Developing Verification Requirements to Assure Project Success

Mark A. Powell

Abstract

A well thought out and planned set of verification requirements can make all the difference between a happy customer and a dissatisfied customer. If you cannot provide confidence to the customer that you met their requirements, you won't have a happy customer. Yet few projects these days invest much effort in developing good verification requirements. Quite often, verification requirements are treated as an afterthought to the performance requirements. But, if we produce the verification requirements concurrently with the performance requirements, the verification requirements can expose problems in the performance requirements they are intended to verify. Of course, this not only leads to better verification requirements, but to better performance requirements, which leads to a happy customer.

Why is it then that most requirements training courses just gloss over the development of verification requirements? Verification requirements are actually very different from the requirements they support. While they share the same syntax and basic requirements writing rules as performance requirements, you usually need many verification requirements to properly verify that a single performance requirement is satisfied.

This tutorial will enlighten both the new SE as well as the grizzled veteran who needs a refresher about how to properly develop good verification requirements. We will go though a number of real world examples of good and bad verification requirements, and how they contributed to success and failure. We will establish the philosophical foundation for writing verification requirements, and present a simple process for developing verification requirements for broad classes of performance and functional requirements.

Biography

Mark A. POWELL, USA, has practiced Systems Engineering for over 35 years in a wide variety of technical environments including DoD, NASA, DOE, and commercial. His roles in these environments have included project manager, engineering manager, chief systems engineer, and research scientist. Mr. Powell began teaching in academia in 1980, and has been teaching Systems Engineering at the graduate level since 1989. He is currently an adjunct member of the Stevens Institute of Technology Systems Engineering Faculty, and of the University of Houston, Clear Lake Systems Engineering Faculty. Mr. Powell maintains an active engineering and management consulting practice (currently in affiliation with SAIC), providing consultation to the Army's Future Combat Systems program during 2003-2005, and now for the NASA's Constellation Program. He is an active member of Sigma Xi, AIAA, ISBA, and helped to found the Texas Gulf Coast Chapter when he joined INCOSE in 1991.

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Attwater Consulting

11 July 2010
Chicago, IS 2010

Tutorial Schedule

13:30 – Preliminaries, Introductions

13:45 – Some Basics

14:55 – Break

15:10 – Verification Requirements and How to Write Them

16:50 – Summary and Evaluation

17:00 – You are free to go

Attendee Introductions
(Time Allowing)

- **Your Name, Employer, and Type of Business**
- **Your Job and Type of Work You Do**
- **Do You Work with Verification?**
- **What you are hoping to gain from today's tutorial**

Your Tutorial Instructor: Mark A. Powell

- **Professor, Systems Engineering**
  - **Stevens Institute of Technology**
  - **University of Houston Clear Lake**
  - **University of Idaho**
- **Over 35 years Experience in Systems Engineering and Project Management**
- **Former Chair, INCOSE Risk Management Working Group**
- **INCOSE Technical Leadership Team, Former Assistant Director for Systems Processes**
- **Contact Information at the End of Tutorial Presentation, Contact Welcomed**

First a Word about Terminology

- **I Hope to Establish a Terminology for Today's Tutorial**
- **Many Uses Abound for Many Terms you will see Today**
  - **Not all Uses in Agreement or Consistent**
  - **Even if Hard Definitions Exist, Terms in Most Projects are *Used Freely*, with Good and Effective Understanding**
- **I will be Using Many Terms, and If you are not Sure about My Meaning in the Particular ad hoc Context**

  PLEASE ASK!
- ***Substance*, *Concepts*, and *Content* in Verification and Verification Requirements are Much *More Important Than Definitions***

Before We Get to Verification Requirements

. . .

Some Basics

I V&V

- **For this Tutorial:**
  - **Integration, Validation, and Verification**
  - ***NOT* Independent Verification & Validation**
- **I V&V are All Intermingled**
  - **Usually Managed Together**
  - **Mostly Contemporaneously Performed**
  - **Sometimes Confounded**

