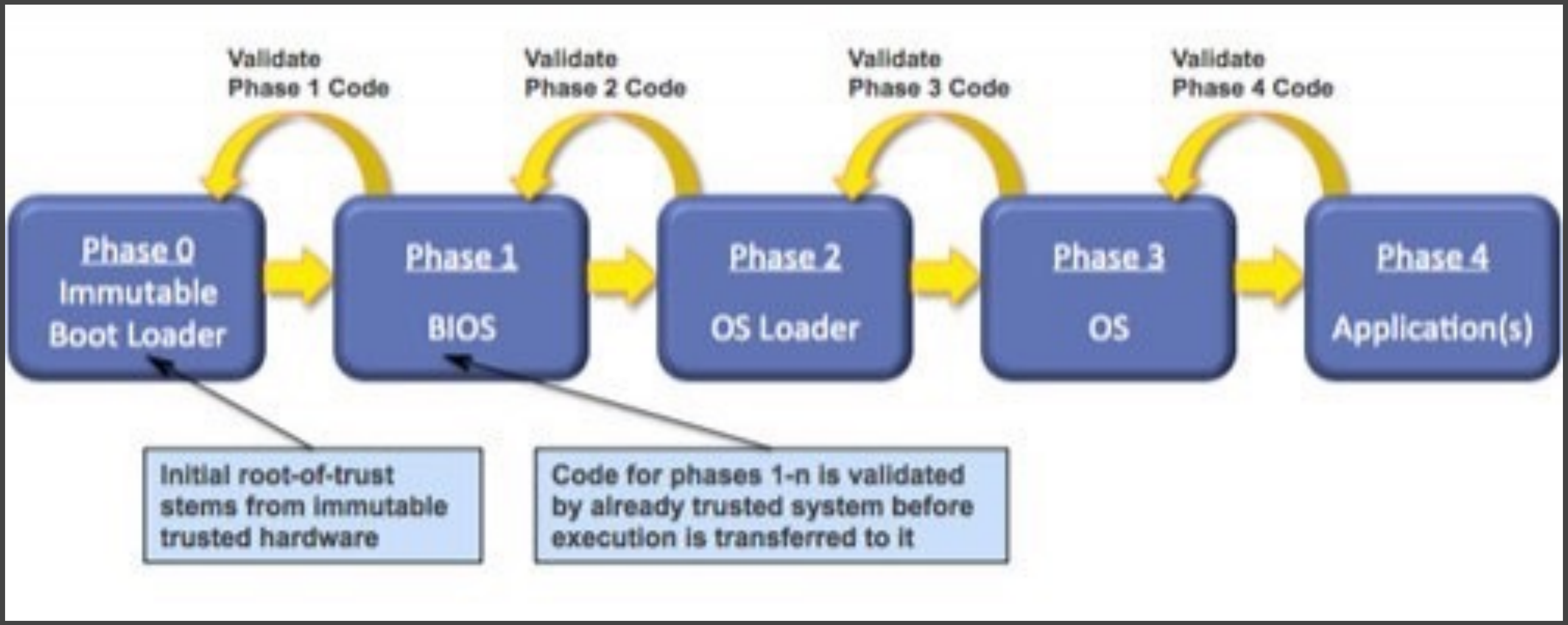
- Anti-Tamper
  - Prevent/deter/detect physical access or tampering of embedded system
  - Resistance, evidence, detection, response
  - See Physical Security Devices for Computer Subsystems: A Survey of Attacks and Defenses, Weingart, CHES 2000
- Run-Time Diagnostics/Failure Modes
  - Ensure device is fully operational at all times (watchdog, periodic system/memory checks)
  - Detect when system is being operated outside of defined conditions (voltage, timing, thermal, optical glitching)
  - Determine how product handles failure (halt/shutdown system, erase critical memory areas)

Best Practices 6

- Encryption
  - For both data at rest and in motion (including firmware, if possible)
  - Consider key management/storage, cipher type
  - Many vendors offer on-chip support for encrypted memory areas
  - Beware of how unencrypted data could be accessed during operation (chip-to-chip communication, debug interface to RAM)
  - For wireless systems, use available security features (check if protocol has already been broken)
  - Use industry standard, publicly scrutinized/analyzed/proven ciphers
    - Don't roll your own!

