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Space systems — Verification programme and management process

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Contents

Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This verification programme document provides top-tier and overarching requirements in space programmes. Implementation will ensure thoroughly verified space systems in a timely and cost-effective manner for verification distributed among all participating organizations (see AIAA S-117).

Many space programmes are very complex systems consisting of numerous elements (such as spacecraft, launch and ground segments, systems, subsystems, units, interfaces). It is common for these elements to be distributed across many international/domestic contractors, subcontractors, and suppliers with little room for failure/mistakes in any part of a space system. This is what is meant as a distributed program in the context of this document. A critical function of any distributed verification programme is to ensure that a thorough and solid specification is established for each level of a system being developed. This is accomplished if the system developer for each level contractually takes responsibility/ownership of developing their specifications in coordination with their systems engineering organization. This approach ensures that requirements establishment and associated verification activities are well integrated. Additionally, cost constraints often require avoidance of additional verification due to late changes. Lack of detailed descriptions in specifications can cause costly late changes and/or post-launch failures. Mission success does not allow unrecoverable post-launch failures; as such, verification of space systems requires technical communication of verification means, data and data aggregation among all involved (system contractors, subcontractors and vendors).

This document ensures that requirements associated with space system missions, concept of operation (mission operation concept), contractual agreed normative references as well as each contractor's command media are thoroughly verified with the use of a distributed verification programme. It defines a standardized set of verification management processes for each element of a space system from the earliest to the latest phase and from the lowest to the highest level of their developments in order to acquire/deliver thoroughly verified systems.

The need for a distributed verification programme was identified based on the evaluation of over 130 space systems failures associated with international, commercial, and government space programmes (see INCOSE Journal).

Every element of a space system can be verified and tracked by each work breakdown structure based working group (WBS-WG; see ISO 21349) utilizing standardized verification management (VM) processes as follows:

a) VM process 1: requirements flow-down and establishment of specification;

b) VM process 2: verification cross-reference matrix (VCRM);

c) VM process 3: integration and test (I&T);

d) VM process 4: use of a specification verification ledger (SVL);

e) VM process 5: acceptance/delivery reviews

f) VM process 6: verification-related risk and issue/watch list management

This document also helps each space programme to integrate any heritage/commercial systems to new programmes by examining whether the applicability of these systems has been thoroughly verified. Appropriate modifications of any heritage/commercial systems for new/modified systems are systematically identified and verification accomplished by applying these uniform six verification management processes.

Space systems — Verification programme and management process

1 Scope

This document establishes a set of requirements for planning and executing verification programmes for commercial/non-commercial manned and unmanned space systems.

This document defines a distributed verification programme for each contractor that engages in the development of any element of a space system, starting from the lowest level (i.e. unit/piece part level) and the earliest phase (i.e. requirement phase) to the acceptance and the delivery review of a system's development as well as the launch site activities.

This document primarily addresses verification associated with space, launch, and ground segment acquisitions. Space support segments including range safety, ground support equipment, and launch operation facilities, which are not otherwise addressed in this document, can also benefit from the described verification programme and management processes.

2 Normative references

There are no normative references in this document.

3 Terms and definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1.1
heritage system
system/item with from the original supplier that has maintained the great majority of the original service, design, performance and manufacturing and has already flown in space

3.1.2
late change
change to the space, launch, ground segments, or their interfaces, procedures or processes, which compromise or potentially invalidate previously executed verification approved at each system level preliminary design review (PDR) and/or critical design review (CDR)

3.1.3
mission critical failure
condition that meets one or more of the following criteria:

a) failure leading to inability to meet/achieve mission objective (e.g. payload or spacecraft bus is no longer capable of supporting the mission objectives);

b) inability to meet minimum performance specifications for primary mission;

c) degrading condition whose trend indicates a loss of mission before mean mission duration or design life;

d) repetitive transient condition(*s*) that, uncorrected, would lead to an unacceptable loss of mission performance, data or services (e.g. satellite with processor susceptibility to single event upsets in orbit with mean time to upset much less than mean time to recovery from upset*)*

3.1.4
operational test and evaluation
test and evaluation that represents the mission in terms of phase, transitions, environments, personnel and events in an end-to-end system configuration (i.e. combination of hardware/software and data when functioning as an integrated system), accepting mission inputs, executing mission functions and producing mission outputs according to the typical operational rhythm, timelines, and sequences resulting in end-user goals (products, services, and timeliness)

3.1.5
specification verification ledger
digital database for verification information of the space system specification

3.1.6
subject matter expert
person with substantial knowledge of, and experience with, the topic at hand, including terms, technology and methods

3.1.7
verification cross-reference matrix
matrix, usually electronic database of some type, maintained to correlate all verification needs within an assigned portion of a program, up to and including a complete program matrix

Note 1 to entry: The matrix does not replace other verification plans or requirements, but is a summary of them.

3.1.8
verification method
method including test, analysis, demonstration, or inspection

Note 1 to entry: See ISO 9000.

