Threat Modelling Strategies

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BCS DevSecOps Group

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Roy Harrow

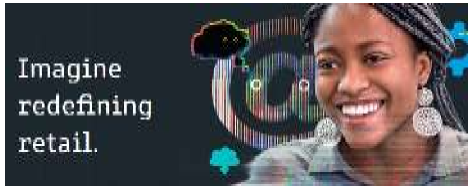
- Applications development
- Methods and Tools
- Standards and procedures
- Change and configuration management
  - Secretary of BCS CMSG
- Design and Architecture
- Security
  - Web Security and IAM
  - Infrastructure / Designed DIY monitoring system
  - Consultancy and architecture
  - Solution design
  - Product assurance

- Sectors
  - Financial services
  - Central and Local Government
  - Communications, Health Care, Transport, Retail + many others

- IBM Security
  - 2008-2022 (14 years)
- Sainsbury’s Information Security
  - September 2022+

- Chair of BCS DevSecOps group

- Huge range of business applications
  - eCommerce: groceries online, general merchandise
  - Store systems, point of sale, warehouse, delivery and logistics
  - Contact centre, corporate services many more
- Wide range of technologies
  - On premise: mainframe, midrange and specialised technologies
  - Cloud hosted services and many SaaS applications
- Large number of engineering teams
  - Linked to product managers
  - Using modern agile practices and CI/CD pipelines integrated with various security processes and tooling



Sainsbury's Argos NECTAR 360 Sainsbury's Bank habitat

https://sainsburys.jobs/roles/digital-tech-data/

Agenda

- What is Threat Modelling?
- Why do it?
- When to perform it?
- How to do threat modelling?
- Who should do threat modelling?
- Threat modelling tools
- Summary & Conclusions

These are my personal views and don't represent policies and processes from my current or previous employers

What is Threat Modelling?

A process to attempt to identify security weaknesses in an application

- ***Before someone else does***

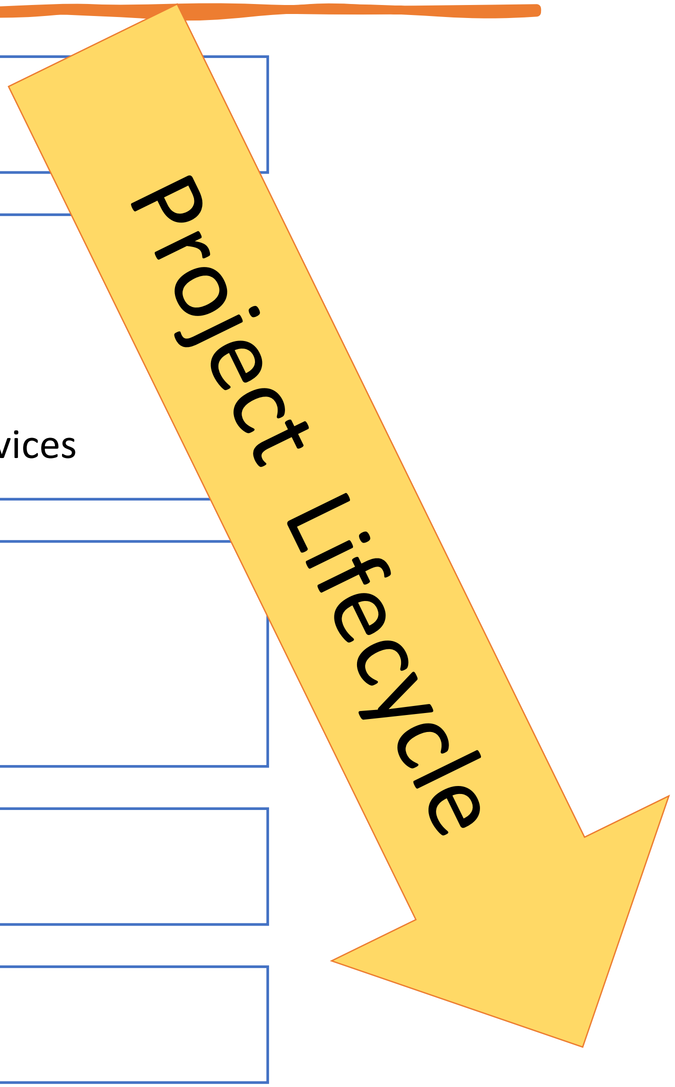
Aims to help to improve the security of IT applications

- Ideally ***before they are built***

The focus tends to be on thinking about deliberate attempts to circumvent an application's security controls - aka "threats"

- But also needs to consider accidents
- Deliberate attempts could be targeted or just "random" / opportunistic

“Traditional” Approach



A focus on functional requirements

- To drive the design, build and testing of applications

Some consideration for non-functional requirements, in particular

- Usability / User Experience
- Performance and availability
- Depending on type of business
  - Regulatory or industry specific compliance requirements e.g. healthcare or financial services

Security requirements/controls

- May be added as application evolves through agile development iterations
- Some driven by compliance
- Some derived from organisational “baseline” security requirements

Penetration testing at the end

- With mixed results

Vulnerability scanning and patching in the live environment

- With mixed results

Why do Threat Modelling?

To identify potential vulnerabilities early	Ideally during design stages To be able to influence design and build before it is too late
To include input from all stakeholders	To ensure all “angles” are considered, both technical and non-technical
To drive security controls based on business priorities	By taking inputs from product owners and business representatives
To encourage a “security mindset”	To influence the selection and design of future IT services

Threat Modelling – Main Steps

- We need to understand the system or application
  - Its business purpose and information being processed
- Then need to consider what could go wrong
- What can we do about it?
- And finally
  - How did we do?

Threat Modelling – Key Activities

- We need to understand the system or application
  - Business purpose and information being processed

- Scope + Context (Business + Technical)
  - A sprint or a component
  - A new release
  - Diagrams are common

- Then need to consider what could go wrong

- Brainstorm possible threats or attacks
  - Application profiling questions
  - Common threat/attack models

- What can we do about it?

- Identify or design countermeasures
  - to reduce risk

- And finally….
  - How did we do?

- “Fit for purpose” given context?
  - Coverage
  - Lessons learned?

