# Assurance Cases and Test Design Analysis

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# Outline

- Scope
- Test Design challenges
- Assurance cases
- Example of test design IV&V for an automobile
- Triggers – How to find the right triggers
- Test Scenarios – All scenarios not created equal
- Results from 2 CSCIs
- Summary and Conclusions

# Scope and Acknowledgement

- Scope
  - Small part of the much larger risk assessment study
  - Work initiated last year
  - Validating Assurance cases approach against the Test analysis work already performed using traditional approach (CoM)
- Acknowledgment
  - IV&V supported Assurance case assessment (2011)
  - Other NASA centers
  - Non-NASA groups (SEI-CMU, Aerospace Corp, Adelard UK)

# Test design V&V

- Test Results Verification
  - Test design to wring out the bugs
  - Was this effort successful?
- Test design Validation – Nominal behaviors
  - Relatively straightforward
  - Not many issues discovered
- Test Design Validation – Off nominal behaviors
  - Takes more thought , What can go wrong? What shouldn't it do? Off nominal behavior. Good number of issues
  - What is "*appropriately*"? Off nominal behavior. Ripe for issues/ finding bugs
  - Application the Safety Critical / Space Systems

# Off-nominal test design

DO-178B

- Normal Range Test Cases:
  - Boundary values on input variables
  - Multiple iterations for time-related functions
  - Transitions for state based software
- Robustness Test Cases:
  - Invalid values for variables
  - System initialization under abnormal conditions
  - Failure modes of incoming data
  - Exceeded time frames
  - Try to provoke illegal state transitions
  - Arithmetic Overflow
  - Loop counts

# Possible Inputs for the Test Design Analysis

- Validated SW requirements
- Test artifacts
  - Test Plan
  - Test procedures
  - Test scripts
  - Test Logs
- Test artifacts associated with multiple builds
- Con Ops, User manuals, Interface documents
- Test validation scope based on PBRA and RBA

# Testing challenges-Space System

- System Initialization
  - Timing constraint
  - Init Failure?
    - Response from other systems or ground
- Startup image management
  - Auto switch to backup image?
    - Appropriate bits commandable?

(continued to next sheet)

# Testing challenges-Space System (Contd.)

- System Safety
  - Fault Detection
    - Fault levels (1, 2, or low level 3 fault)
  - Fault response
    - Autonomous/Manual Response enabled/inhibited
    - Abort sequences (if applicable)
    - Commands to enable / disable response, reset flags
    - Swapping strings (IMOK monitoring)
  - Preventative measures
    - Arm/fire commands
    - Command processing (FSW validates? Executes?)

# Assurance Case

- What is an assurance case?
  - Specialized instance of general case argumentation[1]
    - Claim ← Evidence (Build an argument using Evidence for a given claim)
  - Claims can have sub-claims
- Tools
  - ASCE
  - Excel

# Example: Test design analysis

- Test design
  - From the Test team
  - Before the car is ready for full scale production or
  - A batch of cars is ready to be shipped to the dealer / customer

# Claims

- Claim#1: Radio/MP3 Player will work
- Claim#2: Dome light will work
- Claim#3: Test driver can drive the car along an intended course
  - Sub-Claim#3.1: Car will start
  - Sub-Claim#3.2: Car will stop

# Claim score based on safety, criticality

- Score 1..5 each of the sub-claims
  1. Engine starts up (safely)
  2. Car can be stopped safely
  3. Airbag will deploy in case of an accident
- Prioritization of claims based on score

# Engine Startup claim-evidence analysis

- Startup scenario
  - Key in ignition → Turn clockwise → xx seconds → Engine started
- Claim: Engine will startup safely
  - Evidence: Ignition control will not trigger if Shift selector is in drive (forward or reverse)
  - Evidence: Ignition control will  only trigger if the break pedal is in the specified position
  - Evidence: Ignition control will not trigger if the engine already running
  - Evidence: Ignition control will not trigger if the fuel pump or battery constraints are violated

