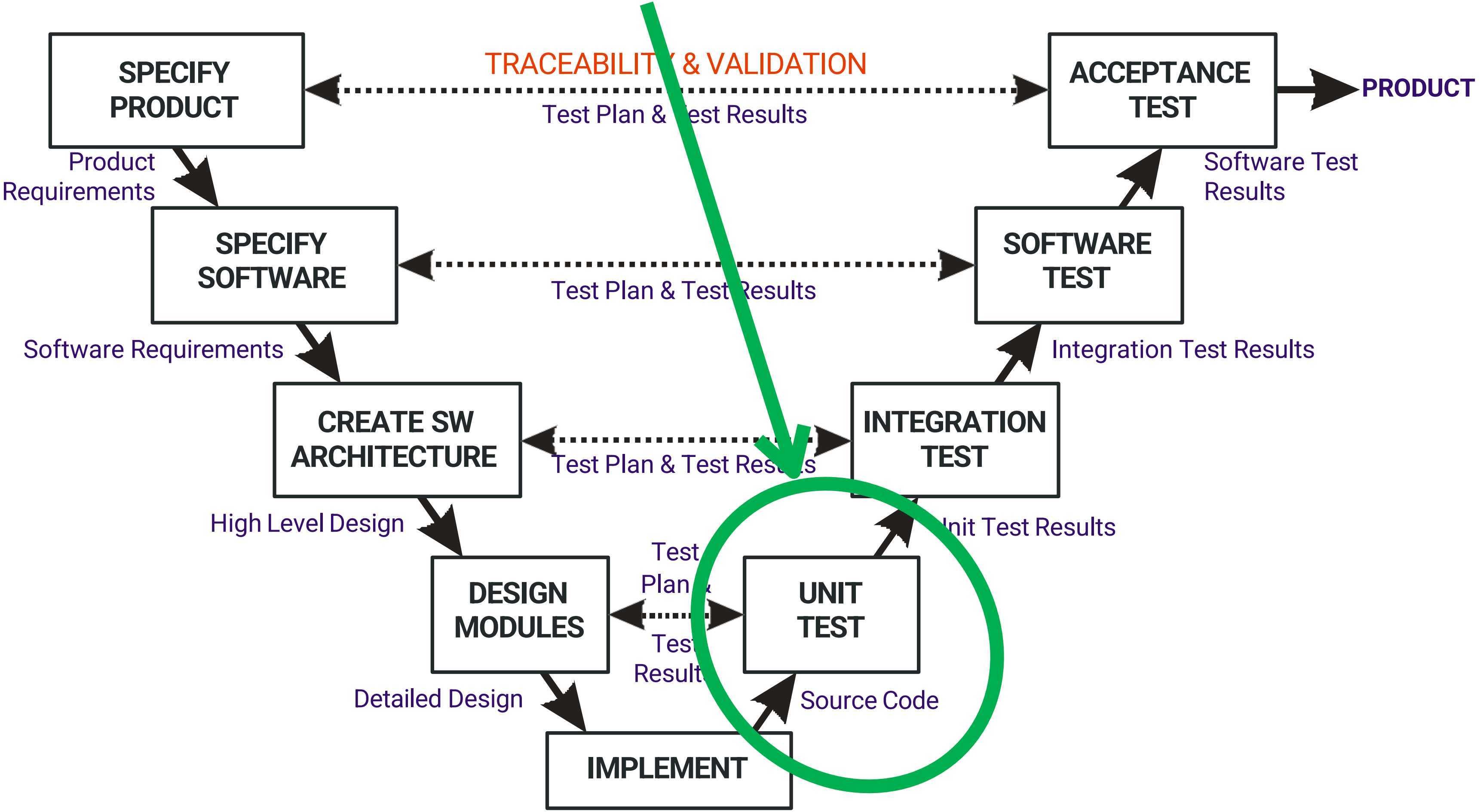
Unit Testing

“Quality is free, but only to those who are willing to pay heavily for it.”