Clarifying Scope and Business Context

- Essential – to drive thinking about relevant risks
- Diagrams are useful – but not essential
  - DFD or Process Flow
- Can be iterative or evolving during a project
- Could use an application profiling questionnaire
  - If combined with some “best practice” or domain specific guidance, such as
    - OWASP Top 10 Proactive Security Controls
    - PCI-DSS Guidance

Threat Modelling Simplified #1

Example Application Profiling Questions

Business purpose

- Importance of the application to the organisation

Information being handled

- Customer data
- Product information

Sensitivity of data being handled

- PCI-DSS cardholder information
- Personal sensitive such as healthcare
- Company secrets
- State secrets

Mode of access

- Internal from trusted devices and networks
- External via Internet

Led by Security Expert

Users of the application

- Internal
- External
- Trusted third-parties

Modes of access

- Browser
- Fat-client
- APIs

Main interfaces – ideally with a diagram

- Inputs
- Outputs

Hosting Arrangements

- On premise
- Cloud
- SaaS

Threat Modelling Simplified #2

Using Checklists for Security Controls

Using the information from the application profiling questionnaire

- Select relevant security controls from a framework
- Create a tailored set of controls

Examples of general security checklists you could use are:

- OWASP Top 10 Proactive Controls 2018
- OWASP Cheat Sheets - includes “Secure Product Design”
- UK National Cyber Security Centre (NCSC) – 14 Cloud Security Principles

Domain specific checklists and compliance frameworks include

- PCI-DSS for the protection of payment card information
- NHS Data Security and Protection Toolkit (DSPT)

Threat Modelling Simplified #3 - Summary

Review proposed new applications as early as possible with the development team

- Ideally before detailed design is completed
- Review and revise the responses as the project progresses
- Review for major changes to the application

Best led by a security expert

- But the questions need input from the application team

Pros

- Relatively “light touch” for project team
- Can be combined with other more formal methods for identifying threats

Cons

- Takes time to develop questionnaire
- “Light touch” involvement from project team
  - May not encourage a true collaborative approach + ownership of security requirements
  - May struggle to scale, given amount of input required from security expert

OWASP Top 10 Proactive Security Controls

- C1: Define Security Requirements
- C2: Leverage Security Frameworks and Libraries
- C3: Secure Database Access
- C4: Encode and Escape Data
- C5: Validate All Inputs
- C6: Implement Digital Identity
- C7: Enforce Access Controls
- C8: Protect Data Everywhere
- C9: Implement Security Logging and Monitoring
- C10: Handle All Errors and Exceptions

Examples of OWASP Cheat Sheets

- **Topical advice for Developers**
  - Authentication
  - Authorisation
  - Cryptographic Storage
    - Encryption of data at rest
  - Database Security
  - Docker and Kubernetes Security
  - Input Validation
  - Secrets Management

- **Advice on defending against common vulnerabilities**
  - Clickjacking Defence
  - Cross Site Scripting Prevention
  - Denial of Service Protection

Beyond Application Profiling

Importance of collaborative approach

- Input from all stakeholders

Needs to be able to scale

- Given low number of “security experts” vs. developers

Requires

- Deeper understanding of the context – to identify more subtle threats
- Techniques and sources of information to help identify threats
- More structure – to have confidence in coverage
- Standardised processes that can be repeated and adapted for many projects

Threat Modelling Manifesto Four Key Questions

1. **What are we working on?**
   - Typically supported using a diagram – such as a DFD
   - With a clear boundary to define the scope of the application – decomposing large and complex applications
   - Identifies key “assets”

2. **What can go wrong?**
   - Threats that could impact the security or privacy of the application
   - List of potential weaknesses in the design or implementation

3. **What are we going to do about it?**
   - Actions to mitigate the impact of the threats identified
   - Countermeasures or additional security controls
   - Prioritisation of actions.

4. Did we do a good enough job?
   - Threats identified?
   - Risks reduced – through effective countermeasures
   - Lessons learned – e.g. new recommended “standard” security controls for the organisation

https://www.threatmodelingmanifesto.org/

Thinking like an Attacker

What can we learn from TV detectives?

Criminal Investigation Techniques

Crime Scene

- **Demarcation**
- Gather evidence
- Background and **context**

Assessment of suspects

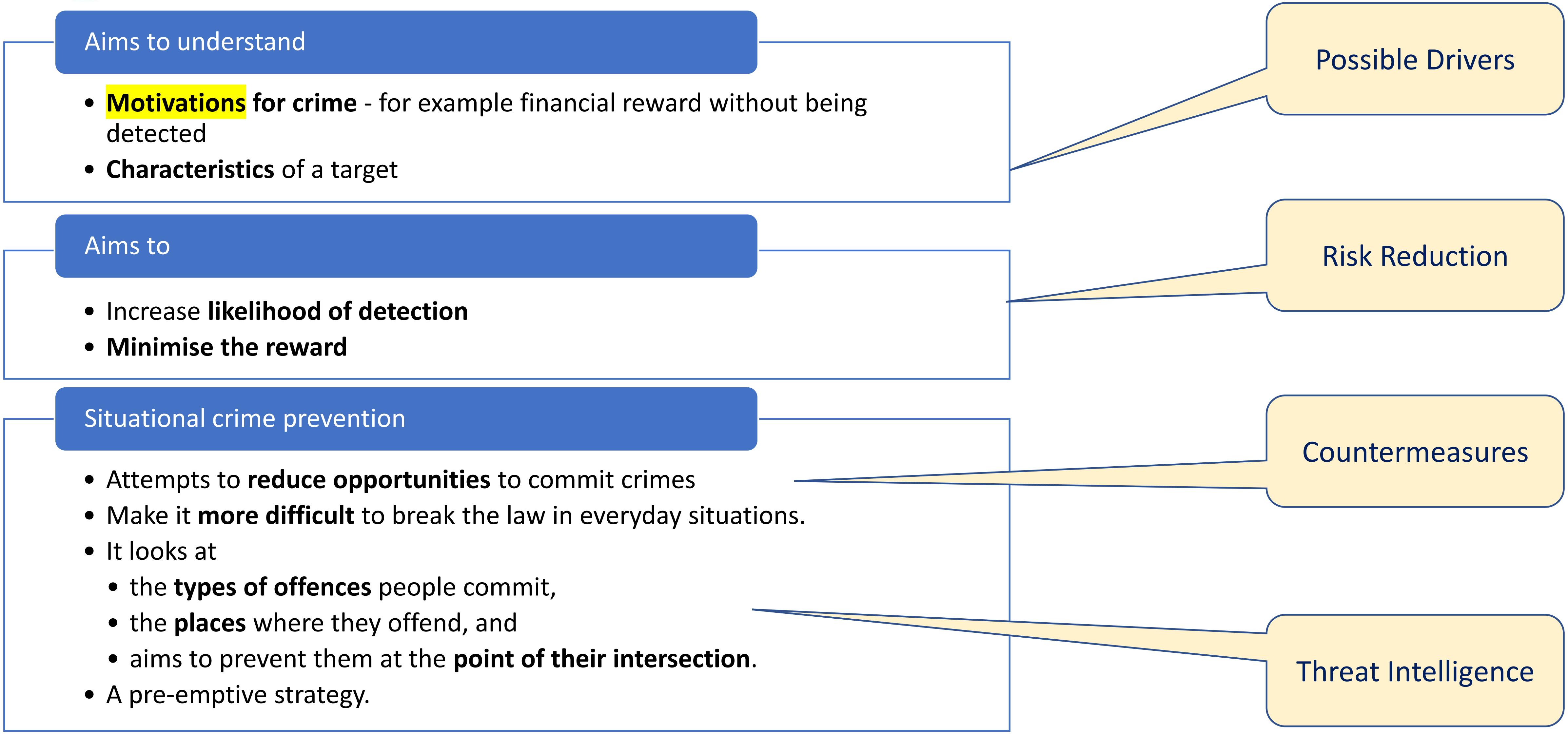
- **Motivation**
  - e.g. financial gain or revenge
- **Means / Method**
  - Tools, skills,
- **Opportunity**
  - e.g. access to crime scene
- **Relationship** with victim
  - May be important to understand motivation

