Foundations of Software Engineering

Part 20: Security Development Lifecycles

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(Based on slides by Michael Maass)

Learning goals

- Understand basic concepts of vulnerabilities and secure software
- Implement security mechanisms across the entire software development lifecycle
- Design and inspect architecture for security with threat modeling
- Decide how do adopt security practices and educate participants. Who, when, and how much?

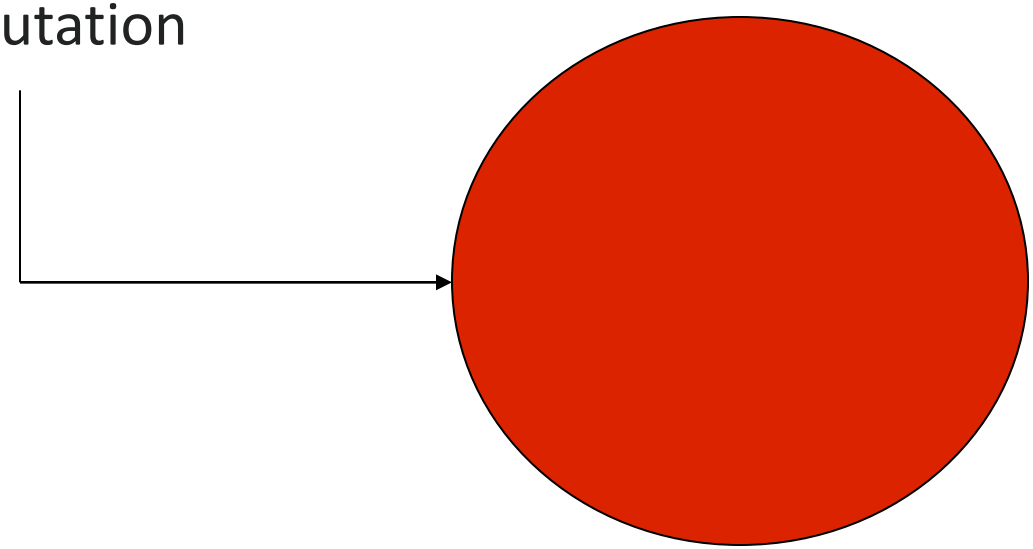
Software is Building Material

1970's: C130E ~8% of functions in software

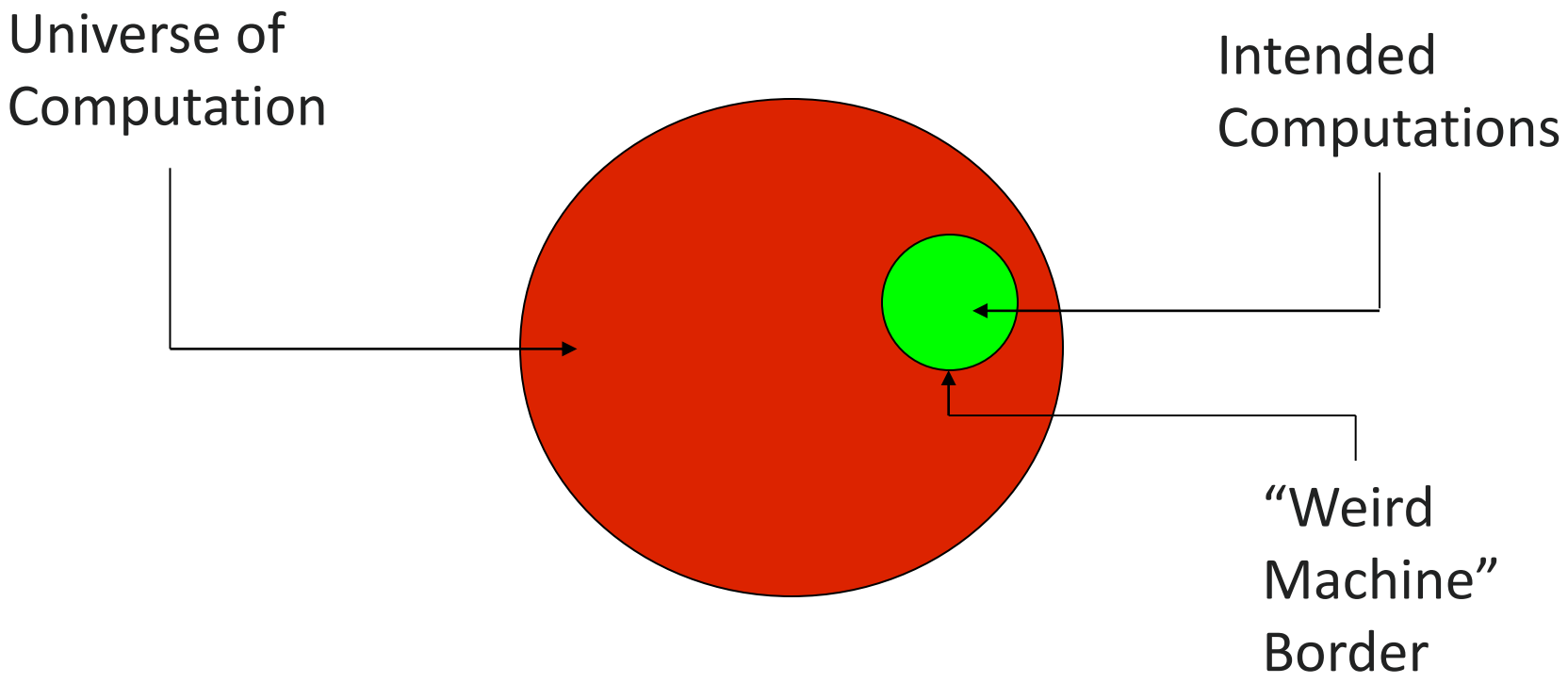
Now: C130J ~80% of functions in software.

