SFWRENG / MECHTRON 3K04 Software Development

Today: Software Challenges

McMaster University
Engineering
Computing & Software

September 8th, 2025

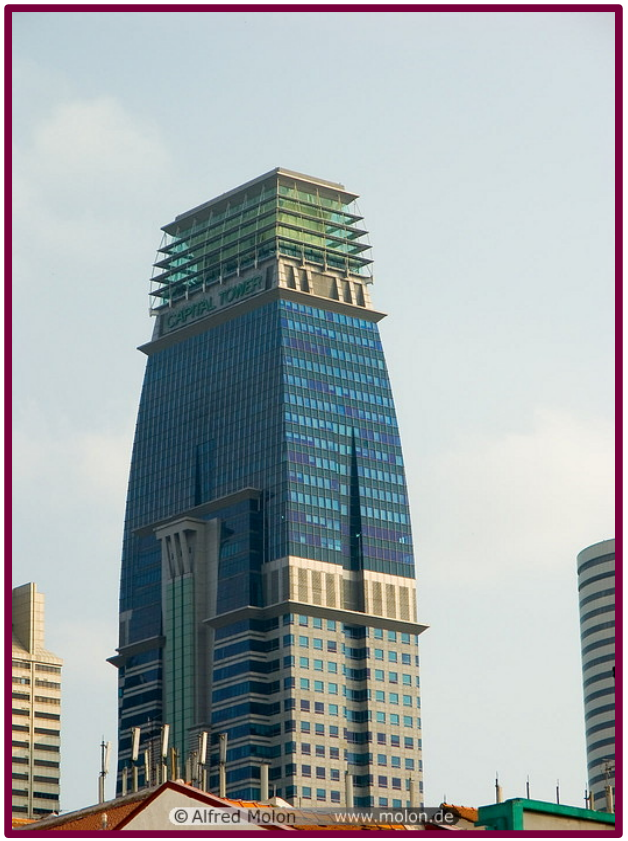
Dr. Angela Zavaleta Bernuy

Software Challenges

- Complexity
- Lack of continuity
- Software does not age in the same way that hardware does
- In general, it is difficult to automate tasks
  - Which is what we do all the time when creating software solutions
- It is easy to write software programs
  - But, it is difficult to get them to be correct, safe, secure and reliable.

Complexity

Three structures of varying complexity:



Complexity: How does it affect us?

Could you build this dog house without instructions?

With some prior experience, I may be able to build this without knowing any requirements or following a design.

Complexity: How does it affect us?

Could you build this house without instructions? (or without knowing the requirements or following a design?)

Maybe … **MAYBE** … we can build this house without requirements, but without a design plan? Or at least blueprint?

Complexity: How does it affect us?

Could you build this building without instructions? (or without knowing the requirements or following a design?)

NO

Without documentation, we cannot really maintain this building.

Complexity: How does it affect us?

The same is true for software!

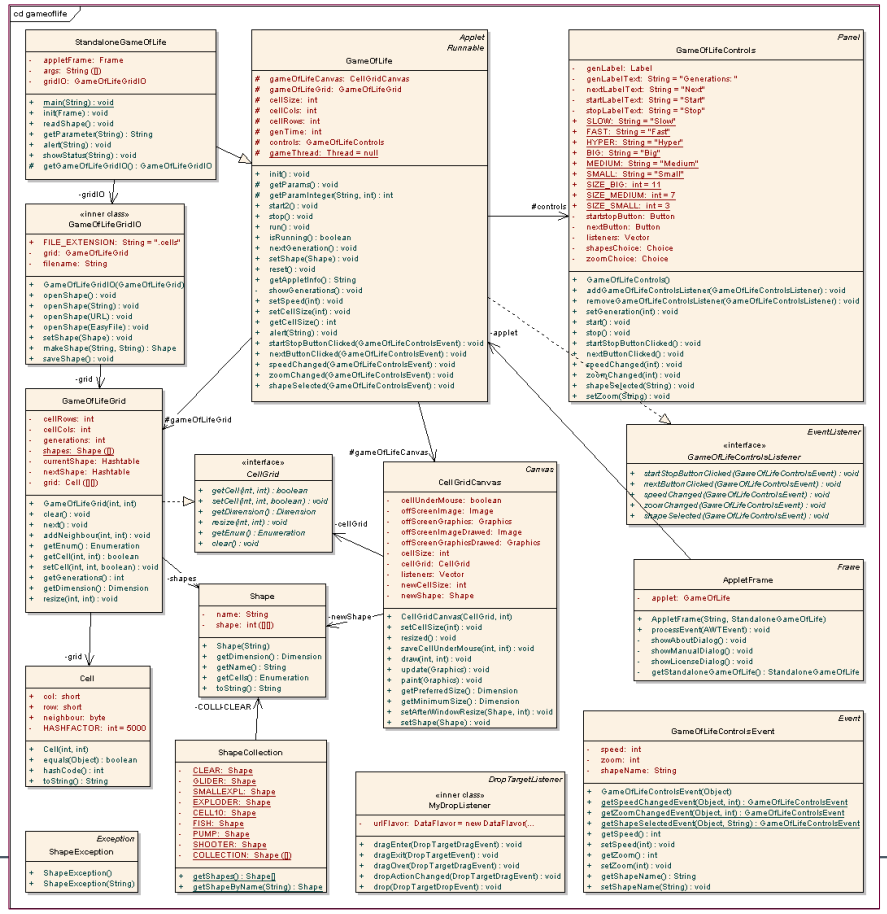
- We accept that we need to *engineer* these structures, but many people resist *engineering* software applications
- The complexity of a physical structure, is at least comparable to a software application.

But how do we measure complexity?

Complexity: Measuring it in Software

Example: UML class diagram.

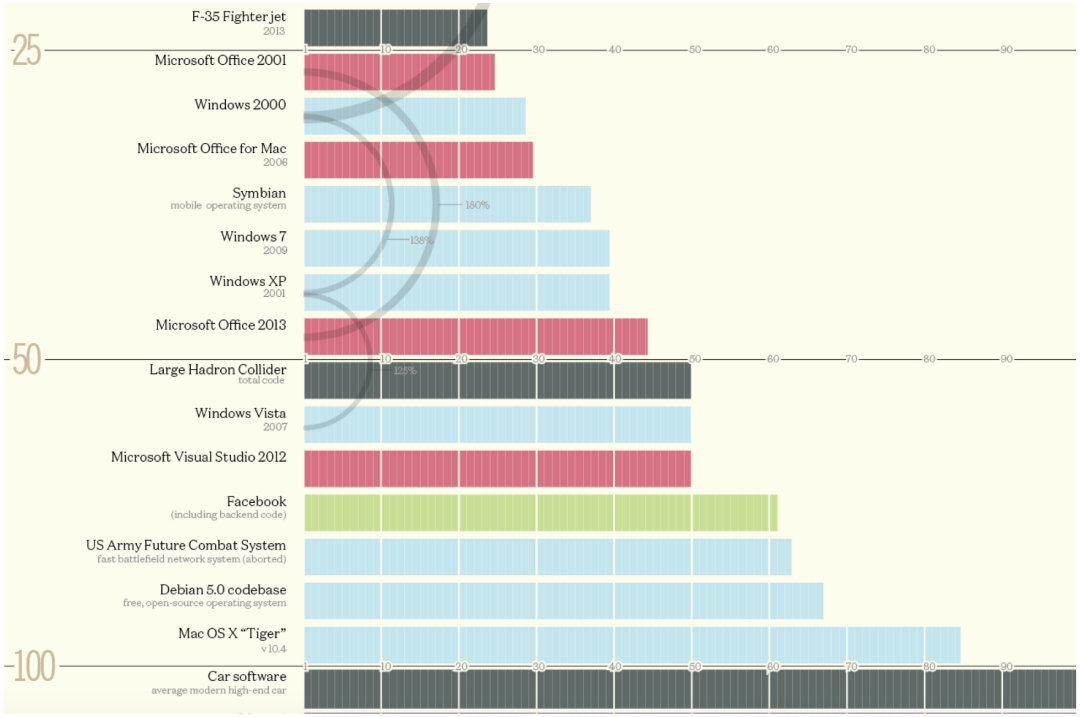
- Each class has a list of attributes (variables, fields) and a list of methods (operations, functions)
- The diagram also show the relationships between classes such as dependencies or inheritance.
- Each method will consist of a number of lines of code.