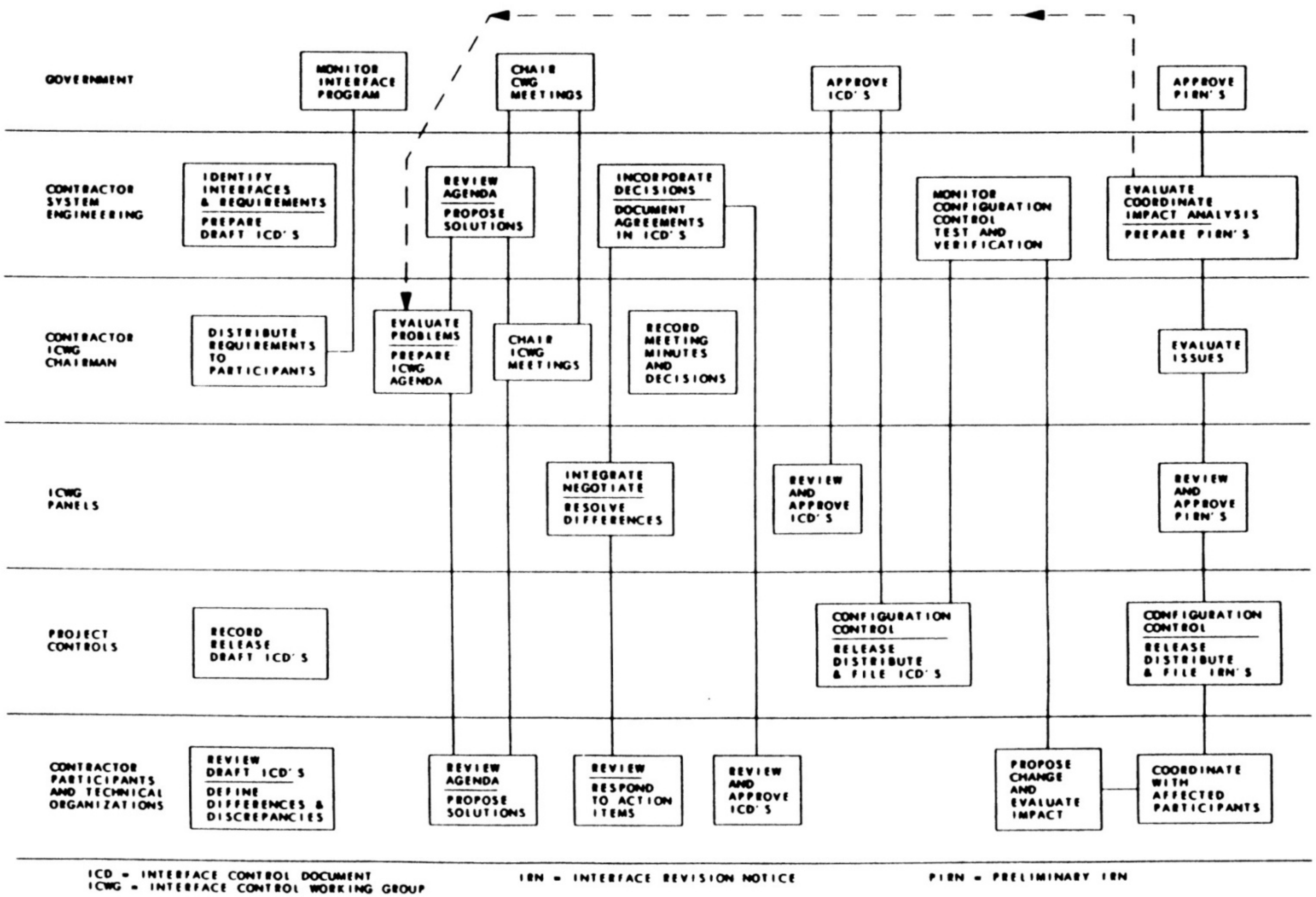
Integration

- **The Word *Integration* has Many Meanings and Uses**
- **For Systems Engineering Practice, Comprises Two Very Important Activities**
  - **Interface Definition, Management, and Control**
  - **System Builds**

Interface Management and Control

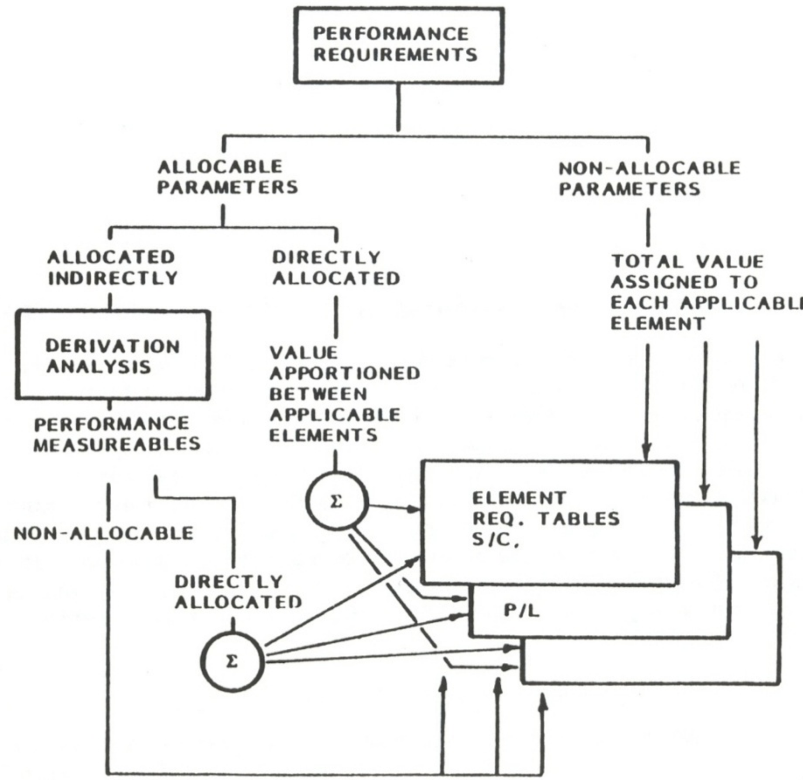
- **In Development of a System of Any Appreciable Size, Potential for *Exponential Growth* in Numbers of Interfaces**
- **The Process to Control and Manage Interfaces should be Documented in the SEMP**
  - **Interfaces Identified in Development Phases**
  - **Definition and Control Usually Performed Through Interface Control Working Groups (or Integration IPT's)**
  - **Interface Control Documents become Part of the Formal Baseline and Provide Means to Manage Interfaces**

A Relevant, but Complex Process



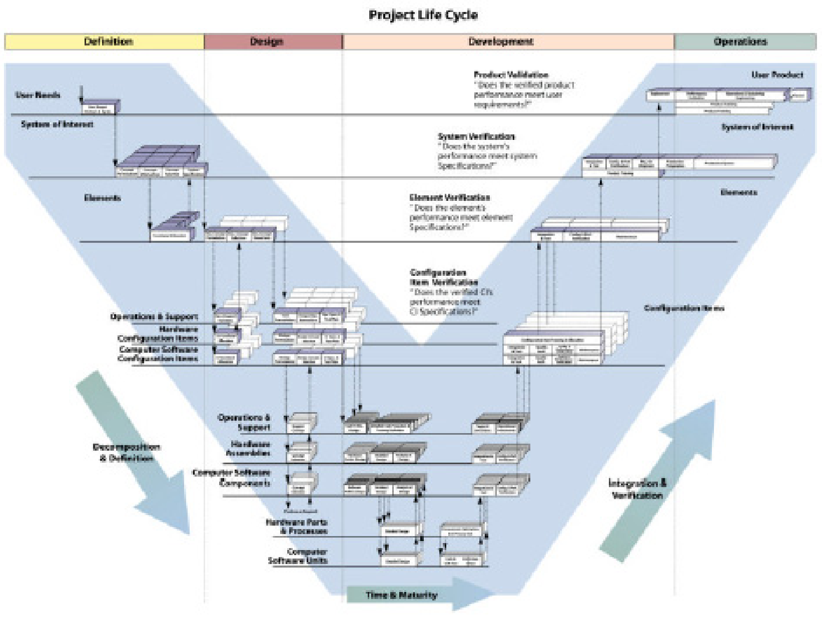
System Builds

- **Actually, just a Build from a Lower Hierarchy Level to the Next Higher – e.g., Components *built* into Subassemblies, Subassemblies into Subsystems, etc.**
- **Consider the Requirements Allocation Process in Functional Analysis and Decomposition**
- **Component Performance Requirements Must Satisfy Subassembly Performance Requirements *after* the Build**



