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A Day in the Life of a Verification Requirement- Tutorial

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Verification Requirements – What Are They And Why Do We Need Them?

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- Verification requirements specify the verification events needed to prove the satisfaction of the product requirements and help to define the verification process and environment

- Verification requirements are necessary for at least two reasons:
  - **Existence of verification requirements demonstrates verifiability of product requirements**
  - **Agreed-to verification requirements define the verification program by which the contractor shows that the product is what the customer contracted for**

A Day in the Life of a Verification Requirement

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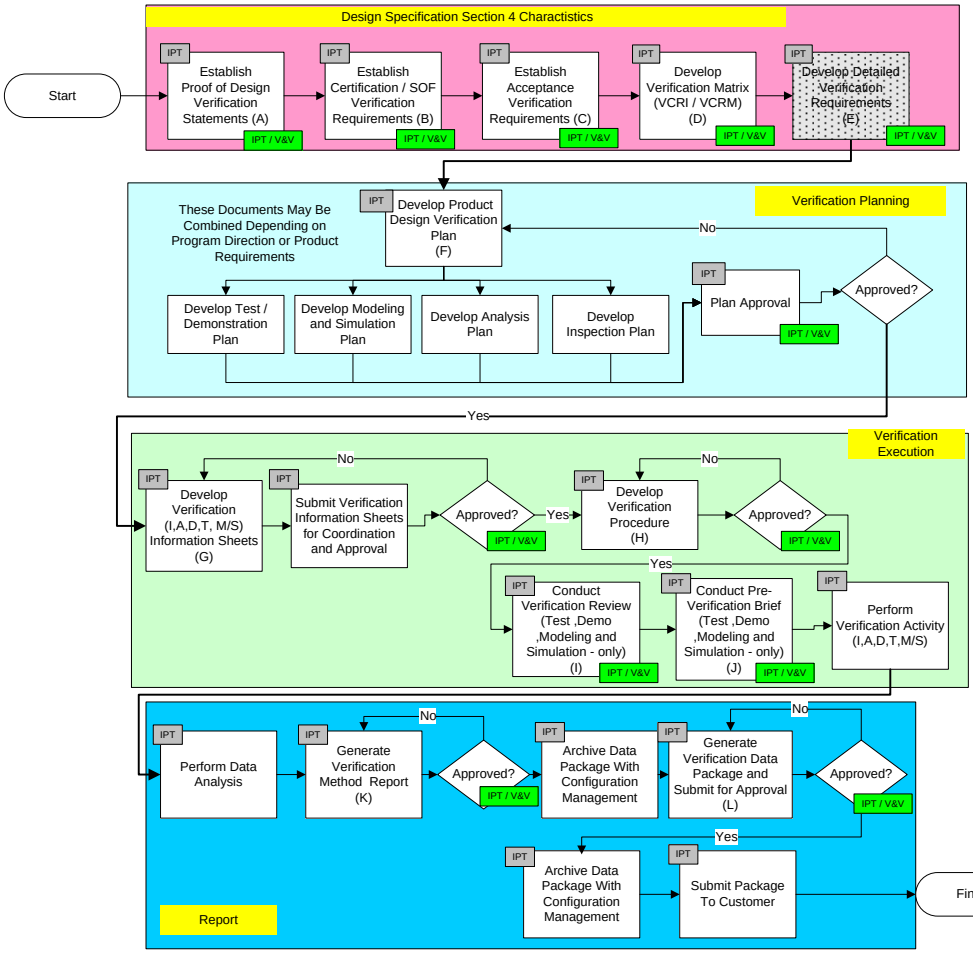
Product Requirements



Verification events satisfy the verification requirements, NOT the product requirements.

Product requirements are never complete until the associated verification requirements are completed

The culmination of the verification activity of the design requirements results in a verified product.

DD-250

Start with Product Requirements

- The verification process begins with authenticated product requirements
- Examples:
  - **PR-1:LRU markings***
    - **The product line-replaceable units shall be marked in accordance with MIL-STD-130M.**
  - **PR-2: Operational availability**
    - **The product shall have an operational availability (A_0) of 97.5% at IOC.**
  - **PR-3: Flight performance**
    - The Transportation Management Center shall handle up to 15 major incidents and 30 minor incidents during peak travel hours.
  - **PR-4: LRU accessibility***
    - **Each product line-replaceable unit shall be able to be removed and replaced without removing any other item or displacing any cables.**
  - **PR-5:Recovery force communication – nominal**
    - **The product shall provide a communications system capable of communicating with the recovery forces pre- and post- landing**

Verify <u>all</u> product requirements, not just functional/performance requirements

Create Verification Criteria

Design Requirement

3.2.2.15.34 Recovery Force Communications
The product shall provide a communications system capable of communicating with the recovery forces pre- and post- landing

SE – Translates Operational Objectives into Design Requirements
Design – Provides assessment of requirements implementation
Test – Provides assessment of requirements verifiability

Design Verification

Verification Objective	Pass / Fail (Success Criteria)
Perform Integrated System Test of the communications system capability to provide a voice communications and beacon with recovery forces pre and post landing within an integrated hardware / software environment	**Testing will show that the communications system can transmit and receive audio at frequencies and ranges (power) represented by standard ground recovery force communications devices as defined in TBD**
Perform a demonstration of the communications systems capability to provide voice and beacon communications with recovery forces pre and post landing while within a representative environment and using a production equipment configuration	**Demonstration will show the ability for the communications systems to verbally communicate with the on-board communication production configuration equipment. The demonstration will also show beacon tracking within communication ranges established by TBD.**

SE – Provides compliance of the design requirement
Test / Implementation Group – Ensures Verification Implementation Feasibility
Advises alternatives to support programmatics
Assesses completeness
Provides verifiability assessment

Traceability

Verification Cross Reference Matrix

Paragraph #	N/A	I	A	M/S	D	T
3.2.2.15.34						VR-5T
3.2.2.15.34					VR-5D	

SE – Verification Allocation and Traceability Assurance

Identifying a verification method is necessary, but not sufficient!

Verification Requirement Attributes

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Verification Requirements
- Inspection
- Analysis
- Modeling and Simulation
- Demonstration
- Test

Must answer 5 Questions

☑Objective

What is the purpose of this verification?

☑Method

What method do you need performed? What are the verification circumstances (e.g., laboratory, desk-top analysis, flight test)?

☑Environment

What are the environmental conditions under which the item will be verified?

☑Special Conditions (if necessary)

Are there any unique conditions (e.g., item configurations) necessary for the execution of the verification?

☑Success Criteria

What results are to expected?

Verification Methods

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- Inspection:
  - **An element of verification that is generally nondestructive and typically includes the use of sight, hearing, smell, touch, and taste; simple physical manipulation; and mechanical and electrical gauging and measurement. (MIL-STD-961E; called Examination)**
- Analysis:
  - **An element of verification that uses established technical or mathematical models or simulations, algorithms, charts, graphs, circuit diagrams, or other scientific principles and procedures to provide evidence that stated requirements were met. (MIL-STD-961E)**
- Demonstration:
  - **An element of verification that involves the actual operation of an item to provide evidence that the required functions were accomplished under specific scenarios. The items may be instrumented and performance monitored. (MIL-STD-961E)**
- Test:
  - **An element of verification in which scientific principles and procedures are applied to determine the properties or functional capabilities of items. (MIL-STD-961E)**

Verification isn't ONLY test!