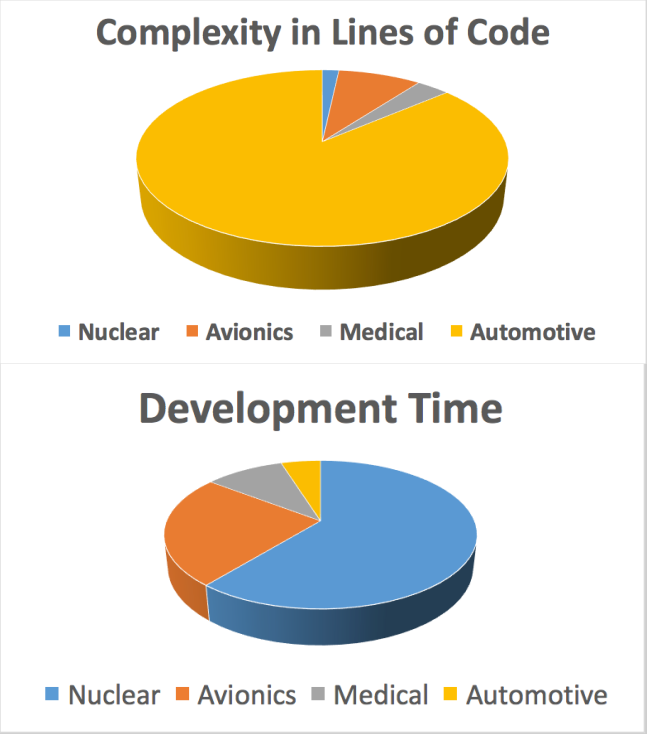


https://bitstorm.org/gameoflife/code/gameoflife-uml.png

Complexity: Lines of Code

Lines of code may not be a great measure of complexity, but they do tell us something about complexity!

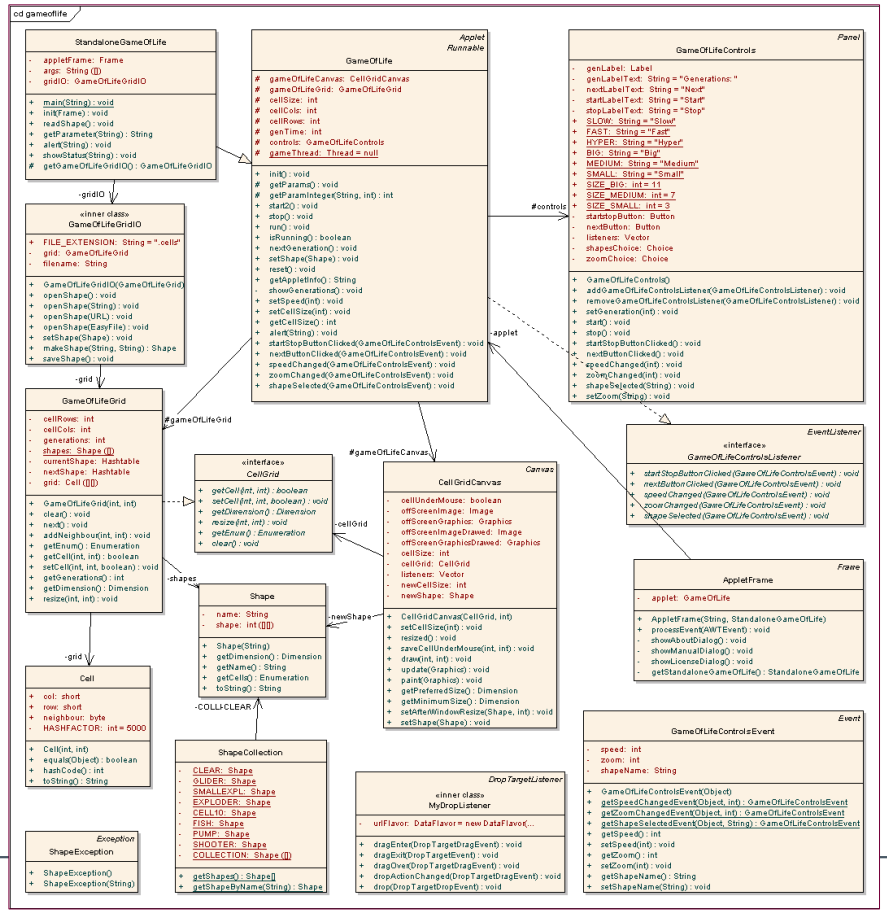




Complexity: Cohesion and Coupling

Example: UML class diagram.

- ***Cohesion*** is determined with how much information is held within a class/component/module (self-contained).
- ***Coupling*** is determined with how much a class/component/module relies on other parts to complete its functionality.

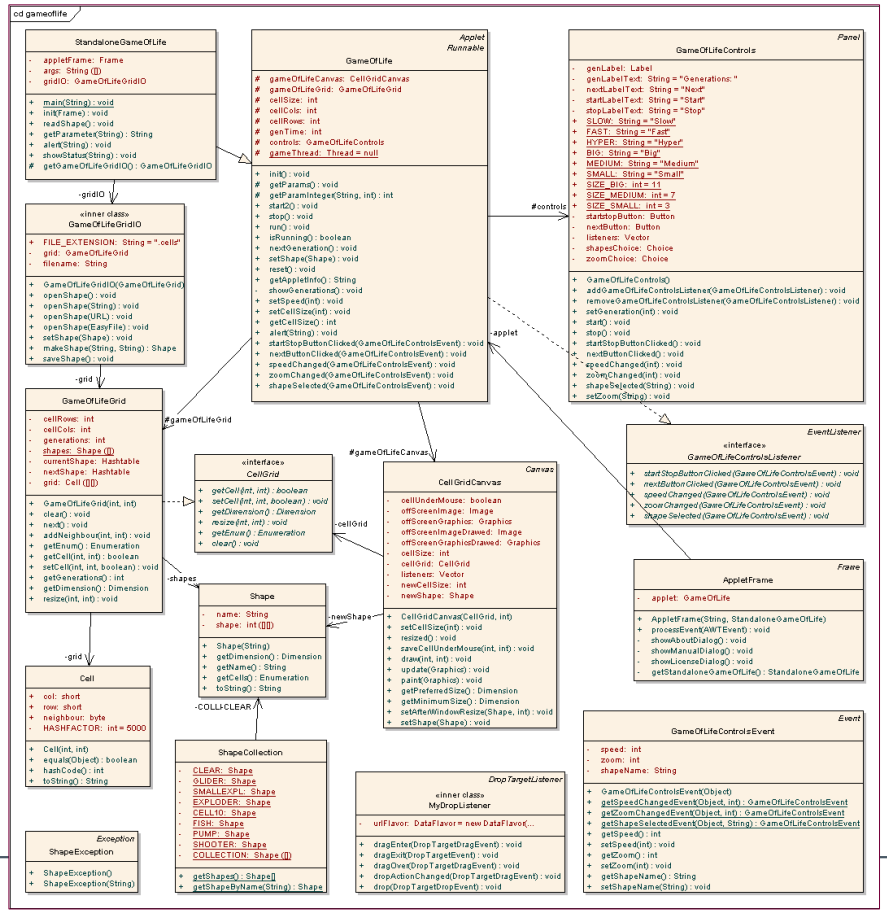


https://bitstorm.org/gameoflife/code/gameoflife-uml.png

Complexity: Cohesion and Coupling

Example: UML class diagram.