Integration Summary

- **Interface Definition, Management, and Control**
  - **Definition: Mostly Left Side of "Vee"**
  - **Management and Control Everywhere**
- **System Builds**
  - **Identified and Planned on Left Side**
  - **Executed on Right Side**



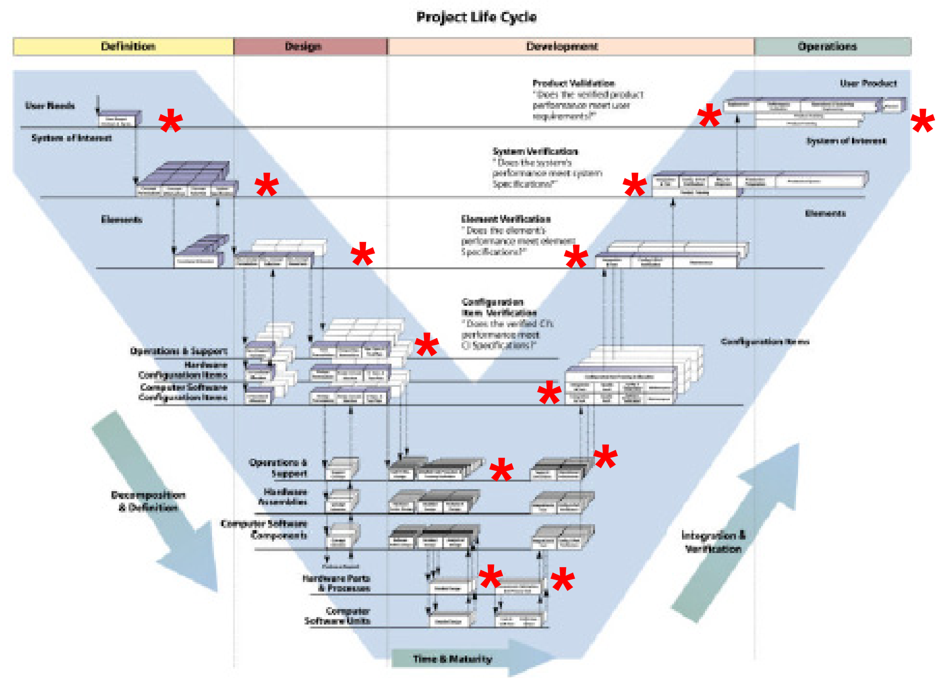
Validation

- **The Root: *VALID***
  - **1. sound; just; well-founded***
  - **2. producing the desired result; effective**
  - **3. having force, weight, or cogency; authoritative**
  - **4. legally sound, effective, or binding; having legal force: a valid contract.**
  - **5. Logic. (of an argument) so constructed that if the premises are jointly asserted, the conclusion cannot be denied without contradiction.**
- **Often *Confused* with Verification**
  - **Sometimes Erroneously**
  - **Sometimes *NOT!***

**** Definitions from Dictionary.com***

Validation

- **Answers Two Fundamental Questions (with a *YES* of Course)**
  - ***Are we Addressing the Right Problem?***
  - ***Is our Solution Solving that Problem?***
- **When Validation Activities Occur**
  - **Continuously, by Every SE on the Project**
  - **The Primary Purpose of Every Control Gate (Review)** * ***One or more simultaneously***



Verification ensures you built it right

Validation ensures you built the right thing

Practical Validation

- **Many Use the Terms *Verification* and *Validation* Interchangeably**
  - **May not Understand the Subtleties**
  - **May just be Using Sloppy Diction**
  - **May be Focused on a Point Solution**

Be Careful!

- **The Problem *Always* Evolves with Time**
  - **By Continuously Validating, You catch Problem Evolution Earlier – *Easier* to Fix Solution and *Cheaper* – *Always!***
  - **By Continuously Validating, You Catch when the Solution Goes Astray Earlier – *Easier* and *Cheaper* to Fix, *Always!***
  - **All Reviews Always Address Problem Space as well as Solution Space**
  - **All Program Documentation Must Evolve with the Evolution of Problem Space to Maintain *a Realistic and Contemporaneous Baseline***

