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DEFINING THE FUTURE

A Day in the Life of a Verification Requirement

Systems Engineering Conference
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Agenda

- Why Verification
- Overall Process
- Verification Cross-Reference Matrix
- Verification Attributes
- Requirement Samples
- Verification Plans
- Benefits
- Summary / Conclusions
- Abstract
- Author Biographies

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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

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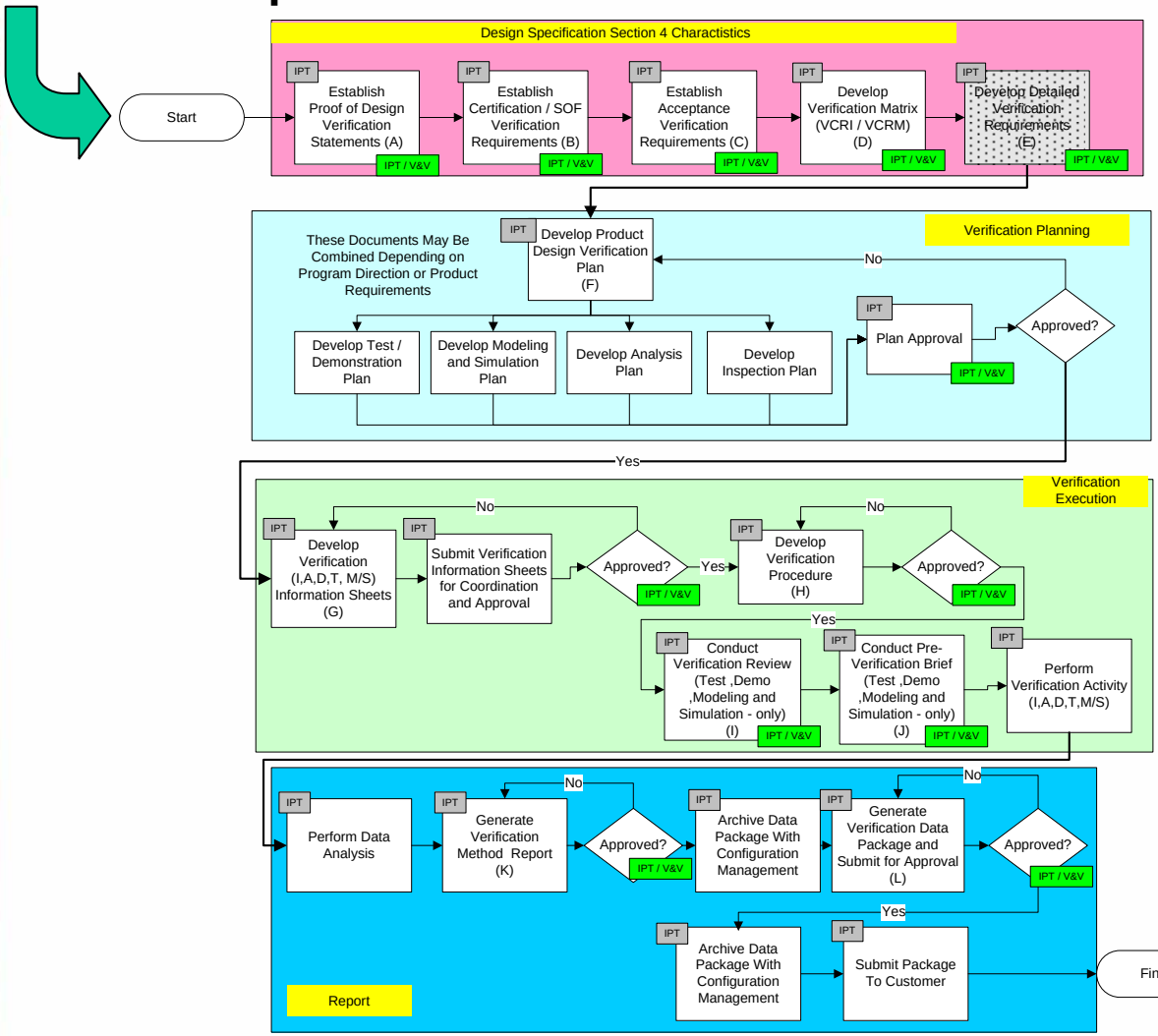
A Day in the Life of a Verification Requirement

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.