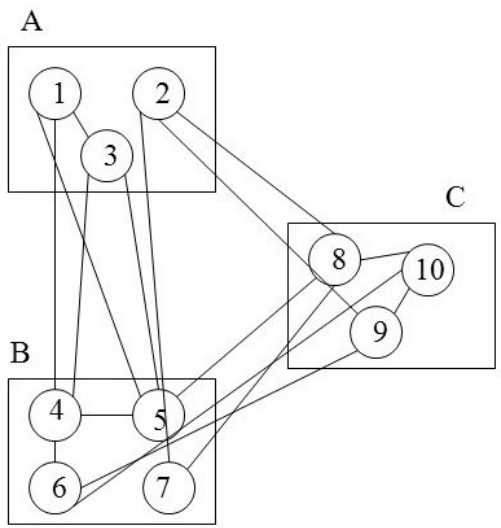
- Each module, should be ***highly cohesive***
  - Module understandable as a meaningful unit
  - Components of a module are closely related to one another
- Modules should exhibit ***low coupling***
  - Modules have low interactions with others
  - Understandable separately
- We need good modularization ☺



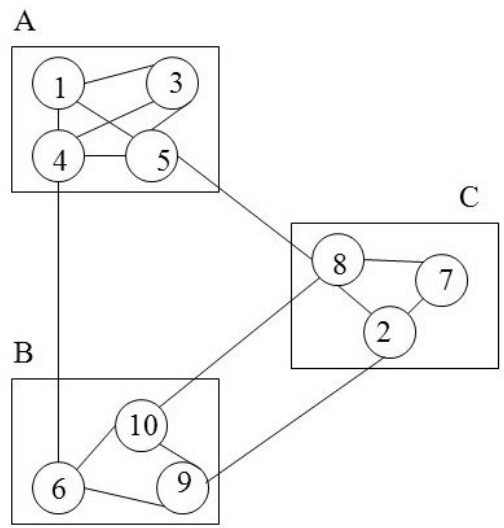
https://bitstorm.org/gameoflife/code/gameoflife-uml.png

Complexity: Cohesion and Coupling – Visually

We can evaluate ***coupling*** from an external view ("uses"), but we need to see internal details to judge ***cohesion***.



Bad modularization:
low cohesion, high coupling



Good modularization:
high cohesion, low coupling

https://devopedia.org/cohesion-vs-coupling

Complexity: Cohesion and Coupling – Match!

A

B

Which of these scenarios represent HIGH cohesion?

Complexity: Cohesion and Coupling – Match!

A

B

Which of these scenarios represent LOW coupling?

Continuity Property

- Most physical products, exhibit a continuity property. That is, an artifact behaves in a continuous, seamless, and unbroken behaviour.
- A small input/change, should result in a predictable small/change in output.
- E.g., a shovel

Continuity Property: Binary Search Example

Table
163
2
-45
3
16
9

Key	3	T
Key	20	F

```python
def binary_search(key, table):
    bottom = 0
    top = len(table) - 1

    while bottom < top:
        if (bottom + top) % 2 == 1:
            middle = (bottom + top - 1) // 2
        else:
            middle = (bottom + top) // 2

        if key <= table[middle]:
            top = middle
        else:
            bottom = middle + 1

    found = (key == table[top])
    return found
```

What if we decide to remove this else block?

Does Software Age?

- Software doesn't really behave different as it gets older.
- Right?!
  - Sort of!
- Software runs on hardware platforms.
  - The platform can change: it can age and malfunction, but it also can be much faster!
- Malfunctions and speed changes have implications for the way that the software behaves.
- If we do our job right, we can plan for those changes so that the software does not "age"

Takeaways!

- The engineering world has found that software is versatile
- Difficult and complex functions are easier to do in software than in hardware.
  - We need good modularity! **High cohesion and low coupling.**
- For centuries, we have learned to build system and test them relying on the fact that physical systems exhibit a continuity property, **but software systems do not!**
- Software does not age in the way that hardware does, so people disregarded this as a problem
  - However, software platforms (and the environment in which the software operates) **do age** and this does affect the way the software behaves!

SFWRENG / MECHTRON 3K04 Software Development

Today: Software Development Styles

McMaster University
Engineering
Computing & Software

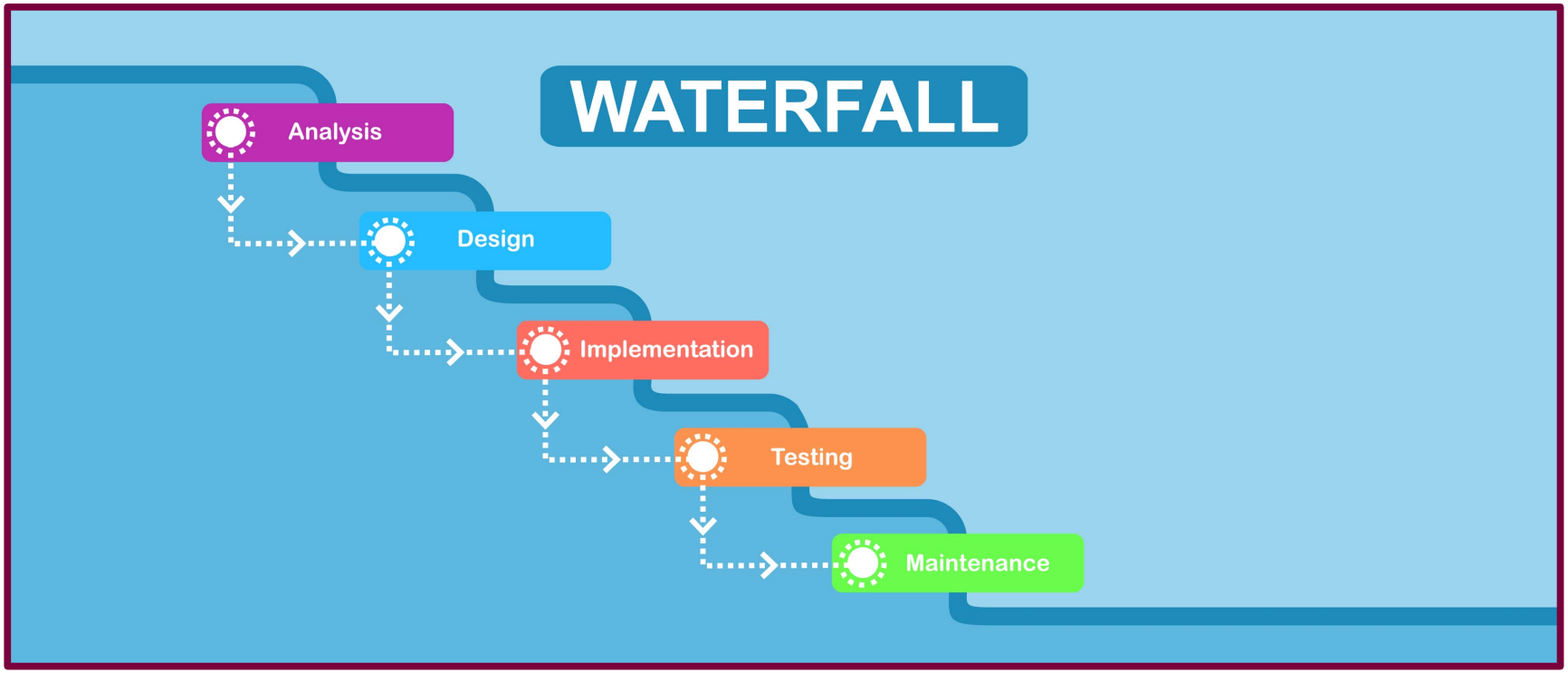
September 10/12th, 2025

Dr. Angela Zavaleta Bernuy

Software Development Styles

- How do you **approach** software development?
- How do you **scope** software?
- How do you **support** software?
- How do you know when **deliver** software?
- Today: Let's look at the many Software Development Life Cycle (SDLC) methodologies / models!