Sample Verification Requirements - 1

- **VR-1I: compliance of product markings shall be verified by examination of design drawings at the LRU supplier's location prior to the LRU CDR. The inspection will show that each marking on the LRU conforms to MIL-STD-130M.**

- **VR-2A: the product operational availability shall be calculated using the results of the government-accredited contractor-developed reliability and maintainability analyses performed during the design in conjunction with the design reference missions documented in report xxxx. The analysis will show that the product, in its operational environment, supported with its support equipment and personnel, across all missions, will have an operational availability of at least 97.5%.**

Sample Verification Requirements - 2

- **VR-3MS: Verification of the TMC's handling of 15 major and 30 minor incidents during peak hours shall be shown through a live simulation. The TMC training simulator shall be configured for peak a peak-travel-hours training class and staffed with trained TMC operators. The training-simulator operator shall inject various combinations of major and minor incidents over the peak-travel period and the TMC performance shall be recorded digitally and using digital cameras. The simulation shall be repeated using different combinations of TMC operators and sets of incident combinations. Verification shall be achieved when the TMC handles all simulated sets of incidents with all combinations of operators with no equipment or software overloads or interrupts and with no operator overloads or interrupts.**

- **VR-4D: Removal and replacement of all LRU's shall be demonstrated on the aircraft to show that each LRU can be removed and replaced without removing any other items or moving any cables.**

- **VR-5D: Perform demonstration to provide a communications system capable of communicating with the ground command team while in a representative environment and production configuration. Demonstration will show capability to communicate with recovery forces at TBD distances in the TBD terrain environment.**

Sample Verification Requirements - 3

- **VR-5T: Prove that the product's communications system is capable of communicating with the ground command team by performing an integrated system test within an integrated hardware/software environment. Testing will show that the product can transmit and receive to standard ground recovery forces audio at frequencies represented by communications devices defined in (TBD).**

Verification Objective

Verification Method

Environment

Note – there are no Special Conditions

Success Criteria

Verification Requirements Flow and Traceability

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PR-1	PR-2	PR-3	PR-4	PR-5
VR-1I	VR-2A	VR-3MS	VR-4D	VR-5D VR-5T

Specification

Design Requirements

Verification Requirements

Verification Requirements Appear in the Same Specification as the Product Requirements to be Verified

Product Requirement	N/A	Insp	Anal	M&S	Demo	Test	Verification Requirement
PR-1		X					VR-1I
PR-2			X				VR-2A
PR-3				X			VR-3MS
PR-4					X		VR-4D
PR-5					X	X	VR-5D VR-5T

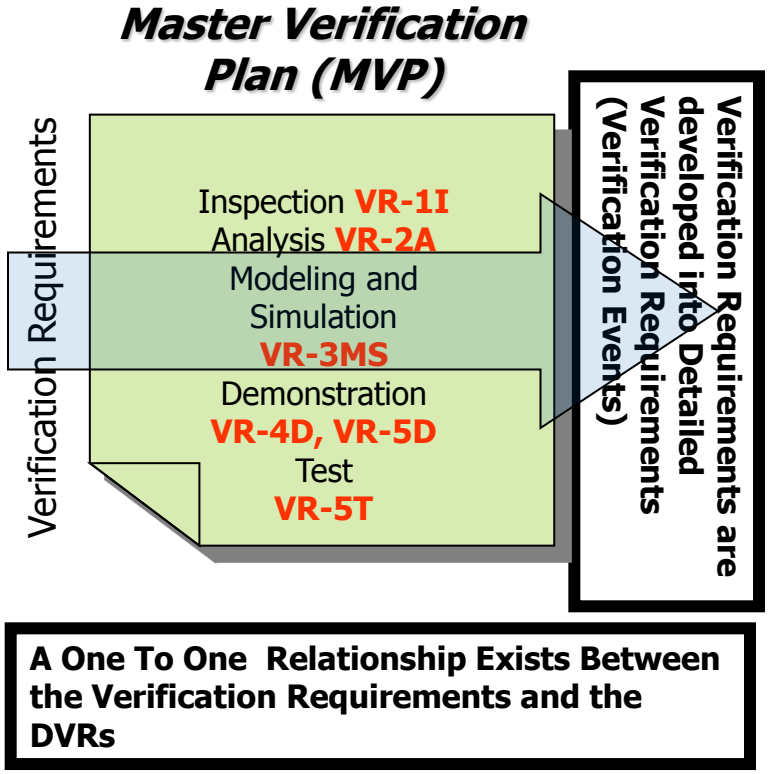
Master Verification Plan

Inspection **VR-1I**
Analysis **VR-2A**
Modeling and Simulation
VR-3MS
Demonstration
VR-4D, VR-5D
Test
VR-5T

Verification Requirements

Verification Traceability

Create Detailed Verification Requirements (Verification Events)

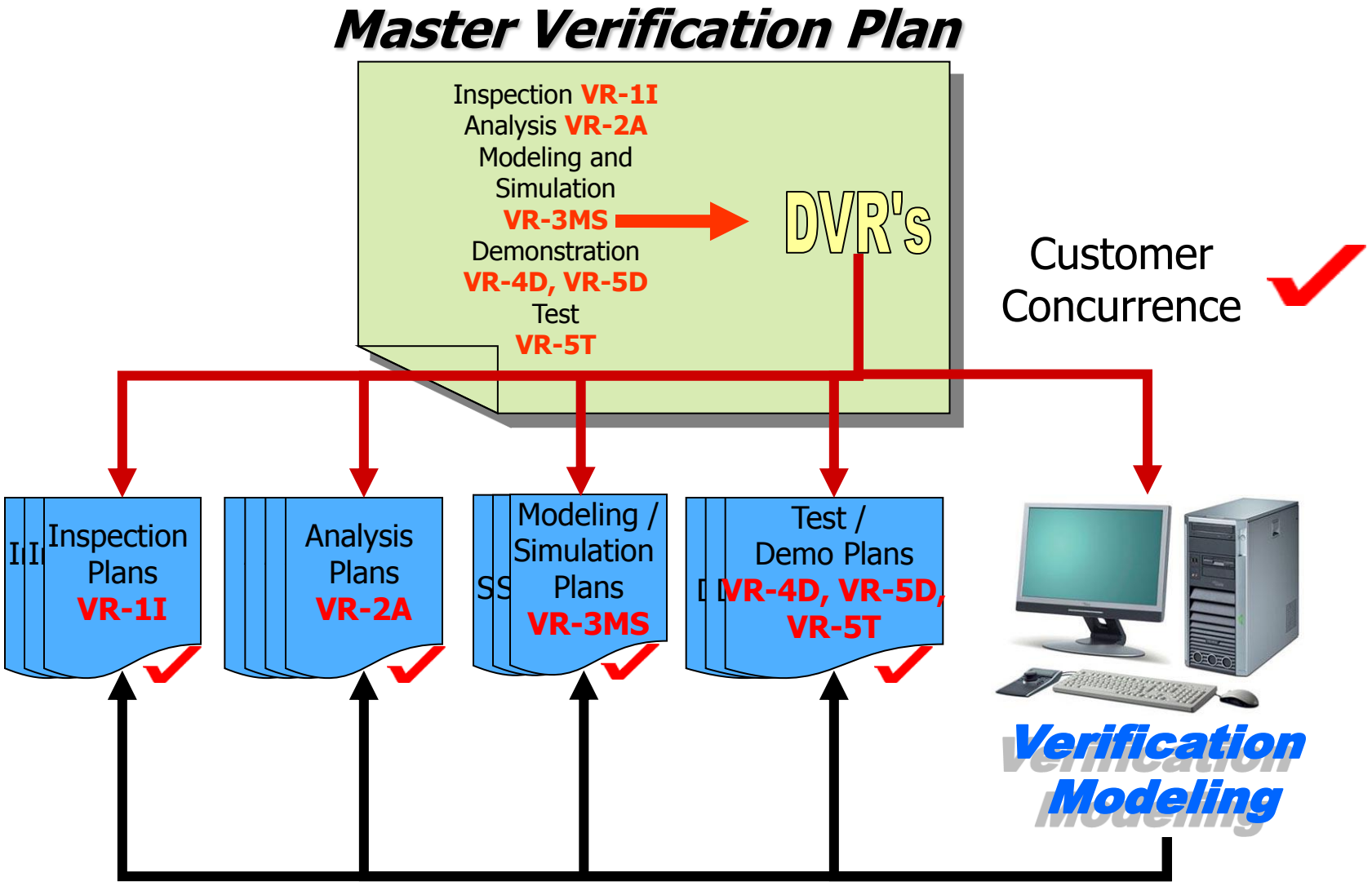


Convert verification statements into detailed verification requirements (verification events) by ----