Best Practices 7

- Secure Boot Process
  - Each stage verifies subsequent stage
  - Only execute trusted code (verified origin/integrity)
  - Prevents arbitrary code execution (unless defeated, commonly done via glitch or patch of hash compare)



Protecting networked designs from intrusion w/ secure FPGAs, Signal Processing Design, Oct. 2013

Best Practices 8

- Side-Channel Prevention
  - Unintentional leakage from system
  - Consider power, EM/RF, timing, thermal
  - See Rambus DPA Countermeasures
  - Many compilers generate side channels unintentionally

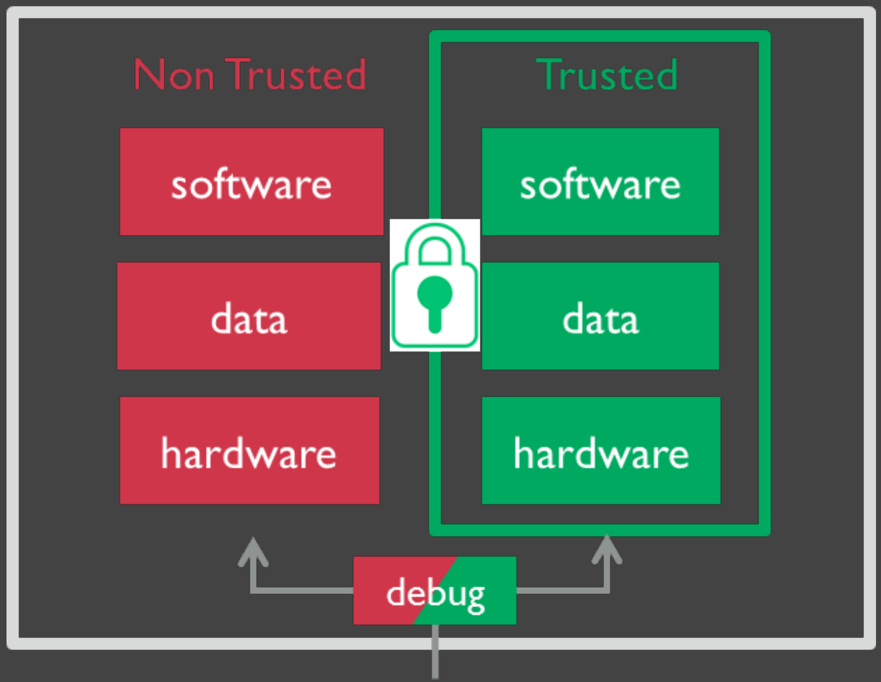
Product / Vendor Resources

Product / Vendor Resources

- No endorsement given!
- Evaluate before implementation
  – Some versions may already have been broken
    - Security Failures in Secure Devices, Tarnovsky, BH DC 2008
    - Hacking the Smartcard Chip (TPM), Tarnovsky, BH DC 2010
- Many vendors require NDA for data sheet
- Just a sampling of what's available for embedded systems

Product / Vendor Resources 2

- Altera (Intel)
  - Secure programmable logic (FPGA, SoC)
  - Root key storage, encrypted bitstream, glitch protection, HW crypto
  - www.altera.com/solutions/technology/security/overview.html
- ARM TrustZone
  - Security extensions/kernel added to ARM architecture
  - Hardware-enforced separation
  - Open source reference implementation
  - www.arm.com/products/ security-on-arm/trustzone



