SS ZG 566

Secure Software Engineering

T V Rao

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Definitions and concepts of security - Part 1
RL 1.1.1

About Subject

"Secure software engineering focuses on creating software that functions correctly and survive any Cyberattack. The main topics of this course include requirements engineering for secure software, secure software architecture and design, considerations for secure coding and testing, common software vulnerabilities, risk analysis, misuse cases, secure programming techniques, analysis of software based attacks (and defenses), code reviews, and security testing."

Modules

No	Title of the Module
M1	Overview of security
M2	Security in SDLC
M3	Threat Modelling
M4	Security Requirements Engineering
M5	Secure Architecture & Design
M6	Testing for security
M7	Vulnerabilities in code
M8	Database security
M9	Web Application Security
M10	Security Mechanisms
M11	Managing for security

Course Objective / Learning Outcomes

CO1	Understand software engineering principles for designing secure systems
CO2	Learn lifecycle models for software security.
CO3	Understand software attacks and techniques of building software that can withstand attacks

No	Learning Outcomes
LO1	Understand causes of security issues in software systems
LO2	Learn practices that enhance security in software development lifecycle.
LO3	Understand techniques of addressing security issues in software

Course Handout

No	Name	Type	Duration	Weight	Day, Date, Session, Time
EC-1	Quiz-1		*	5%	September 1-10, 2023
	Quiz-2		*	5%	October 1-10, 2023
	Assignment		*	10%	November 1-10, 2023
EC-2	Mid-Semester Test	Open Book	2 hours	30%	Saturday, 23/09/2023 (Evening)
EC-3	Comprehensive Exam	Open Book	2 ½ hours	50%	Saturday, 25/11/2023 (Evening)

Schedule

Date	Saturday Lecture (2 Hour 16 Lecture)	Event / Remark
22|07|2023	CS-1	Introduction Class
29|07|2023	CS-2	Assignment -1 (10 marks)
05|08|2023 / 12|08|2023	CS-3 and CS-4	
19|08|2023	CS-5	Quiz – 1 (5 marks)
26|08|2023/ 02|09|2023/09|09|2023/16|09| 2023	CS-6 / 7/8/9	
22,23,24|SEP|2023	30 marks	**Mid-Semester Test Regular (30 Marks)**
30|09|2023	CS-10	
06,07,08|OCT|2023		**Mid-Semester Test Make-up**
14|10|2023/21|10|2023	CS-11/12	
28|10|2023	CS-13	Quiz – 2 (5 marks)
04|11|2023/11|11|2023/18|11|2023	CS-14/15/16	
24,25,26|NOV|2023		**Comprehensive Examination Regular (50 marks)**
01,02,03|DEC|2023		**Comprehensive Exam Make-up**

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Any Query ?

Security Problem

Organizations store, process, transmit their most sensitive information using software-intensive systems.

Private citizens depend on software to shop, bank, invest, and carry out most personal and social activities

Global connectivity makes the sensitive information and software systems vulnerable to unintentional and unauthorized use.

Security Problem

As per some experts, we are in era of

- Information warfare
- Cyber terrorism
- Computer crime

Terrorists, Organized criminals, other criminals are targeting software-intensive systems and are able to gain entry.

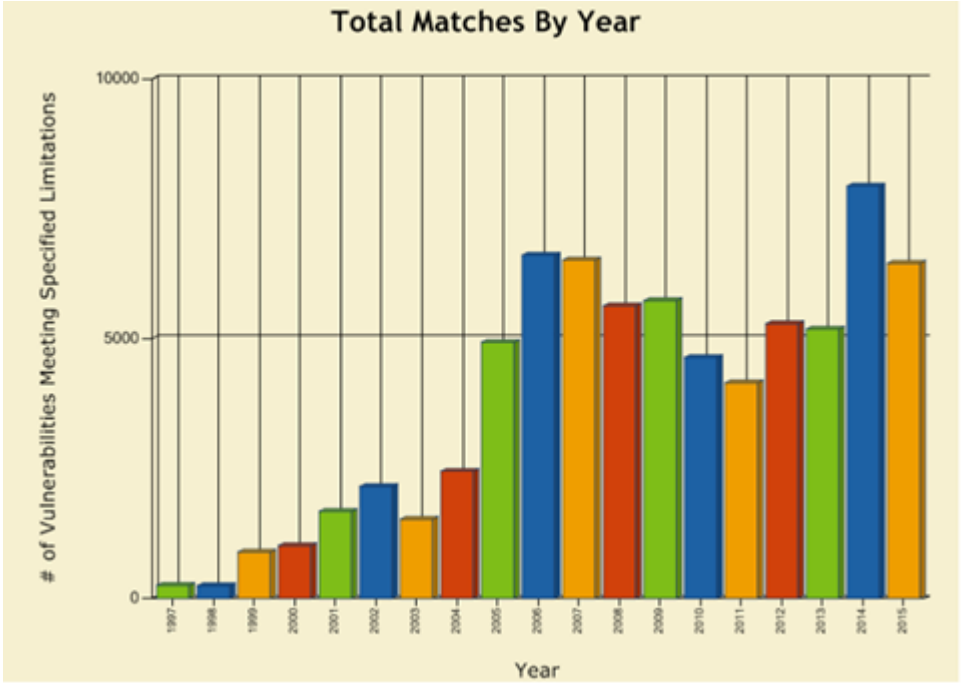
- There are many systems which can not resist attacks

Cyber Security Report to US President

Software development is not yet a science or a rigorous discipline, and the development process by and large is not controlled to minimize the vulnerabilities that attackers exploit. Today, as with cancer, vulnerable software can be invaded and modified to cause damage to previously healthy software, and infected software can replicate itself and be carried across networks to cause damage in other systems. Like cancer, these damaging processes may be invisible to the lay person even though experts recognize that their threat is growing.

- President's Information Technology Advisory Committee[2005]

Trends of reported vulnerabilities



NVD is the U.S. government repository of standards based vulnerability management data. This data enables automation of vulnerability management, security measurement, and compliance

Source : National Vulnerability Database of NIST (National Institute of Standards and Technology)
URL: https://web.nvd.nist.gov/view/vuln/statistics-results?adv_search=true&cves=on&pub_date_start_month=0&pub_date_start_year=1997&pub_date_end_month=11&pub_date_end_year=2015&cvss_version=3

Growth of Threats

Growing internet connectivity of computers and networks and dependence on network-enabled services(e.g. email, online transactions) means

- Increased number and sophistication of attack methods

Growing trend in which system accepts updates and extensions

- Each new extension adds new capabilities, new interfaces, and thus new risks

Unbridled growth in the size and complexity of software systems

- More lines of code produce more bugs and vulnerabilities

Security Principles

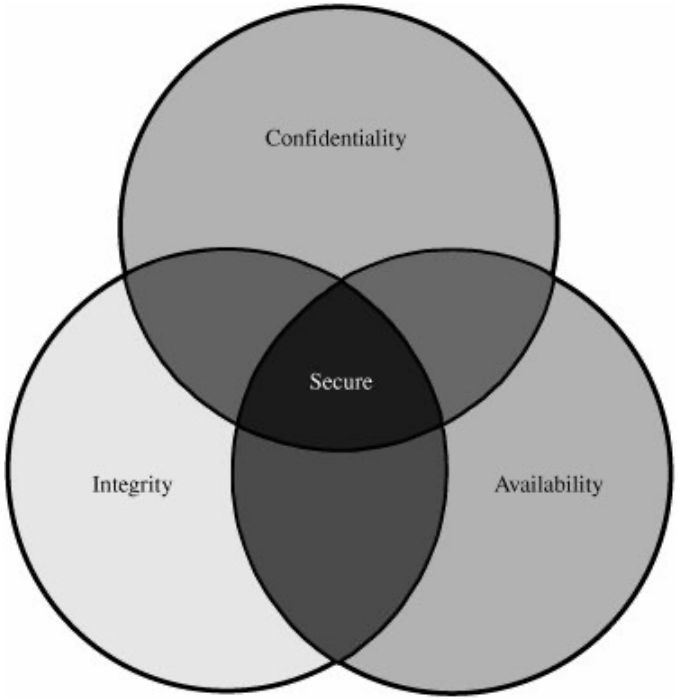
Saltzer and Schroeder defined security as “techniques that control who may use or modify the computer or the information contained in it”

Described the three main categories of concern:

- Confidentiality
- Integrity
- Availability

Saltzer and Schroeder, “The Protection of Information in Computer Systems.” *Communications of the ACM*, 1974

Security Principles



Integrity
Information be protected from improper modification

Availability
Available to user or program with legitimate right

Confidentiality
Protection of data from unauthorized disclosure

Relationship Between Confidentiality, Integrity, and Availability

Security Principles

Two additional properties commonly associated with human users are required in software entities that act as users, e.g. proxy agents, web services etc.

- Accountability : All security-relevant actions of the software-as-user must be recorded and tracked with attribution, both while and after the recorded action occurs
- Non-repudiation : Ability to prevent the software-as-user from disproving or denying responsibilities for actions it has performed

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Definitions and concepts of security - Part 2
RL 1.1.2

Software Assurance

The Committee on National Security Systems (CNSS) defines software assurance as follows:

"Software assurance (SwA) is the level of confidence that software is free from vulnerabilities, either intentionally designed into the software or accidentally inserted at any time during its life cycle, and that the software functions in the intended manner."

Software assurance includes software reliability, software safety, and software security

- Software assurance becomes important since critical infrastructure (viz. power, communication etc.) depend on software-intensive systems

Processes for Secure Software

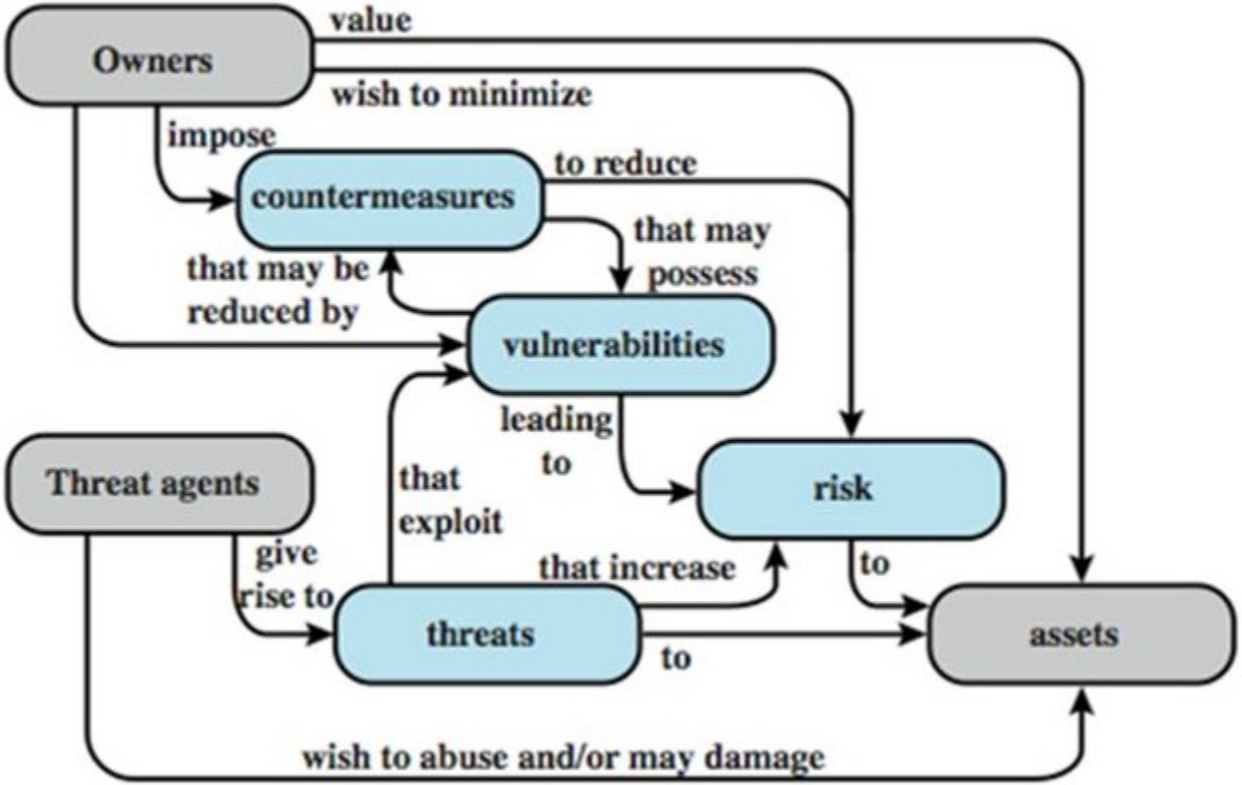
The most critical difference between secure and insecure software lies in the nature of the processes and practices used to specify, design, and develop the software

- Gortzel[2006]

Software vulnerabilities can originate from

- Decisions made by software engineers
- Flaws introduced in specification & design
- Faults from developed code
- Choice of programming language, development tools, operational environment etc.

Security Concepts and Relationships



Security Concepts and Relationships

Threat

- Any circumstance or event with the potential to adversely impact organizational operations (including mission, functions, image, or reputation), organizational assets, individuals, other organizations, or the Nation through an information system via unauthorized access, destruction, disclosure, modification of information, and/or denial of service. [CNSS 2010] 2. Any event that will cause an undesirable impact or loss to an organization if it occurs.

Vulnerability

- Weakness in an information system, system security procedures, internal controls, or implementation that could be exploited by a threat source. [CNSS 2010] 2. The absence or weakness of a safeguard. It can also be described as a weakness in an asset or the methods of ensuring that the asset is survivable.

Risk

- A measure of the extent to which an entity is threatened by a potential circumstance or event, and typically a function of 1) the adverse impacts that would arise if the circumstance or event occurs; and 2) the likelihood of occurrence.

Countermeasure

- Actions, devices, procedures, or techniques that meet or oppose(i.e., counters) a threat, a vulnerability, or an attack by eliminating or preventing it, by minimizing the harm it can cause, or by discovering and reporting it so that corrective action can be taken. NIST SP 800-53: Actions, devices, procedures, techniques, or other measures that reduce the vulnerability of an information system. Synonymous with security controls and safeguards. [CNSS 2010]

Security Concepts and Relationships

The ***attack surface*** of a software environment is the sum of the different points (the "attack vectors") where an unauthorized user (the "attacker") can try to enter data to or extract data from an environment.

An ***attack vector*** is a path or means by which a hacker (or cracker) can gain access to a computer or network server in order to deliver a payload or malicious outcome.

If an attack vector is thought of as a guided missile (e.g. email), its payload can be compared to the warhead (e.g. malicious attachment) in the tip of the missile.

Security Concepts and Relationships

The principle of ***defense-in-depth*** is that layered security mechanisms increase security of the system as a whole. If an attack causes one security mechanism to fail, other mechanisms may still provide the necessary security to protect the system.

Social engineering attack is based on deceiving end users or administrators at a target site. Such attacks are typically carried out by email or by contacting users by phone and impersonating an authorized user, in an attempt to gain unauthorized access to a system or application

Security Concepts and Relationships

In computer security, a ***sandbox*** is a security mechanism for separating running programs. It is often used to execute untested code, or untrusted programs from unverified third parties, suppliers, untrusted users and untrusted websites. A ***sandbox*** typically provides a tightly controlled set of resources for guest programs to run in, such as disk and memory, network access, the ability to inspect the host system or read from input devices (disallowed or heavily restricted).

Sandboxes may be seen as a specific example of virtualization. ***Sandboxing*** is frequently used to test unverified programs that may contain a virus or other malicious code, without allowing the software to harm the host device

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Threats to Software/Assets – Part 1
RL 1.2.1

The Asymmetric Problem of Security

No matter how much effort we spend, we will never get code 100 percent correct

This is an asymmetric problem

- **We** must be 100 percent correct, 100 percent of time, on a schedule, with limited resources, only knowing what we know today
  - And the product has to be reliable, supportable, compatible, manageable, affordable, accessible, usable, global, doable, deployable.
- **They** can spend as long as they like to find one bug, with the benefit of future research

– www.microsoft.com

The Asymmetric Problem of Security

Tools make it easy to build exploit code

Reverse engineering tools

- Situation explained
  - Structural Comparison of Executable Objects by Halvar Flake (available at https://static.googleusercontent.com/media/www.zynamics.com/en//downloads/dimva_paper2.pdf)
  - PCT Bug – “Detecting and understanding the vulnerability took less than 30 minutes”
  - H.323 ASN.1 Bug: “The total analysis took less than 3 hours time”
- Exploitation
  - Penetration testing tools e.g. www.metaspoilt.com

The Asymmetric Problem of Security

In general

- Cost for attacker to build attack is very low
- Cost to your users is very high
- Cost of reacting is higher than cost of defending

Hacking a Politician email

Hacker chooses to hack politician's mail account and possibly impact elections(2008)

The approach was

- Find the mail id
- Use Forgot Password feature
- The mail provider asks standard personal questions
- The politician biography is well known

Security on Cloud (Example)

Code Spaces kept up their security measures, ensured that their server security was tight, and relied on Amazon for the bulk of their infrastructure -- like thousands of other companies.

The attack that brought Code Spaces under was as simple as gaining access to its AWS control panel.

Code Spaces was built mostly on AWS, using storage and server instances to provide its services. Those server instances weren't hacked, nor was Code Spaces' database compromised or stolen.

Attacker gained access to the company's AWS control panel & deleted resources on the cloud.

The demise of Code Spaces at the hands of an attacker shows that, in the cloud, off-site backups and separation of services could be key to survival

http://www.infoworld.com/article/2608076/data-center/murder-in-the-amazon-cloud.html 23 June 2014

In the space of one hour, my entire digital life was destroyed. First my Google account was taken over, then deleted. Next my Twitter account was compromised, and used as a platform to broadcast racist and homophobic messages. And worst of all, my AppleID account was broken into, and my hackers used it to remotely erase all of the data on my iPhone, iPad, and MacBook.

My accounts were daisy-chained together. Getting into Amazon let my hackers get into my Apple ID account, which helped them get into Gmail, which gave them access to Twitter.

– Mat Honan, Sr. Staff Writer, wired.com

http://www.wired.com/2012/08/apple-amazon-mat-honan-hacking/all/

Panama Papers

- As per Forbes, data security experts noted that the company had not been encrypting its emails and furthermore seemed to have been running a three-year-old version of Drupal with several known vulnerabilities. Some reports also suggest that some parts of the site may have been running WordPress with an out of date version of Revolution Slider, a plugin that has suffered from vulnerabilities in the past.
- Drupal has over 100 reported vulnerabilities in CVE database.
  - e.g. CVE-2016-3171 : Drupal 6.x before 6.38, when used with PHP before 5.4.45, 5.5.x before 5.5.29, or 5.6.x before 5.6.13, might allow remote attackers to execute arbitrary code via vectors related to session data truncation.

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Threats to Software/Assets – Part 2
RL 1.2.2

Attack surfaces

Attack surface: the reachable and exploitable vulnerabilities in a system

- Open ports
- Services outside a firewall
- An employee with access to sensitive info
- …

Three categories

- **Network attack surface** (i.e., network vulnerability)
- **Software attack surface** (i.e., software vulnerabilities)
- **Human attack surface** (e.g., social engineering)

Attack analysis: assessing the scale and severity of threats

Automotive Attack Surface

Modern cars are controlled by complex distributed computer systems comprising millions of lines of code executing on tens of heterogeneous processors with rich connectivity provided by internal networks (e.g., Controller Area Network CAN).

This structure has offers significant benefits to efficiency, safety and cost, but also creates the opportunity for new attacks.