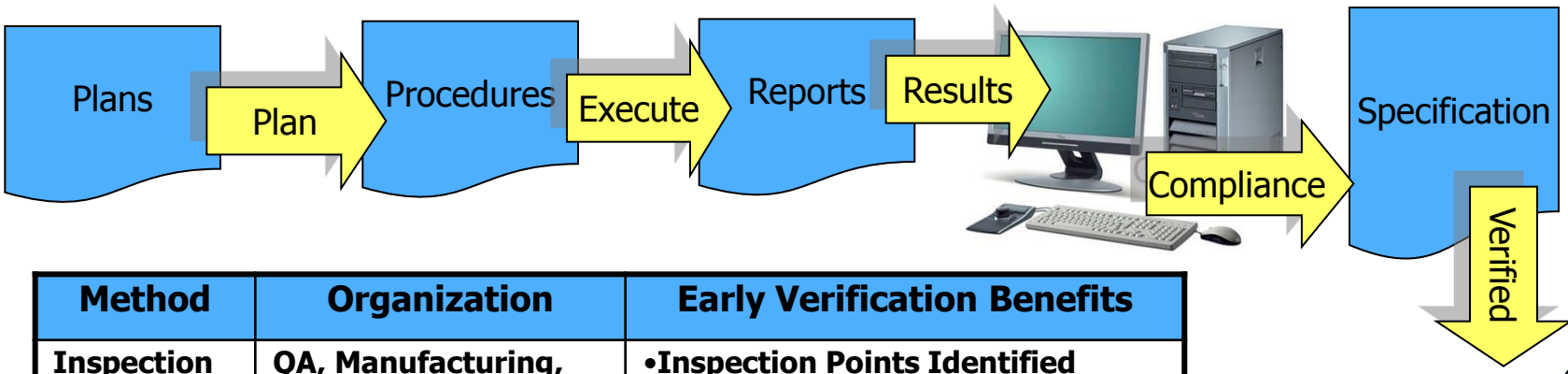
For each verification activity identified in the verification matrix, develop a detailed description of the activity including:

- **Verification configuration and its relationship to production configuration**
- **Associated prerequisites**
- **Constraints**
- **Objectives**
- **Procedures**
- **Relevant environmental conditions**
- **Pass/fail criteria- and necessary Data Set,**
- **Analysis models, if applicable.**
- **Sequence if applicable**
- **Verification Environment (e.g., Lab, Flight, Production)**

Master Verification Plan



Verification Execution Flow



Method	Organization	Early Verification Benefits
Inspection	QA, Manufacturing, Mission Assurance	•Inspection Points Identified •Tooling Requirements Identified
Analysis	Systems Engineering Specialty Engineering Design	•Define / Build / Buy / Train Analysis Prior to Need Date •Accreditation of Analyses Tools Prior to Need Date
Modeling and Simulation	Systems Engineering Specialty Engineering Design, Operational Assessment	•Define / Build / Buy / Train Modeling and Simulation Tools Prior to Need Date •Accreditation of Models Prior to Need Date
Demo & Test	Ground and Flight Test Facilities Development	•Laboratory and Lab Software Requirements Identified •Facilities Requirements Identified •Long Lead Test Items Identified

Early Verification Supports Multiple Organizational Functions' Long Lead Needs and Prevents Costly Late Program Re-Work

Planning for Verification Execution and Product Verification

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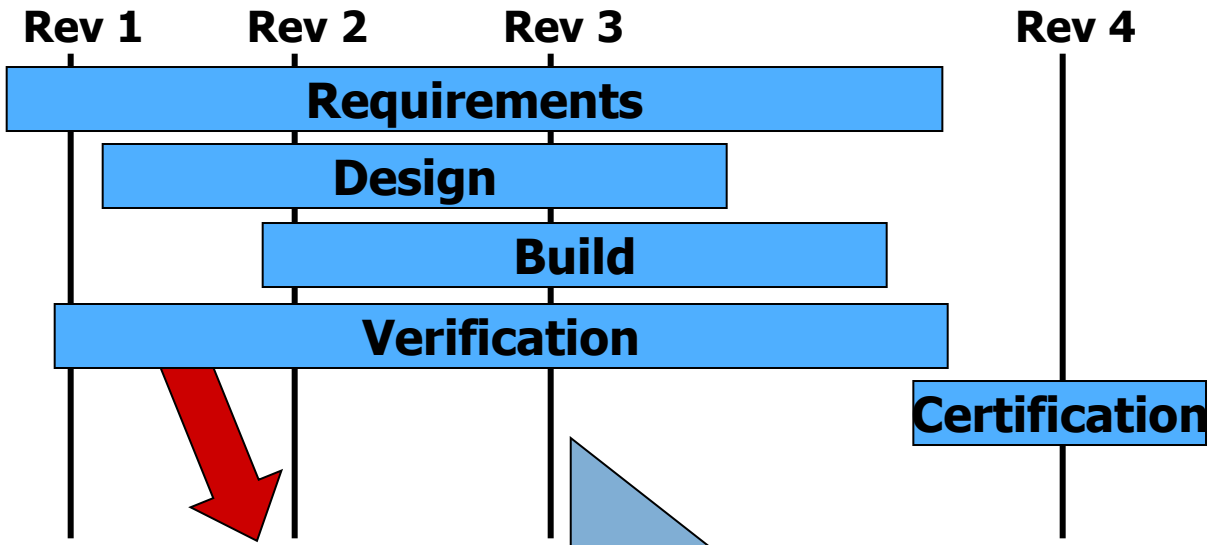

Define Verification Requirements Early and in Detail to Establish the Entire Verification Effort

… and it Costs Relatively little …

Long Lead Facilities
Laboratory Design
Range Coordination
Design Requirements
Software
Analysis Tools

Discover the Verification Requirements Late and Have Enormous Rework to Establish the Entire Verification Effort

… and it Costs a Lot More …

Early Verification Is an Effective Cost Avoidance Approach

Requirements: The Good …

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- The (radio set) design shall allow trained operators and maintainers to perform all critical tasks required to install, operate and maintain the (radio set) correctly on the first attempt 90% of the time.
- The XYZ satellite shall be launched on a Delta IV EELV or on an Atlas V EELV.
- The XYZ spacecraft shall rendezvous with the ISS in accordance with the Interface Definition Document (IDD) for International Space Station (ISS) Visiting Vehicles (VVs), SSP 50235 .
- The XYZ spacecraft shall shall perform the precision approach maneuver to the ISS in accordance with the Interface Definition Document (IDD) for International Space Station (ISS) Visiting Vehicles (VVs), SSP 50235.
- The XYZ spacecraft shall dock with the ISS in accordance with the Interface Definition Document (IDD) for International Space Station (ISS) Visiting Vehicles (VVs), SSP 50235.

Requirements: … The Bad …

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- **The ship and all systems shall be designed to minimize maintenance. Maintenance personnel shall be provided the necessary tools, information, technical documentation and skills to perform maintenance.**

- **The Product shall provide controls and displays to facilitate operator interaction in carrying out all assigned missions.**

- **And, of course, …**
  The Product shall be user-friendly.

Requirements: … And The (Truly) Ugly.

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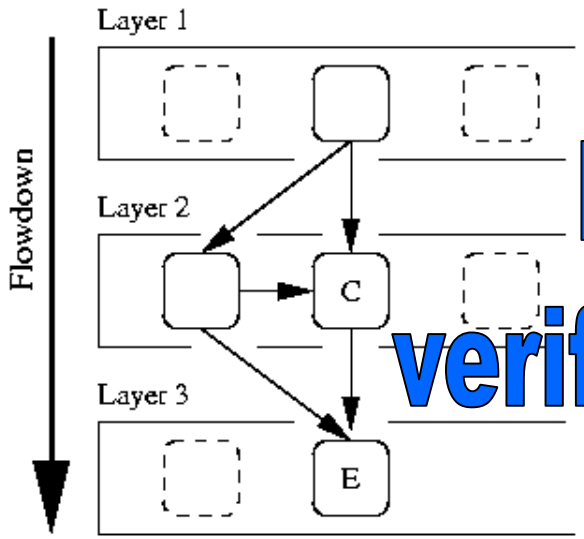
- **Human Systems Integration (HSI) characteristics and capabilities for (the ship) will include human factors engineering, personnel, habitability, manpower, training, environment, safety and occupational health (ESOH) and personnel survivability. HSI processes will be used to maximize human performance effectiveness, reliability, readiness and safety of the ship and crew while minimizing system life-cycle costs through iterative analysis and design tradeoffs.**

- **All systems shall be designed for maintainability. Reductions in manpower requirements for system maintenance (both planned and unscheduled) shall be achieved through an in-depth analysis of maintenance related tasks, early identification of maintenance concepts, and definition of maintenance requirements and constraints early in the design process. Burdens imposed on manpower, personnel and training related to system maintenance shall be identified as early as possible and refined throughout the development process.**

- **The ship shall be capable of being operated and maintained without requiring significant new knowledge, skills, abilities, aptitudes or physical characteristics of the core crew and mission package crews.**

Requirement Generation

- Class Exercise - Generate a good requirement as agreed to by the team and then let's test the theory
  - Generate a Requirement for the following Methods
    - Analysis
    - Test
    - Inspection



Requirements are organized into layers for team development.

