

A Day in the Life of a Verification Requirement

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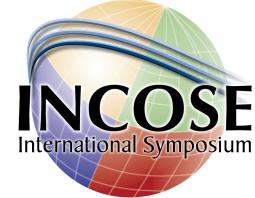
Northrop Grumman Aerospace Systems

Abstract



- One measure of the quality of a product requirement is that it be verifiable. Verifiability assessment is one of the exit criteria for the Systems Requirements Review and is necessary for requirement validity. Nomination of one or more verification methods (inspection, analysis, modeling and simulation, demonstration or test) is often taken as the sole evidence of verifiability. A completed Verification Cross Reference Matrix is frequently considered as the final verifiability assessment and responsibility for the remainder of the verification effort is transferred to the test and evaluation and other implementing communities for completion.
- Lessons learned from many Programs have shown that a more robust application of systems engineering should include the requirements engineers (with detailed knowledge of product requirement intent) working with the implementing organizations as the best combination to define the verification requirements. Such definition should include statement of the verification objectives, success criteria and environment. Including this information in the "Quality Assurance" section of the requirements document allows for buy-in by the customer well in advance of implementing the verification activities. This information is used by verification personnel to generate one or more verification plans and to develop the detailed verification program. Verification requirements are planned into verification events which are executed using the proper system elements and environments. These verification requirements are key to establishing long lead verification facilities, tools and laboratories. Early definition of these requirements helps prevent facility re-designs and verification re-plans that can cause expensive delays. Finally, verification data analysis is performed, and the information compiled into verification reports certifying system product requirements compliance. This robust verification approach will provide proof of requirements satisfaction, leading to systems that meet the customers' needs at a lower life-cycle cost.
- This paper describes these concepts and steps in detail and provides examples for a set of generic aircraft requirements.

Verification and Validation Defined



Verification

Validation

Are the requirements right? Do they meet the basic quality criteria (e.g., correct, complete)	Is there objective evidence that the product satisfies the requirements?
Are the requirements the right requirements, i.e., do they properly represent the customer need?	Does the product, when operated by representative operators, in the representative operational environment, satisfy the customer needs?

