NASA/SP-2011-6128

Requirement Assurance: A Verification Process

Michael G. Alexander
Langley Research Center, Hampton, Virginia

August 2011

NASA STI Program . . . in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA scientific and technical information (STI) program plays a key part in helping NASA maintain this important role.

The NASA STI program operates under the auspices of the Agency Chief Information Officer. It collects, organizes, provides for archiving, and disseminates NASA's STI. The NASA STI program provides access to the NASA Aeronautics and Space Database and its public interface, the NASA Technical Report Server, thus providing one of the largest collections of aeronautical and space science STI in the world. Results are published in both non-NASA channels and by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA counterpart of peer-reviewed formal professional papers, but having less stringent limitations on manuscript length and extent of graphic presentations.
- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.
- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.
- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or co-sponsored by NASA.
- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.
- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services also include creating custom thesauri, building customized databases, and organizing and publishing research results.

For more information about the NASA STI program, see the following:

- Access the NASA STI program home page at http://www.sti.nasa.gov
- E-mail your question via the Internet to help@sti.nasa.gov
- Fax your question to the NASA STI Help Desk at 443-757-5803
- Phone the NASA STI Help Desk at 443-757-5802
- Write to:
  NASA STI Help Desk
  NASA Center for AeroSpace Information
  7115 Standard Drive
  Hanover, MD 21076-1320

NASA/SP-2011-6128

Requirement Assurance: A Verification Process

Michael G. Alexander
Langley Research Center, Hampton, Virginia

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23681-2199

August 2011

Acknowledgments

The Requirement Assurance Process presented in this report would not have been possible if it were not for Mr. Kevin Vipavetz, Systems Engineering and Integrations Office, Engineering Directorate and Mr. Kevin Kempton, Flight Software Systems Branch, Engineering Directorate. Mr. Vipavetz and Mr. Kempton were the Ares I-X Systems Engineering and Integration, Requirements and Verification Manager and Deputy Manager who developed the practices and procedures that are the foundation of this Requirement Assurance Process. The Ares I-X was a highly successful mission that received NASA's prestigious "Systems Engineering Technical Excellence" Award in 2010.

Available from:

NASA Center for AeroSpace Information
7115 Standard Drive
Hanover, MD 21076-1320
443-757-5802

Abstract

Requirement Assurance is an act of requirement verification which assures the stakeholders that a product requirement has produced its "as realized product" and has been verified with conclusive evidence. Product requirement verification answers the question, "did the product meet the stated specification, performance, or design documentation?". In order to ensure the system was built correctly, the practicing system engineer must verify each product requirement using verification methods of inspection, analysis, demonstration, or test. The products of these methods are the "verification artifacts" or "closure artifacts" which are the objective evidence needed to prove the product requirements meet the verification success criteria.

Institutional direction is given to the System Engineer in NPR 7123.1A NASA *Systems Engineering Processes and Requirements* with regards to the requirement verification process. In response, the verification methodology offered in this report meets both the institutional process and requirement verification best practices.

Table of Contents

List of Figures

List of Tables

1 Introduction

The verification process is an important, fundamental element in systems engineering (Ref 1.) and critical to a successful closure of the project's requirements. When the requirements are developed early in the project's life cycle, the verification methods are defined. These methods used in verifying product requirements are inspection, analysis, demonstration and test (Ref 2). Requirement verifications are defined as proof of compliance with specifications. The resultant products of the verification methods are documents that contain the closure artifacts demonstrating proof of compliance.

The Requirement Assurance (RA) verification process is built around the Verification Compliance Sheets (VCS) as seen in Appendix A. This process establishes an auditable verification trail concluding in the absolute verification of requirements and meeting the institutional guidance given in NPR 7123.1A *NASA Systems Engineering Process and Requirement* (Ref. 3). This report articulates the RA process from its initial implementation until the final submittal of the Verification Compliance Document (VCD).

1.1 Purpose

The purpose of this report is to define the Requirement Assurance verification process establishing a proven product requirement verification methodology that meets NPR 7123.1A guidelines which are applicable to any size project and works across all WBS levels.

1.2 History

The Requirement Assurance verification process described herein is adapted from the ARES 1-X project verification process. The ARES 1-X mission was selected as the first suborbital development flight test to help meet Constellation Program (CxP) objectives. The ARES 1-X was launched successfully on October 28, 2009, from the NASA Kennedy Space Center in Florida.

1.3 Requirement Assurance Process Overview

At each Work Breakdown Structure (WBS) level (system, element, subsystem, etc.), product requirements are defined and subsequently placed in the appropriate WBS level requirements document. At this time, the system engineer chooses the best verification method to verify each requirement. Once the requirement document is approved by the WBS level manager, the system engineer ensures the development and approval of a verification plan. This plan is created at each WBS level and details the Requirement Assurance verification process (Figure 1) and its execution at that level.

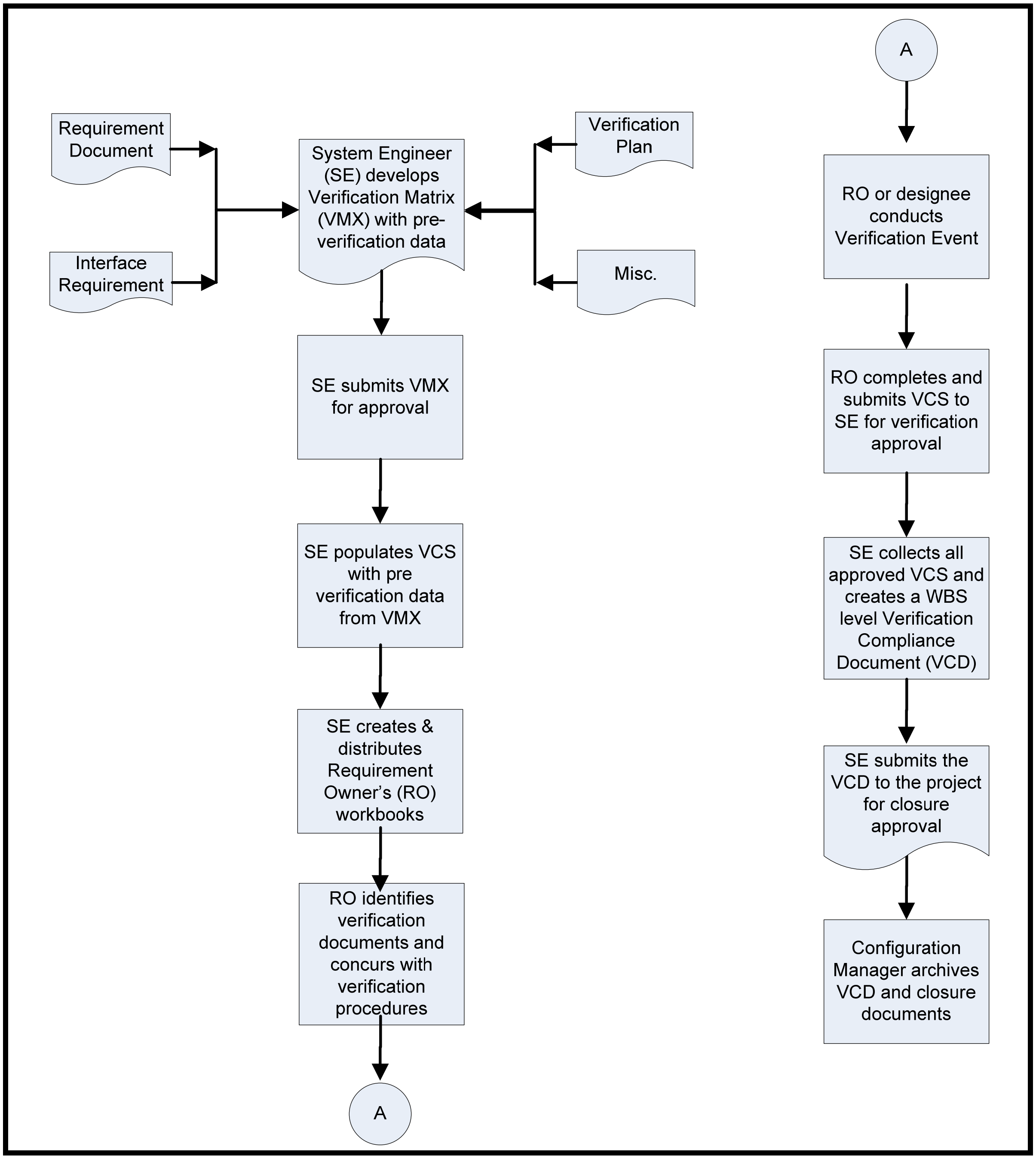


Figure 1 - Requirement Assurance Verification Process

A key to the success of Requirement Assurance is the Requirement Owners (RO). Requirement Owners are assigned by the WBS level project manager to specific requirements as subject matter experts. In addition, the ROs are responsible to ensure assigned requirements are verified in accordance with the verification plan and the Verification Matrix (VMX).