- An attacker connected to a car's *internal network* can circumvent *all* computer control systems, including safety critical elements such as the brakes and engine.
- The long-range wireless attack surface is that exposed by the remote telematics systems (e.g., Ford's Sync, GM's OnStar, Toyota's SafetyConnect, Lexus' Enform, BMW's BMW Assist, and Mercedes-Benz' mbrace) that provide continuous connectivity via cellular voice and data networks for supporting safety (crash reporting), diagnostics (early alert of mechanical issues), anti-theft (remote track and disable), and convenience (hands-free data access such as driving directions or weather).

Comprehensive Experimental Analyses of Automotive Attack Surfaces Stephen Checkoway, Damon McCoy, Brian Kantor, Danny Anderson, Hovav Shacham, and Stefan Savage University of California, San Diego
Karl Koscher, Alexei Czeskis, Franziska Roesner, and Tadayoshi Kohno University of Washington USENIX Security, August 10–12, 2011

Examples of threats

	Availability	Confidentiality	Integrity
Hardware	Equipment is stolen or disabled, thus denying service.	An unencrypted CD-ROM or DVD is stolen.	
Software	Programs are deleted, denying access to users.	An unauthorized copy of software is made.	A working program is modified, either to cause it to fail during execution or to cause it to do some unintended task.
Data	Files are deleted, denying access to users.	An unauthorized read of data is performed. An analysis of statistical data reveals underlying data.	Existing files are modified or new files are fabricated.
Communication Lines and Networks	Messages are destroyed or deleted. Communication lines or networks are rendered unavailable.	Messages are read. The traffic pattern of messages is observed.	Messages are modified, delayed, reordered, or duplicated. False messages are fabricated.

Data in Transit

Attacks on data in networks can be

Passive attacks : eavesdropping on, or monitoring of transmissions

- Release of message contents
- Traffic analysis : Encrypted message can not be read. Location, identity of host, frequency, and length of messages can help opponents make guess

Active attacks

- Replay : passive capture of data & subsequent retransmission to produce an unauthorized effect
- Masquerade : one entity pretends to be another entity.
- Modification of messages : some portion of a legitimate message is altered.
- Denial of service : inhibit normal use of facilities

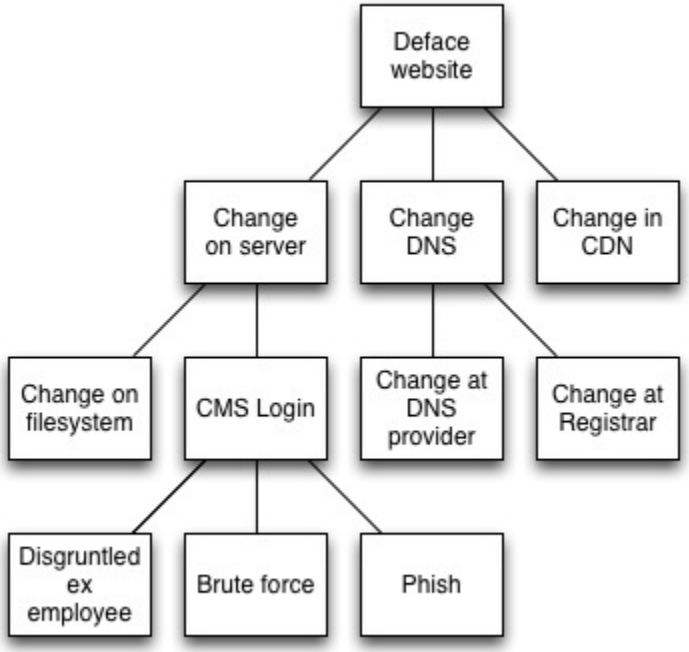
Attack trees

A branching, hierarchical data structure that represents a set of potential vulnerabilities

Objective: to effectively exploit the info available on attack patterns

- published on CERT or similar forums
- Security analysts can use the tree to guide design and strengthen countermeasures

An attack tree (to deface a web site)



Content delivery network (CDN) : System of distributed servers (network) that deliver webpages and other Web content to user based on the geographic locations

Domain Name System (DNS) : Hierarchical decentralized naming system for computers, services, or any resource connected to the Internet or a private network

CMS : Content Management System

http://ertw.com/blog/2015/01/06/thinking-about-cyber-security/

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Malware Nomenclature – Part 1
RL 1.3.1

Malware

“A program that is inserted into a system, usually covertly, with the intent of compromising the confidentiality, integrity, or availability of the victim’s data, applications, or operating system or otherwise annoying or disrupting the victim.”

Malicious software

Programs exploiting system vulnerabilities

Known as malicious software or malware

- program fragments that need a host program
  - e.g. viruses, logic bombs, and backdoors
- independent self-contained programs
  - e.g. worms, bots
- replicating or not

Sophisticated threat to computer systems

Malware Terminology

Virus: *attaches itself to a program*
Worm: *propagates copies of itself to other computers*
Logic bomb: *"explodes" when a condition occurs*
Trojan horse: *fakes/contains additional functionality*
Backdoor (trapdoor): *allows unauthorized access to functionality*
Mobile code: *moves unchanged to heterogeneous platforms*
Auto-rooter Kit (virus generator): *malicious code (virus) generators*
Spammer and flooder programs: *large volume of unwanted "pkts"*
Keyloggers: *capture keystrokes*
Rootkit: *sophisticated hacker tools to gain root-level access*
Zombie: *software on infected computers that launch attack on others (aka bot)*

More terms

Payload: actions of the malware

Crimeware: kits for building malware; include propagation and payload mechanisms

- Zeus, Sakura, Blackhole, Phoenix

APT (advanced persistent threats)

- Advanced: sophisticated
- Persistent: attack over an extended period of time
- Threat: selected targets (capable, well-funded attackers)

Viruses

Piece of software that infects programs

- modifying them to include a copy of the virus
- so it executes secretly when host program is run

Specific to operating system and hardware

- taking advantage of their details and weaknesses

A typical virus goes through phases of:

- dormant: *idle*
- propagation: *copies itself to other program*
- triggering: *activated to perform functions*
- execution: *the function is performed*

Biological Virus : Tiny scraps of genetic code – DNA or RNA – that can take over a living cell and trick it into making replicas of the original virus

Virus structure

Components:

- infection mechanism: enables replication
- trigger: event that makes payload activate
- payload: what it does, malicious or benign

Prepended/postpended/embedded

When infected program invoked, executes virus code then original program code

Can block initial infection (difficult) or propagation (with access controls)

Virus classification

By target

- boot sector: *infect a master boot record*
- file infector: *infects executable OS files*
- macro virus: *infects files to be used by an app*
- multipartite: infects multiple ways

By concealment

- encrypted virus: *encrypted; key stored in virus*
- stealth virus: *hides itself (e.g., compression)*
- polymorphic virus: *recreates with diff "signature"*
- metamorphic virus: *recreates with diff signature and behavior*

Virus Variants

Macro and scripting viruses

- Became very common in mid-1990s since
  - platform independent
  - infect documents
  - easily spread
- Exploit macro capability of Office apps
  - executable program embedded in office doc
  - often a form of Basic
- More recent releases include protection
- Recognized by many anti-virus programs

E-Mail Viruses

- More recent development
- Example : Melissa
  - exploits MS Word macro in attached doc
  - if attachment opened, macro activates
  - sends email to all on users address list and does local damage

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Malware Nomenclature – Part 2
RL 1.3.2

Worms

Replicating program that propagates over net

- using email, remote exec, remote login

Has phases like a virus:

- dormant, propagation, triggering, execution
- propagation phase: searches for other systems, connects to it, copies self to it and runs

May disguise itself as a system process

Concept seen in Brunner's "Shockwave Rider"

Implemented by Xerox Palo Alto labs in 1980's

Morris worm

One of best know worms

Released by Robert Morris in 1988

- Affected 6,000 computers; cost $10-$100 M

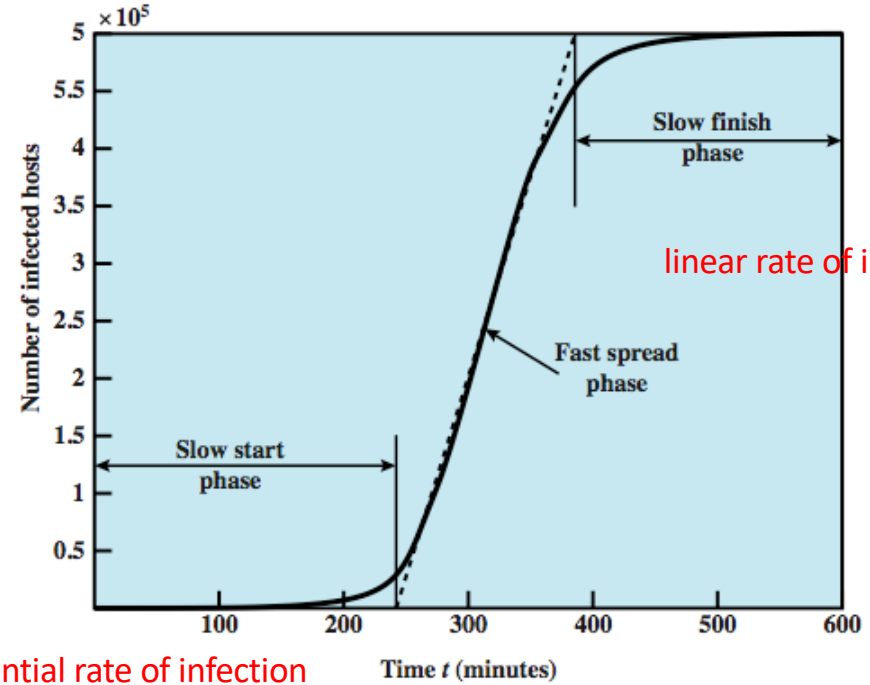
Various attacks on UNIX systems

- cracking password file to use login/password to logon to other systems
- exploiting a bug in the finger protocol
- exploiting a bug in sendmail

If succeed have remote shell access

- sent bootstrap program to copy worm over

Worm Propagation Model (based on recent attacks)



linear rate of infection

exponential rate of infection

Some worm attacks

Code Red

- July 2001 exploiting MS IIS bug
- probes random IP address, does DDoS attack
- consumes significant net capacity when active
- 360,000 servers in 14 hours

Code Red II variant includes backdoor: hacker controls the worm

SQL Slammer *(exploited buffer-overflow vulnerability)*

- early 2003, attacks MS SQL Server
- compact and very rapid spread

Mydoom *(100 M infected messages in 36 hours)*

- mass-mailing e-mail worm that appeared in 2004
- installed remote access backdoor in infected systems

State of worm technology

Multiplatform: not limited to Windows

Multi-exploit: Web servers, emails, file sharing …

Ultrafast spreading: do a scan to find vulnerable hosts

Polymorphic: each copy has a new code

Metamorphic: change appearance/behavior

Transport vehicles (e.g., for DDoS)

Zero-day exploit of unknown vulnerability (to achieve max surprise/distribution)

Worm countermeasures

Overlaps with anti-virus techniques

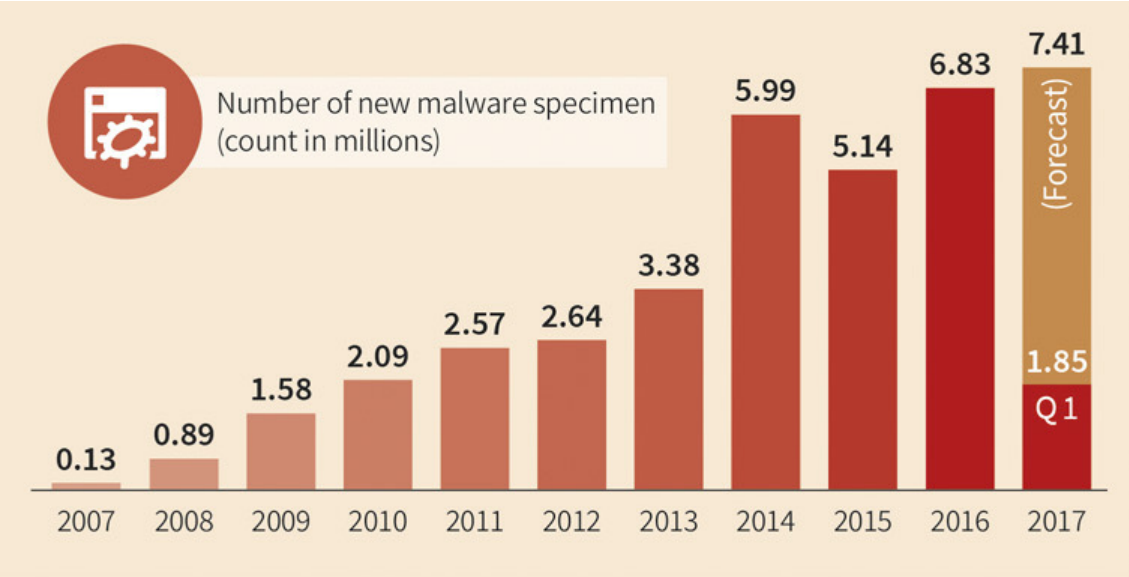
Once worm on system A/V can detect

Worms also cause significant net activity

Worm defense approaches include:

- signature-based worm scan filtering: define signatures
- filter-based worm containment (focus on contents)
- payload-classification-based worm containment (examine packets for anomalies)
- threshold random walk scan detection (limit the rate of scan-like traffic)
- rate limiting and rate halting (limit outgoing traffic when a threshold is met)

Malware Trends



www.gdatasoftware.com

Malware Trends

The vast majority of malware is categorized as Trojan Horse and comprises typical malicious activities like downloading and dropping files, spyware, keyloggers and password stealers, integration into botnets and conducting distributed denial of service attacks (DDoS).

Position two is held by adware.

A sharp rise could also be seen in ransomware(from a small base). Its number increased more than ninefold from the first half of 2016 to the second. Moreover, the number of the latter half of 2016 was almost achieved in the first quarter of 2017. Few ransomware families caused quite some stir.

www.gdatasoftware.com

Malware Trends

The predominant platform for malware is still Windows. It covers 99.1% of the malware specimen. Trailing behind are scripts, Java applets, macros and other operating systems like OSX, Android, and Unix/Linux.

The number of new malware is still rising.

No big changes in terms of malicious activities of Trojan horses

The number of adware is increasing

The share of ransomware is growing substantially.

www.gdatasoftware.com

Software Security Engineering, Julia H. Allen, et al, Pearson, 2008.

Computer Security: Principles and Practice by William Stallings, and Lawrie Brown Pearson, 2008.

Security in Computing by Charles P. Pfleeger, Shari L. Pfleeger, and Deven Shah Pearson Education 2009

Threat Modelling by Adam Shostack, John Wiley 2014

www.gdatasoftware.com

Thank You!

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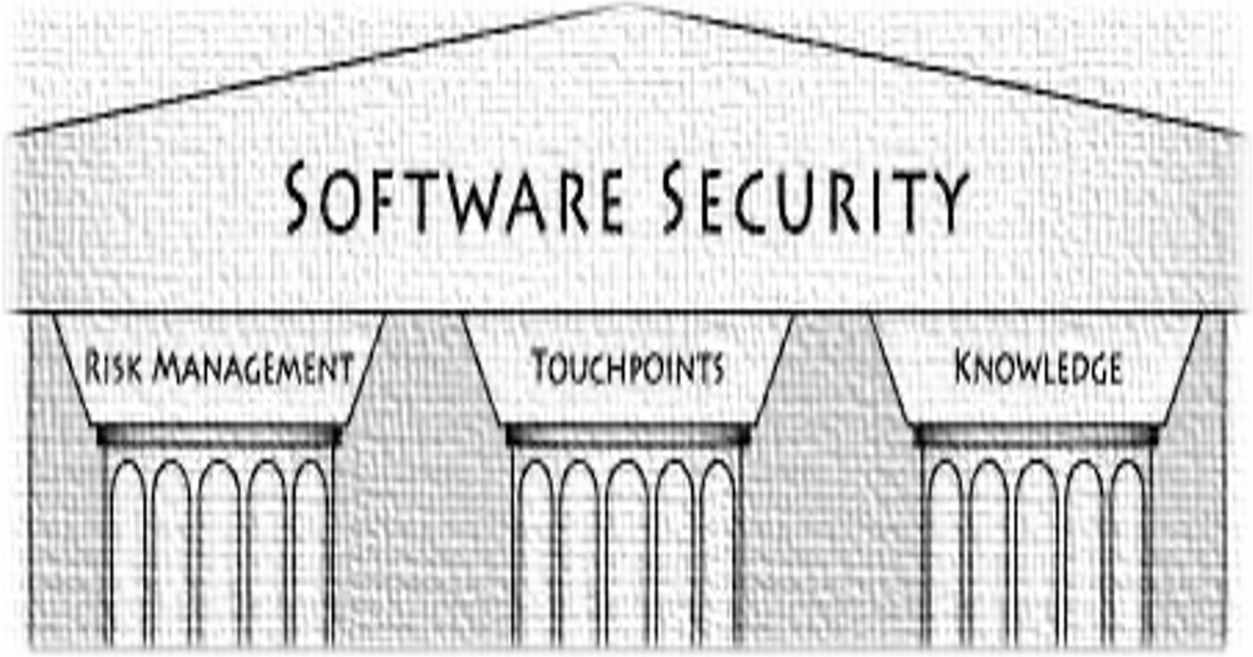
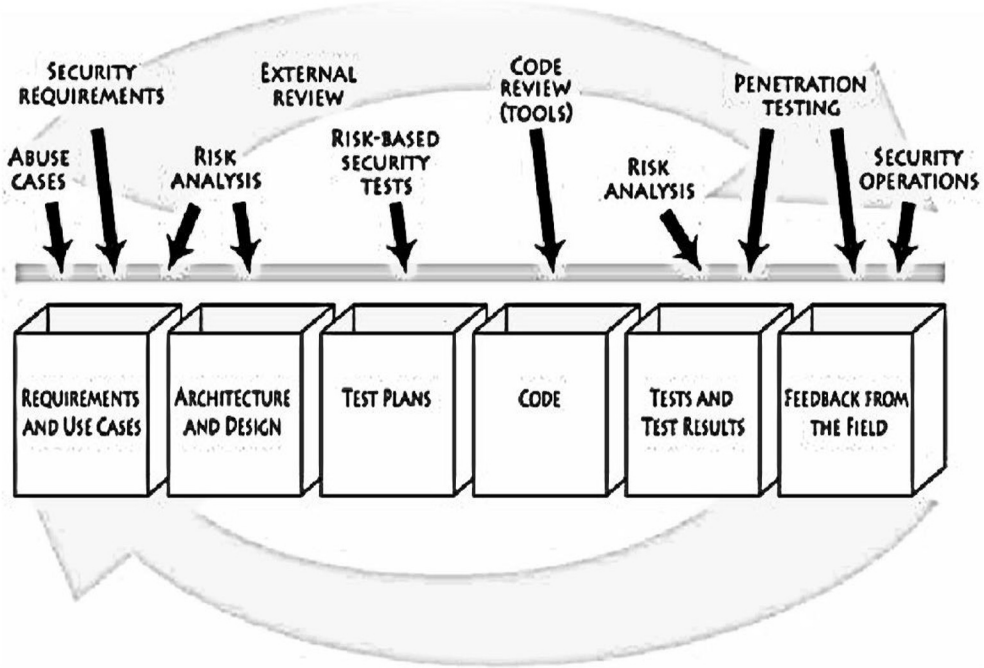
Phases in software development - Part 1
RL 2.1.1