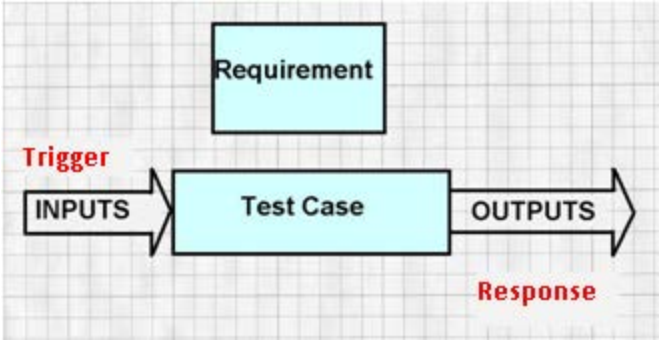
**Complexity of Test**

*Software testing is not about proving conclusively that the software is free from any defects, or even about discovering all the defects. Such a mission for a test team is truly impossible to achieve.  Rex Black, Pragmatic Software Testing , John Wiley & Sons 2007*

# Space System analysis

| Claim Level 1 | | | Claim Level 2 | | | Claim Level 3 | | | Claim Level 4 | | | Claim Level 5 | | | | | Needed Evidence | | | | Actual Evidence | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Claim | Section | Score | Claim | Section | Score | Claim | Section | Score | Claim | Section | Score | Claim | Section | Score | Weight | Rationale | Requirement | Design | Implementation | Test | Requirement | Design | Implementation | Test |

