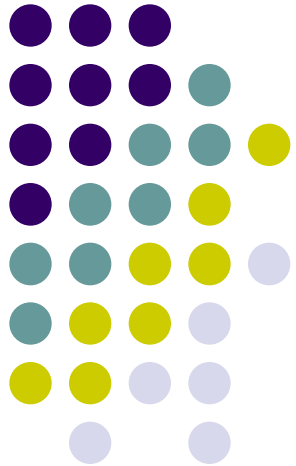
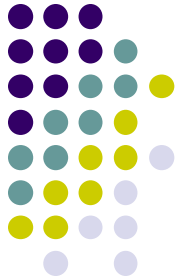
IS 2620: Developing Secure Systems

Building Security *In*



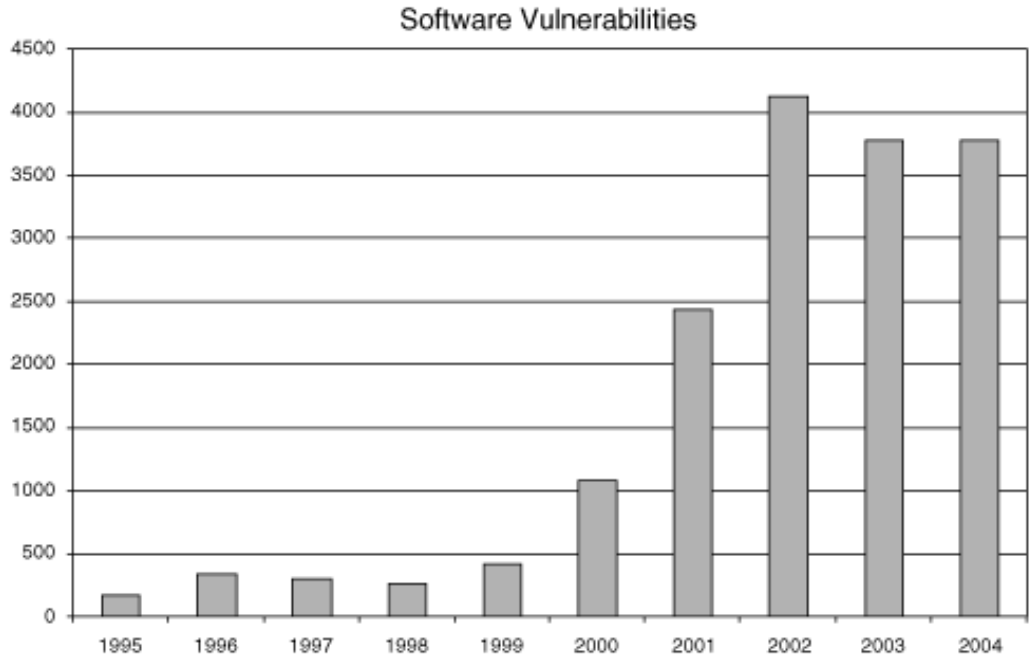
Lecture 2
Jan 15, 2013

Software Security



- Renewed interest
  - “idea of engineering software so that it continues to function correctly under malicious attack”
  - Existing software is riddled with design flaws and implementation bugs
  - “any program, no matter how innocuous it seems, can harbor security holes”
- (Check the CBI report)

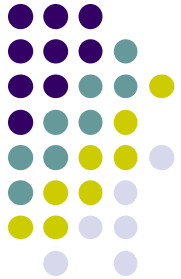
Software Problem



vulnerabilities
Reported by CERT/CC

- More than half of the vulnerabilities are due to buffer overruns
- Others such as race conditions, design flaws are equally prevalent

Software security

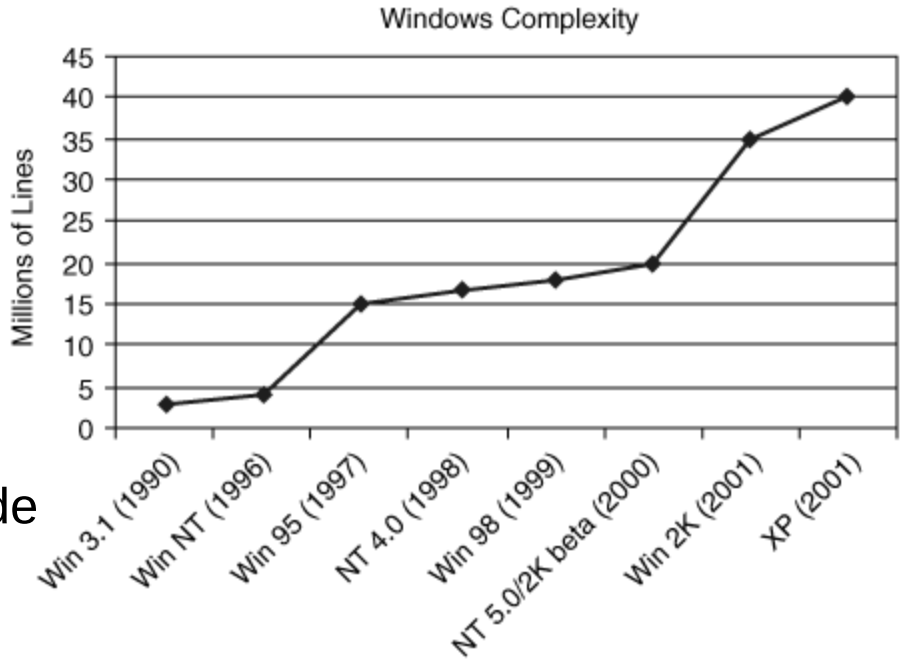


- It is about
  - Understanding software-induced security risks and how to manage them
  - Leveraging software engineering practice,
  - thinking security early in the software lifecyle
  - Knowing and understanding common problems
  - Designing for security
  - Subjecting all software artifacts to thorough objective risk analyses and testing
- It is a knowledge intensive field

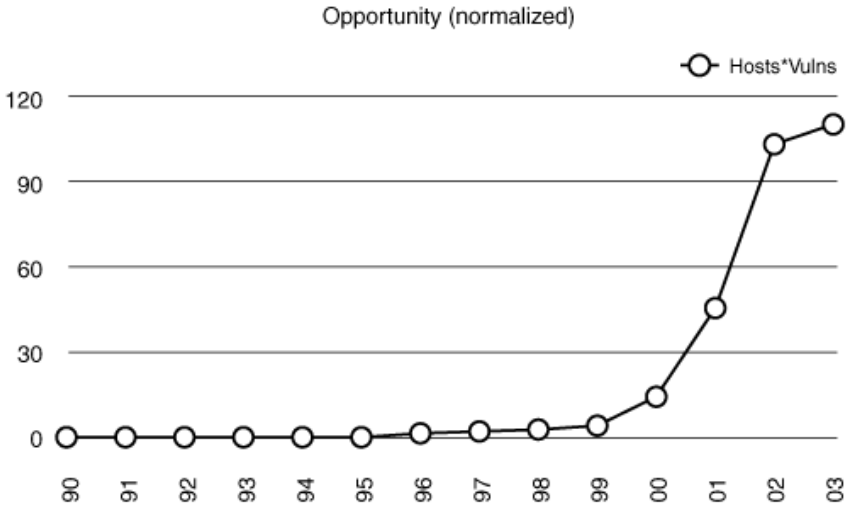
Trinity of trouble

- Three trends
  - Connectivity
    - Inter networked
    - Include SCADA (supervisory control and data acquisition systems)
    - Automated attacks, botnets
  - Extensibility
    - Mobile code – functionality evolves incrementally
    - Web/Os Extensibility
  - Complexity
    - XP is at least 40 M lines of code
    - Add to that use of unsafe languages (C/C++)

