Software Verification & Validation

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Handout 1

Acknowledgement

- Some slides in this lecture are adapted from
  - Slides from **Dr. Jittat Fakcharoenphol**'s Software Verification and Validation course at Kasetsart University
  - Slides from **Prof. George C. Necula**'s Software Engineering course at Stanford University
  - **Ammann and Offutt's Introduction to Software Testing**, Cambridge University Press, 2008

Software Verification and Validation

- Definitions
  - **Software Verification** is the process of checking that the software is built correctly according to its specification
  - **Software Validation** is the process that ensures that the software meets the customer's expectation

- In short,
  - **Software Verifier** asks *"Are we building the software right?"*
  - **Software Validator** asks *"Are we building the right software?"*

Two Main Methods of V&V

In this course, we will look at two main methods for software V&V

1. Software Testing

2. Formal verification

The Adriene Rocket Disaster

- On June 4, 1996 an unmanned Ariane 5 Flight 501 rocket launched by the European Space Agency exploded 37 seconds after its lift-off. The rocket was on its first voyage after decade of development costing $7 billion. The destroyed rocket and its cargo were valued at more that $500 million.

Picture from http://www.ima.umn.edu/~arnold/disasters/ariane.html

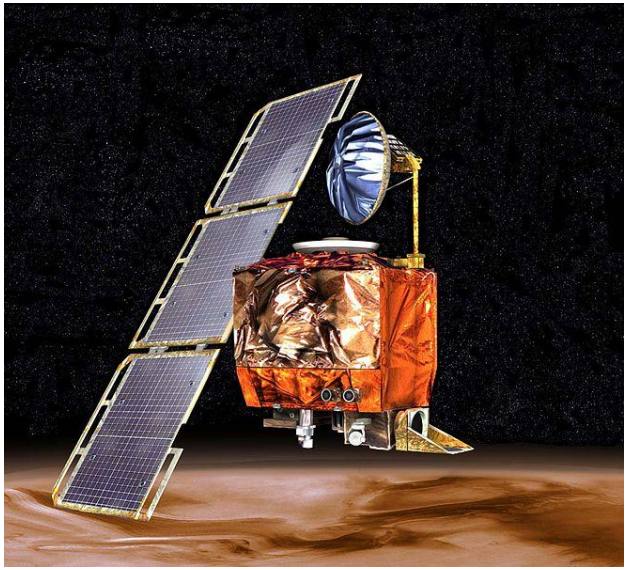
The Adriene Rocket Disaster

- Araine 5 reused the flight control software software from Ariane 4. But the Araine 5 flight path was considerably different and beyond the specification of Ariane 4 software.

- **Cause:** A data conversion from 64-bit floating point to 16-bit signed integer value. The floating point number which was converted had a value greater than what could be represented by a 16-bit signed integer. This created an *exception,* but the handler for this exception was not well designed and written.

Mars Climate Orbiter

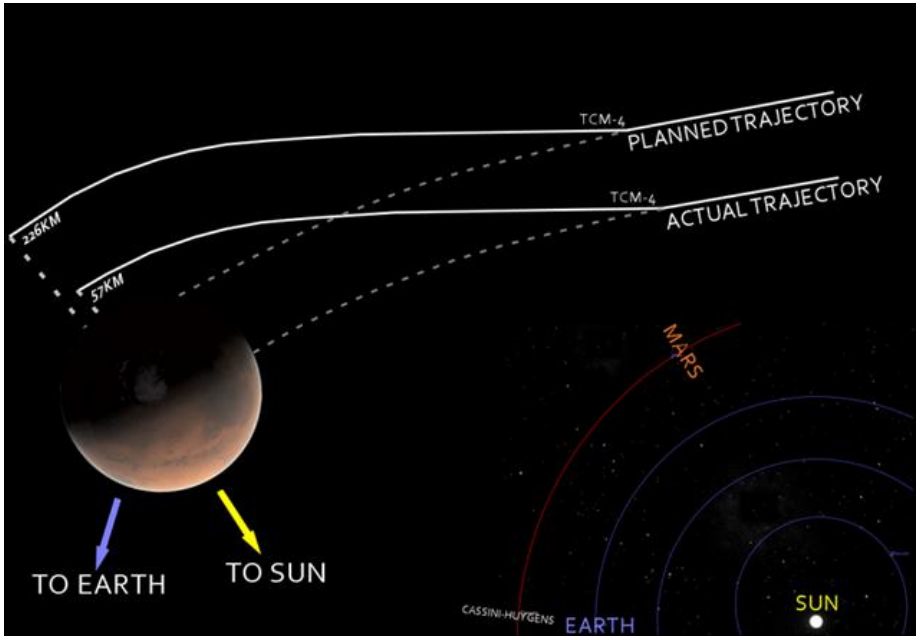
- Mars Climate Orbiter was a robotic space probe launched by NASA on December 11, 1998 to study the Martian climate and acts as a communications relay for Mars Polar Lander.
- The spacecraft entered Mars at an improperly low altitude, causing it to incorrectly enter the atmosphere and disintegrate.



