NATO STANDARD

AEP-4754

NATO GENERIC VEHICLE ARCHITECTURE (NGVA) FOR LAND SYSTEMS

VOLUME VII: VERIFICATION AND VALIDATION

Edition A Version 1
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NORTH ATLANTIC TREATY ORGANIZATION

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NORTH ATLANTIC TREATY ORGANIZATION (NATO)

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NATO LETTER OF PROMULGATION

22 February 2018

1. The enclosed Allied Engineering Publication AEP-4754, Volume VII, Edition A, Version 1 NATO GENERIC VEHICLE ARCHITECTURE (NGVA) FOR LAND SYSTEMS VOLUME VII: VERIFICATION AND VALIDATION, which has been approved by the nations in the NATO Army Armaments Group, is promulgated herewith. The agreement of nations to use this publication is recorded in STANAG 4754.

2. AEP-4754, Volume VII, Edition A, Version 1 is effective upon receipt.

4. This publication shall be handled in accordance with C-M(2002)60.

for

Dieter Schmaglowski
Deputy Director NSO
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Major General, LTUAF
Director, NATO Standardization Office

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RESERVED FOR NATIONAL LETTER OF PROMULGATION

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RECORD OF RESERVATIONS

CHAPTER	RECORD OF RESERVATION BY NATIONS
Note: The reservations listed on this page include only those that were recorded at time of promulgation and may not be complete. Refer to the NATO Standardization Document Database for the complete list of existing reservations.	

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RECORD OF SPECIFIC RESERVATIONS

[nation]	[detail of reservation]
Note: The reservations listed on this page include only those that were recorded at time of promulgation and may not be complete. Refer to the NATO Standardization Document Database for the complete list of existing reservations.	

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CHAPTER 1 INTRODUCTION

1.1. Purpose

The aim of the NGVA Standard AEP-4754 Volumes I through VII is to enable the member nations to realize the benefits of an open architecture approach to Land vehicle platform design and integration, especially in regard to the vehicle platform electronic data and power infrastructure and the associated safety and verification & validation process.

1.2. Application of the NGVA Standard

The NGVA Standard is to be applied to all future land vehicle platforms and vehicle platform sub-system, as well as current vehicle platform refurbishment and upgrade programmes.

This NGVA Standard is applicable to land vehicle platforms, ranging from simple to complex implementations. The requirements for these implementations are determined by the functionality required of the vehicle platform as a whole system including all sub-systems, and not the automotive or power elements alone. The requirements address equipment to be fitted as part of the initial operating capability and equipment likely to be fitted throughout the life of the vehicle platform. These requirements are expressed in the national system requirements documents and/or the sub-system requirements documents for the individual vehicle platforms concerned.

1.3. Agreement

Ratifying nations agree that the NGVA Standard is to be applied to all future land vehicle platforms and vehicle platform sub-systems, as well as current vehicle platform refurbishment and upgrade programmes. Nations may propose changes at any time to the NATO Standardization Office (NSO).

Germany will act as custodian to maintain Configuration Management (CM) and change management of this Standard and its associated AEP Volumes.

Ratifying nations have agreed that national orders, manuals and instructions implementing this Standard will include a reference to the AEP-4754 Volumes I through VII for purposes of identification.

The NGVA Standard and its associated Volumes I through VII shall be considered as the foundation standard for vehicle sub-system integration, and should any conflict arise between this and other extant NATO documentation, this document shall take precedence.

Deviations from the NGVA Standard shall be agreed by the relevant national procurement office.

1.4. Ratification, implementation, and reservations

Ratification, implementation and reservation details are available on request or through the NATO Standardization Office (NSO) (internet: http://nso.nato.int).

1.5. Feedback

Any comments concerning this publication should be directed to: NATO/NSO – Bvd Leopold III - 1110 Brussels - Belgium.

Proposals for changes and improvements of the NGVA Standard AEP-4754 volumes I through VII shall be sent to the NSO and then forwarded to the custodian who will collect them and will propose new editions of the NGVA Standard AEP-4754 Volumes I through VII.

The NGVA Standard Point-of-Contact as assigned by the NGVA Standard Custodian is BAAINBw K1.2, Ferdinand-Sauerbruch-Str.1, D-56073 Koblenz, Germany.

CHAPTER 2 DEVELOPMENT OF NGVA STANDARD

The NATO Generic Vehicle Architecture (NGVA) Standard was developed under the auspices of the Military Vehicle Association (MILVA).

MILVA is an association of government agencies and industries promoting Vehicle Electronics (Vetronics) in the military environment. MILVA provides an open forum to its members and publishes guidelines and standards on Vetronics issues. MILVA works in close co-operation with NATO through the Land Capability Group on Land Engagement of the NATO Army Armament Group (NAAG).

2.1. NGVA Standard Structure

Figure 1 below illustrates the Standard structure, the Volumes relationships and technical areas covered under each Volume.