Attack Surfaces

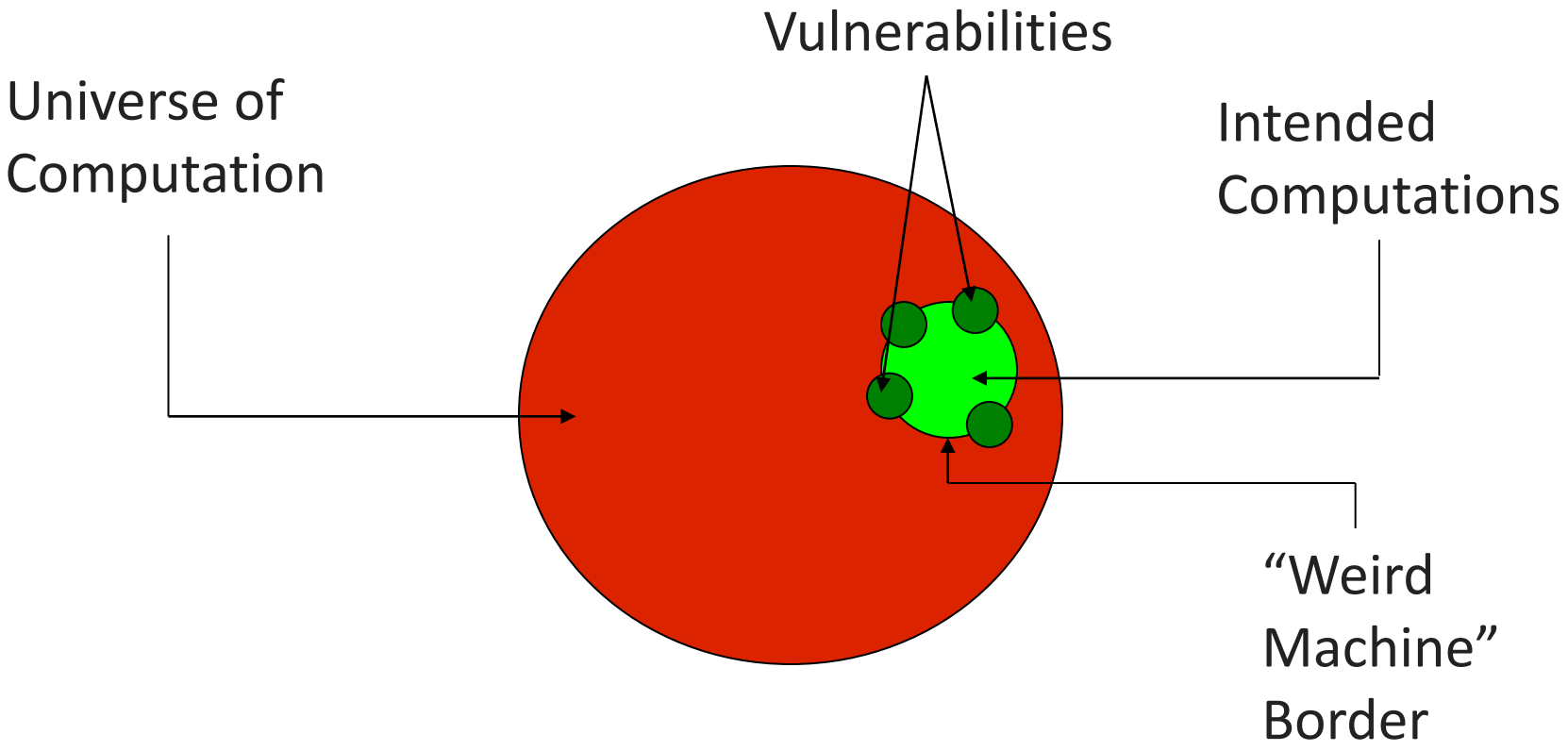
Universe of
Computation



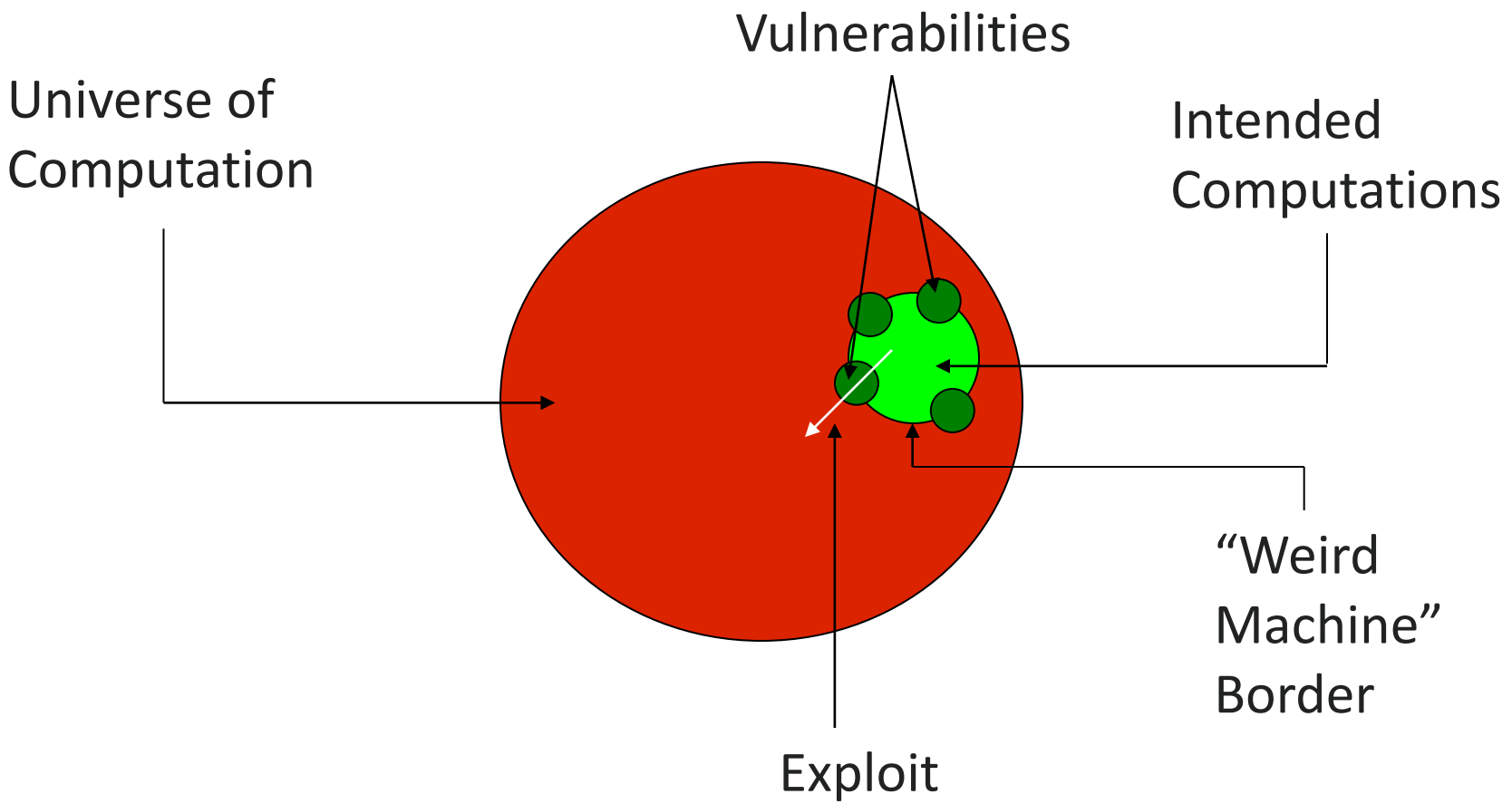
Attack Surfaces



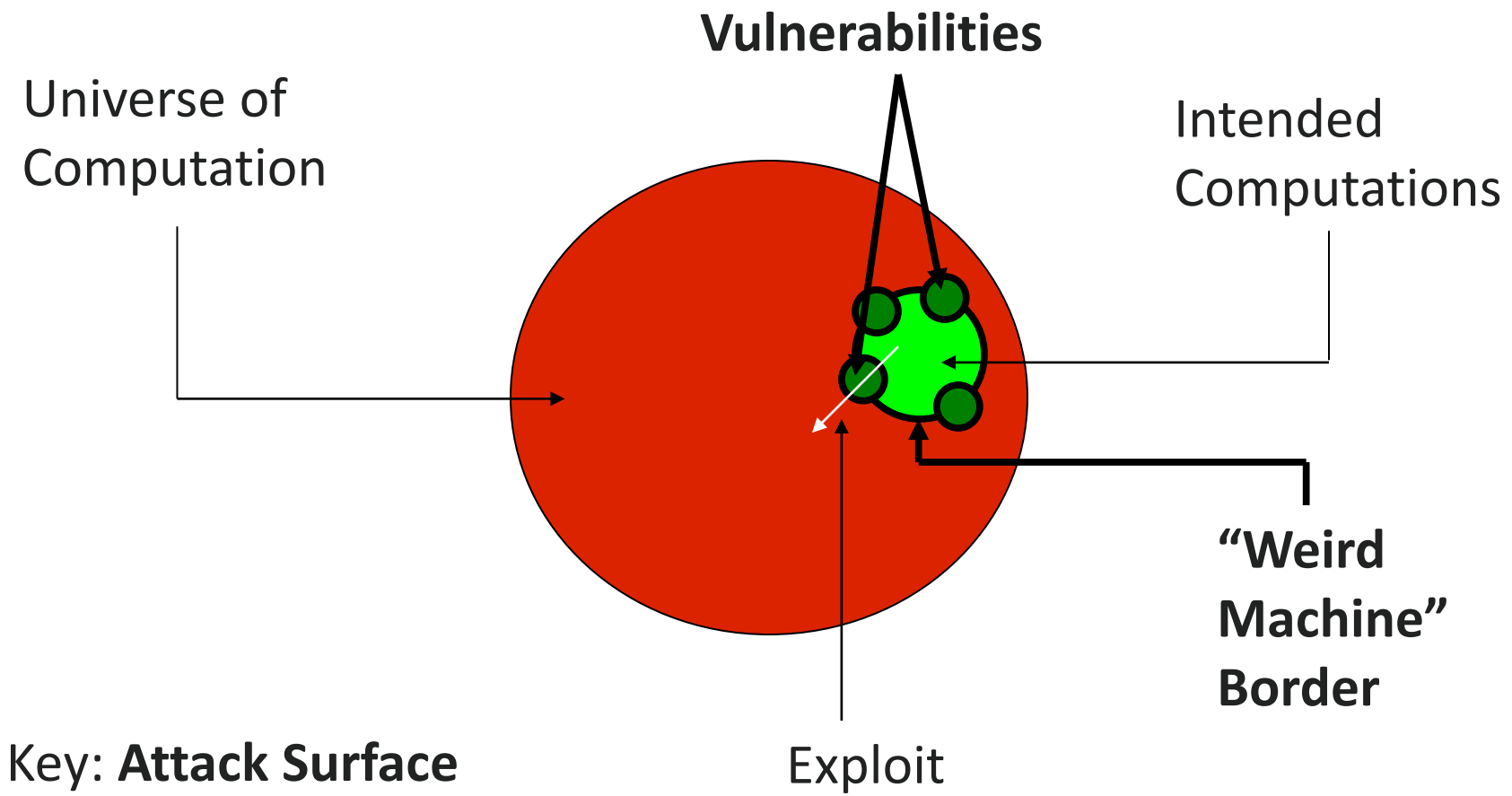
Attack Surfaces



Attack Surfaces



Attack Surfaces



Key: **Attack Surface**

Vulnerabilities Have Utility

- Bugs and vulnerabilities are typically accidentally introduced
- Both can cause a system to fail
- **Bugs** typically cause failures through innocent interactions
- **Bugs** often result in a loss of control with no utility
- **Vulnerabilities** cause failures through intentional and clever interactions initiated by a malicious actor
- **Vulnerabilities** give an attacker a route to seize control

An Airplane Example

- The wings fall off in violent turbulence
- Power shuts off when crossing the international date line

BUGS

- Ground control channels allow anyone to re-route active flights
- The fuel system can be trivially ordered to dump fuel at altitude