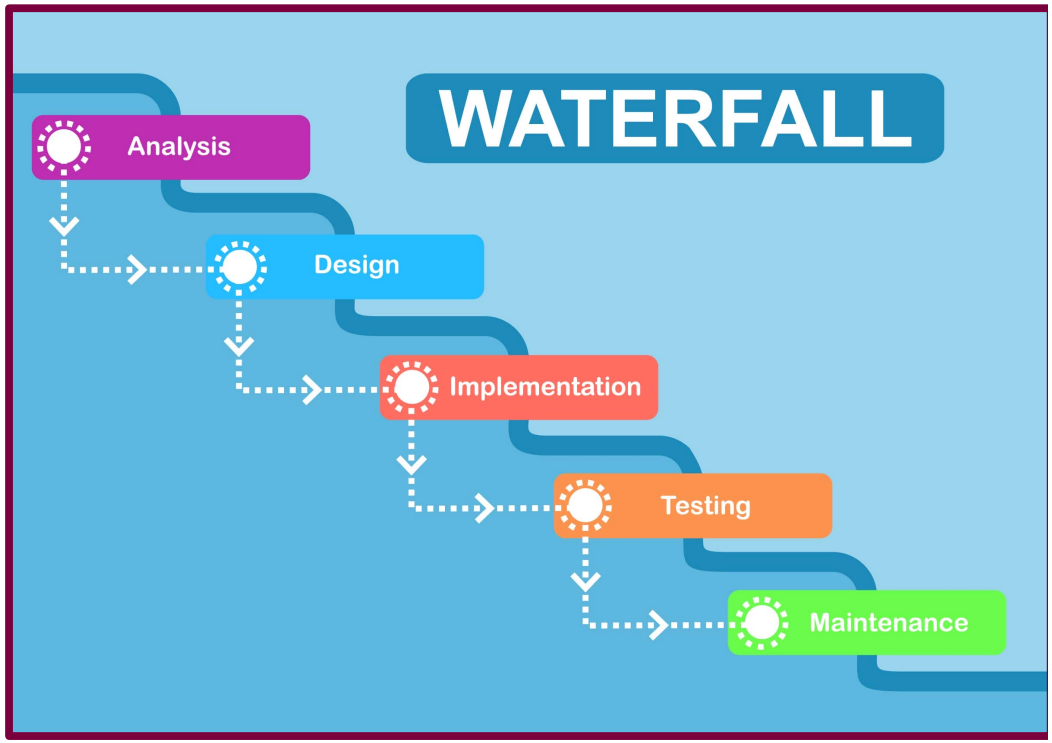
(Traditional) SDLC: Waterfall Model



https://www.chetu.com/blogs/technical-perspectives/understanding-software-development-life-cycle.php

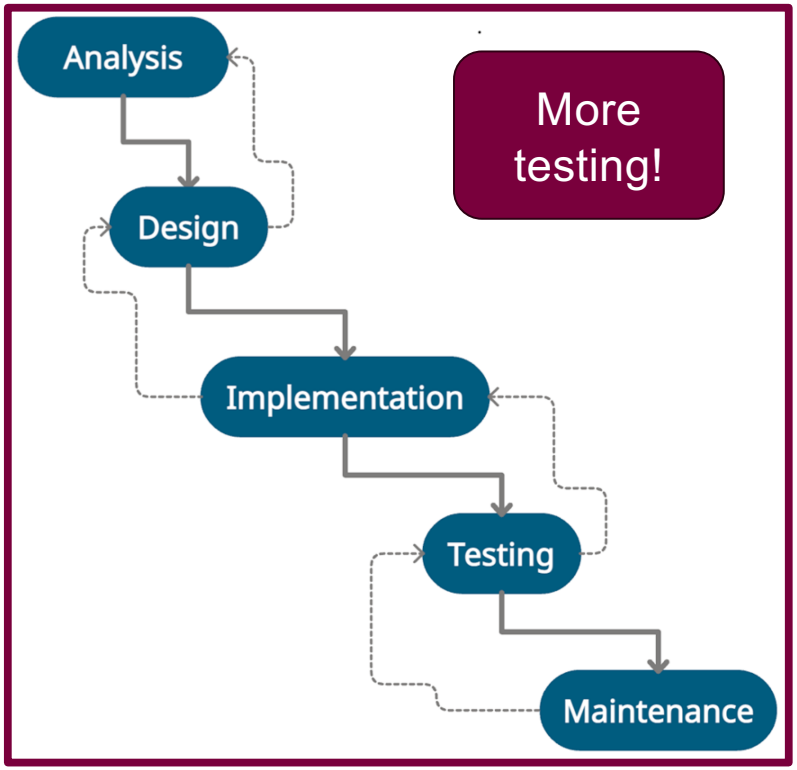
(Traditional) SDLC: Waterfall

- How do you **approach** software development?
  - Development is supported in sequential phases
  - Each phase must be completed before moving to the next
- How do you **scope** software?
  - In the requirements phase
  - A formal requirements baseline is set
- How do you **support** software?
  - In the maintenance phase
- How do you know when **deliver** software?
  - All requirements have been met and verified
  - Delivered in a single, final release



https://www.chetu.com/blogs/technical-perspectives/understanding-software-development-life-cycle.php