NGVA Standard AEP-4754

Volume I:	NGVA Architecture Approach (Describes the NATO Generic Vehicle Architecture (NGVA) concept)
Volume II:	NGVA Power Infrastructure (Defines the design constraints on power interfaces which form the NGVA Power Infrastructure)
Volume III:	NGVA Data Infrastructure (Defines the design constraints on the electronic interfaces that form the NGVA Data Infrastructure)
Volume IV:	NGVA Crew Terminal Software Architecture (Defines the design guidelines and constraints for standardized “Crew Terminal Software Applications”)
Volume V:	NGVA Data Model (Describes the NATO GVA Data Model (NGVA DM), the Model Driven Architecture (MDA) approach used to produce the NGVA DM, the toolset required to produce and manage the configuration control of the NGVA DM and finally the applicability of the NGVA DM to Data Distribution Service (DDS) middleware installed on a GVA compliant platform.)
Volume VI:	NGVA Safety (Outlines the generic procedures to incorporate system safety related planning, development, implementation, commissioning and activities in systems engineering)

Volume VII:	NGVA Verification and Validation (Provides guidance for the verification and validation of NGVA systems regarding their conformity to the AEPs associated with this STANAG)

Figure 1: NGVA Standard AEP-4754

2.2. General Notes

2.2.1. Scope

NGVA is the approach taken by NATO and related industry to standardize the interfaces and protocols for military vehicle systems integration. The Vehicle Architecture (including data and power architectures) is considered as the fundamental enabler that can provide new capabilities on military platforms so as to improve overall effectiveness (including cost) and efficiency within the whole vehicle life cycle. The NGVA Standard does not include standard automotive electronics and power related information.

2.2.2. Warning

National governments, like their contractors, are subject to laws of their respective countries regarding health and safety. Many NATO STANAGs and Standards set out processes and procedures that could be hazardous to health if adequate precautions are not taken. Adherence to those processes and procedures in no way absolves users from complying with their national legal requirements.

2.3. Normative References

The documents and publications shown in Table 1 below are referred to in the text of this AEP Volume. Documents and publications are grouped and listed in alpha-numeric order:

1. IEEE 1012-2012	IEEE Standard for System and Software Verification and Validation
2. ISO 9000:2015	Quality management systems – Fundamentals and vocabulary
3. ISO/IEC 15288:2008(E)	Systems and software engineering – System life cycle Processes
4. ISO/IEC/IEEE 29148-2011(E)	Systems and software engineering -- Life cycle processes -- Requirements engineering
5. ISO/IEC 17000:2004	Conformity assessment – Vocabulary and general principle
6. MIL-STD 498 SSS	Software Development and Documentation – System/Sub-system Specification (Identification Number DI-IPSC-81431)

Table 1: Normative References

Reference in Standard AEP-4754 and its Volumes to any normative references refers to, in any Invitation to Tender (ITT) or contract, the edition and all amendments current at the date of such tender or contract, unless a specific edition is indicated. For some standards, the most recent editions shall always apply due to safety and regulatory requirements.

In consideration of the above and as best practice, those setting the requirements shall be fully aware of the issue, amendment status and application of all normative references, particularly when forming part of an ITT or contract.

2.4. Conventions

For the purposes of all AEP Volumes all requirements are specifically detailed in tables with each requirement classified as in the paragraph 2.6. Where an AEP Volume contains no specific requirement tables they should serve as implementation guidance until technical standardization requirements are developed and included.

2.5. Requirements Classifications

The following classifications are to be used for all NGVA related requirements.

2.5.1. Compulsory Requirement (CR)

The requirement needs to be implemented in order to conform to Standard AEP-4754 and to gain certification. Compulsory requirements are listed in the Requirements Tables inside the AEPs and marked as “CR”.

2.5.2. Optional Enhancement (OE)

Optional Enhancements do not need to be implemented in order to conform to Standard AEP-4754. However, if such a capability is present, it needs to be implemented according to the stated specification in order to be compliant. Optional Enhancements are listed in the Requirements Tables inside the AEPs and marked as “OE”.

2.6. Abbreviations

Abbreviations referred to in this AEP Volume are given in Annex A.

2.7. Terms and Definitions

2.7.1. NGVA Definitions

1. **Base Vehicle**: The basic vehicle structure and those systems needed to enable it to perform its automotive functions and mobility. Where fitted it also includes those systems needed to control turrets and other physical elements e.g. a mine plough.
2. **Base Vehicle Sub-System**: A system that forms part of the base vehicle
3. **Electronic Architecture**: The combination of the electronic based sub-systems and electronic infrastructure that supports the vehicle crew to undertake their operational tasks
4. **NATO Generic Vehicle Architecture (NGVA):** The term ‘NATO Generic Vehicle Architecture’ refers to the open, modular and scalable architectural approach applied to the design of vehicle platforms.
5. **Hard Switching:** The ability to control or operate a sub-system using physically based means.