3.1.9
verification record
record of requirement conformity or compliance based on the assigned *verification method(s)* (3.1.8)

3.2 Abbreviated terms

AIAA   American Institute of Aeronautics and Astronautics

CDR   critical design review

CDRL   contract data requirements list

COTS   commercial, off-the-shelf

CM   configuration management

DT&E   development test and evaluation

EM   engineering module

EMC   electro-magnetic compatibility

EMI   electro-magnetic interference

FCA	functional configuration audit
I&T	integration and test
IF	interface
LRR	launch readiness review
MRR	manufacturing readiness review
NRB	non-conformance review board
OT&E	operational test and evaluation
PCA	physical configuration audit
PDR	preliminary design review
PMPCB	parts, materials, and processes control board
QA	quality assurance
SC	spacecraft
SVL	specification verification ledger
SDR	system design review
SRR	system requirements review
TPRD	test parameters requirements document
TRR	test readiness review
VCRM	verification cross-reference matrix
VM	verification management
WC	worst-case
WBS	work breakdown structure
WBS-WG	WBS-based working group

4 Requirements for space system verification management processes

4.1 General

Each space system and lower-level systems developer shall implement the verification processes detailed in 4.2 through 4.7. To better support a specific programme or project, the processes defined in this document may be tailored to match the actual requirements or needs of the programme.

4.2 VM process 1: requirement flow-down and establishment of specification

4.2.1 General

The developers of each level of the system, in coordination with their systems engineering organizations, develop a system-level specification with both performance and verification requirements for their system. They capture the requirements that are flowed down from the top-level space system to WBS elements, external interface specifications, and concept of operations (CONOPS) of their system.

They capture all the derived and specific requirements including those of normative references that are necessary to design and develop their system. They also capture/modify all the heritage system requirements that are compatible with the top-level requirements determined by the requirements flow-up process.

Each specification shall include sections relating to:

a) the function, performance, constraints, and normative references for the product;

b) a detailed statement of how verification will be made for each separate requirement.

This includes verification methods and associated verification approaches.

NOTE 1   Specifications are defined in ISO 9000.

NOTE 2   See ISO/IEC/IEEE 15288 for flow-down and flow-up in the systems engineering "V".

NOTE 3   See ISO 16404 for general requirement management process including those associated with support to systems engineering activities such as those associated with verification and configuration management.

NOTE 4   See ISO 14711 for CONOPS-related documents.

4.2.2   Specification requirements and review

4.2.2.1   General

Specifications shall be delivered for review at each corresponding system level's review from the top system level to the lowest unit level specification [e.g. system requirements review (SRR), system design review (SDR), preliminary design review (PDR), critical design review (CDR)].

NOTE   See ISO 14300-1 for project phasing and reviews.

4.2.2.2   Top-level requirements flowed-down/up documented traceability

Each of the top space system level requirements flowed down/up shall have documented traceability in the verification record to the lowest level of the work breakdown structure (WBS).

4.2.2.3   Verification of non-derived requirements specific to each system

Verification requirements shall capture all the non-derived requirements that are specific to each of the elements being developed.

NOTE   Non-derived requirements are requirements which do not have a parent requirement in the next higher level, such as those that are needed to satisfy heritage systems.

4.2.2.4   Verification of compatibility of heritage systems requirements

When heritage systems are used, verification requirements shall ensure that each of the requirements in the heritage system specification is compatible with and supports the higher- and lower-level system requirements. If not, they need to modify any noncompliant requirements accordingly (see ISO 16290).

4.2.2.5   Requirement verifiability

Each of the requirements shall be verifiable by analysis, test, inspection or demonstration or a combination of them (see ISO 9000).

4.2.2.6   Normative references flow-down

Each of the normative references listed at any system level shall also be flowed down from the appropriate level specification to any of the applicable lower level specifications.

4.2.2.7   Configuration management (CM)

The system level requirements shall be under CM control upon completion of SRR.

Lower level requirements shall be under CM control upon completion of PDR.

The requirements flow-down and flow-up efforts should be accomplished by utilizing data management software in order to effectively manage any part of system level requirements flowed down/up to/from any other system levels.

Validation of the developed specification may be considered as completed after independent subject matter experts from external organizations have reviewed the specification and their comments are incorporated into the specification.

4.2.3   Data supporting verification method and approach

Each specification verification implementation shall include data and processed data (information) which establishes the satisfaction of the requirement as well as the associated upper level requirements. This includes a synopsis and rationale for the actual implementation approach for each requirement.

4.3   VM process 2: verification cross-reference matrix (VCRM)

4.3.1   Cross-reference of specification requirements and verification method

The VCRM shall cross-reference specification requirements, their verification methods, verification level and milestones.

4.3.2   VCRM for the space system and lower level systems

Verification plans for the space system and all the lower-level systems, including external and internal IFs, are delivered at major reviews (See Clause 5). These plans shall include the VCRM for each level.

4.3.3   Verification by analysis

a)   Design and analysis documents shall be developed for each level of the system being developed (system, subsystem, unit, etc.) and ensure that all the "verify by analysis" requirements in the corresponding specification are documented and satisfied.

   NOTE   A list of analyses along with the approaches and methods, and a set of design reference cases that defines reasonable worst-case conditions and other conditions for each analysis used for "verification by analysis" are identified and documented.

b)   Design analyses sometimes require the support from test results. In these cases, a list of "verify by test" requirements that require development test to support the design analysis shall also be included in the design and analysis list.

c)   When a space safety-critical design or function is only satisfied by "verify by analysis" requirements in the corresponding specification and determined as one of the pass/failure criteria for the associated PDR and CDR, then a risk assessment shall be conducted and included of the contribution to residual risk on people, the space environment, and the mission, because of the space safety-critical design or function in question.

4.3.4   Verification by test

"Verification by test" is accomplished using such tests as development test, prototype test, life test, pre-flight brass board/engineering modules tests, actual flight system integration and acceptance/qualification test, and operational test depending on the nature of the requirements being verified.