Did you write a verifiable requirement?

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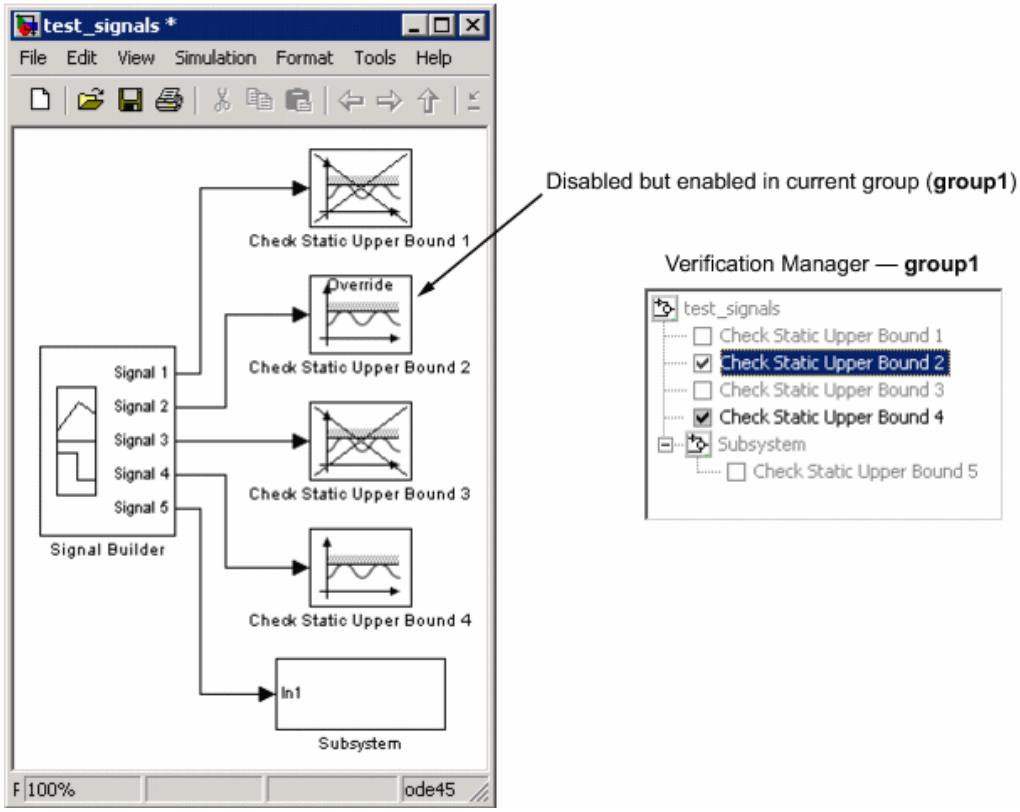
What is Verification ?

What is Verification?

- Confirmation, through the provision of acceptable objective evidence, that specified requirements have been fulfilled. (MIL-STD-961E)



Verification Requirement

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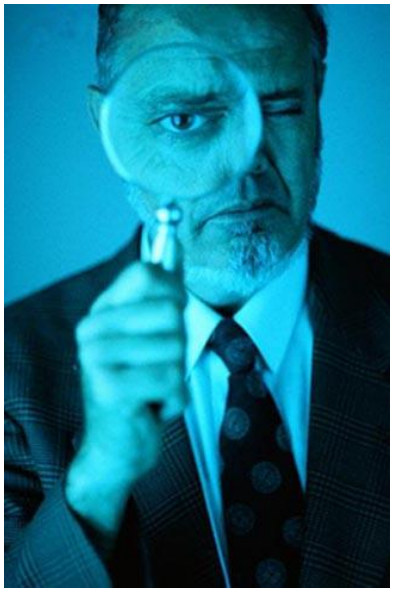
- A Verification Requirement's Purpose
  - Establishes the Requirements Intent
    - "If the Unit-Under-Verification (UUV) performs this way (or has characteristics), it is compliant with the requirement"
  - Establishes the completion criteria
    - "Requirement contract with the customer"



Verification Requirement

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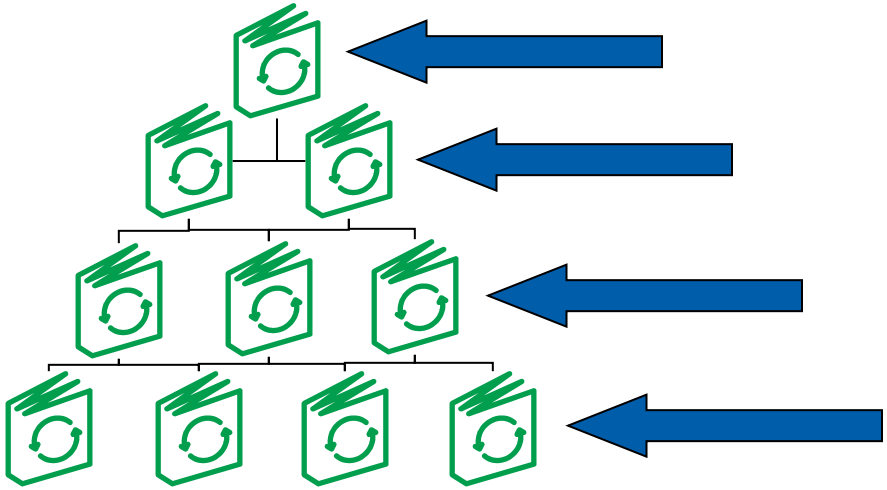
- Verification Requirement Levels
  - Developed for all specification levels (where ever there is a shall)
  - Written at the level of the unit configuration defined by the specification configuration item
    - "The Item Under Verification is the Title of the specification"
    - If you can't generate a Verification Requirement at the level of the specification-defined item, then the requirement is written at the wrong level"



Verification Requirement

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- A one to many relationship exists between the “Shall” and the associated verification requirement's).
  - Example
    - The Product shall provide visual operator status of power to the unit when applied for both proper and improper power conditions established by ICD XXX.
    - Demonstration 1
      - Verify by Demonstration that when power is supplied to the unit in accordance with the established interface defined in ICD XXX the operator is provided visual status. Demonstration will show that when proper power is provided a continuous visual indication is provided to the operator.
    - Demonstration 2
      - Verify by Demonstration that when power is supplied to the unit outside of the limits established by ICD XXX the operator is provided a visual cue different than the nominal power indication. Demonstration will show that when invalid power is provided a visual indication of improper power is provided to the operator for as long as the improper power conditions exist.

- Note – this verification statement should alert the requirements team that a requirement for the unit to prevent unit damage in the event of improper power application should have been written. Another advantage of developing the Verification Requirement early Forgotten Requirements – helps to identify missing Product Requirements.