Bigger problem today .. And growing



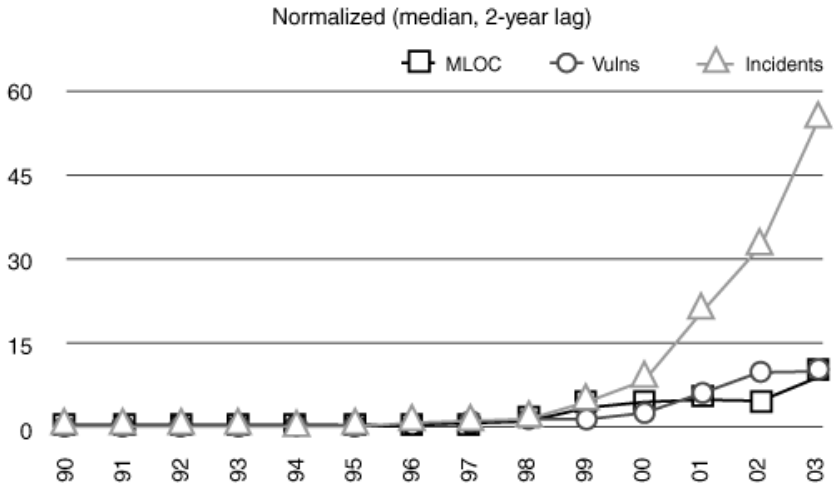
It boils down to …

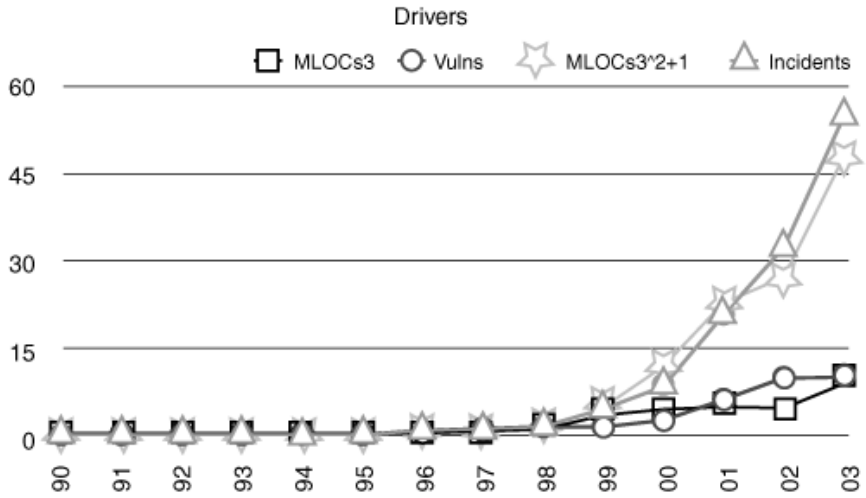


more code,

more bugs,

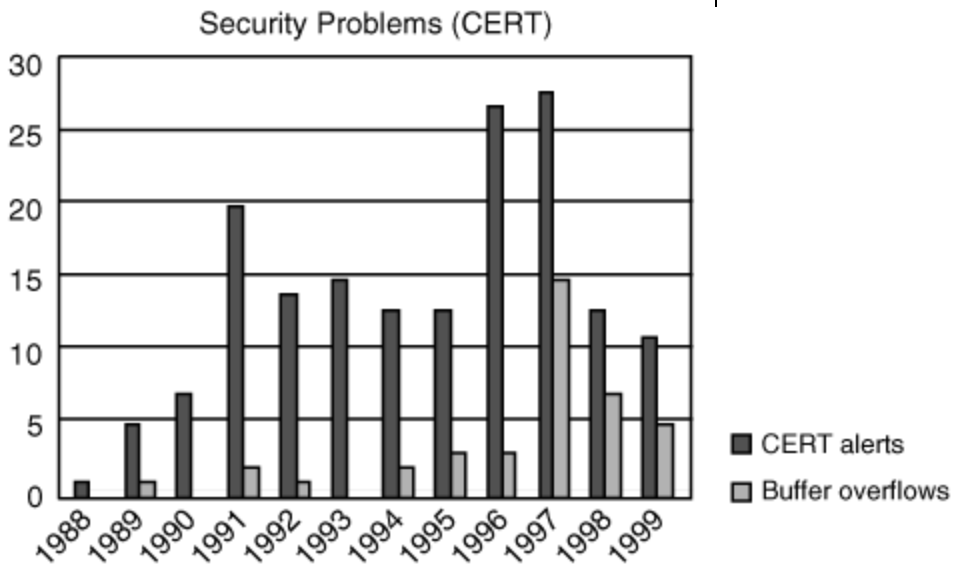
more security problems





Security problems in software

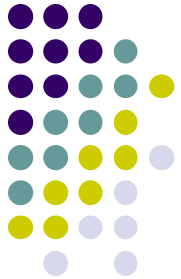
- Defect
  - implementation and design vulnerabilities
  - Can remain dormant
- Bug
  - An implementation level software problem
- Flaw
  - A problem at a deeper level
- Bugs + Flaws
  - leads to Risk



Bug	Flaw
Buffer overflow: stack smashing Buffer overflow: one-stage attacks Buffer overflow: string format attacks Race conditions: TOCTOU Unsafe environment variables Unsafe system calls (fork(), exec(), system()) Incorrect input validation (black list vs. white list	Method over-riding problems (subclass issues) Compartmentalization problems in design Privileged block protection failure (DoPrivilege()) Error-handling problems (fails open) Type safety confusion error Insecure audit log design Broken or illogical access control (role-based access control [RBAC] over tiers) Signing too much code

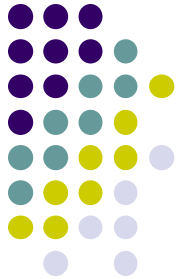
Solution …
Three pillars of security

Pillar I:
Applied Risk management



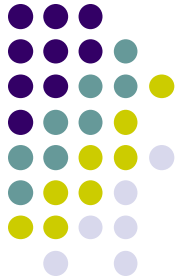
- Architectural risk analysis
  - Sometimes called threat modeling or security design analysis
  - Is a best practice and is a touchpoint
- Risk management framework
  - Considers risk analysis and mitigation as a full life cycle activity

Pillar II:
Software Security Touchpoints



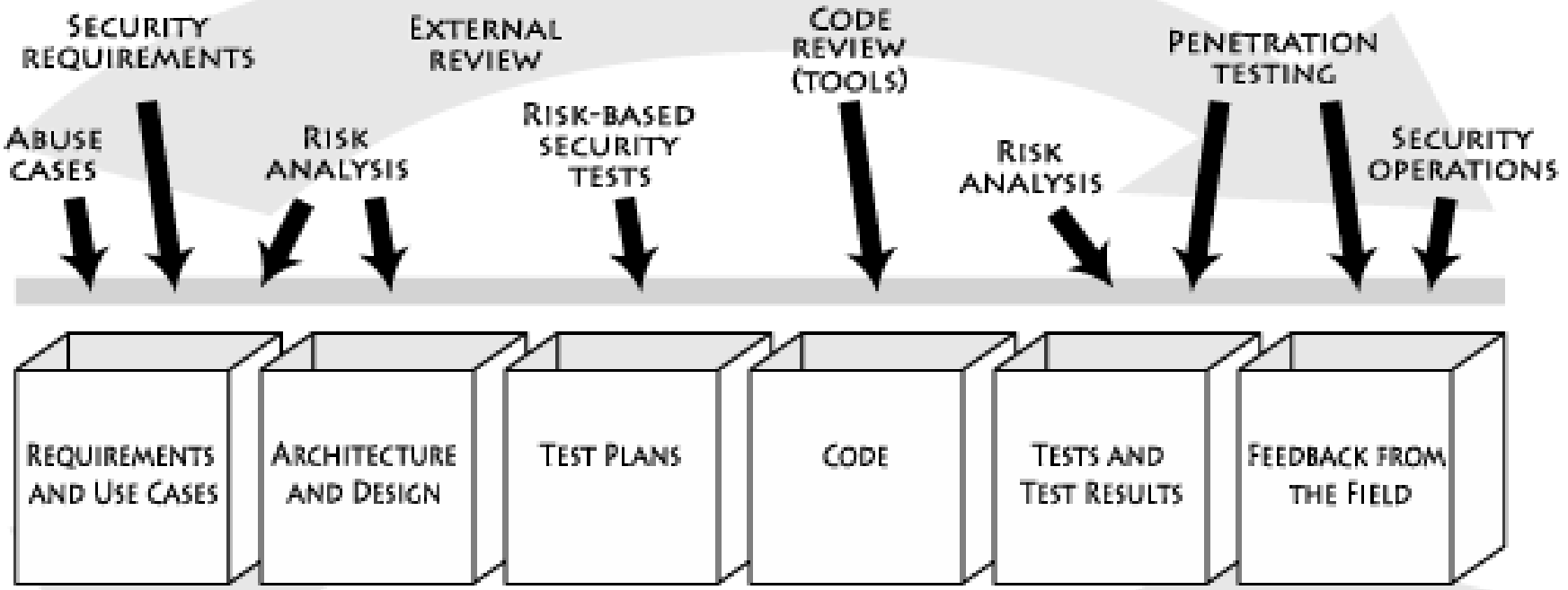
- “Software security is not security software”
  - Software security
    - is system-wide issues (security mechanisms and design security)
    - Emergent property
- Touchpoints in order of effectiveness (based on experience)
  - Code review (bugs)
  - Architectural risk analysis (flaws)
    - These two can be swapped
  - Penetration testing
  - Risk-based security tests
  - Abuse cases
  - Security requirements
  - Security operations

Pillar II: (contd.)



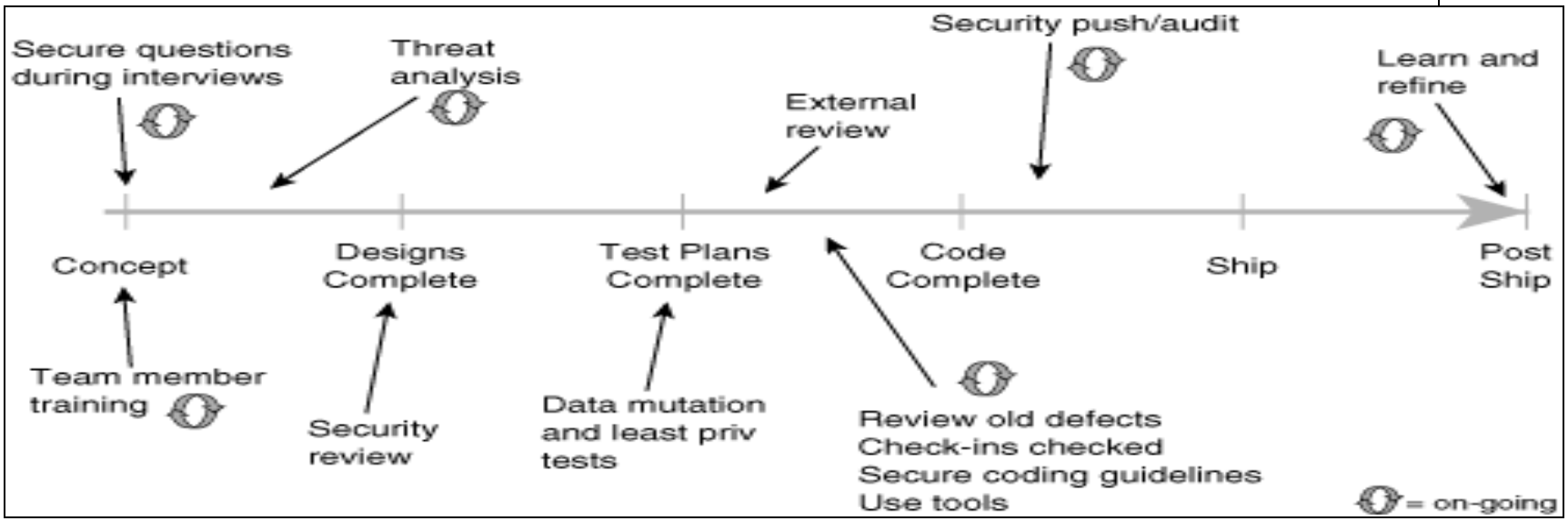
- Many organization
  - Penetration first
    - Is a reactive approach
- CR and ARA can be switched however skipping one solves only half of the problem
- Big organization may adopt these touchpoints simultaneously