6. **Measure of Effectiveness:** A description of how effective a solution candidate is for a particular assessment criterion.
7. **Measure of Performance:** A statement that describes the assessment criterion or criteria needed to satisfy a given requirement.
8. **Modular**: A modular architecture is designed in such a way as to allow the replacement or addition of sub-systems and upgrades as required without any undesirable emerging properties.
9. **NGVA Compliant:** NGVA Compliance applies to the whole vehicle platform and means that any sub-system existing on the platform complies with the requirements defined in STANAG 4754 and associated AEPs.
10. **NGVA Electronic Infrastructure:** The physical cables and connectors that provide means of distributing data around a base vehicle. It also includes any enabling logical components and functions e.g. Core platform management software, interface software, transport protocols and message definitions.
11. **NGVA Power Infrastructure:** The physical cables, connectors and other components that provide the means of distributing and controlling electrical power around a vehicle platform.
12. **NGVA Ready**: NGVA Ready applies at a sub-system level and means that sub-systems and components have been developed to a level where they can be efficiently integrated within a “NGVA Compliant” whole vehicle Electronics. This would mean passing an incremental process with two sequentially-related Compatibility levels:
    a. **Connectivity Compatibility**: Ensures that the (sub-) system can be physically integrated into the NGVA architecture without any negative impacts to existing NGVA components. Physical power and network interfaces comply with the requirements of Power and Data Infrastructure AEPs.
    b. **Communication Compatibility**: Connectivity Readiness and data interfaces (DDS/Video) with associated NGVA Data Model implementation that comply with the requirements of Data Model and Data Infrastructure AEPs.
13. **Operator:** Any person required to interface and control vehicle platform sub-systems.
14. **Power Management:** The means of prioritizing and controlling the electrical power loads throughout the vehicle platform.
15. **Scalable**: The trait of a system in being able to scale in order to handle increased loads of work.
16. **Soft Switching:** The ability to control or operate a sub-system using software functionality.
17. **Sub-System:** Separable elements or collections of equipment or software added to a base vehicle that provides operationally required capabilities over and above those delivered by the base vehicle.
18. **System:** A combination, with defined boundaries, of elements that are used together in a defined operating environment to perform a given task or achieve a specific purpose. The elements may include personnel, procedures, materials, tools, products, facilities, services and/or data as appropriate.
19. **Vehicle Crew:** All personnel located in the vehicle platform with defined roles needed to fulfil the necessary operational functions.
20. **Vehicle Platform**: The vehicle and all its integrated sub-systems.

21. **Vehicle Users:** The individuals and groups of people who interact locally to operate, support, sustain, maintain or otherwise interface directly with the Vehicle Platform and its sub-systems. It includes Service personnel, Reserve personnel, and Civilian employees, and may include personnel under other service supply contracts.

2.7.2. AEP Specific Definitions

1. **Accreditation Body**: Authoritative body that performs accreditation. [ISO/IEC 17000]. NOTE: The authority of an accreditation body is generally derived from government. [ISO/IEC 17000]
2. **Accreditation**: Third-party attestation related to a conformity assessment body conveying formal demonstration of its competence to carry out specific conformity assessment tasks. [ISO/IEC 17000]
3. **Analysis**: The processing of accumulated data obtained from other qualification methods. Examples are reduction, interpolation, or extrapolation of test results. [MIL-STD 498 SSS]
4. **Attestation**: Issue of a statement, based on a decision following review, that fulfillment of specified requirements has been demonstrated. [ISO/IEC 17000]
5. **Certification**: Third-party attestation related to products, processes, systems or persons. [ISO/IEC 17000]. NOTE: Certification is applicable to all objects of conformity assessment except for conformity assessment bodies themselves, to which accreditation is applicable. [ISO/IEC 17000]
6. **Conformity**: Fulfillment of a requirement. [ISO 9000:2005]. NOTE: The term “conformance” is synonymous but deprecated. [ISO 9000:2005]
7. **Conformity Assessment Body**: Body that performs conformity assessment services. [ISO/IEC 17000]. NOTE: An accreditation body is not a conformity assessment body. [ISO/IEC 17000]
8. **Conformity Assessment**: [Objective evidence] that specified requirements relating to a product, process, system, person or body are fulfilled. [Adapted from ISO/IEC 17000]. NOTE: The subject field of conformity assessment includes activities such as demonstration, test, analysis, inspection and certification, as well as the accreditation of conformity assessment bodies. [Adapted from ISO/IEC 17000]
9. **Demonstration**: The operation of the system, or a part of the system, that relies on observable functional operation not requiring the use of instrumentation, special test equipment, or subsequent analysis. [MIL-STD 498 SSS]
10. **Independent Verification and Validation (IV&V):** V&V performed by an organization that is technically, managerially, and financially independent of the development organization. [IEEE 1012]
11. **Inspection**: The [physical] examination of system components, documentation, etc. [adapted from MIL-STD 498 SSS]
12. **Objective evidence**: Data supporting the existence or verity of something. [ISO 9000:2005]. NOTE Objective evidence may be obtained through Demonstration, Test, Analysis, Inspection, or Special qualification methods.
13. **Requirement**: Need or expectation that is stated, generally implied or obligatory. [ISO 9000:2005]
14. **Review**: Verification of the suitability, adequacy and effectiveness of selection and determination activities, and the results of these activities, with regard to

fulfillment of specified requirements by an object of conformity assessment. [ISO/IEC 17000]

15. **Special Qualification Methods**: Any special qualification methods for the system, such as special tools, techniques, procedures, facilities, acceptance limits, use of standard samples, preproduction or periodic production samples, pilot models, or pilot lots. [MIL-STD 498 SSS]
16. **Stakeholder**: Individual or organization having a right, share, claim, or interest in a system or in its possession of characteristics that meet their needs and expectations. [ISO/IEC/IEEE 15288]
17. **Test**: The operation of the system, or a part of the system, using instrumentation or other special test equipment to collect data for later analysis. [MIL-STD 498 SSS]
18. **Third-Party:** A person or body that is independent of the person or organization that provides the system, and of user interests in that system. [Adapted from ISO/IEC 17000]
19. **Validation**: Confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled. [ISO 9000:2005]. NOTE: Validation is the set of activities ensuring and gaining confidence that a system is able to accomplish its intended use, goals and objectives (i.e., meet stakeholder requirements) in the intended operational environment. [ISO/IEC/IEEE 15288]
20. **Verification**: Confirmation, through the provision of objective evidence, that specified requirements have been fulfilled. [ISO 9000:2005]. NOTE: Verification is a set of activities that compares a system or system element against the required characteristics. This may include, but is not limited to, specified requirements, design description and the system itself. [ISO/IEC/IEEE 15288]

CHAPTER 3 VERIFICATION AND VALIDATION

This Volume outlines a generic framework for the verification and validation of NGVA-based systems regarding their conformity to the associated AEPs. The AEP defines a certification process based on multiple conformity levels and describes associated accreditation of conformity assessment bodies. All these procedures are based on a common terminology defined in section 2.7.