Requirements

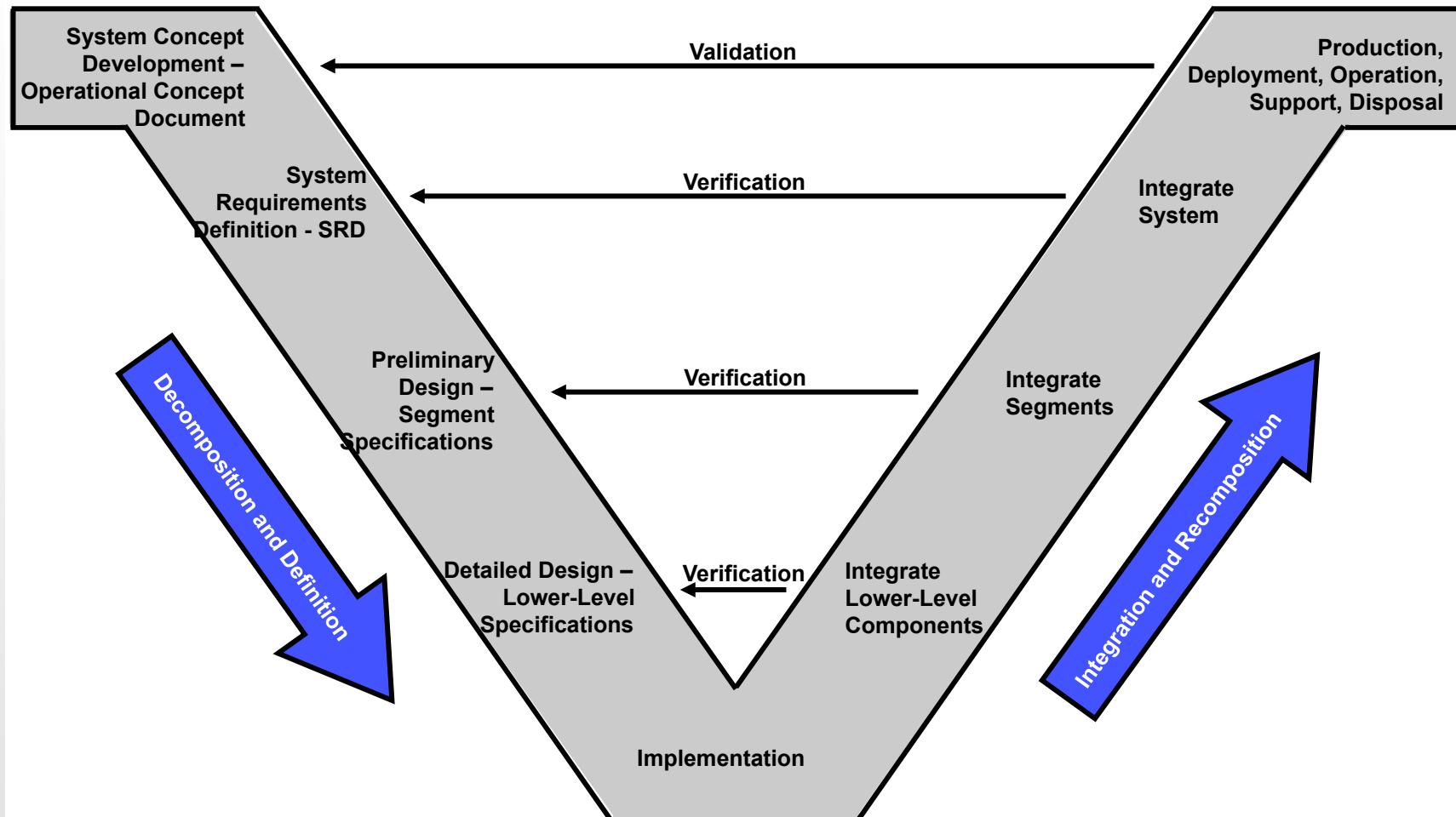
Product

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



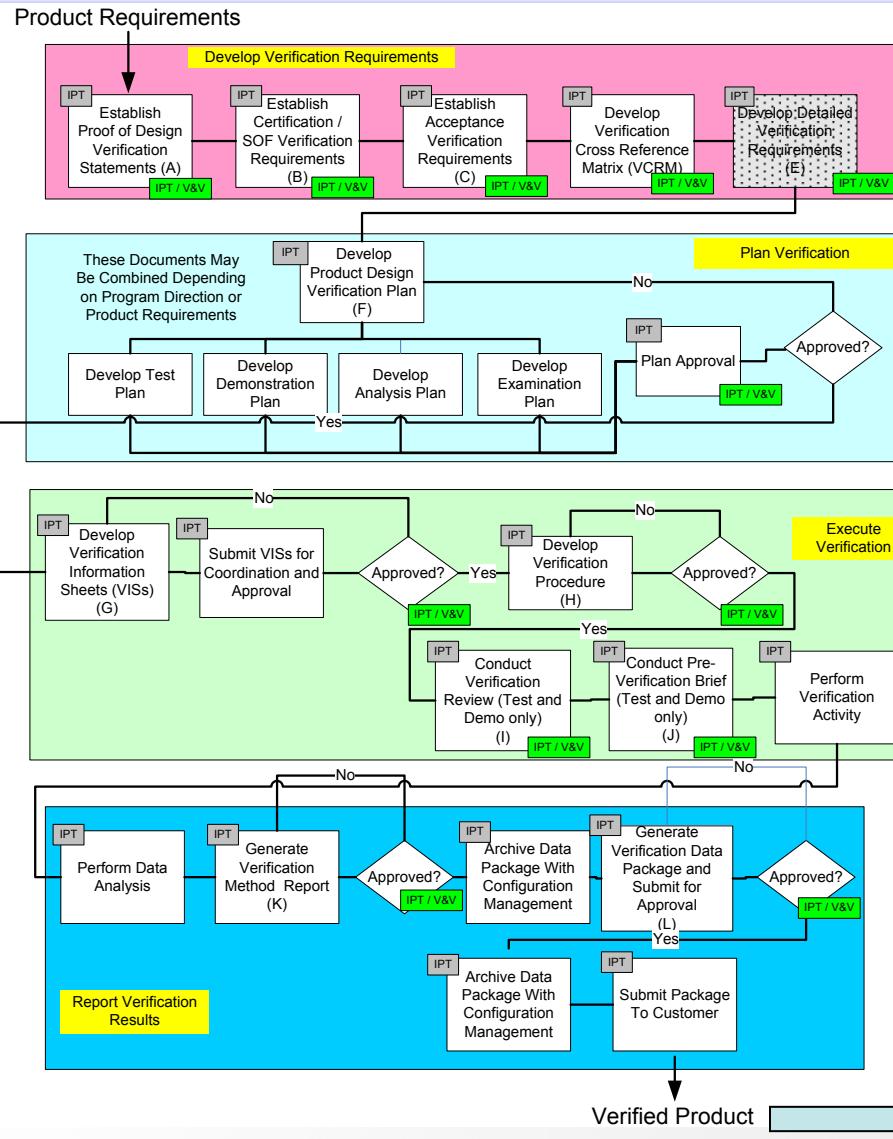
- Verification Requirements Specify the Verification Events Needed to Prove the Satisfaction of the Product Requirements and Help to Define the Verification Process and Environment
- Verification Requirements are Necessary for at Least Two Reasons:
 - Existence of Verification Requirements Demonstrates Verifiability of Product Requirements
 - Agreed-to Verification Requirements Define the Verification Program by Which the Contractor Shows that the Product is What the Customer Needed