Product / Vendor Resources 3

- Atmel (now Microchip)
  - CryptoAuthentication, TPM, CryptoRF, CryptoMemory
  - ATECC508A AWS IoT Secure Provisioning Platform
  - www.atmel.com/products/security-ics/
- Broadcom
  - Secure Applications Processors (ARM + TPM)
  - BCM5880, BCM5882, BCM5892, BCM5830x family
- Cypress
  - Secure MCUs/PSoC (HW crypto, WiFi security features)
  - SecureNAND Flash Memory (Block protection capabilities)

Product / Vendor Resources 4

- Infineon
  - OPTIGA family (Trust, TPM, Mobile)
  - Authentication, secure MCUs
- Macronix
  - Password-protected SPI Flash memory
- Maxim
  - Authentication, secure MCUs (DeepCover), secure memory/managers
  - www.maximintegrated.com/en/products/digital/embedded-security.html
- Mentor
  - Nucleus SafetyCert RTOS (Real Time Operating System)
  - Designed to meet many safety/security/regulatory requirements

Product / Vendor Resources 5

- Microchip
  - CEC1302 Crypto Embedded Controller (ARM Cortex-M4)
  - PIC Microcontrollers w/ Cryptographic Engines, CRC Scan
  - www.microchip.com/design-centers/embedded-security
- Microsemi
  - Secure FPGAs (root of trust, on-chip cryptographic support)
  - SmartFusion2 SoC (ARM Cortex-M3), IGLOO2
  - www.microsemi.com/products/fpga-soc/security
- NXP (Freescale)
  - Kinetis K8x Secure MCU family (ARM Cortex-M4)
  - On-the-fly AES decryption/execution from external Flash, boot ROM for encrypted FW updates, HW crypto, tamper detection (temperature, voltage, clock)

Product / Vendor Resources 6

- Qualcomm
  - Snapdragon
  - Secure boot, trusted execution environment, HW crypto, authentication
  - www.qualcomm.com/products/snapdragon/security
- Renesas
  - Secure MCUs (RS-4, AE-5)
  - www.renesas.com/en-us/products/secure-mcus.html
- Samsung
  - NAND Flash w/ serial interface, inline encryption/decryption
  - https://en.wikipedia.org/wiki/Universal_Flash_Storage
  - http://csrc.nist.gov/groups/STM/cmvp/documents/140-1/140sp/140sp2380.pdf

Product / Vendor Resources 7

- STMicroelectronics
  - ST23, ST31, ST32, ST33 Secure MCU families
  - STSAFE-A authentication
  - www.st.com/en/secure-mcus.html
- Swissbit
  - Secure uSD cards w/ encrypted Flash memory
  - swissbit.com/products/security-products/overwiev/security-products-overview/
- Texas Instruments
  - Secure MCUs, HW crypto, protected memory regions
  - www.ti.com/ww/en/embedded/security/

Product / Vendor Resources 8

- Xilinx
  - Secure programmable logic (FPGA)
  - Root key storage, encrypted bitstream, HW crypto, anti-tamper, DPA countermeasures
  - www.xilinx.com/products/technology/design-security.html
- Zilog (IXYS)
  - eZ80F91 MCU w/ TCP/IP stack & embedded firewall (ZGATE)
  - www.zilog.com/ZGATE

Product / Vendor Resources 9

- CHIPSEC: Platform Security Assessment Framework
  - Test suite for analyzing security of PC platforms (HW, system firmware, platform components)
  - https://github.com/chipsec/chipsec
- SparkFun CryptoShield
  - Open source hardware security reference/experimentation shield for Arduino and compatible
  - Real-time clock, TPM, encrypted EEPROM, authentication chips
  - www.sparkfun.com/products/13183
- CrypTech Alpha
  - Open source Hardware Security Module (HSM) reference design
  - Cryptographic engine and key storage (ARM + FPGA)
  - https://cryptech.is/

What Now?

- Learn from history/prior attacks
- Proactive security means safer products for all
  - Invest in proper design from the beginning
  - Don't wait for legislation before taking responsibility
  - Allocate time for white/black box product security analysis/testing
  - Bug bounty programs, accept/reward outside discoveries
  - Enable security by default

Thanks for your time!