Digital forensics

- **Scope** of system under attack
  - Boundaries
  - Business purpose, context
- **Motivation**
  - Financial gain, digital harm
  - Access to confidential information
- **Means/Method**
  - Tools, Techniques, Procedures (TTP)
- **Opportunity**
  - System access requirements
- **Relationship**
  - May be important to understand

https://en.wikipedia.org/wiki/Criminal_investigation

Crime Prevention



Aims to understand

- **Motivations for crime** - for example financial reward without being detected
- **Characteristics** of a target

Aims to

- Increase **likelihood of detection**
- **Minimise the reward**

Situational crime prevention

- Attempts to **reduce opportunities** to commit crimes
- Make it **more difficult** to break the law in everyday situations.
- It looks at
  - the **types of offences** people commit,
  - the **places** where they offend, and
  - aims to prevent them at the **point of their intersection**.
- A pre-emptive strategy.

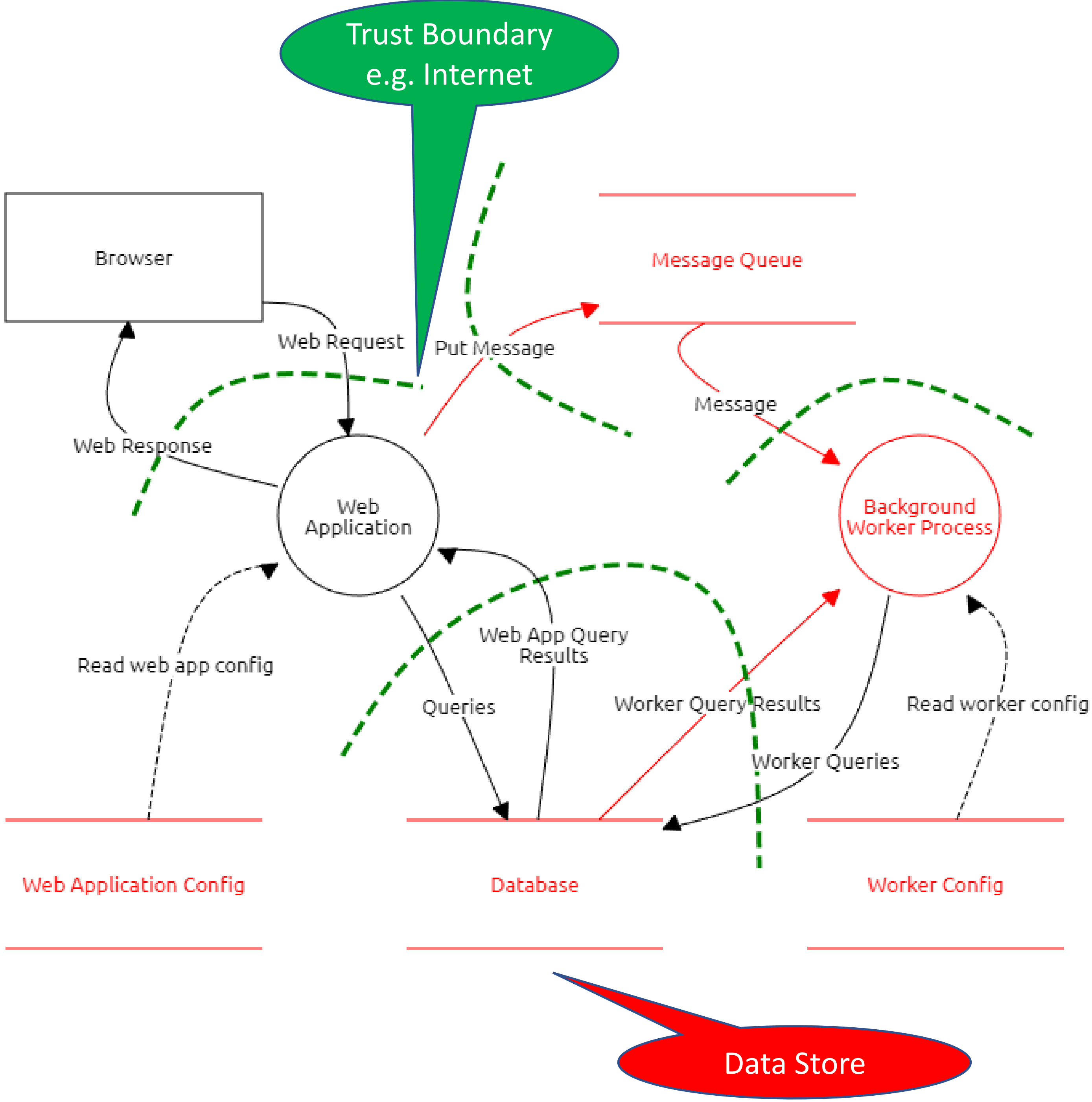
Threat Modelling Diagrams

- Useful for Scoping and Identifying Potential Targets for Attack
  - Data Flow Diagram (DFD)
  - Process Flow Diagram (PFD)
  - C4 Model - architectural diagrams
    - Context, Container, Component and Code

