LECTURE IX

Software Engineering and Version Control

SECTION I

Why Discuss Software Engineering?

Project Failure

Have you worked on a project that failed? (school project, CS project, etc.)

Why did the project fail?

- Missed deadline
- Poor communication
- Budgetary issues

Reasons for Project Failure

- **70% of organizations experienced project failure** (KPMG, 2023)
- The most common factors for project failure were…
  1. **Lack of clear goals** – unclear project objectives
  2. **Poor risk management**
     - Common risks are…
       - **Scope creep** – initial project objectives aren't well-defined and deliverables are slowly added
       - Poor product performance, cost, time, health and safety
  3. **Poor communication**

Reasons for Project Failure (Cont’d)

Which **factors** contributed to each of the following projects’ failure?

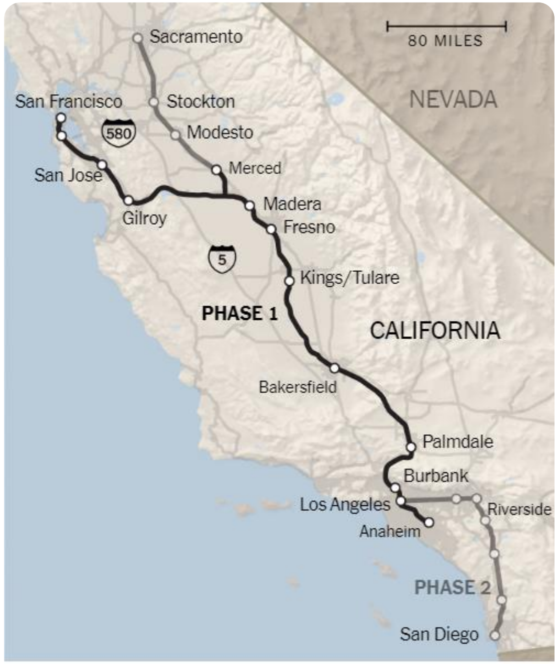
- **Boeing 737 MAX**
  - Poor communication – pilots were not informed of the existence of the flight stabilization software, its potential to fail, and how to handle failure
  - Poor risk management (health and safety) – the lack of pitch sensor redundancy made flight stabilization more likely to fail
- **Baltimore Bridge Collapse**
  - Poor risk management (health and safety) – the bridge was not designed to withstand the impact of the vessel which struck it

Reasons for Project Failure (Cont'd)

I/A

Which **factors** contributed to each of the following projects' failure?

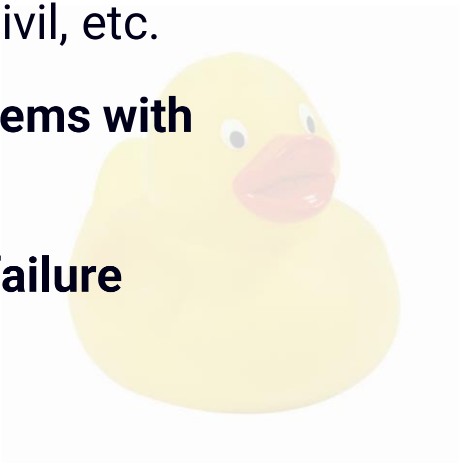
- **California High Speed Rail**
  - Lack of clear goals – the original goal was to connect Bay Area and LA with a nonstop route
    - Detours added as political compromise; construction began in the Central Valley
  - Cost overruns – $33 bil estimate rose to $113 bil
  - Poor time estimates – not projected to be completed in this century



Source: California High Speed Rail Authority • By The New York Times

Software Engineering

- Software engineering is the design, development, testing, and maintenance of software applications
    - It's not about simply writing code; **it's about *how* we write code**
- We will connect the processes behind software engineering to other engineering disciplines… mechanical engineering, electrical engineering, civil, etc.
    - This will give insight into **best practices for building systems with complexity and scale**
    - There are processes to **mitigate the chances of project failure**



Software is Everywhere!