— DeMarco & Lister

YOU ARE HERE



SPECIFY PRODUCT

Product Requirements

SPECIFY SOFTWARE

Software Requirements

CREATE SW ARCHITECTURE

High Level Design

DESIGN MODULES

Detailed Design

IMPLEMENT

Source Code

UNIT TEST

Unit Test Results

INTEGRATION TEST

Integration Test Results

SOFTWARE TEST

Software Test Results

ACCEPTANCE TEST

PRODUCT

TRACEABILITY & VALIDATION

Test Plan & Test Results

Test Plan & Test Results

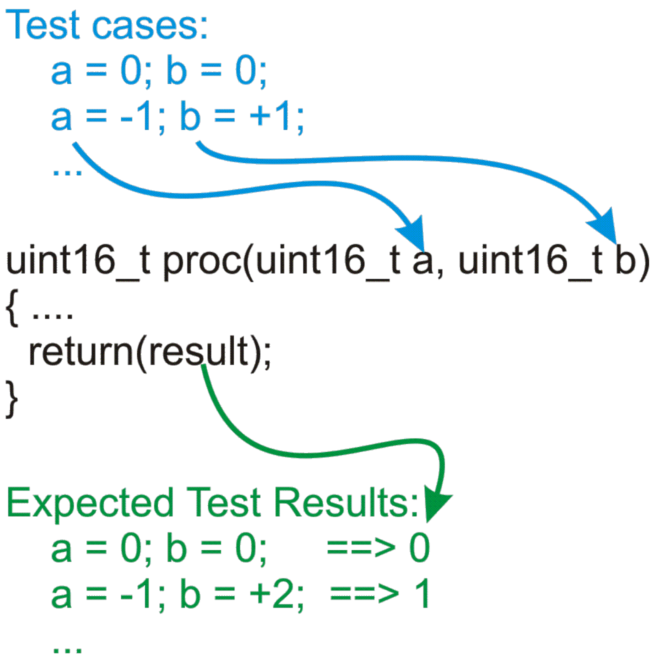
Test Plan & Test Results

Test Plan & Test Results

Unit Testing

- **Anti-Patterns:**
  - Only system testing
  - Testing only "happy paths"
  - Forgetting to test "missing" code

- **Unit testing**
  - Test a single subroutine/procedure/method
    - Use low level interface ("unit" = "code module")
  - Test both based on structure and on functionality
    - White box structural testing + Black box functional testing
  - This is the best way to catch boundary-based bugs
    - Much easier to find them here than in system testing



Test cases:
a = 0; b = 0;
a = -1; b = +1;
...

```
uint16_t proc(uint16_t a, uint16_t b)
{ ....
  return(result);
}
```

Expected Test Results:
a = 0; b = 0;   ==> 0
a = -1; b = +2;   ==> 1
...

Black Box Testing

- Tests designed based on behavior
  - But without knowledge of implementation
  - “Functional” or behavioral testing

https://goo.gl/wJeZ56

- Test the what, but not the how
  - Example: cruise control black box test
    - Test operation at various speeds
    - BUT, no way to tell if special cases in code have been tested
  - Advantage: can be written only based on requirements or design
  - Disadvantage: difficult to exercise all code paths

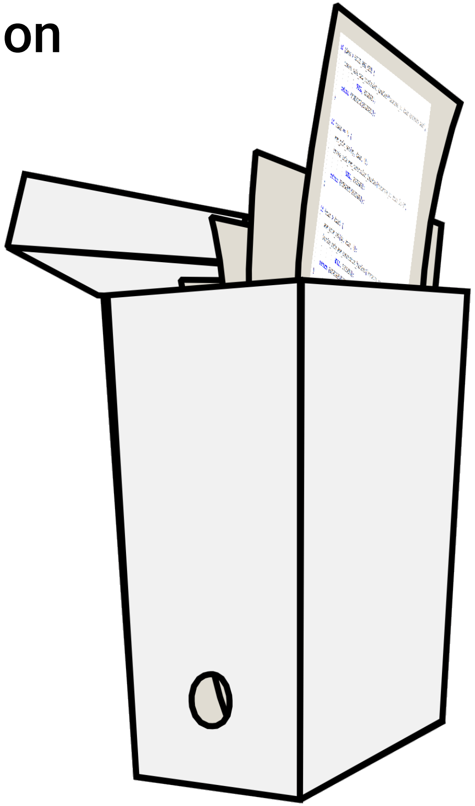
- Black box Unit Testing
  - Tests based on detailed design (statechart, flowchart)

White Box Testing

- Tests designed with knowledge of software implementation
  - Often called “structural” testing
  - Sometimes: “glass box” or “clear box”

- Idea is to exercise software <u>knowing how it is written</u>
  - Example: cruise control white box test
    - Exercise every line of code
      - » Tests that exercise both paths of every conditional branch statement
    - Test operation at every point in control loop lookup table