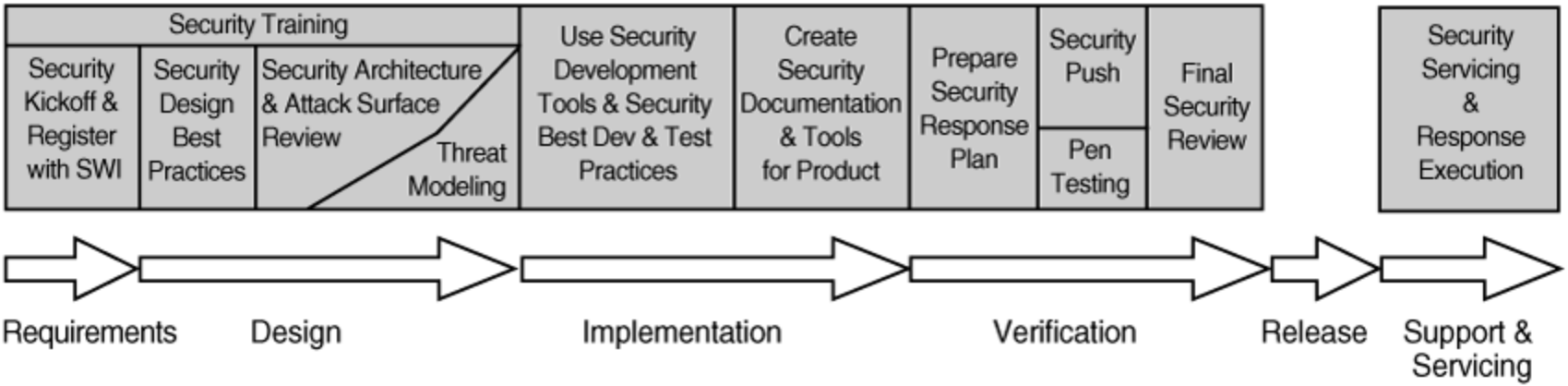
Pillar II: (contd.)



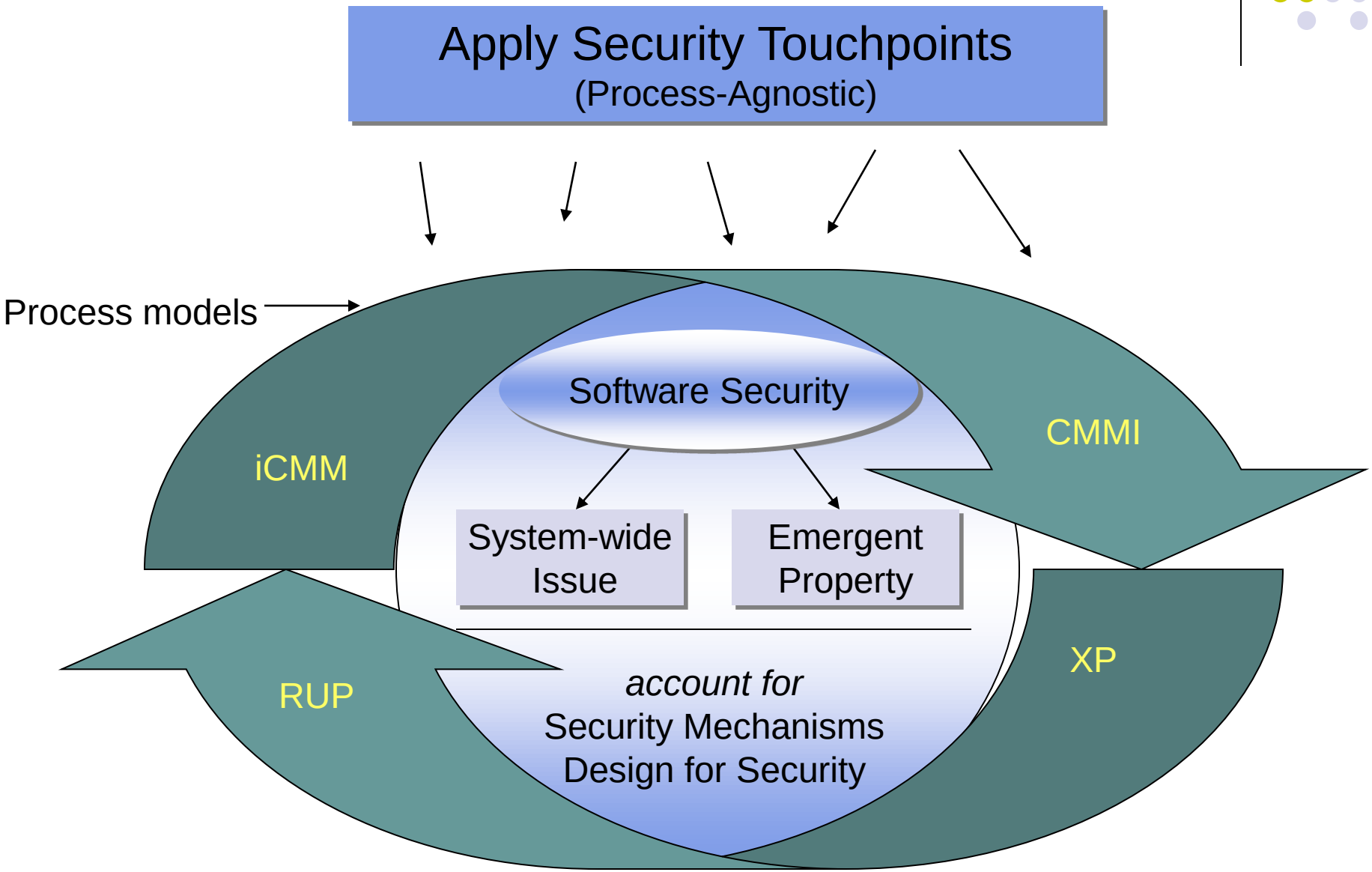
Software security best practices applied to various software artifacts

Pillar II: (contd.) Microsoft's move ..



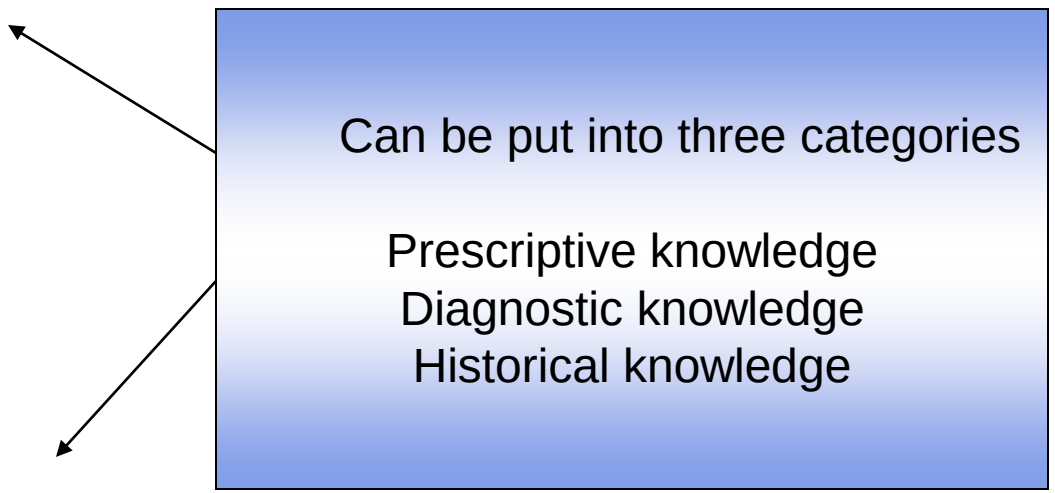


Pillar II: (contd.)