VULNERABILITIES

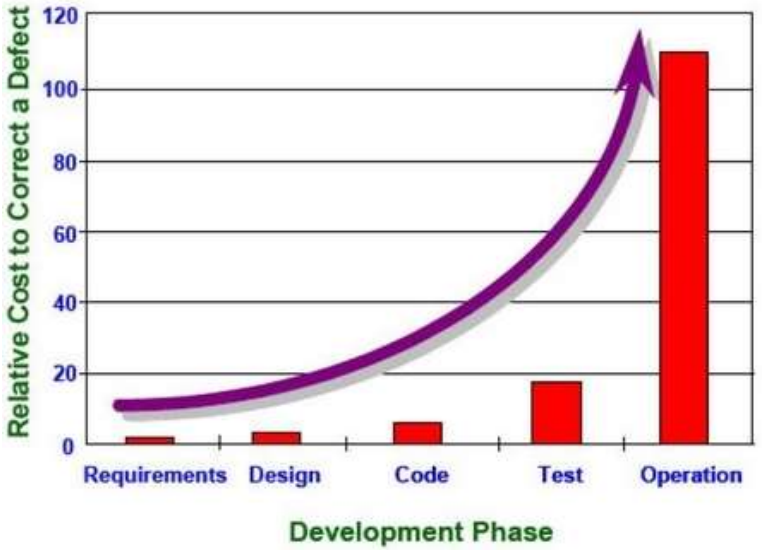
Security

- Confidentiality: Data is only available to the people intended to access it.
- Integrity: Data and system resources are only changed in appropriate ways by appropriate people.
- Availability: Systems are ready when needed and perform acceptably.
- Authentication: The identity of users is established (or you're willing to accept anonymous users).
- Authorization: Users are explicitly allowed or denied access to resources.
- Nonrepudiation: Users can't perform an action and later deny performing it.

Security Development Lifecyles (SDLs) prescribe **security practices** for each phase of a software development project.

Security Practice Goals

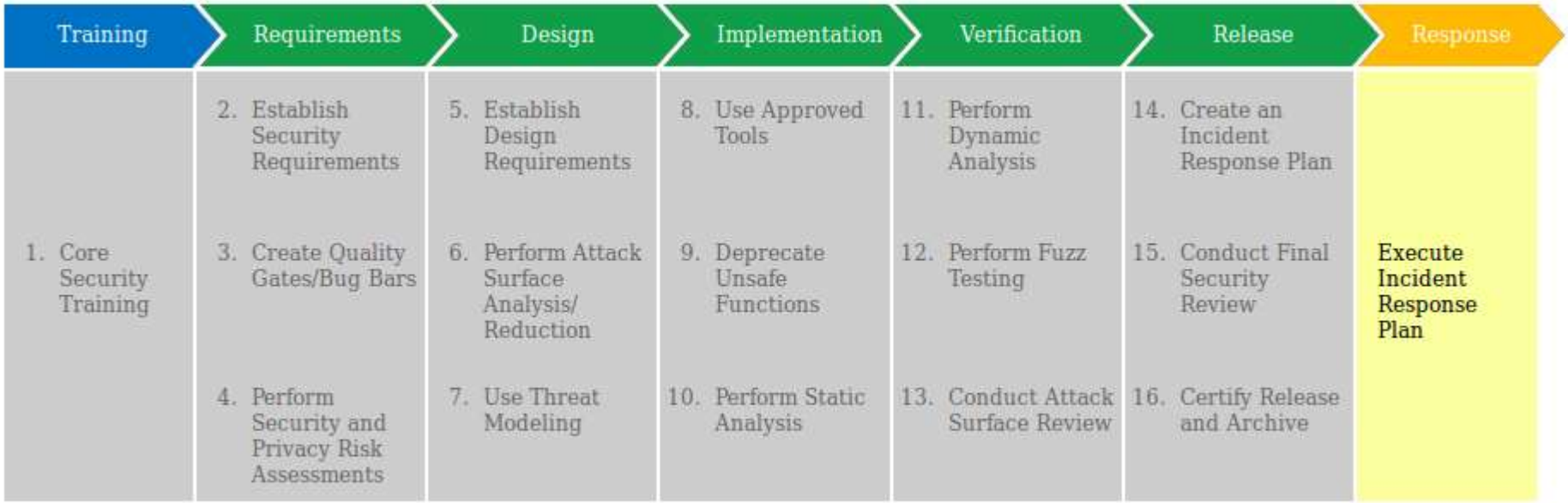
- Find vulnerabilities early
- Identify risks and mitigate them
- Reduce attack surface
- Prepare to fix future vulnerabilities quickly
- Gain confidence that the system is secure
- **Build security in!**