- Many interdisciplinary engineering projects involve writing programs…
    - Control algorithms, device drivers, software for managing manufacturing systems, CAD, CAM, etc.
    - Engineers often **write custom scripts** (small programs) to automate their work in software like MatLab, LabVIEW, Ansys, Solidworks, NX, and Altium
- Again, even if you don’t write code, **software engineering *processes* can improve your project**

SECTION II

Defining the Problem

Problem Definition

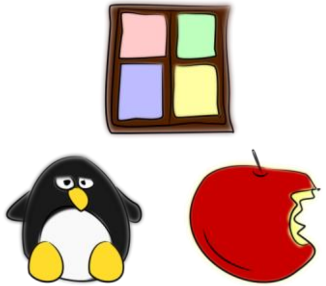
- Most projects that fail do so because of unclear goals or **poor problem definition**
- Your product, whether it's a device, a program, or a structure, **must satisfy the problem provided by a client**
- A **problem** is composed of **requirements** and **design constraints**
    - **Requirements** are statements that define what the product is supposed to do
    - **Design constraints** constrain the ways the product can be designed and implemented

Functional vs Nonfunctional Requirements

- **Functional requirements** – what the product must do
  - Ex) “The coffee maker shall make hot coffee for the user”
- **Nonfunctional requirements** – how the product does the task (how it behaves)
  - These are **often words that end with -ility**
    - Ex) usability, reliability, security, scalability
  - Defines performance requirements, security, usability, etc.
  - Ex) Usability – “The CAD software target audience is engineers.”
  - Ex) Performance – “The cleaning robot must sweep 100ft^2 in 5 minutes”

Design Constraints

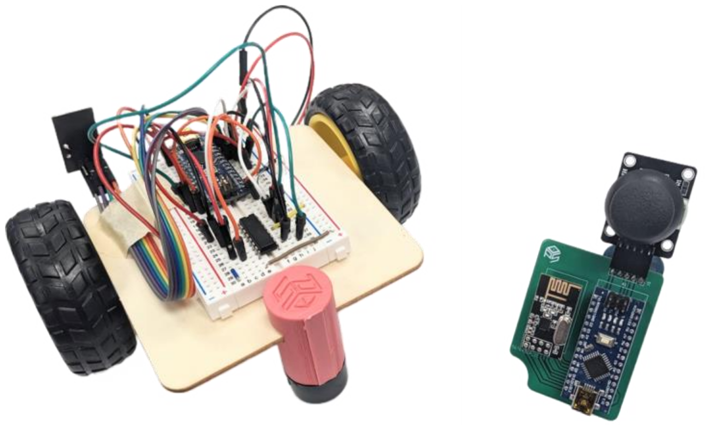
- Design constraints limit how the product can be made
  - Platform requirements – Is the product meant for phone or computer? Mac or Windows?
  - Cost requirements – How much money can be spent on the project’s development?
  - Time requirements – When does the client need the project completed by?



Example Requirements

Determine whether each of the requirements from the 2024 OPS Capstone Project are **functional or nonfunctional requirements or both**. Identify the **design constraints** as well.

2024 Capstone Project Link



SECTION II

Why Methodologies Matter

House Building Analogy

Let’s say a client hires you to build a house.
What are the **steps to build** the house?

- **Ask the client for their requirements** (Requirements)
  - How many stories, how many bedrooms/bathrooms?
- **Draw up a blueprint**; **create a bill of materials** (Design)
- **Build the house** (Implementation)
- **Test the house** for functional plumbing, working electricity etc. (Verification)
- **Give the house to the client** (Deployment)

House Building Analogy (Cont’d)

- In this house-building analogy, you need to do a lot of things for this project to go right…
  - **Planning** - set requirements so the client is happy, make blueprints, source materials
  - **Documentation** – write blueprints, get permits, track expense sheets, make construction schedule
  - **Versioning** - track iterations of the blueprints or bill of materials
- **The same is needed for any other project**… software, mechanical, whatever!