Solving the Problem

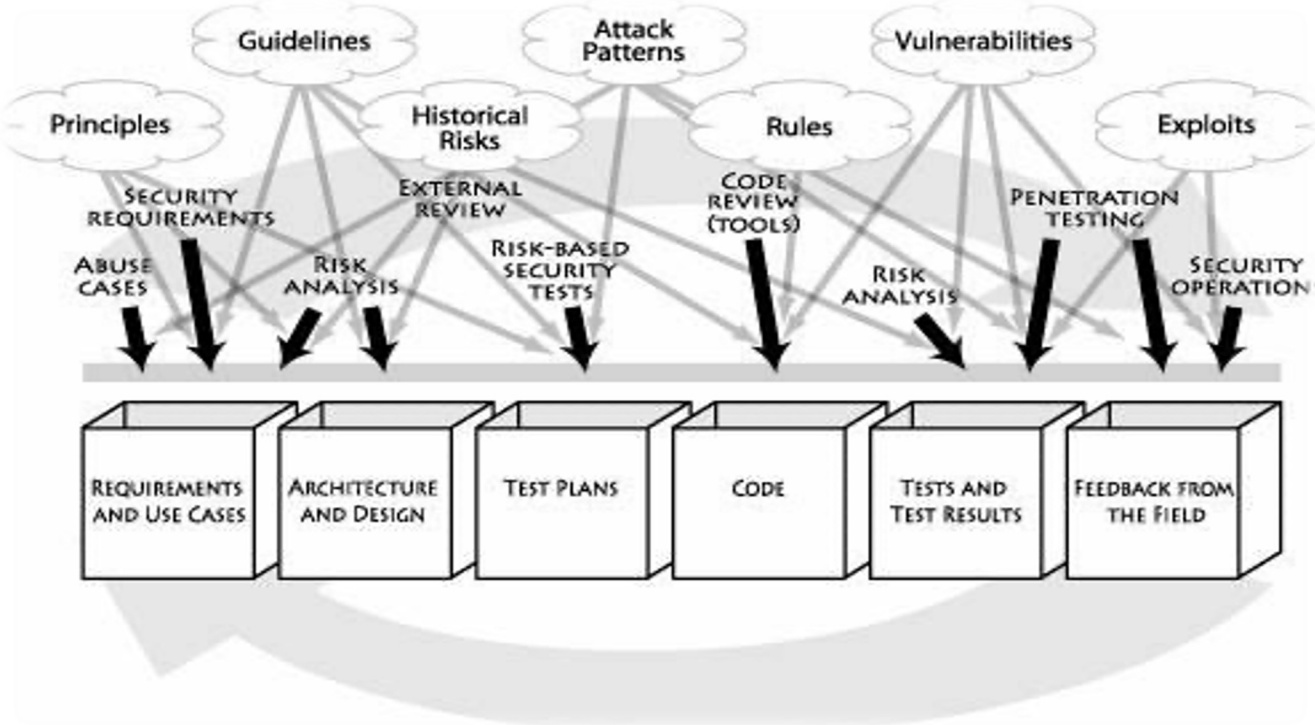
The Three Pillars of Software Security



Some Software security best practices



Some Software security best practices



The Rise of Security Engineering

- Connectivity and distributed computation is so pervasive that the only way to begin to secure our computing infrastructure is to enlist everyone.
  - Builders must practice security engineering, ensuring that the systems we build are defensible and not riddled with holes (especially when it comes to the software).
  - Operations people must continue to architect reasonable networks, defend them, and keep them up.
  - Administrators must understand the distributed nature of modern systems and begin to practice the principle of least privilege.
  - Users must understand that software *can* be secure so that they can take their business to software providers who share their values. (Witness the rise of Firefox.) Users must also

Software Engineering - Definitions

- (1969 – Fritz Bauer) Software engineering is the establishment and use of *sound engineering principles* in order to obtain *economically* software that is *reliable* and works *efficiently* on *real machines*

- (IEEE) The application of a *systematic, disciplined, quantifiable* approach to the *development, operation, and maintenance* of software; that is, the application of engineering to software

Knowledge Areas in v3(2014) of SWEBOK

Requirements Design Construction Testing Maintenance	Configuration Management Quality Processes Models & Methods Engineering Management Project Management Economics

Software Engineering Process KA

A Process defines who is doing what, when, and how to reach a certain goal

-Ivar Jacobson, Grady Booch, and James Rumbaugh

A software process is a set of interrelated activities and tasks that transform input work products into output work products. At minimum, the description of a software process includes required inputs, transforming work activities, and outputs generated.

- SWEBOK

A software process infrastructure can provide process definitions, policies for interpreting and applying the processes, and descriptions of the procedures to be used to implement the processes.

A software development life cycle (SDLC) includes the software processes used to specify and transform software requirements into a deliverable software product.

Prescriptive and agile processes

Prescriptive processes are processes where all of the process activities are planned in advance and progress is measured against this plan.

In agile processes, planning is incremental and it is easier to change the process to reflect changing customer requirements.

In practice, most practical processes may include elements of both plan-driven and agile approaches.

There are NO right or wrong software processes.

How Process Models Differ?

While all Process Models take same primary and supporting activities, they differ with regard to

- Overall flow of activities, actions, and tasks and the interdependencies among them
- Degree to which actions and tasks are defined within each framework activity
- Degree to which work products are identified and required
- Manner in which quality assurance activities are applied
- Manner in which project tracking and control activities are applied
- Overall degree of detail and rigor with which the process is described
- Degree to which customer and other stakeholders are involved in the project
- Level of autonomy given to the software team
- Degree to which team organization and roles are prescribed

Software Requirements

The Software Requirements knowledge area (KA) is concerned with the elicitation, analysis, specification, and validation of software requirements as well as the management of requirements during the whole life cycle.

Software projects are critically vulnerable when the requirements related activities are poorly performed

Functional & Nonfunctional Requirements

Functional requirements describe the functions that the software is to execute; for example, formatting some text or modulating a signal. They are sometimes known as capabilities or features. A functional requirement can also be described as one for which a finite set of test steps can be written to validate its behavior.

Nonfunctional requirements are the ones that act to constrain the solution. Nonfunctional requirements are aka constraints or quality requirements. They can classified according to whether they are performance requirements, maintainability requirements, safety requirements, reliability requirements, security requirements, interoperability requirements

Emergent properties of software

Some requirements represent *emergent properties* of software—that is, requirements that cannot be addressed by a single component but that depend on how all the software components interoperate. The throughput requirement for a call center would, for example, depend on how the telephone system, information system, and the operators all interacted under actual operating conditions. Emergent properties are crucially dependent on the system architecture.

Experts consider ***Security*** as an ***emergent property*** of the software.

Software Design

Software design consists of two activities that fit between software requirements analysis and software construction:

- Software architectural design (sometimes called high-level design): develops top-level structure and organization of the software and identifies the various components.
- Software detailed design: specifies each component in sufficient detail to facilitate its construction.

Software Design

- Software design principles include abstraction; coupling and cohesion; decomposition and modularization; encapsulation/information hiding; separation of interface and implementation; sufficiency, completeness, and primitiveness; and separation of concerns.
- Design for security is concerned with how to prevent unauthorized disclosure, creation, change, deletion, or denial of access to information and other resources. It is also concerned with how to tolerate security-related attacks or violations by limiting damage, continuing service, speeding repair and recovery, and failing and recovering securely.

Software Construction

Software construction refers to the detailed creation of working software through a combination of coding, verification, unit testing, integration testing, and debugging.

Throughout construction, software engineers both unit test and integration test their work. Thus, the Software Construction KA is closely linked to the Software Testing KA.

Code is the ultimate deliverable of a software project, and thus the Software Quality KA is closely linked to the Software Construction KA.

Software Testing

Software testing consists of the *dynamic* verification that a program provides *expected* behaviors on a *finite* set of test cases, suitably *selected* from the usually infinite execution domain

- *Dynamic:* The input value alone is not always sufficient to specify a test, since a system might react to the same input with different behaviors, depending on the system state.
- *Finite:* Even in simple programs, so many test cases are theoretically possible that exhaustive testing is infeasible.
- *Selected:* How to identify the most suitable test set under given conditions is a complex problem; in practice, risk analysis techniques and software engineering expertise are applied.
- *Expected:* It must be possible, although not always easy, to decide whether the observed outcomes of program testing are acceptable or not.

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Phases in software development - Part 2
RL 2.1.2

Software quality

Software quality may refer:

- to desirable characteristics of software products,
- to the extent to which a particular software product possess those characteristics, and
- to processes, tools, and techniques used to achieve those characteristics

Experts defined variously

“conformance to requirements” - Phil Crosby

“achieving excellent levels of fitness for use” - Watt Humphrey

“market-driven quality” where the “customer is the final arbiter” - IBM

Software quality

A healthy software engineering culture includes the understanding that tradeoffs among cost, schedule, and quality are a basic tenant of the engineering of any product.

The tradeoff is best decided by understanding four cost of quality categories: prevention, appraisal, internal failure, and external failure.

Prevention costs include investments in software process improvement efforts, quality infrastructure, quality tools, training, audits, and management reviews

Appraisal costs arise from project activities that find defects.

Costs of internal failures are those that are incurred to fix defects found during appraisal activities and discovered prior to delivery of the software product to the customer

External failure costs include activities to respond to software problems discovered after delivery to the customer.

Configuration management

Configuration management (CM) is the discipline of identifying the configuration of a system at distinct points in time for the purpose of systematically controlling changes to the configuration and maintaining the integrity and traceability of the configuration throughout the system life cycle.

A system can be defined as the combination of interacting elements organized to achieve one or more stated purposes

Configuration of a software system is collection of specific versions of hardware, firmware, or software items combined according to specific build procedures for a purpose.

Software Maintenance

A software product must change or evolve over time. Once a software is in operation, defects are uncovered, operating environments change,and new user requirements surface.

Software maintenance is an integral part of a software life cycle. However, software development used to receive more importance than software maintenance in most organizations. It is changing

- Due to large capital spending needed for software development, organizations are trying to maximize lifespan of existing software
- Due to large scale availability of open source components, organizations increased focus on maintenance

Maintainer's activities

Five key characteristics comprise the maintainer's activities:

- maintaining control over the software's day-to-day functions;
- maintaining control over software modification;
- perfecting existing functions;
- identifying security threats and fixing security vulnerabilities; and
- preventing software performance from degrading to unacceptable levels.

Software Engineering Management

Software engineering management can be defined as the application of management activities — planning, coordinating, measuring, monitoring, controlling, and reporting — to achieve quality etc.

There are aspects specific to software projects and software life cycle that complicate effective management, including

- Clients often don't know what is needed or what is feasible
- As a result of changing requirements, software is often built using an iterative process
- The degree of novelty and complexity is often high
- There is often a rapid rate of change in the underlying technology

Software Engineering Economics

Software engineering economics is about relating the attributes of software and software processes to economic measures

- involves balancing risk and profitability, while maximizing benefits and wealth of the organization.
- identify organizational goals, time horizons, risk factors, and financial constraints
- identify and implement the appropriate portfolio and investment decisions to manage cash flow, and funding;
- measure financial performance, such as cash flow and ROI

Software Engineering Process

software process is a set of interrelated activities and tasks that transform input work products into output work products

a software process includes required inputs, transforming work activities, and outputs generated

a software process may also include its entry and exit criteria and decomposition of the work activities into tasks, which are the smallest units of work

Value individuals & interactions over processes & tools – Agile manifesto

Agile models are designed to facilitate evolution of the software requirements during the project

Software Engineering Professional Practice

Software Engineering Professional Practice includes knowledge, skills, and attitudes that software engineers must possess to practice software engineering in a professional, responsible, and ethical manner

The concept of professional practice becomes applicable within the professions that have a generally accepted body of knowledge

A code of ethics and professional conduct for software engineering was approved by the ACM Council and the IEEE CS Board of Governors in 1999

–Software engineers shall commit themselves to making the analysis, specification, design, development, testing and maintenance of software a beneficial and respected profession. In accordance with their commitment to the health, safety and welfare of the public, software engineers shall adhere to the eight principles concerning the public, client and employer, product, judgment, management, profession, colleagues, and self, respectively

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Work products during SDLC
RL 2.2

Requirement Models

Scenario-based modeling – represents the system from the user's point of view

Flow-oriented modeling – provides an indication of how data objects are transformed by a set of processing functions

Class-based modeling – defines objects, attributes, and relationships

Behavioral modeling – depicts the states of the classes and the impact of events on these states

Use-Cases

A collection of user scenarios that describe the thread of usage of a system

Each scenario is described from the point-of-view of an “actor”—a person or device that interacts with the software in some way

Each scenario answers the following questions:

- Who is the primary actor, the secondary actor (s)?
- What are the actor’s goals?
- What preconditions should exist before the story begins?
- What main tasks or functions are performed by the actor?
- What extensions might be considered as the story is described?
- What variations in the actor’s interaction are possible?
- What system information will the actor acquire, produce, or change?
- Will the actor have to inform the system about changes in the external environment?
- What information does the actor desire from the system?
- Does the actor wish to be informed about unexpected changes?

Use case—detailed example (Pressman)

Example: “SAFEHOME” system (Pressman)

Use case name: ***InitiateMonitoring***

Participating actors: homeowner, technicians, sensors

Flow of events (homeowner):

--Homeowner wants to set the system when the homeowner leaves house or remains in house
--Homeowner observes control panel
--Homeowner enters password
--Homeowner selects “stay” or “away”
--Homeowner observes that read alarm light has come on, indicating the system is armed

Use case—detailed example (Pressman)

Pre condition(s)

Homeowner decides to set control panel

Post condition(s)

– Control panel is not ready; homeowner must check all sensors and reset them if necessary

– Control panel indicates incorrect password (one beep)—homeowner enters correct password

– Password not recognized—must contact monitoring and response subsystem to reprogram password

– *Stay* selected: control panel beeps twice and lights *stay* light; perimeter sensors are activated

– *Away* selected: control panel beeps three times and lights away light; all sensors are activated

Use case—detailed example (Pressman)

Quality requirements:

Control panel may display additional text messages

time the homeowner has to enter the password from the time the first key is pressed

Ability to activate the system without the use of a password or with an abbreviated password

Ability to deactivate the system before it actually activates

Misuse case (techtarget.com)

Name: Attack on "forgot password" functionality

Summary: A malicious user tries to attack the "forgot password" functionality in order to gain access to the Web application or guess a valid e-mail address

Author: Anurag Agarwal

Date: April 15, 2006

Possible Attacks:

- SQL injection attack
- Brute force attack to guess a valid user
- Sniffing attack on e-mail sent with password on an insecure transmission channel

Trigger Point: Can happen anytime

Preconditions: None

Assumptions:

- The attacker can perform this attack remotely over the Internet
- The attacker can be an anonymous user

Misuse case (techtarget.com)

Worst case threat (post condition) :

- Attacker gains entry into the company database and steals sensitive information
- Attacker is able to modify an existing e-mail address to its own e-mail address and mails the password to himself to gain unauthorized entry into the system

Related business rule:

- The system should e-mail the password to a valid e-mail address entered

Capture guarantee (post condition) :

- Attacker cannot gain access to the database to steal or modify information
- Attacker cannot identify the e-mail address of a valid user
- Attacker cannot view the password sent in an e-mail to an e-mail address of a valid user

Misuse case (techtarget.com)

Potential misuser profile:

- Script kiddie
- Skilled attacker

Threat level: High

Mitigation steps:

- SQL injection attack
  - List all the mitigation steps to avoid a SQL injection attack.
- Brute force attack
  - Accept first name, last name along with e-mail address
  - Have proper error handling so as not to reveal information to the attacker
  - Delay 3 to 5 seconds before re-entering the e-mail address
  - Lock out page for that IP address after 10 attempts
- Sniffing attack
  - Send password e-mail on a secure transmission channel with strong encryption

Data Flow Modeling

Data Flow Diagram

- Depicts how input is transformed into output as data objects move through a system

Process Specification

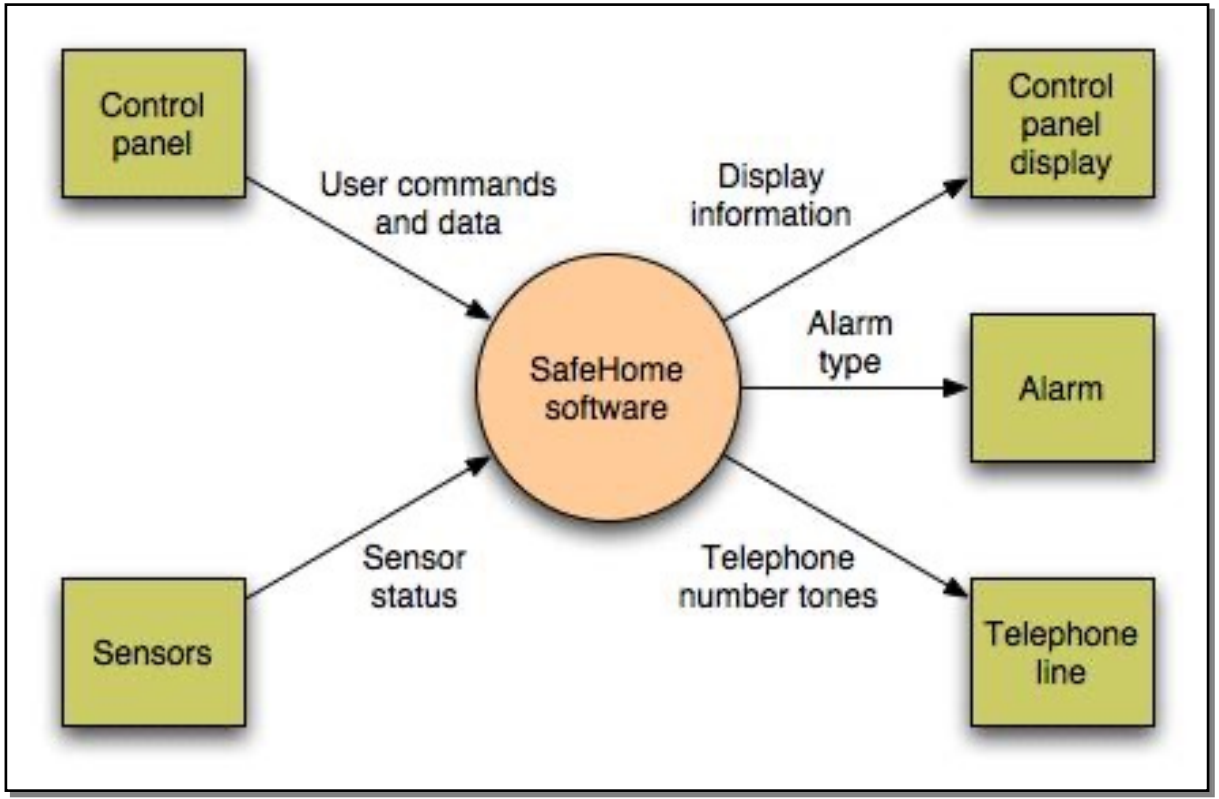
- Describes data flow processing at the lowest level of refinement in the data flow diagrams

Data Flow Modeling

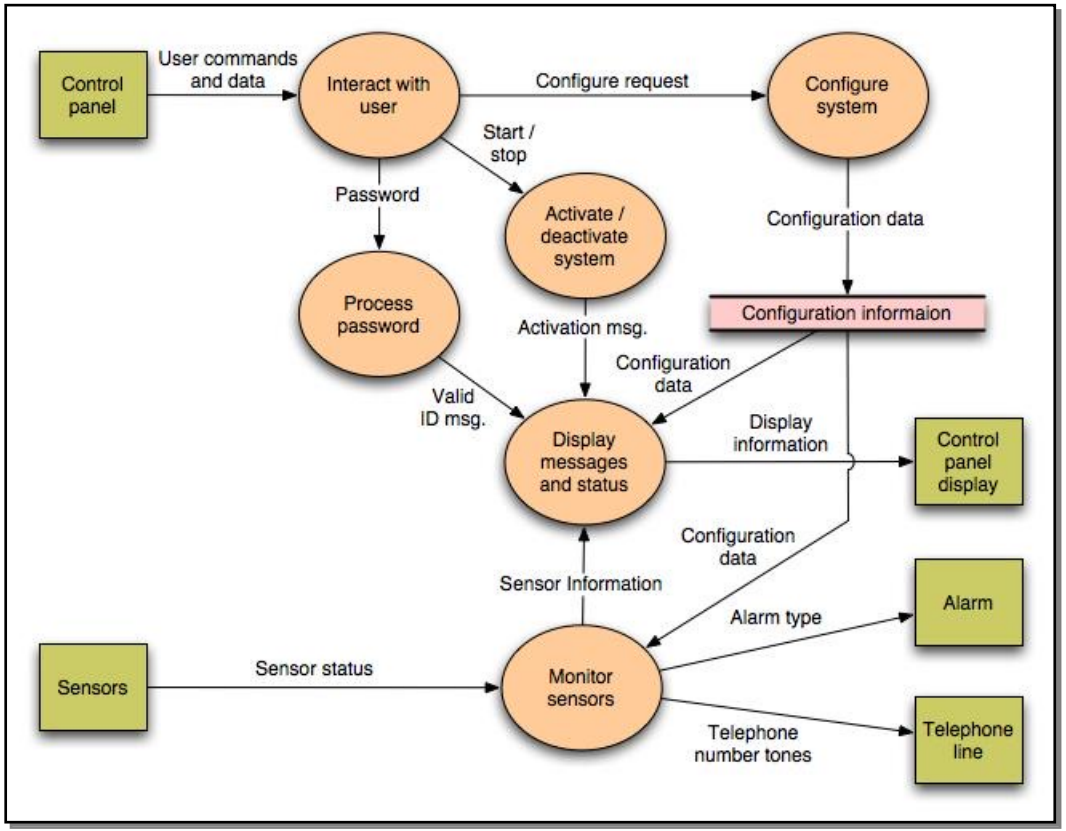
Guidelines

- Depict the system as single bubble in level 0.
- Carefully note primary input and output.
- Refine by isolating candidate processes and their associated data objects and data stores.
- Label all elements with meaningful names.
- Maintain information conformity between levels.
- Refine one bubble at a time.