- Attack Tree Diagrams
  - Explains the steps of an attack
    - Bruce Schneier, 1999
    - Synopsis, 2015

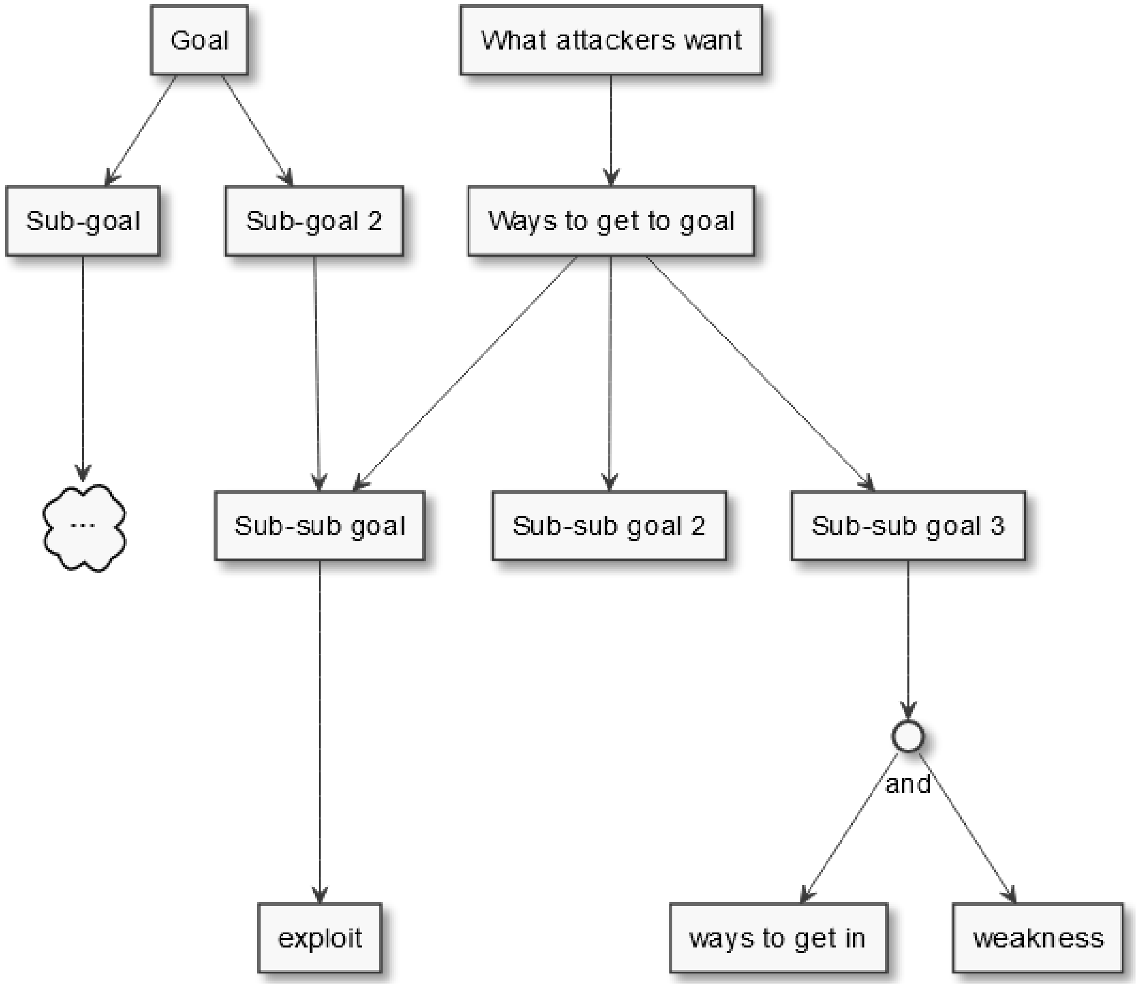
Data or Process Flow Diagrams

- Helps define scope
- Aids understanding of data flows
- Provides structure for assessing risks
- Data Flow Diagrams (DFD) are the most common, for example



Attack Trees

- Commonly combined with other techniques such as STRIDE.
- Show attacks on a system in tree form.
- The tree root is the goal for the attack, and the leaves are ways to achieve that goal.
- Each attack goal is represented as a separate tree.



Threat Modelling Techniques

Threat Identification

- **Q. What might cause us to breach…. ?**
- CIA - Confidentiality, Integrity and Availability
- Compliance framework

Threat Classification

- **Q. Could we be vulnerable to certain types of attack?**
  - STRIDE
    - Spoofing, Tampering, Repudiation, Information Disclosure, Denial of Service, Elevation of Privilege
  - OWASP lists of top 10 types of common security vulnerabilities
    - Browser-based web applications
    - Mobile applications
    - API services

CIA approach to Threat Modelling

Confidentiality

- Will we be storing or handling any sensitive information?
- How will we be protecting it?

Integrity

- What are the consequences of an accidental or deliberate data corruption of unauthorised change?
- Why might someone want to change some data?
- What controls exist to prevent or detect unauthorised changes?

Availability

- How long could the business operate without the system?
- Have we planned any controls to help ensure availability?