Picture from Wikipedia

Mars Climate Orbiter

- *Mars Climate Order* was built by Lockheed Martin. NASA Jet Propulsion Lab was responsible for the flight.
- **Cause:** The flight system software on the *Mars Climate Orbiter* was written to calculate thruster performance using the metric unit *Newtons (N),* while the NASA team entered data using the Imperial unit *Pound-force (lbf)*.
- **Total Loss:** > $100 million



Testing

- **Testing** is the process of finding faults in the software.

- Testing can help increase the confidence that the software is correct against the specification.

- However, testing **cannot** 100% guarantee that the program is correct.

Faults, Error, and Failure

- **Definitions**
  - **Software Fault**: a defect in the software, also called a **bug**
  - **Software Error**: an incorrect internal state caused by some fault
  - **Software Failure**: Incorrect behaviors when the software runs

Medical Analogy

Got a headache and a sore throat = **Failure**

Physical Examination

High body temperature and inflammation of the throat = **Error**

Diagnosis

Common cold virus = **Fault**

The First Bug

9/9

0800 Arctan started { 1.2700 9.037 847 025
1000 " stopped - arctan ✓ 9.037 846 ?95 correct
13"c (032) MP - MC ~~1.6821[illegible]000~~ ~~2.13047[illegible]15 (-3)~~ 4.615925059(-2)
(033) PRO 2 2.130476415
correct 2.130676415
Relays 6-2 in 033 failed special speed test
In relay " 11.00 test.
Relays changed
1100 Started Cosine Tape (Sine check)
1525 Started Multy Adder Test.

1545 Relay #70 Panel F
(moth) in relay.
First actual case of bug being found.
1630 Arctangent started.
1700 closed down.

Faults, Error, and Failure

```
public static int numZero(int[] x) {
    // Effects: if x == null throw NullPointerException
    //          else return the number of occurrences of 0 in x

    int count = 0;
    for(int i = 1; i < x.length; i++) {
       if (x[i] == 0)  count++;
    }
    return count;
}
```

Test case 1: `numZero([2, 7, 0])` **Expected output** = 1

Test case 2: `numZero([0, 7, 2])` **Expected output** = 1

Testing and Debugging

- **Definitions**
  - **Testing:** evaluates the software by observing its execution
  - **Test failure:** a failure observed during testing
  - **Debugging:** identifies the faults which cause the test failure and correct them

- Testing may not trigger a fault into an incorrect behavior (i.e. a failure).

- Conditions for a fault to create a failure during a test:
  - The location in the program that contain the fault must be reached.
  - After executing the location, the state of the program must be incorrect (i.e. error must occur).
  - The incorrect state must create observable incorrect output or behavior.

Testing in the SDLC

- The V model of software development processes and testing levels.