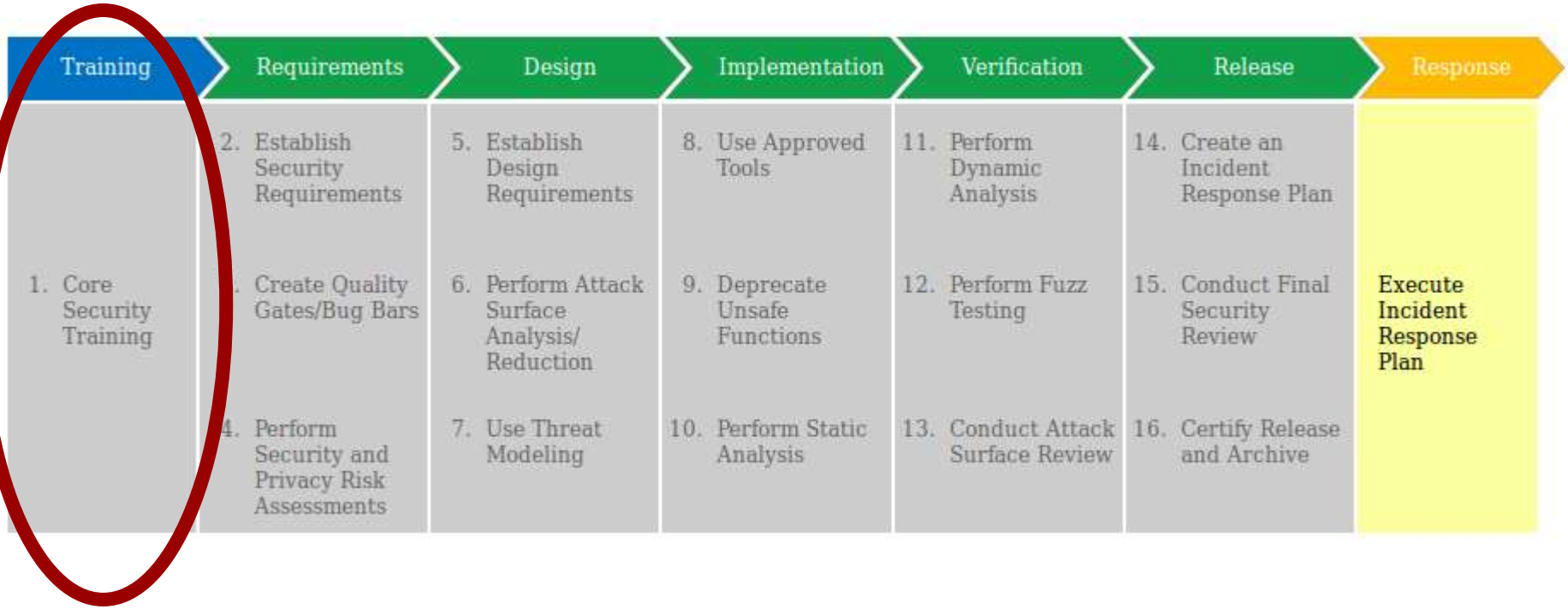
Microsoft Trustworthy Computing Initiative (2002)

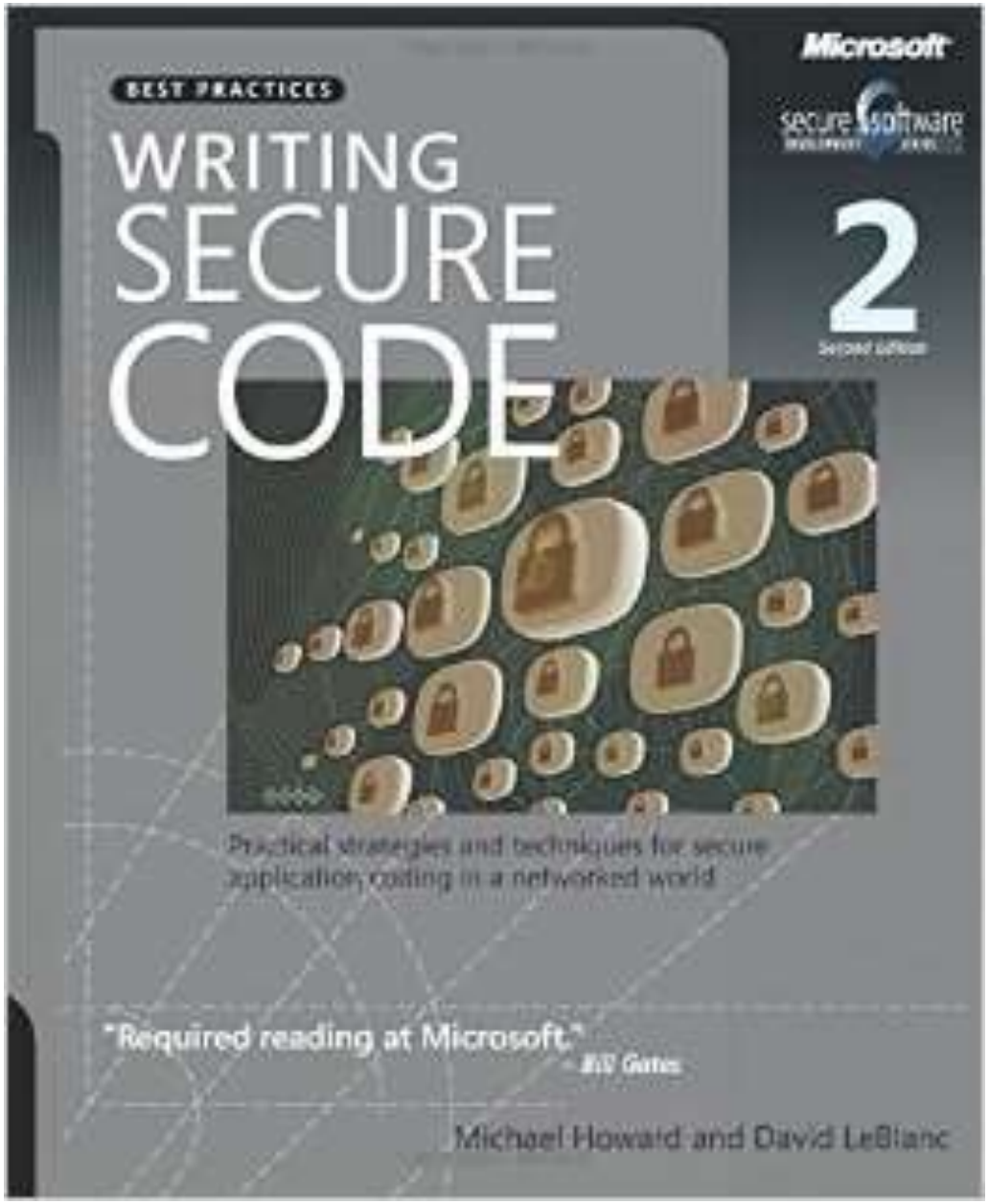
- see memo

Microsoft SDLs



Microsoft SDLs




Microsoft
BEST PRACTICES
WRITING SECURE CODE
2
Practical strategies and techniques for secure application coding in a networked world
"Required reading at Microsoft."
Michael Howard and David LeBlanc

CERT: Secure Coding Standards

- https://www.securecoding.cert.org/

(Academic) Design Principles

Principle	Explanation
Open design	Assume the attackers have the sources and the specs.
Fail-safe defaults	Fail closed; no single point of failure.
Least privilege	No more privileges than what is needed.
Economy of mechanism	Keep it simple, stupid.
Separation of privileges	Don't permit an operation based on a single condition.
Total mediation	Check everything, every time.
Least common mechanism	Beware of shared resources.
Psychological acceptability	Will they use it?

Saltzer and Schroeder's design principles

"8 Simple Rules for Developing More Secure Code" (M. Howard, MSDN Magazine Nov 2006)

1. Take Responsibility
2. Never Trust Data
3. Model Threats against Your Code
4. Stay One Step Ahead
5. Fuzz!
6. Don't Write Insecure Code
7. Recognize the Strategic Asymmetry
8. Use the Best Tools You Can

Microsoft SDLs

Security Requirements

- Security requirements are as important as any other requirement category
- Must include individuals with security expertise
- Deploy vulnerability tracking system
  - Can be the same as the bug tracker for most projects

Example

- “The application shall provide passwords, smart cards, and one-time passwords to support user authentication.”
- “The mechanisms for performing cryptographic operations shall be easily replaceable at runtime.”

Microsoft SDLs

Certify Security Requirements in Design

- Traceability from security requirements to design (and implementation)
- Inspection of design
- Involve security experts

Microsoft SDLs

Threat Modeling

- A structured approach to find threat scenarios that apply to a product
- Typically:
  - Create a data flow diagram showing system components and the data flowing between them (requires some expertise in deciding what to model)
  - Apply the STRIDE threat model at each data flow to enumerate threats

STRIDE

- **Spoofing** – can an actor use someone else's data as their own or trick the system into using fake data?
- **Tampering** – is malicious modification of data possible?
- **Repudiation** – can an actor claim they didn't perform an action or easily make it look like someone else did it?
- **Information Disclosure** – is an actor given private or sensitive information they don't need?
- **Denial of Service** – can an actor prevent valid users from using the system?
- **Elevation of Privilege** – can an actor gain higher privileges than they should have?