The VMX is typically a spreadsheet that contains the requirement's pre-verification data that is needed to perform the product requirement verification such as the verification scope (requirement), success criteria, rational, and etc. Based on a small project size and project management approval, some system engineer practitioners have continued to populate the VMX with verification data and submitted it as the project's VCD.

Once the information in the VMX is approved or concurred with, the data can be transferred using the mail merge function to the Verification Compliance Sheet (VCS) which is typically a Microsoft Word document. Each row of the VMX spreadsheet is a requirement verification and after the mail merge the requirement verification now has its own VCS. The pre-verification data-filled VCSs are organized and bound together to create a verification workbook for each RO. At this time, the VCS are partially completed and are not an official VCS until completely filled out and approved.

The RO workbook is an unofficial working level document given to the RO to record notes, results, data, and any information the RO deems necessary to support the verification of a product requirement. When the RO approves the verification artifact(s) and populates the VCS with final data, the RO submits the VCS to the system engineer for requirement verification approval.

The system engineer places the approved VCSs into the appropriate WBS level Verification Compliance Document (VCD) and submits the VCD to the project for approval and baselining upon completion. When approved, the requirements listed in the VCD are verified and closed.

1.4 Verification Hierarchy

As requirements are allocated down the WBS levels, each lower level WBS verification supports the verification of that WBS level and its parent requirement's verification. To ensure this verification hierarchy flow is not compromised, the responsibility of the RO at each WBS level is to ensure all of his/her assigned requirement verifications also support the parent requirement's verification. However, the greater verification responsibility lies with a System level RO who is verifying the system and determining whether all verifications (including lower level WBS verifications) support the assigned system requirements. The System level RO declares his/her assigned system requirements are verified when the system level verifications and the lower WBS level *allocated* requirement verifications are approved.

2 NPR 7123.1A Process

The Product Verification Process in NPR 7123.1A can be found in section C.2.3: *"The product verification process is used to demonstrate that an end product generated from product implementation or product integration conforms to its design solution definition requirements as a function of the product-line life-cycle phase and the location of the WBS model end product in the system structure. Special attention is given to demonstrating satisfaction of the Measure of Performances (MOPs) defined for each Measure of Effectiveness (MOE)."*

"A typical process flow diagram for product verification is provided in Figure 2 *(Figure C-8 from NPR 7123.1A) with inputs and his/her sources and the outputs and his/her destinations. The activities of the product verification process are truncated to indicate the action and object of the action."*

Figure 2 illustrates the Product Verification Process as defined in section C.2.3.4 of NPR 7123.1A. The figure shows the requirement verification activities that the Requirement Assurance process must meet.

2.1 Product Verification Process

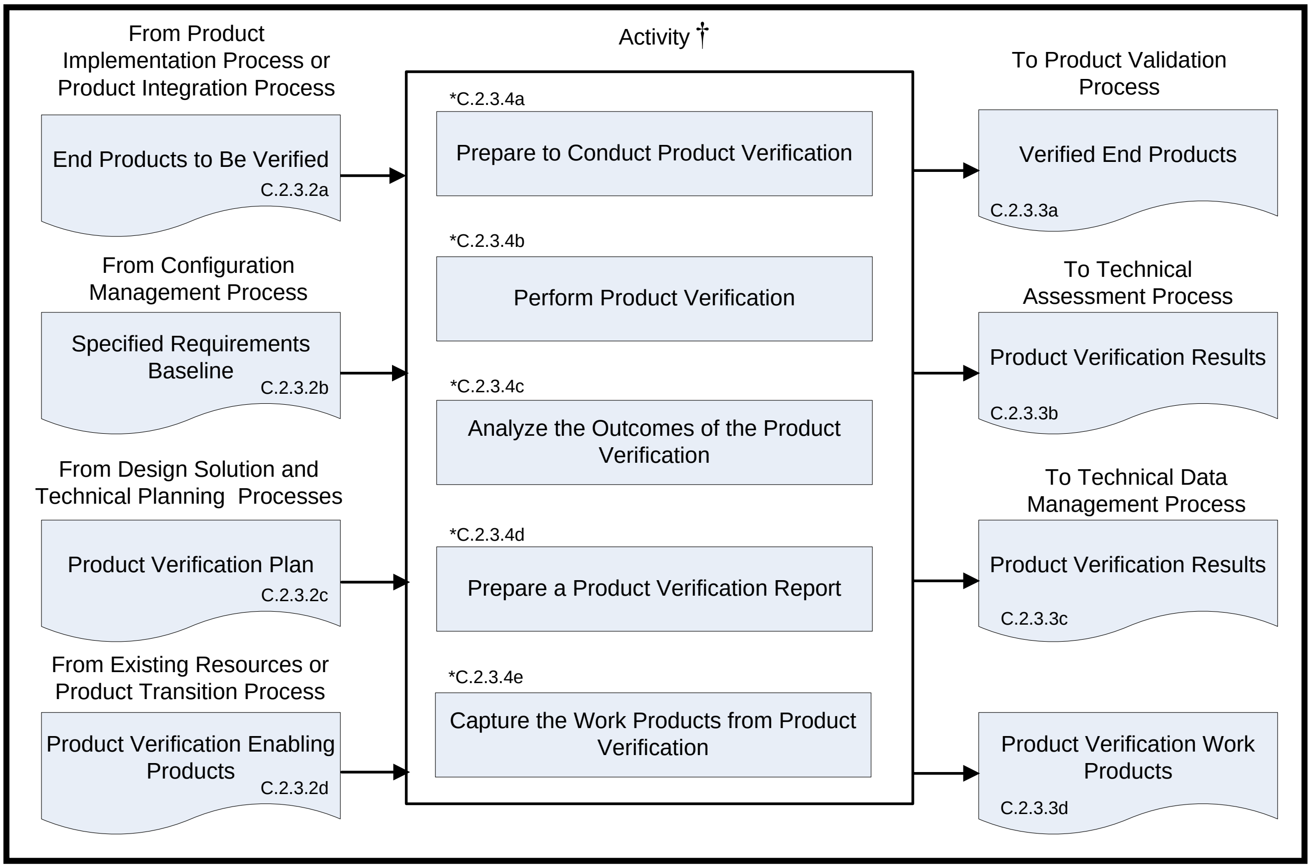


Figure 2 - NPR 7123-1A Product Verification Process
(* NPR 7123-1A section number)

3 Requirement Assurance Process

The Requirement Assurance (RA) process is a product requirement verification process that allows the WBS level system engineers to create a verification process that can be scaled to fit the project size and tailored to meet the project needs. The RA process is mapped (Figure 3) to its applicable NPR 7123.1A Activity† which demonstrates the RA process is in compliance with the guiding document.

3.1 Requirement Owner

Every requirement has a Requirement Owner (RO) assigned by the WBS level project manager. The RO is considered the subject matter expert of that requirement and is responsible to ensure assigned requirements are verified. The RO can delegate the responsibility to perform/record the verifications for which he/she is responsible. When the VCS is completed, the RO reviews it for completeness and accuracy and approves the closure artifacts as the conclusive proof/evidence necessary to verify the requirement. The RO submits the VCS to the WBS level system engineer for verification approval.