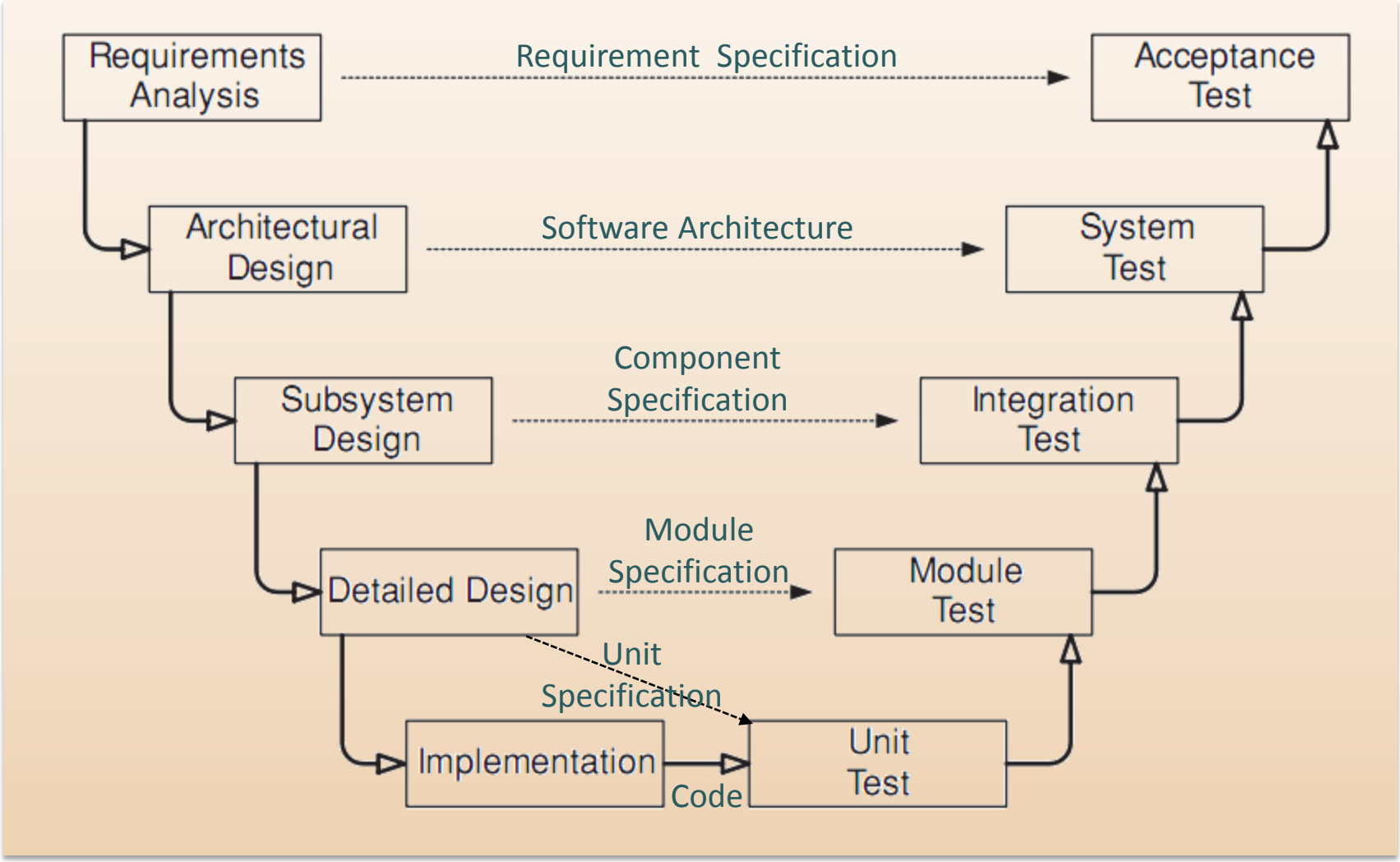


Figure from Ammann and Offutt's Introduction to Software Testing

Levels of Testing

- **Requirement analysis phase:** produces the requirement specification which captures the customer's needs.
  - **Acceptance testing**: check whether the completed system meets those needs. Involves customers or users with domain knowledge.

- **Architectural design phase**: designs which components (SW and/or HW) and how they are connected to obtain the system satisfying the specification.
  - **System testing**: check that the system as a whole meets the specification, assuming that each individual component works correctly.

Levels of Testing

- **Subsystem design phase**: designs the structure and behavior of each component to satisfy the overall architecture
  - **Integration testing**: checks that the modules in the software component work together correctly, assuming that each individual module works correctly.