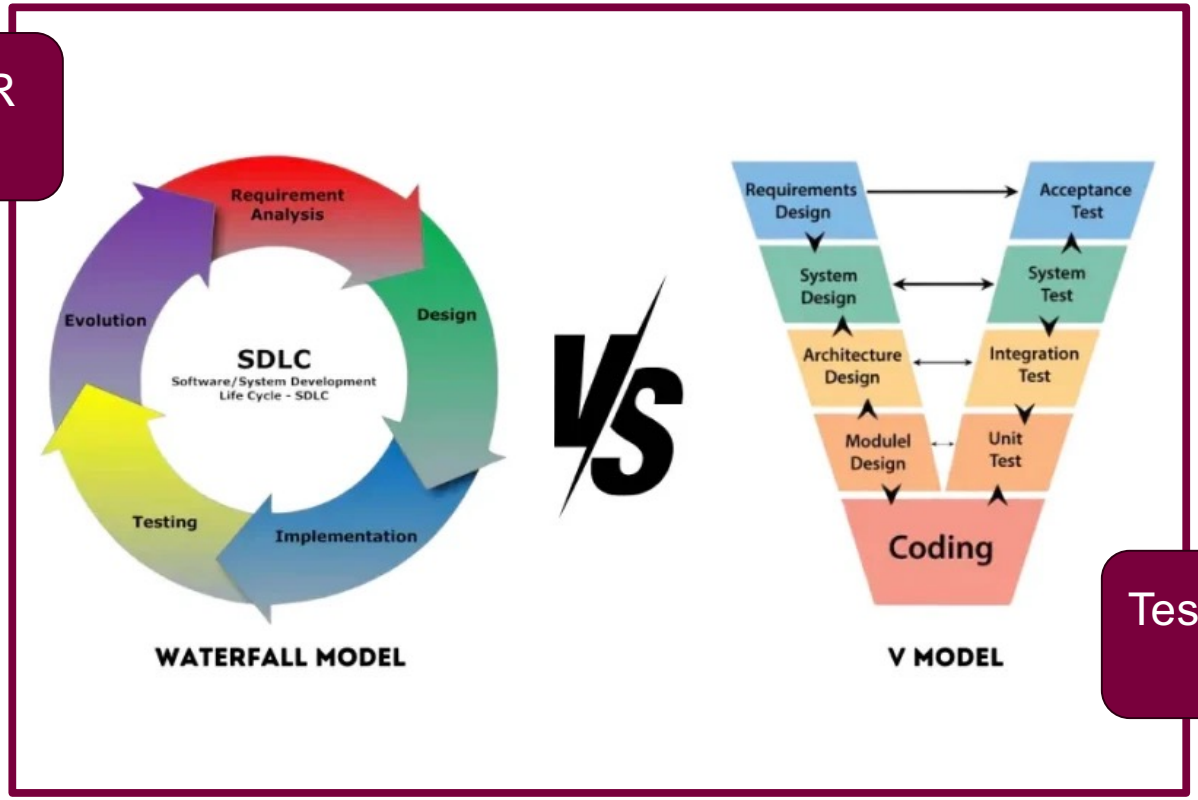
(Traditional) SDLC: Modified Waterfall



https://www.mdpi.com/2571-5577/6/6/108

(Traditional) SDLC: V Model

Testing AFTER development

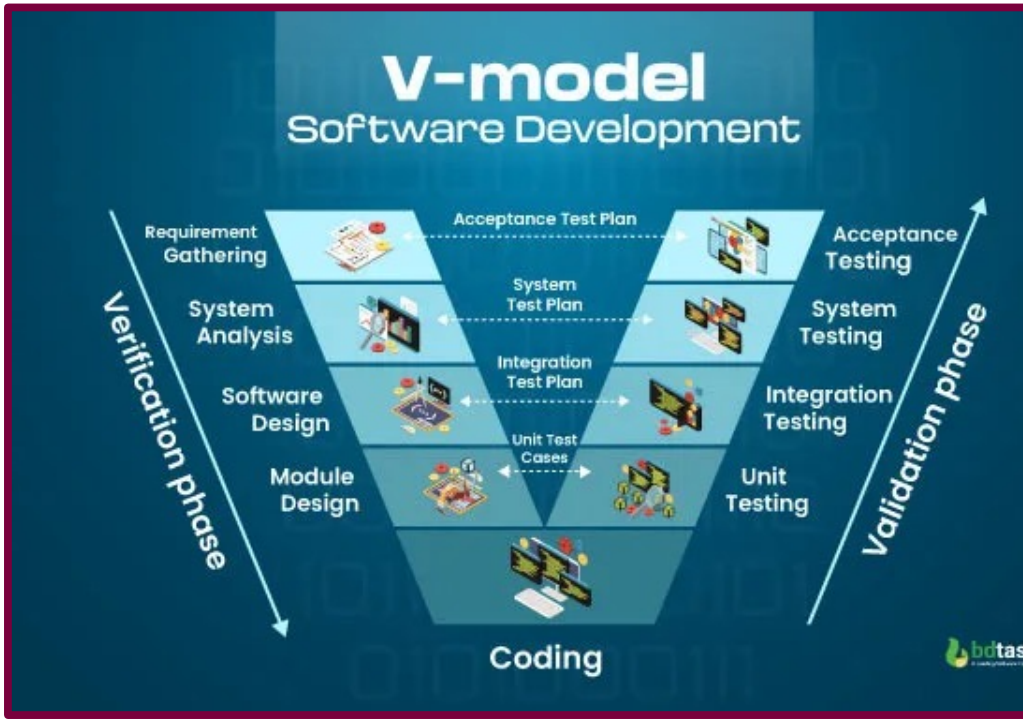


Testing ALONGSIDE development

https://stepmediasoftware.com/blog/v-model-and-waterfall-model/

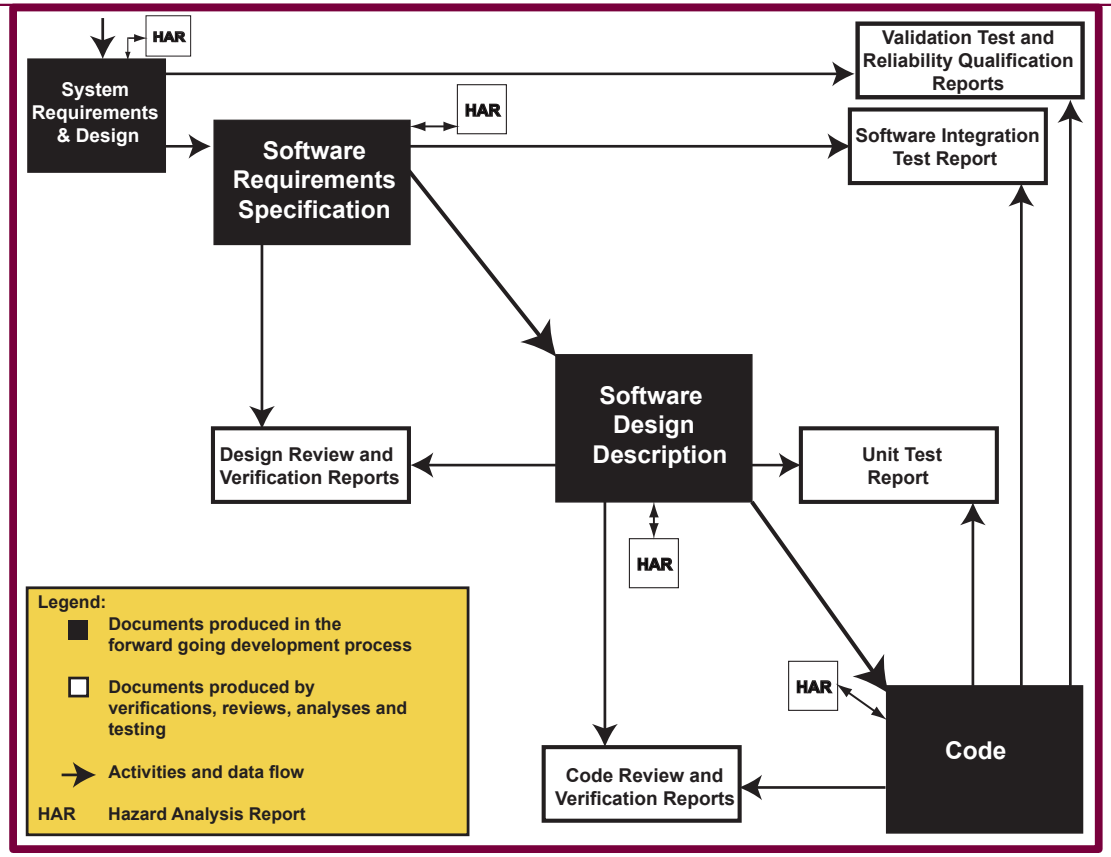
(Traditional) SDLC: V Model

- How do you **approach** software development?
  - Development is supported in sequential phases
  - Testing activities are planned in parallel
- How do you **scope** software?
  - In the requirements phase
  - A formal requirements baseline is set
- How do you **support** software?
  - In the maintenance phase
- How do you know when **deliver** software?
  - All requirements have been met and verified
  - Delivered in a single, final release