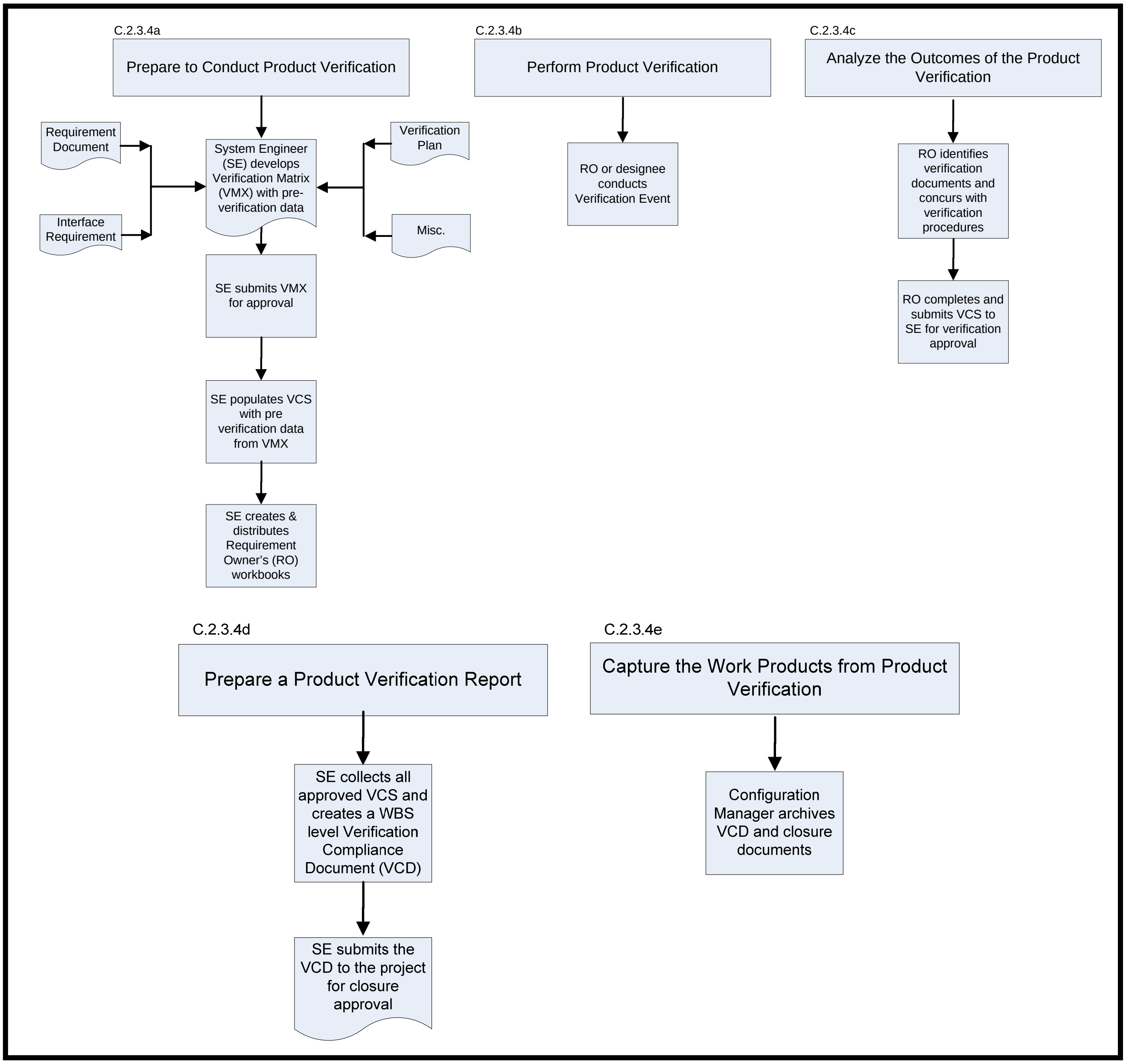


Figure 3 - NPR 7123.1A and Requirement Assurance Process Integration

3.2 Product Verification Preparation

In preparing to conduct requirement verifications, NPR 7123.1A section C.2.3.4a directions suggest the following:

> *"(1) reviewing the verification plan for any specific procedures, constraints, conditions under which verification will take place, pre- and post-verification actions, and criteria for determining the success or failure of verification methods and procedures;*
>
> *(2) arranging the needed product-verification enabling products and support resources;*
>
> *(3) obtaining the end product to be verified;*
>
> *(4) obtaining the specification and configuration baseline against which the verification is to be made; and*
>
> *(5) establishing and checking the verification environment to ensure readiness for performing the verification."*

In the Requirement Assurance process, the verification phase does not begin until the requirement document and verification plan have been approved. The suggested review topics in (1) above are conducted as a part of the verification event planning effort.

Directions given in (2), (3), and (4) occur during the initial planning of the verification method activity and are added to the verification method's procedure(s) as a check-off. The evidence of meeting (2), (3), and (4) in section C.2.3.4a is found in the closure documentation (procedure, process, checklist, etc.).

3.2.1 Verification Matrix

The Verification Matrix (VMX) (Appendix B - Figure B1) is a document that contains all the requirement pre-verification data needed to perform the requirement verification. It establishes the verification scope (requirement), success criteria, rational, traces, and environments of who, what, when, and where the verification event is to occur. The VMX is an optional document[1] depending on the verification strategy of the project. The RO is responsible to provide the pre-verification data and the system engineer works collaboratively with the RO. Once submitted, the system engineer can directly populate the VCSs, or uses the VMX as suggested to hold all the pre-verification data and mail merges it into the VCS. If the project is small, the system engineer can develop the VMX directly into a VCD.

To fulfill (5) of section C.2.3.4a (*establishing and checking the verification environment to ensure readiness for performing the verification)*, a VMX is constructed at each WBS level using a spreadsheet. The VMX should not be confused with the Verification Cross Reference Matrix found in a WBS level requirement document. When the VMX is fully populated with pre-verification data, the WBS level system engineer can submit the VMX to the project to baseline all the pre-verification data. Another example of a VMX is found in reference 2 in Appendix D.

[1] This SP assumes the Verification Matrix (VMX) is being used to hold pre-verification data.

From section C.2.3.3c, the VMX will have a minimum set of pre-verification information for each product requirement verification:

"*(1) the source paragraph references from the baseline documents for derived technical requirements, technical requirements, and stakeholder expectations;*

(2) bidirectional traceability among these sources (**NOTE**: The system engineer can place traces to IRDs or ICDs);

(3) verification type(s) to be used in performing verification of the specified requirement;

(4) reference to any special equipment, conditions, or procedures for performing the verification";

(5) verification scope (verification requirement);

(6) verification success criteria (containing any MOPs or MOEs);

(7) the approximate date when the closure artifact/document will be available;

(8) anticipated scheduled occurrence of the verification event;

(9) requirement number;

(10) requirement text;

(11) requirement owner's name; and

(12) any other information the system engineer requires such as a verification rationale.

3.2.2 Verification Compliance Sheet

When the project approves the requirement pre-verification data in the VMX, the system engineer accomplishes a simple mail merge between the VMX spreadsheet and the word processor's VCS which populates the VCS with all the required pre-verification information. The system engineer collates the pre-verification VCSs by RO and places them in an electronic workbook (typically a Microsoft Word file) specific for each RO. A pre-verification VCS is observed in Appendix A, Figure A-1.

When the verification event occurs and the VCS is populated with the final verification information (Result Summary and Closure Artifacts/Document sections, etc.), it becomes the requirement's verification approval/closure documentation. As the RO or designee completes the VCS, the amount or type of data presented in the VCS, as seen in Appendix A, Figures A-2 through A-5, is unrestricted. The RO approves each closure artifact and reviews the VCS prior to sending it to the WBS level system engineer for verification approval.

3.2.3 Workbook

The workbook is an unofficial working level word processing document (typically Microsoft Word) created by the system engineer for the RO. The workbook contains all the RO's assigned verifications as VCSs as well as any other supportive information. These VCSs are first populated with the required pre-verification data and then placed in the workbook. The workbook allows the RO to record, highlight, add working notes, and any information deemed necessary to support the verification of a requirement.

3.2.4 Cross Reference Table

Prior to a verification event such as testing, concurrence by the RO or his/her designee should be required in the procedure's or process's signature page which signifies that all applicable requirements for that event are identified and included in the procedure or process. A table should exist in the procedure or process similar to the Cross Reference Table example seen in Table 1 below that identifies the requirement and where its verification is located.

Requirement Number being Verified	Closure Document Page Number	Closure Document Section	Closure Document Procedure Step Number
AI1-CML-009	14	1.2.3	N/A
DTO2-AV-1029	17	3.2.4.1a	25 and 26
HYT-008	35	4.5.1.2.e	3

Table 1 – Cross Reference Table Example

3.3 Product Verification Execution

In accordance with NPR-7123.1A section C.2.3.4b: "*Perform the product verification in accordance with the product verification plan and defined procedures to collect data on each specified requirement with specific attention given to Measure of Performance (MOPs).*"

When the verification event occurs, its outcome is measured against the requirement's verification success criteria found in the VCS's Verification Success Criteria section. Upon the event's conclusion, the RO takes the workbook and completes the Result Summary and Closure Artifact/Document sections in the VCS. When the closure document ("as run" procedure, signed off reports, "as built drawings", etc.) or closure artifact becomes available, the RO places a copy of it onto the project's server and adds its filename and server URL to the Closure Artifact/Document section of the VCS (Appendix A, Figure A4). Once the VCS is completed and the RO has approved the closure artifact(s) or document, the VCS is submitted to the system engineer for verification approval.

3.4 Product Verification Analysis of Outcomes

In accordance with NPR-7123.1A section C.2.3.4c: "*Analyze the outcomes of the product verification, including identifying verification anomalies, establishing recommended corrective actions, and establishing conformance to each specified requirement under controlled conditions.*"

Further direction is given from section 2.3.3c of the NPR-7123.1A, "*…(5) results of verification conducted; (6) variations, anomalies, or out-of-compliance results; (7) corrective actions taken; and (8) results of corrective actions.*"

The verification outcome analysis occurs following the completion of the verification event where the results are compared to the verification success criteria. When the analysis and comparisons are completed, the RO writes the results in the VCS Results Summary section. If a discrepancy or non-conformance is found, then it is entered in the WBS level non-conformance resolution process for corrective action. The VCS is left open until resolution.