STRIDE

	Threat	Property Violated	Threat Definition
S	Spoofing Identity	Authenticity	Pretending to be something or someone other than yourself
T	Tampering with data	Integrity	Modifying data at rest, in transit or in memory
R	Repudiation	Non-repudiation	Denying that you did something
I	Information disclosure	Confidentiality	Giving sensitive information to someone not authorised
D	Denial of service	Availability	Exhausting computing resources needed to support the service
E	Elevation of privilege	Authorisation	Allowing someone to do something they are not authorised to perform

https://www.microsoft.com/en-us/security/blog/2007/09/11/stride-chart/

Threat Modelling Using Lists of Common Vulnerabilities

OWASP lists of top 10 types of common security vulnerabilities	• Browser-based web applications • Mobile applications • API services	Start Here
Cloud Security Alliance	• Generic cloud security weaknesses	Then Here
Common Attack Pattern Enumeration and Classification (CAPEC)	• Similar to OWASP Top 10	
Common Vulnerability Scoring System (CVSS)	• Can be used to prioritise vulnerabilities • e.g. NIST National Vulnerability Database (NVD)	

Common Attack Pattern Enumeration and Classification (CAPEC)

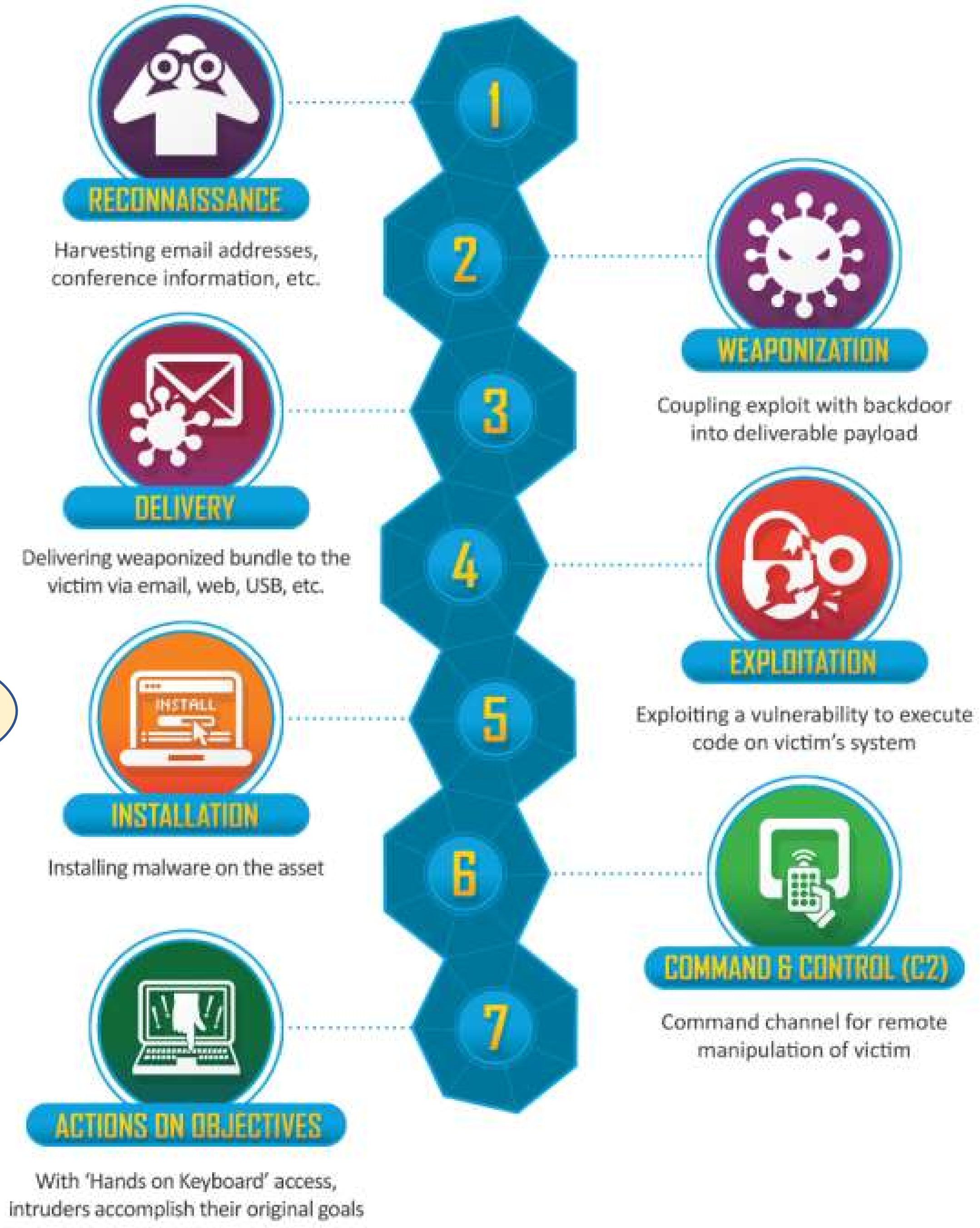
https://capec.mitre.org/

- A catalogue of common **attack patterns** that helps explain how adversaries exploit weaknesses in applications
- **Attack Patterns** are descriptions of the common attributes and approaches employed by adversaries to exploit known weaknesses in cyber-enabled capabilities
- Some well-known **attack patterns**
  - SQL Injection (CAPEC-66)
  - Cross-Site Scripting (CAPEC-63)
  - Buffer Overflow (CAPEC-100)
  - Clickjacking (CAPEC-103)
  - Cross Site Request Forgery (CAPEC-62)

Lockheed Martin Cyber Kill Chain

- 7 steps attackers commonly use
  - Reconnaissance
  - Weaponization
  - Delivery
  - Exploitation
  - Installation
  - Command and Control (C2)
  - Actions on Objectives
- Threat modelling would assess the potential for each of these

Think like a Hacker



1 RECONNAISSANCE

Harvesting email addresses, conference information, etc.

2 WEAPONIZATION

Coupling exploit with backdoor into deliverable payload

3 DELIVERY

Delivering weaponized bundle to the victim via email, web, USB, etc.

4 EXPLOITATION

Exploiting a vulnerability to execute code on victim's system

5 INSTALLATION

Installing malware on the asset

6 COMMAND & CONTROL (C2)

Command channel for remote manipulation of victim

7 ACTIONS ON OBJECTIVES

With 'Hands on Keyboard' access, intruders accomplish their original goals

https://www.lockheedmartin.com/en-us/capabilities/cyber/cyber-kill-chain.html

MITRE ATT@CK Knowledge Base

https://attack.mitre.org/

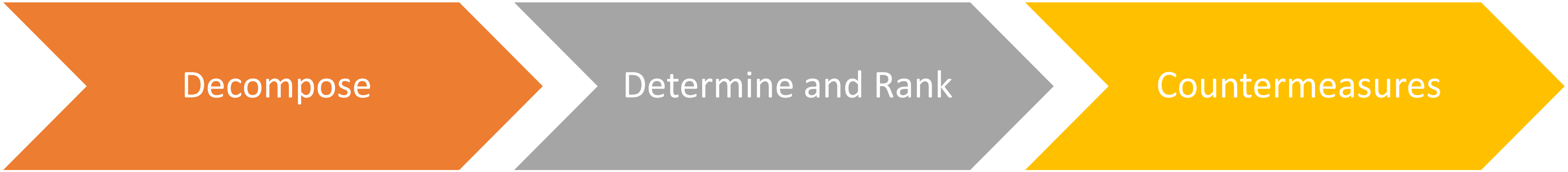
- Attack tactics and techniques by platform, such as
  - Cloud
  - Mobile
  - Operating system family: Window, Linux
  - At a lower-level than Lockheed Martin Cyber Kill Chain or STRIDE
- Classified by stage of attack, e.g.
  - Reconnaissance
  - Initial Access
  - Execution
  - Persistence etc…
- Mitigations