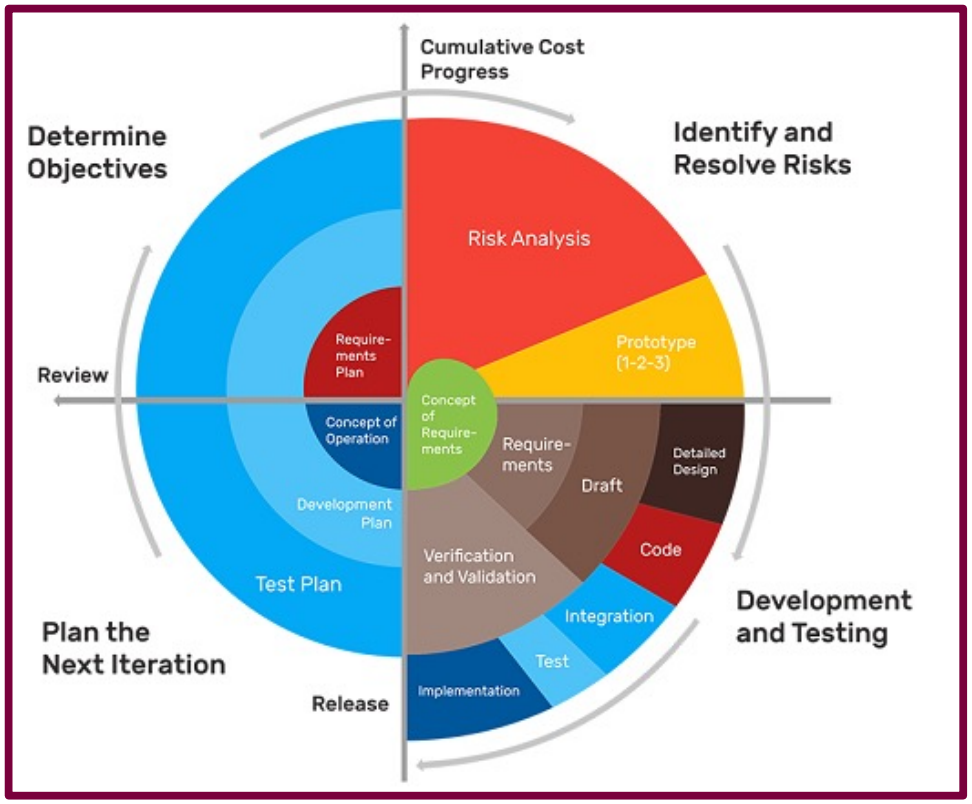
https://www.bdtask.com/blog/v-model-in-software-development

(Traditional) SDLC: Assurance in Critical Env.



https://www.cl.cam.ac.uk/archive/mjcg/FMStandardsWorkshop/talks/MLawford.pdf

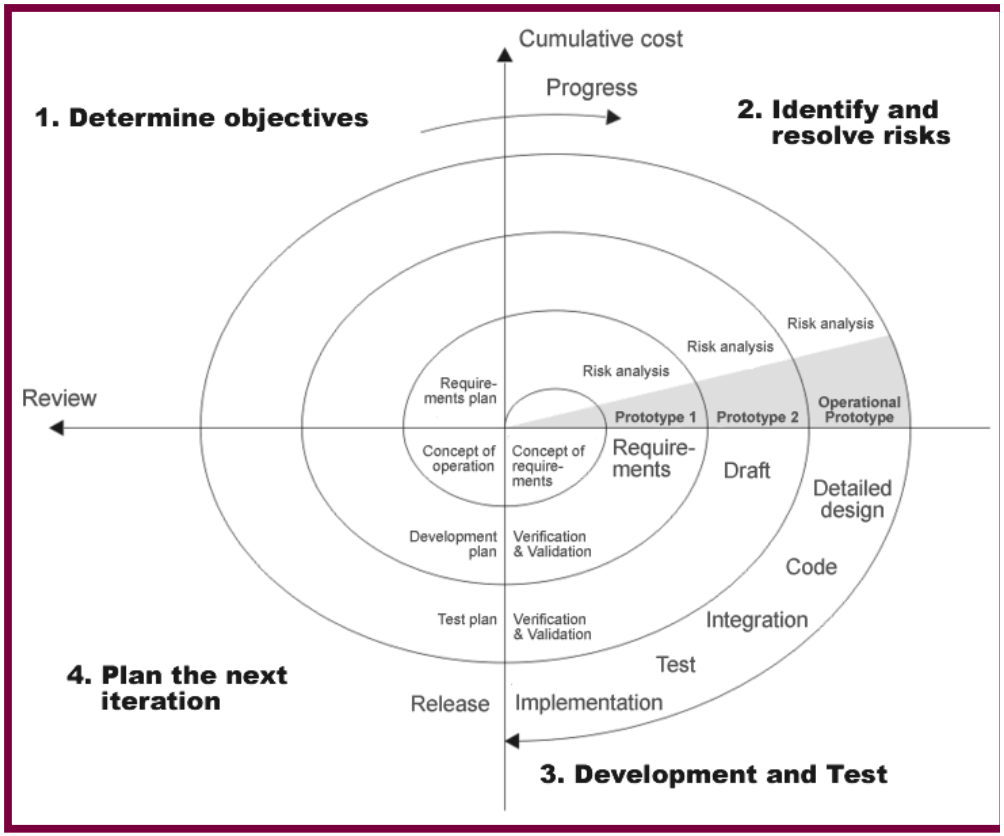
(Traditional) SDLC: Spiral Model



https://www.sovereignconsult.com/blog/spiral-model-methodology/.

(Traditional) SDLC: Spiral Model

- How do you **approach** software development?
  - Development is supported in iterative cycles
  - Planning, risk analysis, engineering, and evaluation
- How do you **scope** software?
  - Scope is defined incrementally at every cycle
  - Adapt to changing needs!
- How do you **support** software?
  - In the maintenance phase, but also during development
- How do you know when **deliver** software?
  - It can be incremental!