Verification Requirements

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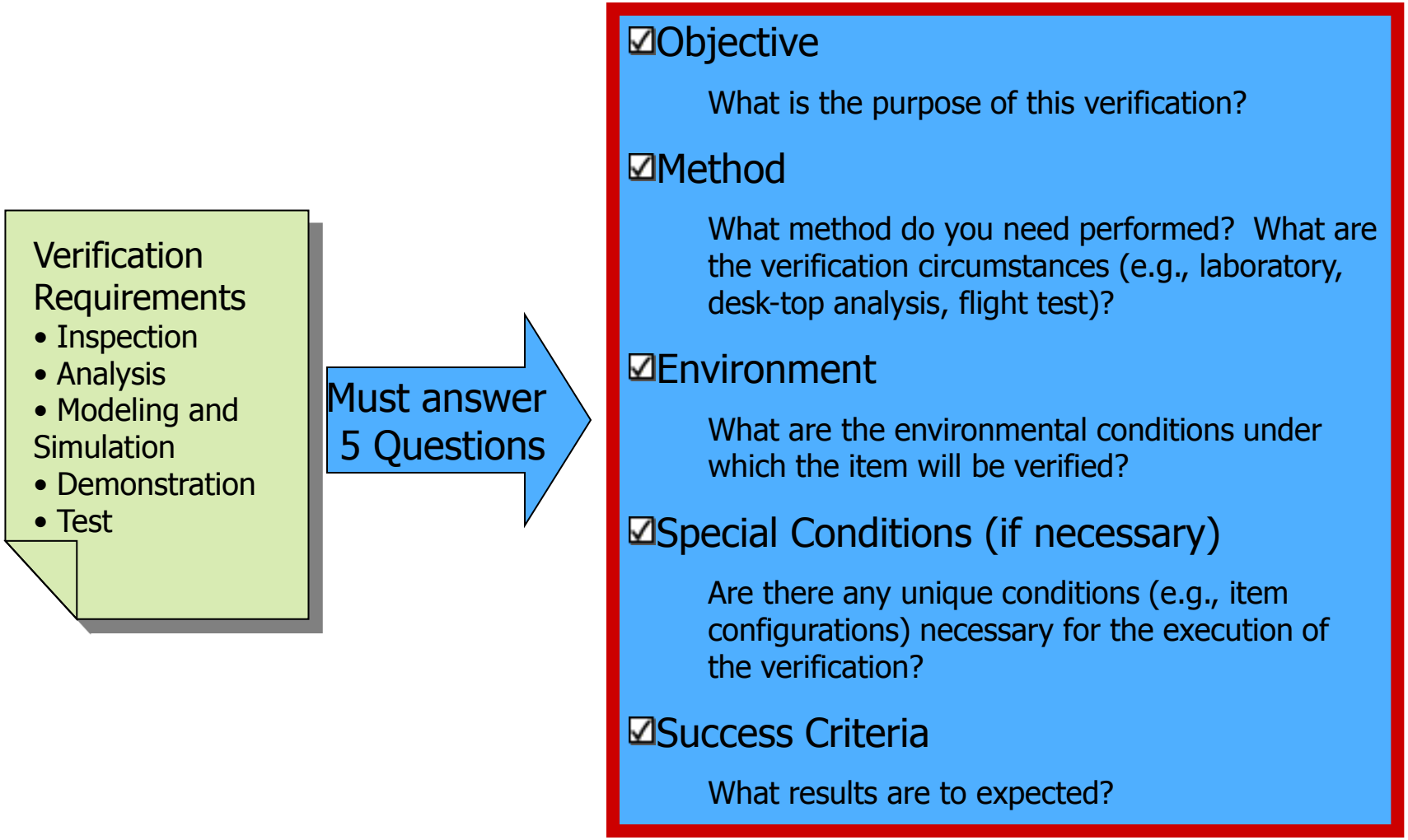
- Key points to writing a good verification requirement
  - Verify by (insert method here) that …..
  - The (use above method) will show that ……
- Ability to create a verification requirement ensures that the Product requirement is verifiable

Verification Requirement Attributes



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What is Verification ?

Class exercise

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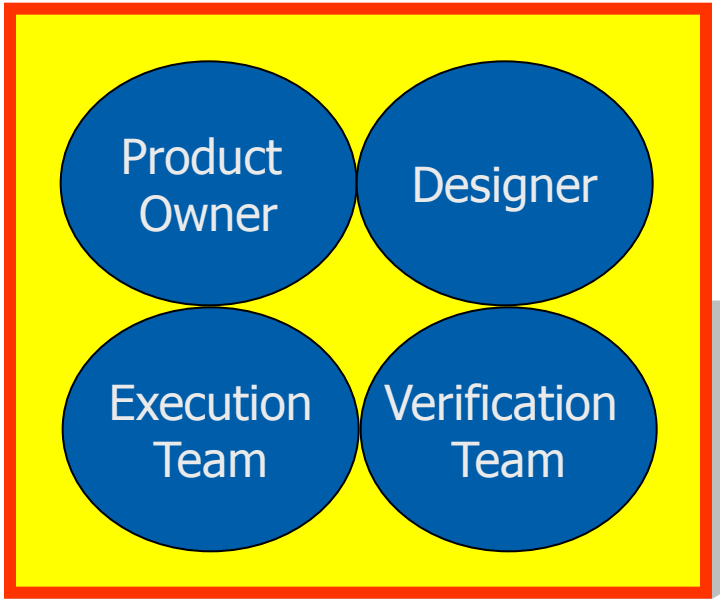
- Break into teams
  - 4 people per team
    - Product Requirement Owner (IPT, SEIT, Other)
    - Designer (Hardware, Software)
    - Verification Execution Representative (I&T, Q.A., Analyst etc;)
    - Verification Team



Class Exercise

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- Product Requirement Owner
  - Establishes the requirement intent with a verification requirement
  - Creates the initial VR
- Design Team
  - Agrees that the design is capable of performing the success criteria
- Verification Team
  - Ensures depth and breadth of the requirements are met with the success criteria (nominal / off nominal, needed analysis, modeling and simulation techniques)
- Verification Execution team (T&E, Analysis Group, QA etc;)
  - Can the verification requirement be completed?
  - Is it cost effective ?

Verification Requirement Evaluation

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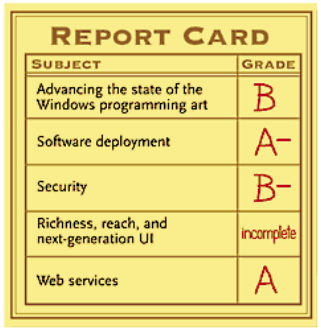
- Evaluate the generated Product requirement and verification requirement(s) set
  - Did you have to re-write your Product requirement?
  - Did the Product requirement provide data to establish the success criteria?
  - Is the specified verification environment consistent with the operational objectives as established in the Product requirement?



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Verification Benefits

Examine Programmatic Benefits

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- The Customer Benefits ??
  - Knows how the Product requirements will be satisfied from the beginning
- Cost Benefits ??
  - Better Cost Estimates. You know what you need to do.
- Schedule Benefits ??
  - Better Schedule Estimates. You can scope the entire task early providing a better schedule
- The PMO Benefits ??
  - Knows what the needs are to prove satisfaction of the Product requirement. Knows what “Customer Satisfaction” means at the start of the program.
- Better Understanding of program change impacts
  - Establish impact of change early

Win, Win, Win

Early Verification Benefits Examples

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Method	Customer / Organization	Early Verification Benefits
Inspection	QA, Manufacturing, Mission Assurance	•Inspection Points Identified •Tooling Requirements Identified
Analysis	Systems Engineering Specialty Engineering Design	•Define / Build / Buy / Train Analysis Prior to Need Date •Accreditation of Analyses Tools Prior to Need Date
Modeling and Simulation	Systems Engineering Specialty Engineering Design, Operational Assessment	•Define / Build / Buy / Train Modeling and Simulation Tools Prior to Need Date •Accreditation of Models Prior to Need Date
Demonstration and Test	Ground and Flight Test Facilities Development	•Laboratory and Lab Software Requirements Identified •Facilities Requirements Identified •Long Lead Test Items Identified