Verification in the Product Development Life-Cycle



After Forsberg, K, Mooz, H and Cotterman, H,
Visualizing Project Management, 2nd Edition, J Wiley
and Sons, New York, 2000.

A Day in the Life of a Verification Requirement



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: 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-4: Recovery Force Communication - Nominal
 - The product shall provide a communications system capable of communicating with the ground command.

Verification Requirement Attributes



Verification Requirements

- Examination
- Analysis
- 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)

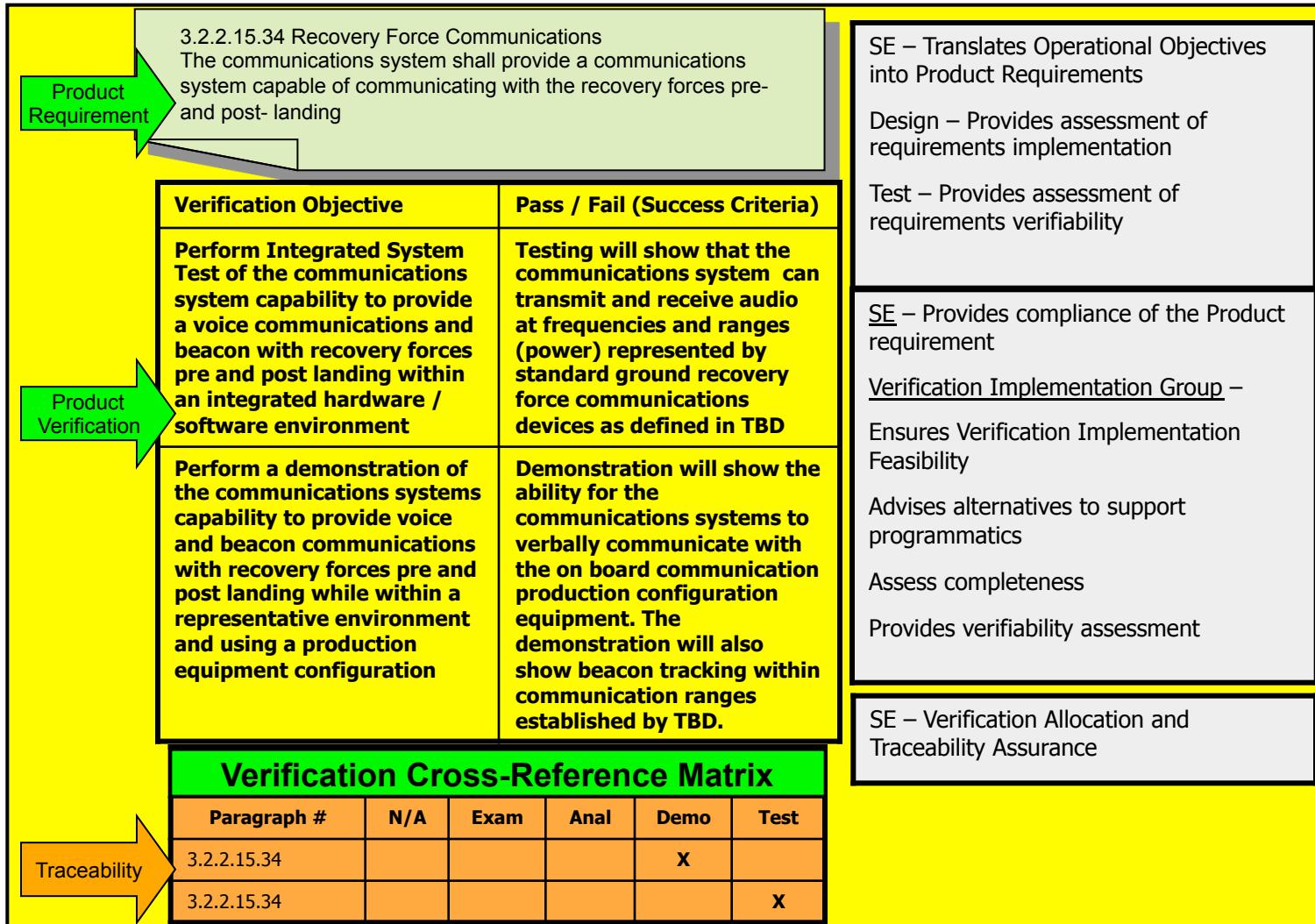
Are there any unique conditions (e.g., item
configurations) necessary for the execution
of the verification?