3.4.1 Discrepancy or Non-Conformances

When the verification outcome is compared to the success criteria and the verification anomalies are observed, the RO ensures the product is entered into a recognized institutional non-conformance process which establishes corrective actions that must occur prior to the approval of the product/requirement verification.

All non-conformances and discrepancies such as any procedural, equipment, operator or setup problems, etc., are annotated in the requirement's VCS "NFR" section. The requirement cannot be verified until all non-conformances have been officially closed by corrective action or by an approved variance (waiver or deviation). Non-conformance and discrepancy actions and results are placed in the Results Summary section of the VCS by the RO.

3.4.2 Closure Artifacts

The closure artifact is the conclusive and indisputable evidence used during the outcome analysis that proves the requirement verification. Closure artifacts are stand alone "artifacts" or found in a closure document. These closure documents may be test, analysis or demonstration reports, "as-run" procedures, "as built" drawings, and in some cases, photographs. However, design drawings and procedures without signatures or Quality Assurance sign-offs are not acceptable as closure documents or artifacts. The closure artifact and document references are found in the Closure Artifact/Document section of the VCS.

3.4.3 Result Summary

The Requirement Owner or designee writes a summary of the verification result of each test, analysis, demonstration, inspection, corrective actions, etc., for that requirement. It should make "*reference to any special equipment, conditions, or procedures for performing the verification.*" Enough written information should be evident so the reader has a basic understanding of what occurred for this requirement's verification. The RO is not restricted on the type of information or the use of references included or the length of this section.

3.5 Product Verification Report Preparation

In accordance with NPR-7123.1A section C.2.3.4d: "*Prepare a product verification report providing the evidence of product conformance with the applicable design solution definition specified requirements baseline to which the product was generated, including bidirectional requirements traceability and actions taken to correct anomalies of verification results.*"

To meet this guidance, the Verification Compliance Document (VCD) is developed using information from section C.2.3.4d. The recommended content of this document (report) can be found in section 2.3.3c. of NPR-7123.1A.

3.5.1 Verification Compliance Document

When the verification data matures and the closure artifacts are approved, the RO completes and delivers the VCS to the system engineer for verification approval. The WBS level system engineer reviews the information on the VCS for completeness, accuracy, and details, and the closure artifacts for approval. If the system engineer cannot approve the VCS, the system engineer works with the RO to resolve any issues such that the requirement verification obtains approval.

After all the VCSs have been submitted and approved by the system engineer, the Verification Compliance Document (VCD) is developed by the WBS level system engineer by placing the approved VCSs within the document. The system engineer submits the VCD to the appropriate WBS level approval authority for baselining. After baselining, the requirements and closure artifacts are closed.

.

3.6 Work Product Capture

In accordance with NPR-7123.1A section C.2.3.4e: *"Capture the work products from the product verification. Note: Work products include verification outcomes; records of procedural steps taken against planned procedures; any failures or anomalies in the planned verification procedures, equipment, or environment; and records citing satisfaction or non-satisfaction of verification criteria. Also, records should document:*

(1) the version of the set of specification and configuration documentation used;
(2) the version of the end product verified;
(3) the version or standard for tools and equipment used, together with applicable calibration data;
(4) results of each verification including pass or fail declarations; and
(5) discrepancies between expected and actual results."

The products listed from section C.2.3.4e and seen from (1) through (5) are found in the VCD. When a VCD is approved and baselined, all closure artifacts and documents are made available and archived in accordance with the WBS level data management or verification plan.

4 Conclusion

The Requirement Assurance process presented provides the system engineering practitioner a process that ensures product requirement verification that meets NPR 7213.1A direction. This process is mapped into the NPR 7213.1A section C.2.3 - *Product Verification Process* which provides a confidence of applicability. The Requirement Assurance verification process defines and demonstrates how the process components fit within each Activity in section C.2.3. This verification process easily allows product requirement verification to occur on one Verification Compliance Sheet or multiple continuation sheets. In addition to its effectiveness, this method can be scaled to any size project and tailored for any WBS level (system, element, subsystem, etc.). This process integrates with industry standard requirements and Systems Engineering tools.

References

1. Hooks, Ivy F.; and Farry, Kristin A.: *Customer Centered Products: creating successful products through smart requirements management.* AMACOM, 2001, pp.103-107.
2. NASA SP/2007-6105 Rev1.; *NASA System Engineering Handbook*; 2007, pp. 86.
3. NPR 7123.1A.; *NASA Systems Engineering Process and Requirement* w/Change 1 (11/04/09), March 26, 2007.

Acronyms

ERD	Element Requirement Document
IAW	In Accordance With
ICD	Interface Control Document
IRD	Interface Requirement Document
LPR	Langley Procedural Requirement
MOE	Measure of Effectiveness
MOP	Measure of Performance
NFR	Non-conFormance Report
NPR	NASA Procedural Requirement
RA	Requirement Assurance
RO	Requirement Owner
SE	System Engineer
SRD	System Requirements Document
VCD	Verification Compliance Document
VCS	Verification Compliance Sheet
VMX	Verification MatriX
WBS	Work Breakdown Structure

Definitions

Applicable documents: - Further sources of detailed information for meeting this verification (e.g., NASA test or analysis standards, project documents, etc.)

Closure Artifact: - This is the basic datum that is the conclusive proof or evidence by which the requirement is verified and closed. A closure artifact can be where a MOP or MOE has clearly shown with independent assurance (typically a Quality Assurance sign-off) has been met. The closure artifact is under configuration control and cannot change. In some rare instances, the closure artifact can be the closure document (i.e. inspection sheet).

Closure Documents: – A document that contain the closure artifact(s) used to conclusively prove the requirement was verified. closure documents include test reports, analysis reports, inspection reports, and as-run procedures, as-built drawings, etc. In some rare instances, the closure document can be the closure artifact (i.e. test report or "as run" procedure).

Measure of Effectiveness (MOE): – A measure by which a stakeholder's expectations are judged in assessing satisfaction with products and systems produced and delivered in accordance with the associated technical effort. The MOE is deemed to be critical to not only the acceptability of the product by the stakeholder, but also critical to the operational / mission usage. An MOE is typically qualitative in nature or not able to be used directly as a "design-to" requirement.

Measure of Performance (MOP): – A quantitative measure that, when met by the design solution, will help ensure that an MOE for a product or system will be satisfied. These MOPs are given special attention during design to ensure that the MOEs to which they are associated are met. There are generally two or more measures of performance for each MOE.

NFR: - This is a non-conformance report written against a verification anomaly which must have corrective action done prior to verification approval.

Requirement Owner: - This person is the subject matter expert of his/her assigned requirements. They're also responsible to ensure assigned requirements are verified. They also approve closure artifacts.

Scheduled Activity: - The activity on the project schedule where the verification event should occur. The verification event does not necessarily need to be scheduled on the project schedule, just tied to and existing one. This information is used to help manage verification activities where there may be multiple verifications occurring at a single facility or resource. This information is not used to measure performance or delivery dates.

Verification Rationale: – An explanation and justification for "why" the specific method, success criterion, measure, constraints, conditions, and assumptions were stated.

Verification Scope or Requirement: **-** Description of the work to be performed, described in one or more "shall" statements (requirements) stating the measure (a parameter, quantity, or condition) for the verification success criterion. This part should state how to obtain (generally, not calling out a specific tool) values or states for this measure. This part may state required assumptions and conditions for the verification.

Verification Success Criteria: - A single "shall" statement (requirement) stating the required criterion (MOPs/MOEs) for the verification to be considered successful in terms of the measure for the success criterion.

WBS level: - Level(s) of assembly at which the requirement will be verified (e.g., system, element, subsystem, etc.).

Appendix A: Verification Compliance Sheet Examples

Appendix A contains example of VCSs. Figure A-1 is an example of a VCS completed with only "pre-verification data" that goes into the Requirement Owner's workbook. Figures A-2 through A-5 are examples of a completed VCS of different project sizes and WBS levels.

Figure A-1
Verification Compliance Sheet (Workbook Example)
Populated with Pre-Verification Data

<table>
<tr><td>Requirement Title:
Bending Stiffness Profile</td><td>Requirement No.:
CML-062</td><td>Verification Method:
Analysis</td></tr>
<tr><td>Requirement Text: The CM/LAS bending stiffness shall be within +/- 10% of the EI profile shown in the CM/LAS portion of the SRD requirement FTV-008.</td><td>Parent Rqmt:
FTV-008, 011</td><td></td></tr>
<tr><td colspan="3">Description of Verification Activity (Verification Scope):CM/LAS personnel shall show by analysis found in AI1-CML-SAR-CM that the joint stiffness between the CM/LAS and USS is greater than 20% of the adjacent sectional bending stiffness.