Now Something to Add to the Confusion

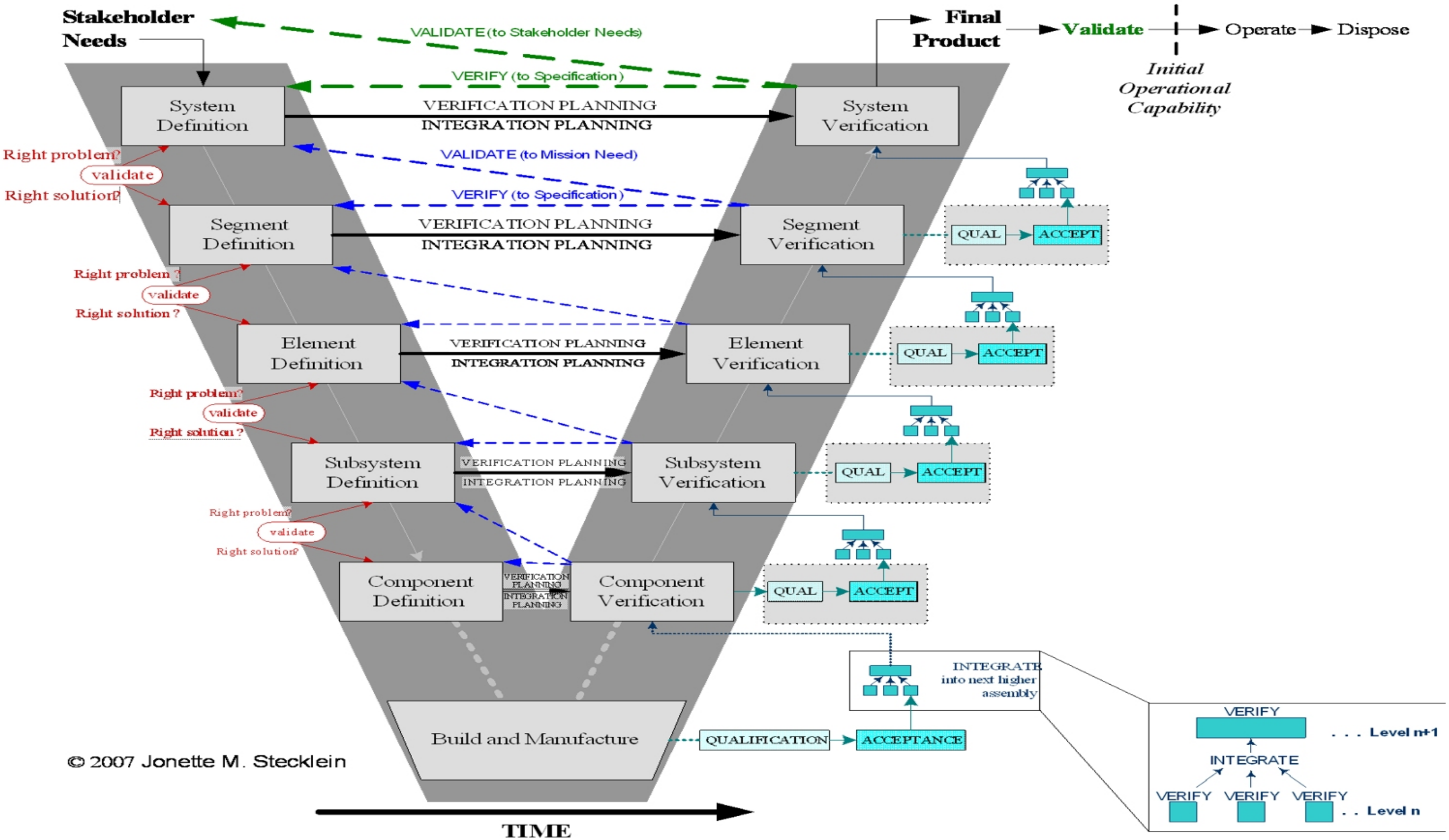
- **You have to *Verify* that the Problem Space is *Valid***
- **You have to *Verify* that the Solution Space is *Valid***
- **The Term *Verify* in this Case is Not Always a *Formal Verification* Process**
  - **Typically, a Lot of SE Audits are Used to Verify *Validity***
  - **Reviews also Use a Lot of SE Audits**
  - **However, If Uncertainty Exists about the *Validity* of a Solution – Formal Verification Process may be Needed**
- ***Be Careful in your Communications!***
  - **Validation Always Answers the Two Questions**
  - **Verification of the Correct Problem and that the Solution Solves the Problem Provides the Validation**
- **Most Importantly, Be *SURE* it Gets Done!**

Verification

The Fundamental Concept of Verification

- **Verification is a *Risk Mitigation* Process**
  - **If we could be *Absolutely Certain* that the Contractor would *Build Exactly What we Intend* in our Specifications, there would be No Risk**
    - **BUT, *Not Always Sure* Our Requirements will Be *Understood and Interpreted* Properly**
    - ***Not Always Sure* Our Requirements are *Complete and Consistent***
  - **Verification *Reduces* this Risk, but Cannot Completely Eliminate it**
- ***How Well* Verification Requirements are Written Determines *How Well* Execution of Verification Mitigates the Risk**

A Summary View of IV&V



Short Break!

Please Be Back by 15:15

Now to Verification Requirements

- **Background on Verification and Verification Requirements – *To Answer the Question of Why?***
- **A Process for Writing Verification Requirements – *To Answer the Question of How?***
  - **Verification Methods, Some Clues How to Select One**
  - **Structure of Verification Requirements**
  - **How to Write Verification Requirements**

What Can Happen without Verification Requirements

- **Space Station *PRD* Requirement**
  - ***The Space Station orbit shall be nominally circular.***
  - **No Corresponding Verification Requirement in PRD**
- **Author had Air Force background: "nominally circular" means Orbit Eccentricity < 10^{-2} for the Air Force**
  - **For Space Station, Eccentricity of 10^{-2} is *physically impossible***
  - **Max Possible Eccentricity for LEO: ~5e-4**
- ***Could* have Written a Simple Verification Requirement**
  Analysis shall show that the Space Station GN&C Systems will maintain Space Station orbits with eccentricities less than 10^{-2}.

What Happened without a Verification Requirement

- **Work Package 2 Contractor *Interpreted “nominally circular” a little Differently***
  - **Interpreted it to mean orbit eccentricity of *identically zero* (perfectly circular orbits) during *“nominal operating conditions”* (eventually at end of reboost)**
  - **Required Very Expensive GN&C System On-board to Plan and Control Trajectory to Achieve Zero Eccentricity**
  - **Required $25M GPS Development to Measure or Verify Zero Eccentricity (Huge Cost Growth!)**
- **Major Contributor to *Cancellation of Work Package 2*, after Five Years of Unsuccessful Customer Change Requests**
- ***A Simple Verification Requirement Could have Changed Everything***