A list of tests, approaches (such as with the use of flight units, engineering units, breadboard, coupons, software/hardware-in-the-loop test), and test conditions for "verification by test" shall be included in the VCRM and reviewed at the corresponding system's PDR, CDR and TRR.

a) "Verification by test" based on development hardware/software or breadboard testing may be required to substantiate related analyses or vice versa. These development test lists, approaches, conditions and results are normally reviewed along with the associated analyses.

b) "Verification by test" requirements under the acceptance/qualification tests, shall be listed in a test parameters requirement document (TPRD) and incorporated into the corresponding test plan that is developed based on VM process 3, explained in 4.4.

4.3.5 Verification by inspection and demonstration

A list of and detailed approaches for "verification by inspection" and "verify by demonstration" requirements shall be developed for each of the applicable space system and lower level system specifications.

4.4 VM process 3: integration and test (I&T) process

4.4.1 General

In preparation for the I&T life cycle phase, system I&T plans shall be developed for the space system and each of the lower-level systems to ensure that the "as built" system is rigorously tested for acceptance tests, qualification tests or tests related to the mitigation of potential mission critical failures.

NOTE   See ISO 17566, ISO 17401, ISO 14303, and ISO 15864 which define test documentation, spacecraft interface requirements document, launch-vehicle-to-spacecraft interfaces, and general test methods respectively.

4.4.2 Review of I&T plans for the space system and lower level systems

I&T plans for each of the spacecraft, launch vehicle, ground system and each of the internal and external interfaces including those developed by subcontractors and vendors shall be delivered for review and approval at each corresponding PDR, CDR, and TRR.

4.4.3 Space system and lower-level I&T sequence and test environments

A test sequence, environment types/levels, duration, and test monitoring approaches/methods, with documented rationales for selecting the acceptance, proto-qualification, or qualification test programme shall be established and documented for each of the space system and lower-level systems including those developed by subcontractors and vendors.

4.4.4 Operational tests for space system

An operational test plan shall be developed and executed prior to launch/operations to verify critical mission characteristics including the planned mission sequences, events, transitions, timelines, processes, configurations, command operations, data/telemetry downlinks and processing, and deployment functions.

NOTE   An operational test is based on effectiveness (can the system perform the mission) and suitability (can the system perform the mission in a manner that is affordable and sustainable) without artificial constraints to the fullest extent possible.

4.4.5 Test readiness review (TRR) and entry/exit criteria

TRR shall be conducted prior to each of the space system and lower level systems I&T based on the entry and exit criteria that are reviewed and approved at PDR, CDR, and/or pre-TRR.

The entry/exit criteria to hold TRR for each space system and lower level systems shall be planned and updated throughout its PDR, CDR, and pre-TRR to ensure all the "verify by test" requirements are satisfied.

4.4.6 Test discrepancy resolution and retest

Test discrepancies at any level of flight hardware/software system integration and test shall be reported, investigated and resolved.

As an example, a non-conformance review board (NRB) may coordinate the failure investigation and resolution such as with the parts, materials, and processes control board (PMPCB); quality assurance (QA), if required along with the appropriate WBS lead; and the programme management for their approval. ISO 23461 contains further information for this example.

4.4.7 Test summary and "as tested" data review

Each test level shall include a list of discrepancies, their disposition, and retest history which have been well documented, reviewed and approved.

To continue the example above, by QA, the NRB, the PMPCB, the appropriate WBS lead, and space system verification programme management at the conclusion of the test and before the item is transferred to the next level of integration and test phase.

4.4.8 I&T plans for launch site operations for each element

The launch site I&T plan and procedures shall be developed for each of the flight space vehicle, launch vehicle, ground elements, and ground test equipment to ensure that each element is functioning and ready for launch throughout the pre-launch count and the launch count procedures.

4.4.9 I&T plans for launch site operations for integrated system

The launch site I&T plan and detailed test procedures shall be developed for the integration and testing of all combined spacecraft, launch, ground, ground test equipment, and range safety systems.

4.5 VM process 4: specification verification ledger (SVL) process

4.5.1 General

The SVL process shall be implemented for the space system from the unit through system levels, including associated IFs and normative references, using a form that summarizes information for verification traceability. Referencing the VCRM, the SVL shall contain data and processed data (information) which confirms the satisfaction of the requirement as well as the associated upper level requirements.

NOTE   All of the SVL columns help to expedite the acceptance, latent troubleshooting, or independent readiness review process, since the data can be easily tracked down and obtained when required. Also, it helps to ensure the applicability of the system to other programmes such as an upgraded or a brand new programme.

4.5.2 SVL content

The SVL for each of space system and lower level systems shall include, but is not limited to, a requirement description/ID number in the specification, a synopsis of the verification method/approach, the organization responsible for verification, and the verification product ID such as the analysis or test report. An example of a set of minimally required contents for SVL is provided in Annex D. The order of information (columns) is not prescriptive, as long as the hierarchy of information is maintained.

4.5.3 SVL documentation

The content of SVLs for the space system and lower-level items shall be stored electronically by the programme to assure that the proof of full requirements' verification is complete for all the elements and also to ensure configuration management of the contents.

4.5.4 Subcontractor/vendor SVL plans for the space system element including subsystems, and units

SVL plans and results for each element including those developed by subcontractors/vendors shall be delivered for review and approval at SRR, SDR, PDR, CDR, and acceptance/delivery review.

4.6 VM process 5: acceptance and delivery review process

4.6.1 General

A set of entry and exit criteria and a standardized set of review data packages shall be developed for each of the space system and lower level systems' acceptance/delivery review activities.