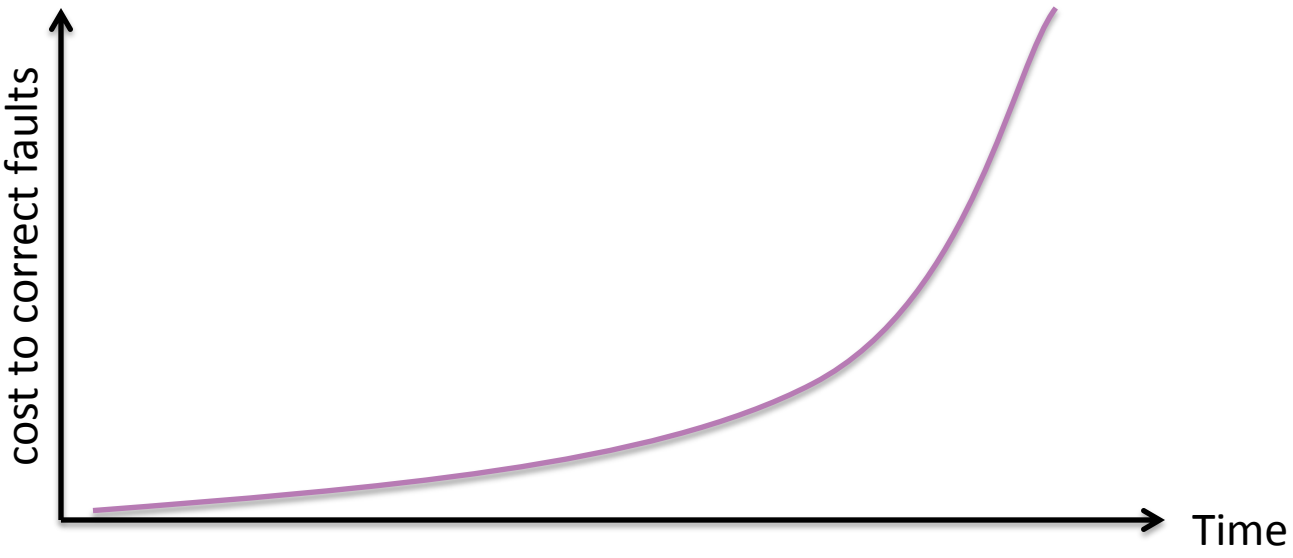
- **Detailed design phase:** designs the structure and behavior of each module
  - **Module testing:** check that each individual module works as expected, assuming that each individual unit in the modules works correctly.

Levels of Testing

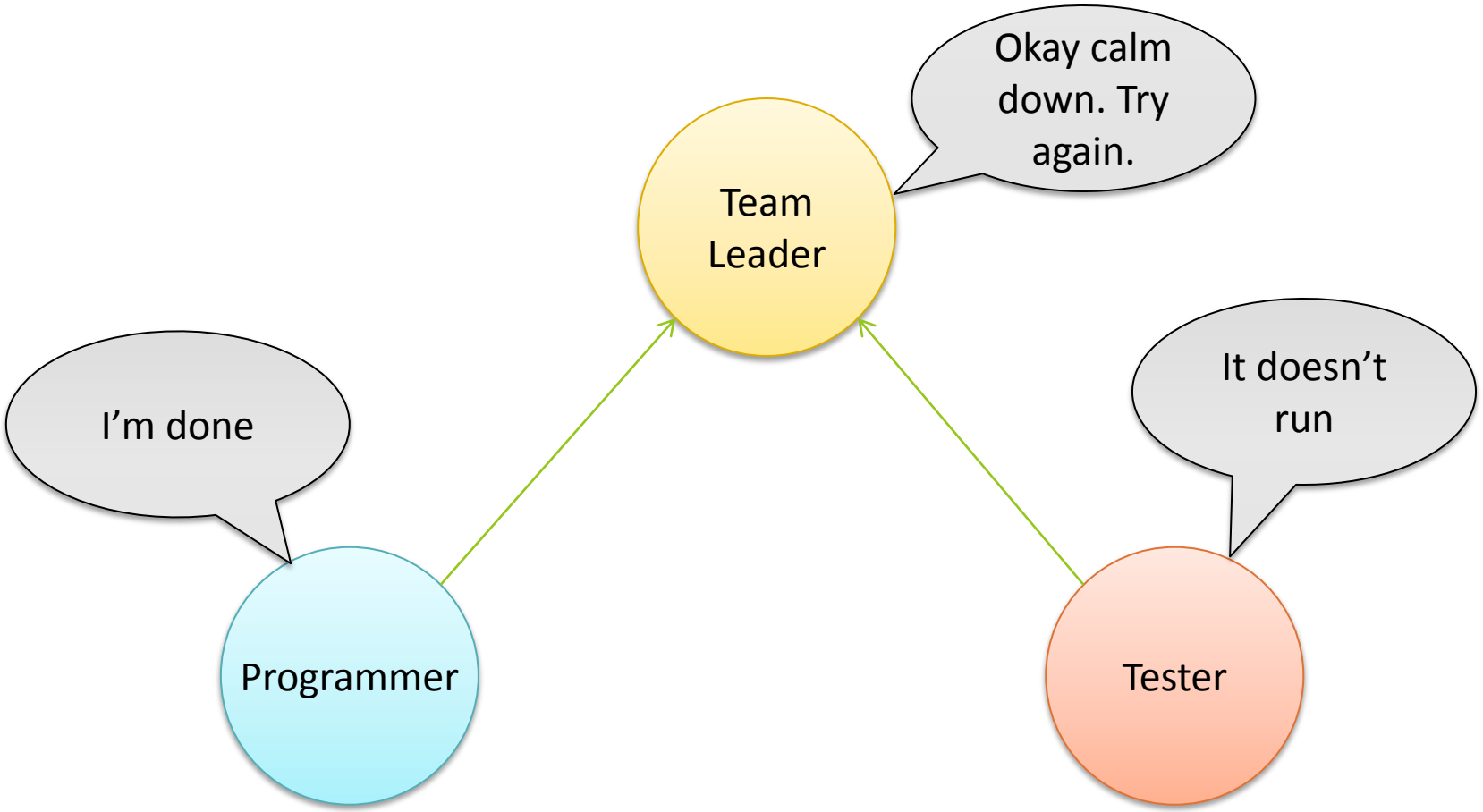
- **Implementation phase**: produces code according to design specification
  - **Unit testing**: checks that each unit behaves as expected. The lowest level of testing.