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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.

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Create Verification Cross-Reference Matrix

Design Requirement

3.2.2.15.34 Recovery Force Communications
The communications system 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	Testing 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

Assess completeness

Provides verifiability assessment

Traceability

Verification Cross Reference Matrix

Paragraph #	N/A	I	A	M/S	D	T
3.2.2.15.34						T3
3.2.2.15.34						T5

SE – Verification Allocation and Traceability Assurance

Identifying a verification method is necessary, but not sufficient!

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Verification Requirement Attributes

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

Must answer 5 Questions

Verification isn't ONLY test!

- ☑ 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?

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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%.**

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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.**

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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

Environment

Success Criteria

Note – there are no Special Conditions

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Verification Requirements Flow and Traceability

PR-1	PR-2	PR-4	PR-5
VR-1I	VR-2A	VR-4D	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	Analy	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
Demonstration
VR-3D, VR-4D
Test
VR-4T

Verification Requirements

Verification Traceability

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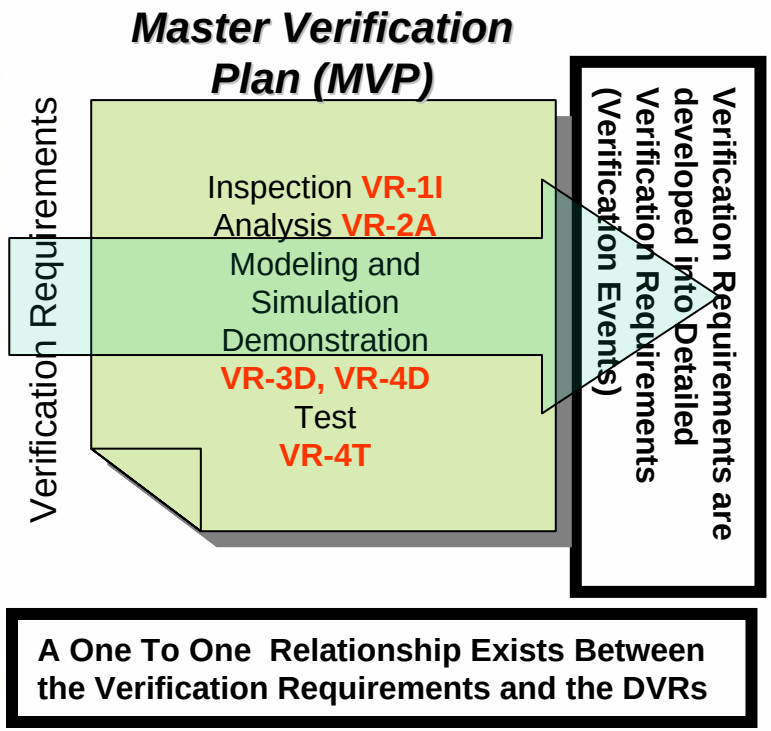
Create Detailed Verification Requirements (Verification Events)