NOTE 1   When each element completed VM process 5 is ready to be delivered to the next step of integration activities (acceptance activities) or to the launch site (delivery review activities), these processes ensure these elements have been verified (and validated if the customer is involved with these efforts).

NOTE 2   Entry/exit criteria for the acceptance and delivery reviews are not necessarily the same because the completion of a space system acceptance/delivery review sometimes requires the results of higher-level I&T results.

4.6.2 Space system and lower level systems acceptance and delivery review data package

A data package for each of the space system and lower level systems' acceptance and delivery review shall include the approval statement as follows:

a)   SVL;

b)   as-tested test report;

c)   test summary, including environment test history, test anomaly, and disposition summary;

d)   NRB/PMPCB summary, including approved/waived part lists;

e)   deviations/waivers summary;

f)   disposition status of action items generated at associated system's PDR, CDR, TRR, and test data review;

g)   disposition status of all the issue/concern items associated with each of the space system and lower level systems;

h)   summary of functional configuration audit (FCA) and physical configuration audit (PCA).

4.6.3 Acceptance and delivery review plans for the systems developed by subcontractors/vendors

Acceptance and delivery review plans and the results for space system and lower level systems including those developed by subcontractors/vendors shall be delivered for review and approval at SRR, SDR, PDR, CDR, and acceptance/delivery review milestones.

4.6.4 FCA and PCA summary as a part of acceptance package

An FCA and PCA shall be conducted; and their results are provided as a part of acceptance activities.

4.6.5 Acceptance/delivery review entry/exit criteria

The entry/exit criteria to conduct successful acceptance/delivery reviews for each space system and lower level systems shall be planned and updated to ensure throughout its PDR, CDR, and pre-acceptance/delivery reviews to shipping to ensure the completion of documented and traceable proof of verification as explained in 4.6.2 through 4.6.4.

NOTE   Inclusion or non-inclusion of shipping is determined by program.

4.7 VM process 6: verification-related risk and issue/watch list management process

4.7.1 General

Verification-related issue-and-concern items shall be identified, resolved, and documented for each verification activity throughout the requirements flow-down, design, manufacturing, test, and acceptance/delivery review and launch site I&T phases of the programme.

ISO 17666 should be used to determine which concerns/problems should remain on issue/watch lists and which concerns should be reported to the overall programme level risk items.

4.7.2 Status tracking of verification-related issue and concern items

Each of the verification-related issue and concern items shall be documented, including the problem description, responsible organization/engineers, problem identification and required resolution date, its resolution status and tracked by the corresponding WBS-WG.

4.7.3 Reporting of verification-related issues to the programme risk management board

All verification-related concerns that can impact the cost, performance, and/or schedule of the programme shall promptly be reported to the programme-level risk management board so that the board can determine whether the concern needs to be elevated to a programme risk

4.7.4 Verification-related risk and issue/watch list management plans for the space system and lower level systems including those developed by subcontractors/vendors

A verification-related issue/watch list management plan and the status for each of the space system and the lower level systems including those developed by subcontractors/vendors shall be delivered for review at SRR, SDR, PDR, CDR, and acceptance/delivery review.

5 Requirements for space systems verification programme management

5.1 General

Each space programme shall establish a space system verification programme in order to manage verification processes by implementing a standard set of verification management activities at each level and phase of system development as specified in Clause 4.

NOTE   Verification processes apply to planning and executing activities starting at the requirements definition phase and extending through the launch, post-launch phase.

5.2 Verification programme managed by each WBS element

The verification programme shall utilize subject matter experts under each WBS element to plan and execute verification of their space system element(s) by following the requirements specified in Clause 4.

NOTE 1   See ISO 21349.

NOTE 2   See Annex A.

This group may be designated by joining work breakdown structure (WBS) and verification working group.

5.3   Integration of distributed verification programme

The overall system level WBS-WG shall manage planning and execution such that the end-to-end system verification approaches and results satisfy each requirement in the overall system specification including mission requirements, mission operation concept, and internal/external Interface requirements.

5.4   Verification programme review

At space programme management reviews [e.g. SDR, PDR, CDR, launch readiness review (LRR)], WBS-WG verification activities shall be reviewed for planning, execution and results such that their end-to-end activities are consistent with the overall verification programme.

5.5   Verification programme flow-down to subcontractors and vendors

The requirement for establishing the verification programme and verification management process described in 4.2 shall be flowed down from the top-tier contractor to all the subcontractors and vendors who supply hardware, software, or both used by the higher tier systems.

NOTE   It is imperative for the top-tier contractor to have contractual agreements with their subcontractors and vendors to satisfy the requirements specified in Clause 4.

5.6   Verification activities coordinated with other review boards

Each of the WBS based verification activities shall be conducted in coordination with programmatic and technical review boards (e.g. requirement change board, configuration management board).

In a multiple tier programme, all top-tier requirements shall be traceable at programmatic and technical review boards.

5.7   Validation of the verification process

5.7.1   General

The verification process shall include validation for intended use. Validation primarily coincides with major programme reviews (such as SDR, PDR, and CDR).

5.7.2   DT&E and OT&E support

If the DT&E and/or OT&E processes are contractually required, the I&T plan shall include plans for accomplishing the required DT&E and/or OT&E.

NOTE   Most of the mass-production type space programmes require plans for accomplishing the flight system production phase DT&E.