Data Flow Diagram



Data Flow Diagram (Next Level)



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Security implications to SDLC – Part 1
RL 2.3.1

OWASP (Open Web Application Security Project) SAMM

SAMM (Software Assurance Maturity Model) is the OWASP framework to help organizations assess, formulate, and implement a strategy for software security, that can be integrated into their existing Software Development Lifecycle (SDLC)

SAMM is based around a set of 12 security practices, which are grouped into four business functions

Every security practice contains a set of activities, structured into three maturity levels (1-3).

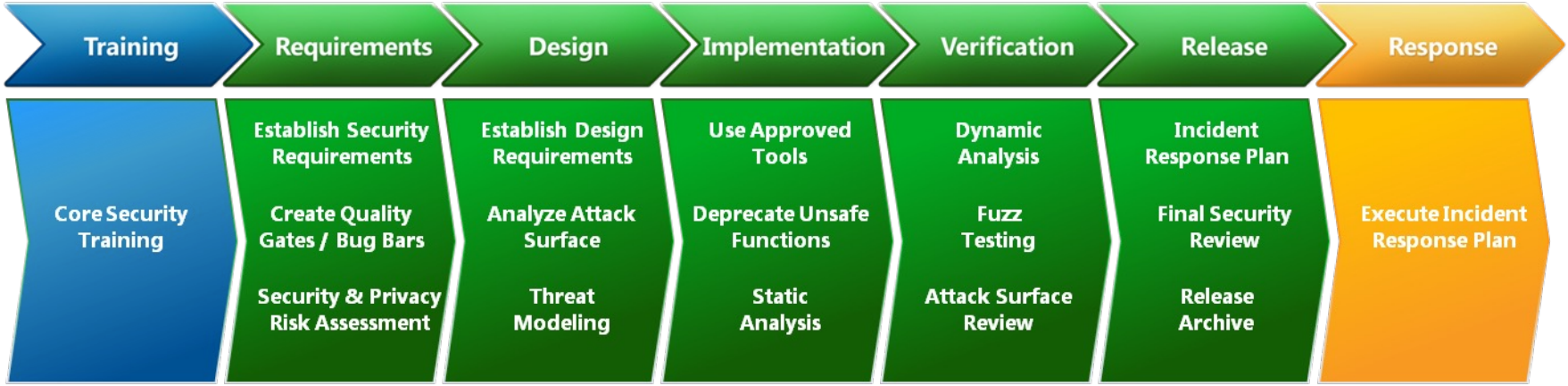
Security Development Lifecycle

The Security Development Lifecycle (SDL) is a security assurance process developed by Microsoft as a company-wide initiative and a mandatory policy to reduce the number and severity of vulnerabilities in software products.

The Microsoft SDL is based on three core concepts —

- *education,*
- *continuous process improvement, and*
- *accountability*

Security Development Lifecycle



SDL - Core Security Training

Basic software security training should cover foundational concepts such as:

- Secure design, including the following topics: Attack surface reduction, Defense in depth, principle of least privilege, Secure defaults
- Threat modeling, including the following topics: Overview of threat modeling, Design implications of a threat model, Coding constraints based on a threat model
- Secure coding, including the following topics: Buffer overruns (for applications using C and C++), Integer arithmetic errors (for applications using C and C++), Cross-site scripting (for managed code and Web applications), SQL injection (for managed code and Web applications), Weak cryptography
- Security testing, including the following topics: Differences between security testing and functional testing, Risk assessment, Security testing methods
- Privacy, including the following topics: Types of privacy-sensitive data, Privacy design best practices, Risk assessment, Privacy development best practices, Privacy testing best practices

SDL Roles

SDL roles are designed to provide project security and privacy oversight and have the authority to accept or reject security and privacy plans from a project team.

Security Advisor/Privacy Advisor. This role is filled by subject-matter experts (SMEs) from outside the project team. The person chosen for this task must fill two sub-roles:

- Auditor: monitors each phase of the software development process and attest to successful completion of each security requirement
- Expert: must possess verifiable subject-matter expertise in security.

Team Champion. should be filled by SMEs from the project team. Responsible for the negotiation, acceptance, and tracking of minimum security and privacy requirements

Some SDL Practices

Threat Modeling

- used in environments where there is meaningful security risk
- allows development teams to consider, document, and discuss the security implications of designs in the context of their planned operational environment
- Threat modeling is a team exercise, encompassing program/project managers, developers, and testers, performed during the software design stage

Attack Surface Reduction

- a means of reducing risk by giving attackers less opportunity to exploit a potential weak spot or vulnerability
- encompasses shutting off or restricting access to system services, applying the principle of least privilege, and employing layered defenses wherever possible

Some SDL Practices

Static Analysis

- The team should be aware of the strengths and weaknesses of static analysis tools and be prepared to augment static analysis tools with other tools or human review as appropriate

Dynamic Program Analysis

- specify tools that monitor application behavior for memory corruption, user privilege issues, and other critical security problems

Fuzz Testing

- a specialized form of dynamic analysis used to induce program failure by deliberately introducing malformed or random data to an application

Some SDL Practices

Final Security Review

- a deliberate examination of all the security activities performed on a software application prior to release
- performed by the security advisor with assistance from the regular development staff and the security and privacy team leads
- includes an examination of threat models, exception requests, tool output, and performance against the previously determined quality gates or bug bars
- If a team does not meet all SDL requirements and the security advisor cannot approve the project, the project cannot be released
- Teams must either address whatever SDL requirements that they can prior to launch or escalate to executive management for a decision

Software Engineering: A Practitioner's Approach, 7/e Roger Pressman
Software Engineering, Pearson Education, 9th Ed., 2010. Ian Sommerville
SWEBOK by IEEE/ACM
www.owasp.com
www.microsoft.com

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Threat Modelling Concepts
RL 3.1

Securing a Computer Based System

A computer-based system has three separate but valuable components (Assets) :

- Hardware
- Software
- Data

Vulnerabilities

- Weaknesses in a system that may be able to be *exploited* in order to cause loss or harm
  - e.g., a file server that doesn't authenticate its users

Threats

- A loss or harm that might befall a system
  - e.g., users' personal files may be revealed to the public

Characteristics of Computer Intrusion

By computing system, we include

- Hardware
- Software
- Storage media
- Data and
- People

A system is most vulnerable at its weakest point

- A robber will not attempt to penetrate a 2-inch-thick metal door if a window gives easy access

Principle of Easiest Penetration

An intruder must be expected to use any available means of penetration. The penetration may not necessarily be by the most obvious means, nor is it necessarily the one against which the most solid defense has been installed. And it certainly does not have to be the way we want the attacker to behave.

Threat Model

When designing a system, we need to state the threat model

Threat Model

- Set of threats we are undertaking to defend against
- Whom do we want to prevent from doing what?

Attack

- An action which exploits a vulnerability to execute a threat
- e.g., telling the file server you are a different user in an attempt to read or modify their files

Threats to Assets

According to Pfleeger, the threats are

- **Interruption** – an asset is destroyed, unavailable or unusable (*availability*)
- **Interception** – unauthorized party gains access to an asset (*confidentiality*)
- **Modification** – unauthorized party tampers with asset (*integrity*)
- **Fabrication** – unauthorized party inserts counterfeit object into the system (*authenticity*)

Threat Consequences (IETF RFC 4949)

Threat Consequence	Threat Action (Attack)
Unauthorized Disclosure A circumstance or event whereby an entity gains access to data for which the entity is not authorized	**Exposure:** Sensitive data are directly released to an unauthorized entity. **Interception:** An unauthorized entity directly accesses sensitive data traveling between authorized sources and destinations. **Inference:** A threat action whereby an unauthorized entity indirectly accesses sensitive data (but not necessarily the data contained in the communication) by reasoning from characteristics or by-products of communications. **Intrusion:** An unauthorized entity gains access to sensitive data by circumventing a system's security protections.
Deception A circumstance or event that may result in an authorized entity receiving false data and believing it to be true	**Masquerade:** An unauthorized entity gains access to a system or performs a malicious act by posing as an authorized entity. **Falsification:** False data deceive an authorized entity. **Repudiation:** An entity deceives another by falsely denying responsibility for an act
Disruption A circumstance or event that interrupts or prevents the correct operation of system services and functions	**Incapacitation:** Prevents or interrupts system operation by disabling a system component. **Corruption:** Undesirably alters system operation by adversely modifying system functions or data. **Obstruction:** A threat action that interrupts delivery of system services by hindering system operation
Usurpation A circumstance or event that results in control of system services or functions by an unauthorized entity	**Misappropriation:** An entity assumes unauthorized logical or physical control of a system resource. **Misuse:** Causes a system component to perform a function or service that is detrimental to system security

Who are Attackers

One approach to prevention is to understand who carries out attacks and why

Amateurs

- Ordinary computer professionals or users who, while doing their jobs, discover they have access to something valuable. Amateurs may be disgruntled employees who vow to get even with management

Crackers or Malicious Hackers

- Attempt to access computing facilities for which they have not been authorized (often students who see it as victimless crime). Some carry out for curiosity, personal gain or self-satisfaction

Who are Attackers

Career Criminals

- Understands the targets of computer crime; often begin as computer professionals, then shift to crime finding payoff. “They don’t want to write a worm that destroys your hardware. They want to assimilate your computers and use them to make money”

Terrorists

- They use computers in three ways
  - Targets of attack – denial of service, web site defacement attacks are popular to attract attention to the cause and bring undesired negative attention to the targets of attack
  - Propaganda vehicles – inexpensive way to get a message to many
  - Methods of attack – use computers to launch attacks

Method, Opportunity, Motive

A malicious attacker must have three things

- Method : the skills, knowledge, tools, and other things with which to be able to pull off the attack
- Opportunity : the time and access to accomplish the attack
- Motive : a reason to want to perform this attack against this system

Deny any of those three things and the attack will not occur.

Methods of defense

How can we defend against a threat?

- Prevent it: prevent the attack
- Deter it: make the attack harder or more expensive
- Deflect it: make yourself less attractive to attacker
- Detect it: notice that attack is occurring (or has occurred)
- Recover from it: mitigate the effects of the attack

Methods of defense

Threat: your car may get stolen

How to defend?

- Prevent: Immobilizer? Is it possible to absolutely prevent?
- Deter: Store your car in a secure parking facility
- Deflect: Have sticker mentioning car alarm, keep valuables out of sight
- Detect: Car alarms
- Recover: Insurance

Structured Approach to Threat Modeling

According to Adam Shostack, you begin threat modeling by focusing on four key questions

- What are you building?
- What can go wrong?
- What should you do about those things that can go wrong?
- Did you do a decent job of analysis (retrospect)

Structured Approach to Threat Modeling

People often use an approach centered on

- Models of their assets (Valuable things they have),
- Models of attackers (People who might go after assets), or
- Models of their software (Common way to attack is via the deployed software)

Centering on one of these is preferable to using approaches that combine them because the combinations tend to be confusing

According to Adam Shostack, first two sets of models help in engaging with non-technical people and third type of models are important for software development

What Threat Modelling is (not)

What threat modelling is	What threat modelling is not
A team activity	An activity performed by a single team member in isolation
An activity that helps identify security vulnerabilities in a variety of software applications	Just for large software projects
An activity that should be performed for every iteration or sprint during agile development	An activity done once during the lifecycle of the project

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OWASP Threat Modelling Process – Part 1
RL 3.2.1

OWASP Threat Modeling

According to OWASP, the threat modeling process for software application can be decomposed into 3 high level steps

- Decompose the Application
- Determine and rank threats
- Determine countermeasures and mitigation

Decompose the Application (step 1)

Understanding of the application and how it interacts with external entities.

- involves creating use-cases to understand how the application is used,
- identifying entry points to see where a potential attacker could interact with the application,
- identifying assets i.e. items/areas that the attacker would be interested in, and
- identifying trust levels which represent the access rights that the application will grant to external entities.

Produce data flow diagrams (DFDs) for the application. The DFDs show the different paths through the system, highlighting the privilege boundaries.

Determine and rank threats (step 2)

A threat categorization such as STRIDE can be used,

- Spoofing
- Tampering
- Repudiation
- Information disclosure
- Denial of service
- Elevation of privilege

The STRIDE categorization helps to identify threats from the attacker perspective.

Determine and rank threats (step 2)

A threat categorization ASF (Application Security Framework) defines threat categories such as

- Auditing & Logging,
- Authentication,
- Authorization,
- Configuration Management,
- Data Protection in Storage and Transit,
- Data Validation,
- Exception Management.

The ASF categorization helps to identify threats from the defensive perspective.

Determine and rank threats (step 2)

DFDs produced in step 1 help to identify the potential threat targets from the attacker's perspective, viz.

- data sources,
- processes,
- data flows, and
- interactions with users.

Use and abuse cases can illustrate how existing protective measures could be bypassed, or where a lack of such protection exists.

Determine and rank threats (step 2)

These threats can be identified further as the roots for threat trees;

- one tree for each threat goal.

From the defensive perspective, ASF categorization helps to identify the threats as weaknesses of security controls for such threats.

The determination of the security risk for each threat can be determined using a value-based risk model such as DREAD

Determine countermeasures and mitigation

A lack of protection against a threat might indicate a vulnerability whose risk exposure could be mitigated with the implementation of a countermeasure.

Countermeasures can be identified using threat-countermeasure mapping lists.

Based on risk ranking assigned to the threats, it is possible to sort threats from the highest to the lowest risk, and prioritize the mitigation effort, such as by responding to such threats by applying the identified countermeasures

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OWASP Threat Modelling Process – Part 2
RL 3.2.2

OWASP Threat Modeling Example

Application Description:

The college library website is the first implementation of a website to provide librarians and library patrons (students and college staff) with online services. As this is the first implementation of the website, the functionality will be limited. There will be three users of the application:

1. Students
2. Staff
3. Librarians

Staff and students will be able to log in and search for books, and staff members can request books. Librarians will be able to log in, add books, add users, and search for books.

External Dependencies

External dependencies are items external to the code of the application that may pose a threat to the application. These items are typically still within the control of the organization, but possibly not within the control of the development team

ID	Description
1	The database server will be MySQL and it will run on a Linux server. This server will be hardened as per the college's server hardening standard. This will include the application of the latest operating system and application security patches.
2	The connection between the Web Server and the database server will be over a private network.

Trust Levels

Trust levels represent the access rights that the application will grant to external entities.

The trust levels are cross referenced with the entry points and assets.

This allows us to define the access rights or privileges required at each entry point, and those required to interact with each asset

Trust Levels

ID	Name	Description
1	Anonymous Web User	A user who has connected to the college library website but has not provided valid credentials.
2	User with Valid Login Credentials	A user who has connected to the college library website and has logged in using valid login credentials.
3	User with Invalid Login Credentials	A user who has connected to the college library website and is attempting to log in using invalid login credentials.
4	Librarian	The librarian can create users on the library website and view their personal information.
5	Database Server Administrator	The database server administrator has read and write access to the database that is used by the college library website.
6	Website Administrator	The Website administrator can configure the college library website.
7	Web Server User Process	This is the process/user that the web server executes code as and authenticates itself against the database server as.
8	Database Read User	The database user account used to access the database for read access.
9	Database Read/Write User	The database user account used to access the database for read and write access.

Entry Points

Entry points define the interfaces through which potential attackers can interact with the application or supply it with data. In order for a potential attacker to attack an application, entry points must exist.