Note: USS personnel will also analyze this joint since it is shared between the CM/LAS and USS IPTs (Requirement ICMLAS-USS.003 in AI1-IRD-C2U). The CM/LAS analysis results will be compared with those obtained by Upper Stage Simulator (USS). Modal test data obtained by SE&I for the Stack 5 hardware in the VAB will provide additional, corroborating information for these analyses.
.</td></tr>
<tr><td colspan="3">Verification Success Criteria: The verification shall be successful when the joint stiffness between the CM/LAS and USS is shown by analysis to be greater than 20% of the adjacent sectional bending stiffness and the CM/LAS results compare well with the USS results.</td></tr>
<tr><td colspan="3">Rationale: Simulation using independent and validated analysis tools and techniques (by both CM/LAS and USS IPTs) is an accepted method to verify requirements for such properties that can only be accurately tested at an assembly level. Modal test data for Stack 5 at KSC will be available from SE&I to substantiate the analysis results.</td></tr>
<tr><td colspan="3">Result Summary (Compliance Statement):</td></tr>
<tr><td colspan="3">Closure Artifact/Document(s):</td></tr>
<tr><td>Waivers/ (NFRs):</td><td>Requirement Owner:</td><td>Verification Closed</td></tr>
</table>

Figure A-2 (Large Project Example)
Verification Compliance Sheet (System level)

Ares I–X FTV System
Verification Requirement Definition Sheet

FTV SRD Requirement to be Verified

Verification Number: VR-FTV-001	Requirement Number: FTV-001	

Requirement Title: **FTV Elements**

Verification Requirements

Verification method: Verification that the FTV consists of the following elements (CM/LAS, USS, RoCS, FS, & Avionics) shall be by **Inspection**.

Description of verification activities to be performed:

The Ares I-X Vehicle Assembly and Integration Lead will review final designs that have been approved at the Ares I-X CDR to verify inclusion of the five listed elements.

The Ares I-X Interface Custodians shall review artifacts from each IPT showing compliance with his/her side of the interfaces defined in the applicable Element to Element IRD. When all element-level interface requirements associated with an Element to Element IRD have been verified to his/her satisfaction, each Interface Custodian shall provide a summary of the interface verifications to the Ares I-X Lead Systems Engineer. The summary report shall include any waivers or deviations to the interface requirements.

The Ares I-X Lead Systems Engineer shall review the interface verification summary reports and the integrated vehicle drawing to verify that the FTV is constructed from the five elements listed.

Success Criterion:

CDR approved design of the Ares I-X FTV includes the five elements listed in FTV-001 and Interface Verification Summary Reports for all Element to Element IRDs.

Rationale:

Verification by inspection of CDR designs is appropriate for the requirement.

Verification Implementation

Level: The Ares I-X FTV System does comply with FTV-001. See attached compliance statement.
Applicable documents: CDR Data from all FTV IPTs.
Nonconformance history: *List any waivers below; address them later in the compliance statement.* • CR-AIX-0344 "CM/LAS CM Flange Flatness Local Exceedance. (AIX-IRD-C2U [ICMLAS-USS.001.5] Flatness)" • CR-AIX-0359 "USS SM to CM/LAS Mechanical Interface" • CR-AIX-0363 "USS US-1 US RCS Cover Protuberance Pressure Transducer with No Bonding Check" • Plus 50 Element IRD/ICD waivers, listed in the Interface Custodian Verification Summary reports in Section 1.2
Closure data/documentation required: Electronic/Written confirmation from the Ares I-X Lead Systems Engineer that the approved CDR design includes the required elements and that the element to element interfaces have been verified. **Event preceding Verification Activity:** Element to Element Interface Requirements are closed. **Estimated Duration of Verification Activity**: 5 Days

Closure Of FTV SRD Requirement		
Requirement Owner: ________________ **Richard Harris** (with compliance statement write-up support from Paul Luz)	**Systems Engineer:** ________________ **Cheryl Harrison**	**Technical Management Approval:** ________________ **Joe Smith**
Date Closed: ________________	**S&MA Approval:** ________________ **Dave Jones**	**SE&I Lead Engineer Approval:** ________________ **Stewart Long**

Compliance Evaluation for Ares I-X Verification Number: VR-FTV-001 "FTV Elements"

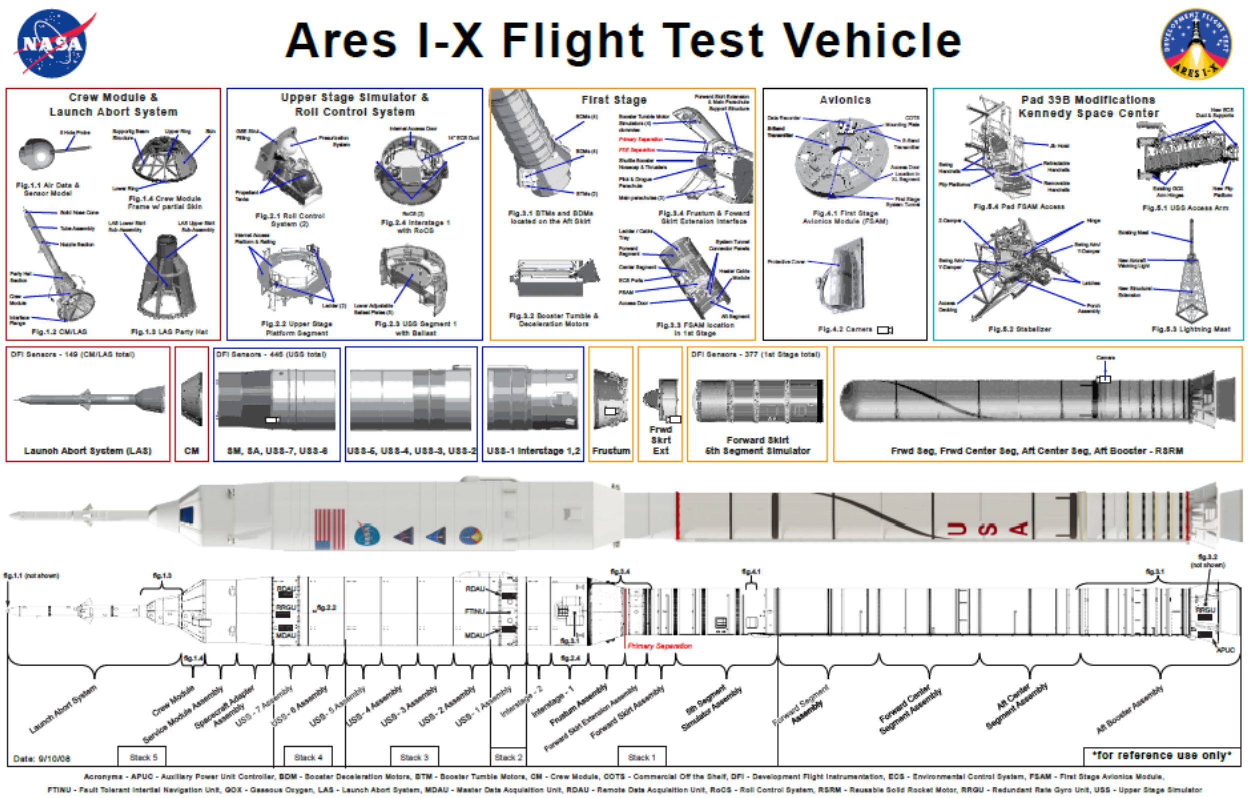
The Ares I-X FTV **is in compliance** with requirement FTV-001, "***The FTV shall consist of the following five elements: FS, USS, CM/LAS, Avionics, and RoCS***." A summary of the analysis and a review of verification artifacts are provided below.

The design snapshot below and photographic evidence on the next page show compliance with paragraph 1 of 3 in the Verification Requirement Definition Sheet (VRDS) for requirement VR-FTV-001, which states, "*The Ares I-X Vehicle Assembly and Integration Lead will review final designs that have been approved at the Ares I-X CDR to verify inclusion of the five listed elements.*"

Ares I-X High Level Poster/Drawing

E-mail from Bruce Askins, the Ares I-X Project Integration Manager, "*The high level Ares I-X posted has been updated to reflect the configuration and detail as of 9/1/08 by Jonathan Behun with contributions from Terry White and Roosevelt Wright. It is set-up where it can be printed as a 22 x 36 poster.* [2]

Ares I-X top level assembly drawing is 1264846.

