Verification of Use Cases (VUC)

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VUC Outline

- Introduction
- Benefits
- VUC Method
- Example
- Results
- Conclusion
- Questions
VUC - Introduction

- Requirements phase
  - 40% of all project failures
  - 60% of all project errors
  - 10 to 20 times less costly to fix

- DOD Acquisition Process Overhauled
  - Requirements now addressed in Pre-System Phase

- Imperative to *Build Right System*
VUC - Introduction

- Requirements analysis
  - 40% of all project failures
  - 60% of all project errors
  - 10 to 20 times less costly to fix
- DOD Acquisition Process Overhauled
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- Imperative to *Build Right System*
VUC - Definition

- **Verification** is the process of evaluating a system or component to determine whether the products or deliverables from a given development phase satisfy the conditions imposed at the start of that phase, rendering formal proof of a program correctness (Wasson, 2006)
  - Proving that the right system was built
- **Use Case (UC)** - Statement that express how the user envisions deploying, operating, supporting or disposing of a system product, or a service to achieve a desired performance based outcome (Wasson, 2006)
  - Illustrates the Functional Requirements of the system
- **VUC - Verification of Use cases**
  - Method to track and flow down use cases thru design process, and build test cases from the use cases to allow subsystems to be tested to their system requirement. Proving that each level of a system fulfills the customers wants.
VUC - Benefits

- **Lean Systems Engineering** - the application of lean six sigma principles, practices and tools to system engineering in order to enhance the delivery of value to the systems stakeholders.

- INCOSE states that the Lean Enablers for System Engineering are captured in six lean principles:
  1. **Customer defines Value**
  2. Map the Value Stream
  3. **Make Flow Continuous**
  4. Let the Customer Pull Value
  5. **Pursue Perfection**
  6. Respect People
VUC - Benefits: Lean Principals

- Customer defines Value
  
  the initial phase of every program should not only capture the comprehensive, unambiguous, and detailed understanding of value to the customer, but also the needs, context, and interpretations of the requirements.

  - VUC confirms customer needs are met at all levels of the design process
  - Reduces uncertainty
  - Encourages frequent interaction w/ customer
  - Capture, develops, and disseminates value w/ clarity
  - Promotes ‘customer first’ & ‘first time right’ culture
    - Added cost for up front work negated by saved cost of no backend work
  - Example: A12 Avenger II
    - Failed Requirements: Carrier based & Stealthness
    - Largest contract termination in DOD history
VUC - Benefits: Lean Principles

- Make Flow Continuous
  
  *Flow is to work through the planned and streamlined value adding steps and processes, without stopping or idle time, unplanned rework, or backflow*

- Clarification, derivation, and prioritization of Req
  - Accomplished by utilization of UC’s

- “Fail early - Fail Often” through rapid learning technique such as testing

- VUC incorporates UC’s into Req doc
  - Gets the SE and TE to work as partners

- Communicates all expectations, context, and need to the supplier
VUC - Benefits: Lean Principals

- Perfection
  *This principle strives for excellence and continuous improvement of the SE process and related Enterprise Management.*
  - Makes imperfection visible
  - Problems not passed along
  - Not relying on final inspection

- Respect for People/System
  *This principle promotes high level of human relations at work based on respect for people.*
  - Have a vision which draws & inspires best system
  - Use flow down of Accountability
  - Example: Southwest Airlines
    - Employees know that their work contributes to meeting goals of corporation
    - Ensures subsystem will indeed contribute to system goals
VUC - Method

- Tracking
  - UC: V4R18UC1
  - TC: V4R18TC2
    - Any Tracking method works
      - Child Requirement ID’ed

- Use Cases
  - Any format works
  - Important to have story/scenario’s
VUC - Method

- Test Cases
  - Requirements and UC’s in same doc
    - Flowed down to Test Engineer (TE)
  - Generate from UC
    - Jim Heumann’s method
      - Test Case Matrix states validity and applicability per scenario
      - Expected test output added, used to test system against
      - TE actually tests to what the customer wants, not someone else’s interpretation of what the customer wants
VUC - Example