https://www.bdtask.com/blog/v-model-in-software-development

Let's get into the timeline…

1970s
Waterfall

- Sequential, plan-driven

→

1980s
V Model

- Verification and validation at every stage

→

Mid-1980s
Spiral Model

- Risk-driven iteration

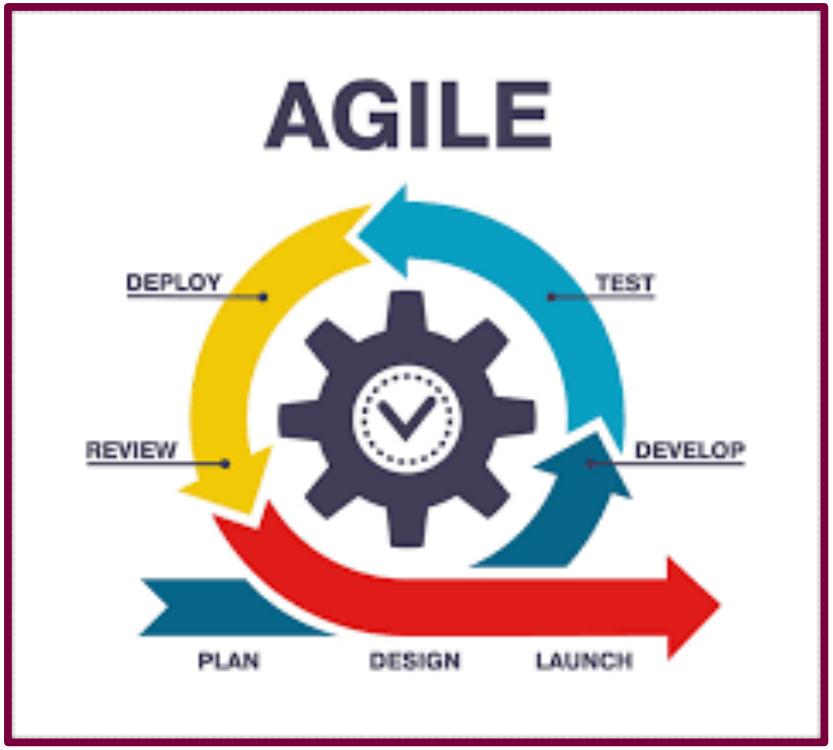
→

2000s

- We need **FASTER** results

SDLC: Agile

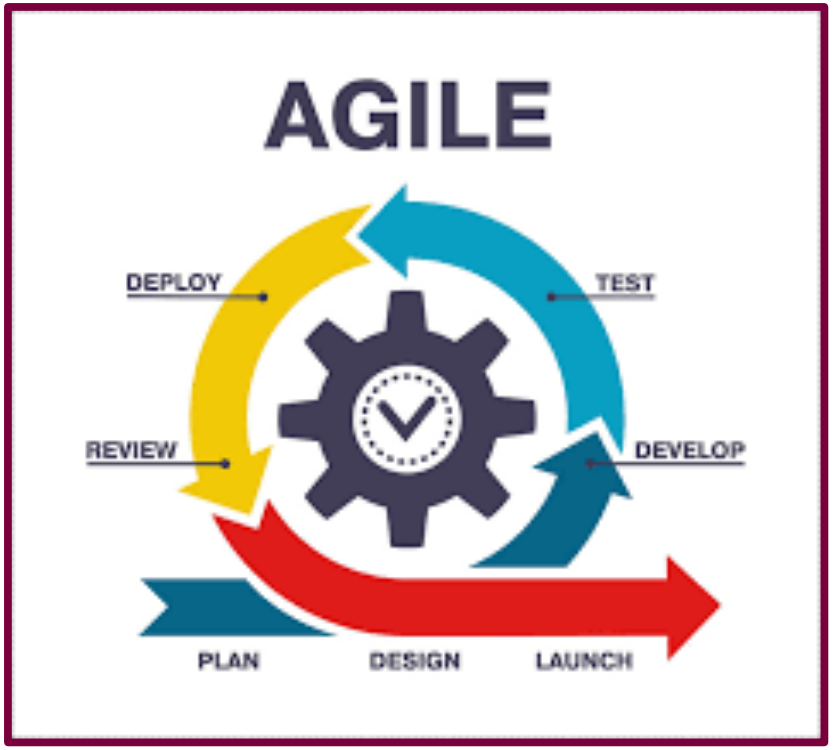
- Iterative and flexible approach that breaks projects into small, manageable cycles (*iterations*)
- More suitable to address changes in software development
- Incremental development, successive release of products
- Follow the Agile Manifesto principles: https://agilemanifesto.org/
- Different versions:
  - SCRUM
  - Extreme Programming (XP)
  - Kanban
  - Etc.



https://yuktisolutions.com/blog/agile-sdlc-for-your-project

SDLC: Agile

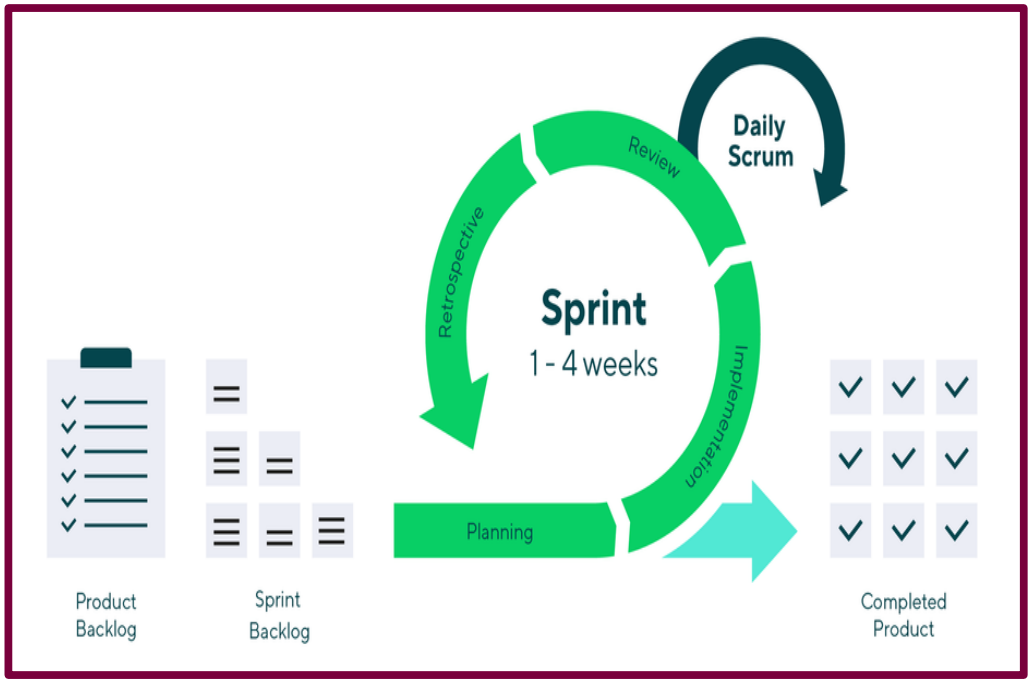
- How do you **approach** software development?
  - Iterative and incremental
  - Work is divided into short cycles (iterations)
- How do you **scope** software?
  - Managed in a prioritized backlog of features or user stories
  - Requirements are not all fixed upfront
- How do you **support** software?
  - Continuous support and ongoing improvement
- How do you know when **deliver** software?
  - Early and often
  - Working, tested and valuable



https://yuktisolutions.com/blog/agile-sdlc-for-your-project

SDLC: Agile – SCRUM

- Origin of the word: rugby
  - Players huddle and work together to move the ball forward
  - Which is what Agile teams should do!
- Users involved:
  - Product owner
  - Scrum master
  - Other members
- Workflow:

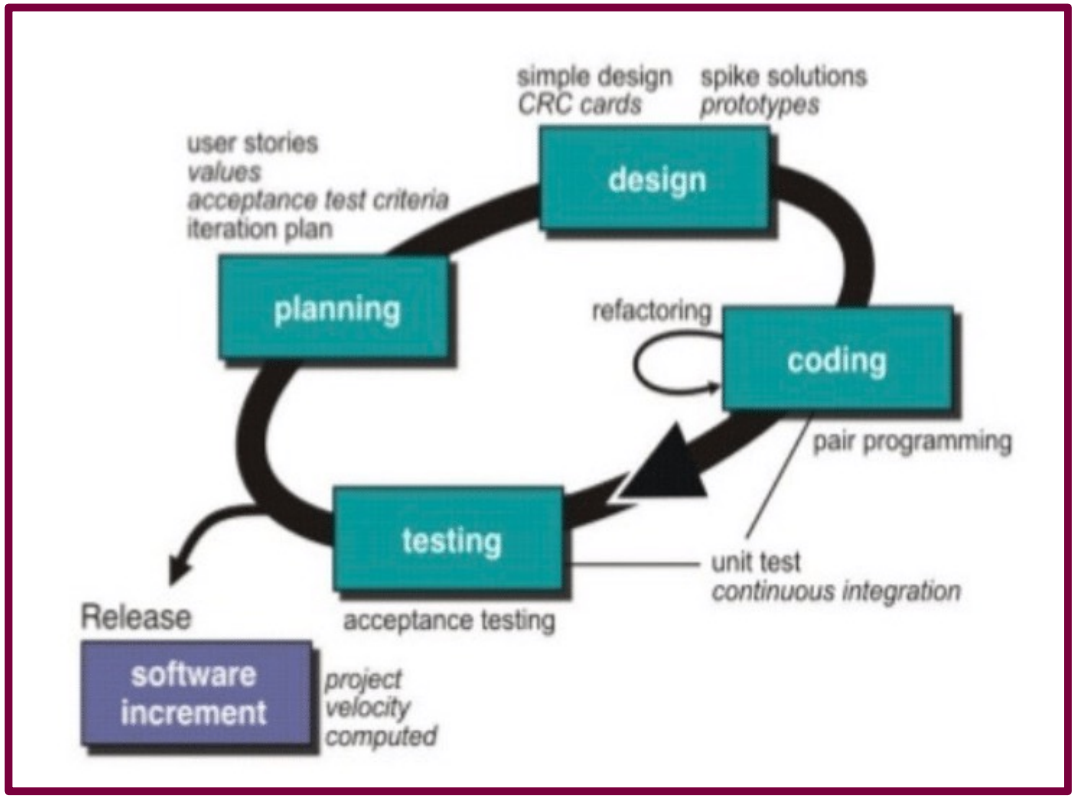


https://www.wrike.com/agile-guide/agile-development-life-cycle/

SDLC: Agile – Extreme Programming (XP)