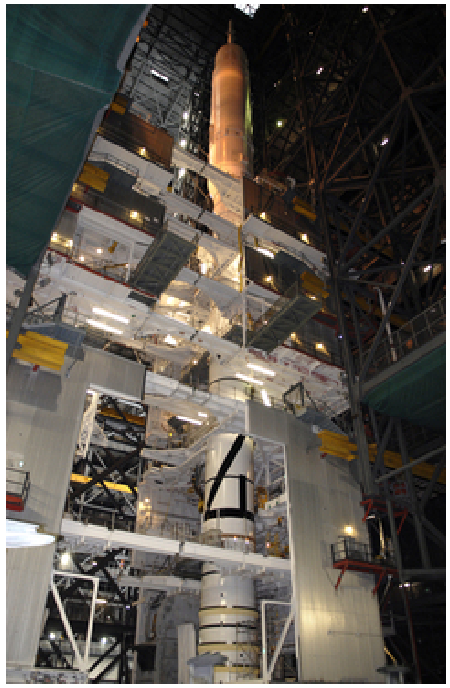


NASA KSC Media Photo release KSC-2009-4954 on August 31, 2009

"CAPE CANAVERAL, Fla. – Work platforms surround the Ares I-X launch vehicle in the Vehicle Assembly Building's High Bay 4 at NASA's Kennedy Space Center in Florida. The rocket has undergone a sway test that simulated conditions the rocket could experience during rollout to Launch Pad 39B…"

---

[2] Ares I-X Project Integration Manager Bruce Askins, e-mail to NASA-DL-AresIX-Primary-Contacts distribution list, "Ares I-X High Level Poster/Drawing Update", September 22, 2008 at 6:39 AM.



Bottom line: All 5 elements have been delivered and assembled, demonstrating that requirement FTV-001 has been fulfilled. For a summary recap that lists when each element was delivered, please see Section 5.0.

Paragraph 2 of 3 in the VRDS for FTV-001 states, "*The Ares I-X Interface Custodians shall review artifacts from each IPT showing compliance with his/her side of the interfaces defined in the applicable Element to Element IRD. When all element-level interface requirements associated with an Element to Element IRD have been verified to his/her satisfaction, each Interface Custodian shall provide a summary of the interface verifications to the Ares I-X Lead Systems Engineer. The summary report shall include any waivers or deviations to the interface requirements*."

Interface Requirement Documents (IRDs)	Interface Custodian	Delivery Date Interface Custodian's Summary Report delivered to the Ares I-X LSE
USS to CM/LAS (AI1-IRD-C2U v3.01)	LaRC/ Mark McMillin	2009-10-16 via e-mail, AI1-SYS-IVSR. 3 CM/LAS waivers, all were approved by XCB.
USS to Roll Control (AI1-IRD-R2U v2 04)	LaRC/ Mark McMillin	2009-10-16 via e-mail, AI1-SYS-IVSR. 3 RoCS waivers, all were approved by XCB.
USS to First Stage (AI1-IRD-U2F v2.02)	LaRC/ Mark McMillin	2009-10-16 via e-mail, AI1-SYS-IVSR. 4 FS waivers, all were approved by XCB.
Flight Test Vehicle to Ground Systems (AI1-IRD-F2G v5.05)	JSC / Jim Wiehoff	2009-10-20 9 GS waivers, all were approved by XCB.
Avionics to Ground System (AI1-IRD-F2G Appendix I v5.05)	LaRC / Jose Ortiz	2009-10-13 via e-mail. 1 waiver; it was approved by XCB.
Lockheed Martin Ground Command, Control, Communications (GC3) To NASA Ground Element (AI1-IRD-F2G Appendix II v5.05)	LaRC / Jose Ortiz	2009-10-13 via e-mail. 1 waiver; it was approved by XCB.
Avionics to Flight Vehicle Elements (AI1-ICD-A2V v5.0)	LaRC / Jose Ortiz	2009-10-13 via e-mail. 28 waivers, all were approved by XCB.

Paragraph 3 of 3 in the VRDS for FTV-001 states, "*The Ares I-X Lead Systems Engineer shall review the interface verification summary reports and the integrated vehicle drawing to verify that the FTV is constructed from the five elements listed.*"

In regard to the LSE review of interface verification summary reports is covered by XCB Approval.

In regard to the LSE review of the integrated vehicle drawing to verify that the FTV is constructed from the five elements listed, please see the drawing and photograph provided within Section 1.1. Bottom line: All 5 elements have been delivered and assembled, demonstrating that requirement FTV-001 has been fulfilled. For a summary recap that lists when each element was delivered, please see Section 5.0.

Requirement Recap

Ares I-X requirement FTV-001 is documented in the "System Requirements Document for the Ares I-X Flight Test Vehicle", AI1-SYS-SRD v4.15a, December 7, 2008, pp28-29:

4.2.1.1 FTV-001: FTV Elements

- The FTV shall consist of the following five elements: FS, USS, CM/LAS, Avionics, and RoCS.

28

Ares I-X Flight Test		
Title Ares I-X Flight Test Vehicle System Requirements Document	Document No: AI1-SYS-SRD-VER 4.15	Baseline
	Effective Date: Dec. 07, 2008	Page 29 of 103

[Rationale: The FTV is a developmental model for the CLV Ares I/Orion. Significant planning and analysis has been done around these functional elements. This architecture is inferred in the FTP in Sections 3 and 5. In order to be similar to the Ares I/Orion, these elements are mandated by the Ares I-1 flight test.]

[Trace: P1-P5, S1- S7]

[Allocation: All elements]

[Priority: 1]

Trace Analysis

Table 3.0-1 IPT Children Requirements that were traced to SRD Requirement FTV-001

Child Reqmt	Title	Disposition
CML		
CML-001	CM/LAS Sub-Elements	Submitted to the XCB via CR-AIX-0435. *Approved by XCB 20090625* *RAVEN comment: "Closed 9/24 per Barry"*
RoCS		
RoCS-037	RoCS Installation	Submitted to the XCB via CR-AIX-0313. *Approved by XCB 20090605.*
RoCS-039	RoCS Ordnance	
RoCS-040	RoCS Engine	
USS		
USS-001	USS Element Simulators	Submitted to the XCB via CR-AIX-0318. *Approved by XCB 20090331*
USS-041	RoCS Interfaces	Submitted to the XCB via CR-AIX-0463. *Approved by XCB 20090728.*
USS-053	FS Mechanical Interfaces	Submitted to the XCB via CR-AIX-0570. *Approved by XCB 20090929.*
USS-054	CM/LAS to USS Mech. Interfaces	Submitted to the XCB via CR-AIX-0463. *Approved by XCB 20090728*
USS-055	Avionics Structural Interfaces	Submitted to the XCB via CR-AIX-0570. *Approved by XCB 20090929.*
USS-056	Avionics G&B Interfaces	
USS-115	FS to USS Interface Markings	Submitted to the XCB via CR-AIX-0377. *Approved by XCB #USS AR (XCB 20090505).*
USS-117	FS Human Access	Submitted to the XCB via CR-AIX-0570. *Approved by XCB 20090929.*
USS-118	CM/LAS to USS Interface Markings	Submitted to the XCB via CR-AIX-0348. *Approved by XCB 20090421*
USS-119	CM/LAS to USS Human Access	
USS-120	RoCS to USS Electrical Bonding	Submitted to the XCB via CR-AIX-0377.

Child Reqmt	Title	Disposition
USS-121	FS to USS Electrical Bonding	*Approved by XCB #USS AR (XCB 20090505).*
USS-122	CM/LAS to USS Electrical Bonding	Submitted to the XCB via CR-AIX-0348. *Approved by XCB 20090421*
USS-124	RoCS Mass Interface	Submitted to the XCB via CR-AIX-0377. *Approved by XCB #USS AR (XCB 20090505).*
USS-125	RoCS Human Access Interface	Submitted to the XCB via CR-AIX-0377. *Approved by XCB #USS AR (XCB 20090505).*
AVI		
AVI-200	Avionics [Baseline]	Submitted to the XCB via CR-AIX-0372. *Approved by XCB 20090428.*
AVI-208	USS Electrical [Baseline]	Submitted to the XCB via CR-AIX-0627. Approved by XCB 20091020
AVI-209	CM/LAS-Electrical [Baseline]	Submitted to the XCB via CR-AIX-0404. *Approved by XCB OSB on 20090803.*
AVI-210	First Stage-Electrical [Baseline]	Submitted to the XCB via CR-AIX-0627. Approved by XCB 20091020
AVI-215	USS-Physical [Baseline]	Submitted to the XCB via CR-AIX-0627. Approved by XCB 20091020
AVI-216	CM/LAS-Physical [Baseline]	Submitted to the XCB via CR-AIX-0404. *Approved by XCB OSB on 20090803*
AVI-217	First Stage-Physical [Baseline]	Submitted to the XCB via CR-AIX-0574. *Approved by XCB 20091006.*
AVI-242	FSAM [Baseline]	Submitted to the XCB via CR-AIX-0627. Approved by XCB 20091020
AVI-261	RoCS-Physical [Baseline]	Submitted to the XCB via CR-AIX-0453. *Approved by XCB OSB on 7-27-2009.*
AVI-262	RoCS-Electrical [Baseline]	Submitted to the XCB via CR-AIX-0627. Approved by XCB 20091020
FS		