ID	Name	Description	Trust Levels
1.1	Library Main Page	The splash page for the college library website is the entry point for all users.	(1) Anonymous Web User (2) User with Valid Login Credentials (3) User with Invalid Login Credentials (4) Librarian
1.3	Search Entry Page	The page used to enter a search query.	(2) User with Valid Login Credentials (4) Librarian

Assets

Attacker is interested in the system because it has Assets
Assets can be

Physical – Private Data, List of customers etc.
Privilege – System has ability to update/process data
Abstract – Reputation of the organization

Assets are documented in the threat model as follows:

ID,
Name,
Description
Trust Level (required for access)

Assets

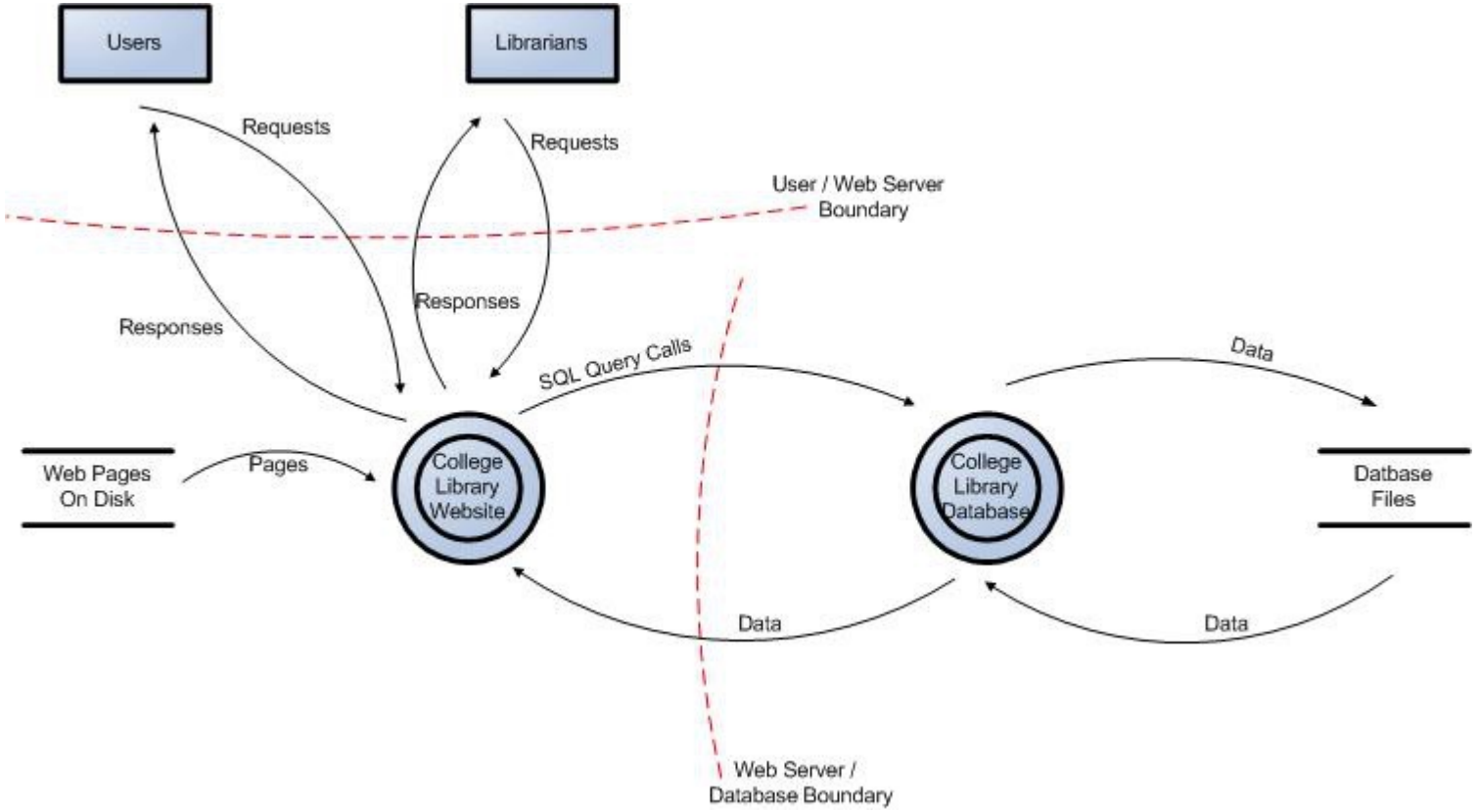
ID	Name	Description	Trust Levels
1	Library Users and Librarian	Assets relating to students, faculty members, and librarians.	
1.1	User Login Details	The login credentials that a student or a faculty member will use to log into the College Library website.	(2) User with Valid Login Credentials, (4) Librarian, (5) Database Server Administrator, (7) Web Server User Process, (8) Database Read User, (9) Database Read/Write User
1.3	Personal Data	The College Library website will store personal information relating to the students, faculty members, and librarians.	(4) Librarian, (5) Database Server Administrator, (6) Website Administrator, (7) Web Server User Process, (8) Database Read User, (9) Database Read/Write User
2	System	Assets relating to the underlying system.	
2.2	Ability to Execute Code as a Web Server User	This is the ability to execute source code on the web server as a web server user.	(6) Website Administrator, (7) Web Server User Process
2.4	Ability to Execute SQL as a Database Read/Write User	This is the ability to execute SQL. Select, insert, and update queries on the database and thus have read and write access to any information stored within the College Library database.	(5) Database Server Administrator, (9) Database Read/Write User
3	Website	Assets relating to the College Library website.	
3.1	Login Session	This is the login session of a user to the College Library website. This user could be a student, a member of the college faculty, or a Librarian.	(2) User with Valid Login Credentials, (4) Librarian
3.3	Ability to Create Users	The ability to create users would allow an individual to create new users on the system. These could be student users, faculty member users, and librarian users.	(4) Librarian, (6) Website Administrator

Data Flow Diagrams

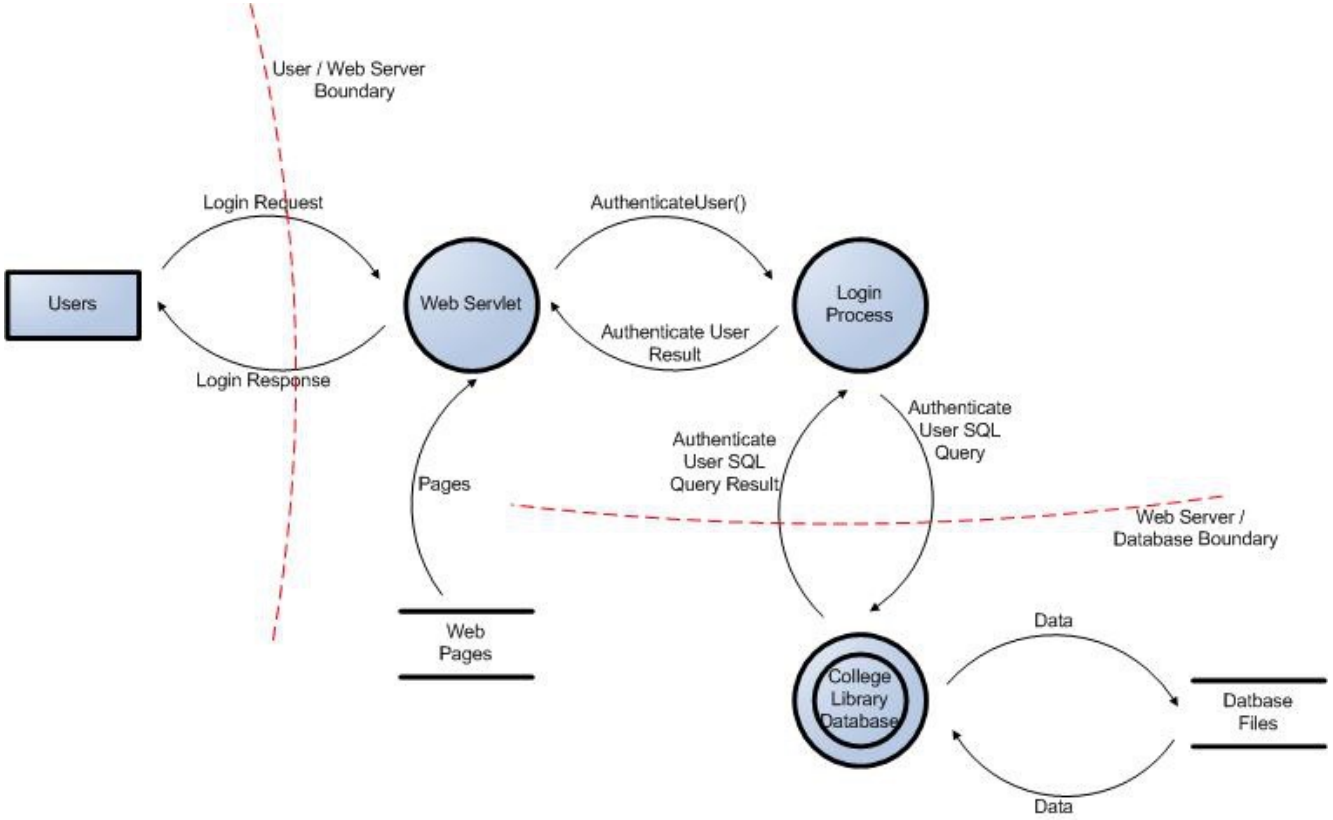
Knowledge of Assets, Entry points, etc. help in creating DFDs.

- The DFDs will allow us to gain a better understanding of the application by providing a visual representation of how the application processes data
- DFDs focus on how data moves through the application and what happens to the data as it moves
- DFDs are hierarchical in structure, so they can be used to decompose the application into subsystems and lower-level subsystems

DFD for the example



Partially Expanded DFD



Trust Boundaries in DFD

Add trust boundaries that intersect data flows

- Points/surfaces where an attacker can interject
  - Machine boundaries, privilege boundaries, integrity boundaries are examples of trust boundaries
  - Threads in a native process are often inside a trust boundary, because they share the same privileges, rights, identifiers and access
- Processes talking across a network always have a trust boundary
  - They may create a secure channel, but they're still distinct entities
  - Encrypting network traffic doesn't address tampering or spoofing

Iterate over processes, data stores, and see where they need to be broken down

Threats (STRIDE)

Type	Examples
Spoofing	Threat action aimed to illegally access and use another user's credentials, such as username and password.
Tampering	Threat action aimed to maliciously change/modify persistent data, such as persistent data in a database, and the alteration of data in transit between two computers over an open network, such as the Internet.
Repudiation	Threat action aimed to perform illegal operations in a system that lacks the ability to trace the prohibited operations.
Information disclosure	Threat action to read a file that one was not granted access to, or to read data in transit.
Denial of service	Threat aimed to deny access to valid users, such as by making a web server temporarily unavailable or unusable.
Elevation of privilege	Threat aimed to gain privileged access to resources for gaining unauthorized access to information or to compromise a system.

Example Countermeasures (ASF)

Threat Type	Countermeasure
Authentication	1.Credentials and authentication tokens are protected with encryption in storage and transit 2.Protocols are resistant to brute force, dictionary, and replay attacks
Authorization	1.Strong ACLs are used for enforcing authorized access to resources 2.Role-based access controls are used to restrict access to specific operations
Configuration Management	1.Least privileged processes are used and service accounts with no administration capability 2.Auditing and logging of all administration activities is enabled
Data Protection in Storage and Transit	1.Standard encryption algorithms and correct key sizes are being used 2.Hashed message authentication codes (HMACs) are used to protect data integrity
Data Validation / Parameter Validation	1.Data type, format, length, and range checks are enforced 2.No security decision is based upon parameters (e.g. URL parameters) that can be manipulated
Error Handling and Exception Management	1.All exceptions are handled in a structured manner 2.Error messages are scrubbed so that no sensitive information is revealed to the attacker
User and Session Management	1.No sensitive information is stored in clear text in the cookie 2.Cookies are configured to expire
Auditing and Logging	1.Sensitive information (e.g. passwords, PII) is not logged 2.Integrity controls (e.g. signatures) are enforced on log files to provide non-repudiation

Thank You!

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SDL Threat Modeling – Part 1
RL 3.3.1

Objectives

Produce software that's secure by design

- Improve designs the same way we've improved code

Because attackers think differently

- Creator blindness/new perspective

Allow you to predictably and effectively find security problems early in the process

Responsibilities

Building a threat model (at Microsoft)

- –Program Manager (PM) owns overall process
- –Testers
  - •Identify threats in analyze phase
  - •Use threat models to drive test plans
- –Developers create diagrams

Customers / Work Products

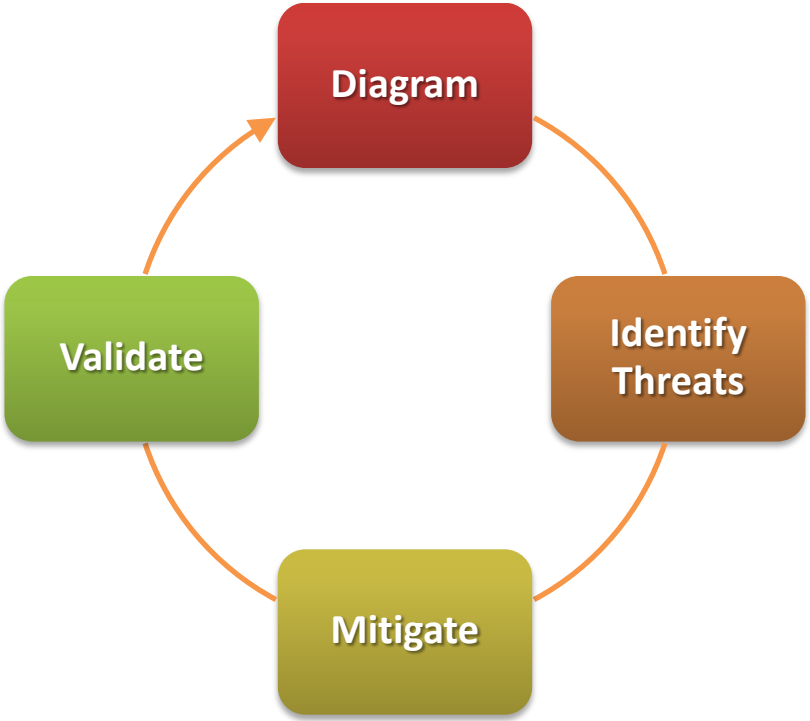
Customers for threat models

- Your team
- Other features, product teams
- Customers, via user education
- “External” quality assurance resources, such as pen testers

Threat model documentation

- The product as a whole
- The security-relevant features
- The attack surfaces

The Process in a Nutshell



Diagramming

Use DFDs (Data Flow Diagrams)

- Include processes, data stores, data flows
- Include *trust boundaries*
- Diagrams per scenario may be helpful

Update diagrams as product changes

Enumerate assumptions, dependencies

Number everything (if manual)

Effective Threat Modeling Meetings

Develop draft threat model before the meeting

- Use the meeting to discuss

Start with a DFD walkthrough

Identify most interesting elements

- Assets (if you identify any)
- Entry points/trust boundaries

Walk through STRIDE against those elements

Threats that cross elements/recur

- Consider library, redesigns

Validating Threat Models

Validate the whole threat model

- Does diagram match final code?
- Are threats enumerated?
- Minimum: STRIDE per element that touches a trust boundary
- Has Test / QA reviewed the model?
  - Tester approach often finds issues with threat model or details
- Is each threat mitigated?
- Are mitigations done right?

Did you check these before Final Security Review?

- Shipping will be more predictable

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SDL Threat Modeling – Part 2
RL 3.3.2

Threat: Spoofing

Threat	**S**poofing
Property	Authentication
Definition	Impersonating something or someone else
Example	Pretending to be any of billg, microsoft.com, or ntdll.dll

Threat: Tampering

Threat	**T**ampering
Property	Integrity
Definition	Modifying data or code
Example	Modifying a DLL on disk or DVD, or a packet as it traverses the LAN

Threat: Repudiation

Threat	**R**epudiation
Property	Non-Repudiation
Definition	Claiming to have not performed an action
Example	“I didn’t send that email,” “I didn’t modify that file,” “I didn’t visit that web site”

Threat: Information Disclosure

Threat	Information Disclosure
Property	Confidentiality
Definition	Exposing information to someone not authorized to see it
Example	Allowing someone to read the Windows source code; publishing a list of customers to a Web site

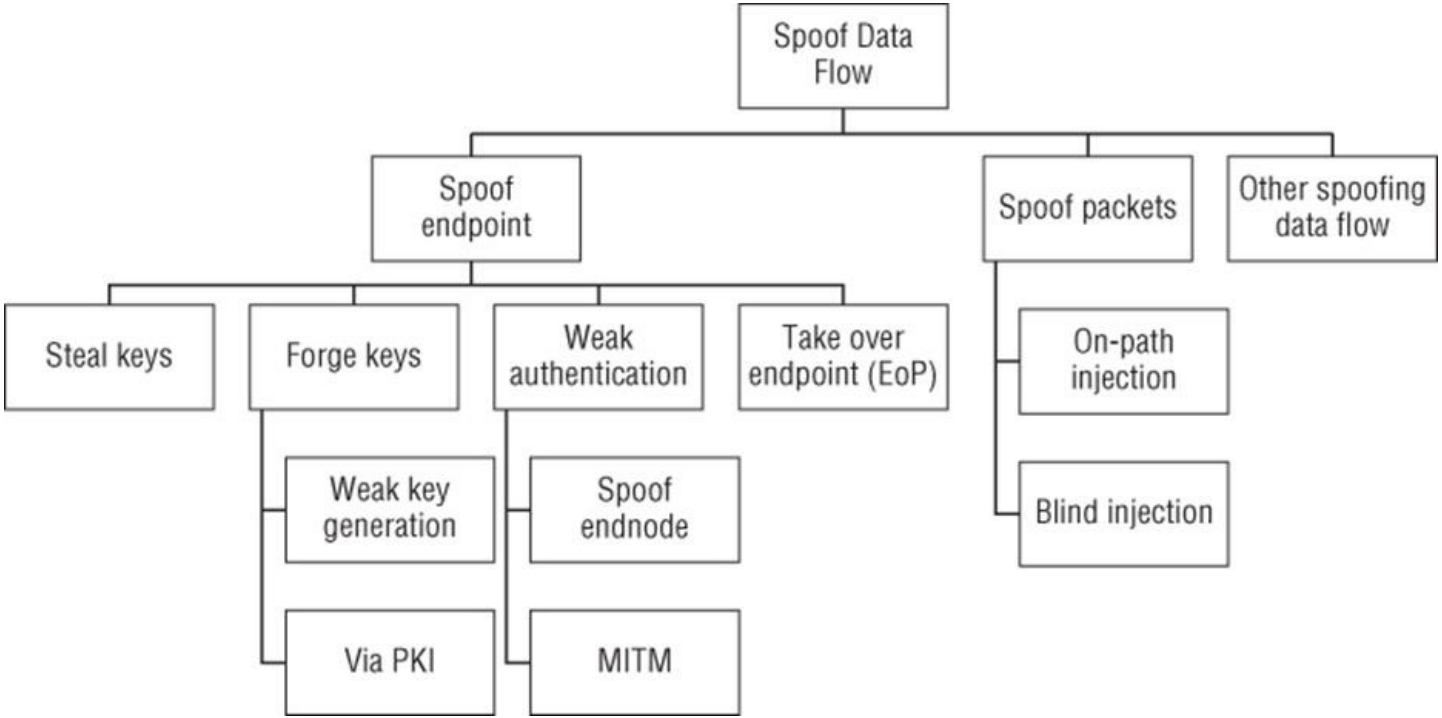
Threat: Denial of Service

Threat	**D**enial of Service
Property	Availability
Definition	Deny or degrade service to users
Example	Crashing Windows or a Web site, sending a packet and absorbing seconds of CPU time, or routing packets into a black hole

Threat: Elevation of Privilege

Threat	**E**levation of Privilege (EoP)
Property	Authorization
Definition	Gain capabilities without proper authorization
Example	Allowing a remote Internet user to run commands is the classic example, but going from a “Limited User” to “Admin” is also EoP

Threat Tree (Spoofing data flow)



How to Mitigate

Address each threat

Four ways to address threats

1. Redesign to eliminate
2. Apply standard mitigations
   - What have similar software packages done and how has that worked out for them?
3. Invent new mitigations (riskier)
4. Accept vulnerability in design

Standard Mitigations

Spoofing	Authentication	To authenticate principals: • Cookie authentication • Kerberos authentication To authenticate code or data: • Digital signatures
Tampering	Integrity	•ACLs • Digital signatures
Repudiation	Non Repudiation	• Secure logging and auditing • Digital Signatures
Information Disclosure	Confidentiality	• Encryption • ACLS
Denial of Service	Availability	• ACLs • Filtering • Quotas
Elevation of Privilege	Authorization	• ACLs • Group or role membership • Privilege ownership • Input validation

DREAD

In the Microsoft DREAD threat-risk ranking model, the technical risk factors for impact are Damage and Affected Users, while the ease of exploitation factors are Reproducibility, Exploitability and Discoverability. This risk factorization allows the assignment of values to the different influencing factors of a threat. To determine the ranking of a threat, the threat analyst has to answer basic questions for each factor of risk

- For Damage: How big would the damage be if the attack succeeded?
- For Reproducibility: How easy is it to reproduce an attack to work?
- For Exploitability: How much time, effort, and expertise is needed to exploit the threat?
- For Affected Users: If a threat were exploited, what percentage of users would be affected?
- For Discoverability: How easy is it for an attacker to discover this threat?