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)**

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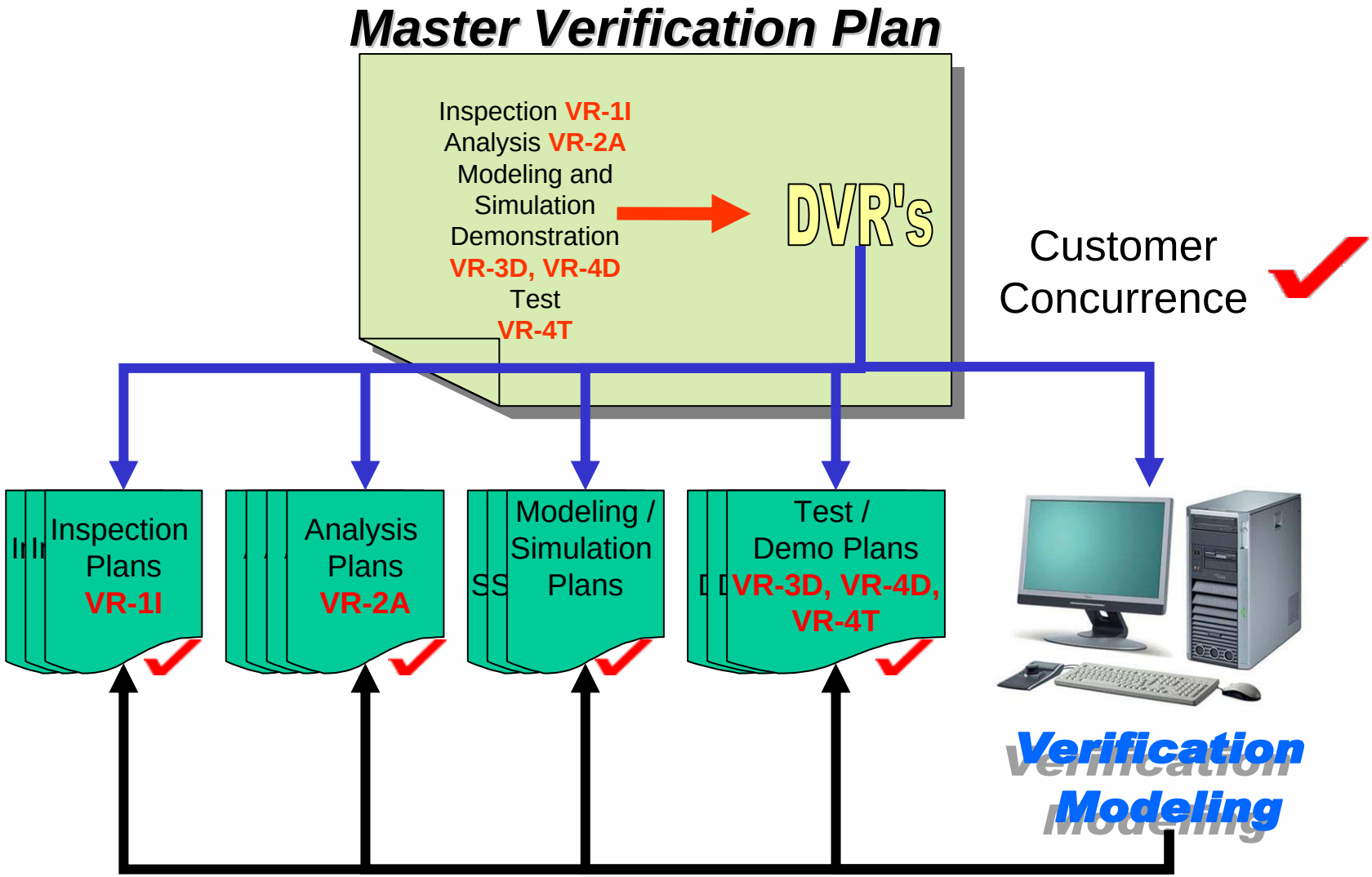
Master Verification Plan