Software Development Methodologies

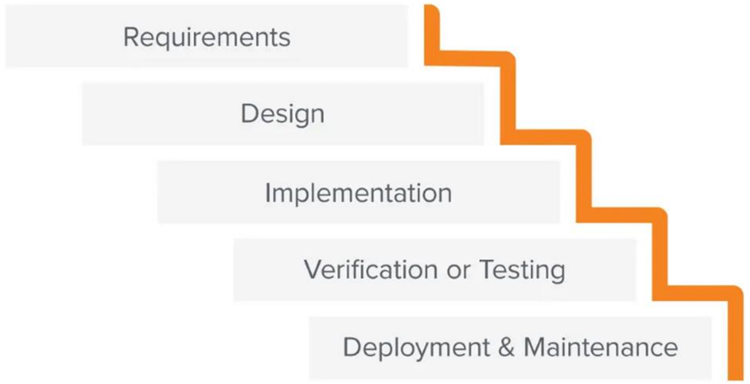
- A software development methodology is a **series of processes** used in software development…
  - Ex) Requirements specification, design, implementation, verification, deployment
  - These processes are facilitated by **planning**, **documentation**, and **version control**
- Applying a method to your project…
  - Improves team communication and collaboration
  - Reduces errors and rework

SECTION III

Software Development Methodologies

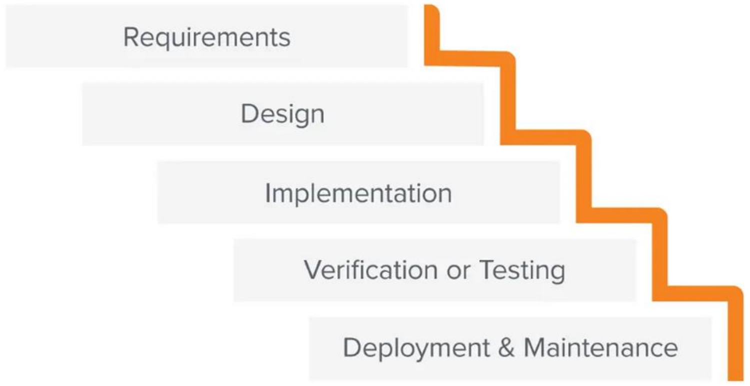
Waterfall Methodology

- The **Waterfall** model is a sequential development process that flows through project phases:
    - Analysis, design, development, and testing
    - Each phase is completed before the next phase
- Notice how **the phases are universal to any engineering project**, not just software



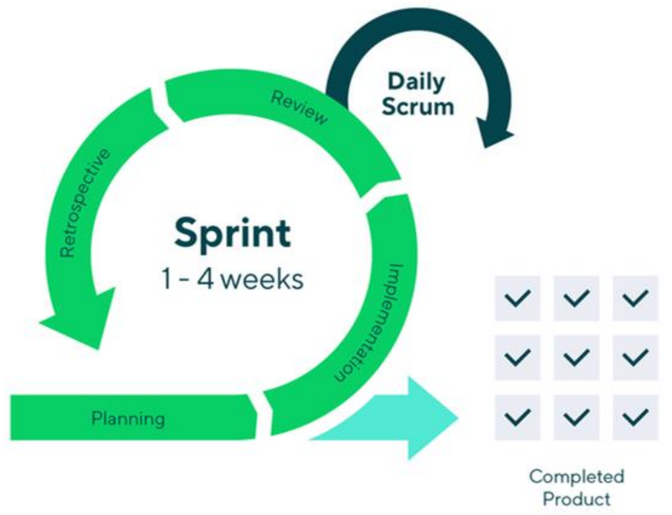
Waterfall Methodology (Cont'd)

- The documentation, requirements, and constraints are fleshed out very early on
  - Since research is done at the beginning, **time and cost estimates are more accurate**
- There is no backtracking - **parameters are harder to change** after they're set, unlike Agile



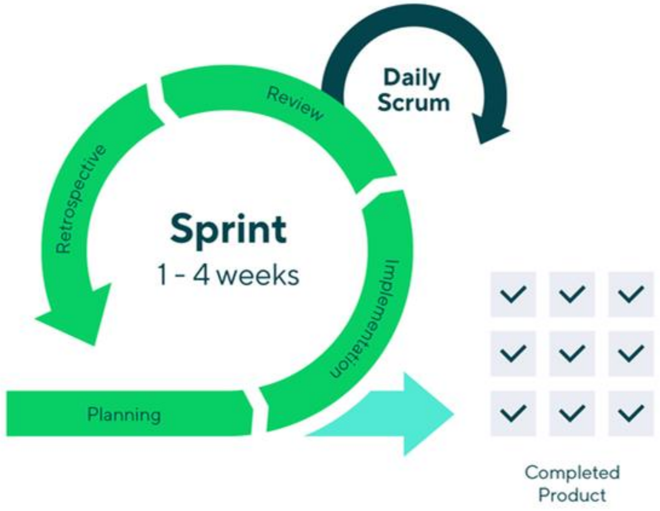
Agile Methodology

- **Agile** is an approach that reduces large projects into smaller tasks
    - The tasks are completed in **iterations**
- Each requirement is represented as a **user story** which is written from the user's perspective
- During a **sprint** – a 1–4 week iteration – developers work on tasks determined in an initial **sprint planning meeting**