  - Advantage: helps getting high structural code coverage
  - Disadvantage: doesn’t prompt coverage of “missing” code
    - E.g., missing special case, missing exception handler

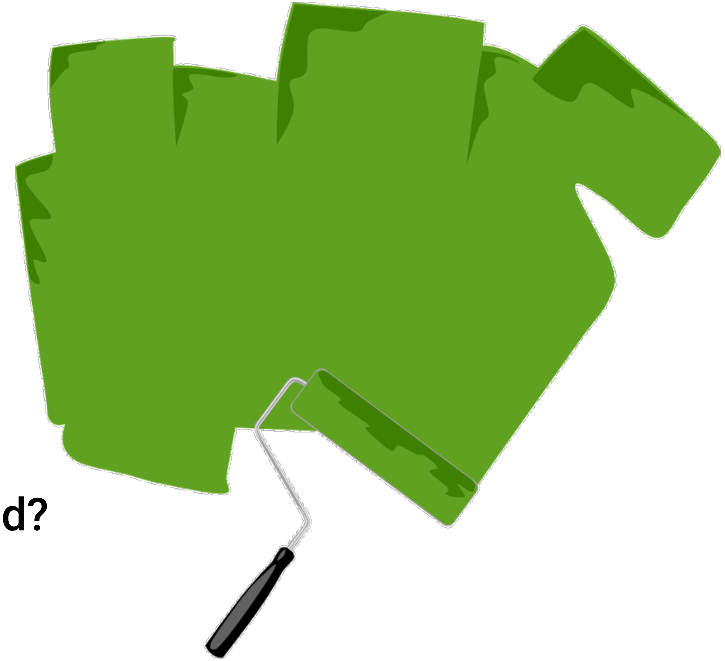


Unit Testing Coverage

Coverage is a metric for how thorough testing is

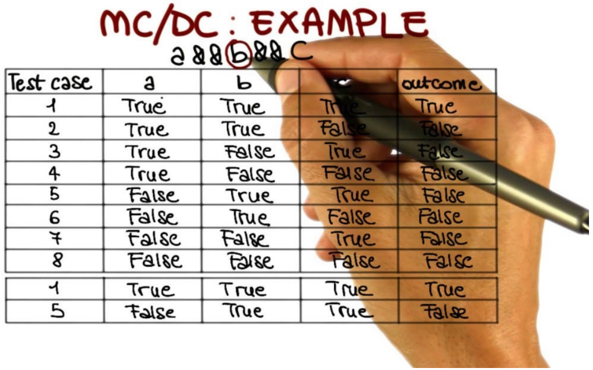
- Function coverage
  - What fraction of functions have been tested?
- Statement coverage
  - What fraction of code statements have been tested?
    - (Have you executed each line of code at least once?)
- Branch coverage (also Path Coverage)
  - Have both true and false branch paths been exercised?
  - Includes, e.g., testing the false path for if (x) { … }
- MCDC coverage (next slide)

- Getting to 100% coverage can be tricky
    - Error handlers for errors that aren't supposed to happen
    - Dead (unused) code that should be removed from source



MCDC Coverage

- Modified Condition/Decision Coverage (MC/DC)
  - Used by DO-178 for critical aviation software testing
  - Exercise all ways to reach all the code
    - Each entry and exit point is invoked
    - Each decision tries every possible outcome
    - Each condition in a decision generates all outcomes
    - Each condition in a decision is shown to independently affect the outcome of the decision
  - For example: "if (A == 3 || B == 4)" ➔ you need to test at least
    - A == 3 ; B != 4 (A causes branch, not masked by B)
    - A !=3 ; B == 4 (B causes branch, not masked by A)
    - A !=3 ; B != 4 (Fall-through case)
    - A == 3 ; B == 4 is NOT tested because it's redundant (no new information gained)
  - Might need trial & error test creation to generate 100% MCDC coverage



MC/DC : EXAMPLE

a && b && c

Test case	a	b	[illegible]	outcome
1	True	True	True	True
2	True	True	False	False
3	True	False	True	False
4	True	False	False	False
5	False	True	True	False
6	False	True	False	False
7	False	False	True	False
8	False	False	False	False