- *Useful when a more detailed assessment is required*

Threat Modelling Methods

- OWASP Threat Modelling Method
- The Process for Attack Simulation and Threat Analysis (PASTA)
  - Risk-centric modelling method
- LINDDUN
  - A privacy focussed method
  - Linkability, Identifiability, Nonrepudiation, Detectability, Disclosure of information, Unawareness, Noncompliance
- NIST Data-Centric System Threat Modelling – SP 800-154
- Persona non Grata (PnG)
  - Focuses on the motivations and skills of human attackers.
- The SEI Hybrid Threat Modelling Method (hTMM)
- Vendor approaches
  - e.g. Microsoft and Synopsys
  - Visual, Agile, and Simple Threat (VAST) – from Threatmodeler

OWASP Threat Modelling



Decompose

Determine and Rank

Countermeasures

- Decompose the Application
  - External Dependencies
  - Entry Points and Exit Points
  - Assets
  - Trust Levels
  - Data Flow Diagrams

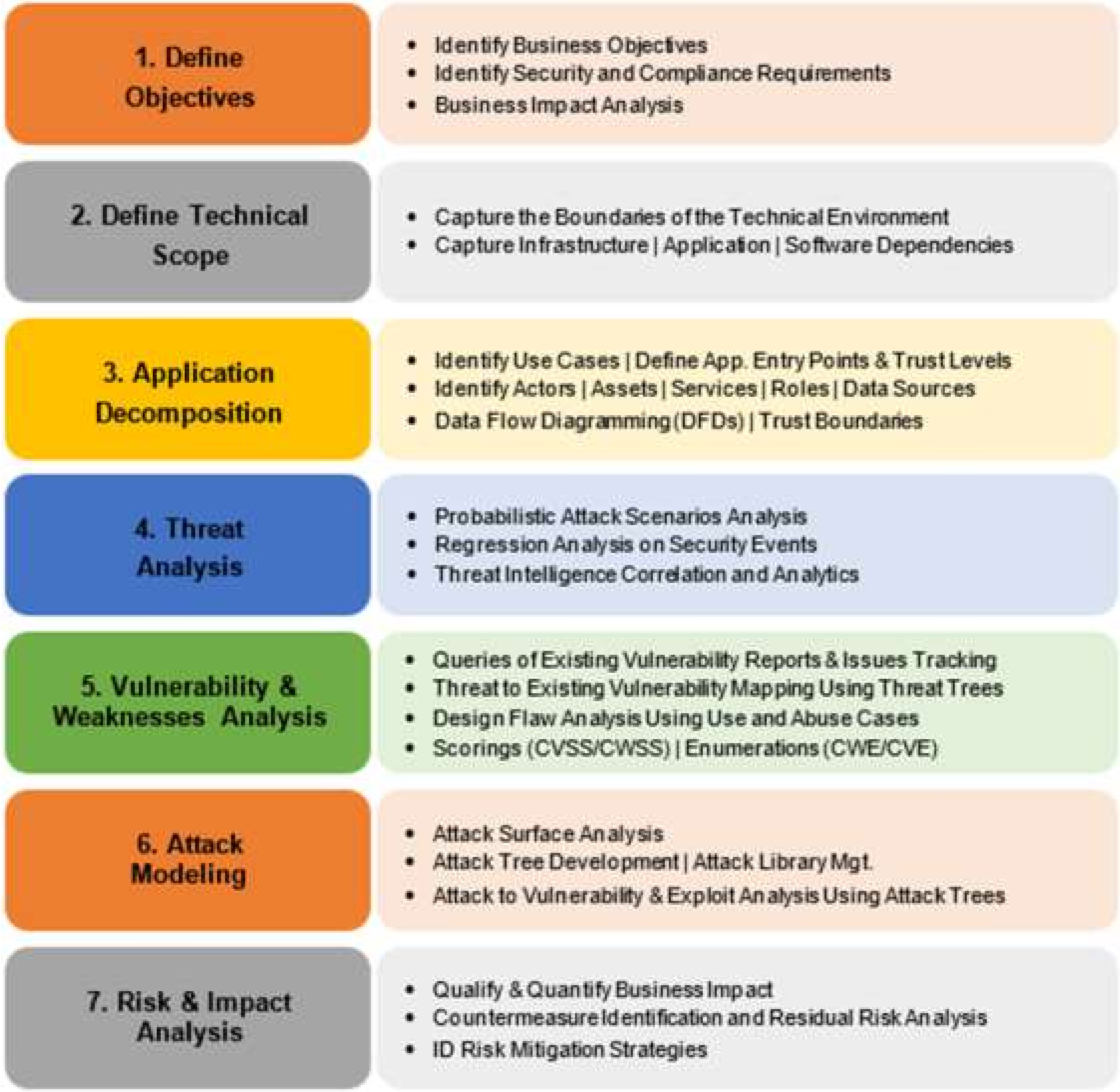
- Determine and Rank Threats
  - Threat Categorisation e.g. using STRIDE

- Determine Countermeasures and Mitigation
  - Typically uses the OWASP Application Security Framework (ASF) or
  - STRIDE threat mitigations

https://owasp.org/www-community/Threat_Modeling

Process for Attack Simulation and Threat Analysis (PASTA)

- Risk-centric
  - Identification
  - Classification and prioritisation
  - Highest and most relevant
  - Not just technical issues
- Seven step process to ensure business objectives are understood
- Benefits
  - Business Context is Prime
  - Tests viability
  - Attacker perspective
- Invented in 2015 by Tony UcedaVélez