- Autonomous Ground Vehicle (AGV)
  - Robotic vehicle designed for DARPA Urban Challenge
    - Goal to safely and effectively execute military relevant missions
    - 60 miles in less than 6 hours autonomously
    - GPS as guide
    - Obey CA driving and traffic laws
    - Average Speed of 10 mph, Top speed of 30 mph
    - Designated course provided day of event
      - Consist of any scenario that normal vehicles face in urban environment
  - Obstacle Avoidance
  - Emergency Safety System
VUC - AGV Architecture

AGV System

- Maintenance & Support Segment
  - Transportation Element
  - Spares Element
  - Repair Tools Element
  - Structure Subsystem
  - Paper Work & Records Element

- Hardware Segment
  - Vehicle Element
  - Sensors Element
  - Processors Element
  - Generators Element

- Safety Segment
  - E-Stop Element
  - Warning Element
  - Speed Controller Element
  - Software Health Element

- Autonomous Segment
  - Data Collection Element
  - Navigation Element
  - Data Process Element
VUC - R18 UC Diagrams

AGV

Interprets

decreases

increases

zero

MDF/RNDF

System Boundary

Speed

recognition

(*Upon full stop*)

<<(extend>>

<<(extend>>

(six seconds elapsed)

Timer begins

Stop Sign
System Requirement: **R18UC Name: Stop Sign**

- **Description:**

  This use case covers the AGV stopping within 1 meter of the stop line at a stop sign and resuming movement within 10 seconds. **R18: Vehicle shall stop safely within 1 meter of the stop line at a stop sign intersection and proceed without excessive delay (less than 10 seconds) according to intersection precedence rules.**

- **Actors and Goals:**
  - 1) AGV to stop
  - 2) Stop sign to be obeyed

- **Assumption and Precondition:**
  - 1) Requirement #9
  - 2) Requirement #10
  - 3) Requirement #2

- AGV in autonomous mode
VUC - AGV Example

- **Basic Course:**
  1) AGV interprets MDF and RNDF
  2) AGV recognizes that stop sign is approaching in 10 feet
  3) AGV slows down
  4) AGV comes to full stop within 1 meter of stop sign line
  5) Timer begins upon stop
  6) AGV waits 6 seconds before proceeding
  7) AGV resumes moving on DARPA specified path

- **Alternatives:**
  None

- **Post Condition:**
  Before 10 seconds is elapsed, AGV has resumed movement
## Table 3: AGV System Requirement Test Case

<table>
<thead>
<tr>
<th>Test Case</th>
<th>Scenario</th>
<th>AGV has GPS coverage</th>
<th>AGV out of GPS coverage range</th>
<th>MDF &amp; RRDF Interpreted</th>
<th>MDF &amp; RRDF NOT Interpreted</th>
<th>Waypoint = stop sign approaching</th>
<th>AGV decelerates</th>
<th>AGV accelerates</th>
<th>AGV speed = zero</th>
<th>Stop sign line &lt; 1 meter from AGV front bumper</th>
<th>Stop sign line &lt; 1 meter from AGV front bumper</th>
<th>AGV timer starts</th>
<th>AGV timer does not start</th>
<th>AGV timer &gt; 6 seconds &lt; 10 seconds</th>
<th>AGV timer &lt; 10 seconds</th>
<th>AGV accelerates on designated path</th>
<th>AGV does not accelerate on designated path</th>
<th>AGV does not accelerate on designated path</th>
<th>Onboard computer/control panel emergency brake</th>
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<tbody>
<tr>
<td>R1BRTC79</td>
<td>AGV interprets MDF &amp; RRDF</td>
<td>V</td>
<td>T/V</td>
<td>V</td>
<td>T/V</td>
<td>N/A</td>
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<td>Timer begins stop 6 seconds, brakes are released</td>
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<td>R1BTC85</td>
<td>AGV recognizes stop sign approaching with 10 feet</td>
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<td>T/V</td>
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<td>AGV brakes down</td>
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<tr>
<td>R1BTC88</td>
<td>AGV comes to full stop 6 seconds, brakes are released</td>
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<td>N/A</td>
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<tr>
<td>R1BTC89</td>
<td>Timer begins stop 6 seconds</td>
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<tr>
<td>R1BTC90</td>
<td>AGV accelerates moving on DARPA specified path</td>
<td>N/A</td>
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</tbody>
</table>

*Note: The table entries represent specific scenarios and outcomes for AGV system requirement test cases.*
VUC - V4R18 UC Diagrams