Child Reqmt	Title	Disposition
FS-001	RSRM	Submitted to the XCB via CR-AIX-0583.
FS-002	FS Safe and Arm System	Submitted to the XCB via CR-AIX-0508.
FS-003	System Tunnel	Submitted to the XCB via CR-AIX-0554.
FS-004	Aft Skirt Assembly	Submitted to the XCB via CR-AIX-0583.
FS-005	Thrust Vector Control	Submitted to the XCB via CR-AIX-0554 (Electrical) and also CR-AIX-0618 (Interstage).
FS-008	First Stage Deceleration Subsystem	Submitted to the XCB via CR-AIX-0554.
FS-009	Nosecap	Submitted to the XCB via CR-AIX-0560.
FS-010	Thrusters	Submitted to the XCB via CR-AIX-0624.
FS-012	Parachutes	Submitted to the XCB via CR-AIX-0518.
FS-013	Booster Deceleration/Tumble Motor	Submitted to the XCB via CR-AIX-0469. RAVEN comment: "A-PYR-6124-7/10PLN-0060A-Baselined"
FS-206	Ignition Separation Controller	Submitted to the XCB via CR-AIX-0605.
FS-207	Recovery Controller Unit	Submitted to the XCB via CR-AIX-0605.
FS-208	Heritage Altitude Switch Assembly	Submitted to the XCB via CR-AIX-0605.
FS-209	APUC Heritage	Submitted to the XCB via CR-AIX-0605.
FS-210	ISC Interface	Submitted to the XCB via CR-AIX-0605.
FS-211	RCU Interface	Submitted to the XCB via CR-AIX-0605.
FS-212	SRB Heritage ASA	Submitted to the XCB via CR-AIX-0605.

NOTE: FS verifications are considered approved upon receipt of the CR per MMO directive CR-AIX-0537.

There is a subfolder for each XCB that was held. The CR's are in the folder that corresponds to the date the XCB was held. For example, the RoCS IPT CR-AIX-0313 can be found in folder "XCB 20090605".

Waivers against FTV-001

This section only identifies and discusses the system-level waivers that were written directly against system-level verification requirement FTV-001 in the "System Requirements Document for the Ares I-X Flight Test Vehicle", AI1-SYS-SRD v4.15a, December 7, 2008, pp28-29.

For a review of the element-level IRD/ICD waivers (these were waivers to the IRDs and not waivers to AI1-SYS-SRD), please see the Interface Custodian Verification Summary reports listed in Section 1.2. There were 50 IRD/ICD waivers from the elements, all of which were approved by the XCB.

CR-AIX-0344 "CM/LAS CM Flange Flatness Local Exceedance (AIX-IRD-C2U [ICMLAS-USS.001.5] Flatness)"

- This waiver was traced to requirements FTV-001 and AI1-IRD-C2U v3.00, Section 4.1.1 Mechanical Assembly Joint, Requirement [ICMLAS-USS.001.5] - Flatness.
- *The waiver was "Approved as presented" by XCB 20090512.*
- *Conclusion: Given that this waiver really affects an IRD requirement and not the higher system-level requirement FTV-001, "The FTV shall consist of the following five elements: FS, USS, CM/LAS, Avionics, and RoCS"; and given that the waiver was approved by the XCB in any case; the waiver therefore does not impact the verification of FTV-001.*

CR-AIX-0359 "USS SM to CM/LAS Mechanical Interface"

- This waiver was traced to requirements USS-054. One could argue that this waiver is also relevant to the verification of FTV-101 "Stack/Destack Assembly Joints". The verification compliance statement for FTV-101 already does include an evaluation of this waiver for completeness.
- The waiver was submitted *"… to communicate several non-conformances to the SM segment top flange mechanical interface as documented in the CM/LAS to USS IRD, AI1-IRD-C2U*", and specifically "*Flange local flatness, Tension bolt hole spotface depth/flange thickness, Flange O.D. tolerance*".
- *The waiver was "Approved as presented" by XCB 20090512.*
- Furthermore, Ares I-X finished stacking CM/LAS onto USS on August 13, 2009.
- *Conclusion: Given that this waiver really affects requirement FTV-101 "Stack/Destack Assembly Joints" and not requirement FTV-001, "The FTV shall consist of the following five elements: FS, USS, CM/LAS, Avionics, and RoCS"; and given that the waiver was approved by the XCB in any case; the waiver therefore does not impact the verification of FTV-001.*

CR-AIX-0363 "USS US-1 US RCS Cover Protuberance Pressure Transducer with No Bonding Check"

- This waiver was elevated from CR-AIX-DXCB-0006 "USS US-1 US RCS Cover Protuberance Pressure Transducer with No Bonding Check".
  - The DXCB waiver traced to requirements FTV-001, USS-056, and AI1-ICD-A2V.
  - The DXCB waiver was submitted "…to communicate one non-conformance on the US-1 segment for the requirement to perform a bonding check on all DFI sensors that are installed into segment skins and the OML protuberances."

    - The DXCB waiver was "Approved" by DXCB Chair Lanny Upton on March 23, 2009 and elevated to the XCB as CR-AIX-0363.

- On April 7, 2009, XCB Secretariat Heather Altizer distributed an e-mail stating:
    - "CR AIX-0363 was withdrawn per email notification from DxCB secretariat."
    - "Waiver was dispositioned at DxCB and upon futher investigation system level documents identified as affected products on the DxCB waiver were not affected."

- <u>Conclusion</u>*: Given that this waiver was withdrawn, and given XCB statement above that "…upon further investigation system level documents identified as affected products on the DxCB waiver were not affected";the waiver therefore does* <u>*not*</u> *impact the verification of FTV-001.*

Example A-3 (Large Project Example)
Verification Compliance Sheet (Element Level)

Verification No. ***ERD Requirement No.***
VR-CML-009 CML-009

Requirement Title: Joint Stiffness

Verification Method: Analysis

Description of Verification Activity (Verification Scope): CM/LAS personnel shall show by analysis found in AI1-CML-SAR-CM that the joint stiffness between the CM/LAS and USS is greater than 20% of the adjacent sectional bending stiffness.

Note: USS personnel will also analyze this joint since it is shared between the CM/LAS and USS IPTs (Requirement ICMLAS-USS.003 in AI1-IRD-C2U). The CM/LAS analysis results will be compared with those obtained by Upper Stage Simulator (USS). Modal test data obtained by SE&I for the Stack 5 hardware in the VAB will provide additional, corroborating information for these analyses.

Verification Success Criteria: The verification shall be successful when the joint stiffness between the CM/LAS and USS is shown by analysis to be greater than 20% of the adjacent sectional bending stiffness and the CM/LAS results compare well with the USS results.

Rationale: Simulation using independent and validated analysis tools and techniques (by both CM/LAS and USS IPTs) is an accepted method to verify requirements for such properties that can only be accurately tested at an assembly level. Modal test data for Stack 5 at KSC will be available from SE&I to substantiate the analysis results.

FTV-Trace: FTV-002, 004, 006, 009, 124

Scheduled Activity: UID - 1591 Final Structural Analysis Doc Complete

Closure Report No.: AI1-CML-SAR-CM

AI1-IRD-C2U Trace: *CMLAS-USS.003*

Requirement Owner: David Alexander

Figure A-3 (concluded)
Verification Compliance Sheet

<table>
<tr><td>Requirement Title: Joint Stiffness</td><td>Requirement No.
CML-009</td><td>Verification Method
Analysis</td></tr>
<tr><td>Verification No.
VR-CML-009</td><td>CM/LAS–USS Trace:
ICMLAS-USS.003</td><td>FTV-Trace:
FTV-002, 004, 006, 009, 124</td></tr>
<tr><td colspan="3">Result Summary:

This requirement was verified by a nonlinear NASTRAN structural analysis (SOL 600), which is documented in Section 11.4 of the CM Structural Analysis Report, AI1-CML-SAR-CM, version 1.0. This analysis used a bolt preload of 36,000 lbs, an applied load of 5000 lb, symmetry constraints, and 36-inch total joint length. (The 5000 lb applied load was selected based on predicted CM-to-SM fastener load distributions, documented in Section 10.4 of AI1-CML-SAR-CM, and the 36-inch total joint length was a directive from the Ares I-X SE&I Office.) The results are compared with the predicted deflection for a solid steel plate of the same size but without the bolted joint. This detailed analysis shows that the CM-to-SM joint has a predicted stiffness of 27.5% of the adjacent sectional bending stiffness, which satisfies the 20% minimum stiffness requirement.

Structural analysts at Glenn Research Center conducted an independent analysis of this joint, and his/her results also show that the stiffness of this joint is greater than 20% of the adjacent sectional bending stiffness.