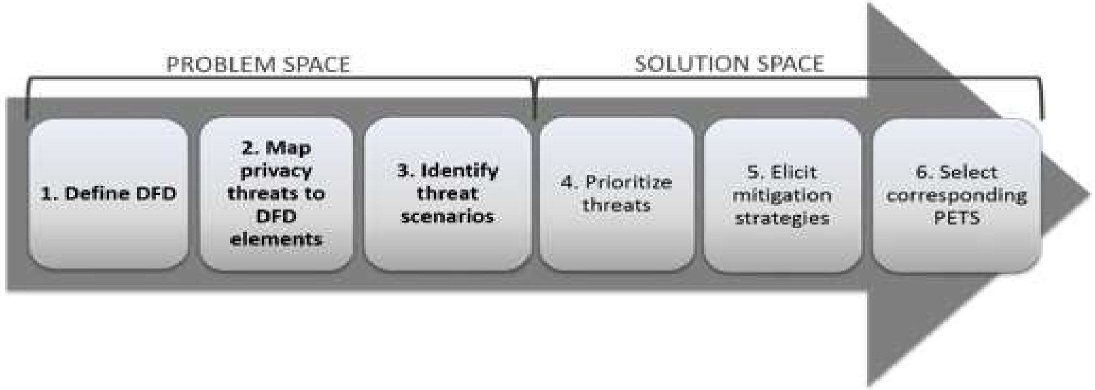
1. Define Objectives	• Identify Business Objectives • Identify Security and Compliance Requirements • Business Impact Analysis
2. Define Technical Scope	• Capture the Boundaries of the Technical Environment • Capture Infrastructure | Application | Software Dependencies
3. Application Decomposition	• Identify Use Cases | Define App. Entry Points & Trust Levels • Identify Actors | Assets | Services | Roles | Data Sources • Data Flow Diagramming (DFDs) | Trust Boundaries
4. Threat Analysis	• Probabilistic Attack Scenarios Analysis • Regression Analysis on Security Events • Threat Intelligence Correlation and Analytics
5. Vulnerability & Weaknesses Analysis	• Queries of Existing Vulnerability Reports & Issues Tracking • Threat to Existing Vulnerability Mapping Using Threat Trees • Design Flaw Analysis Using Use and Abuse Cases • Scorings (CVSS/CWSS) | Enumerations (CWE/CVE)
6. Attack Modeling	• Attack Surface Analysis • Attack Tree Development | Attack Library Mgt. • Attack to Vulnerability & Exploit Analysis Using Attack Trees
7. Risk & Impact Analysis	• Qualify & Quantify Business Impact • Countermeasure Identification and Residual Risk Analysis • ID Risk Mitigation Strategies

https://versprite.com/blog/what-is-pasta-threat-modeling/

LINDDUN – Privacy Threat Modelling

- Designed to help identify and mitigate privacy threats:

- Linkability
- Identifiability
- Non-repudiation
- Detectability
- Disclosure of information
- Unawareness
- Non-compliance

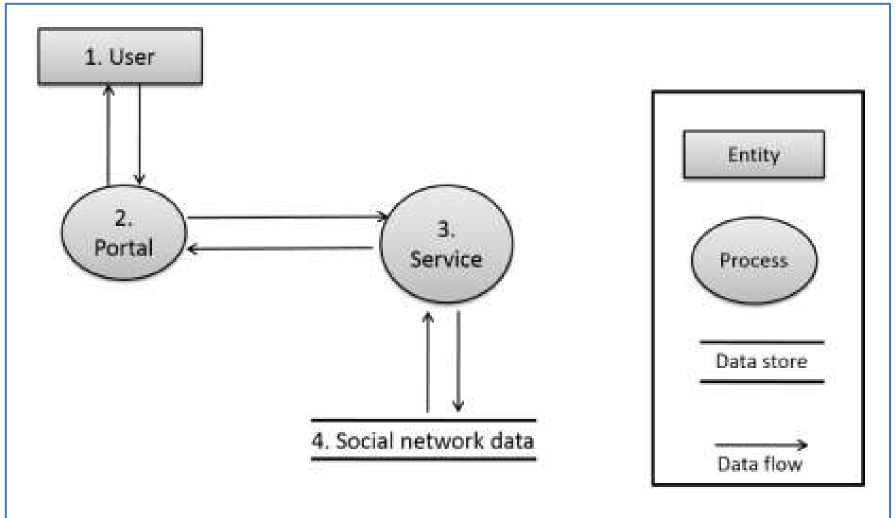


PROBLEM SPACE

SOLUTION SPACE

1. Define DFD
2. Map privacy threats to DFD elements
3. Identify threat scenarios
4. Prioritize threats
5. Elicit mitigation strategies
6. Select corresponding PETS

- Likely to be used alongside a security oriented method, such as STRIDE



EXAMPLE DFD OF SOCIAL NETWORK APPLICATION

https://www.linddun.org/

NIST SP800-154 Data Centric Threat Modelling

- Threat modelling is a form of risk assessment that models aspects of the attack and defence sides of a particular logical entity, such as a piece of data, an application, a host, a system, or an environment.
- Data-centric threat modelling
  - Focused on protecting particular types of data within systems.
- This standard defines principles for data-centric threat modelling.
- https://csrc.nist.gov/publications/detail/sp/800-154/draft

Risk Treatment

Assess / prioritise risks

- Focus on impact – if it is too hard to assess likelihood

Potential treatment strategies

- Reduce – the best outcome, if feasible and affordable
- Transfer – e.g. insure or outsource
- Avoid – e.g. disable or isolate
- Accept – if within risk appetite

Identify potential countermeasures

- Security controls

Risk Acceptance

- Risk Register

Common Mitigations or Controls by type of Risk or Threat

Type of Risk	Mitigation Strategy / Security Controls
Spoofing	Strong authentication Digital signatures
Tampering	Access controls Check-sums, hash-totals and signatures on data items
Repudiation	Strong authentication Audit logs
Information Disclosure	Access controls Encryption
Denial of Service	Quotas / throttling of transaction volumes
Elevation of Privilege	Access controls Hardened system configuration

Different Types of Threat Modelling Tools

Attack Trees

- A graphical representation of an attack scenario, which helps identify possible threats and their relationships with each other.