System Boundaries

- AGV
  - Speed
    - upon initiation, decreases
    - (6 seconds elapsed)
  - Timer
    - initiated
    - (Upon full stop, begins)
  - AGV Brakes
  - Linear Actuator
  - Message
  - Sends/Receives
  - Sends/Receives
  - Emergency Brake
    - equals zero
  - Onboard Computer
    - Activated

Receives/Sends
VUC - AGV Example

Subsystem Requirement: V4R18: Braking System Use Case

- **Description:**
  This use case covers the ability for the AGV to stop within 1 meter of the stop line at a stop sign. **R18:** AGV shall stop safely within 1 meter of the stop sign intersection and proceed without excessive delay (less than 10 seconds) according to intersection precedence rules.

- **Actors and Goals:**
  1) AGV brakes
  2) Onboard computer sends instructions to other systems
  3) Linear Actuator controls brakes

- **Assumptions and Pre-Conditions:**
  1) Mission Data File and Route Network Definition File is uploaded
  2) Onboard computer recognizes stop sign approaching in 10 feet
Basic Course:

1) Linear Actuator receives message from onboard computer to initiate brakes
2) Linear Actuator pushes on brakes until AGV is at complete stop
3) After 6 seconds brakes are released
4) AGV resumes moving on designated path

Alternate Course:

2a) System detects error with the linear actuator
   1) Onboard computer ceases to accelerate AGV
   2) Emergency brake is activated
   3) AGV begins decelerating to 5 mph until stop sign line is within 1 meter
   4) Emergency brake initiated
   5) Repeat as necessary

Post Condition:

AGV at complete stop for 10 seconds before continuing on route
VUC - Results

- VUC method ensured AGV:
  - Stops w/in 1 meter prior to stop sign
  - resumes moving after 10 sec stop

- Neither of these were subsystem requirements
- Failure of either results in Disqualification
<table>
<thead>
<tr>
<th>Test Case ID</th>
<th>Scenario/Condition (V4R18UC)</th>
<th>Onboard computer reads MDF and RNDF</th>
<th>Onboard computer interprets MDF and RNDF</th>
<th>Onboard computer controls linear actuator</th>
<th>Linear Actuator controls AGV brakes</th>
<th>Linear Actuator does not control brakes</th>
<th>Onboard computer communicates w/ TORC system</th>
<th>TORC system working</th>
<th>TORC system monitors and controls speed</th>
<th>AGV speed = zero</th>
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<tbody>
<tr>
<td>TC85</td>
<td>Onboard computer recognizes that stop sign is approaching in 10 feet</td>
<td>V</td>
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<td>TC86</td>
<td>Onboard computer sends message to initiate linear actuator initiating brakes</td>
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<td>V</td>
<td>V</td>
<td>I/V</td>
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<td>TC87</td>
<td>linear actuator pushes on brakes until AGV at complete stop</td>
<td>N/A</td>
<td>N/A</td>
<td>V</td>
<td>I/V</td>
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<td>System detects error w/ the brake actuator</td>
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<td>Onboard computer activates parking brake</td>
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<td>Onboard computer sends message to initiate linear actuator initiating brakes</td>
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<td>displays first checkpoint</td>
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<td>linear actuator pushes on brakes until AGV comes to complete stop</td>
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<td>brake lights flash</td>
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Table 5: AGV Vehicle Subsystem Requirement VUC Test Case