5.7.3   Independent readiness review (IRR) and launch readiness review (LRR) support

Proof of verification such as the SVL, verification by analysis, as-tested data, and specifically any test discrepancies shall be provided upon request to associated IRR and LRR Teams when they exist for a programme.

NOTE   See ISO 18676.

5.8 Verification plan

5.8.1 General

A verification plan that implements the verification management approach and processes shall be developed for each of the space elements (space vehicle, launch vehicle and ground, spacecraft bus or payload, subsystem, and unit, etc. such as utilizing ISO 17566).

NOTE   A sample contract data requirements list (CDRL) is provided in Annex B including some specific requirements such as those relating to delivery/review. It also provides a set of detailed plans for the verification management processes explained in 4.2.

5.8.2 Review of verification plans

The results of the plans and the execution progress status of each space system verification plan, including those developed by subcontractors and vendors shall be captured in the verification record and reviewed at each of their review milestones (e.g. SRR, SDR, and PDR).

NOTE   Annex C provides documents deliverable/review requirements associated with each verification management process that can be included in the data item description referenced in a CDRL calling for the plan.

6 Use of verification management for late changes and heritage/commercial systems

6.1 General

"Late changes" or "heritage systems" applications can occur at any level of a space system being developed, including but not limited to those associated with piece-part, materials, unit, subsystem, and interfaces.

"System is built right" verification shall be achieved for "late changes" and "heritage systems" applications as long as they also utilize the verification programme and associated processes explained in Clause 4.

6.2 Late change verification management

6.2.1 Verification of late changes utilizing VM processes 1 through 6

6.2.1.1 General

Verification of "late changes" shall utilize a set of VM processes delineated in 4.2 through 4.7 in order to ensure that any changes are exposed to the rigorous verification processes explained in this document.

6.2.1.2 Verification of late changes for direct and collateral impacts

Late changes shall be assessed for both direct and collateral impacts to verify the compliance of the SC to the programme requirements and mission goals as follows:

a)   encompass re-execution, or addition, of analysis, inspection, test and demonstration, as necessary;

b)   assure applicability and validity of the verification criteria and methodology, as warranted by the change;

c)   recommend a set of checklists for planning and executing late changes, as explained in Annex E.

6.2.2   Late change categories

Late changes may typically be introduced, but not limited to, the space, launch, or ground segment:

a)   late changes caused by requirements issues:

    1)   improper, incomplete, or late allocation of requirements;

    2)   system element-to-element (e.g. space-to-ground, spacecraft-to-launch vehicle) interface requirements issues;

    3)   technical design changes due to mission operations concept modifications such as in the redundancy management, command sequences, and other general telemetry and command managements requirements;

b)   late changes caused by design synthesis issues:

    1)   both flight and non-flight design issues or changes, including hardware–software interface compatibility;

    2)   late changes due to commercial off-the-shelf (COTS) software or hardware changes;

c)   late changes caused by pre-system integration manufacturing issues:

    flight and non-flight hardware non-compliance or non-conformance occurring during fabrication, manufacturing, and assembly, including repair, removal, and replacement issues;

d)   late changes caused by system integration and test issues:

    1)   a discrepancy or anomaly associated with a test or a process;

    2)   hardware assembly and integration issues (including flight or non-flight hardware build or process issues);

    3)   a "cause unknown" scenario;

e)   late changes caused by alerts;

    1)   internal: contractor- or supplier-initiated alert, notice, or communication;

    2)   external: customer- or industry-initiated directive, notice, or communication.

6.3   Heritage/commercial systems verification management

6.3.1   General

Verification of heritage/commercial hardware and software shall utilize a set of VM processes delineated in 4.1.1 through 4.1.6 in order to ensure that heritage/commercial hardware/software, including COTS has been exposed to the verification processes explained in this document.

6.3.2   Heritage/commercial hardware and software applications

Heritage/commercial hardware and software applications shall be assessed for both direct and collateral impacts to verify and validate the compliance of the SC to the programme requirements and mission goals by including following activities:

a)   encompass re-execution, or addition, of analysis, inspection, test, and demonstration as necessary;

b)   assure applicability and validity of the verification criteria and methodology as warranted by the heritage applications;

c) follow the minimum set of checklists for planning and executing late changes as explained in Annex E.

6.3.3 Verification of heritage hardware and software

Verification of heritage hardware and software activities shall examine the application with regard to the following categories:

a) heritage/commercial systems requirements issues;

   1) improper, incomplete, or late allocation of requirements;

   2) system element-to-element (e.g. space-to-ground, spacecraft-to-launch vehicle) interface requirements issues;

   3) technical design changes due to mission operations concept modifications such as in the redundancy management, command sequences, and other general telemetry and command managements requirements;

b) heritage/commercial systems design synthesis issues:

   1) both flight and non-flight design issues, including hardware-software interface compatibility;

   2) COTS software or hardware compatibility;

c) heritage/commercial systems pre-system integration manufacturing issues;

d) hardware manufacturing and process issues, including flight or non-flight hardware build or process issues;

e) heritage/commercial systems system integration and test issues:

   1) test plan, procedures, or a processes-related issues;

   2) test equipment issues.

f) heritage/commercial piece parts and materials issues;

   1) heritage/commercial piece parts and materials issues;

   2) replacement of heritage/commercial piece parts or materials due to alerts.

