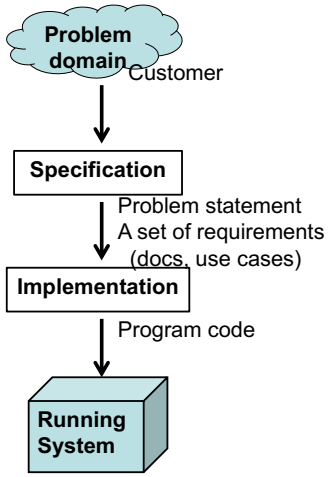
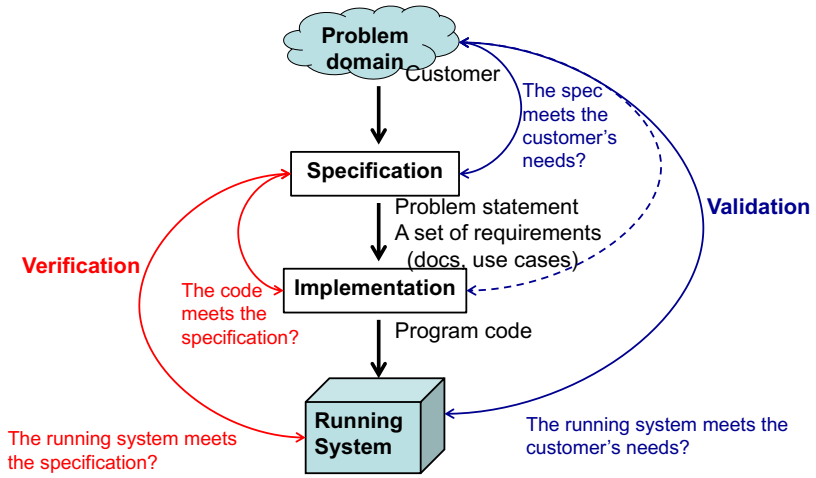
Software Testing: Verification and Validation

Software Development



Verification and Validation (V&V)

- Verification
  - Testing whether a system is developed in accordance with its specification (i.e., a set of gathered requirements).
    - Ensures you built it right.
- Validation
  - Testing whether a system meets your customer's needs.
    - Ensures you built the right thing.



Defects in V&V

- Defects found in verification
  - Occur when the implementation and/or running system fail to meet the specification.
    - e.g., The spec. of a printer's firmware states that the printer stops printing when its paper tray becomes empty.
      - However, the firmware doesn't stop the printer when a tray is empty.
- Defects found in validation
  - Occur when a specification is wrong or misses the customer's needs.
    - e.g., The firmware's spec. states nothing about what it should do when a tray is empty.
      - Thus, the firmware does not stop printing when a tray is empty.
      - However, the customer wants the printer to stop.

Importance of Validation

- It is possible to correctly define requirements in a specification, so…
  - Developers can clearly tell what needs/features to implement and how to implement them.
- However, it is not easy to make the specification sufficiently comprehensive, so..
  - Developers do not miss the customer's needs.
  - Requires numerous "what-if" questions.
    - What if a tray becomes empty? The current printing job should stop? What if another tray has papers? Can the printer still accept extra print jobs from computers?
  - Requires "acceptance test" by the customer

An Example Defect in Validation

- Firmware for Boeing 787's generator control unit (GCU)
  - Does periodic "status check" every 10 milliseconds.
  - Has a counter (timestamp) with signed 32-bit integer.
    - 2^31=2,147,483,648
    - 10 msec * 2,147,483,648 = 248.551 days
    - An integer overflow occurs once GCU has continuously operated for 248.551 days.

Counter	Status
0	G
1	G
2	G
⋮	⋮

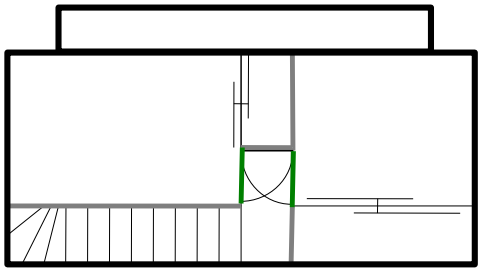
- GCUs fall into a failsafe mode if they are powered on for 248+ days.
  - A 787 aircraft has 4 GCUs.
  - If all of them are powered on at the same time, the aircraft can lose its control completely.