The NGVA STANAG AEPs are structured in such a way that requirements pertinent to each technical area are presented in table form with an accompanying description of the requirements. This should allow to construct more consistent NGVA system requirements and to better understand how to achieve NGVA compliance or readiness. Thus, this Volume does not contain any additional requirements that NGVA (sub-) systems have to fulfil. If the “shall” or “should” are used in this Volume, they are meant to describe how the conformity assessment shall be conducted.

In its current version, this AEP addresses the verification of NGVA systems, mainly. There are a number of areas, including validation and accreditation, in which further work is needed. Future iterations will cover these processes to the appropriate level of maturity.

3.1. Verification

As stated in section 2.7.2 definition 20, verification confirms that the characteristics and behaviour of an equipment or system comply with the requirements specified in the system requirements document or equivalent. Verification is an assessment of the results of both the design/development processes and verification process carried out by a supplier, system integrator, designer or an independent assessment body.

In the context of NGVA, it sets out to prove that the requirements defined in the AEPs have been followed and met. Verification is not simply testing, as testing alone cannot always show the absence of errors. It is a combination of reviews, analysis and tests based on a structured verification plan. Verification is usually performed at sub-system as well as system level.

3.2. Validation

According to section 2.7.2 definition 19, validation generates objective evidence that the capability enabled by the equipment or system satisfies the needs defined in the user requirements document or equivalent. Therefore, validation is an assessment to confirm that the requirements defining the intended use or application of the system have been met.

The overall intention is to build a vehicle fit for purpose that operates correctly for all the defined scenarios in the system concept of use, noting that the concept of use may change through life. Validation must also address the ability of the system to cope with various faults and failure modes.
Validation evaluates the correct operation of the complete system on specific use cases. Therefore, an operational context is needed which varies with the particular

purpose of the system. These specifics are not considered in this part of the NGVA. Nevertheless, the compliance with overarching NGVA concepts such as openness, modularity, scalability, and availability should be validated.

3.3. Accreditation

Accreditation refers to the appointment of assessment bodies, for example test sites, which are authorized to conduct conformity assessment of (sub) systems that are to-be NGVA Ready. Accreditation is different from the issue of a NGVA conformity statement.

According to section 2.7.2 definition 1 and definition 2, governments appoint national accreditation bodies which have the authority to perform accreditation of NGVA conformity assessment bodies.

These national accreditation bodies are usually governmental organizations. The national accreditation bodies agree on procedures and aligned conditions to appoint conformity assessment bodies.

The appointed conformity assessment bodies perform the assessment services which include such as demonstration, test, analysis, inspection as well as certification.

Only products certified by accredited conformity assessment bodies will be able to claim conformity to a NGVA Compatibility Level (see CHAPTER 5).

CHAPTER 4 VERIFICATION PLAN

A verification plan tailored to the specific NGVA system shall be written to define the verification process. NGVA system may refer to single sub-system or a composition of sub-systems to be verified to-be NGVA ready.

This NGVA verification plan shall include:

a. Organizational verification responsibilities;
b. Verification methods;
c. Review methods,
d. Analysis methods,
e. Methods for verification independence;
f. Description of verification tools;
g. Re-verification guidelines in case of system/design modifications;
h. Guidelines for previously developed or off-the-shelf equipment.

4.1. Verification Responsibilities

For the development of a verification plan of a NGVA system, the different stakeholders have to be defined and their responsibilities have to be determined.

As given in Figure 1 these stakeholders may include:

a. The System Designer and Supplier; possibly represented by the same stakeholder. The System Supplier is responsible for the Electronic Infrastructure of the NGVA system by outlining and providing means for power distribution and data exchange between the Sub-Systems forming the NGVA system.
b. The Sub-System Designer and Supplier; potentially subcontractors of the System Designer. The Sub-System Suppliers are responsible for the provision of the individual Sub-Systems.
c. The System Integrator may be the same player as the System Supplier initially, but may change during the maintenance phase. The System Integrator delivers the complete system.
d. The Customer, e.g. the Procurement Office, is typically handling the acceptance of the verification plan to ensure that it meets the initial (or refined) stakeholder requirements.
e. The Conformity Assessment Authority is often a governmental institution or independent authority which provides verification and validation of the system (organizationally, procedurally and technically).