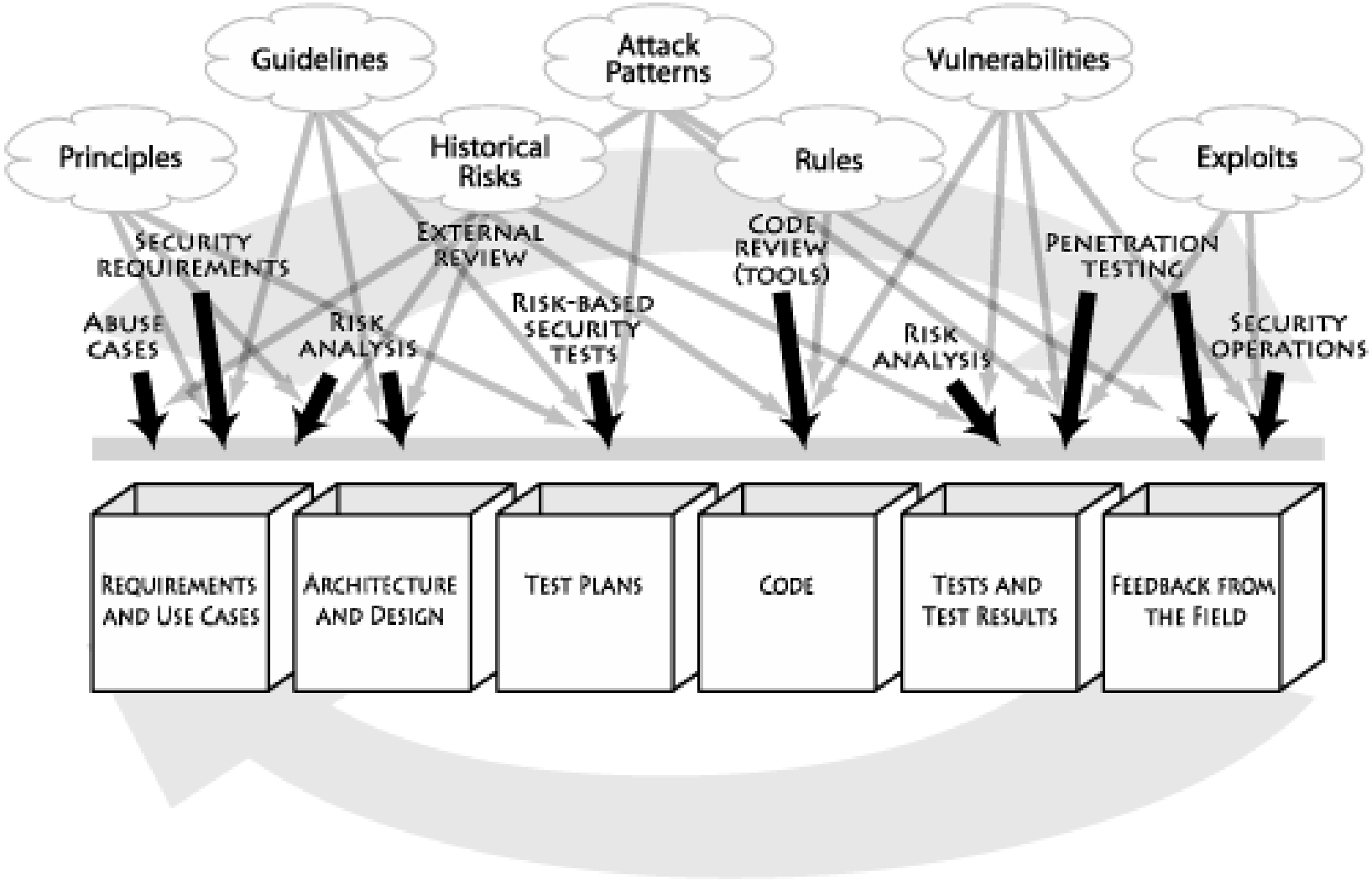


Pillar III: Knowledge

- Involves
  - Gathering, encapsulating, and sharing security knowledge
- Software security knowledge catalogs
  - Principles
  - Guidelines
  - Rules
  - Vulnerabilities
  - Exploits
  - Attack patterns
  - Historical risks

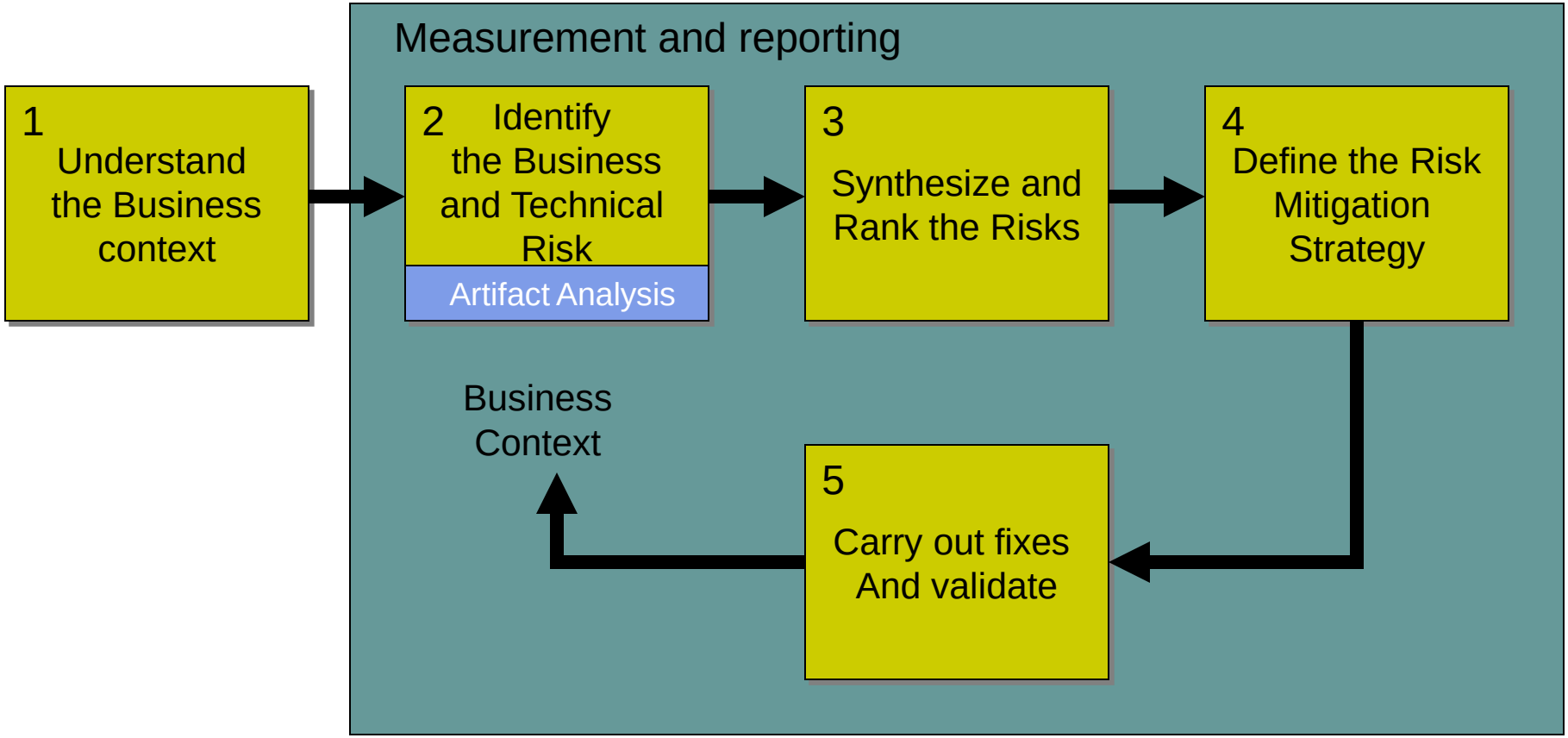


Pillar III: Knowledge catalogs to s/w artifacts

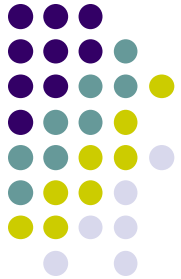


Risk management framework: Five Stages

- RMF occurs in parallel with SDLC activities

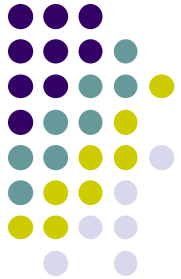


Stage 1: Understand Business Context



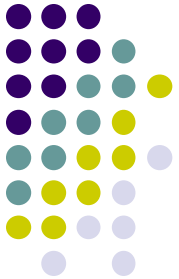
- Risk management
  - Occurs in a business context
  - Affected by business motivation
- Key activity of an analyst
  - Extract and describe business goals – clearly
    - Increasing revenue; reducing dev cost; meeting SLAs; generating high return on investment (ROI)
  - Set priorities
  - Understand circumstances
- Bottomline – answer the question
  - who cares?