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Verification Modeling

Verification Modeling

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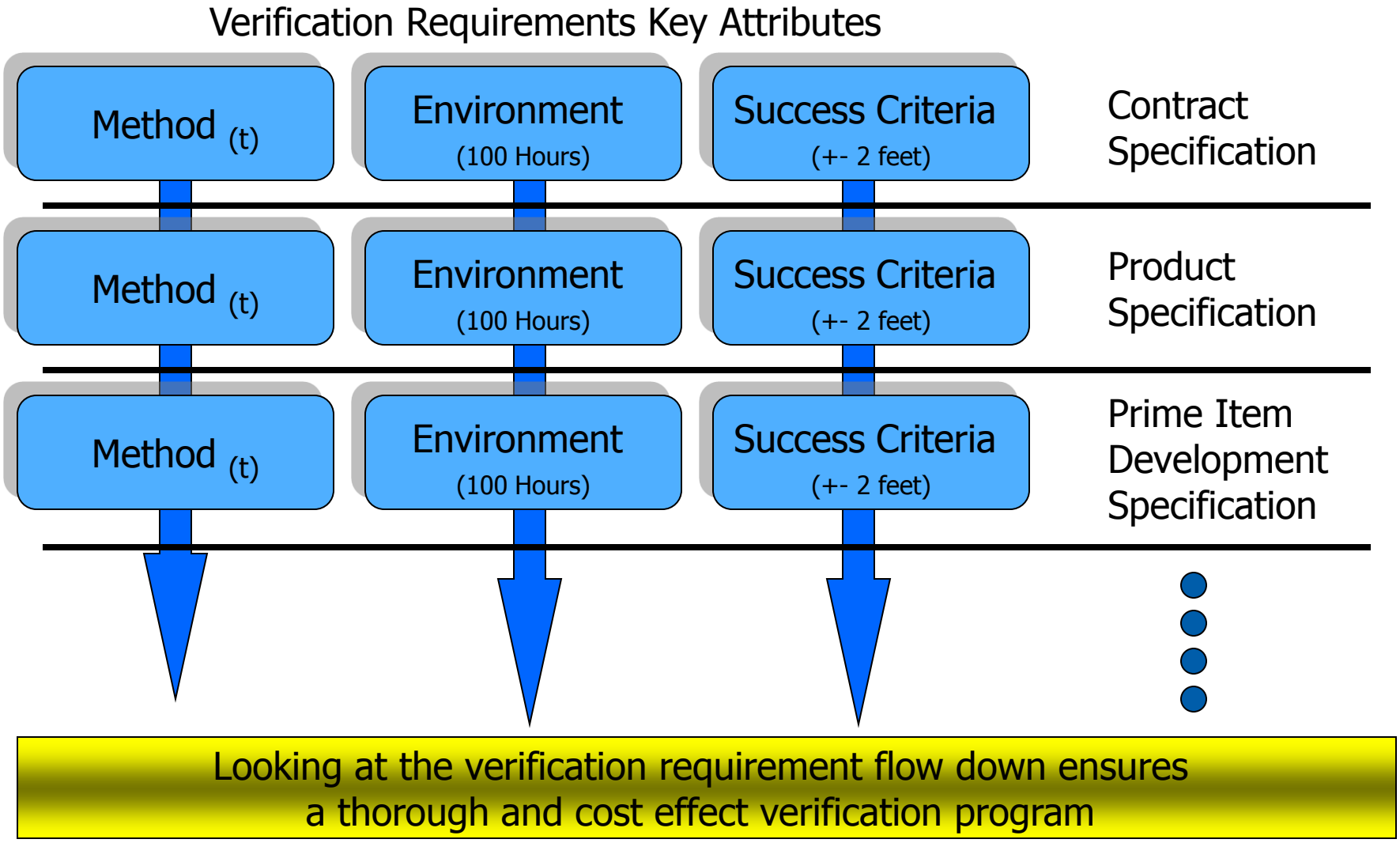
- Parent-Child Relationship
  - Method
  - Environment
  - Success Criteria
  - The Verification Pyramid
    - Verify at the lowest level
    - Verify Once
    - Verify under operational environmental conditions

By Configuration / Level

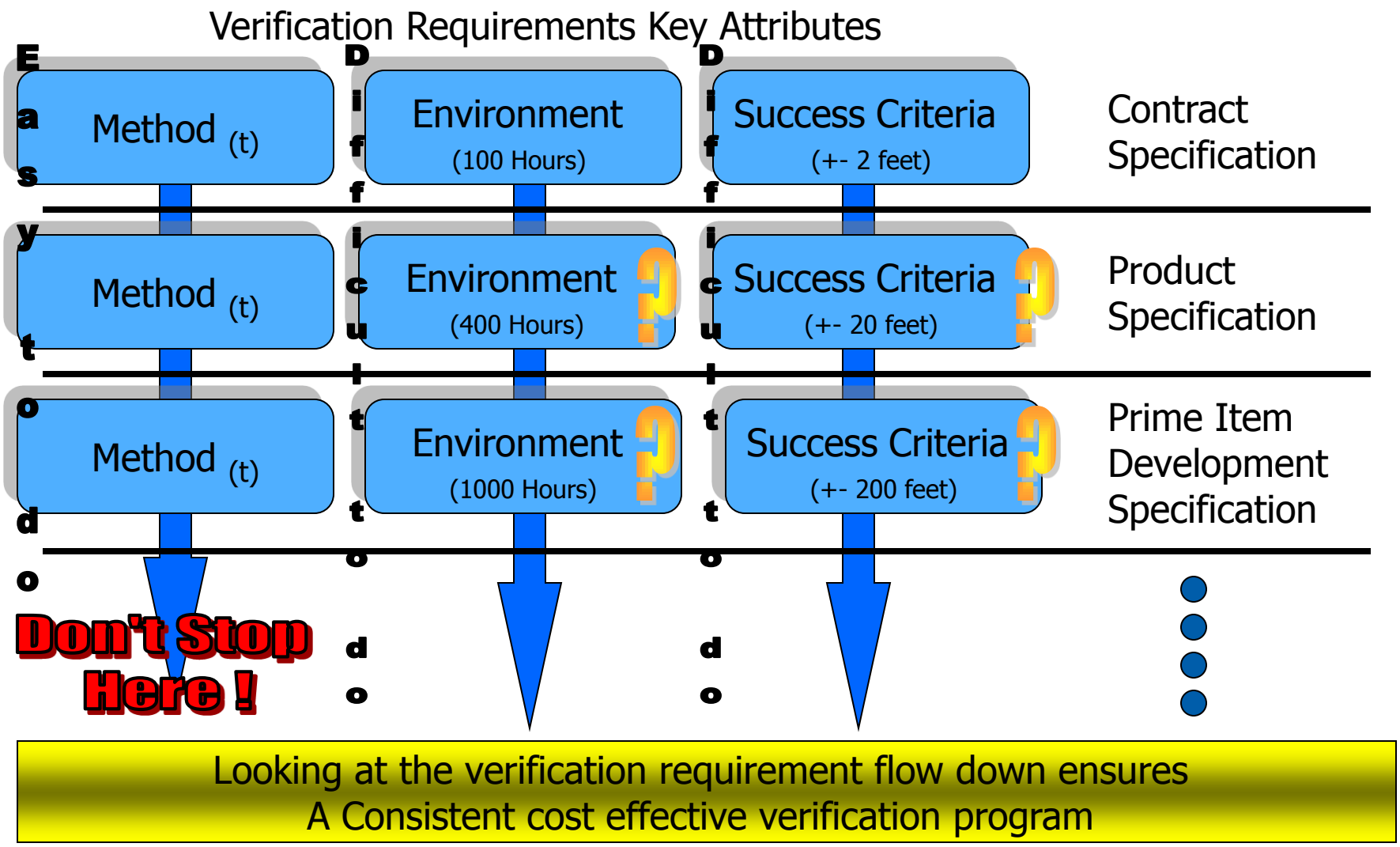
That Really Means

You only conduct environmental qualification on a UUV one time at the Box Specification level