Test early and often

- Testing should be done at all **stages** in the SDLC and **as early and often as** possible.



Problem of testing only at the last stage



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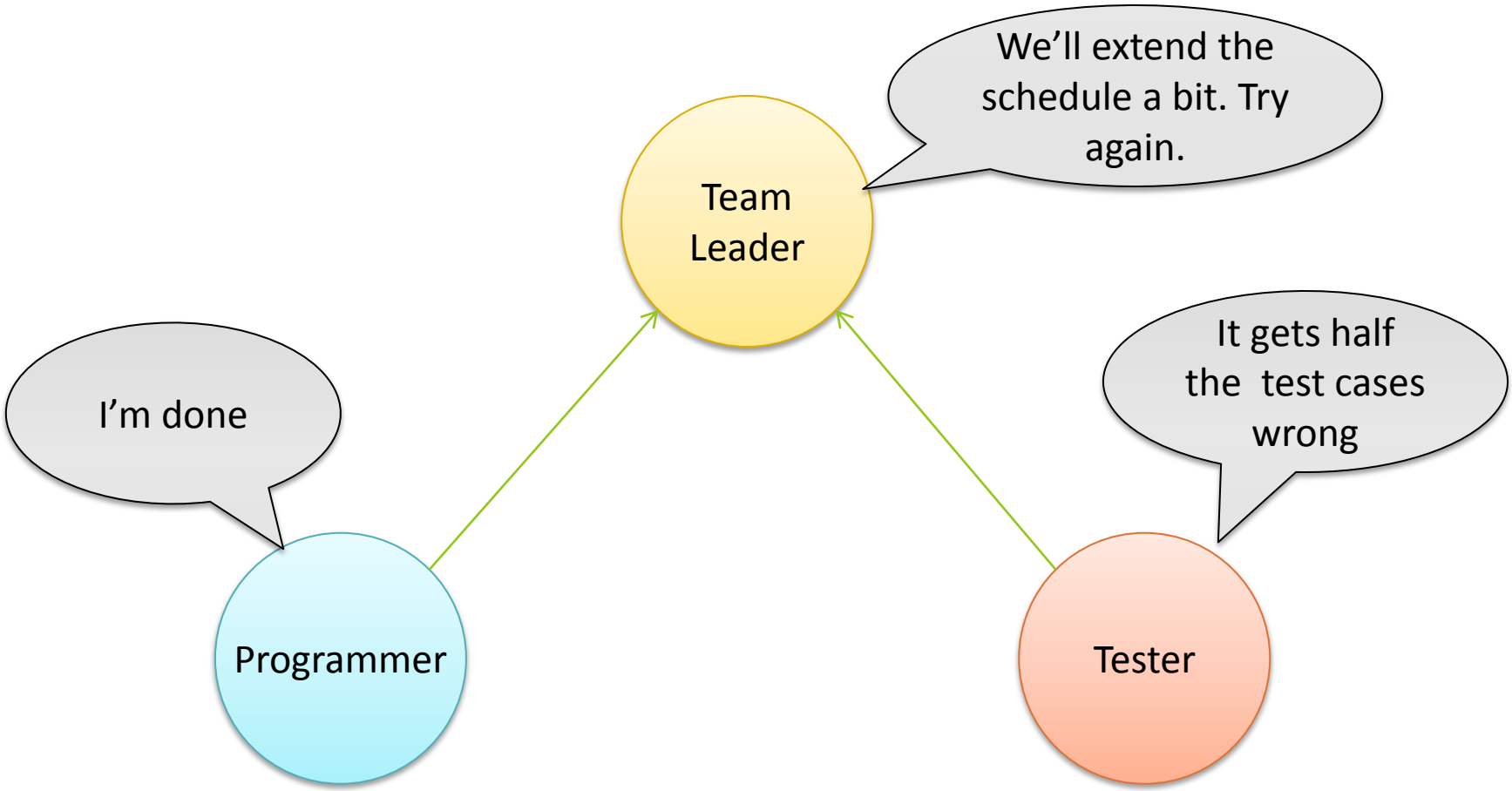