Stage 2: Identify the business & technical risks



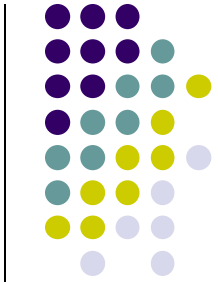
- Business risks have impact
  - Direct financial loss; loss of reputation; violation of customer or regulatory requirements; increase in development cost
- Severity of risks
  - Should be capture in financial or project management terms
- Key is –
  - tie technical risks to business context

Stage 3: Synthesize and rank the risks



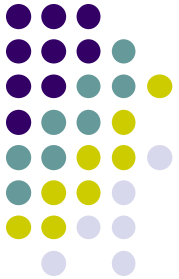
- Prioritize the risks alongside the business goals
- Assign risks appropriate weights for resolution
- Risk metrics
  - Risk likelihood
  - Risk impact
  - Number of risks mitigated over time

Stage 4: Risk Mitigation Strategy



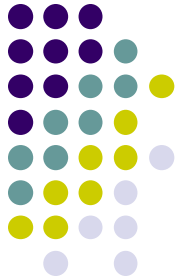
- Develop a coherent strategy
  - For mitigating risks
  - In cost effective manner; account for
    - Cost
    - Completeness
    - Likelihood of success
    - Implementation time
    - Impact
- A mitigation strategy should
  - Be developed within the business context
  - Be based on what the organization can afford, integrate and understand
  - Must directly identify validation techniques

Stage 5: Carry out Fixes and Validate



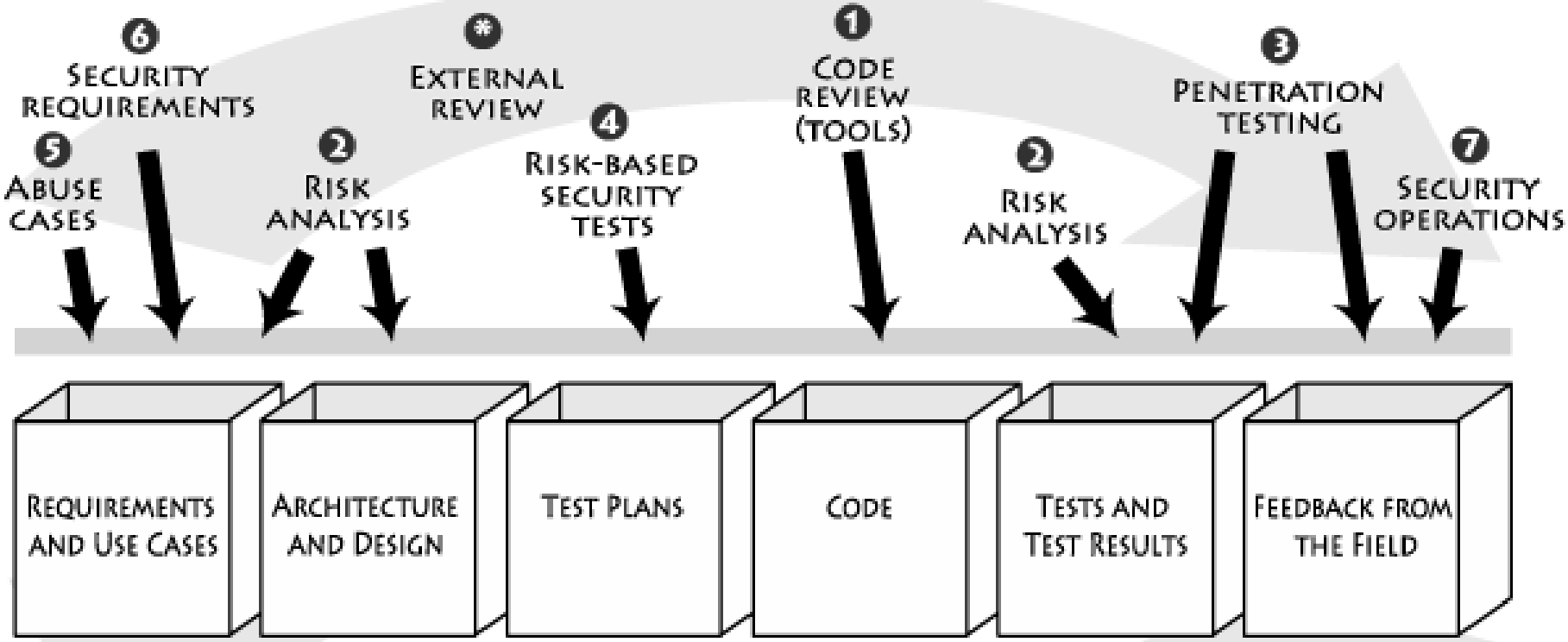
- Execute the chosen mitigation strategy
  - Rectify the artifacts
  - Measure completeness
  - Estimate
    - Progress, residual risks
- Validate that risks have been mitigated
  - Testing can be used to demonstrate
  - Develop confidence that unacceptable risk does not remain

RMF - A Multi-loop

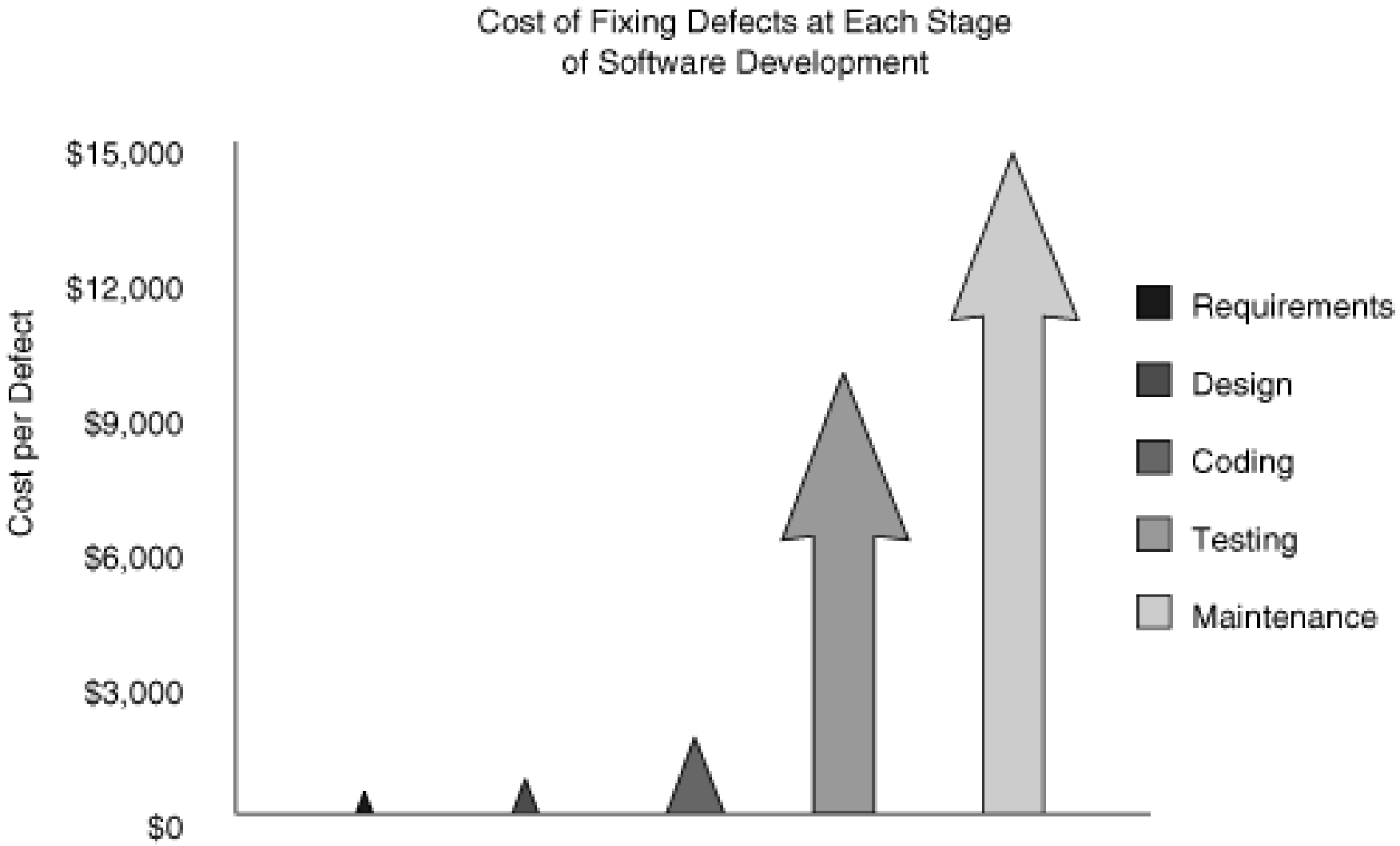


- Risk management is a continuous process
  - Five stages may need to be applied many times
  - Ordering may be interleaved in different ways
    - Risk can emerge at any time in SDLC
      - One way – apply in each phase of SDLC
    - Risk can be found between stages
- Level of application
  - Primary – project level
    - Each stage must capture complete project
  - SDLC phase level
  - Artifact level
- It is important to know that RM is
  - Cumulative
  - At times arbitrary and difficult to predict

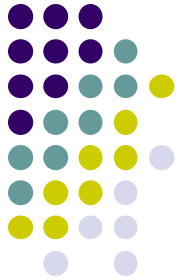
Seven Touchpoints



Cost of fixing defect at each stage

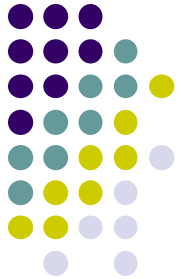


Code review



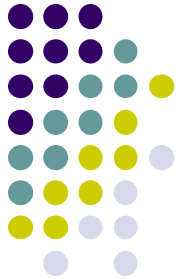
- Focus is on implementation bugs
  - Essentially those that static analysis can find
  - Security bugs are real problems – but architectural flaws are just as big a problem
    - Code review can capture only half of the problems
  - E.g.
    - Buffer overflow bug in a particular line of code
  - Architectural problems are very difficult to find by looking at the code
    - Specially true for today's large software

Code review



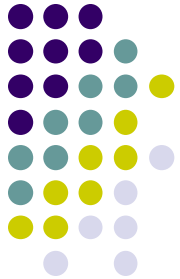
- Taxonomy of coding errors
  - Input validation and representation
    - Some source of problems
      - Metacharacters, alternate encodings, numeric representations
      - Forgetting input validation
      - Trusting input too much
      - Example: buffer overflow; integer overflow
  - API abuse
    - API represents contract between caller and callee
    - E.g., failure to enforce principle of least privilege
  - Security features
    - Getting right security features is difficult
    - E.g., insecure randomness, password management, authentication, access control, cryptography, privilege management, etc.