What Can Happen with Poor Verification Requirements

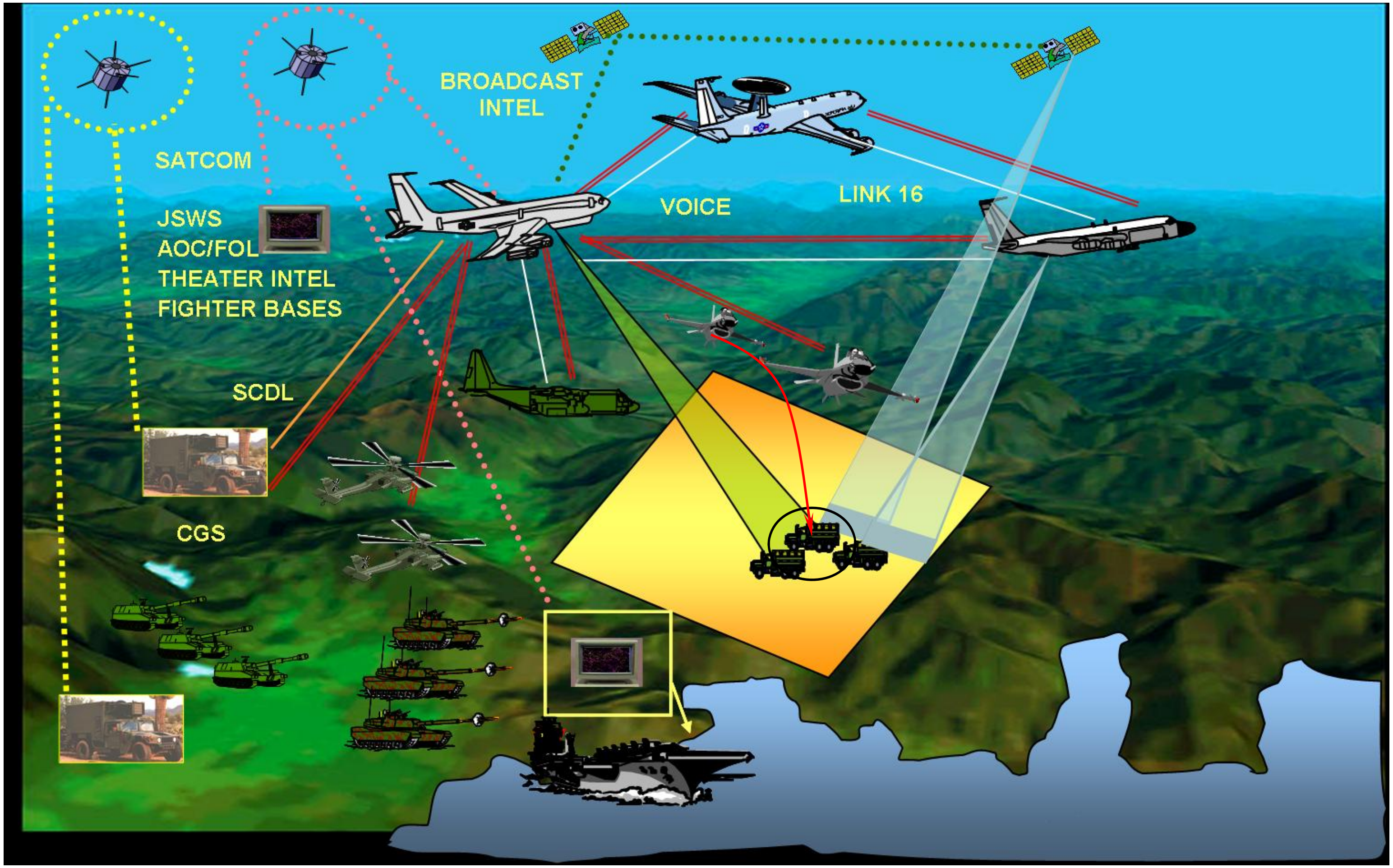
- **Contractors *Always* Design and Build to the Verification Requirements, *Not Section 3!***

Very Important Concept!

They want to get Paid!

- **Example: Joint STARS**
  - **Section 3.2.x: *System Shall Direct and Deliver Ballistic Bombs with 100m CEP Accuracy.* (100m Value Made Up)**
    - **CEP is circle about Target containing 50% probability**
    - **Aside for Section 3: CEP's Great Way to Specify 2D Accuracy Requirements (SEP is 3D analog)**
  - **Section 4.3.2.x: *JSTARS bomb delivery accuracy shall be satisfied if 5 or more of 10 bomb drop tests land within 100m of target.***
  - **Sounds *Very Reasonable*, Doesn't It?**

Joint STARS


BROADCAST
INTEL
SATCOM
JSWS
AOC/FOL
THEATER INTEL
FIGHTER BASES
VOICE
LINK 16
SCDL
CGS

What Happens with Poor Verification Requirements

- **Suppose the Contractor Met the Requirement: *JSTARS System as Built would Deliver Bombs within 100m of Target with 50% Probability***
- **What was the *Probability* that the Contractor would Pass this Test and *Get Paid*?**
  - **Rather Straightforward Binomial Probability Calculation**
  - **Answer: *Just 62.3%!***
- **How the Contractor Responded to This Result**
  - ***Over-designed System* to Deliver 80% of all Bombs within 100m, *Increasing Cost Several Fold***
  - ***Obtained 99.4% Probability of Passing Test and Getting Paid***

What Else Can Happen

- **Verification Requirements *Establish the Level of Risk* the Customer will Accept for Satisfaction of a Section 3 Requirement, *Whether Stated or Not!***
  - **Usually, Acceptable Risk is Not Specified, But Could Be (Test)**
  - **A Thorough Analysis of Verification Requirements for Acceptable Risk is a useful SE and Management Practice**
- **What *Acceptable Level of Risk* did this Joint STARS Verification Requirement Establish for the Customer?**
  - **Can be Calculated**
  - **The Answer: *The Customer Accepted a 50% Risk***
  - **The Probability that the Contractor Really Provided a System with a 100m CEP, *given* that 5 or more of 10 Bombs landed within 100m (*they passed the test*), was *only 50%***

How to Fix It

- **This Verification Requirement for Joint STARS**
  - ***NOT Good for the Contractor***
  - ***NOT Good for the Customer***
- **Write a *Better* Verification Requirement:**
  JSTARS bomb delivery accuracy shall be satisfied if bomb drop tests show a 90% probability that 50% of bombs dropped will land within 100m of target, with at least 3 and no more than 10 bomb drop tests.
  - **The 90% Probability (for example) indicates the government will accept a 10% risk that the completed system will satisfy this accuracy requirement – *Very Clear to Everybody***
  - **Note the opportunity for Cost Savings – Does not require all 10 bomb drop tests**
  - **Note that the Probability for the Contractor passing the Test is Purely Dependent on whether or not they Satisfied the Section 3 Requirement**

Advantages of Writing Good Verification Requirements

- ***Improves*** **the Section 3 Requirements**
  - ***Measure of Verifiability*** **of Section 3 is the** ***Ease*** **of Writing Section 4 Requirements**
  - ***Measure of Clarity*** **of Section 3 is** ***Number of Iterations*** **on Writing Section 3's and Section 4's for Consistency**
- ***Quantifies*****, or enables Quantification, of** ***Acceptable Risk*** **to the Project for Section 3's**
- ***Establishes*** **a priori** ***Agreement*** **on Evidence Customer will Accept that Section 3's are Satisfied**
- **Enables Good** ***Life Cycle Cost Estimates*** **and Early** ***Planning***

Very Important Concept

The Morals of these Examples

- **You *Want* to Write Verification Requirements *to be Sure* your Section 3 Requirements are *Understood Properly*, *the way you mean them!***
  - **Verification Requirements Provide Further Clarification and Communication – *Writing the Verification for a Section 3 concurrently Really Helps!***
  - **Good Verification Requirements Can Go a Long Ways to Compensate for Poorly Written Section 3's**
- **You *Want* to Write *Good* Verification Requirements!**
  - **Good Verification Requirements Establish *the Acceptable Risk* for the Customer**
  - **Good Verification Requirements Establish the Risk to the Contractor**
  - **Good Verification Requirements *Eliminate* or Reduce the Potential for *Wasteful* Contractor Costs**

Who Should Write the Verification Requirements?