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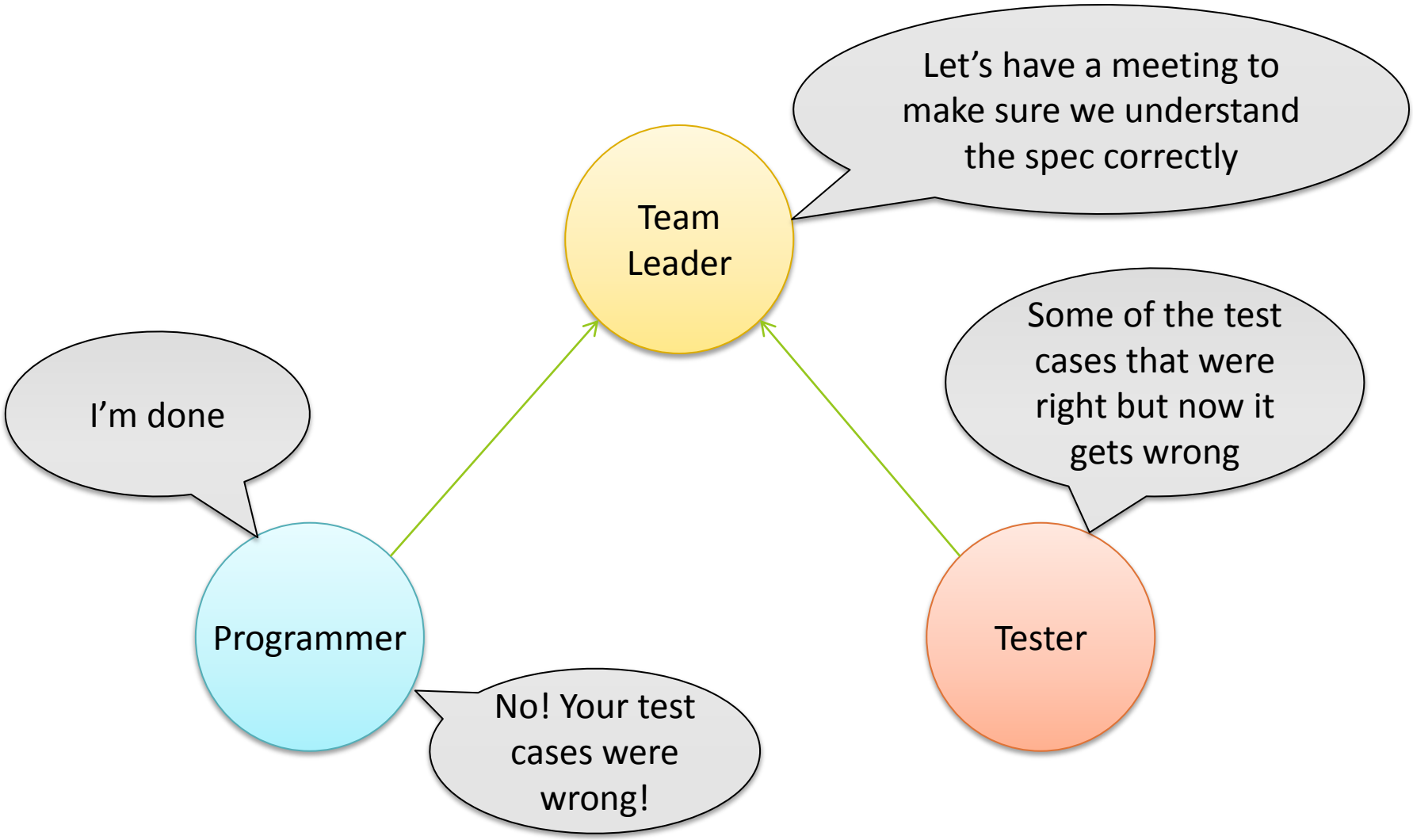