Annex A
(informative)

Exemplar space system and an example of WBS-based verification management structure
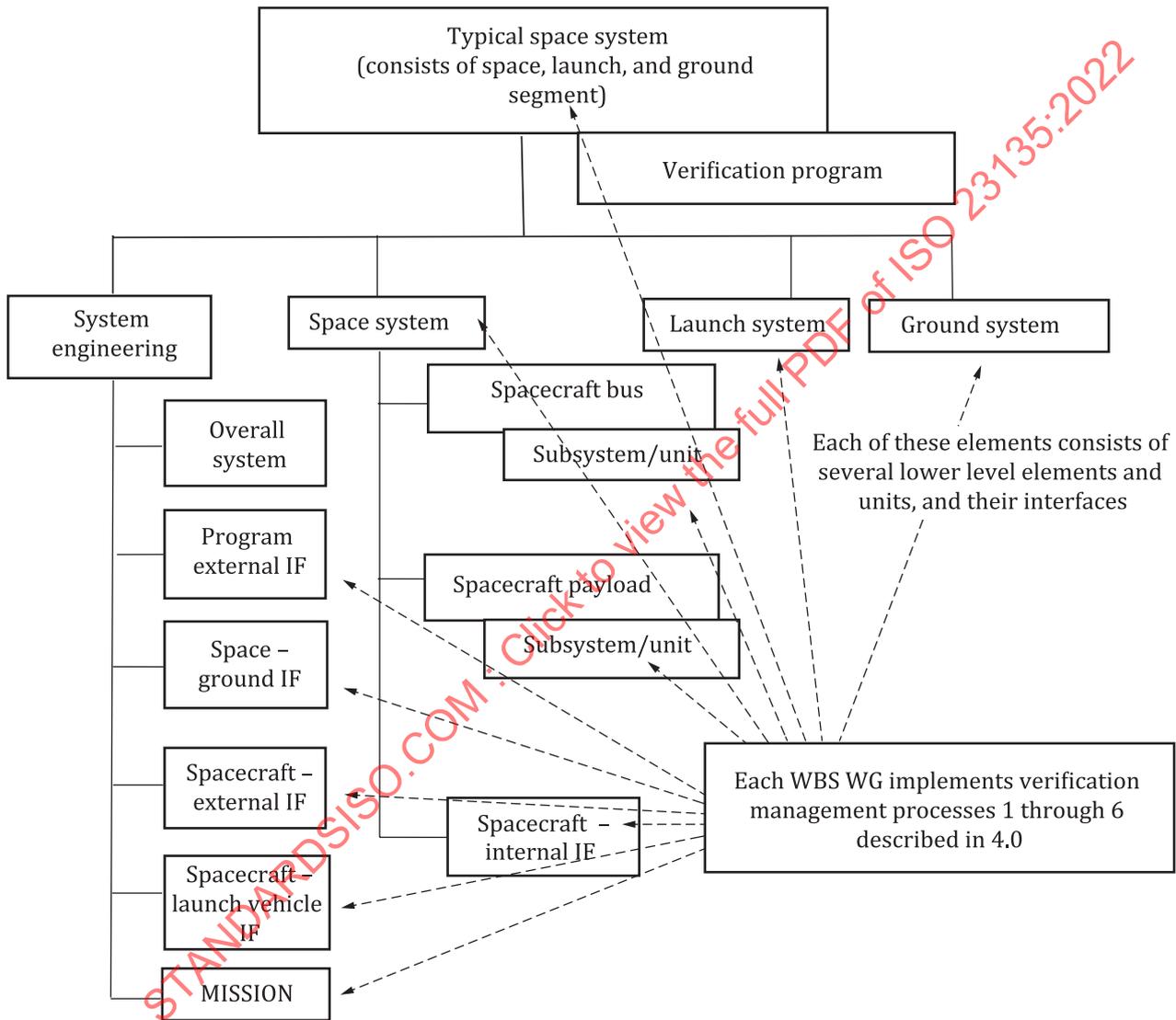
Figure A.1 — Example of distributed verification management structure

User segment and other parts of launch segments such as range safety, ground support equipment, and launch operation facilities are not included due to space limitation in Figure A.1 although commonly associated systems may utilize WBS structure as a part of their acquisition activities.

Annex B
(informative)

Review of verification plans for space system and lower system level, including those developed by subcontractors/vendors

B.1 Outline requirement

The outline is generally common to each of the plans for space system, segment, higher-level programme external IF, module, and key subcontractors and vendors providing systems. A single verification plan is permitted for all the space system, segment external IF, and module, if one contractor develops all. If not, a separate plan should be produced for each contractor, subcontractor, and vendor.

a) Describe verification programme management approaches, and organization based on WBS-WG that involves government and contractor experts' participation in each of their applicable WBS(s):

   1) explain who is responsible for managing each WBS verification programme and the relationship with the programme manager;

   2) explain the frequency of the WBS-WG meetings;

   3) explain the verification programme flow-down to each subcontractor/vendor and how/what/when the progress status is monitored;

   4) inclusion of verification management board is highly encouraged.

b) Describe, in detail, the implementation plan for each required verification management process:

   1) VM process 1: requirement flow-down and establishment of specification;

   2) VM process 2: verification cross-reference matrix;

   3) VM process 3: integration and test (I&T);

   4) VM process 4: specification verification ledger (SVL);

   5) VM process 5: acceptance/delivery reviews;

   6) VM process 6: verification-related risk and issue/watch list management

B.2 Document delivery requirement

Each plan is delivered at the time of proposal, SRR, SDR, PDR, and CDR.