1	True	True	True	True
5	False	True	True	False

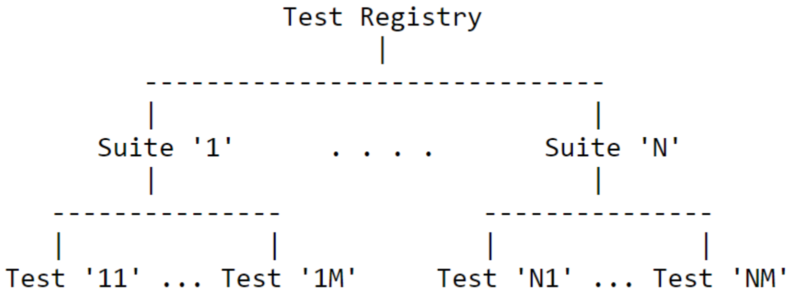
https://www.youtube.com/watch?v=DivaWCNohdw

Unit Testing Coverage Strategies

- Boundary tests:
  - At borders of behavioral changes
  - At borders of min & max values, counter rollover
  - Time crossings: hours, days, years, …
- Exceptional values:
  - NULL, NaN, Inf, null string, …
  - Undefined inputs, invalid inputs
  - Unusual events: leap year, DST change, …
- Justify your level of coverage
  - Trace to unit design
  - Get high code coverage
  - Define strategy for boundary & exception coverage

Unit Testing Frameworks

- Cunit as an example framework
  - Test Suite: set of related test cases
  - Test Case: A procedure that runs one or more executions of a module for purpose of testing
  - Assertion: A statement that determines if a test has passed or failed



http://cunit.sourceforge.net/doc/introduction.html

- Test case example: (http://cunit.sourceforge.net/doc/writing_tests.html#tests)

```
int    maxi(  int    i1,    int    i2)
{ return (i1 > i2) ? i1 : i2; }
…
void    test_maxi    (void)
{ CU_ASSERT(maxi(0,2) == 2);    // this is both a test case + assertion
   CU_ASSERT(maxi(0,  - 2) == 0);
   CU_ASSERT(maxi(2,2) == 2); }
```

Best Practices For Unit Testing

- Unit Test every module
  - Use high coverage combination of white box & black box
  - Use a unit testing framework
    - Multiple simple tests better than one huge, complex test
  - Get good coverage of data values
    - Especially, validate all lookup table entries
- Unit Testing Pitfalls
  - Creating test cases is a development effort
    - Code quality for test cases matters; test cases can have bugs!
  - Difficult to test code can lead to dysfunctional "unit test" strategies
    - Breakpoint debugging is not an effective unit test strategy
    - Using Cunit to test 100K lines of code is not really unit testing
  - Pure white box testing is "doomed to succeed" (neglects "missing" code)
  - Don't substitute unit tests for peer reviews and static analysis