The finite element models used for these analyses are available upon request.

Interface Requirement ICMLAS-USS.003 is identical to CM/LAS Requirement CML-009, and is therefore also verified.</td></tr>
<tr><td>W.O. No. / Tracker No.:
1) 76158/D213B08T0015
2) 76783/D213A08F00556</td><td>Closure Report(s):
AI1-CML-SAR-CM</td><td>Drawing No.:
1243204, 1261200, 1261209, 1261214, 1261231, 1261248, 1261249, 1261280, 1261200,</td></tr>
<tr><td>Non-Conformance Reports (NFRs):
None</td><td>Requirement Owner:
David Alexander</td><td>Reference Docs.
AI1-SYS-SDB
AI1-SYS-TDB
AI1-SYS-ACO
AI1-SYS-ARO</td></tr>
</table>

Figure A-4 (Medium Project Example)
Verification Compliance Sheet (Subsystem Level)

<table>
<tr><td>Requirement Title:
Mounting</td><td>Requirement No.:
DTO2-AV-1008</td><td>Verification Method:
Inspection</td></tr>
<tr><td>Requirement Text: The Avionics Assembly shall mechanically interface to an Adaptive Payload Carrier (APC).</td><td>Parent Rqmt:
DTO1-SYS-1605
DTO1-AVENC-1004</td><td></td></tr>
<tr><td colspan="3">Description of Verification Activity (Verification Scope): The Mechanical Lead shall verify by inspection that the Avionics Assembly is designed to mount to an APC carrier in Port side bay 3.</td></tr>
<tr><td colspan="3">Verification Success Criteria: The verification shall be succesful when:
- the Avionics Enclosure meets the APC interface spec.
- the Avionics mounting plate is fit checked with the APC carrier.</td></tr>
<tr><td colspan="3">Result Summary (Compliance Statement)): The AEA baseplate was fit checked to an APC at KSC and was found to fit correctly, prior to the buildup of the AEA. It was designed to the APC interface drawing given in ICD-A-21551, Figure 3.0.4.2.1.3.1-1.</td></tr>
<tr><td colspan="3">Closure Artifact/Document(s):
STORRM ICD-A-21551: http://www.unitedspacealliance.com/icd/RNS/contents.html

STORRM Drawing 1250637_REV_A AEA Mounting Plate dwg.pdf

Fit check photos: SN -001 Picture 1.jpg</td></tr>
<tr><td>Waivers/ (NFRs):
None</td><td>Requirement Owner:
Kevin Taylor</td><td>Verification Closed
3-16-2010-MA</td></tr>
</table>

Figure A-5 (Small Project Example)
Verification Compliance Sheet (System Level)

Req. No.	**Requirement Title**	**Verification method**	**SRD No.**
VR-09 Spatia	l Resolution	Analysis HYT	-009

Description of Verification Activity (Verification Scope): HYTHIRM personnel shall show by analysis of the Imaging Assets IR Imaging system is less than 18-inches per pixel using the Rayleigh Criteria.
Success Criteria: The verification shall be successful when the analysis is confirmed and the Spatial Resolution is determined to be 18-inches per pixel or less.
Result Summary (Compliance Statement): 1) **CAST GLANCE**: I verify by Analysis of the calibration data and mathematical calculations that the Spatial Resolution is less than 18-inches per pixel. 2) **MARS**: (Mobile Aerospace Reconnaissance System):

Closure Artifact/Document(s)::	**Req. R.O.:**	**NFR:**
1) APL_HYTHIRM_Radiance_Modeling_v1.5_v1_0.pdf **2)** STS-125 ViDi MARS & CG Imagery Asset Placement 4/28/2009.ppt	Richard Harris	None

Applicable Documents:	

Appendix B: Verification Matrix Example

Figure B-1

Verif No.	REQ ID	REQ TITLE	REQ Text	VM	REQ OWNER	Verification Scope	Verification Success Criteria	Verification Rational	Scheduled Activity	Verification Doc	SYS Req Trace	IRD/ ICD Trace
VR-CML-0091	CML-009	Joint Stiffness	• The joint stiffness between the CM/LAS and USS shall be greater than 20% of the adjacent sectional bending stiffness as set forth in section 4.1.3 Joint Stiffness of the document; Ares I-X Crew Module and Launch Abort System and Upper Stage Segment Interface Requirement Document - AI1-IRD-C2U	Analysis	Harris	CM/LAS personnel shall show by analysis found in AI1-CML-SAR-CM that the joint stiffness between the CM/LAS and USS is greater than 20% of the adjacent sectional bending stiffness.	:The verification shall be successful when the joint stiffness between the CM/LAS and USS is shown by analysis to be greater than 20% of the adjacent sectional bending stiffness and the CM/LAS results compare well with the USS results.	Simulation using independent and validated analysis tools and techniques (by both CM/LAS and USS IPTs) is an accepted method to verify requirements for such properties that can only be accurately tested at an assembly level. Modal test data for Stack 5 at KSC will be available from SE&I to substantiate the analysis results	UID - 1591 Final Structural Analysis Doc Complet	AI1-CML-SAR-CM	FTV-002, 004, 006, 009, 124	CMLAS-USS.003
VR-CML-012	CML-012	Data Collection	• The CM/LAS shall provide location and orientation of sensors as defined in the document AI1-SYS-DFI, DFI/OFI Measurement List	Inspection	Miller	CM/LAS personnel shall show by reviewing the inspection reports of all DFI locations, orientations, alignments, and correct PSM ID# labeling of all CM/LAS sensors that they are in compliance with the document AI1-SYS-DFI, DFI/OFI Measurement List and approved drawings	The verification shall be successful when CM/LAS personnel determine sensor location, orientation, and alignment coincide with those defined in the inspection reports, AI1-SYS-DFI and DFI/OFI Measurement list	: Verification of the proper location, alignment, and correct PSM ID# labeling of all CM/LAS sensors is critical. Verification of the approved flight drawings and hardware will be performed by inspection of these items at the assembly level.	UID-1521 - Rotate LAS to Vertical Position; Install on to CM	AI1-CML-IP-001; As run procedure	FTV-028	
VR-CML-019	CML-019	Element Weight	• The CM/LAS shall meet its unballasted mass allocation as stated in the Ares I-X Mass Allocation Baseline - AI1-SYS-MAB	Test	Young	:CM/LAS personnel shall show by using a calibrated scale to weigh the CM and LAS assemblies that the CM/LAS meets the unballasted mass allocated in the AI1-SYS-MAB.	The verification shall be successful when the actual mass is demonstrated to meet the requirement.	The mass requirement was generated by analysis, and the verification of the mass will be determined by lifting the CM and LAS. CM/LAS is weighing all the individual pieces/parts and some of the sub-assemblies. These data are used to verify the ProE model.	UID-1521 - Rotate LAS to Vertical Position; Install on to CM	AI1-CML-TR-1009 ProE Model # 1261000-1.asm	FTV-002, 004, 006, 008, 011, 012, 044,163	
VR-CML-052	CML-052	Individual Sub-Element Hoisting	• The CM/LAS Simulator sub-elements shall have lifting points for vertical and horizontal handling.	Demo	Lewis	CM/LAS personnel shall demonstrate, by lifting and handling the CM and LAS, that the sub-elements have lifting points for vertical and horizontal handling.	The verification shall be successful when the demonstration verifies the provision for the lifting points per the AI1-CML-AIT and conforms to the drawings.	Demonstration is the most effective method to show compliance with the specification.	UID-1521 - Rotate LAS to Vertical Position; Install on to CM	AI1-CML-SAR-CM AI1-CML-SAR-LAS AI1-CML-SAR-GSE	FTV-101	
VR-CML-065	CML-065	Workmanship (Electronics)	• The CM/LAS shall comply with workmanship standards per NASA-STD-8739.1-8739.5, NASA series of Workmanship Standards, and ANSI/ESD s20.20, Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices) for non-heritage hardware.	Inspection, Test	Jones	Quality Assurance with CM/LAS personnel shall show by inspection of the workmanship that the CM/LAS complies with workmanship standards per NASA-STD-8739.1-8739.5, NASA series of Workmanship Standards, and ANSI/ESD s20.20.** This inspection shall address QA inspection of cable installation, verification of termination, verification of workmanship related to bonding, grounding, and certification of compliance with s20.20 ESD processes. CM/LAS personnel shall perform liveness and continuity tests on all sensors. **CM/LAS is using NASA-STD-8739.7 in lieu of ANSI/ESD s20.20. Jose Otriz has concurred that 8739.7 meets the intent of s20.20, and no waiver is required.	The verification shall be successful when inspection of the approved drawings and hardware demonstrates compliance with the specification and the ICD.	Inspection and test demonstrate compliance with the specification.	@KSC after Umbilical Installed	AI1-CML-DFI-TP-1015		CMLAS-USS.002