DREAD Example

The college library website use case:

Threat: Malicious user views confidential information of students, faculty members and librarians.

- **Damage potential:** Threat to reputation as well as financial and legal liability:8
- **Reproducibility:** Fully reproducible:10
- **Exploitability:** Require to be on the same subnet or have compromised a router:7
- **Affected users:** Affects all users:10
- **Discoverability:** Can be found out easily:10

Overall DREAD score: (8+10+7+10+10) / 5 = 9

In this case having 9 on a 10 point scale is certainly a high risk threat

Threat Modelling by Adam Shostack, John Wiley 2014

Security in Computing by Charles P. Pfleeger, Shari L. Pfleeger, and Deven Shah Pearson Education 2009

Computer Security: Principles and Practice by William Stallings, and Lawrie Brown Pearson, 2008.

www.owasp.com

www.microsoft.com

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Security Requirements Engineering – Part 1
RL 4.1.1

Importance of Requirements Engineering

Some studies have shown that requirements engineering defects cost 10 to 200 times as much to correct once the system has become operational than if they were detected during requirements development.

According to Charette[2005], Requirements problems are among the top causes of the following undesirable phenomena

- Projects are significantly over budget, go past schedule, have significantly reduced scope, or are cancelled
- Development teams deliver poor-quality applications
- Products are not significantly used once delivered

Requirements Engineering Challenges

Requirements Engineering on individual projects often suffers from the following problems:

- Requirements identification typically does not include all relevant stakeholders and does not use the most modern or efficient techniques.
- Requirements are often statements describing architectural constraints or implementation mechanisms rather than statements describing what the system must do.
- Requirements are often directly specified without any analysis or modeling. When analysis is done, it is usually restricted to functional end-user requirements, ignoring
    1) quality requirements such as security,
    2) other functional and nonfunctional requirements, and
    3) architecture, design, implementation, and testing constraints.

Requirements Engineering Challenges

Requirements specification is typically haphazard, with specified requirements being

- ambiguous,
- incomplete (e.g., nonfunctional requirements are often missing),
- inconsistent,
- not cohesive,
- infeasible,
- obsolete,
- neither testable nor capable of being validated, and
- not usable by all of their intended audiences.

Requirements management is typically weak, with ineffective forms of data capture

- e.g., in one or more documents (rather than in a database or tool) and missing attributes.
- often limited to tracing, scheduling, and prioritization, without change tracking or other configuration management.

Quality Requirements

Project teams often neglect *quality* requirements, such as performance, safety, security, reliability, and maintainability.

- Developers of certain kinds of mission-critical systems and systems in which human life is involved, such as the space shuttle, have long recognized the importance of quality requirements and have accounted for them in software development.
- In many other systems, however, quality requirements are treated in an inadequate way. Hence we see the failure of software associated with power systems, telephone systems, unmanned spacecraft, and so on.

This inattention to quality requirements is exacerbated by the desire to keep costs down and meet aggressive schedules.

Security Requirements Engineering

According to BSI[09], if security requirements are not effectively defined, the resulting system cannot be ***evaluated*** for success or failure prior to its implementation

Operational environments and business goals often change ***dynamically***, with the result that security requirements development is not a one-time activity.

Requirements engineering research and practice pay a lot of attention to the functionality of the system from the user's perspective, but little attention is devoted to what the system should ***not*** do [Bishop 2002]

Security Requirements Engineering

Users have implicit assumptions for the software applications and systems to be secure and are surprised when they are not. These user assumptions need to be translated into security requirements for the software systems when they are under development.

It is important for requirements engineers to think about the attacker's perspective and not just the functionality of the system from the end-user's perspective.

- An attacker is not particularly interested in functional features of the system, unless they provide an avenue for attack. Instead, the attacker typically looks for defects and other conditions outside the norm that will allow a successful intrusion to take place.

Security Is Not a Set of Features

Security features such as password protection, firewalls, virus detection tools etc. are, in fact, not security requirements.

They are rather implementation mechanisms that are intended to satisfy unstated requirements, such as authenticated access

A systematic approach to security requirements engineering will help avoid the problem of generic lists of features and take into account the attacker's perspective.

No convenient security pull-down menu that will let you select "security" and do the needful.

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Security Requirements Engineering - Part 2
RL 4.1.2

Security Is Not a Set of Features

Security is an ***emergent*** property of a system, not a feature

Because security is not a feature, it cannot be bolted on after other software features are codified, nor can it be ***patched*** in after attacks have occurred in the field. Instead, security must be built into the product from the ground up

Most cost-effective approach to software security incorporates thinking beyond normative features and maintains that thinking throughout the development process

Every time a new requirement, feature, or use case is created, the developer or security specialist should spend some time thinking about how that feature might be unintentionally misused or intentionally abused

Thinking Beyond Normal

When we design and analyze a system, we're in a great position to know our systems better than potential attackers do.

We can leverage this knowledge to the benefit of security and reliability, by asking and answering the critical questions:

- Which assumptions are implicit in our system?
- Which kinds of things make our assumptions false?
- Which kinds of attack patterns will an attacker bring to bear?

Thinking like an attacker

System's creators are not the best security analysts of that system.

- 'Thinking like an attacker' is extremely difficult for those who have built up a set of implicit assumptions

System Creators make excellent subject matter experts (SMEs).

- Together, SMEs and security analysts can ferret out base assumptions in a system under analysis and think through the ways an attacker will approach the software

Creating Useful Misuse Cases

Misuse cases is to decide and document *a priori* how software should react to illegitimate use

Unlike the functional requirements, designers/developers play the role of user and explain design and underlying assumptions to security expert documents

To guide brainstorming, software security experts ask many questions of a system's designers to help identify the places where the system is likely to have weaknesses. This activity mirrors the way attackers think.

The brainstorming covers user interfaces, environmental factors, and events that developers assume a person can't or won't do

- "Users can't enter more than 50 characters because the JavaScript code won't let them"
- "Users don't understand the format of the cached data, so they can't modify it."

Misuse vs. Abuse

According to Chun Wei,

Misuse cases are defined as “behavior that the system/entity owner does not want to occur”

- An interaction results in a session key being revealed to an actor who should not see the session key

Abuse cases are defined as “… where the results of the interaction are harmful to the system …”

- the actor posts the session key on a public website, then an abuse case takes place

But some authors do not distinguish

Specifying Abuse Cases

The process of specifying abuse cases makes a designer very clearly differentiate appropriate use from inappropriate use.

The security expert/designer must ask the right questions:

- How can the system distinguish between good input and bad input?
- Can it tell whether a request is coming from a legitimate application or from a rogue application replaying traffic?
- where might a bad guy be positioned? On the wire? At a workstation? In the back office?
- Any communication line between two endpoints or two components is a place where an attacker might try to interpose himself or herself
- what can this attacker do in the system? Watch communications traffic? Modify and replay such traffic? Read files stored on the workstation? Change registry keys or configuration files? Be the DLL?

Trying to answer such questions helps software designers explicitly question design and architecture assumptions, and it puts the designer squarely ahead of the attacker by identifying and fixing a problem before it's ever created.

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CMU SQUARE Process Model RL 4.2.1

SQUARE Process Model

Security Quality Requirements Engineering (SQUARE) is a process model that was developed at Carnegie Mellon University [Mead 2005].

SQUARE provides a means for eliciting, categorizing, and prioritizing security requirements for information technology systems and applications.

The focus of the model is to build security concepts into the early stages of the SDLC. It can also be used for documenting and analyzing the security aspects of systems once they are implemented in the field and for steering future improvements and modifications to those systems.

The SQUARE work is supported by the Army Research Office through grant (“Perpetually Available and Secure Information Systems”) to Carnegie Mellon University’s CyLab.

SQUARE Process Steps

1. Agree on definitions
2. Identify security goals
3. Develop artifacts to support security requirements definition
4. Perform (security) risk assessment
5. Select elicitation techniques
6. Elicit security requirements
7. Categorize requirements as to level (e.g., system, software) and whether they are requirements or other kinds of constraints
8. Prioritize requirements
9. Inspect requirements

SQUARE Process Steps

No	Step	Input	Techniques	Participants	Output
1	Agree on definitions	Candidate definitions from IEEE and other standards	Structured interviews, focus group	Stakeholders, requirements engineers	Agreed-to definitions
2	Identify security goals	Definitions, candidate goals, business drivers, policies and procedures, examples	Facilitated work session, surveys, interviews	Stakeholders, requirements engineers	Goals
3	Develop artifacts to support security requirements definition	Potential artifacts list (e.g., scenarios, misuse cases, templates, forms)	Work session	Requirements engineers	Needed artifacts: scenarios, misuse cases, models, templates, forms

SQUARE Process Steps

No	Step	Input	Techniques	Participants	Output
4	Perform (security) risk assessment	Misuse cases, scenarios, security goals	Risk assessment method, analysis of anticipated risk against organizational risk tolerance, including threat analysis	Requirements engineers, risk expert, stakeholders	Risk assessment results
5	Select elicitation techniques	Goals, definitions, candidate techniques, expertise of stakeholders, organizational style, culture, level of security needed, cost–benefit analysis	Work session	Requirements engineers	Selected elicitation techniques

SQUARE Process Steps

No	Step	Input	Techniques	Participants	Output
6	Elicit security requirements	Artifacts, risk assessment results, selected techniques	QFD, Joint Application Development, interviews, surveys, model based analysis, checklists, lists of reusable requirements types, document reviews	Stakeholders facilitated by requirements engineers	Initial cut at security requirements
7	Categorize requirements as to level (e.g., system, s/w) and whether they are requirements or other kinds of constraints	Initial requirements, architecture	Work session using a standard set of categories	Requirements engineers, other specialists as needed	Categorized requirements

SQUARE Process Steps

No	Step	Input	Techniques	Participants	Output
8	Prioritize requirements	Categorized requirements and risk assessment results	Prioritization methods such as Analytical Hierarchy Process (AHP - structured technique for organizing information) etc.	Stakeholders facilitated by requirements engineers	Prioritized requirements
9	Inspect requirements	Prioritized requirements, candidate formal inspection technique	Inspection method such as Fagan (formal approach with exit criteria) and peer reviews	Inspection team	Initial selected requirements, documentation of decision-making process and rationale

Sample: Identify Security Goals

Work with the client to identify security goals that mapped to the company's overall business goals.

Consider Asset Management System (AMS) of Acme Co.

Business goal of AMS: To provide an application that supports asset management and planning.

Security goals: Three high-level security goals were derived for the system:

- Management shall exercise effective control over the system's configuration and use.
- The confidentiality, accuracy, and integrity of the AMS shall be maintained.
- The AMS shall be available for use when needed.

Attack Patterns

Attack patterns are descriptions of common methods for exploiting software. Act as a mechanism to capture and communicate the attacker's perspective.

They derive from the concept of design patterns [Gamma 95] applied in a destructive rather than constructive context and are generated from in-depth analysis of specific real-world exploit examples

The following typical information is captured for each attack pattern:

- Pattern name and classification
- Attack prerequisites
- Description
- Targeted vulnerabilities or weaknesses
- Method of attack
- Attacker goal
- Attacker skill level required
- Resources required
- Blocking solutions
- Context description
- References

Attack Patterns

- **Pattern Name and Classification**: A unique, descriptive identifier for the pattern.
- **Attack Prerequisites**: What conditions must exist or what functionality and what characteristics must the target software have, or what behavior must it exhibit, for this attack to succeed?
- **Description**: A description of the attack including the chain of actions taken.
- **Related Vulnerabilities or Weaknesses**: What specific vulnerabilities or weaknesses does this attack leverage?
- **Method of Attack**: What is the vector of attack used (e.g., malicious data entry, maliciously crafted file, protocol corruption etc.)?

Attack Patterns

- **Attack Motivation-Consequences**: What is the attacker trying to achieve by using this attack?
- **Attacker Skill or Knowledge Required**: What level of skill or specific knowledge must the attacker have to execute such an attack?
- **Resources Required**: What resources (e.g., CPU cycles, IP addresses, tools, time) are required to execute the attack?
- **Solutions and Mitigations**: What actions or approaches are recommended to mitigate this attack, either through resistance or through resiliency?
- **Context Description**: In what technical contexts (e.g., platform, OS, language, architectural paradigm) is this pattern relevant? This information is useful for selecting a set of attack patterns that are appropriate for a given context.
- **References**: What further sources of information are available to describe this attack?

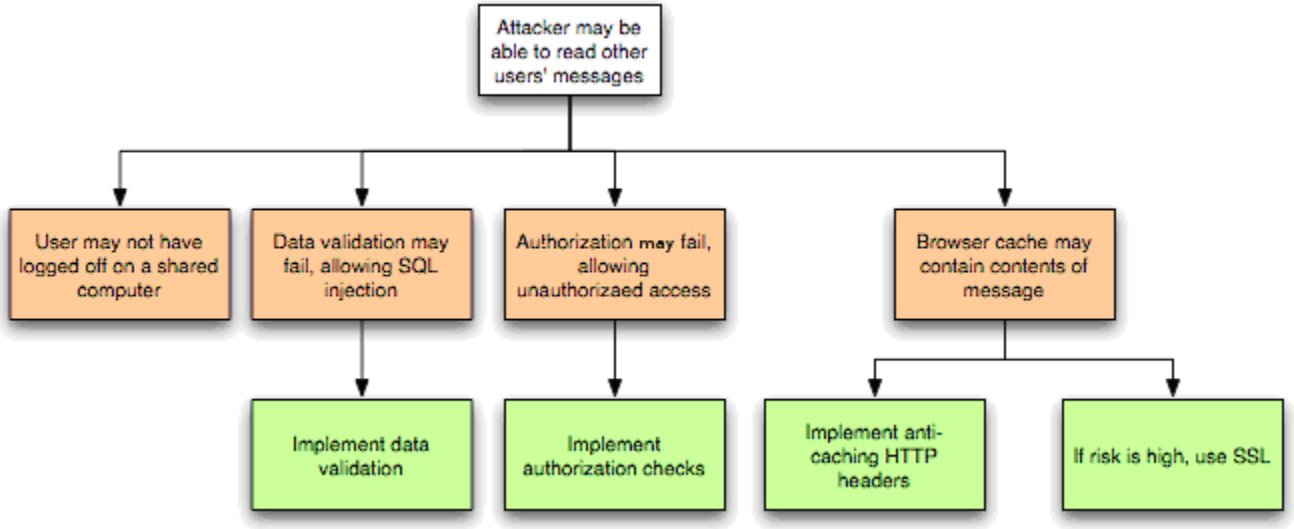
Attack Pattern Example

- **Pattern name and classification**: Shell Command Injection—Command Delimiters.
- **Attack Prerequisites**: The application must pass user input directly into a shell command.
- **Description**: Using the semicolon or other off-nominal characters, multiple commands can be strung together. Unsuspecting target programs will execute all the commands. An example may be when authenticating a user using a web form, where the username is passed directly to the shell as in: exec("cat data_log_" + userInput + ".dat").
  - The "+" sign denotes concatenation. The developer expects that the user will only provide a username. However, a malicious user could supply "username.dat; rm –rf / ;" as the input to execute the malicious commands on the machine running the target software. In the above case, the actual commands passed to the shell will be: cat data_log_username.dat; rm –rf /; .dat
  - The first command may or may not succeed; the second command will delete everything on the file system to which the application has access, and success/failure of the last command is irrelevant.

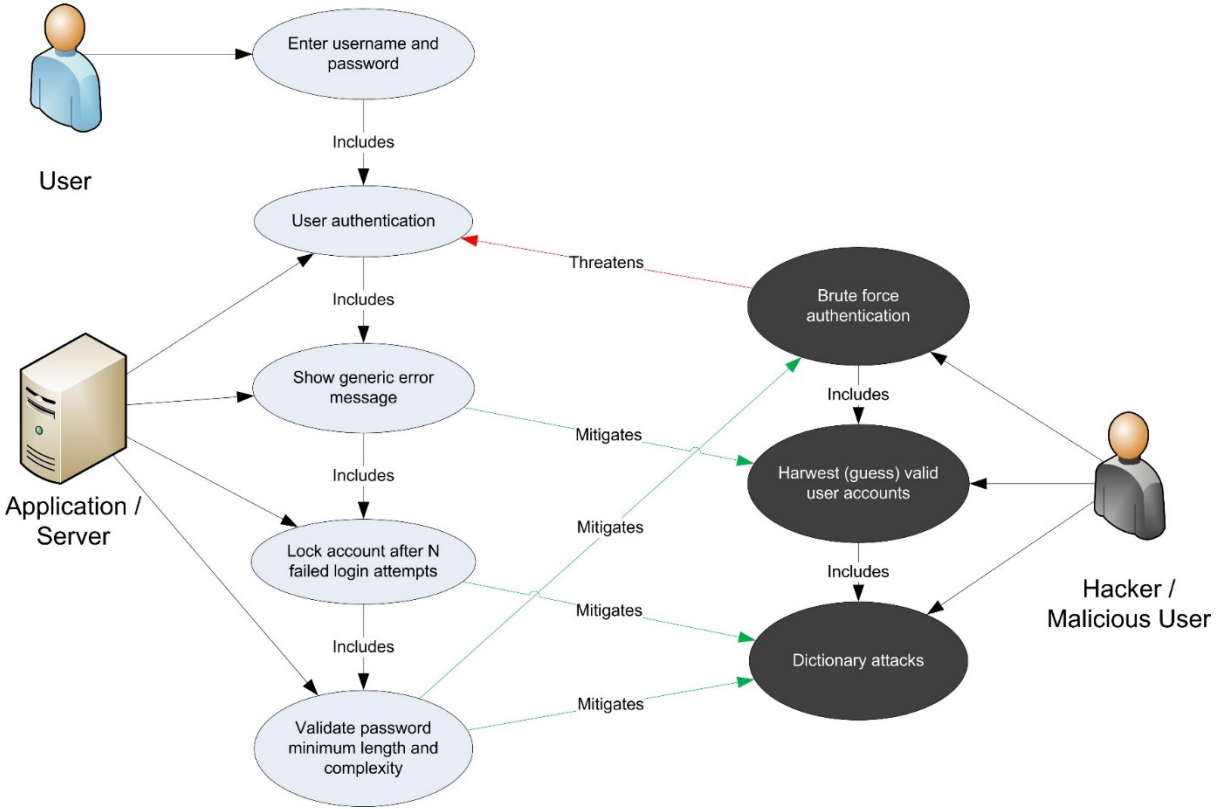
Attack Pattern Example

- **Related Vulnerabilities or Weaknesses**: : CWE-OS Command Injection, CVE-1999-0043, CVE-1999-0067, CVE-1999-0097, CVE-1999-0152, CVE-1999-0210, CVE-1999-0260, 1999-0262, CVE-1999-0279, CVE-1999-0365, etc.
- **Method of Attack**: By injecting other shell commands into other data that are passed directly into a shell command.
- **Attack Motivation-Consequences**: Execution of arbitrary code.
- **Attacker Skill or Knowledge Required**: Finding and exploiting this vulnerability does not require much skill.
- **Resources Required**: No special or extensive resources are required for this attack.
- **Solutions and Mitigations**: Define valid inputs to all fields and ensure that the user input is always valid. Also perform white-list and/or black-list filtering as a backup to filter out known command delimiters.
- **Context Description**: OS: UNIX.
- **References**: Exploiting Software [Hoglund 04].