Code review



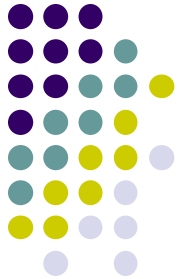
- Taxonomy of coding errors
  - Time and state
    - Typical race condition issues
    - E.g., TOCTOU; deadlock
  - Error handling
    - Security defects related to error handling are very common
    - Two ways
      - Forget to handle errors or handling them roughly
      - Produce errors that either give out way too much information or so radioactive no one wants to handle them
    - E.g., unchecked error value; empty catch block

Code review



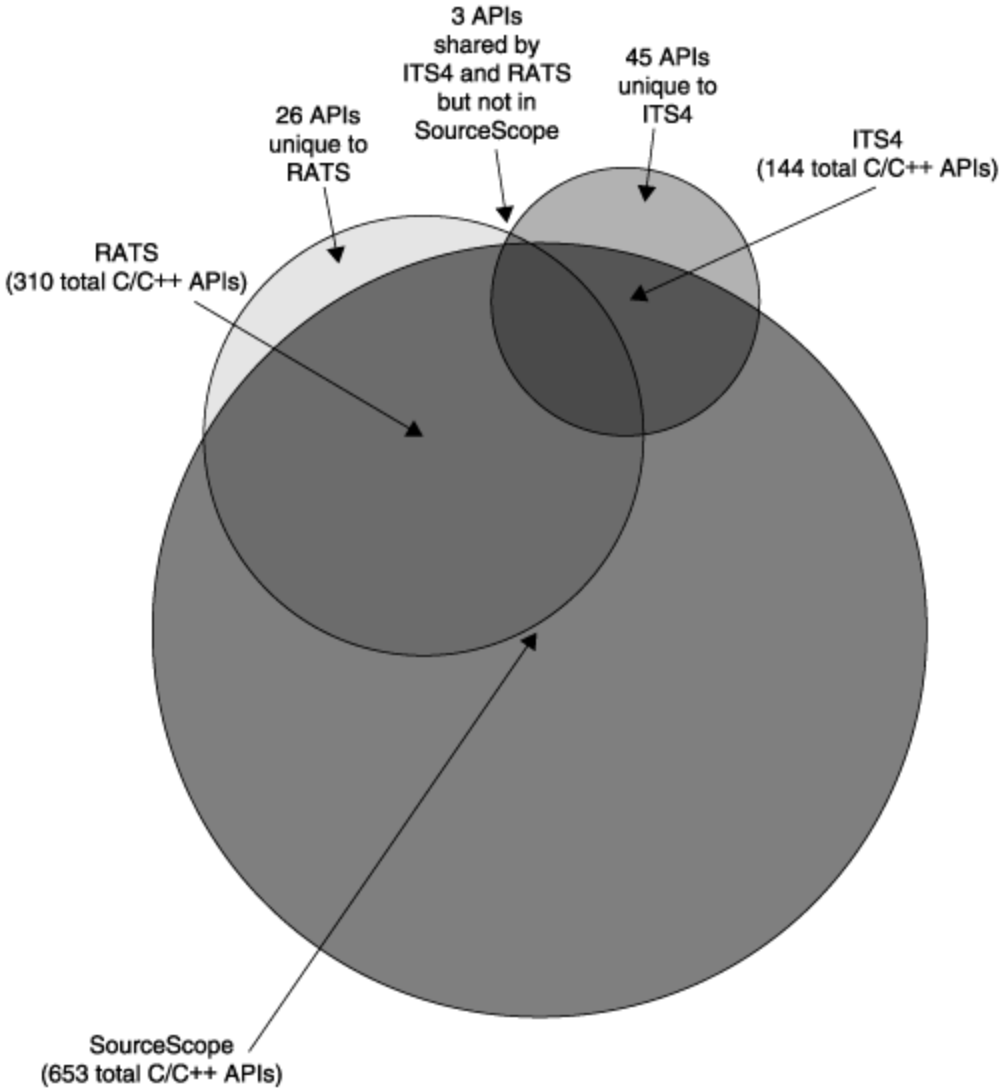
- Taxonomy of coding errors
  - Code quality
    - Poor code quality leads to unpredictable behavior
    - Poor usability
    - Allows attacker to stress the system in unexpected ways
    - E.g., Double free; memory leak
  - Encapsulation
    - Object oriented approach
    - Include boundaries
    - E.g., comparing classes by name
  - Environment
    - Everything outside of the code but is important for the security of the software
    - E.g., password in configuration file (hardwired)

Code review

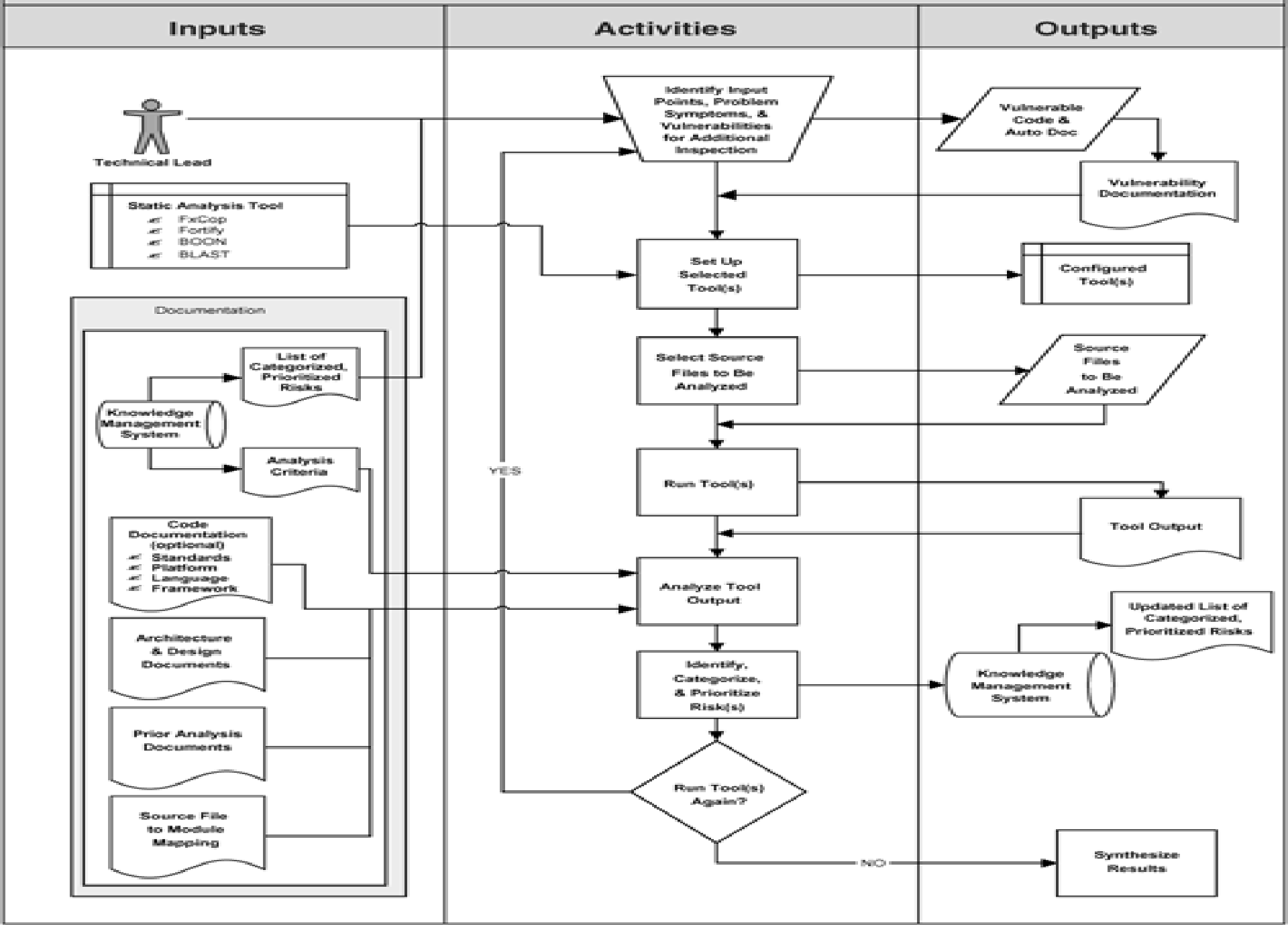


- Static analysis tools
  - False negative (wrong sense of security)
    - A sound tool does not generate false negatives
  - False positives
  - Some examples
    - ITS4 (It’s The Software Stupid Security Scanner);
    - RATS; Flawfinder