Inspection per component

STRIDE vs Security Properties

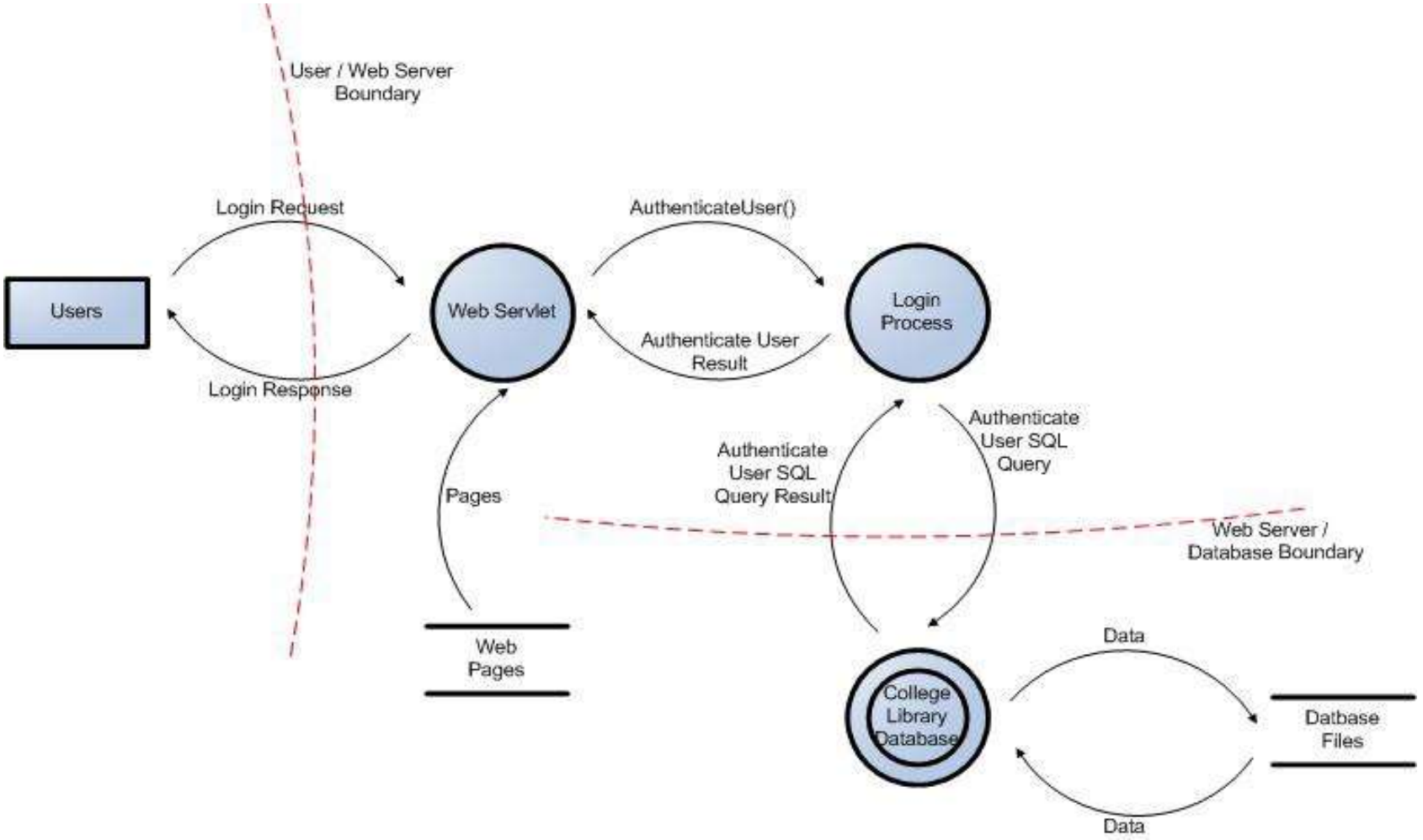
Threat	Security Property
Spoofing	Authentication
Tampering	Integrity
Repudiation	Non-repudiation
Information disclosure	Confidentiality
Denial of service	Availability
Elevation of privilege	Authorization

STRIDE process

- Identify relevant components and data flows
- Analyze each component for each threat
- Mitigate threats

- -> Gain confidence (no proof)

Data Flow Diagram



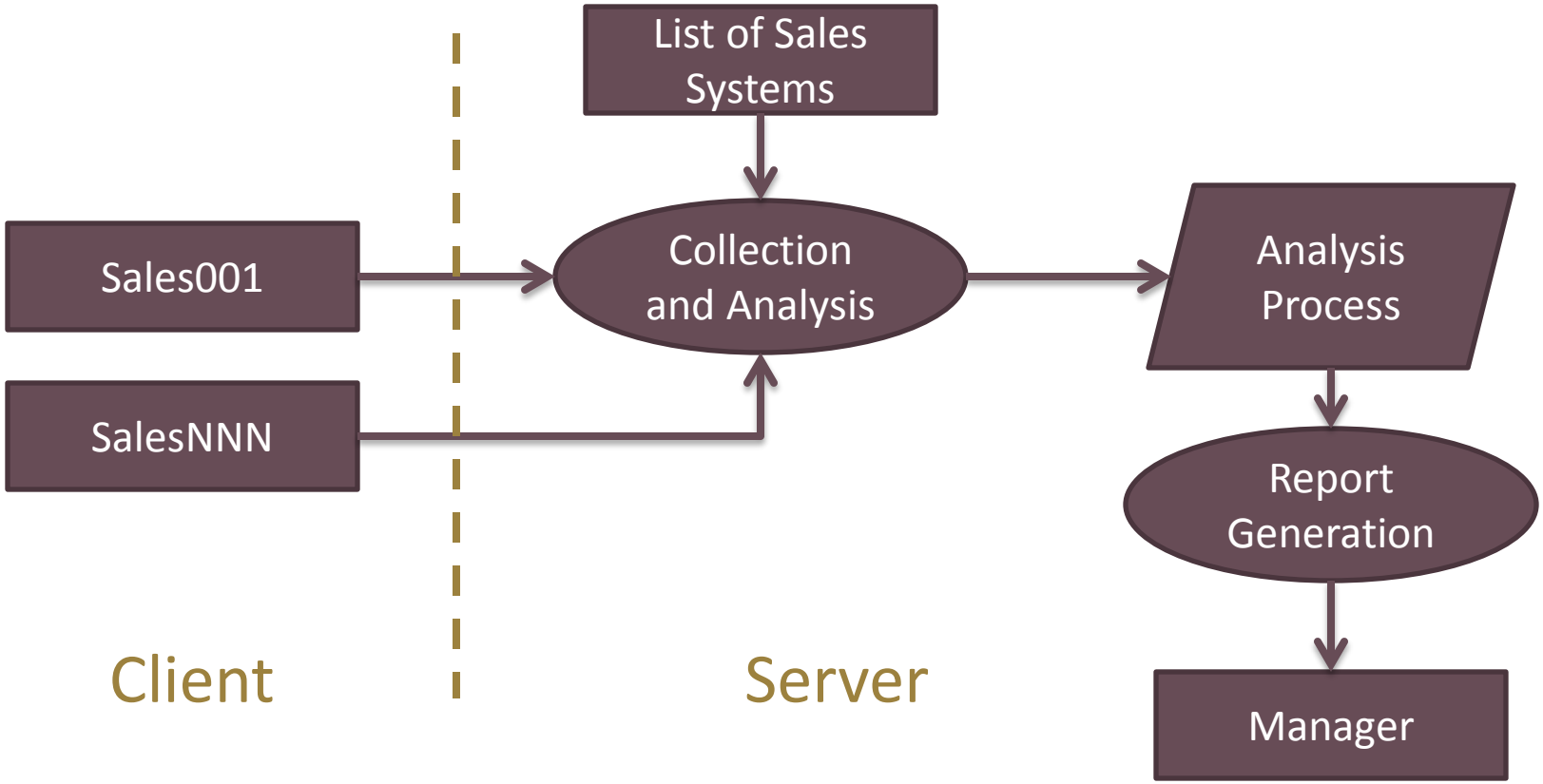
Data flows, data stores, processes, interactors, and trust boundaries