Success Criteria

What results are to be expected?

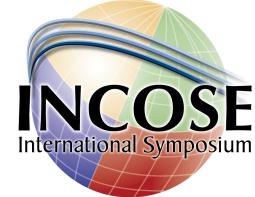
Verification isn't ONLY test!

Create Verification Cross-Reference Matrix



Identifying a verification method is necessary, but not sufficient!

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-3D: Removal and replacement of all LRUs 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-4D: 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-4T: 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 audio at frequencies represented by standard ground recovery forces communications devices defined in (TBD).

Verification Objective

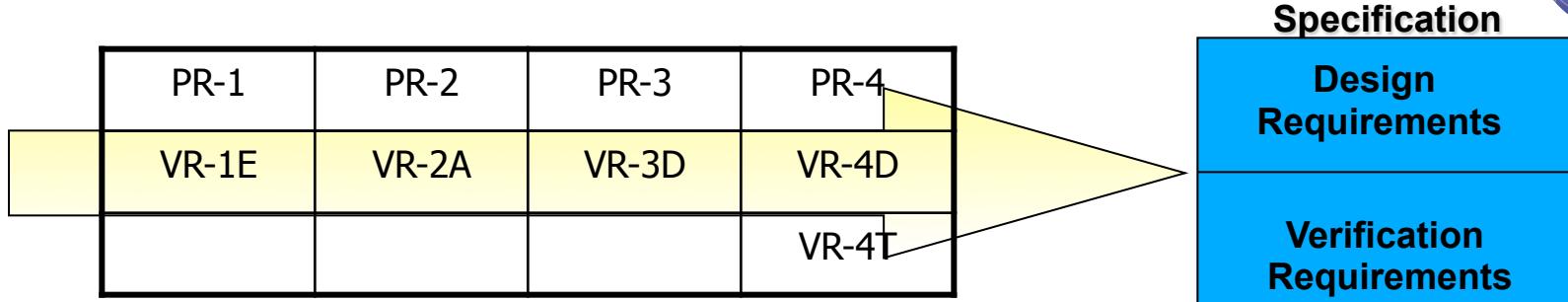
Verification Method

Note – there are no Special Conditions

Environment

Success Criteria

Verification Requirements Flow and Traceability



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

Product Requirement	N/A	Exam	Anal	Demo	Test	Verification Requirement
PR-1		X				VR-1I
PR-2			X			VR-2A
PR-4				X		VR-3D
PR-5				X	X	VR-4D VR-4T