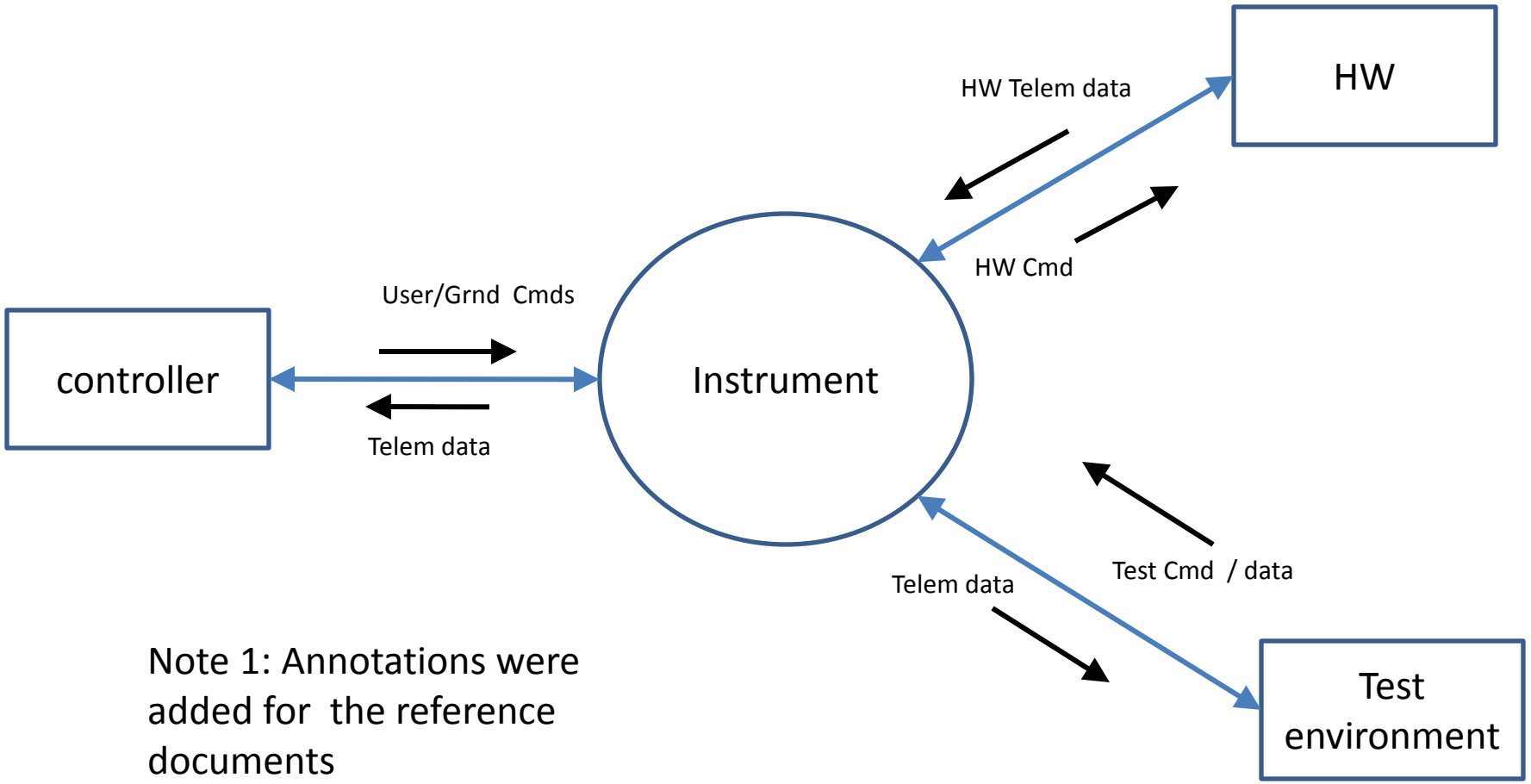
# Test scenario




Trigger -> Response

- For each Claim, generate the list of triggers
- For each trigger generate test scenarios
- Test scenario
  - The trigger for the requirement(s),
  - Corresponding requirements and
  - The type of data being processed / touched by the requirement(s)

# Trigger -> Response




Note 1: Annotations were added for the reference documents

Note 2: Generic diagram/table in the backup slides

# Space System Triggers / Responses

- Triggers
  - External commands / HW telem aka across the interfaces
  - Internal (a relatively small number) to the system
- Group the triggers (Single / multiple interfaces)
    - User cmd impacting user interface only
    - User cmd impacting User interface and hw interface
- Responses
  - Internal to the system
  - To the external interfaces

# Test Design Validation Analysis & Evidence

- Test Scenario
  - Test scenario trigger
  - Test scenario step #
  - Step description / behavior
- Reference info
  - Source (document section number, Req tag number)
  - Safety or criticality related to the test step
  - Adverse conditions (if any)
- Evidence info
  - Correlation to the test plan section
  - Correlation to the test procedure (number, step)
  - Correlation to the test script (code line number)
- Observations / Issues (if any)

# Test Design Issues verified

- Incomplete Arm / fire Commands tests
- Missing “Alternative” steps in the abort scenario tests
  - Off nominal for abort-sequence
- Inadequate fault flag responses tests
- Incomplete Command parameter verification tests
- Missing mode verification tests

# Two CSCIs of a Space system

- ~ 250 requirements each (Validated)
- ~ 45 ground commands each
- Ground/SW interface
- SW/HW interface
- ~60 test scripts each
  - One with separate test design
  - The second with high-level test procedure embedded in the test script (as comments)

# Summary

Assurance cases  can help to

- Develop comprehensive test scenarios
- Systematic steps to uncover Off nominal conditions
  - Off nominal conditions are the source of high severity issues with Test design and the system being tested
- Identify and use system triggers as part of the test design analysis
- Look for safety-critical test scenarios
- Verify the test results
- Review the issue resolutions for additional/new bugs

# Future Work

Using Assurance cases for

- Analyzing test design
- Test Coverage assessment
  - Automated mapping
- Independent testing

# Questions ?

# Backup slides

# Verifying the test results

- Test results Review
  - Test logs
  - Test terminal screen dumps
- Test results show
  - Commands executed
  - Triggers identifiable
  - Trigger occurred at the correct time
  - System responses as expected
  - Time stamps show if any deadlines violated