Use case: Sales entry

- Collect accounting files from sales force
- Compute sales data
- Produce weekly reports

for details see
Hernan, Shawn, Scott Lambert, Tomasz Ostwald, and Adam Shostack. "Uncover security design flaws using the STRIDE approach (2006)." *MSDN Magazin Nov 2006*

Use case: Sales entry



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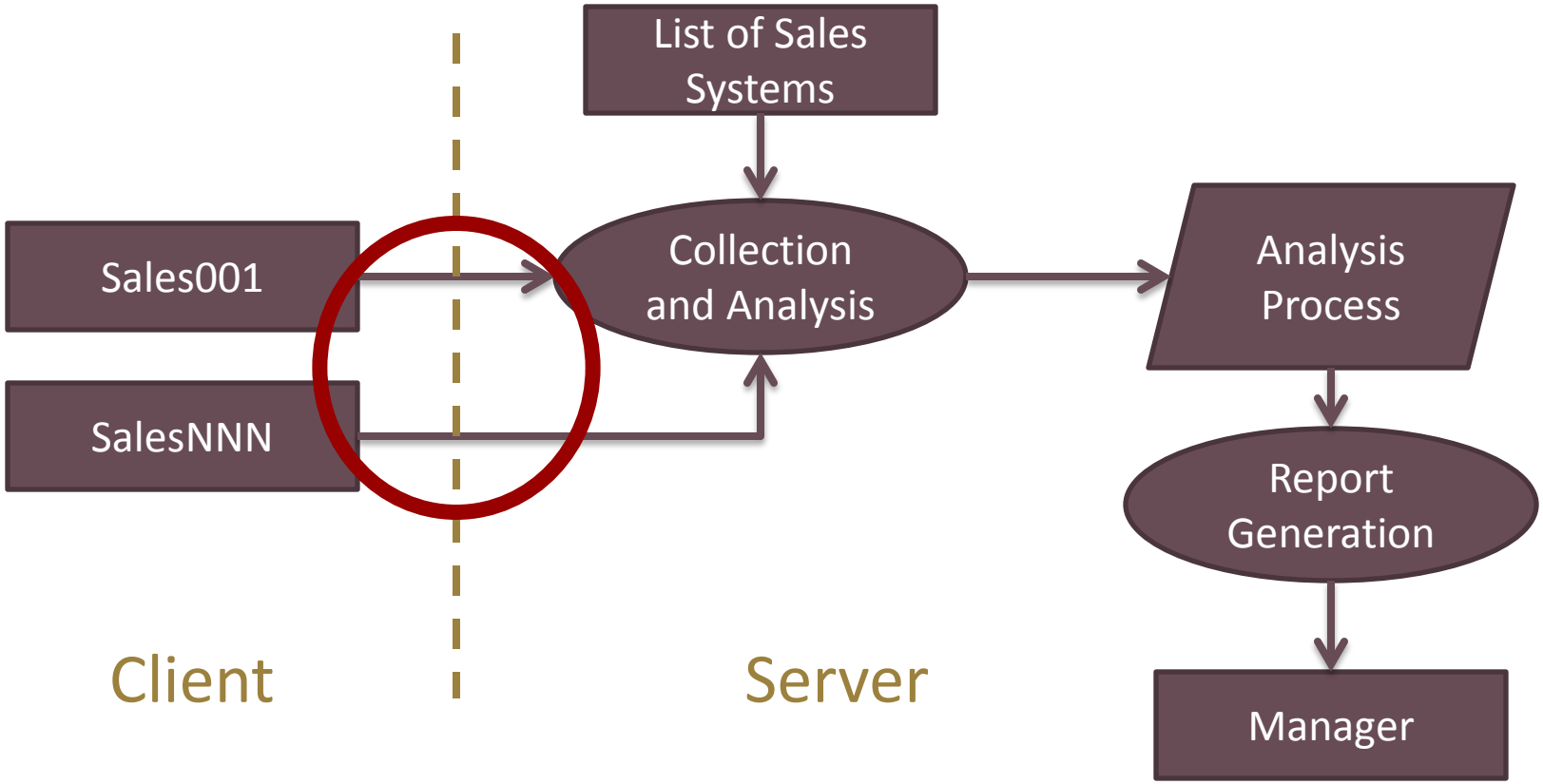

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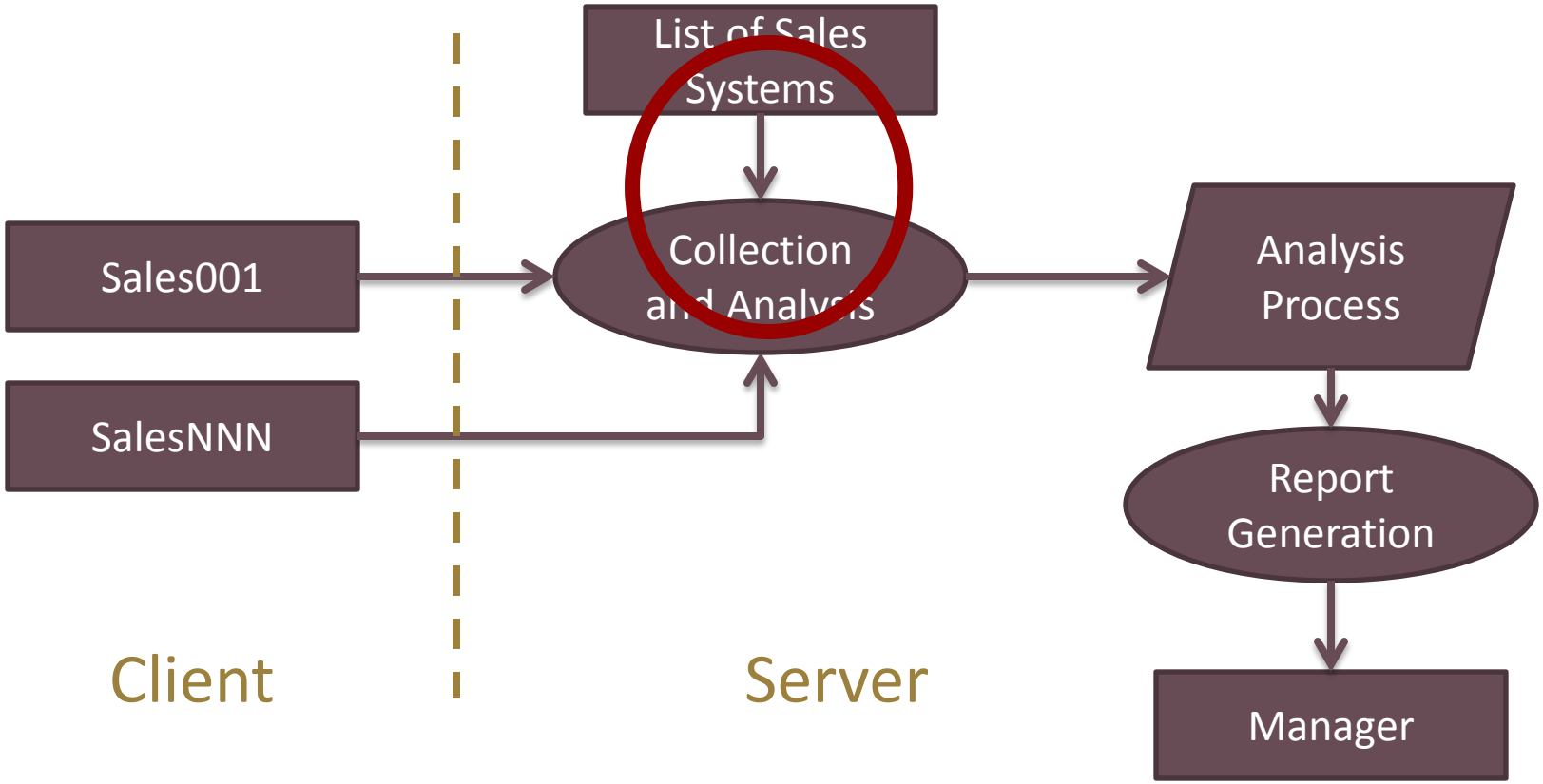