Master Verification Plan

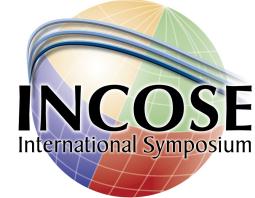
Examination **VR-1E**
Analysis **VR-2A**
Demonstration
VR-3D, VR-4D
Test
VR-4T

Verification Requirements

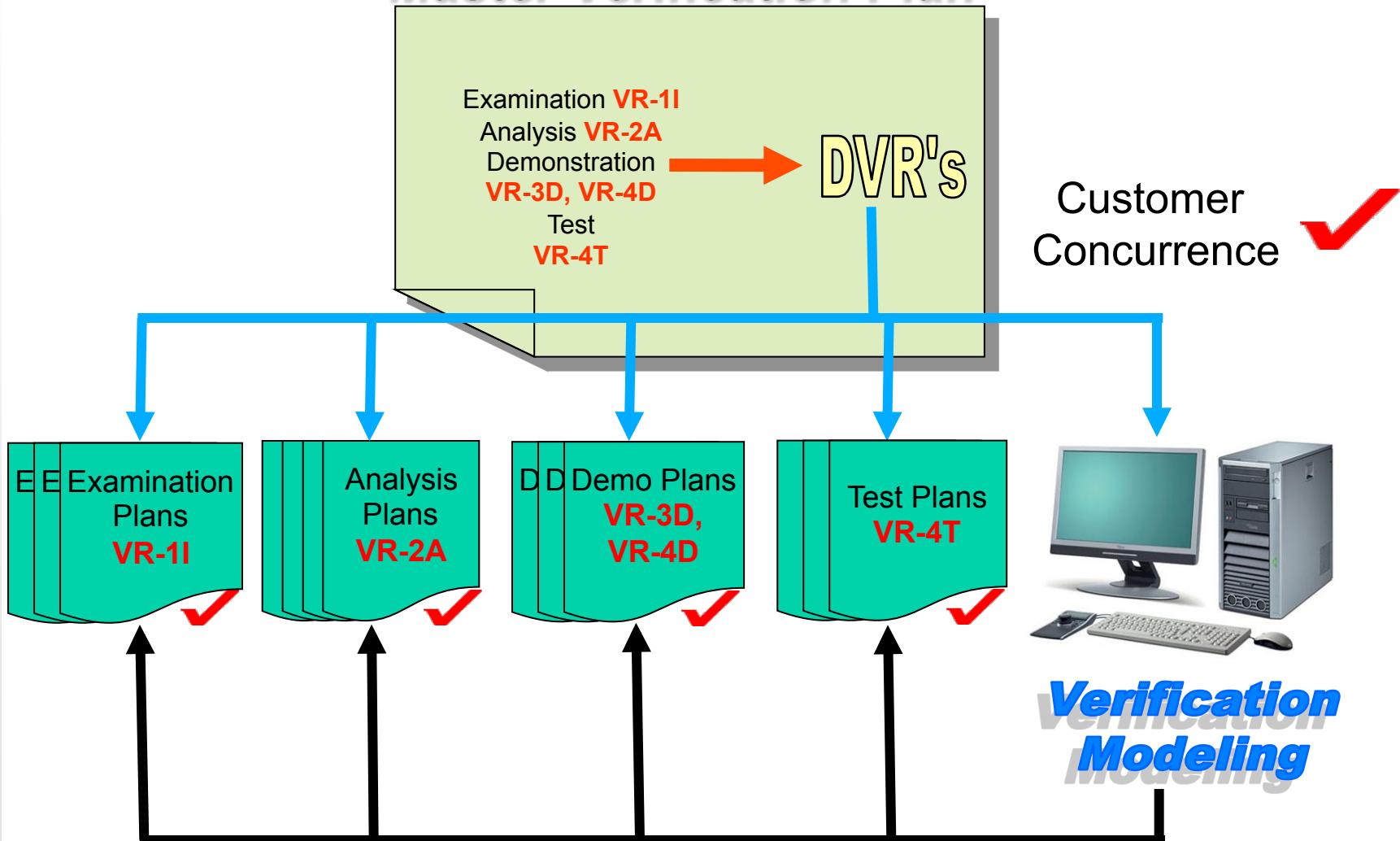


Verification Traceability

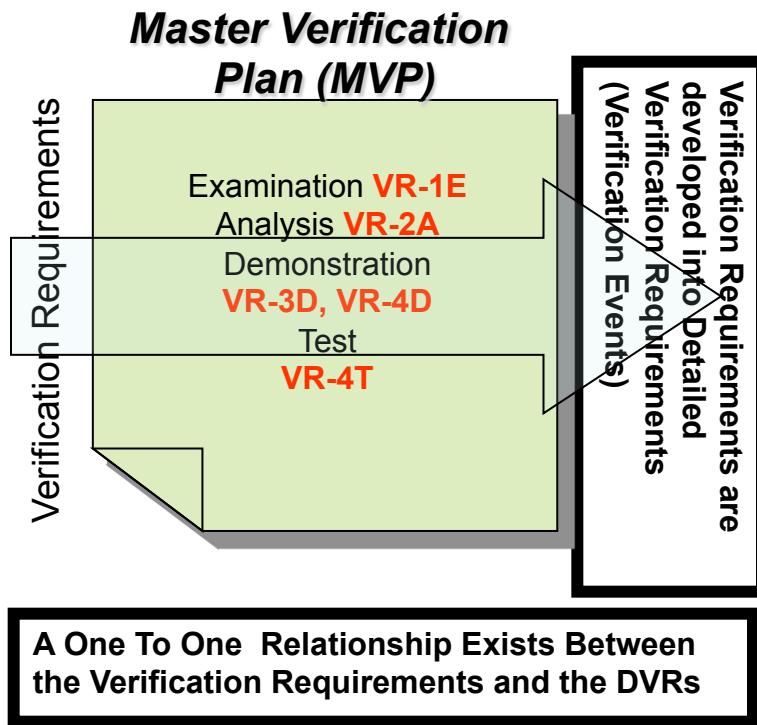
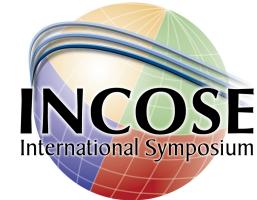
Master Verification Plan



Master Verification Plan



Create Detailed Verification Requirements (Verification Events)