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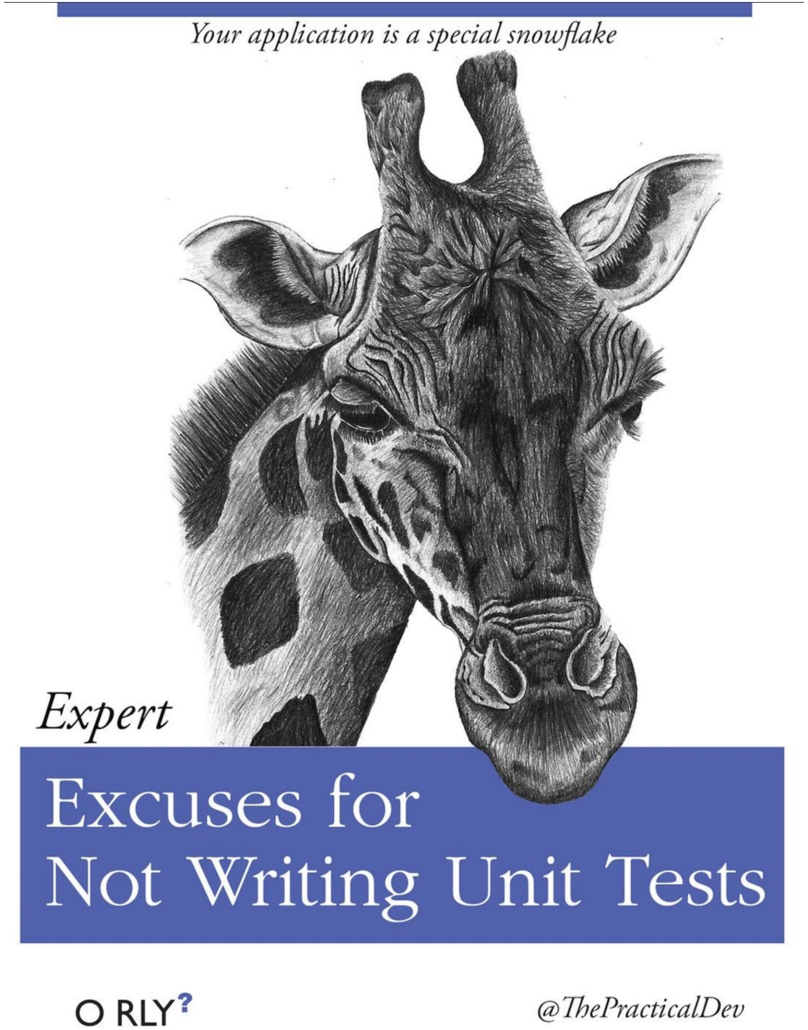
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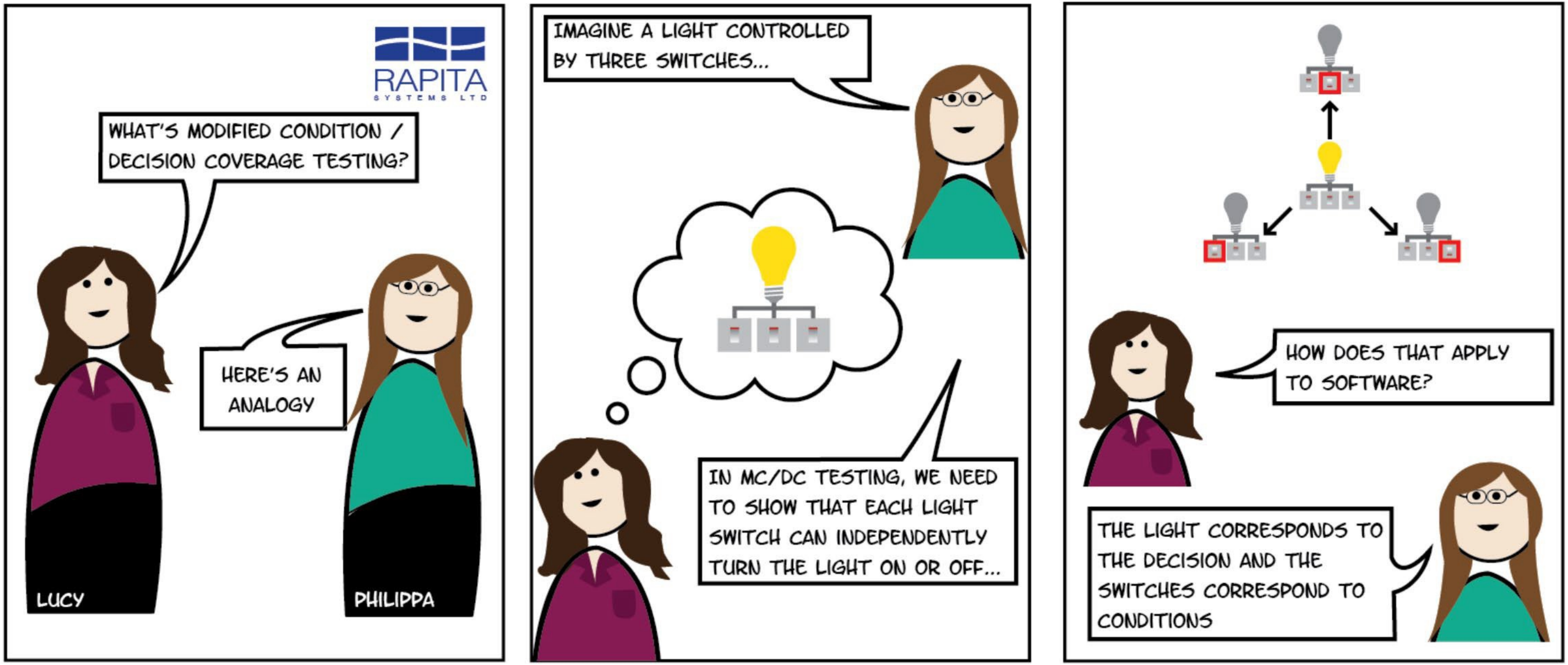
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This lecture contains materials from:

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