B.3   Review of requirement flow-down and establishment of specification

B.3.1   Outline for requirement flow-down and VCRM plan

The outline is generally common to each of the plans for space system, segment, higher-level programme external IF, module, and key subcontractor and vendor providing systems as follows:

a)   requirement flow-down planning:

1)   categorize, by function, the top-level space system requirements into such functions as mission performance, operational environments, reliability, safety, housekeeping, fault management, etc.;

2)   describe rationale for each requirement flow-down from space system to each lower-level system;

3)   describe approaches for ensuring each requirement is well defined and "objectively" verifiable;

4)   explain approaches/methods to document the traceability of each requirement flow-down;

b)   requirement flow-up planning:

1)   if a heritage system is used as a part of a space system being developed, assess each requirement of the heritage system specification to ensure that all of the requirements in the specification are compatible with upper level system requirements by conducting requirement flow-up process and modify the heritage system, if required;

2)   describe rationale for the use of each requirement "as is" and "need for modification";

c)   VCRM:

explain the rationale for selecting the particular assigned verification method(s) for each requirement.

B.3.2   Delivery requirement

Each plan is delivered at the time of SRR, SDR, PDR, and CDR.

B.4   Analysis, test, inspection, and demonstration plan for space system and lower level systems (based on VCRM process)

B.4.1   Outline for verification by analysis, test, inspection, and demonstration plan

The outline is common to each of the plans for space system, segment, higher-level programme external IF, subsystem, and unit including those developed by subcontractors and vendors providing systems as follows:

a)   list all the requirements (with requirement ID and brief description of the requirement) by each verification category, verify by analysis, test, inspection, and demonstration for each specification;

b)   explain scope and approaches to verify each category of the verification methods such that they will ensure each requirement listed for each category will be verified;

c)   explain the design reference case associated with each "verify by analysis" requirement;

d)   explain test approaches/methods for each "verify by test" requirement;

e)   explain the rationale for "verify by similarity" for each applicable requirement such that none of the constraints relating to its application to the system/programme, software/hardware design, environments, safety, and life, etc. has changed from the earlier system.

B.4.2 Delivery requirement

Each plan is delivered at the time of proposal, SRR, and SDR and the preliminary and final results of the design and Analyses list are presented at the corresponding PDR and CDR, respectively.

NOTE   These planning and the results become a critical part of PDR and CDR success criteria.

B.5   I&T plans for the space system and lower level systems

The outline is generally common to each of the plans for space system; and lower-level systems including those built by subcontractors and vendors providing systems as follows:

a)   explain the objectives and the scope of the test in terms of factory test, acceptance, proto-flight, qualification level test as well as launch site I&T, and post-launch on-orbit test;

b)   explain using a test matrix to indicate that all the "verify by test" in the associated specification will be identified in the corresponding TPRD that need to be tested at different test phases (such as at different environment sequence);

c)   explain test conditions (such as the environments test sequence and durations as well as monitoring and telemetry data, and frequency/timing of the monitoring);

d)   explain approaches, methods, NRB, and PMPCB, QA, WBS lead involvement with regard to test discrepancy/anomaly resolution retest and approval to proceed with the next level test;

e)   explain approaches/methods for documentation and approval for the "as tested" sequence and results;

f)   explain test result documentation and review approval approaches/methods for test completion/ summary report for system certification, or acceptance/delivery review activity.

B.6   SVL plans for the space system segment, system, subsystem, unit, and contractor/subcontractor/vendor

B.6.1   Outline for the SVL plan

The outline is generally common to each of the plans for space system, segment, higher-level programme external IF, module, and key subcontractor and vendor providing systems as follows:

a)   explain approaches/methods for implementing/managing the SVL process such that the content of each SVL is reviewed (by each WBS-WG expert and other appropriate functions) and ensure that each requirement of a specification has proof of verification, and traceability to the responsible party and the appropriate documents/data set;

b)   explain approaches/methods for accessing the pre-approved/approved SVL data for each unit, subsystem, module, segment and system by the government, independent readiness review, and other applicable experts and members.

B.6.2   Delivery requirement

Each plan is delivered at the time of SRR, SDR, PDR, CDR, and acceptance/delivery review.

B.7 Space system and lower level systems acceptance and delivery review data package

B.7.1 Outline for acceptance/delivery review plan

The outline is generally common to each of the plans for space system, segment, higher-level programme external IF, module, and key subcontractor and vendor providing systems as follows:

a) describe approaches/methods for implementing/managing/approving the acceptance/delivery review process;

b) explain entry/exit criteria for conducting successful acceptance/delivery review for each system;

c) describe FCA and PCA plans;

d) describe a standard acceptance/delivery review data package that includes SVL results, an "as-tested" test report, test summary including environment test history, test anomaly and disposition summary, NRB/PMPCB summary (including approved/waived part lists), deviations/waivers summary, disposition status of action items generated at associated system's CDR, TRR, and test data review, and disposition status of all the issue/concern items, FCA and PCA results associated with each space system.

B.7.2 Delivery requirement

Each plan is delivered at the time of SRR, SDR, PDR, CDR, and acceptance/delivery review.

B.8 Verification issue/watch list management plan for space system, segment, higher level external IF, and module

B.8.1 Outline for verification-related issue/watch list management plan

The outline is generally common to each of the plans for space system, segment, higher-level programme external IF, module, and key subcontractor and vendor providing systems.