- ***Who Knows Best*** **what the Section 3 Requirement to be Verified** ***Really Means*****?**
- **Practice of Throwing Section 3's** ***over-the-fence*** **for Someone Else to Write Section 4's is** ***Very Expensive*****,** ***if Ever Effective***

Obvious Answer:

The Section 3 Requirement Author

Cost Considerations

- **Planning for Verification Can Identify Needs for *New Major Projects or Facilities***
  - **E.g., Projects to Build Test Articles and Test Facilities**
  - **Early Identification Enables Most *Cost Effective* New Projects**
- ***How* you Verify Can Pose Very Different Costs**
  - ***Repeated Experiments* on Actual HW/SW to Collect Observations/Data for Statistical Processing (Often Test Method): *Most Expensive***
  - ***Actually Operating the System HW/SW to show that it Works* (Often Demonstration Method): *Can be Very Expensive***
  - ***High Fidelity Simulations* (Often Analysis Method): Can be Expensive, but *Usually More Cost Effective***
  - ***Observing Compliance by Examination* (Often Inspection Method): Almost always *Cheapest***

Verification Activities Can Consume the Vast Majority of Project Resources!

Verification in the Project Life Cycle

- Verification Activities *Change as the Project Matures*
  - Different Levels of Design Detail Lead to Different Verifications
  - Verification Method Usage Changes with Maturity Level
- *Top Down* Design Leads to *Bottoms Up* Verification
- *Bottoms Up* Verification Execution Occurs *after* Stages of Integration
  - Integration Occurs *after* Sub-pieces have been Verified Individually and Successfully
  - Verification that the Integrated Piece Meets its Requirements *May Consider* Sub-piece Verification Results
- Verification Requirements written for Highest Levels of Design Detail Cannot Well Anticipate Lower Level Verification Results – so *Use some Thought when Writing*

Verification Categories

- ***Development***: Conducted on new items to demonstrate proof of concept. Testing may be done on breadboard, brassboard, engineering prototype, or partial model. Often used to reduce risk, prove feasibility, and provide Validation.
- ***Qualification***: On aerospace equipment these ground tests are conducted to prove the design on the first flight article produced, using elevated environmental conditions for hardware. The hardware qualification test items cannot generally be used in an operational test due to overstress.
- ***Acceptance***: Conducted to prove workmanship and materials on the second and succeeding articles. Tests conducted are a subset of the qualification tests, performed at lower stress levels.
- ***Operational***: Conducted to verify that the item meets its specification requirements when subjected to the actual operational environment. Some requirements, such as radiation hardening, may be fully verified at the parts level by testing. Many requirements at the system level may be verified only by simulation (supported by test data from lower levels).

Verification Methods

- **The Method Selected is *not as Important* as Specifying What the *Success Criteria* should be and How it is Obtained**
- **The Methods – *Test*, *Analysis*, *Demonstration*, *Inspection***
- **You Can Use *Almost* Any Method for Any Section 3, but There are Consequences and Limitations**
  - **Risks Vary by Requirement and Verification Process**
  - **Costs Can Vary Widely**
- **You will Need to *Use some Thought* and *Best Engineering Judgment***

Verification Method Definitions

Inspection: **an examination of the item against applicable documentation to confirm compliance with requirements. Inspection is used to verify properties best determined by *examination and observation* (e.g., - paint color, weight, etc.).**

Test: **an action by which the operability, supportability, or performance capability of an item is verified when subjected to controlled conditions that are real or simulated. These verifications often use special test equipment or instrumentation to obtain very accurate *quantitative data for analysis*.**

Demonstration: **a qualitative exhibition of functional performance, usually accomplished with no or minimal instrumentation. Demonstration (a set of test activities with system stimuli selected by the system developer) may be used to *show that* system or subsystem *response to stimuli is suitable*.**

Analysis: **use of analytical data or simulations under defined conditions to show *theoretical* compliance. Used where testing to realistic conditions cannot be achieved or is not cost-effective. Analysis (including simulation) may be used when such means establish that the appropriate requirement, specification, or derived requirement is met by the proposed solution.**

Some Guidance for Selecting *Inspection*

- If a Human Being can *Observe* or Use *a Simple Measurement* to Determine if the Requirement is Satisfied or Not – then use *Inspection*
  - *Binary Decision*, *Go/NoGo*
  - Simple Judgment Required of Tester *using Their Senses*
  - May be *Simple Measurements* (Torque, Length, etc.)
  - Generally, Non-destructive and Executed on Actual System HW/SW
- *Risk* with this Method is Generally *Inherent with the Inspector*
- *Least Expensive* Verification Method
- Used Extensively To Verify *CDR Level of Design Detail Requirements*

Some Guidance for Selecting *Test*

- **If the Section 3 is an *"ilities"* Requirement, then You should Use *Test* or *Analysis***
- **If you are thinking that to Verify a Section 3 that you need to run an *Experiment* on *Actual System HW/SW*, *Collect Data* and *Statistically Analyze* it, then the Method should be *Test***
- **Specification of *Test* Does *Not* Require the Design of the Experiment, *but a Thorough Description* of the Experiment**
- **The *Test* Method *Success Criteria* is best stated *Probabilistically* (Recall Joint STARS Example)**
- ***Test* - the *Best and Most Effective Method* to Really Quantify and Reduce *Risk* for Requirement, but Expensive**
- **Usually Used Extensively To Verify *CDR Level of Design Detail Requirements***