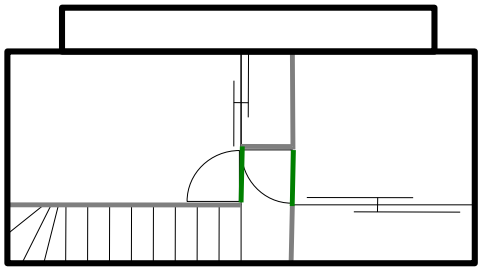
- Customer
  - Didn't think and wasn't asked how long a GCU should be able to keep running if it is not turned off.
    - Status check might look like a minor feature in GCU development.
- Developer
  - Didn't think and wasn't instructed (by the specification) about up to how long a GCU can/should run if it is not turned off.
  - Decided to use the simplest data type for the counter and didn't have a chance to think more about it.
    - Status check might look like a minor feature in firmware development.

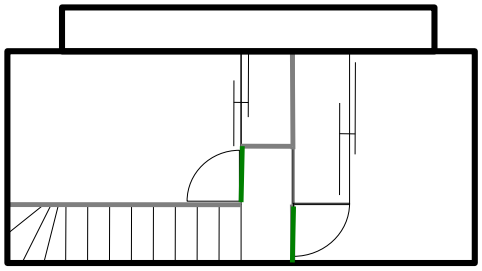
XXX-day Problems

- 248-day problem
- 494-day problem
  - Occurs if a counter/timer relies on an unsigned 32-bit integer
    - Server OSes, WiFi routers, network switches, etc. etc.
- 24-day and 49-day problems
  - Occur if a counter/timer relies on an signed/unsigned 32-bit integer and its counting/timing resolution is 1 millisecond.
- 830-day problem
  - Occurs if a counter/timer relies on an unsigned 32-bit integer and its counting/timing resolution is 60 Hz (1/60 second; 16.67 msec)
- Year 2038 problem (Unix millennium bug)
  - Many OSes have a timer that counts time in second from 1970/1/1 0:00:00, using a signed integer. The timer will overflow at January 19 in 2038.

When I was a kid...

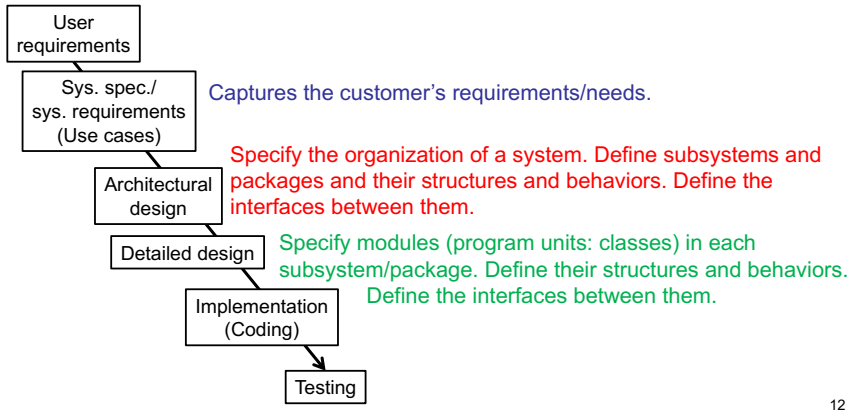






Waterfall Process Model

- One of the earliest models to describe development processes.