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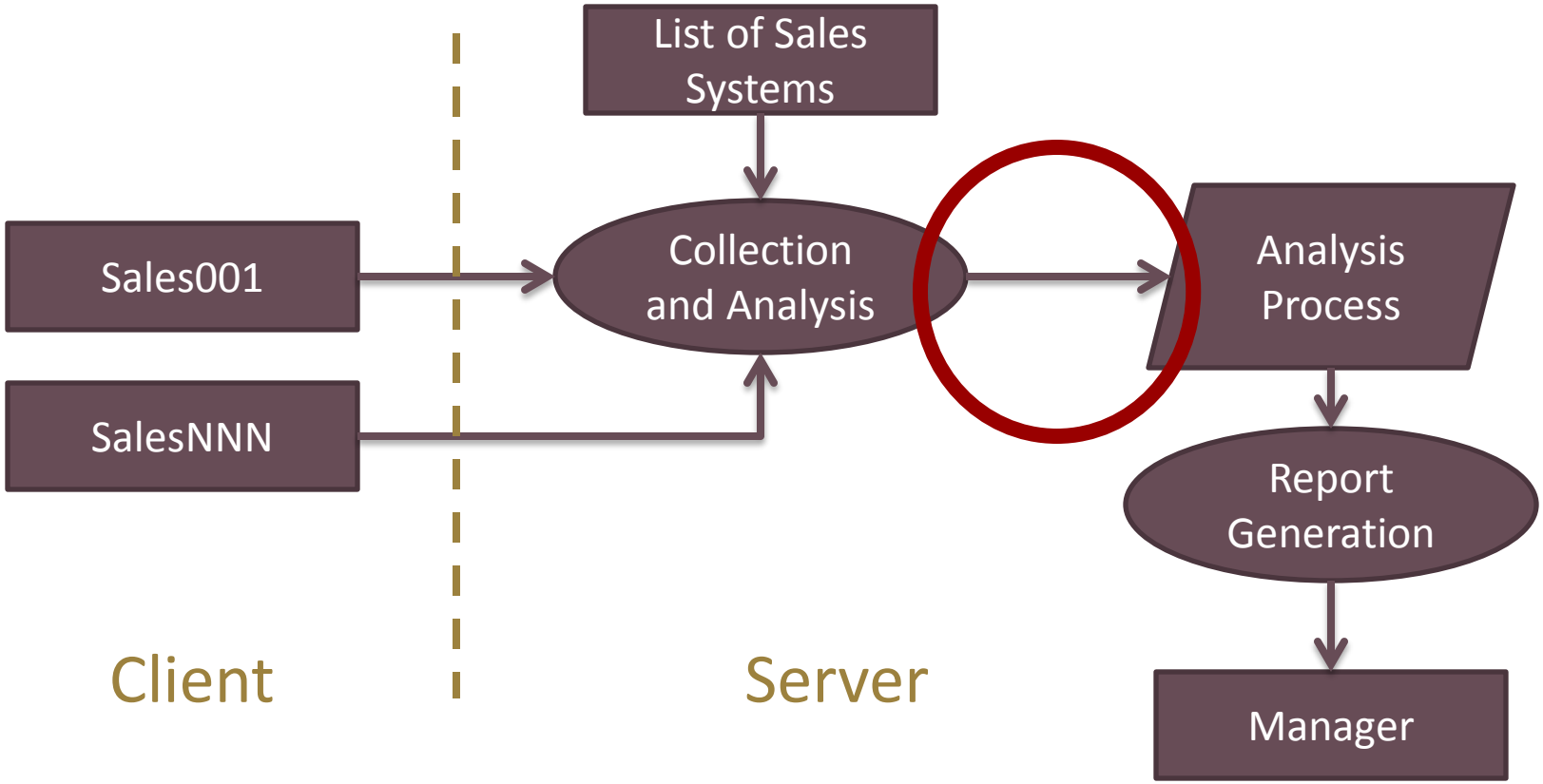

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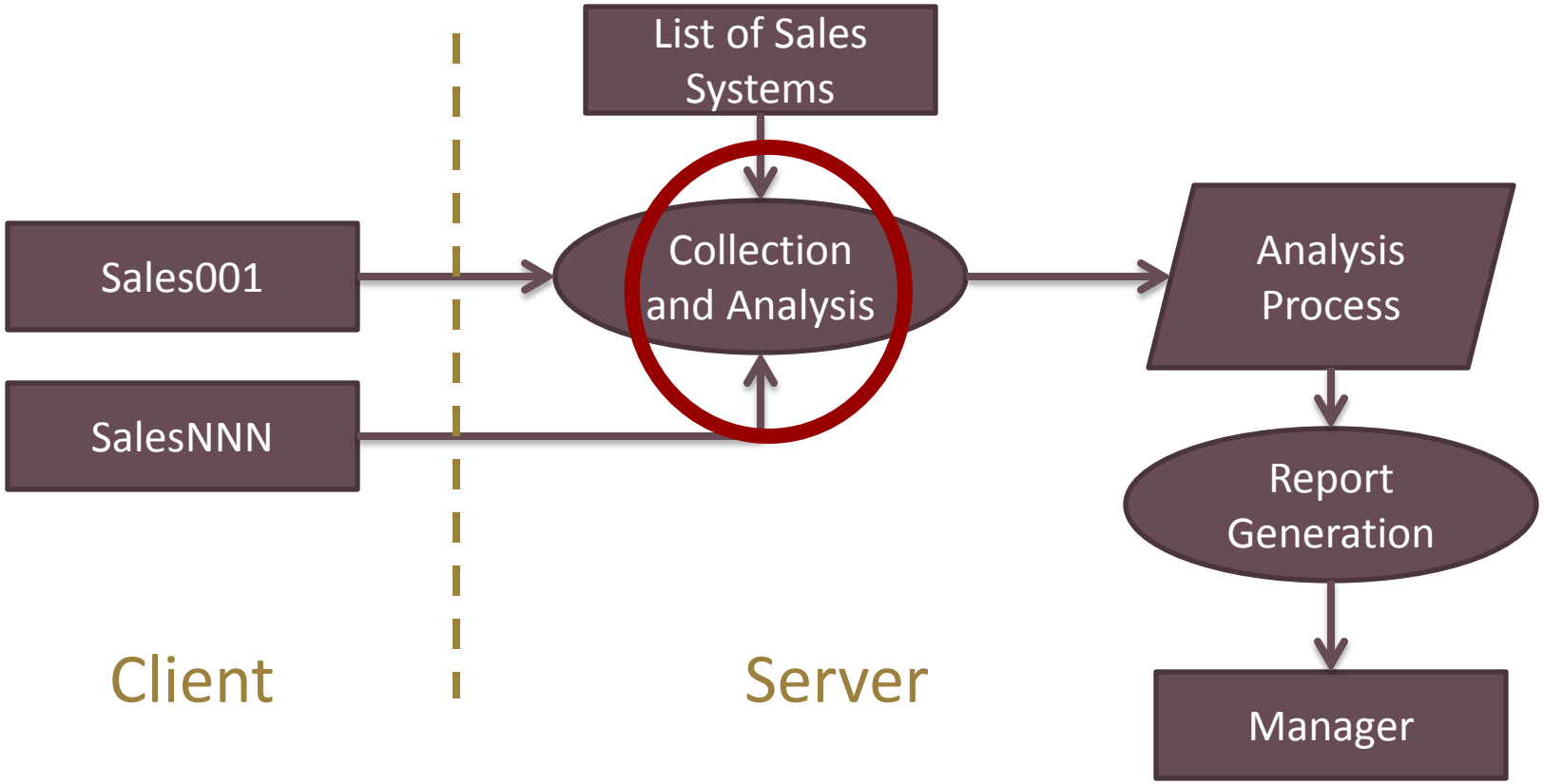


Any unhandled threats turned up by threat modeling must be tracked!