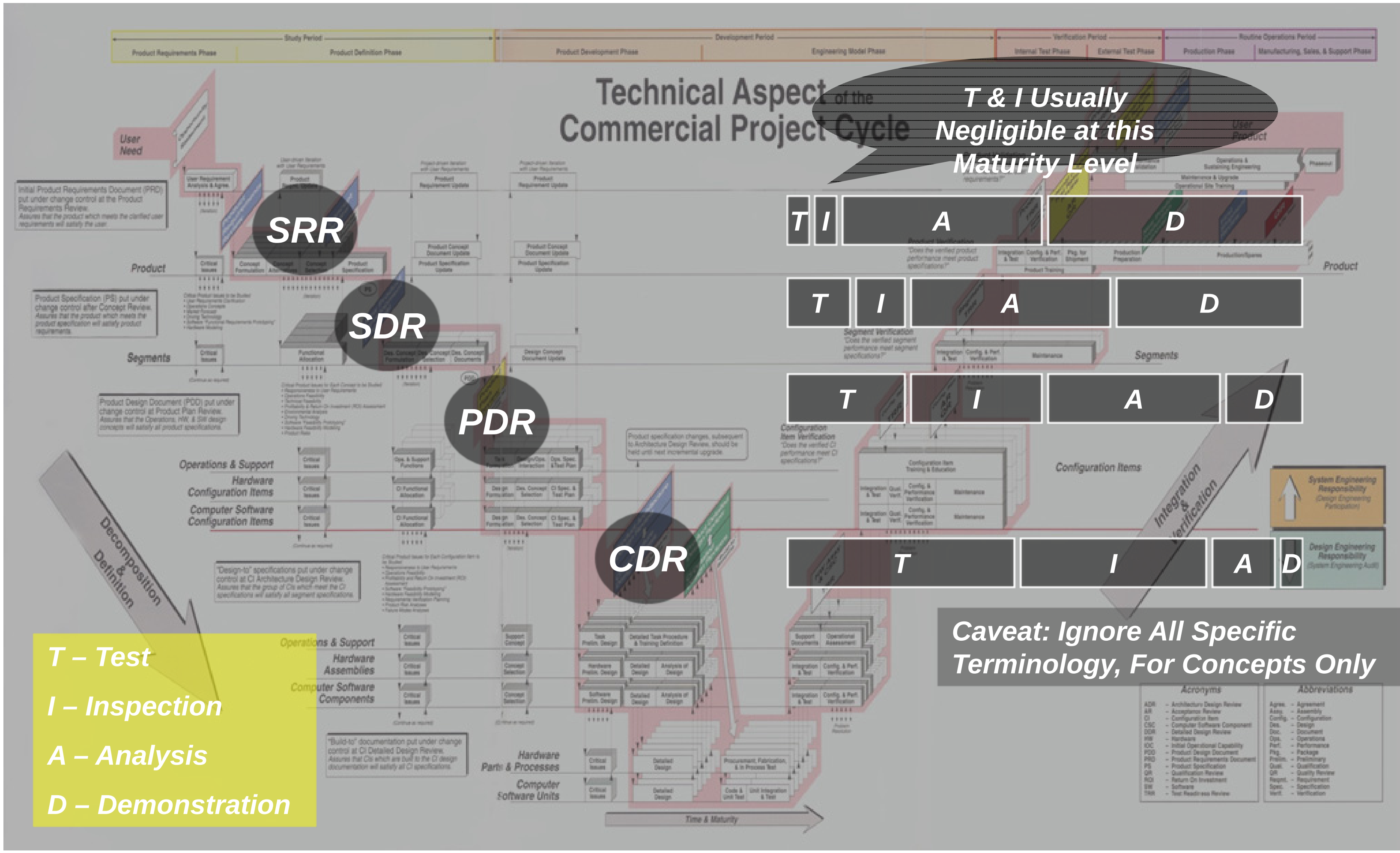
Some Guidance for Selecting *Analysis*

- If the Section 3 can be Verified by *Evaluation of Equations* (say from physics, or from Integration equation from a Lower Level), then the Method is *Analysis*
- If *Test* would be *Preferred, but is Impractical*, and You can use a Simulated Experiment, the Method is *Analysis*
- *Mathematical Models* are Typically Used to Represent the System, Scenario, and/or Environment
- May be *More Difficult to Specify Than Test*, May have to Completely Specify Experiment and All Assumptions
- Generally *Much Cheaper than Test*
- *Risk* is Inherent in *Assumptions* and *Model Fidelities*
- May Require Extensive Model Validation
- Used to Verify Requirements At *All Levels* of Design Detail

Some Guidance for Selecting *Demonstration*

- If you are thinking that to Verify a Section 3 that you need to run an *Experiment* on *Actual System HW/SW*, and see only One Datum or Result to be Satisfied (*No Statistics*, Simple *Go/NoGo*), then the Method should be *Demonstration*
- Specification of *Demonstration* Does *Not* Require the Design of the Experiment, *but a Good Description* of the Experiment
- Usually Performed at *Extremes* of Range of Performance (worst case environment, scenarios, etc.)
- When Successful, Generally Non-destructive
- *Risk*: Only one Repeat of the Experiment, *Only One Datum* on which the *Go/NoGo* Decision is Made – Is one enough?
- Generally used to Verify *Highest Level* of Design Detail Requirements

Verification Method Life Cycle Compositions



How to Select a Verification Method

Ask Yourself Some Questions:

- **How *Important* is this Section 3 Requirement?**
  - ***Properly Written*, all Section 3 Requirements are Equally Important, all are Mandatory or Mission Fails**
  - **System Cannot Perform the Mission if Any Properly Written Section 3 is not Satisfied**
  - ***Back to the Real World!***
- **How *Risky* is this Section 3 Requirement?**
- **How *Precise* is this Section 3 Requirement?**
- **How *Sensitive* is this Section 3 Requirement?**
- **What are the *Consequences* of not Satisfying this Section 3 Requirement?**