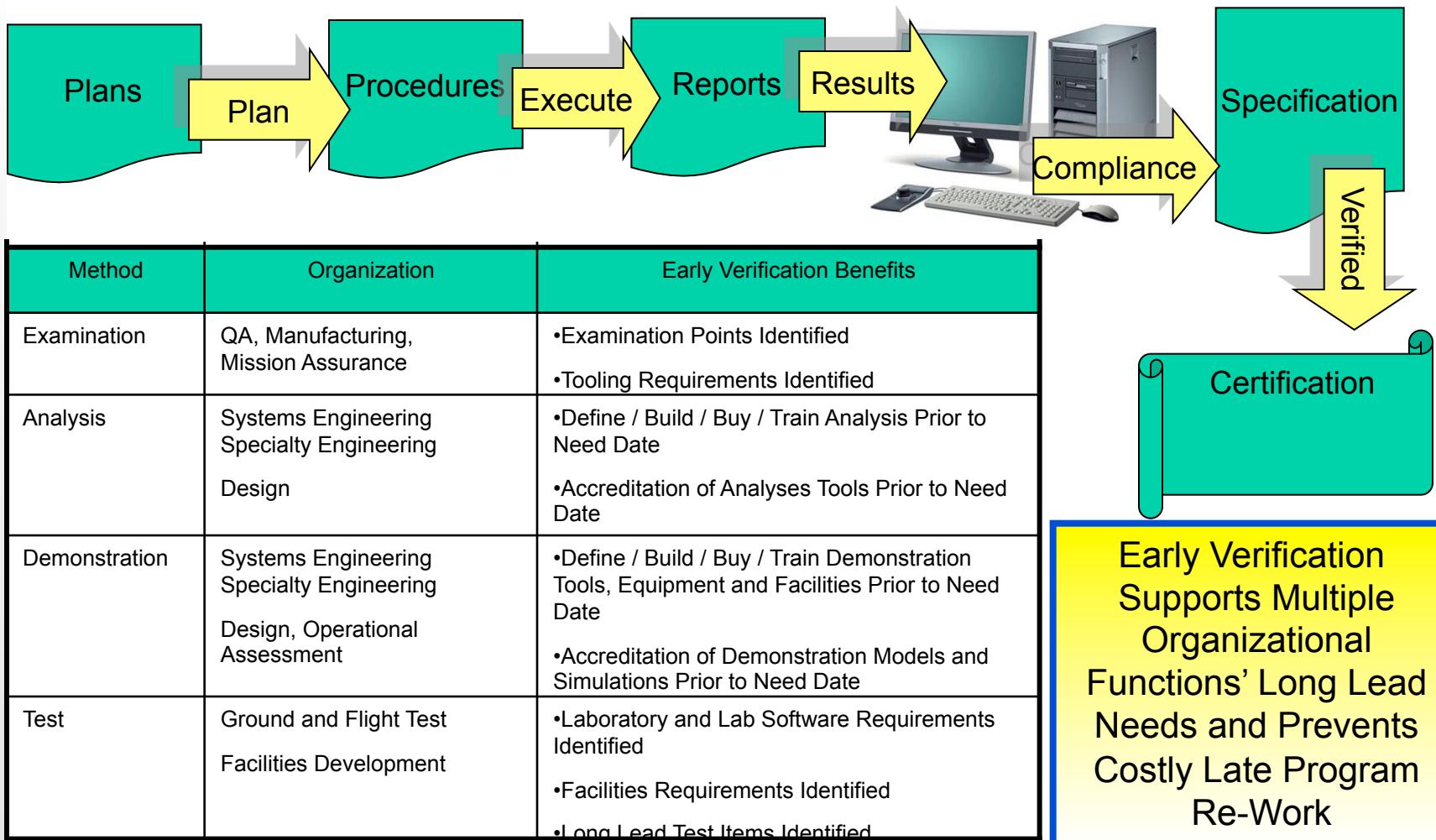


Convert Verification Statements into Detailed Verification Requirements (Verification Events) by ----