Microsoft SDLs

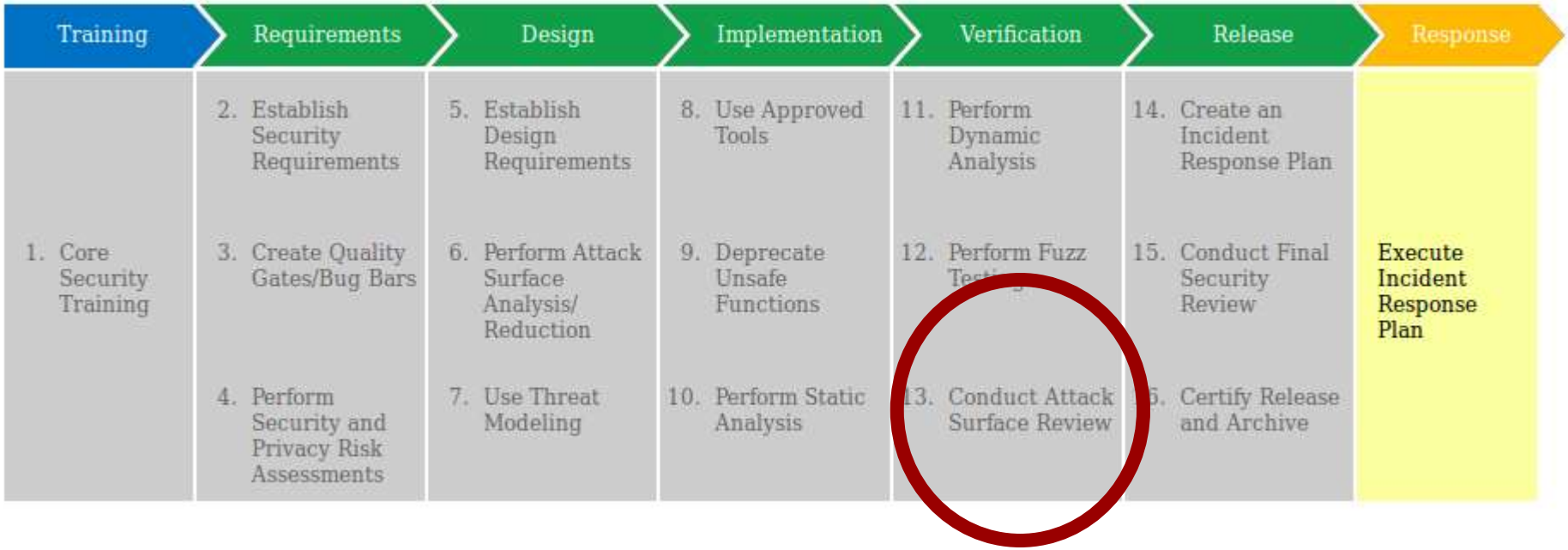
Use Approved Tools

- Some libraries are vulnerable and have safe alternatives (e.g. string.h bad vs strsafe.h good)
- Modern compilers automatically mitigate a number of vulnerabilities (e.g. stack canaries, heap integrity checks, SAFESEH, etc.)
- Appropriate static and dynamic analysis tools automate the enforcement of security practices

Static Analysis, Deprecation

- Microsoft runs static checkers at checking (quality gates)
- Banned over 100 C functions for new code

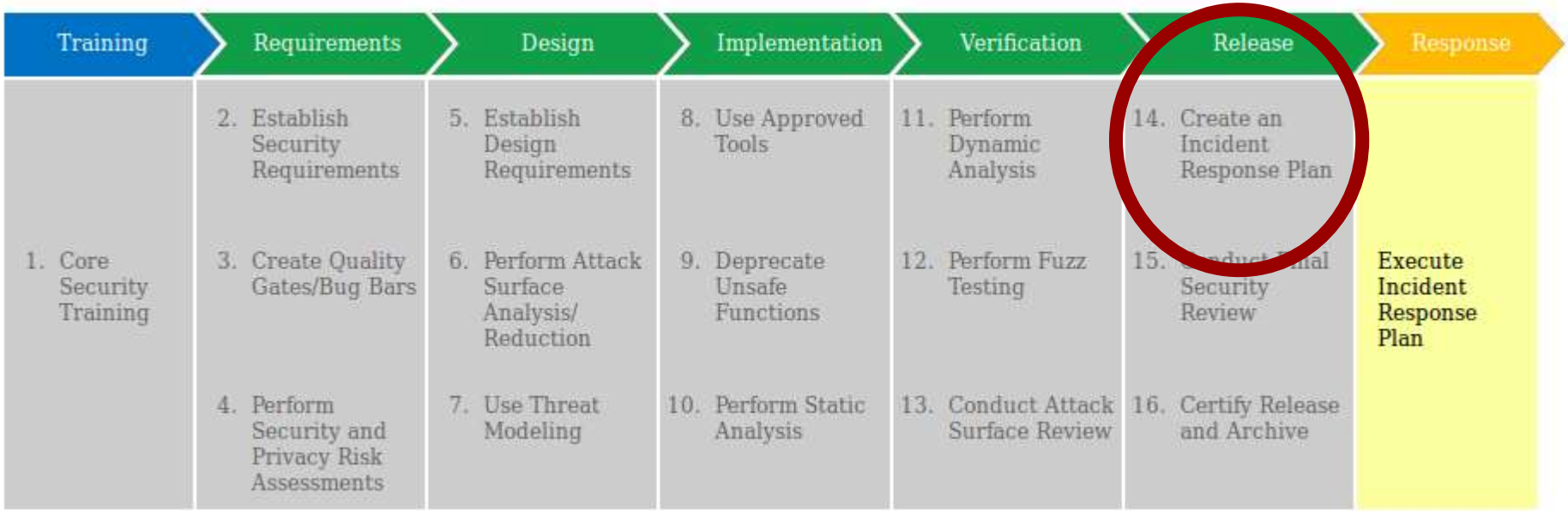
Microsoft SDLs



Conduct Attack Surface Review

- What is every source of input to the application?
- Are there any new sources since the last milestone?
- Much more fine grained than threat modeling
- All sources of input must have a defensive approach applied
- Tools help automate this practice

Microsoft SDLs



Create Incidence Response Plan

- Attacks always get better
- New threats emerge every day
- Vulnerabilities always exist in non-trivial systems
- Who should be contacted when an incident occurs?
- Who should deal with third-party code?
- What priority should be applied to fixing new vulnerabilities?

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Who should implement these security practices?

Security Roles

- **Everyone**: “security awareness” – buy into the process
- **Developers**: know the security capabilities of development tools and use them, know how to spot and avoid *relevant*, common vulnerabilities
- **Managers**: *enable* the use of security practices
- **Security specialists**: everything security

Organizational Architectures

- **Centralized**: development teams consult with a core group of security specialists when they need help
- **Distributed**: development teams hire security specialists to be a first-class member of the team
- **Weak Hybrid**: centralized group of security specialists and teams with security critical applications hire specialists
- **Strong Hybrid**: centralized group of security specialists and most teams also hire specialists

Tuning SDLs

- No one set of security practices work across every industry... or even for every project in a given company
- Expertise is required to determine what set of practices is the most cost effective

BSIMM

- Building Security In Maturity Model
- See what practices other companies utilize
- Understand, measure, and plan software security initiatives

The Software Security Framework (SSF)			
Governance	**Intelligence**	**SSDL Touchpoints**	**Deployment**
Strategy and Metrics	Attack Models	Architecture Analysis	Penetration Testing
Compliance and Policy	Security Features and Design	Code Review	Software Environment
Training	Standards and Requirements	Security Testing	Configuration Management and Vulnerability Management

None of this is scientifically validated.

Future: Measures and Standards

- NHTSA inspired star ratings
- Building Codes for Software
- Security Guarantees
- Liability
- Science