Verification Modeling

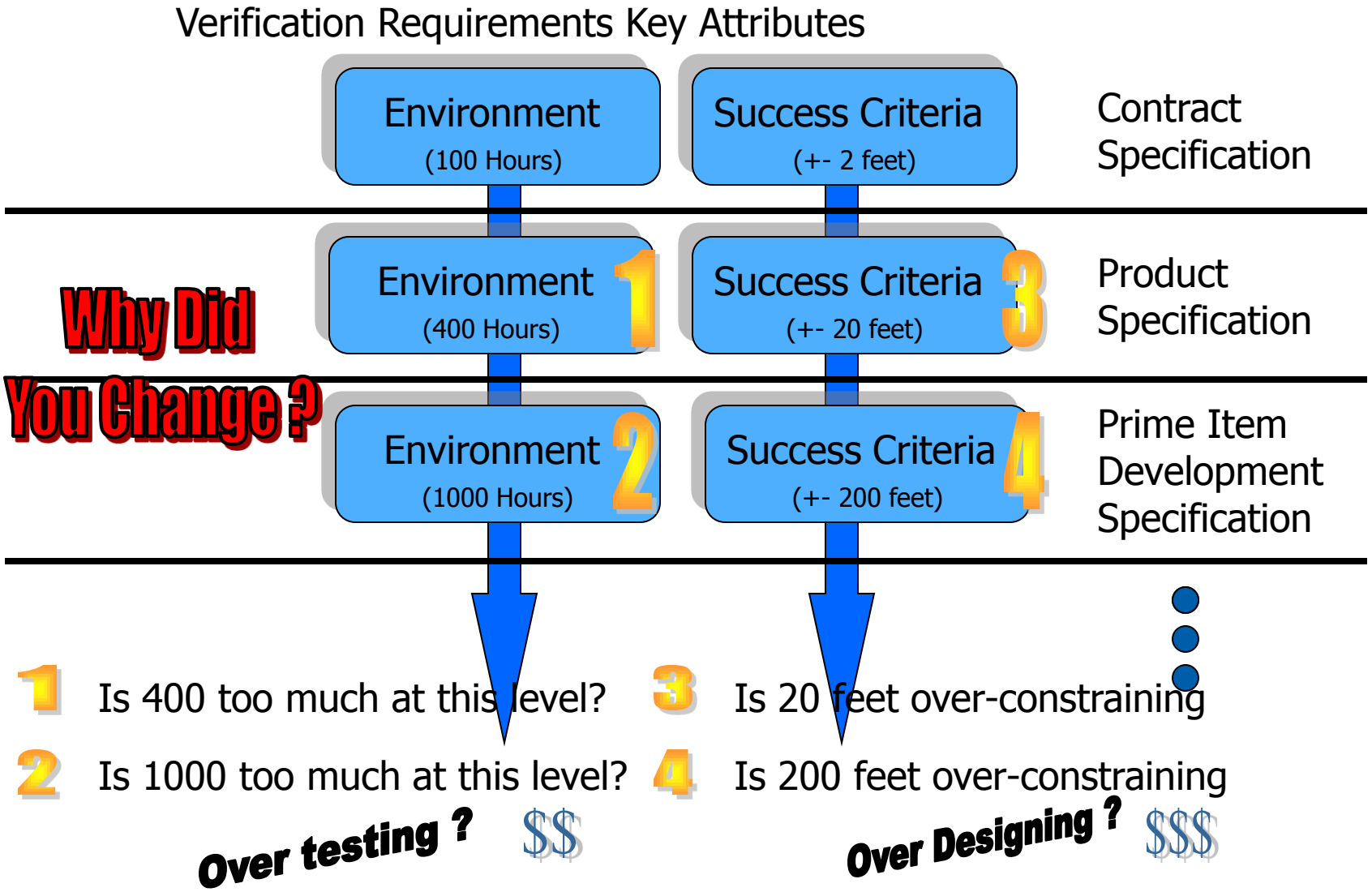


Verification Modeling Example



Looking at the verification requirement flow down ensures
A Consistent cost effective verification program

Verification Modeling – A Closer Look



Verification Modeling Another Example

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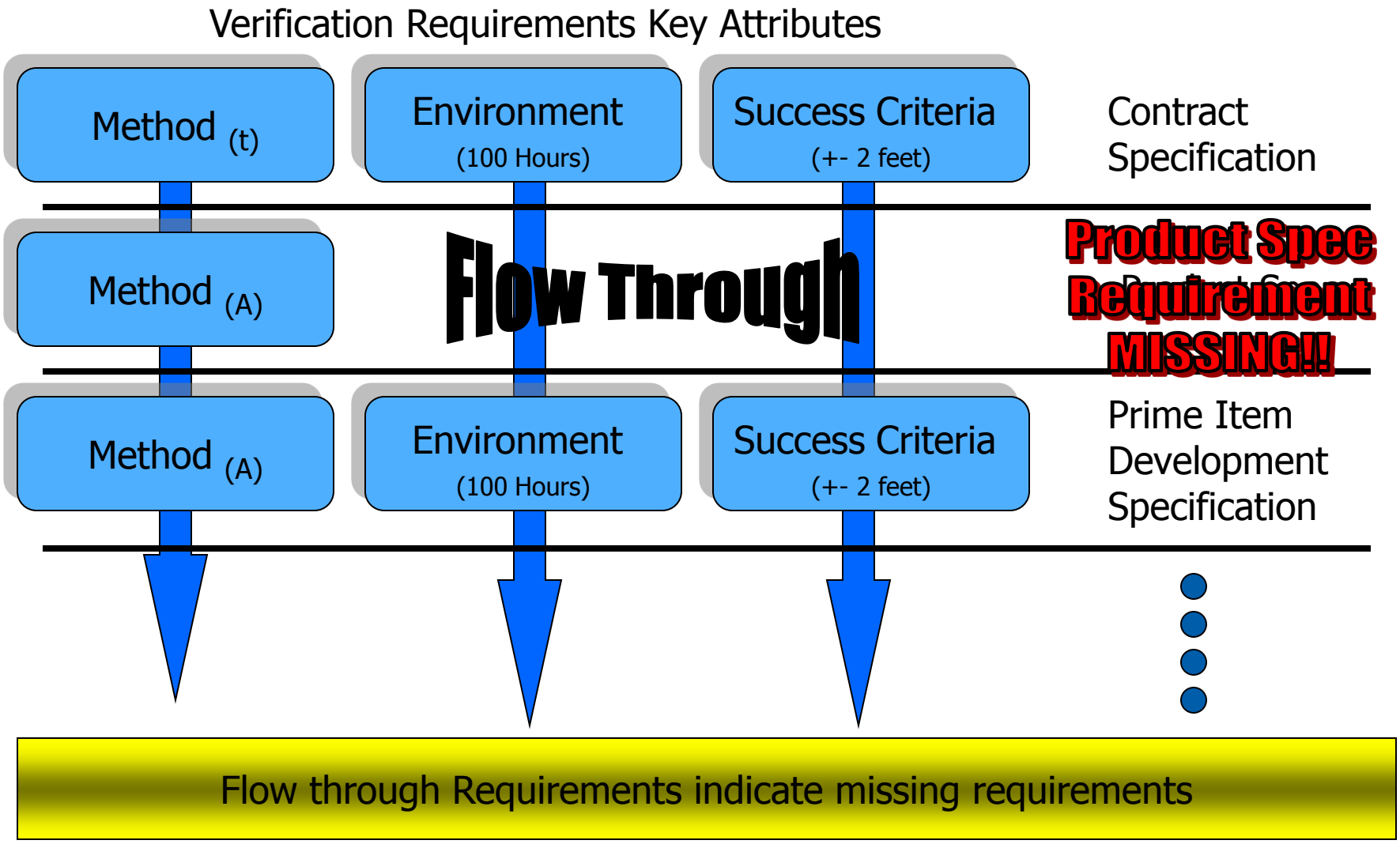
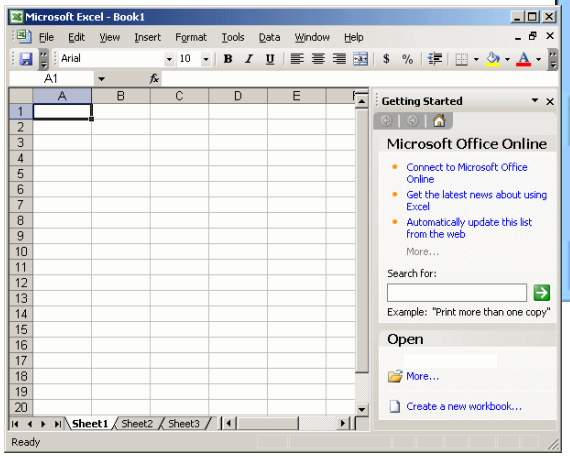
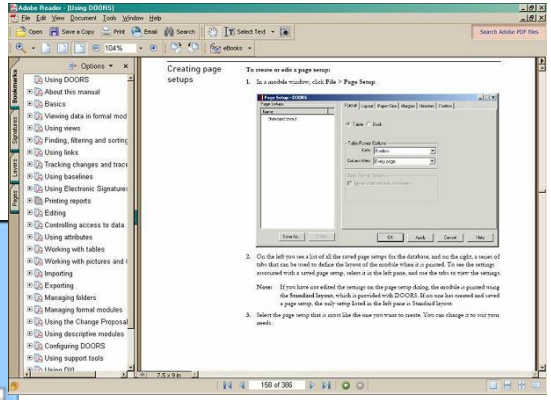


Modeling Tools

- Several Standard tools exist to conduct the modeling activities:
  - DOORS
  - CORE
  - Excel (doable but it's the hard way)
  - Others?