| Test Case | Acceleration | AGV has GPS coverage | AGV out of GPS coverage range | GPS & MDF coordinated | MDF & MDF not coordinated | Waypoint to stop if signal lost | AGV accelerates | AGV deaccelerates | AGV speed > 50 | AGV stops > 5 seconds from AGV stop trigger | AGV timer does not start | AGV timer > 20 seconds < 30 seconds | AGV timer > 30 seconds | AGV accelerates on designated path | AGV deaccelerates on designated path | AGV does not accelerate on designated path | AGV does not accelerate on designated path |
|-----------|--------------|----------------------|-----------------------------|----------------------|---------------------------|--------------------------------|----------------|-----------------|----------------|------------------------------------------|--------------------------|-------------------------------|---------------------|------------------------------------------|------------------------------------------|------------------------------------------|
| V4R18TC20 | X            | X                    | X                           | X                    | X                         | X                              | X               | X               | X              | X                                                        | X                        | X                             | X                   | X                                                        | X                                                        | X                                                        |
| V4R18TC21 | X            | X                    | X                           | X                    | X                         | X                              | X               | X               | X              | X                                                        | X                        | X                             | X                   | X                                                        | X                                                        | X                                                        |
| V4R18TC22 | X            | X                    | X                           | X                    | X                         | X                              | X               | X               | X              | X                                                        | X                        | X                             | X                   | X                                                        | X                                                        | X                                                        |
| V4R18TC23 | X            | X                    | X                           | X                    | X                         | X                              | X               | X               | X              | X                                                        | X                        | X                             | X                   | X                                                        | X                                                        | X                                                        |
| V4R18TC24 | X            | X                    | X                           | X                    | X                         | X                              | X               | X               | X              | X                                                        | X                        | X                             | X                   | X                                                        | X                                                        | X                                                        |
| V4R18TC25 | X            | X                    | X                           | X                    | X                         | X                              | X               | X               | X              | X                                                        | X                        | X                             | X                   | X                                                        | X                                                        | X                                                        |
| V4R18TC26 | X            | X                    | X                           | X                    | X                         | X                              | X               | X               | X              | X                                                        | X                        | X                             | X                   | X                                                        | X                                                        | X                                                        |
| V4R18TC27 | X            | X                    | X                           | X                    | X                         | X                              | X               | X               | X              | X                                                        | X                        | X                             | X                   | X                                                        | X                                                        | X                                                        |
| V4R18TC28 | X            | X                    | X                           | X                    | X                         | X                              | X               | X               | X              | X                                                        | X                        | X                             | X                   | X                                                        | X                                                        | X                                                        |
| V4R18TC29 | X            | X                    | X                           | X                    | X                         | X                              | X               | X               | X              | X                                                        | X                        | X                             | X                   | X                                                        | X                                                        | X                                                        |
| V4R18TC30 | X            | X                    | X                           | X                    | X                         | X                              | X               | X               | X              | X                                                        | X                        | X                             | X                   | X                                                        | X                                                        | X                                                        |
| V4R18TC31 | X            | X                    | X                           | X                    | X                         | X                              | X               | X               | X              | X                                                        | X                        | X                             | X                   | X                                                        | X                                                        | X                                                        |
| V4R18TC32 | X            | X                    | X                           | X                    | X                         | X                              | X               | X               | X              | X                                                        | X                        | X                             | X                   | X                                                        | X                                                        | X                                                        |
| V4R18TC33 | X            | X                    | X                           | X                    | X                         | X                              | X               | X               | X              | X                                                        | X                        | X                             | X                   | X                                                        | X                                                        | X                                                        |
| V4R18TC34 | X            | X                    | X                           | X                    | X                         | X                              | X               | X               | X              | X                                                        | X                        | X                             | X                   | X                                                        | X                                                        | X                                                        |
| V4R18TC35 | X            | X                    | X                           | X                    | X                         | X                              | X               | X               | X              | X                                                        | X                        | X                             | X                   | X                                                        | X                                                        | X                                                        |
| V4R18TC36 | X            | X                    | X                           | X                    | X                         | X                              | X               | X               | X              | X                                                        | X                        | X                             | X                   | X                                                        | X                                                        | X                                                        |
| V4R18TC37 | X            | X                    | X                           | X                    | X                         | X                              | X               | X               | X              | X                                                        | X                        | X                             | X                   | X                                                        | X                                                        | X                                                        |
| V4R18TC38 | X            | X                    | X                           | X                    | X                         | X                              | X               | X               | X              | X                                                        | X                        | X                             | X                   | X                                                        | X                                                        | X                                                        |
| V4R18TC39 | X            | X                    | X                           | X                    | X                         | X                              | X               | X               | X              | X                                                        | X                        | X                             | X                   | X                                                        | X                                                        | X                                                        |
| V4R18TC40 | X            | X                    | X                           | X                    | X                         | X                              | X               | X               | X              | X                                                        | X                        | X                             | X                   | X                                                        | X                                                        | X                                                        |

Note: X indicates the test case is applicable; no symbol indicates not applicable.
VUC - Conclusion

- VUC method ensures
  - UC and Req are always linked
  - TC developed from UC
    - Customer gets what customer wants
- Decrease odds of missing req
- VUC adds TC, which increases costs
  - But cheaper than rework later in program
- Helps avoid Program cancellation
Questions?
VUC - References


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