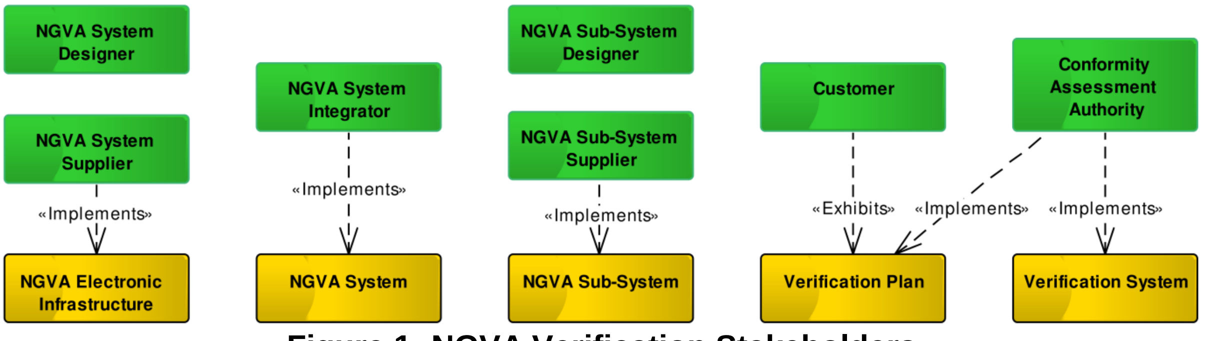

Figure 1: NGVA Verification Stakeholders

The stakeholder roles may change during the systems development and procurement process. Depending on the level of the verification activity the same stakeholder or NGVA (sub-) system may have different roles. This can be illustrated by an example of a camera C which should be integrated in a surveillance unit U that in turn is mounted on a scout vehicle.

On the lowest level, the system to be verified to-be NGVA ready is the camera C itself. In this case, C is the NGVA (Sub-) System and provides internally “its infrastructure”; while the camera manufacturer CM is Designer and Integrator. Thus, C and its manufacturer CM adopt the three left roles of Figure 1. The surveillance unit manufacturer UM is the customer and may even conduct conformity assessment according to the UM requirements.

Assuming that the surveillance unit U is directly procured by the government to be deployed in several vehicles and should be verified, U is the NGVA System that provides the infrastructure for the NGVA Sub-System C. This results in CM being the Sub-System Supplier and UM taking the roles of System Integrator and System Supplier. Hence, the government procurement office has the role of the Customer and can be supported be an independent assessment authority.

The highest abstraction level is the integration of the components in an actual scout vehicle. Therefore, a Platform Manufacturer acts as the System Supplier providing the foundation with the power and data distribution Infrastructure. The UM from the last paragraph would provide U, being one of the Sub-Systems to-be integrated, as a Sub-System Supplier. The integration of all Sub-Systems on the platform is conducted by the System Integrator which can be Platform Manufacturer again or a different prime contractor. He is responsible to deliver the entire NGVA System to be verified as NGVA Ready. The System is checked for acceptance by the Customer, e.g. the Procurement Office, according to the Verification Plan possibly with the help of an Independent Assessment Authority.

4.2. Verification Methods

Four standard verification methods are commonly used to obtain the objective evidence that the requirements have been fulfilled: inspection, analysis or simulation, demonstration, and test. This section gives detailed overview of the different methods based on ISO/IEC/IEEE 29148-2011(E).

4.2.1. Inspection

Inspection proves the item against applicable documentation to verify properties best determined by examination and observation (e.g., - paint color, weight, etc.). Inspection is generally non-destructive and typically includes the use of sight, hearing, smell, touch, and taste; simple physical manipulation; mechanical and electrical gauging; and measurement.

4.2.2. Analysis (including modeling and simulation)

Analysis uses analytical data or simulations under defined conditions to show theoretical compliance where testing to realistic conditions cannot be achieved or is not cost-effective. Analysis may be based on 'similarity' by reviewing a similar item's prior verification and confirming that its verification status can legitimately be transferred to the present system element. Similarity can only be used if the items are similar in design, manufacture, and use; equivalent or more stringent verification specifications were used for the similar system element; and the intended operational environment is identical to or less rigorous then the similar system element.

4.2.3. Demonstration

Demonstration is a qualitative exhibition of functional performance, usually accomplished with no or minimal instrumentation or test equipment. Demonstration uses a set of test activities with system stimuli selected by the supplier to show that system or system element response to stimuli is suitable or to show that operators can perform their allocated functions when using the system. Observations are made and compared with predetermined responses. Demonstration may be appropriate when requirements or specifications are given in statistical terms (e.g., mean time to repair, average power consumption, etc.).

4.2.4. Test

Test quantitatively verifies the operability, supportability, or performance capability of an item when subjected to controlled conditions that are real or simulated. These verifications often use special test equipment or instrumentation to obtain very accurate quantitative data for analysis.

4.3. Review Methods

Throughout the verification process, formal system reviews and audits are performed at different phases of the verification, e.g. Test Readiness Reviews. The verification plan should include necessary reviews as well as corresponding review methods.

E.g., these reviews should ensure that all relevant NGVA requirements for specific system are captured by the verification plan, appropriate verification methods are used, and verification is conducted properly. Therefore, checklists or other aids should be used.

4.4. Analysis Methods

The verification plan should include means to assure traceability and coverage analysis of requirements. All requirements must be traceable to an implementation/realization in the system. This should allow comprehensible proving that all relevant requirements are covered/fulfilled. Additionally, provisions to link requirements and verification activities or test cases should be described in the verification plan.

Therefore, a requirements traceability matrix, also known as requirements coverage matrix, can be used.

4.5. Verification Tools and Techniques

Usually, hardware and software tools are used to assist and automate verification processes. For example, software tools support test coverage analysis and regression testing.

The verification plan should include guidelines for these tools and any hardware test equipment. This includes detailed description of the needed tools, explanations of each tool's performance, required inputs and outputs generated.

Additionally, the verification plan should address test facilities and integration and system test laboratories supporting the verification effort, e.g. specific conformance or interoperability test labs.

4.5.1. Conformance and Interoperability Tests

The main objective of NGVA is the assurance of interoperability between NGVA (Sub-) Systems. To evaluate systems conformity to standards in this vein, typically conformance and interoperability testing are used. Both techniques are complementary; often, conformance testing addresses protocols and lower-layer communication aspects while interoperability testing is selected for entire systems and applications.