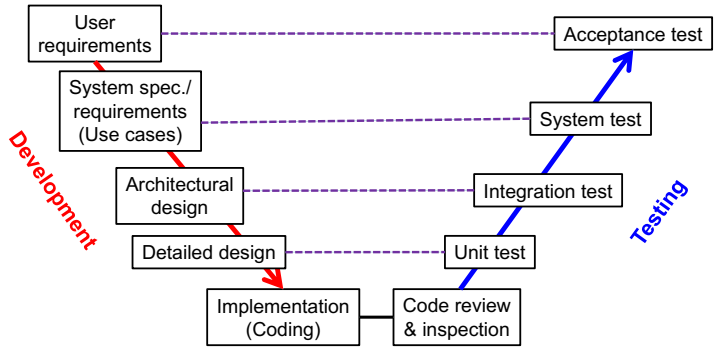


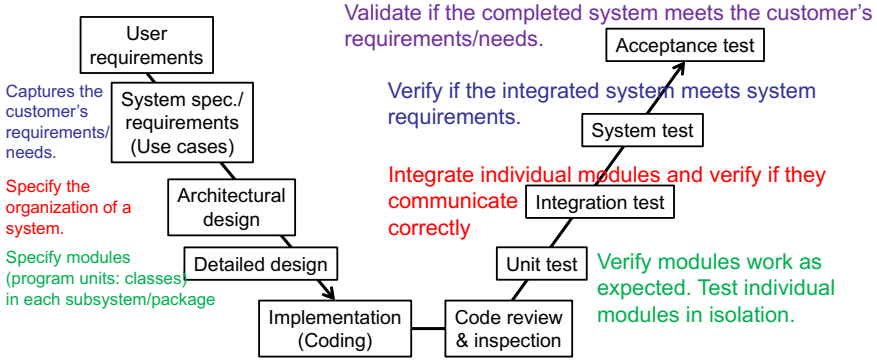
Problems in Waterfall Process

- Defects are found at the end of the project.
  - Testing does not take place until the end of the project.
- It is often too late and too expensive to push feedback up the waterfall.

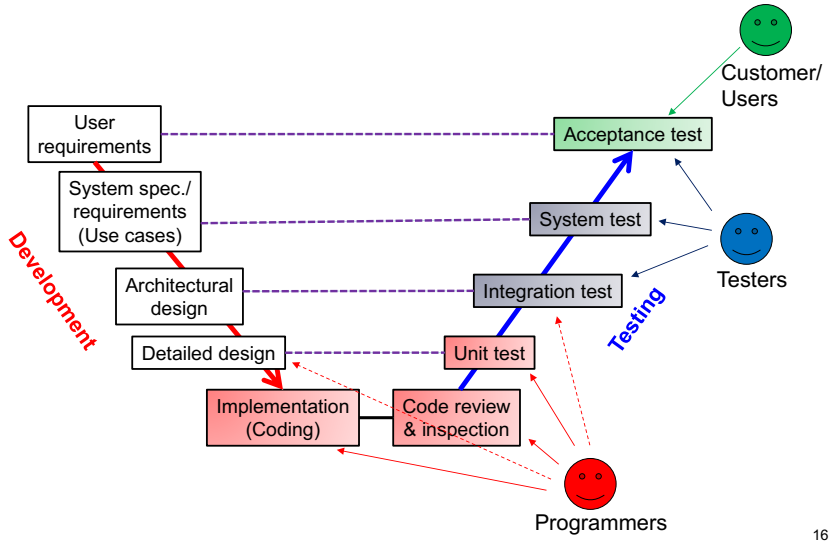
V-Model

- Extends the waterfall model.
  - Testing phase is expanded
- Explicitly states which testing phase corresponds to which development phase.





Division of Responsibilities



Test Levels and Test Types

- Test level
  - A group of test activities that are organized and managed together.
  - Corresponds to a “development level.”
  - e.g., unit test, integration test, system test and acceptance test.
- Test type
  - Focuses on a particular test objective.
    - e.g. functional test, non-functional test, structural test, confirmation test, etc.
  - Takes place at one test level or at multiple levels.

- Test levels and test types are orthogonal.

	Functional test	Non-functional test	Structural test	Confirmation test
Acceptance test				
System test				
Integration test				
Unit test				
Code rev&insp.				

- Different projects have difference policies on which test types involve in which levels.
- For example…

	Functional test	Non-functional test	Structural test	Confirmation test
Acceptance test	X	X		
System test	X	X		X
Integration test	X	?	X	X
Unit test	X	?	X	X
Code rev&insp.	X	?	X	X

Test Types: Functional Test

- Functional test
  - Focuses on the behaviors of tested code/software
    - Driven by the descriptions and use cases specified in the specification.
  - Black-box testing
    - Treat the tested code/software as a black-box
      - Testing *without* knowing the internals of tested code/software
    - Give an input to tested code/software and compare its output with the expected result.
      - Coarse-grained testing: Testing the external behaviors of tested code/software

	Functional test	Non-functional test	Structural test	Confirmation test
Acceptance test	X	X		
System test	X	X		X
Integration test	X	?	X	X
Unit test	X	?	X	X
Code rev&insp.	X	?	X	X