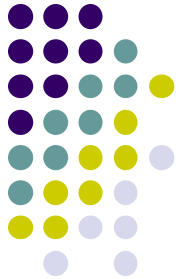
Rules overlap



Static Code Analysis

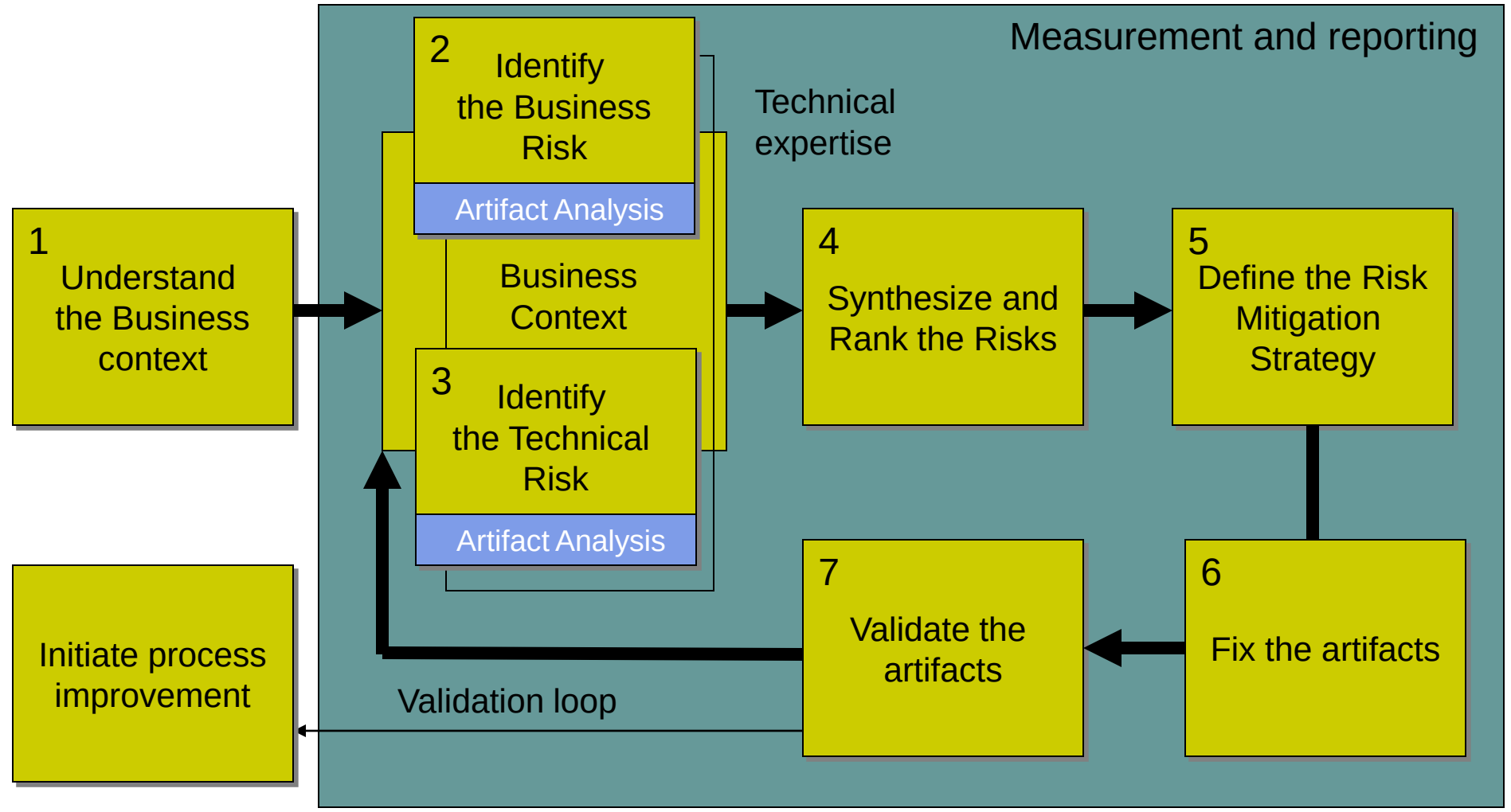


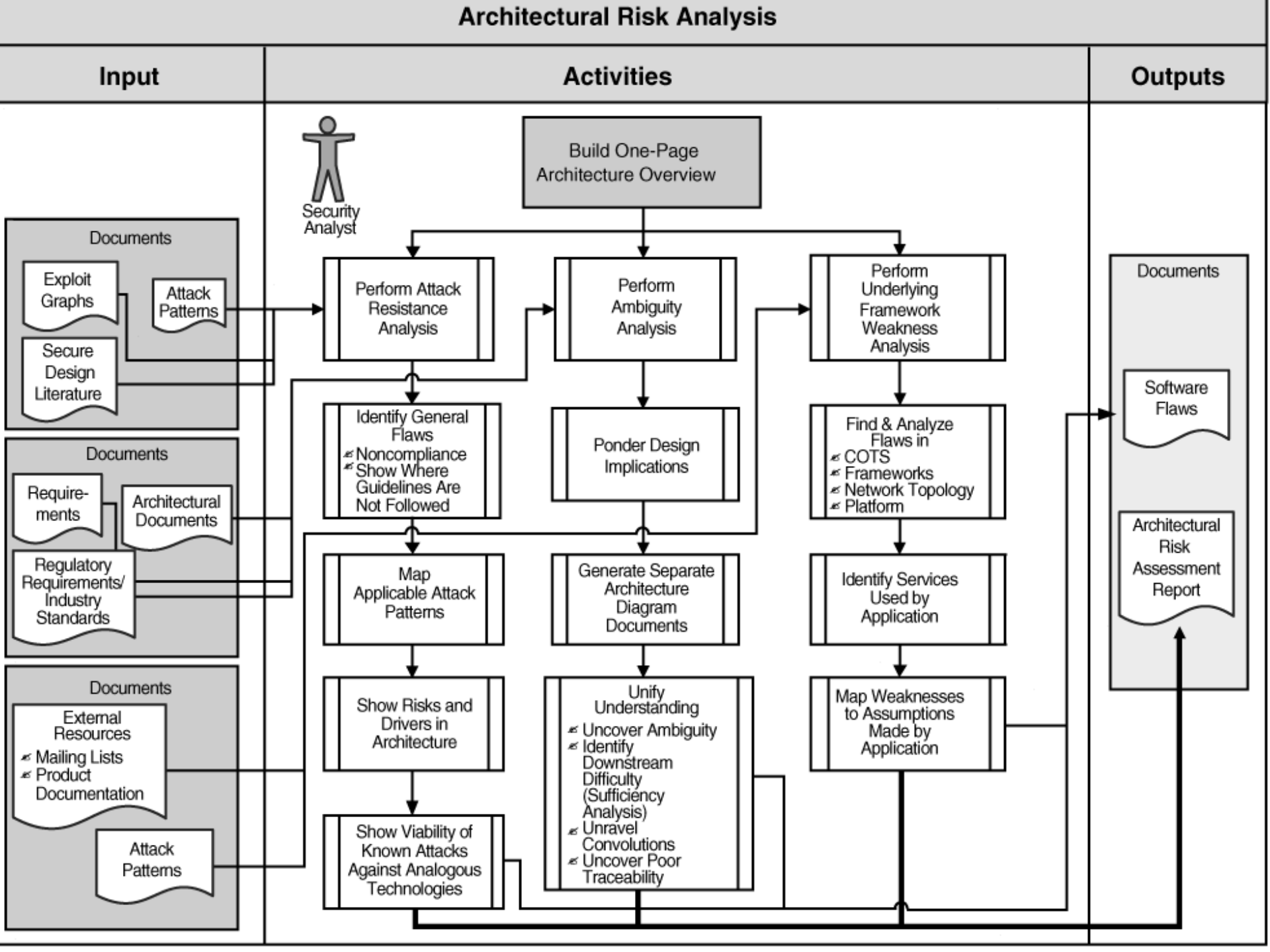
Architectural risk analysis



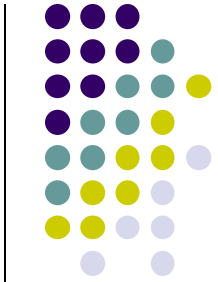
- Design flaws
  - about 50% of security problem
  - Can’t be found by looking at code
    - A higher level of understanding required
- Risk analysis
  - Track risk over time
  - Quantify impact
  - Link system-level concerns to probability and impact measures
  - Fits with the RMF

ARA within RMF




Architectural Risk Analysis
Input
Activities
Outputs
Security Analyst
Build One-Page Architecture Overview
Documents
Exploit Graphs
Attack Patterns
Secure Design Literature
Perform Attack Resistance Analysis
Perform Ambiguity Analysis
Perform Underlying Framework Weakness Analysis
Documents
Software Flaws
Architectural Risk Assessment Report
Identify General Flaws
Noncompliance
Show Where Guidelines Are Not Followed
Ponder Design Implications
Find & Analyze Flaws in
COTS
Frameworks
Network Topology
Platform
Documents
Require-ments
Architectural Documents
Regulatory Requirements/ Industry Standards
Map Applicable Attack Patterns
Generate Separate Architecture Diagram Documents
Identify Services Used by Application
Documents
External Resources
Mailing Lists
Product Documentation
Attack Patterns
Show Risks and Drivers in Architecture
Unify Understanding
Uncover Ambiguity
Identify Downstream Difficulty (Sufficiency Analysis)
Unravel Convolutions
Uncover Poor Traceability
Map Weaknesses to Assumptions Made by Application
Show Viability of Known Attacks Against Analogous Technologies