STRIDE Analysis

- Evaluates the threat landscape from the perspective of six common risks (Spoofing, Tampering, Repudiation, Information Disclosure, Denial of Service and Elevation of Privilege).
- Allows for a more comprehensive assessment of potential risk by helping to identify any weaknesses in the system that could be exploited by attackers.
- Typically uses diagramming techniques such as DFD to create a model of the system.

Failure Mode and Effects Analysis (FMEA)

- This type of analysis looks at what might occur if specific components of a system fail or do not function as intended.
- It allows developers to anticipate possible failures and establish proactive measures to prevent them from occurring.

Attack Surface Analysis

- Analyses the attack surface available to attackers when attempting to compromise a system or organization.
- Identifies elements of an application or network where an attacker can gain access or leverage an exploit.

Risk Management Process

- Designed to help organizations analyse, prioritize and respond to potential security risks they face in their environment.
- Typically involves assessing potential risks, determining acceptable levels of risk and then taking steps to mitigate those risks through countermeasures such as implementing security policies or deploying security tools.

Features of Threat Modelling Tools

Systems modelling

- Typically as a flow diagram

Threat intelligence

- To inform and prompt
- e.g. using a scheme like MITRE’s CAPEC

Dashboard of vulnerabilities identified

- Showing severity

Dashboard of mitigations defined

- Potentially mapping mitigations top vulnerabilities and threats
- Guidance for developers

Rules engine

- To add value by interpreting policies when applied to the system model

Scalability and Collaboration

Integration with existing processes and tools

- other CI/CD pipeline tools
- task/issue tracking tools such as Jira
- Diagramming tools

Reporting and Exporting of Information e.g. in PDF and CSV formats

Some Tools that Can Help

- Microsoft Threat Modeling Tool – free
- OWASP Threat Dragon – free
- IriusRisk – commercial – has a free community tier
- SD Elements by Security Compass – commercial
- Elevation of Privilege (EoP) Security Cards – Microsoft + OWASP Cornucopia
- Cairis – open source
- Threagile – open source
- ThreatModeler – commercial with a free tier

Summary and Conclusions

Threat Modelling Manifesto
Four Key Questions

1. What are we working on?

- Typically supported using a diagram – such as a DFD
- With a clear boundary to define the scope of the application – decomposing large and complex applications
- Identifies key "assets"

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4. Did we do a good enough job?

- Threats identified?
- Risks reduced – through effective countermeasures
- Lessons learned – e.g. new recommended "standard" security controls for the organisation

https://www.threatmodelingmanifesto.org/

Position of Threat Modelling in the SDLC

- Gartner’s View
  - Build Security Into the Design Phase
    - Translate Security Requirements
    - **Adopt Threat Modelling Practices**
    - Distribute and Promote Secure Coding Practices
    - Automate Governance of Open-Source Software

https://www.gartner.com/en/documents/3986517

Microsoft Secure Development Lifecycle (SDL)

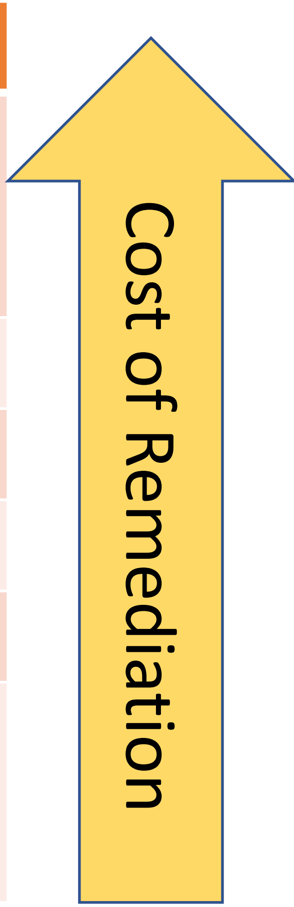
- Training / Education on Security Best Practices
- Define Security Requirements – linked to Threat Modelling
- Define Metrics and Compliance Reporting – for security quality e.g. severity thresholds
- **Threat Modelling**
- Establish standard security features / design requirements
- Cryptographic standards and requirements
- Management of third-party components
- Approved tools
- Static Analysis Security Testing (SAST)
- Dynamic Analysis Security Testing (DAST)
- Penetration Testing
- Incident Response Plan and Processes

See https://www.microsoft.com/en-us/securityengineering/sdl/practices

Approaches to Finding Security Vulnerabilities

Often left until late in the development lifecycle

Life Cycle Stage	Manual Methods	Automated Methods
Runtime / Live	Bug-bounty programme Reviewing security bulletins from vendors	Vulnerability scanning Attack surface management
Deployment	Manual checks	Scanning for vulnerabilities
Testing	Penetration testing	Dynamic scanning
Build	Code review/pair programming	Static code analysis
Design	Threat modelling	Analysis of flow diagrams
Requirements	Selecting security non-functional requirements	Computer assisted generation of security NFRs (e.g. from profile questionnaire)



Benefits of Threat Modelling

- Helps identify and prioritise threats, early in the lifecycle
  - Helping to optimise resources and limited budgets
  - Reducing risk exposure
- Considers evolving threat landscape
- Helps developers design and build secure software.
- Develops security skills/mindset within project/engineering teams
- Encourages collaboration on security initiatives

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The Chartered Institute for IT

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BCS DevSecOps Group

https://www.bcs.org/membership-and-registrations/member-communities/devsecops-specialist-group/

Roy Harrow - chairdevsecops@bcs.org

Q + A

Some Useful Talks on YouTube

- IT-SECX 2019 | Keynote - Adam Shostack: Threat Modeling Lessons from Star Wars
  - https://youtu.be/nd02oPnMdR4
- PASTA Threat Modeling for Cybersecurity | OWASP All Chapters 2020 Presentation
  - https://youtu.be/8k-I3vn8C2A
- Using the Threat Modeling Manifesto to Build an Enterprise Threat Modeling Program, 2022
  - https://youtu.be/jeHL8PXtezc
- Threat Modeling 2.0 - Developer's flavour - Emil Kvarnhammar, DevSecOps London Meeting, 2023
  - https://www.youtube.com/live/_4gbV7Roc_o
- Threat Modeling using Microsoft Threat Modeling Tool, 2021
  - https://youtu.be/Wry2get_RRc
- Threat modelling with OWASP Threat Dragon, 2022
  - https://youtu.be/mL5G8HeI8zI