Conformance testing (Figure 2) is conducted by a Test System which stimulates a System under Test. This System under Test often contains an Implementation under Test, which is subject to conformance testing. Conformance testing is a formal process, deterministic and repeatable, and ensures that a system meets a defined set of requirements, for example, a correctly implemented protocol stack.

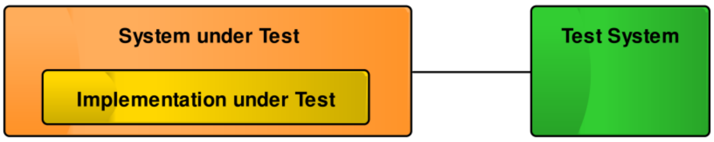

Figure 2: Conformance Testing

Interoperability testing (Figure 3), in contrast, is performed at system interfaces, which offer only normal user control and observation. Therefore, it is based on functionality as experienced by a user and not specified at the protocol level. The purpose of interoperability testing is to prove that end-to-end functionality between at least two NGVA (sub-) systems, the Equipment under Test and the Qualified Equipment, is as defined by the NGVA.

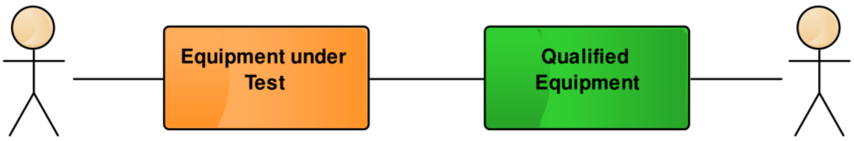

Figure 3: Interoperability Testing

Interoperability testing as well as Conformance testing should be tackled by the NGVA verification process. Therefore the verification plan should describe which following tests are planned to be conducted.

4.5.2. NGVA Data Model Conformance Test System

One verification key aspect is NGVA Data Model Conformance Testing. This evaluation may be conducted by independent conformity assessment bodies, which provide appropriate test systems potentially over a Virtual Private Network (VPN) or the Internet.

These Conformance Test Systems verify the NGVA Data Model conformity of NGVA systems. Therefore, NGVA sub-systems (System under Test) are considered as black boxes and system specific tests to evaluate the system response for valid, inopportune and invalid input are run. These formalized test suites support an automatic execution of test cases as well as an automatic and unbiased assignment of test verdicts.

Centrally maintained NGVA Data Model Conformance Test Systems assure that all vendors always have access to the latest release of the test suite. Restricted by spatial distribution, they cannot reflect a real vehicle bus and are not suitable for real-time testing.

4.5.3. Test Laboratories and Test Beds

For overarching conformance and interoperability tests, vendors as well as vendor-independent authorities should maintain test beds to conduct tests prior to the initial release of products or upgrades. These test beds allow a collocated testing to verify that all real-time, safety, and security requirements are met.

In particular, the test beds should provide the infrastructure to which NGVA systems, the Equipment under Test, have to be interoperable in order to be verified. Therefore, the test beds may consist of components that can control and request data from the Equipment under Test or gateway components may be necessary.

4.5.4. Demonstrators and Experiments

Especially for the confirmation of functional and operational requirements demonstrators and experiments should be used. They can be used for verification as well as validation to prove the intended use of the system. Thereby, the defined concept of use of the system is validated in predefined operational scenarios.

4.6. Verification Independence

Verification by independent authorities may be necessary for, but not limited to, requirements that are safety-critical or of high-security nature. Therefore, the verification plan should include provisions to take an appropriate amount of independence into account. According to IEEE 1012-2012, Independent Verification and Validation (IV&V) is defined by three parameters:

1. **Technical Independence** requires the verification and validation effort to use personnel who are not involved in the development of the system or its elements. This “fresh viewpoint” is an important method to detect subtle errors overlooked by those too close to the solution.
2. **Managerial Independence** requires that the responsibility for the IV&V effort be vested in an organization separate from the development and program

management organizations. This allows submitting results, anomalies, and findings without any restrictions or adverse pressures, direct or indirect.

3. **Financial Independence** requires that control of the IV&V budget be vested in an independent organization to prevent situations where the IV&V effort cannot complete its analysis or test or deliver timely results because funds have been diverted or adverse financial pressures or influences have been exerted.

Depending on the complexity of the NGVA system to be verified, different forms of independence have to be adopted for a verification organization. The five most prevalent are as follows:

1. Classical
2. Modified
3. Integrated
4. Internal
5. Embedded

The verification plan should state the appropriate form for the addressed NGVA system.

4.6.1. Classical IV&V

Classical IV&V embodies all three independence parameters. The IV&V responsibility is vested in an organization that is separate from the development organization. The IV&V organization establishes a close working relationship with the development organization to assure that IV&V findings and recommendations are integrated rapidly back into the development process. Typically, classical IV&V is performed by one organization (e.g., supplier) and the development is performed by a separate organization (i.e., another vendor).

Classical IV&V is generally required for Safety Integrity Level (SIL) 4 (i.e., loss of life, loss of mission, significant social loss, or financial loss) through regulations and standards imposed on the system development. Further information on Safety is given in the NGVA Safety Volume.