- XP considers four basic activities: coding, testing, listening and designing
- Coding: "*Without code, there is no working product*"
  - Practices: pair programing, code review
- Testing: Test-driven development, continuous testing
- Listening:
  - Planning game: short planning session each iteration, typically once a week
  - Release planning: set goals for near-term releases
  - Iteration planning: details tasks for developers during the next short cycle
- Designing
  - Simple design: build the simplest system that works, then improve it continuously
  - Refactoring

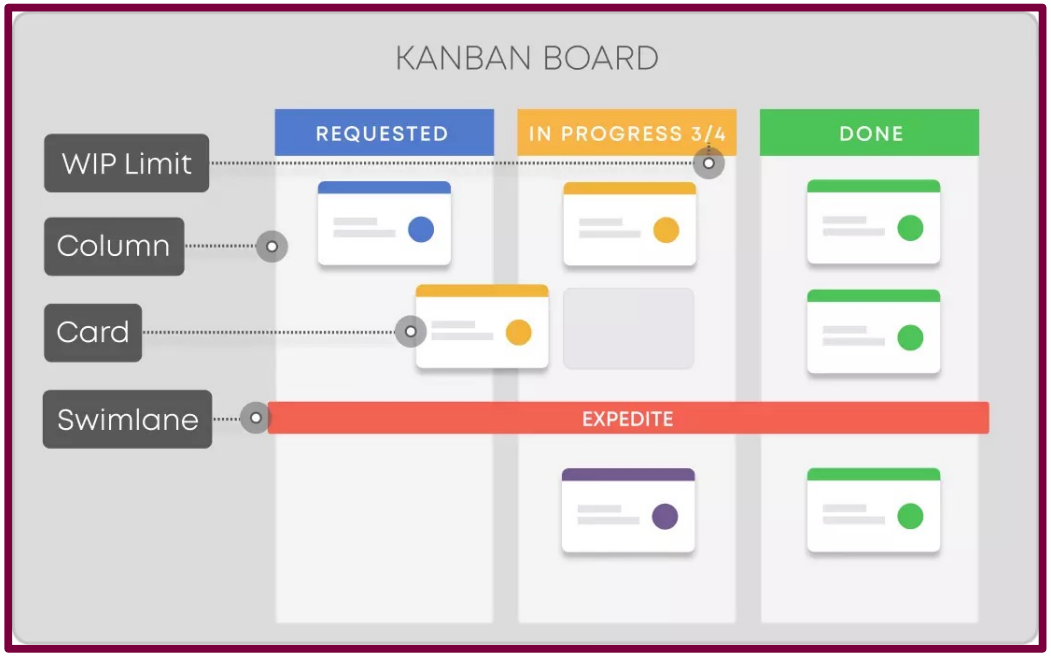
SDLC: Agile – Extreme Programming (XP)



https://www.researchgate.net/figure/Extreme-Programming-XP_fig2_356185795

SDLC: Agile – Kanban

- ”Visual card” in Japanese
- Focuses on visualize work, limit work in progress and improve flow
  - Visualizing work: Kanban board
  - Only allow a small number of tasks per column
  - Track how smoothly tasks move across
- Make process policies explicit
- Continuous improvement



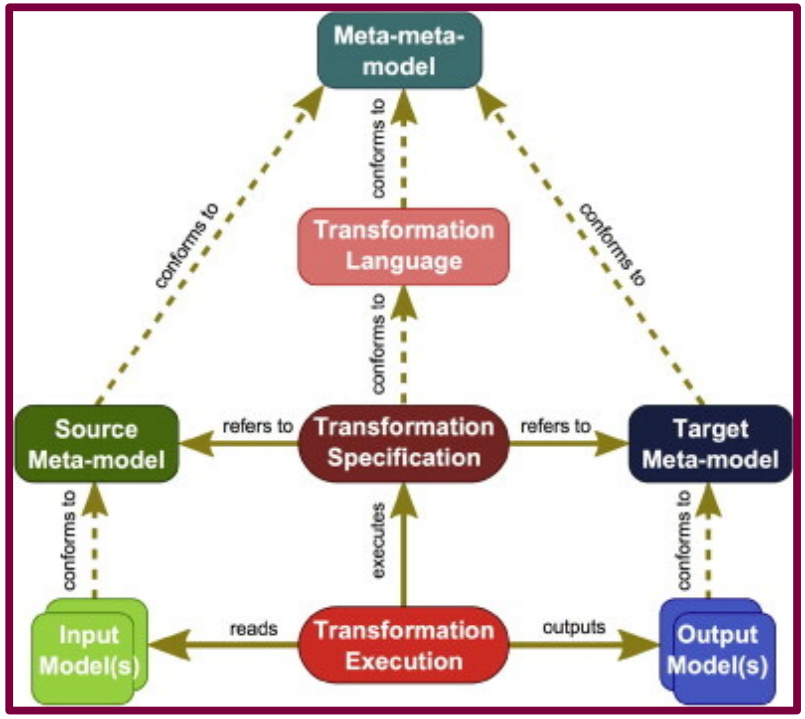
https://businessmap.io/kanban-resources/getting-started/what-is-kanban-board

Modern Trends in SDLC

- Agile:
  - Meant for smaller teams and smaller development cycles
  - Some people are distrustful of how Agile can be used to handle safety critical engineering
- Waterfall
  - Meant for bigger teams and bigger projects
  - Some people dislike how long it takes to develop using waterfall
  - Tried and tested for development of critical components
- We need a methodology that can fit in the SDLC to make development of safety critical systems efficient
  - Model-Driven Engineering!

Model-Driven Engineering (MDE)

- It makes models the main artifact of development instead of raw code
  - Code can be generated automatically from these models
  - E.g., we can transform a UML diagram into Java classes, or a state machine model into embedded system code ;)
- Goal: raise the level of abstraction so developers think in **domain concepts** rather than low-level programming
- Reduce manual coding and relies on code generation and automation tools
- **Is MDE an SDLC?**



https://www.sciencedirect.com/topics/computer-science/model-driven-engineering

MDE in Safety-critical Systems

- **Assurance**: Making statements about properties of a system and demonstrate that we have some adequate level of confidence that statements are true.
- In safety-critical systems, we want to *assure* that the system is safe, secure and dependable
- Traditionally, assurance was implicit
  - Developers would provide assurance by providing the documentation and test results of the system
- With MDE, assurance can be explicit
  - We will talk about this throughout the course

Takeaways!

- A number of SDLC models are being used and have been transformed across the years
  - Our focus is safety critical systems, for which spiral and V model are used often
  - In particular, the spiral model emphasizes the iterative nature of hazard analysis
  - Of course, we can use other SDLC models, but keep hazard/risk analysis in mind
- MDE is prevalent in many industries, specially for safety-critical systems
- Explicit assurance is needed to ensure the systems we develop are safe, secure and dependable

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September 18, 2025

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JHE Lobby

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Brighter World

Next Week!

- Project:
  - You will get your board
  - Team contracts
  - Two more tutorials
- Requirements!