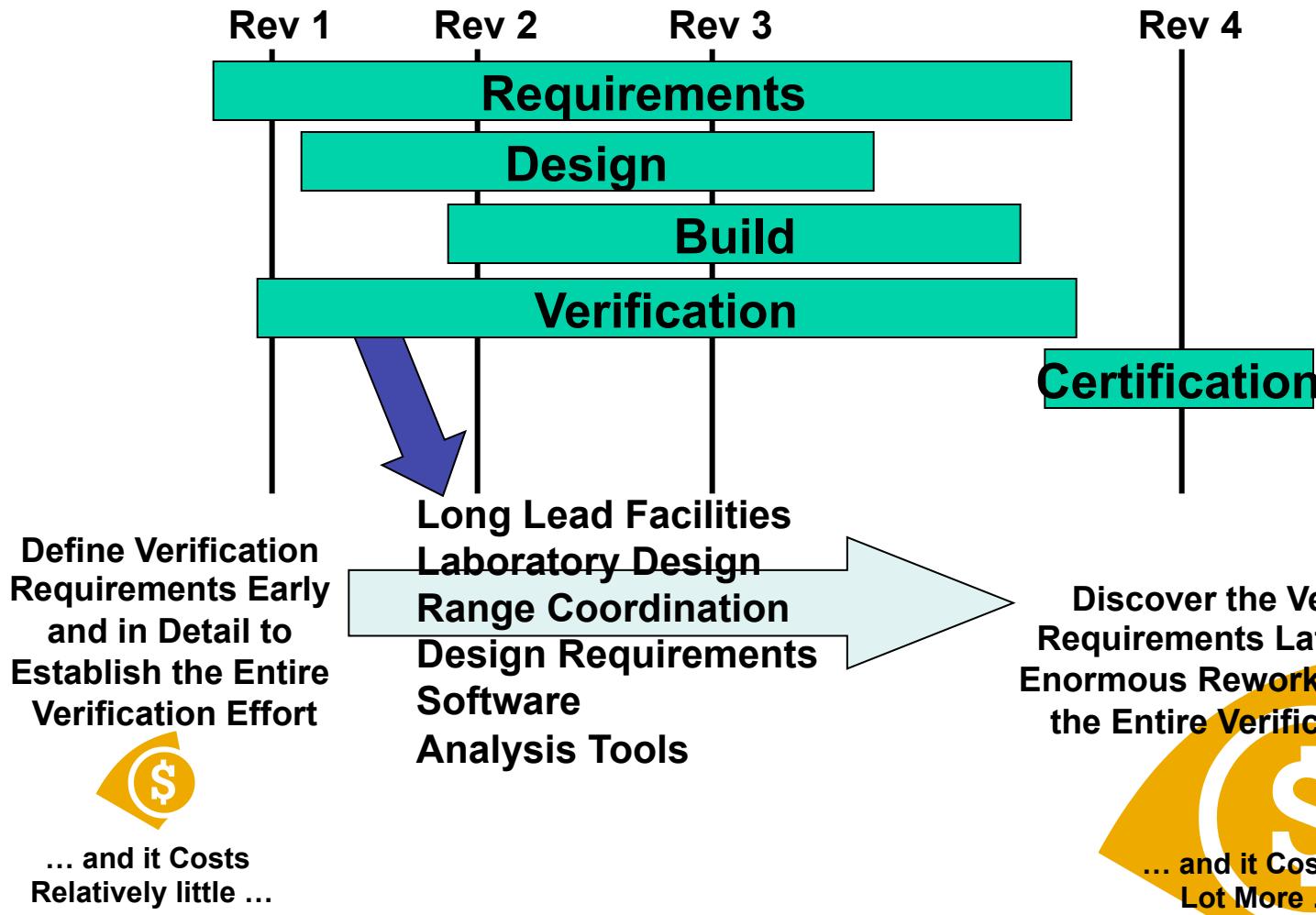
For each verification activity identified in the verification matrix, a detailed description of the activity including:

- Verification configuration & 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 (i.e.; Lab, Flight, Production)

Verification Execution Flow



Planning for Verification Execution and Product Verification



Early Verification Is an Effective Cost Avoidance Approach

Summary and Conclusions



- **The Verification Process Begins With Authenticated Product Requirements**
- **Define Verification Requirements, not Just Methods**
 - The VCRI Is the Last Thing Developed in the Specification
- **Verification Requirements Must State the Objective, Method, Environment, and Expected Results. There May Also be Special Conditions.**
- **The Master Verification Plan is the Guidance for the Verification Program**
- **Verification is Conducted Against the Product Defined by the Title of the Specification**
- **Verification Program Benefits are not Limited to Just the Systems Engineering and Test Organizations**
- **Define the Verification Requirements Early to Reduce the Overall Program Cost**

Author Biographies



- **Steve Scukanec** has spent over 25 years as an Aerospace Engineer on various complex programs including the B-2, B-2 Long Term Software Support, F-35. With a focus on test and evaluation, Steve has been able to participate in programs from inception to completion. This experience over several programs has provided Steve with a rare understanding of the values of a well executed Verification program as well as the problems caused by the lack of one. His experience as a “requirements generator”, “requirements customer”, “requirements manager” and verifier gives him insight into the lifecycle of a requirement and a large lessons learned knowledge base.
- **Jim van Gaasbeek** has 35 years experience analyzing and developing rotary-wing and fixed-wing aircraft, launch vehicles and spacecraft, both in the United States and European defense environments. Beginning as a rotor aeroservoelastician, his career has progressed with experience in constructive and virtual simulation, accident investigation, vehicle-management system design and systems engineering, concentrating in risk management and requirements development, management and verification.

Just in Case

Requirements: The Good ...



- The XYZ spacecraft shall dock with the ISS at the Node 3 nadir docking adaptor using the Androgynous Peripheral Docking System (APAS), JSC-26938
- The XYZ aircraft shall carry 400 international-standard passengers, a crew of 24, their luggage and 20 tons of cargo, 8,000 still-air nautical miles in 17.5 hours block time on an ISA+20 day.



Requirements: ... The Bad ...



- 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.



- 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.