Ask a Few More Questions

- **Can Someone with but a *High School Education Use Their Senses* to Determine if this Section 3 requirement is Satisfied with little Risk? If so, *Inspection* is a Good Candidate**
- **Would a Simple *One-shot Test* , Perhaps at an Extreme Scenario or Environmental Conditions, Reduce the Risk Enough? If so, then *Demonstration* is a Good Candidate**
- **Do you Need to Examine *Performance over a Wide Range of Scenarios or Environments*? Or is it an *"ilities"* Requirement? If so, then you should Use *Test* or *Analysis***
  - ***Cost* is One Discriminator between *Test* and *Analysis***
  - ***Feasibility* of the *Test* is Another**
  - **Is the *Expense* of *Test* Justified to Reduce the Risk?**

There is More to Specify Besides the Method

- Each Verification Method has *Different Aspects* that Must be Specified
  - As with Any Section 3, Section 4 Requirements Must not be Subject to Interpretation – *Write Good Requirements*
  - Method Designation is Insufficient
  - Each Method *Needs Subtier Verification Requirements* for Clarity to Achieve Risk Reduction
- One Attribute Common to All Methods
  - Verification Method *Success Criterion*
  - Specified Last in Subtier Verification Requirements
- Other Attributes Relate to How the Verification is to be Performed, e.g., the experiment

Inspection Attributes

- ***What*** **is to be Inspected**
- ***How*** **it is to be Inspected**
- ***Who*** **will Inspect it**
- **Inspection *Success Criterion***

3.2.x.y The MPLM RSR Locker door shall be retained and remain closed during shuttle ascent and descent.

Design Architecture described in Section 3.1: Screws Used to Retain Door with sufficient hold down torque and keensert (Last Thread Malformation) as secondary locking mechanism.

4.2.x.y Requirement 3.2.x.y shall be verified by inspection.

---- MPLM RSR Locker Door Retention screws shall be inspected by measurement for minimum hold down torque.

---- Retention screws shall be inspected visually for keensert engagement.

---- Inspection personnel shall be certified for torque measurement systems.

---- Verification of 3.2.x.y shall be considered successful if all screws are observed with hold down torques of at least 15 in-lbs and all screws protrude at least one thread beyond back of screw holes.

Test Attributes

- **Specify the *Measure* for the Test**
- **Specify the *Initial Conditions* and All other Important *Assumptions***
- **Describe the *Experiment*, e.g.,**
  - **Minimum Numbers of Samples**
  - **Minimum Numbers of Test Items**
  - **What can be Simulated, and Simulation Assumptions**
  - **Specify what *System HW/SW* will be Used**
- **Specify *Success Criterion* in terms of the Measure**

An Auto Industry Test Example

3.2.x.y The vehicle shall have 95% reliability at 100,000 miles.

The Method

4.2.x.y Vehicle reliability shall be verified by Test.

The IC's and Assumptions

---- The test shall use accelerated life testing procedures in accordance with TSP 432-1.

System HW/SW

---- The test shall use at least 3 prototype vehicles.

---- The test shall use as data simulated mileage at failure and total simulated mileage for prototype vehicles that do not fail by the end of the test.

Specific Directions

---- The test shall statistically process the data to calculate the probability that the vehicle provides 95% reliability at 100,000 miles.

The Measure

---- The test shall succeed if the probability that the vehicle provides 95% reliability at 100,000 miles exceeds 90%.

Success Criterion

Analysis Attributes

- ***Also*, Almost the Same as Test**
  - **Specify the *Measure* for the Analysis**
  - **Specify the *Initial Conditions*, All other *Assumptions*, and Sources of *Equations***
  - **If a *Simulation*, Specify the Extent of the Simulation**
    - **How many *Repetitions* (think Monte Carlo)**
    - **Extent and Range of *Simulated Environmental Conditions* to be Considered**
  - **Specify if *System HW/SW* will be Used**
  - **Specify *Success Criterion* in terms of the Measure**

An Auto Industry Analysis Example

3.2.x.y The vehicle shall have 95% reliability at 100,000 miles.

4.2.x.y Vehicle reliability shall be verified by Analysis.

---- The analysis shall simulate accelerated life testing procedures, environmental conditions, and maintenance in accordance with TSP 543-2.

---- The analysis shall use 100 simulated vehicles and simulate driving for 200,000 miles.

---- The analysis shall use as data simulated mileage at failure and 200,000 miles for simulated vehicles that do not fail.

---- The analysis shall statistically process the simulated data to calculate the probability that the vehicle provides 95% reliability at 100,000 miles.

---- The verification shall succeed if the probability that the vehicle provides 95% reliability at 100,000 miles exceeds 90%.

The Method

The IC's and Assumptions

Simulated HW/SW

Specific Directions

The Measure

Success Criterion

Demonstration Attributes

- ***Almost* the Same as Test**
  - **Specify the Measure or *Function* to be Demonstrated**
  - **Specify the *Initial Conditions*, *Environmental Conditions*, and All other Important *Assumptions***
  - **Specify *Specific Directions***
  - **Specify *System HW/SW* that will be Used**
  - **Specify if Anything (usually environment) is to be Simulated**
  - **Specify *Success Criterion* in terms of the Measure or Function**

An Auto Industry Demonstration Example

3.2.x.y The vehicle shall have 95% reliability at 100,000 miles.

4.2.x.y Vehicle reliability shall be verified by Demonstration.

---- The demonstration shall use accelerated life testing procedures in accordance with TSP 432-1.

---- The demonstration shall drive 3 prototype vehicles for 100,000 miles.

---- The verification shall succeed if all 3 prototype vehicles survive to 100,000 miles.

The Method

The IC’s and Assumptions

System HW/SW

Specific Directions

Success Criterion

A Verification Requirements Practice to Avoid

- **Picked Completely at Random From ISS Requirements Document Section 4**

  "This Requirement shall be verified by Analysis. An Analysis of the USOS Specification shall be performed to determine the segment-level requirements that are derived from this system requirement. The verification shall be considered successful when the analysis shows that the requirements have been successfully verified."

- ***Huh?***

Summary

- Verification Requirements are ***Extremely Important***
  - Establish Contractual Customer and Contractor Risks
  - Good Verification Requirements Can Save Project Resources
  - Good Verification Planning ***Really*** Can Save Project Resources
- Thanks for your Participation!

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