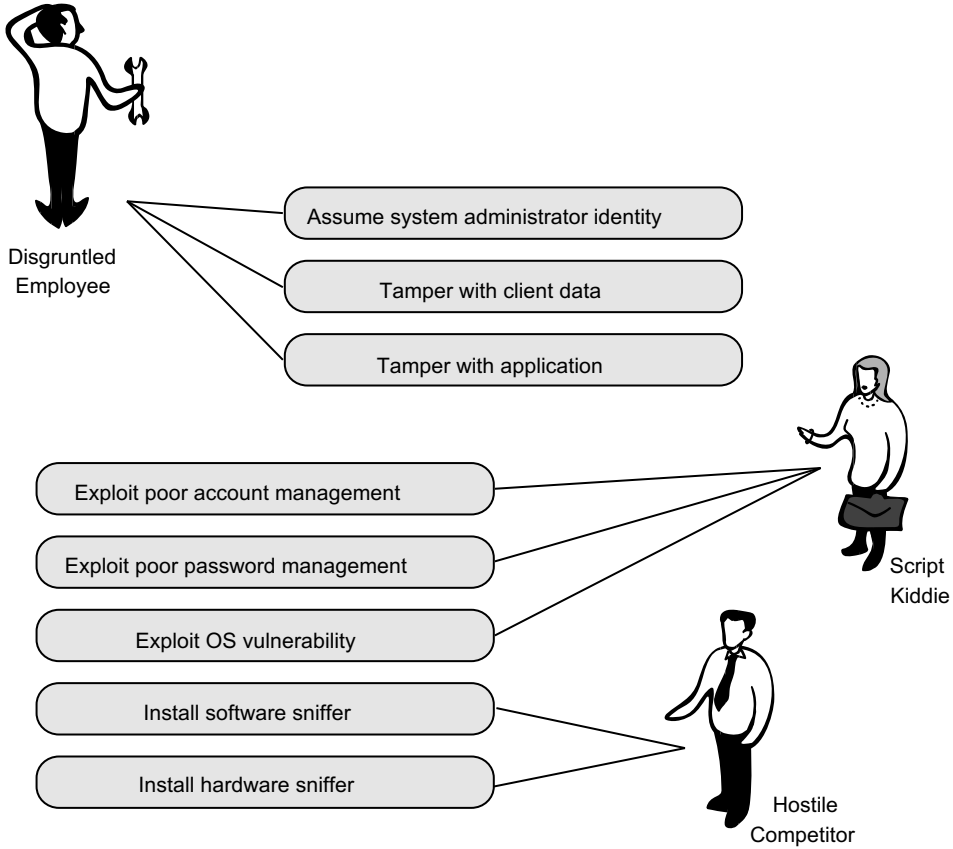
A Threat Tree Example



Use Case with Abuse Case



Abuse case example



Sample: Perform Risk Assessment

There are two essential assets in this system.

The first is the Windows Server computer, which houses the majority of the production system's intellectual assets (that is, the code that runs the system). This computer acts as a server that allows remote users to access the Asset Management System.

The second essential asset is the information inside the Windows Server computer—specifically, the files stored in the Microsoft IIS server and the information stored in the Sybase database and MapGuide database are critical for making informed decisions. If this information is lost or compromised, the ability to make accurate decisions is lost.

Elicitation Methods

- Misuse/Abuse cases:
  - Misuse/abuse cases apply the concept of a negative scenario—that is, a situation that the system's owner does *not* want to occur—in a use-case context. Business leaders, military planners, and game players are familiar with the strategy of analyzing their opponents' best moves as identifiable threats
- QFD
  - As per Dr. Yoji Akao, who originally developed Quality Function Deployment (QFD) in Japan in 1966, it is a "method to transform qualitative user demands into quantitative parameters, to deploy the functions forming quality, and to deploy methods for achieving the design quality into subsystems and component parts, and ultimately to specific elements of the process"
- Joint Application Development (JAD)
  - The JAD methodology [Wood 1995] involves all stakeholders via highly structured and focused meetings. In the preliminary phases of JAD, the requirements engineering team is charged with fact-finding and information-gathering tasks. Typically, the outputs of this phase, as applied to security requirements elicitation, are security goals and artifacts. The actual JAD session is then used to validate this information by establishing an agreed-on set of security requirements for the product.

Sample: Elicit and Categorize Security Requirements

Security requirements are identified and then organized to map to the high-level security goals (from Step 2).

Examples include :

- Requirement 1: The system is required to have strong authentication measures in place at all system gateways and entrance points (maps to Goals 1 and 2).
- Requirement 2: The system is required to have sufficient means to govern which system elements (e.g., data, functionality) users can view, modify, and/or interact with (maps to Goals 1 and 2).
- Requirement 3: A continuity of operations plan (COOP) is required to assure system availability (maps to Goal 3).

Incorporating SQUARE in SDLC

- All nine steps of SQUARE fall under the requirements analysis and specification phase.
- The software requirements specification (SRS) should accommodate the outcome of the first eight SQUARE steps
  - The SRS must clearly specify the security definitions agreed on (Step 1). It is necessary to document security goals (Step 2) along with the project goals and constraints. Develop artifacts (Step 3) such as misuse cases and scenarios to support security requirements definition
  - Categorize the security requirements (Step 7) and prioritize them (Step 8) along with documented functional requirements. (For clarity, it is preferable to separate security requirements from functional requirements.)

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OWASP Recommendations
RL 4.3.1

OWASP SAMM

SAMM (Security Assessment Maturity Model) divides activities associated with software development into 4 business functions for incorporating security

- Governance
  - Includes strategy, metrics, policy, compliance, education and guidance
- Construction
  - Includes threat assessment, security requirements, and security architecture
- Verification
  - Includes design review, implementation review, and security testing
- Operations
  - Includes issue management, environment hardening, operational enablement

SAMM Security Requirements

SAMM expects the following as part of security requirements:

–Consider security explicitly during the software requirements process

–Increase granularity of security requirements derived from business logic and known risks.

–Mandate security requirements process for all software projects and third-party dependencies.

Consider security explicitly
(during the software requirements process)

Objective	Activities	Assessment	Results
Consider security explicitly during the software requirements process.	• Derive security requirements from business functionality • Evaluate security and compliance guidance for requirements	• Do project teams specify security requirements during development? • Do project teams pull requirements from best practices and compliance guidance?	• High-level alignment of development effort with business risks • Ad hoc capturing of industry best-practices for security as explicit requirements • Awareness amongst stakeholders of measures being taken to mitigate risk from software

Increase granularity

(of security requirements derived from business logic and known risks)

Objective	Activities	Assessment	Results
Increase granularity of security requirements derived from business logic and known risks.	• Build an access control matrix for resources and capabilities (e.g. For data resources, it will be in terms of creation, read, update, and deletion) • Specify security requirements based on known risks	• Do stakeholders review access control matrices for relevant projects? • Do project teams specify requirements based on feedback from other security activities?	• Detailed understanding of attack scenarios against business logic • Prioritized development effort for security features based on likely attacks • More educated decision-making for tradeoffs between features and security efforts • Stakeholders that can better avoid functional requirements that inherently have security flaws

Mandate security requirements process

(for all software projects and third-party dependencies)

Objective	Activities	Assessment	Results
Mandate security requirements process for all software projects and third-party dependencies.	• A. Build security requirements into supplier agreements • B. Expand audit program for security requirements	• Do stakeholders review vendor agreements for security requirements? • Are audits performed against the security requirements specified by project teams?	• Formally set baseline for security expectations from external code • Centralized information on security effort undertaken by each project team • Ability to align resources to projects based on application risk and desired security requirements

Assessment Matrix for Security Requirements

Score ->	0.0	0.2	0.5	1.0
Do project teams specify security requirements during development?	No	Some	Half	Most
Do project teams pull requirements from best practices and compliance guidance?	No	Per Team	Org wide	Integrated Process
Do stakeholders review access control matrices for relevant projects?	No	Some	Half	Most
Do project teams specify requirements based on feedback from other security activities?	No	Some	Half	Most
Do stakeholders review vendor agreements for security requirements?	No	Some	Half	Most
Are audits performed against the security requirements specified by project teams?	No	Once	Every 2-3 years	Annual

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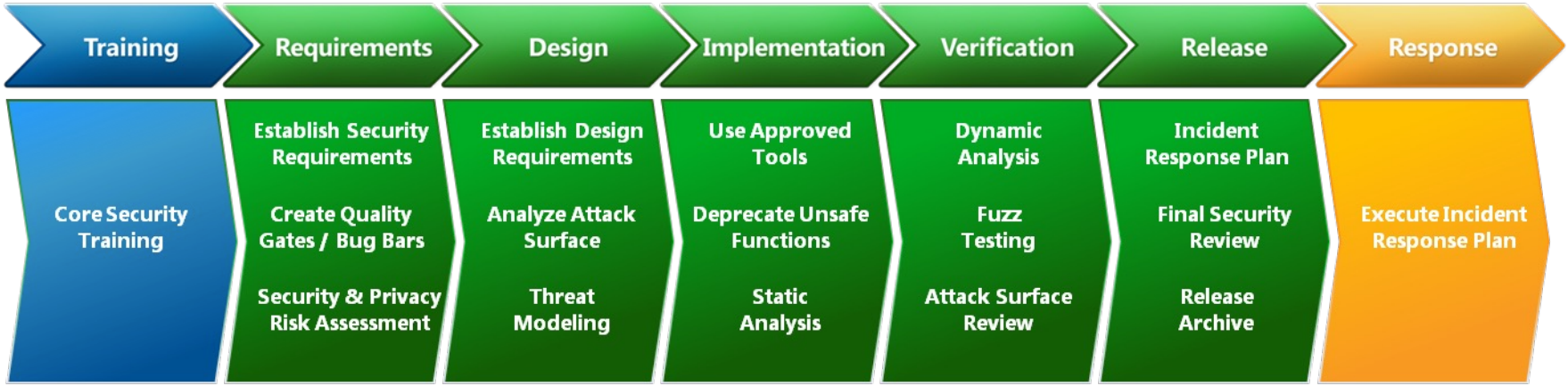
SDL Recommendations
RL 4.3.2

Security Development Lifecycle (SDL)



SDL Requirements Practices

The major SDL practices during requirements analysis are

- Establish Security & Privacy Requirements
- Create Quality Gates/Bug Bars
- Create Security/Privacy Risk Assessments

Establish Security & Privacy Requirements

Define and integrate security and privacy requirements early

- identify key milestones and deliverables and minimize disruptions to plans and schedules.

Security and privacy analysis including

- assigning security experts,
- defining minimum security and privacy criteria for an application, and
- deploying a security vulnerability/work item tracking system.

When should this practice be implemented?

- Traditional Software development: Requirements Phase
- Agile development: One Time

Create Quality Gates/Bug Bars

Defining minimum acceptable levels of security and privacy quality

- the team understand risks associated with security issues,
- Team identifies and fixes security bugs during development, and
- Team apply the standards throughout the entire project.

Set a bug bar to clearly define the severity thresholds of security vulnerabilities

- (for example, no known vulnerabilities in the application with a “critical” or “important” rating at time of release)

When should this practice be implemented?

- Traditional Software development: Requirements Phase
- Agile development: One Time

Security/Privacy Risk Assessments

Identify portions of a project requiring threat modeling and security design reviews before release

Determine the Privacy Impact Rating of a feature, product, or service

When should this practice be implemented?

- Traditional Software development: Requirements Phase
- Agile development: One Time

Software Security Engineering, Julia H. Allen, et al, Pearson, 2008.

Security in Computing by Charles P. Pfleeger, Shari L. Pfleeger, and Deven Shah Pearson Education 2009

Computer Security: Principles and Practice by William Stallings, and Lawrie Brown Pearson, 2008.

www.owasp.com

www.microsoft.com

Thank You!

SS ZG 566

Secure Software Engineering

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Secure Architecture & Design - Introduction
RL 5.1.1

Nomenclature (SWEBOK)

Software design is the activity that uses software requirements to produce a description of the software's internal structure that will serve as the basis for its construction

Software design consists of two activities :

- Software architectural design (sometimes called high-level design): develops top-level structure and organization of the software and identifies the various components.
- Software detailed design: specifies each component in sufficient detail to facilitate its construction.

Understanding Software Architecture

The software architecture of a program or computing system is the structure or structures of the system which comprise

- The software components
- The externally visible properties of those components
- The relationships among the components

Software architectural design represents the structure of the data and program components that are required to build a computer-based system

An architectural design model is transferable

- It can be applied to the design of other systems
- It represents a set of abstractions that enable software engineers to describe architecture in predictable ways

Importance of Software Architecture

Representations of software architecture are an enabler for communication between all stakeholders interested in the development of a computer-based system

The software architecture highlights early design decisions that will have a profound impact on all software engineering work that follows and, as important, on the ultimate success of the system as an operational entity

The software architecture constitutes a relatively small, intellectually graspable model of how the system is structured and how its components work together

Uses of software architecture descriptions

Reuse: Architecture descriptions can help software reuse. The software engineering world has, for a long time, been working towards a discipline where software can be assembled from parts that are developed by different people and are available for others to use.

Construction and Evolution: As architecture partitions the system into parts, some architecture provided partitioning can naturally be used for constructing the system, which also requires that the system be broken into parts such that different teams (or individuals) can separately work on different parts.

Analysis: It is highly desirable if some important properties about the behaviour of the system can be determined before the system is actually built. This will allow the designers to consider alternatives and select the one that will best suit the needs.

General Objectives of Software Architecture and Design

Completeness

- Supports the full scope of the defined requirements

Stability

- Consistently performs as intended within its defined operational context

Flexibility

- Can adapt to changing conditions
- Decompose such that selected components can be replaced going forward with minimal impact to the software

Extensibility

- Leverages industry standards
- Long-lived and resistant to obsolescence

Scalability

- Operates effectively at any size and load

Security-Specific Objectives of Software Architecture and Design

Comprehensive functional security architecture

- Security features and capabilities are fully enabled

Attack resistance

- Contains minimal security weaknesses that could be exploited

Attack tolerance

- While resisting attack, software function and capability are not unduly affected

Attack resilience

- In the face of successful attack, the effects on the software are minimized
- Operates effectively at any size and load

How to Design

A designer must practice diversification and convergence -[Belady]

- The designer selects from design components, component solutions, and knowledge available through catalogs, textbooks, and experience
- The designer then chooses the elements from this collection that meet the requirements defined by requirements engineering and analysis modeling
- Convergence occurs as alternatives are considered and rejected until one particular configuration of components is chosen

Software design is an iterative process

- As design iteration occurs, refinements lead to design representations at lower levels of abstraction

Architectural Issues

Security architecture (the architecture of security components, e.g. firewall, encryption mechanism) is not same as secure architecture (i.e. resilient and resistant to attacks)

Secure architecture not only must address known weaknesses and attacks, but must be flexible and resilient under changing security conditions

Architects (and designers) must focus on minimizing the risk profile. It requires complex and diverse knowledge (both on threats and technologies).

Architectural Risk Analysis

- The risk assessment methodology (Build Security In) encompasses six fundamental activity stages:
  - application characterization
  - architectural vulnerability assessment
  - threat analysis
  - risk likelihood determination
  - risk impact determination
  - risk mitigation

https://buildsecurityin.us-cert.gov/articles/best-practices/architectural-risk-analysis/architectural-risk-analysis

Application Characterization

- Assessing the architectural risks for a software system is easier when the boundaries of the software system are identified, along with the resources, integration points, and information that constitute the system
- The artifacts required for review:

- software business case
- functional and non-functional requirements
- enterprise architecture requirements
- use case documents
- misuse and abuse case documents
- software architecture documents describing logical, physical, and process views
- data architecture documents
- detailed design documents such as UML diagrams that show behavioral and structural aspects of the system
- software development plan
- transactions
- security architecture documents
- identity services and management architecture documents
- quality assurance plan
- test plan/acceptance plan
- risk list / risk management plan
- problem resolution plan
- issues list
- project metrics
- programming guidelines
- configuration and change management plan
- project management plan
- disaster recovery plan
- system logs
- operational guides

Architectural Risk Analysis

- Architectural risk analysis examines the preconditions that must be present for vulnerabilities to be exploited and assesses the states that the system may enter upon exploitation.
  - assess vulnerabilities not just at a component or function level, but also at interaction points
  - risk analysis testing can only prove the presence, not the absence, of flaws

- Three activities can guide architectural risk analysis:
  - known vulnerability analysis,
  - ambiguity analysis, and
  - underlying platform vulnerability analysis

Known Vulnerability Analysis

- Consider the architecture against a body of known bad practices or known good principles for confidentiality, integrity, and availability
  - e.g., the good principle of "*least privilege*" prescribes that all software operations should be performed with the least possible privilege.
  - Diagram the system's major modules, classes, or subsystems and circle areas of high privilege versus areas of low privilege. Consider the boundaries between these areas and the kinds of communications across those boundaries.

Ambiguity Analysis

- Ambiguity can be a source of vulnerabilities when it exists between requirements or specifications and development.
  - Note places where the requirements are ambiguously stated and the implementation and architecture either disagree or fail to resolve the ambiguity.
    - e.g. , a requirement for a web application might state that an administrator can lock an account and the user can no longer log in while the account remains locked. What about sessions for that user that are actively in use at the time the administrator locks the account? Is the user suddenly and forcibly logged out, or is the active session still valid until the user logs out?

Underlying Platform Vulnerability Analysis

- Carry out analysis of the vulnerabilities associated with the application's execution environment including operating system vulnerabilities, network vulnerabilities, platform vulnerabilities, and interaction vulnerabilities resulting from the interaction of components.
- There are web sites that aggregate vulnerability information. These sites and lists should be consulted regularly to keep the vulnerability list current for a given architecture.

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Principles for Secure Design
RL 5.2

Fundamental Design Concepts

Abstraction—data, procedure, control

Patterns—”conveys the essence” of a proven design solution

Separation of concerns—any complex problem can be more easily handled if it is subdivided into pieces

Modularity—compartmentalization of data and function

Information Hiding—controlled interfaces

Functional independence—single-minded function and low coupling

Refinement—elaboration of detail for all abstractions

Aspects—a mechanism for understanding how global requirements affect design

Refactoring—a reorganization technique that simplifies the design

The beginning of wisdom (for a software engineer) is to recognize the difference between getting program to work, and getting it right
– M A Jackson

Design Principles for Software Security

- Securing the Weakest Link
- Defense in Depth
- Failing Securely
- Least Privilege
- Separation of Privilege
- Economy of Mechanism
- Least Common Mechanism
- Reluctance to Trust
- Never Assuming that your Secrets are Safe
- Complete Mediation
- Psychological Acceptability
- Promoting Privacy

https://buildsecurityin.us-cert.gov/articles/knowledge/principles/design-principles

Securing the Weakest Link

- A software security system is only as secure as its weakest component
- Some cryptographic algorithms can take many years to break, but the endpoints of communication (e.g., servers) may be much easier to attack.
- Attackers don't attack a firewall unless there's a well-known vulnerability in the firewall itself (something all too common, unfortunately). they'll try to break the applications that are visible through the firewall, since these applications tend to be much easier targets
- Sometimes it's not the software that is the weakest link in your system; e.g., consider social engineering, an attack in which a bad guy uses social manipulation to break into a system

Defense in depth

- Layered security mechanisms increase security of the system as a whole
- If an attack causes one security mechanism to fail, other mechanisms may still provide the necessary security to protect the system
- Implementing a defense-in-depth strategy can add to the complexity of an application, that might bring new risks with it
  - e.g., increasing the required password length from eight characters to 15 characters may result in users writing their passwords down, thus decreasing the overall security to the system
  - however, adding a smart-card requirement to authenticate to the application would add a complementary layer to the authentication process & can be beneficial.