Test Types: Non-Functional Test

- Non-functional test
  - Focuses on the non-functional quality characteristics of tested code/software.
    - Driven by the descriptions specified in the specification.
  - Security test
    - Check if security vulnerability exists in tested code/software.
  - Usability test
    - Ease of use/browse/comprehension, intuitive page/screen transition
  - Efficiency test
    - Performance (e.g. response time, throughput), resource utilization (e.g. memory, disk, bandwidth)

- Reliability test
  - Stress test (load test)
    - How does tested code/software behave under an excessive load?
      - » Example loads: huge data inputs, numerous network connections
  - Long-run test
    - Does performance degrade when tested code/software runs for a long time?
  - High frequency test
    - How does tested code/software behave when it repeats a certain task at excessively high frequency?
  - Fault-tolerance test
    - Can a tested code/software continue its operation under a fault?
  - Recoverability test
    - How can a tested code/software recover its operation and data after a disaster (e.g. physical damages of hardware, blackout)?
  - Compliance test
    - Data retention, access control, logging, etc.

- Environmental test
  - Configuration/compatibility test
    - Can the tested code/software be installed on certain OS(es) and HW(s)?
    - How does the tested code/software behave on certain OS(es) and HW(s)?
    - How does the tested code/software interact with an external required service(s)?
      - » Does it work with Version X of the service? How about Version Y?
  - Co-existence test
    - Can the tested code/software run correctly when other software/services run on the same machine?

	Functional test	Non-functional test	Structural test	Confirmation test
Acceptance test	X	X		
System test	X	X		X
Integration test	X	?	X	X
Unit test	X	?	X	X
Code rev&insp.	X	?	X	X

Test Types: Structural Test

- Testing the structure of an individual module or a set of (integrated) modules.
  - The structure of a system (i.e. a full set of (integrated) modules) = system architecture
- Revise the structure, if necessary, to improve maintainability, flexibility and extensibility.
  - Refactoring
    - » e.g. Replacing conditionals with polymorphism, replacing a magic number with a symbolic constant.
    - » Revising the interfaces of modules if an integration test fails.
      - » Interface: How modules interact with each other
  - Use of design patterns
    - » e.g., Replacing conditionals with the *State* design pattern
- White-box testing
  - Treat tested code/software as a white-box
    - Testing *with* the knowledge about the internals of the tested code/software
  - Fine-grained testing: Taking care of inetrnal behaviors of tested code/software

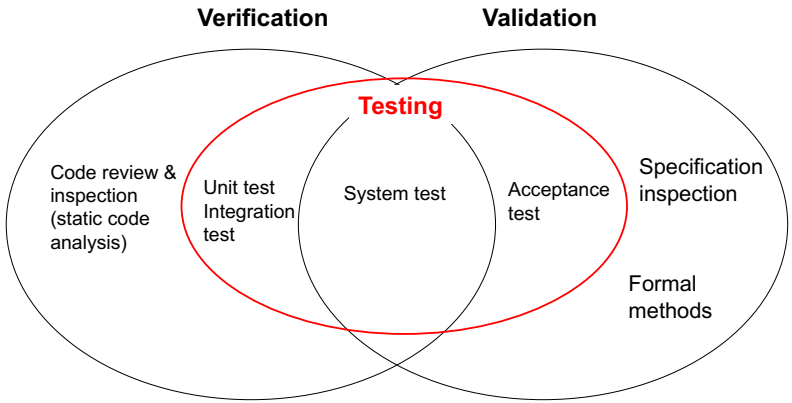
	Functional test	Non-functional test	Structural test	Confirmation test
Acceptance test	X	X		
System test	X	X		X
Integration test	X	?	X	X
Unit test	X	?	X	X
Code rev&insp.	X	?	X	X

Test Types: Confirmation Test

- Re-testing
  - When a test fails, detect a defect and fix it. Then, execute the test again
    - To confirm that the defect has been fixed.
- Regression testing
  - In addition to re-testing, execute ALL tests to check that the tested code/software has not regressed.
    - That is, it does not have extra defects as a result of fixing a bug.
    - Verifying that a change in the code/software have not caused unintended negative side-effects and it still meets the specification.

	Functional test	Non-functional test	Structural test	Confirmation test
Acceptance test	X	X		
System test	X	X		X
Integration test	X	?	X	X
Unit test	X	?	X	X
Code rev&insp.	X	?	X	X

V/V Methods



V-Model and Development Process

- V-Model can be used to define various iterative development process,
  - beyond waterfall process