4.6.2. Modified IV&V (No managerial independence)

Modified IV&V is used in many large programs where the system prime integrator is selected to manage the entire system development including the IV&V. The prime integrator selects organizations to assist in the development of the system and to perform the IV&V. In the modified IV&V form, the procurer reduces its own acquisition time by passing this responsibility to the prime integrator. Because the prime integrator performs all or some of the development, the managerial independence is compromised by having the IV&V effort report to the prime integrator. Technical independence is preserved because the IV&V effort formulates an unbiased opinion of the system solution and uses an independent staff to perform the IV&V. Financial independence is preserved because a separate budget is set aside for the IV&V effort.

Modified IV&V effort would be appropriate for systems with SIL3 (i.e., an important mission and purpose). Further information on Safety is given in the NGVA Safety Volume.

4.6.3. Integrated IV&V (No technical independence)

This type is focused on providing rapid feedback of V&V results into the development process and is performed by an organization that is financially and managerially independent of the development organization to minimize compromises with respect to independence. The rapid feedback of V&V results into the development process is facilitated by the integrated IV&V organization: working side by side with the development organization, reviewing interim work products, and providing V&V feedback during inspections, walkthroughs, and reviews conducted by the development staff. This integration causes potential impact to technical independence which is counterbalanced by benefits associated with a focus on interdependence between the integrated IV&V organization and the development organization. Interdependence means that the successes of the organizations are closely coupled, ensuring that they work together in a cooperative fashion.

4.6.4. Internal IV&V

Internal IV&V exists when the developer conducts the IV&V with personnel from within its own organization, although preferably not the same personnel involved directly in the development effort. Technical, managerial, and financial independence are compromised. Technical independence is compromised because the IV&V analysis and test is vulnerable to overlooking errors by using the same assumptions or development environment that masked the error from the developers. Managerial independence is compromised because the internal IV&V effort uses the same common tools and corporate influence how aggressively the system is analyzed and tested by the IV&V effort. Financial independence is compromised because the development group controls the IV&V budget. IV&V funds, resources, and schedules may be reduced as development pressures and needs redirect the IV&V funds into solving development problems.

The benefit of an internal IV&V effort is access to staff who knows the system and its software. This form of IV&V is used when the degree of independence is not explicitly stated and the benefits of pre-existing staff knowledge outweigh the benefits of objectivity.

4.6.5. Embedded V&V

This type is similar to internal IV&V in that it uses personnel from the development organization who should not be involved directly in the development effort. Embedded V&V is focused on ensuring conformity to the development procedures and processes. The embedded V&V organization works side by side with the development organization and attends the same inspections, walkthroughs, and reviews as the development staff (i.e., compromise of technical independence). Embedded V&V is not tasked specifically to assess independently the original solution or conduct independent tests (i.e., compromise of managerial independence). Financial independence is compromised because the V&V staff resource assignments are controlled by the development group.

Embedded V&V allows rapid feedback of V&V results into the development process but compromises the technical, managerial, and financial independence of the V&V organization.

4.7. Re-Verification Guidelines

After modifications of design or implementation, NGVA equipment has to be re-verified. Depending on the level of change, the complete system may need to be re-verified. Thus, the verification plan should describe re-verification guidelines depending on the type and level of (sub-) system changes.

If there are no guidelines given, the complete system has to perform the full verification process.

4.8. Legacy Equipment Guidelines

For any previously developed or off-the-shelf equipment, a description of the methods to satisfy the objectives of this STANAG shall be given. These methods may incorporate the development of software and hardware adapters as well as descriptions for dealing with safety and power issues. In addition, a roadmap for a long-term NGVA adaption has to be outlined.

If there are no descriptions given, all legacy and off-the-shelf equipment are treated as a genuine NGVA system.

CHAPTER 5 CONFORMITY BASED ON NGVA COMPATIBILITY LEVELS

The possible approaches to a verification plan presented in the previous section provide the basis for the verification and conformity certification of NGVA systems by recommending methods and tools that shall be used in the verification and certification processes.

Certification is the issue of a statement by a third-party, based on a decision following review that fulfillment of specified requirements has been demonstrated [section 2.7.2 definition 5]. Hence, NGVA Certification is an assurance that the system has been developed in accordance with the NGVA and meets its requirements. System verification results and reviews form the foundation for certification.

For the systems verification and conformity certification concerning NGVA requirements, an incremental process shall be followed. This process is based on three sequentially-related levels (Figure 4): Connectivity Compatibility, Communication Compatibility, and Functional Compatibility. These levels are sequential; Communication Compatibility includes Connectivity Compatibility and Functional Compatibility includes all others.

Figure 4: NGVA Compatibility Levels

The different levels allow evaluating the specific system requirements in a structured manner by arranging the order of verification.

5.1. Connectivity Compatibility

The first level, Connectivity Compatibility ensures that the (sub-) system can be physically integrated into the NGVA architecture without any negative impacts to existing NGVA components. Physical power and network interfaces comply with the requirements of Power and Data Infrastructures AEPs.

Thus, this level applies to requirements that concern the electrical and physical specifications of the connectors as well as low level means to transfer data between NGVA (sub-) systems, e.g. OSI Layer 1-4 protocols. Additionally, the first level contains requirements that may compromise other services; for example, requirements that are related to EMC-safety and power supply.

These first level requirements are mainly verified by physical inspection or testing. In some cases like EMC, even the inspection of conformity statements from vendors can be sufficient.

5.2. Communication Compatibility

If applicable to a (sub-) system, Communication Compatibility refers to the correct implementation of the NGVA Data Model and video streaming standards. On the basis of achieved Connectivity Compatibility, data interfaces (e.g. Data Distribution Service, Video/Audio Protocols) and associated NGVA Data Model implementation (e.g. Topic Types, Quality of Service) need to comply with the NGVA Data Model Volume.