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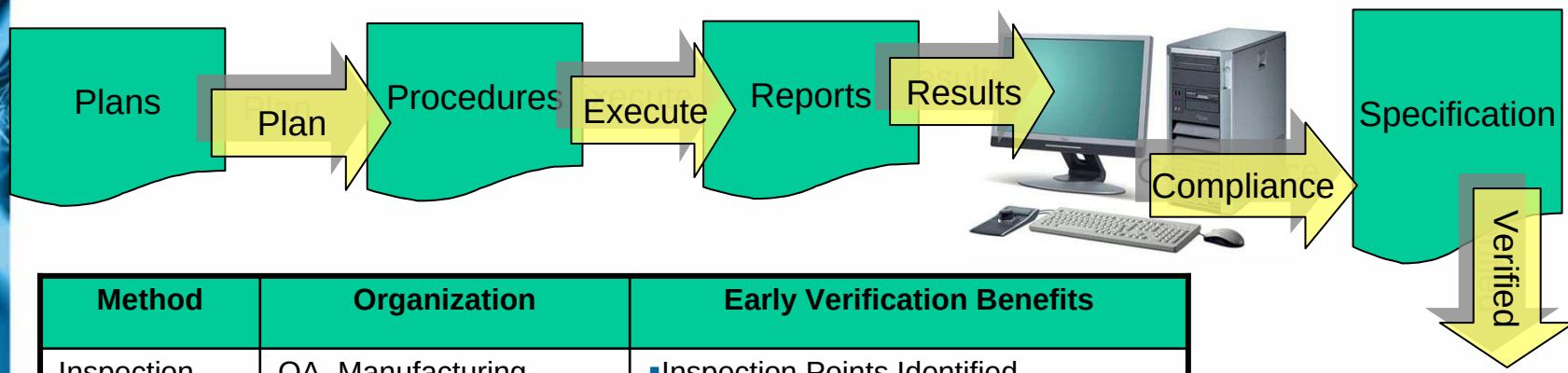
Verification Execution Flow



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

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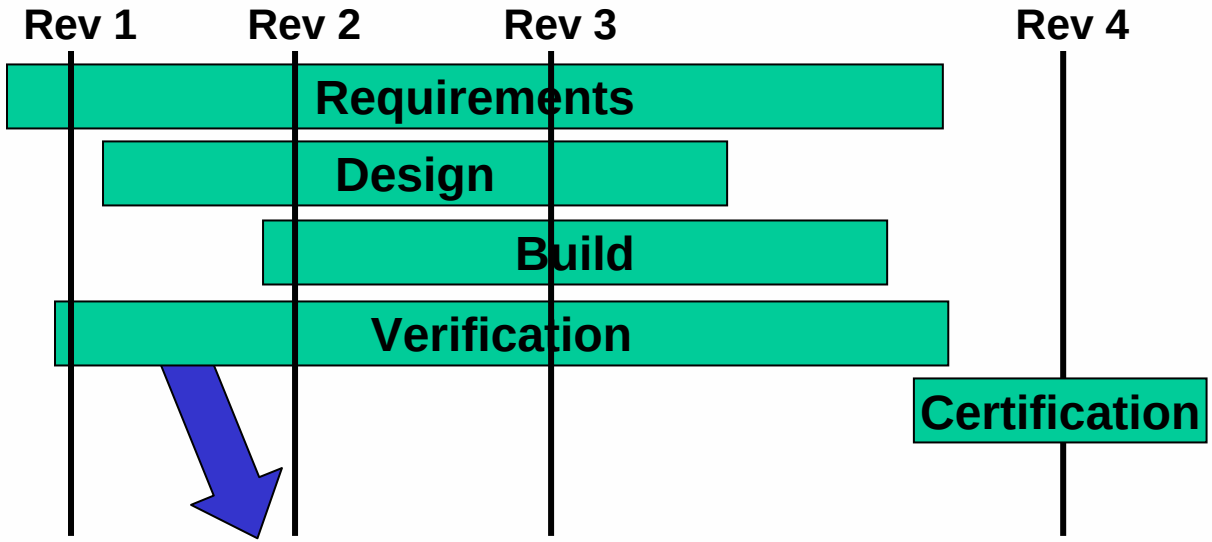
Planning for Verification Execution and Product Verification



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

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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

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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.

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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.**

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