Failing Securely

When a system fails, it should do so securely.

– e.g. on failure undo changes and restore to a secure state; always check return values for failure; and in conditional code/filters make sure that there is a default case that does the right thing. The confidentiality and integrity of a system should remain even though availability has been lost.

```
DWORD dwRet = IsAccessAllowed(...);
if (dwRet == ERROR_ACCESS_DENIED) {
  // Security check failed.
  // Inform user that access is denied.
} else {
  // Security check OK.
}
```

```
DWORD dwRet = IsAccessAllowed(...);
if (dwRet == NO_ERROR) {
  // Secure check OK.
  // Perform task.
} else {
  // Security check failed.
  // Inform user that access is denied.
}
```

Least Privilege

- Only the minimum necessary rights should be assigned to a subject that requests access to a resource and should be in effect for the shortest duration necessary (remember to relinquish privileges).
- According to Saltzer and Schroeder [Saltzer 75] in "Basic Principles of Information Protection," Every program and every user of the system should operate using the least set of privileges necessary to complete the job. if a question arises related to misuse of a privilege, the number of things that must be audited is minimized.
  - a programmer who may need to read some sort of data object, but assigns higher privilege, since "Someday I might need to write to this object, and it would suck to have to go back and change this request."

Separation of Privilege

- A system should ensure that multiple conditions are met before granting permissions to an object. If an attacker is able to obtain one privilege but not a second, he or she may not be able to launch a successful attack.
- a protection mechanism that requires two keys to unlock it is more robust and flexible than one that allows access to the presenter of only a single key
    - This principle is often used in bank safe-deposit boxes. It is also at work in the defense system that fires a nuclear weapon only if two different people both give the correct command.

Economy of Mechanism

- If the design, implementation, or security mechanisms are highly complex, then the likelihood of security vulnerabilities increases. Subtle problems in complex systems may be difficult to find, especially in copious amounts of code.
- Simplifying design or code is not always easy, but developers should strive for implementing simpler systems when possible.
- The checking and testing process is less complex, because fewer components and cases need to be tested.
- Complex mechanisms often make assumptions about the system and environment in which they run. If these assumptions are incorrect, security problems may result.

Least Common Mechanism

- Avoid having multiple subjects sharing mechanisms to grant access to a resource. For e.g., serving an application on the Internet allows both attackers and users to gain access to the application.
- Every shared mechanism (especially one involving shared variables) represents a potential information path between users and must be designed with great care to be sure it does not unintentionally compromise security.
- Example : A web site provides electronic commerce services for a major company. Attackers flood the site with messages, and tie up the electronic commerce services. Legitimate customers are unable to access the web site and, as a result, take their business elsewhere.
  - Here, the sharing of the Internet with the attackers' sites caused the attack to succeed. The appropriate countermeasure would be include proxy servers or traffic throttling. The former targets suspect connections; the latter reduces load on the relevant segment of the network indiscriminately.

Reluctance to Trust

- Developers should assume that the environment in which their system resides is insecure
- Trust in external systems, code, people, etc., should always be closely held and never loosely given.
- software engineers should anticipate malformed input from unknown users
- users are susceptible to social engineering attacks, making them potential threats to a system
- no system is one hundred percent secure, so the interface between two systems should be secured.

Reluctance to Trust

- Point to remember is that trust is transitive. Once you dole out some trust, you often implicitly extend it to anyone the trusted entity may trust
- Hiding secrets in client code is risky. talented end users will be able to abuse the client and steal all its secrets
- According to Viega and McGraw, there are hundreds of products from security vendors with gaping security holes; Many security products introduce more risk than they address
  - Beware of vendors who resort to technobabble using newly invented terms or trademarked terms without actually explaining how the system works
  - Avoid software which uses secret algorithms. ``hackers'' can reverse-engineer the program to see how it works anyway
- According to Bishop, an entity is trustworthy if there is sufficient credible evidence leading one to believe that the system will meet a set of given requirements. Trust is a measure of trustworthiness, relying on the evidence provided. These definitions emphasize that calling something "trusted" or "trustworthy" does not make it so

Never Assuming That Your Secrets Are Safe

Relying on an obscure design or implementation does not guarantee that a system is secured. You should always assume that an attacker can obtain enough information about your system to launch an attack.

- Tools such as decompilers and disassemblers allow attackers to obtain sensitive information that may be stored in binary files.
- According to Viega and McGraw, for years, there was an arms race and an associated escalation in techniques of vendors and hackers; vendors would try harder to keep people from finding the secrets to "unlock" software, and the software crackers would try harder to break the software. For the most part, the crackers won.
- According to Viega and McGraw, the most common threat to companies is the insider attack; but many companies say "That won't happen to us; we trust our employees." The infamous FBI spy Richard P. Hanssen carried out the ultimate insider attack against U.S. classified networks for over 15 years.

Complete Mediation

A software system that requires access checks to an object each time a subject requests access, especially for security-critical objects, decreases the chances of mistakenly giving elevated permissions to that subject.

- A system that checks the subject's permissions to an object only once can invite attackers to exploit that system.
- According to Bishop, When a UNIX process tries to read a file, the operating system determines if the process is allowed to read the file. If so, the process receives a file descriptor encoding the allowed access. Whenever the process wants to read the file, it presents the file descriptor to the kernel. The kernel then allows the access. If the owner of the file disallows the process permission to read the file after the file descriptor is issued, the kernel still allows access. This scheme violates the principle of complete mediation, because the second access is not checked. The cached value is used, resulting in the denial of access being ineffective.

Psychological Acceptability

- Accessibility to resources should not be inhibited by security mechanisms. If security mechanisms hinder the usability or accessibility of resources, then users may opt to turn off those mechanisms.
  - Where possible, security mechanisms should be transparent to the users of the system or at most introduce minimal obstruction. Security mechanisms should be user friendly to facilitate their use and understanding in a software application.
- Configuring and executing a program should be as easy and as intuitive as possible, and any output should be clear, direct, and useful.
  - If security-related software is too complicated to configure, system administrators may unintentionally set up the software in a non-secure manner.
- Similarly, security-related user programs must be easy to use and output understandable messages.

Promoting Privacy

- Protecting software systems from attackers that may obtain private information is an important part of software security.
- Many users consider privacy a security concern. Try not to do anything that might compromise the privacy of the user.

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Secure Architectural Patterns
RL 5.3.1

Secure Patterns

- A software design pattern is a general repeatable solution to a recurring software engineering problem.
- Secure design patterns a general solution to a security problem that can be applied in many different situations.
- Secure design patterns are not restricted to object-oriented design approaches but may also be applied, in many cases, to procedural languages.

Secure Architectural-level Patterns

Architectural-level patterns focus on the high-level allocation of responsibilities between different components of the system and define the interaction between those high-level components.

- Architectural-level Patterns
  - Distrustful Decomposition
  - Privilege Separation (PrivSep)
  - Defer to Kernel

Distrustful Decomposition

Separate the functionality of your software into *mutually untrusting chunks*, so as to shrink the attack windows into each chunk

- Design each chunk under the assumption that other software chunks with which it interacts have been attacked, and it is attacker software rather than normal application software that is running in those interacting chunks.
- Do not expose your data to other chunks via shared memory.

As a result of mutually untrusting chunking, your entire system will not be given into the hands of an attacker if any one of its chunks has been compromised

Distrustful Decomposition (cont..)

Motivation : Many attacks target vulnerable applications running with elevated permissions

Some examples of this class of attack are

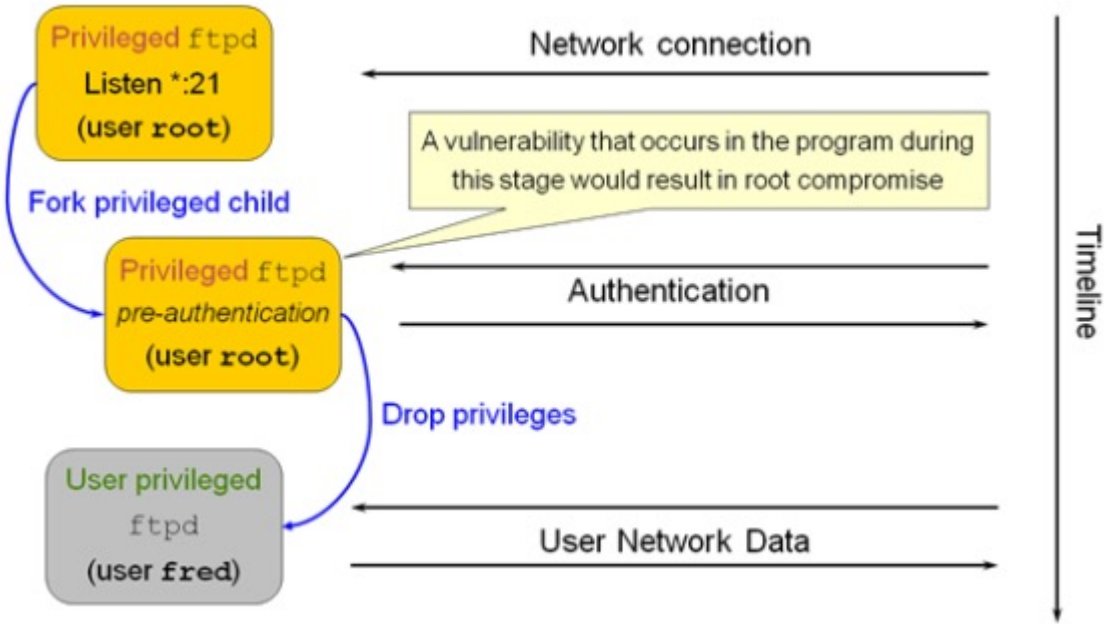
- Attacks in which versions of IE browser running in an account with administrator privileges is compromised
- Security flaws in Norton AntiVirus 2005 that allowed attackers to run arbitrary VBS scripts when running with administrator privileges
- A buffer overflow vulnerability in BSD-derived telnet daemons that allows an attacker to run arbitrary code as root

Consequences : Prevents an attacker from compromising an entire system in the event that a single component program is successfully exploited because no other program trusts the results from the compromised one

Privilege Separation (PrivSep)

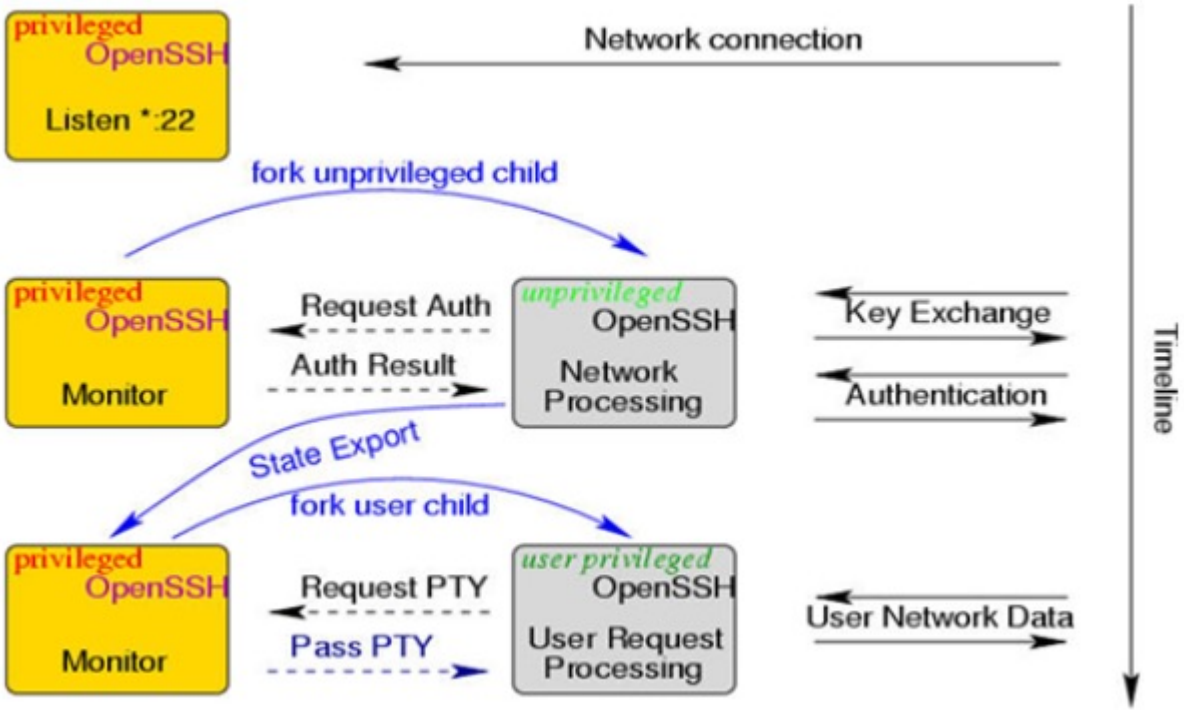
- The PrivSep pattern is a more specific instance of the Distrustful Decomposition pattern.
- Keep to a minimum the part of your code that executes with special privilege.
- If an attacker succeeds in breaking into software that's running at a high level of privilege, the attacker will be operating at a high level of privilege too. That'll give him an extra-wide open "attack window" into your system
- The pattern is applicable if the system performs a set of functions do *not* require elevated privileges, but have relatively large attack surfaces (e.g. communication with untrusted sources, potentially error-prone algorithms)

Privilege Separation (cont..)



Here is a vulnerable implementation where a privileged process is trying to authenticate an unauthenticated user

Privilege Separation (cont..)



- The implementation as per PrivSep pattern.
- The interactions with user and authentication are moved into an unprivileged process.

Defer to Kernel

The intent of this pattern is to clearly separate “functionality that requires elevated privileges” from “functionality that does not require elevated privileges and to take advantage of existing user verification functionality available at the kernel level.

Designers tend to take control of authorization functionality into their hands. The pattern discourages the tendency

The pattern is applicable to systems:

- That run by users who do not have elevated privileges;
- Where some (possibly all) of the functionality of the system requires elevated privileges; or
- Where the system must verify that the current user is authorized to execute any functionality that requires elevated privileges

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Secure Design Patterns
RL 5.3.2

Classes of Patterns

Design-level patterns. Design-level patterns describe how to design and implement pieces of a high-level system component, that is, they address problems in the internal design of a single high-level component, not the definition and interaction of high-level components themselves.

- Secure Factory
- Secure Strategy Factory
- Secure Builder Factory
- Secure Chain of Responsibility
- Secure State Machine
- Secure Visitor

Classes of Patterns

Implementation-level patterns. Implementation-level patterns address low-level security issues. Patterns in this class are usually applicable to the implementation of specific functions or methods in the system. Implementation-level patterns address the same problem set addressed by the CERT Secure Coding Standards

- Secure Logger
- Clear Sensitive Information
- Secure Directory
- Input Validation

Secure Factory

- Secure Factory secure design pattern is a security specific extension of the Abstract Factory pattern
- The Secure Factory secure design pattern is applicable if
  - The system constructs different versions of an object based on the security credentials of a user/operating environment.
  - The available security credentials contain all of the information needed to select and construct the correct object.

Secure Strategy Pattern

- The strategy pattern enables an algorithm's behavior to be selected at runtime
- Strategy pattern provides a means to define a family of algorithms, encapsulate each one as an object, and make them interchangeable during runtime
- a class that performs validation on incoming data may use a strategy pattern to select a validation algorithm based on the type of data, the source of the data, user choice, or other discriminating factors
- The secure strategy object performs a task based on the security credentials of a user or environment

Secure Builder Factory

- Secure Builder Factory design pattern is to separate the security dependent rules, involved in creating a complex object, from the basic steps involved in the actual creation of the object.
  - Identify a complex object whose construction depends on the level of trust associated with a user or operating environment. Define the general builder interface using the Builder pattern for building complex objects of this type.
  - Implement the concrete builder classes that implement the various trust level specific construction rules for the complex object.

Secure Chain of Responsibility

The intent of the Secure Chain of Responsibility pattern is to decouple the logic that determines user/environment-trust dependent functionality from the portion of the application make it relatively easy to dynamically change the user/environment-trust dependent functionality.

Motivation

In an application using a role-based access control mechanism, the behavior of various system functions depends on the role of the current user

Consequence

The security-credential dependent selection of the appropriate specific behavior for a general system function logic is hidden from the portions of the system that make use of the general system function.

Secure State Machine

The intent of the Secure State Machine pattern is to allow a clear separation between security mechanisms and user-level functionality by implementing the security and user-level functionality as two separate state machines.

Motivation

Intermixing security functionality and typical user-level functionality in the implementation of a secure system can increase the complexity of both. The increased complexity makes it more difficult to test, review, and verify the security properties of the implementation.

Consequences

- Can test and verify the security mechanisms separately from the user-level functionality
- New security implementation could be implemented with lesser effort

Secure Visitor

Secure systems may need to perform various operations on hierarchically structured data where each node in the data hierarchy may have different access restrictions. The pattern idea is to incorporate security mechanism in data node rather than visitor code.

Motivation

Secure Visitor pattern allocates all of the security considerations to the nodes in the data hierarchy, leaving developers free to write visitors that only concern themselves with user-level functionality

Consequences

The use of this pattern requires that the nodes in the data hierarchy, not the visitors themselves, implement security

Secure Logger

- The intent of the Secure Logger pattern is to prevent an attacker from gathering potentially useful information about the system from system logs and to prevent an attacker from hiding their actions by editing system logs.
- The Secure Logger pattern is applicable if
  - The system logs information to a log file or some other form of logging subsystem.
  - The information contained in the system log could be used by an attacker to devise attacks on the system.
  - System logs are used to detect and diagnose attacks on the system.

Clear Sensitive Information

It is possible that sensitive information stored in a reusable resource may be accessed by an unauthorized user or adversary if the sensitive information is not cleared before freeing the reusable resource. The use of this pattern ensures that sensitive information is cleared from reusable resources before the resource may be reused.

Reusable resources include things such as the following:

- dynamically allocated memory
- statically allocated memory
- automatically allocated (stack) memory
- memory caches
- disk
- disk caches

Secure Directory

The intent of the Secure Directory pattern is to ensure that an attacker cannot manipulate the files used by a program *during* the execution of the program.

The Secure Directory pattern is applicable for use in a program if

- The program will be run in an insecure environment; that is, an environment where malicious users could gain access to the file system used by the program.
- The program reads and/or writes files.
- Program execution could be negatively affected if the files read or written by the program were modified by an outside user while the program was running.

The program should check that a directory offered to it is secure, and refuse to use it otherwise. Implementation of the Secure Directory pattern involves the following steps:

- Find the canonical pathname of the directory of the file to be read or written.
- Check to see if the directory, as referenced by the canonical pathname, is secure.
  - If the directory is secure, read or write the file.
  - If the directory is not secure, issue an error and do not read or write the file.

Input Validation

Input validation requires that a developer correctly identify and validate all external inputs from untrusted data sources

Motivation

- The use of unvalidated user input is the root cause of many serious security exploits, such as buffer overflow attacks, SQL injection attacks, and cross-site scripting attacks.
- In a client-server architecture, it is problematic if only client-side validation is performed. It is easy to spoof a web page submission and bypass any scripting on the original page

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Thank You!