Verification Modeling

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- A technique to
  - Establish verification metrics
  - Track the verification program
  - Track risk activities assigned to the verification program
  - Ensure proper verification flow down
  - Ensure operational environment properly flowed
  - Help determine lost requirements
  - Help track design functions
  - Assist in verification program prioritization
- Can be connected to requirements traceability tools
- Allows for easier design completeness assessments

The Verification Cross Reference Index (VCRI)

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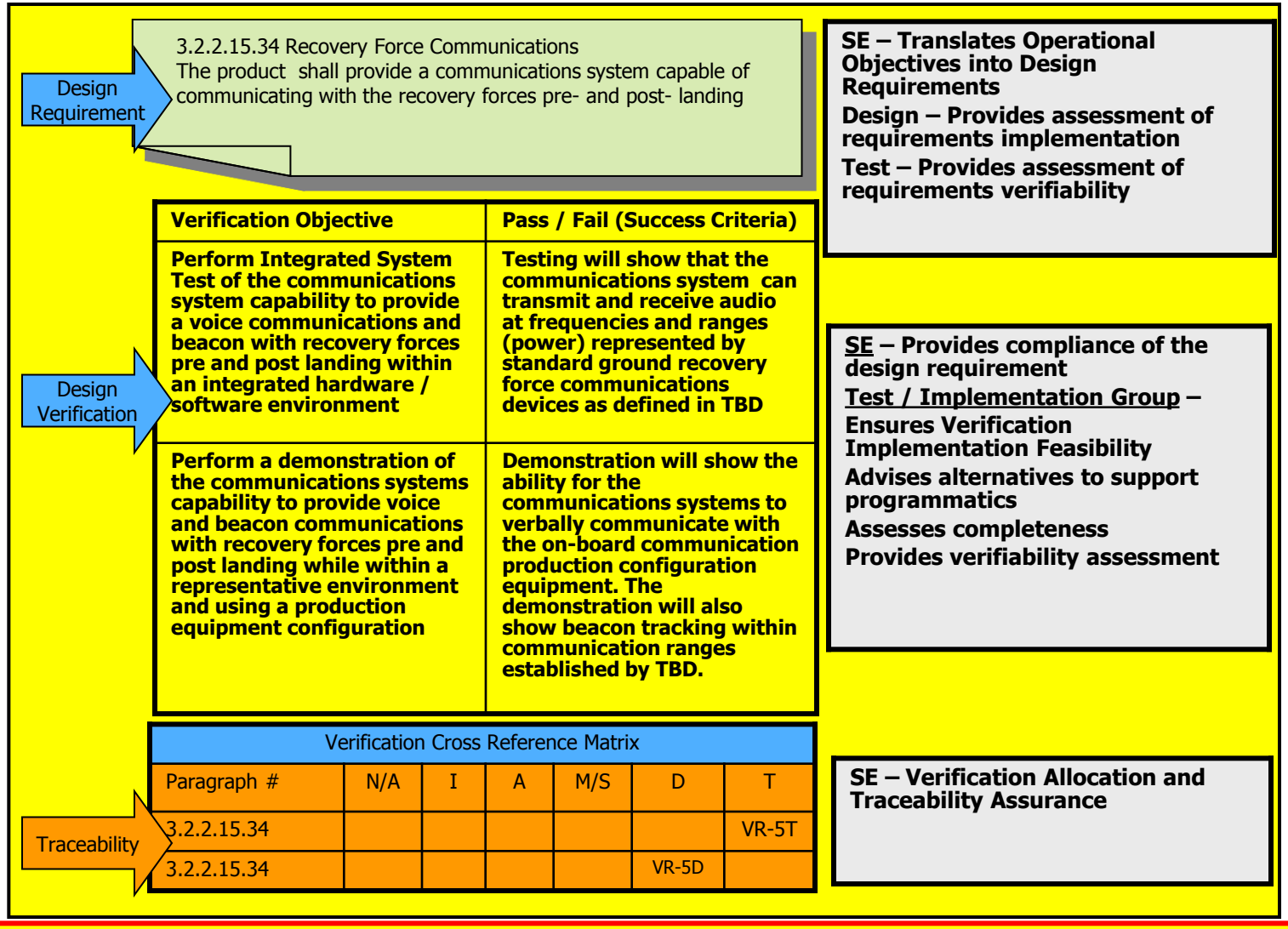
- Why A VCRI*
  - A tool for tracking requirements compliance
  - A tool to quickly assess that at least one verification condition exists for each requirement
- What a VCRI is not
    - Not the verification requirement set
    - Not the definition of the verification requirements
- Some Conclusions
    - The VCRI results from the development of the Verification Requirement
    - Having only a VCRI can develops “Bad Habits”
    - Adds no value without the Verification Requirement

***Also known as the Verification Cross Reference Matrix (VCRM)**

Create Verification Cross-Reference Matrix



Identifying a verification method is necessary, but not sufficient!

Verification Program Events

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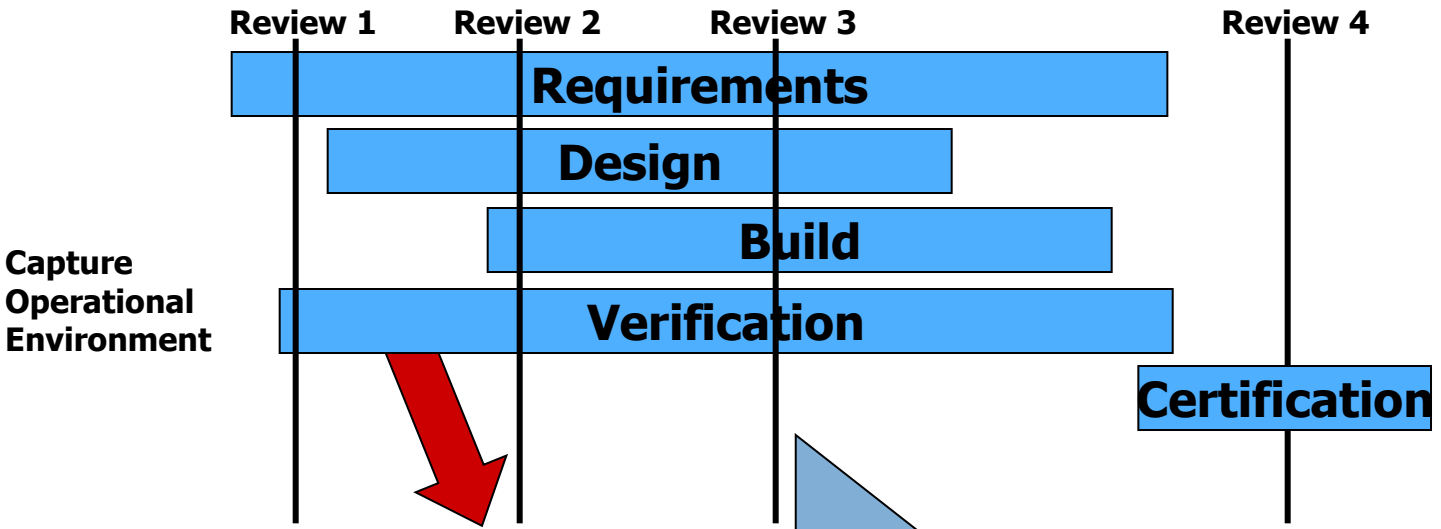
- Pre-Contract Award
  - Establish operational environment construct
    - Use system specification and develop verification criteria
      - Customer Should Pass operational environment to the contractor
- Contract Award
  - Establish Project Specification Verification Statements and get customer concurrence
- At Specification Requirements Review (SRR) / Subordinate reviews
  - Determine Requirements Verifiability

Verification starts when the program starts

Planning for Verification Execution and Product Verification



Define Verification Requirements Early and in Detail to Establish the Entire Verification Effort

… and it Costs Relatively little …

Long Lead Facilities
Laboratory Design
Range Coordination
Design Requirements
Software
Analysis Tools

Discover the Verification Requirements Late and Have Enormous Rework to Establish the Entire Verification Effort

… and it Costs a Lot More …

Early Verification Is an Effective Cost Avoidance Approach

Summary

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- Early development of verification requirements helps develop good product requirements
- Early development of verification requirements helps identify missing requirements
- Verification is the communications link to the design and execution teams
- Verification customers are across the entire program
- Verification identifies when the design is complete
- Early development of verification requirements can ensure the operational environment is captured across the test / demonstration program
- The VCRI / VCRM is necessary, but not sufficient, for verification
- Verification modeling helps develop a “one time only” verification program
- Verification increases the Program’s cost effectiveness

Contact Information

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