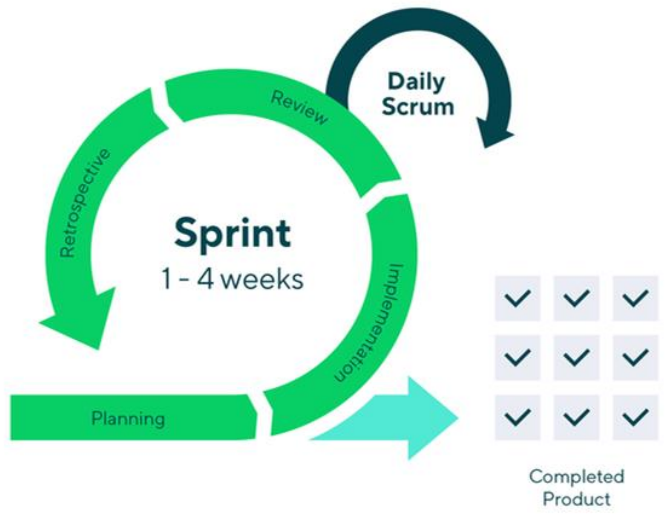
Agile Methodology (Cont'd)

- Developers hold a short, 10-minute **stand-up** meeting or **daily scrum** to discuss task progress
- Each sprint ends with…
    - **New features added** to the product
        - In the Waterfall model, the entire implementation is released at once
    - A **retrospective** meeting to evaluate areas of team and product improvement



Agile Methodology (Cont'd)

- Agile encourages **responsiveness** and **frequent collaboration** through repeated planning and regular meetings
  - If team members are not strong communicators, they may struggle to use Agile
- It is **easy for a team to veer off-course** when requirements (user stories) can be reassessed between sprints



SECTION IV

Version Control Systems

Version Control

- Version control tools save lives!
  - They **record changes to files** over time
    - Keeping track of different revisions of code, circuit designs, CAD model, etc.
  - You can **revert back to previous versions** if necessary
- We will look at two popular but different version control systems…
  - **Git** and **Perforce**

git PERFORCE

Git

- Git is a free, open source, and *distributed* version control system
  - A project is downloaded onto your local computer as a **repository**
  - You, the developer, makes changes to the repository, which they record as **commits** on your local repository
  - New versions of the repository are created as **branches**
- What does it mean to be distributed?
  - In a **distributed** version control system, multiple copies of the repository exist on different computers
  - A developer team must eventually merge all their code to one **main branch**

Perforce

- **Perforce** is a licensed, enterprise-oriented, and *centralized* version control system
  - Developers commit changes to a **central server** with one main copy of the project
    - This one project copy is the **single source of truth**
    - This creates less of a hassle when looking for the true project version
  - Developers **checkout** individual files and lock them to prevent others from making changes and creating merge conflicts
  - Nothing is local – all changes are submitted to the server, which can be **slower than a distributed version control system when changes are small**

Choosing a Version Control System

- **Git** is by far the **most widely used version control system** (VCS)
    - Why? It’s free, versatile, reliable, and also… very, very free
    - Developers can use it for free and remotely with services like GitHub
- Large files and code bases
    - **Git is not designed to handle large file storage** without additional plugins
        - There is natively a 2 gb limit on commits
    - **Git merge conflicts are really nasty in large, active repositories**
        - Enterprise companies with many files may prefer to use Perforce for this reason

SECTION V

Final Thoughts

Being a Better Engineer

- Bring intent to your next project by adopting a methodology
  - Why do projects fail? Unclear objectives, poor risk management, and bad communication
  - Successful projects are **well-planned** and **well-documented**
- Try using Git with your future projects
  - View the Version Control with Git Workshop material for more details
  - **Git can be used for more than just code!** Images, documents, and some CAD files can be archived with Git

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