Based on System Requirements stating what services are provided by the system and what NGVA-related sub-systems are integrated into the system; relevant parts of the NGVA Data Model covered by the equipment are derived and tested. These tests cover the systems or components data exchange specified in the NGVA Data Model, e.g. correct publishing of specification topics and correct response to mode changes.

5.3. Functional Compatibility

Underpinned by Communication Compatibility, Functional Compatibility evaluation ensures that data flows conform to data exchange, performance and specific functional requirements.

Having passed the lower level tests, Functional Compatibility of the system shall be tested. Concerning data exchange, NGVA Data Model tests which cover the system or component response for valid, inopportune and invalid inputs are conducted. This includes for the publishing of correct information and data format (e.g. for the current GPS position) and the proper behavior for commands (for example mount movements).

Additionally, this level evaluates if real-time and bandwidth requirements are met and specific functional requirements regarding security are in line with this level. If further operational requirements are provided, they are tested here as well.

5.4. Relationship of Conformity and NGVA Ready/NGVA Compliant

The specified compatibility levels should not be confused with the terms NGVA Ready [section 2.7.1 definition 12] and NGVA Compliant [section 2.7.1 definition 9]. These terms distinguish between sub-system level and platform level verification.

The certification process outlined in this chapter is applicable to both sub-system and platform level. Rather, combined with specific requirements of the other AEPs the process gives guidance on a coherent sequence to handle the versatile requirements.

CHAPTER 6 VERIFICATION PROCESS

This chapter outlines a NGVA Verification Process consisting of five steps. Typically, this process is performed by the developer that realized the NGVA end-system, with participation of the end user and independent conformity assessment bodies. The Verification Plan of CHAPTER 4 and the System Requirements Document (SRD) are the key inputs for the Verification Process.

6.1. Verification Planning

Planning of the verification process is a first key step. Based on the System Requirements Document and the requirements of the NGVA STANAG AEPs, the specific requirements are collected and verification types (e.g., analysis, demonstration, inspection or test) for them are established.

Additionally, the verification plan should be reviewed for any specific procedures, constraints or further measures that have to be considered prior to the actual verification.

6.2. Verification Preparation

In preparation for verification, the specified requirements are reviewed, confirmed, and allocated to the different NGVA Compatibility Levels.

The NGVA system to be verified is acquired, as well as any enabling products and support resources that are necessary for verification. The verification preparation includes the verification environment. For Connectivity Compatibility this may cover tools or measuring devices for a particular pin-out. In case of Communication Compatibility, an account for the NGVA Data Model Conformance Test System has to be requested or further measures to connect to this system have to be considered. To test Functional Compatibility simulations may have to be prepared.

The particular measures depend on the specific system requirements.

6.3. Verification Performance

In this step, the verification of NGVA systems is conducted and conformity to each specified verification requirement is established. Therefore, the responsible stakeholder should ensure that the procedures are followed and performed as specified in the verification plan and the data is collected and recorded for verification analysis.

In this phase, the tests for the three NGVA Compatibility Levels are conducted in sequential order from Connectivity over Communication to Functional Compatibility. The different test procedures and outcomes are linked to the requirements by appropriate means, e.g. a requirements traceability matrix.

6.4. Verification Outcomes Analysis

Once the verification activities have been completed, the collected results are analyzed, in particular for quality and correctness.

Based on this analysis and possible defects, it could be necessary to re-realize the system or to re-engineer the sub-systems assembled and integrated into the system verified and to re-perform the NGVA verification process.

Additionally, verification test outcomes can be unsatisfactory for other reasons. This includes poor conduct of the verification process (e.g., procedures not properly followed, use of un-calibrated equipment, etc.). This would cause re-performing of the affected verification steps, as well.

6.5. Capturing of Verification Results

As last step, verification results shall be produced from the verification process activities. These verification results shall:

1. Identify the verified system including its configuration or version number;
2. State verifier and verification date;
3. Specify the used tools including their configuration and version numbers;
4. Indicate each procedure that passed or failed during the activities;
5. Contain any corrective action taken and the lessons learned (including feedback to improve this specification);
6. Include a traceability analysis;
7. Capture the final pass/fail results for each requirement;
8. Document proof that the realized system did (not) satisfy the requirements;
9. Include conclusions and recommendations for further verification activities;
10. Mention consequences for the validation of the system.

ANNEX A ABBREVIATIONS

COTS	Commercial Off The Shelf
DC	Direct Current
DDS	Data Distribution Service
DDSI	Data Distribution Service Interoperability
Def Stan	Defence Standard
ECM	Electronic Counter Measures
EMC	Electro-Magnetic Compatibility
GVA	Generic Vehicle Architecture
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
ISO	International Standards Organization
IV&V	Independent Verification and Validation
LAN	Local Area Network
MILVA	Military Vetronics Association
MOD	Ministry of Defence
MOTS	Military Off-The-Shelf
NATO	North Atlantic Treaty Organization
NGVA	NATO Generic Vehicle Architecture
NGPOC	NGVA Point of Contact
OMG	Object Management Group
PDT	Power Distribution Terminal
PE	Platform Equipment
RFC	Request for Comments
RFU	Reserved for Future Use
RoHS	Restriction of Hazardous Substances
SA	Situational Awareness
SIL	Safety Integrity Level
SAE	Society of Automotive Engineers
SRD	System Requirement Document
TE	Terminal Equipment
USB	Universal Serial Bus

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