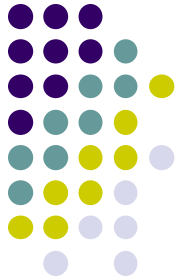
ARA process



- Attack resistance analysis
  - Steps
    - Identify general flaws using secure design literature and checklists
      - Knowledge base of historical risks useful
    - Map attack patterns using either the results of abuse case or a list of attack patterns
    - Identify risk based on checklist
    - Understand and demonstrate the viability of these known attacks
      - Use exploit graph or attack graph

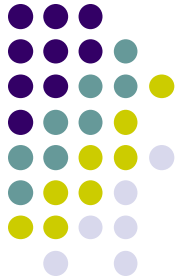
  - Note: particularly good for finding known problems

ARA process



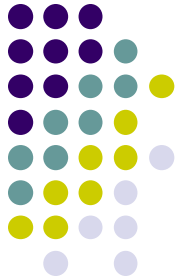
- Ambiguity analysis
  - Discover new risks – creativity requried
  - A group of analyst and experience helps – use multiple points of view
    - Unify understanding after independent analysis
  - Uncover ambiguity and inconsistencies
- Weakness analysis
  - Assess the impact of external software dependencies
  - Modern software
    - is built on top of middleware such as .NET and J2EE
    - Use DLLs or common libraries
  - Need to consider
    - COTS
    - Framework
    - Network topology
    - Platform
    - Physical environment
    - Build environment

Software penetration testing



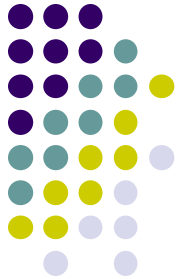
- Most commonly used today
- Currently
  - Outside->in approach
  - Better to do after code review and ARA
  - As part of final preparation acceptance regimen
  - One major limitation
    - Almost always a too-little-too-late attempt at the end of a development cycle
      - Fixing things at this stage
        - May be very expensive
        - Reactive and defensive

Software penetration testing



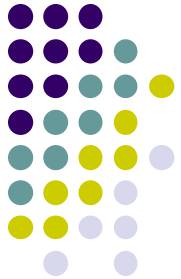
- A better approach
  - Penetration testing from the beginning and throughout the life cycle
  - Penetration test should be driven by perceived risk
  - Best suited for finding configuration problems and other environmental factors
  - Make use of tools
    - Takes care of majority of grunt work
    - Tool output lends itself to metrics
    - Eg.,
      - fault injection tools;
      - attacker's toolkit: disassemblers and decompilers; coverage tools monitors

Risk based security testing



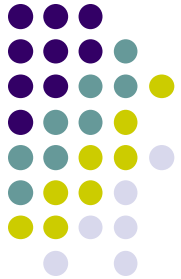
- Testing must be
  - Risk-based
  - grounded in both the system's architectural reality and the attacker's mindset
    - Better than classical black box testing
  - Different from penetration testing
    - Level of approach
    - Timing of testing
      - Penetration testing is primarily on completed software in operating environment; outside->in

Risk based security testing



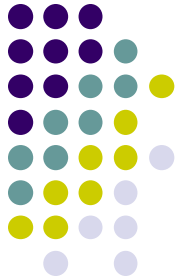
- Security testing
  - Should start at feature or component/unit level testing
  - Must involve two diverse approaches
    - Functional security testing
      - Testing security mechanisms to ensure that their functionality is properly implemented
    - Adversarial security testing
      - Performing risk-based security testing motivated by understanding and simulating the attacker's approach

Abuse cases

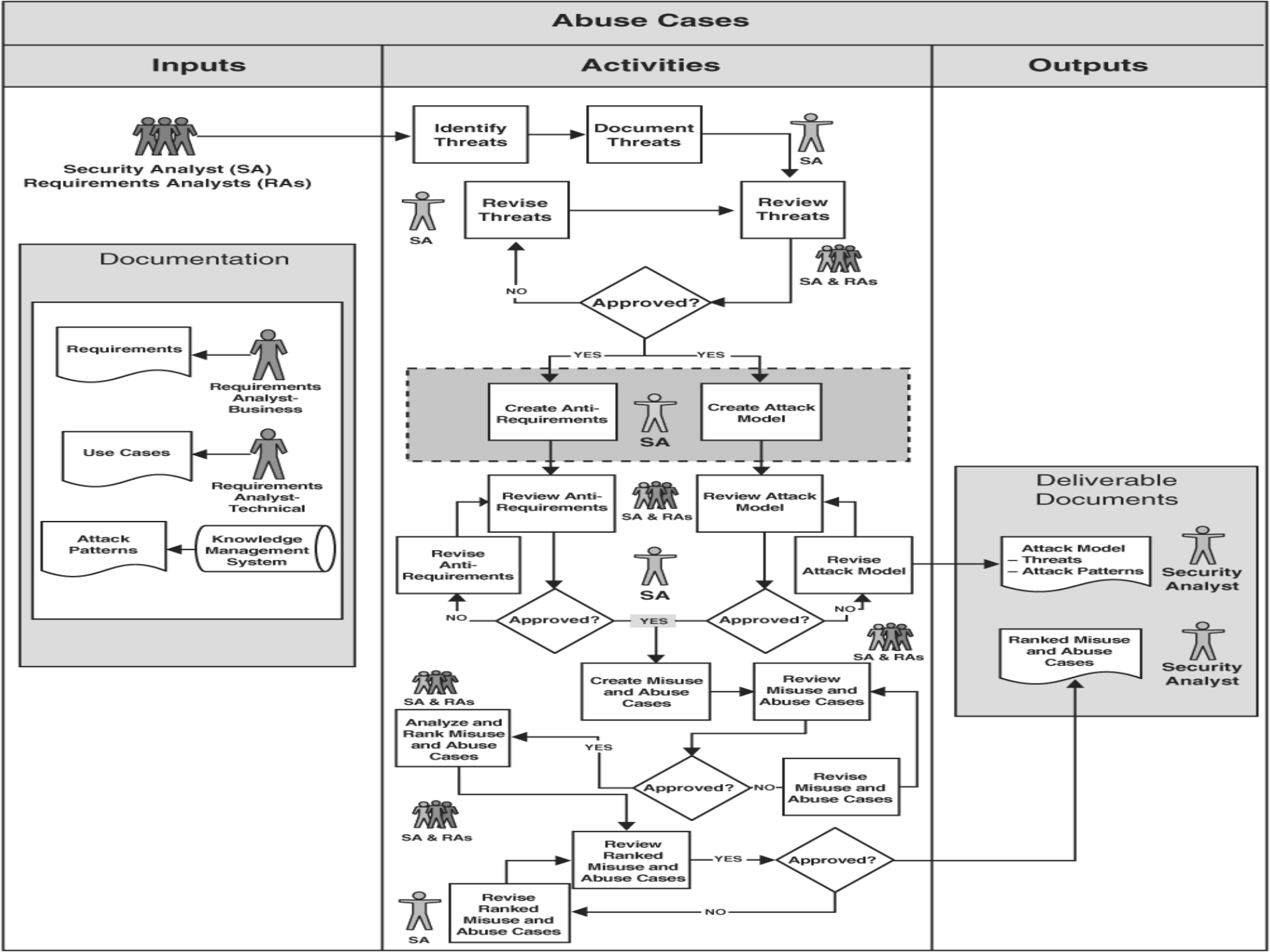


- Creating anti-requirements
  - Important to think about
    - Things that you don’t want your software to do
    - Requires: security analysis + requirement analysis
  - Anti-requirements
    - Provide insight into how a malicious user, attacker, thrill seeker, competitor can abuse your system
    - Considered throughout the lifecyle
      - indicate what happens when a required security function is not included

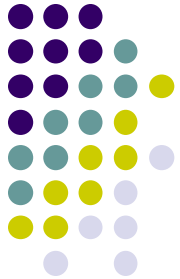
Abuse cases



- Creating an attack model
  - Based on known attacks and attack types
  - Do the following
    - Select attack patterns relevant to your system – build abuse case around the attack patterns
    - Include anyone who can gain access to the system because threats must encompass all potential sources
  - Also need to model attacker


Abuse Cases
Inputs
Activities
Outputs
Security Analyst (SA)
Requirements Analysts (RAs)
Documentation
Requirements
Requirements Analyst-Business
Use Cases
Requirements Analyst-Technical
Attack Patterns
Knowledge Management System
Identify Threats
Document Threats
SA
Revise Threats
Review Threats
SA
SA & RAs
NO
Approved?
YES
YES
Create Anti-Requirements
SA
Create Attack Model
Review Anti-Requirements
SA & RAs
Review Attack Model
Revise Anti-Requirements
SA
Revise Attack Model
NO
Approved?
YES
Approved?
NO
SA & RAs
Create Misuse and Abuse Cases
Review Misuse and Abuse Cases
SA & RAs
Analyze and Rank Misuse and Abuse Cases
YES
Approved?
NO
Revise Misuse and Abuse Cases
SA & RAs
Review Ranked Misuse and Abuse Cases
YES
Approved?
SA
Revise Ranked Misuse and Abuse Cases
NO
Deliverable Documents
Attack Model
– Threats
– Attack Patterns
Security Analyst
Ranked Misuse and Abuse Cases
Security Analyst

Security requirements and operations



- Security requirements
  - Difficult tasks
  - Should cover both overt functional security and emergent characteristics
    - Use requirements engineering approach
- Security operations
  - Integrate security operations
    - E.g., software security should be integrated with network security