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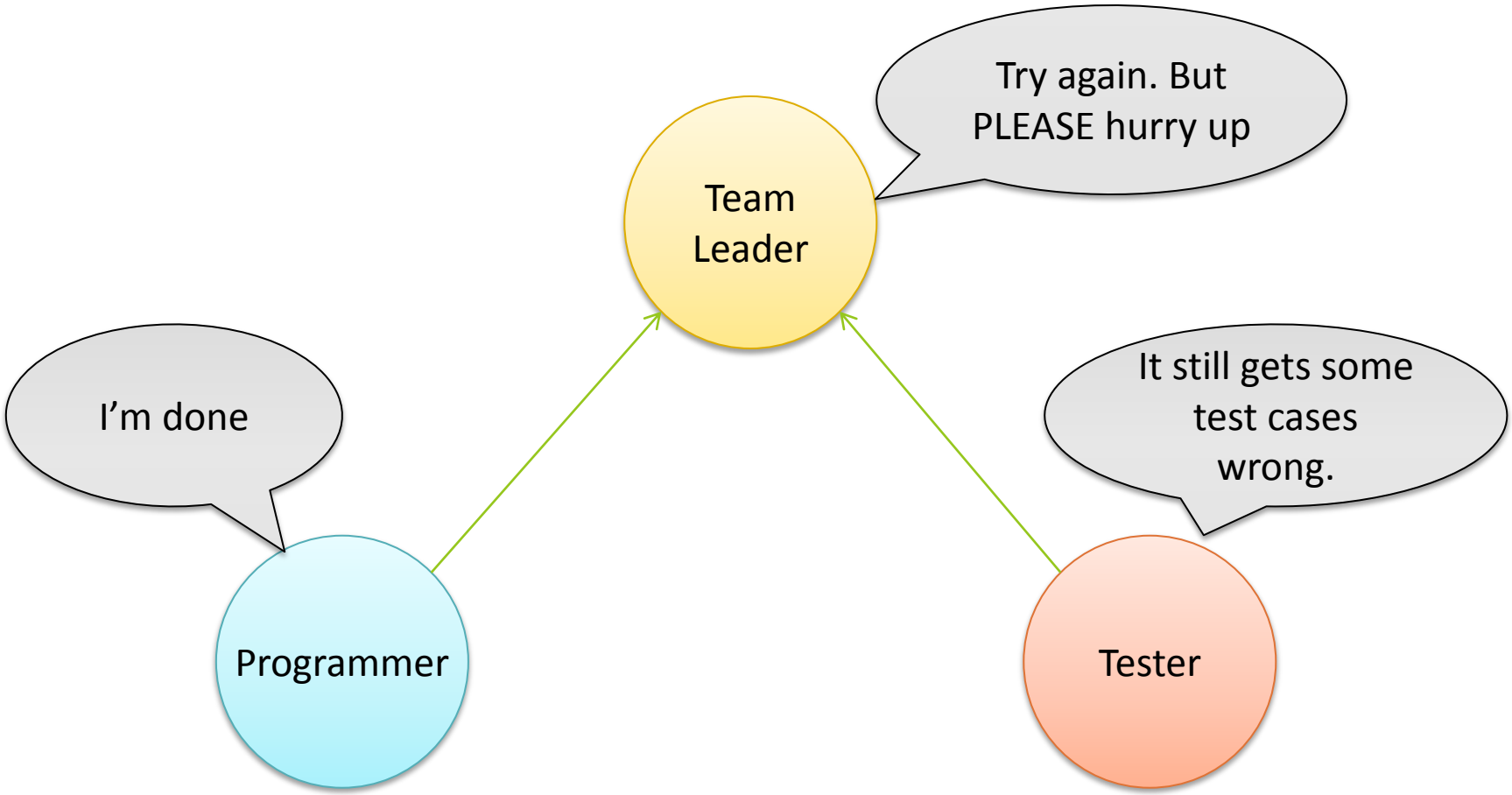

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