It explains the WBS-WG-based issue/watch list identification and resolution management approach, in which the WG experts identify and disposition verification related-risk items in a proactive and continuous manner to ensure that potential risks are identified and resolved in a timely manner to reduce the likelihood that late changes or post launch failures will occur. Issue/watch list items may include those relating to verification of requirements, design/analysis, manufacturing, test, acceptance/delivery review, and others as appropriate.

a) Verification-related issues may include those that impact cost, performance, and/or schedule; require consultation with an upper-level WBS-WG and ultimately may become programme-level risks if not resolved by the WBS-WG in a timely manner.

b) Watch list (or concern) items are those that have either been judged to be low risk and do not require a formal risk handling plan or have not been included in a formal risk management process but can be included should their probability and/or consequence of occurrence increase sufficiently to exceed the minimum threshold established for evaluating candidate risks.

c) Explain the approaches/methods and issue/watch list documentation format for capturing/tracking each item in terms of origination date, area/synopsis, responsibility/assignment, status, resolution approach, and approval authority/status.

d) Explain the approaches/methods for raising high risks and selected medium risks to the upper-level WBS-WG and to the programme-level risk management board as warranted.

B.8.2 Delivery requirement

Each plan is delivered/reviewed at the time of SRR, SDR, PDR, CDR, and acceptance/delivery review.

Annex C
(informative)

Deliverable/review documents associated with each verification management rrocess

The planning and progress associated with space systems verification programme and management process is reviewed for each of the prime contractor, subcontractors, and vendors as explained in Table C.1;

a)   VM process 1: requirement flow-down and establishment of specification;

b)   VM process 2: verification cross-reference matrix (VCRM);

c)   VM process 3: integration and environment test (I&T);

d)   VM process 4: specification verification ledger (SVL);

e)   VM process 5: acceptance/delivery review;

f)   VM process 6: verification-related risk and issue/watch list management.

Table C.1 — Space systems verification programme and plan developments and reviews requirements for prime contractor, subcontractors, and vendors

Verification programme and management process	Deliverable documents	RFP	SRR	SDR	PDR	CDR	MRR and TRR	Acceptance/delivery review
Space system verification programme and planning	Space system verification programme plan	Propose end-to-end verification programme and plan	Review end-to-end verification programme and plan	Review initial verification plans for all levels	Review preliminary verification plans for all levels	Review CDR verification plans for all levels	Review drawings and test procedures	
VM process 1	Specification	Propose top system levels specs	Review top system levels specs	Review initial specs for all levels	Review preliminary specifications for all levels	Review CDR specs for all levels		Verify no requirement discrepancy
VM process 2	VCRM plan and results	Propose end-to-end system VCRM plan	Review end-to-end system VCRM plan	Review initial VCRM plan for ea. requirement for all specifications	Review preliminary VCRM results (analysis, development, and life tests)	Review CDR VCRM results (analysis, development, and life tests)	Review post-CDR VCRM results (verify by inspection and demonstration including MRR)	
VM process 3	Accept, qual, or proto-qual I&T plan, procedure and results	Propose end-to-end I&T process	Review end-to-end system I&T plan	Review initial I&T plan for all levels	Review preliminary I&T plan for all levels	Review final complete I&T plan for all levels	Review detailed test procedures for all levels (TRR)	Verify all system levels passed I&T
VM process 4	SVL plan and results	Propose end-to-end process	Review end-to-end SVL planning	Review initial SVL plan for all levels	Review preliminary SVL documents (mostly regarding analysis)	Review CDR SVL documents (mostly analysis, demonstration)	Review post-CDR SVL documents (development tests, demonstration, inspection)	Verify SVL complete for each requirement of all specifications
VM process 5	Acceptance/delivery review plan and results	Propose end-to-end process	Review end-to-end process	Review initial plan for all levels	Review preliminary acceptance documents	Review CDR acceptance documents	Review post-CDR acceptance documents	Review all required acceptance data
VM process 6	Verification issue/watch list plan and results	Propose end-to-end system plan	Review end-to-end system plan	Review detailed plan for all levels	Review preliminary lists for each level	Review CDR lists for each level	Review post-CDR lists for each level	Verify all Issue/Watch list Items resolved

Annex D
(informative)

Contents of specification verification ledger (SVL)

Use of the SVL ensures that each requirement of a specification has proof of verification, as well as traceability to the responsible party and the appropriate documents/data set. The SVL generally consists of a traditional verification cross-reference matrix, which specifies the verification method for each requirement of a specification and also identifies who performed the verification and where, as well as which document captures the verification results.

NOTE   It is the same as individual specification dedicated verification ledger (ISDVL) in AIAA S-117.

Table D.1 defines a minimum set of contents that is included in an SVL using an exemplar space system. The ordering of columns is tailorable but re-ordering may impact ledger compatibility.

a)   The first column, "Paragraph or requirement number," identifies the requirement or paragraph numbers designated in a specification.

b)   The second column, "Requirement description," provides a synopsis of each requirement.

c)   The third column, "Verification method," indicates the assigned verification method for each requirement.

d)   The fourth column, "Verification level," identifies at what level of space system the requirement is actually verified. It should be noted that it is possible that some of the requirements (specifically some system-level space system specification requirements) are necessarily verified at this level. Some of these requirements can be directly flowed-down to lower-level specifications where the actual verification takes place. This column is particularly useful for the verification planning and acceptance of a higher-level space, launch and ground, since it identifies a particular unit(s) or subsystem where the requirement has been or is to be verified.

e)   The column, "Responsible person or department," identifies the designated parties responsible for performing the verification and will help those individuals with regard to discussions/inquiries about planning or the results.

f)   The "Documentation" column, which consists of two sub-columns ("Verification approach summary" and "Verification product"), is a summary of the verification and the data package/reports. This column is important because it forces official publication of the data.