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Validation & Verification Management Plan

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1.2	2025-12-05	Version 1.2 for public release	2.2.1/Traceability Management, 2.2.2/Mitigation Strategies

Contents

Glossary

ARP4754A
: Aerospace Recommended Practice (ARP) Guidelines for Development of Civil Aircraft and Systems, is a published standard from SAE International, dealing with the development processes which support certification of Aircraft systems, addressing "the complete aircraft development cycle, from systems requirements through systems verification.". 9

CE
: Chief Engineer. 11

IEEE Std 1012™-2024
: Defines the processes and activities required to plan, perform, and document V&V throughout the system lifecycle. 10

IEEE Std 15288:™-2023
: Provides a framework for system life cycle processes, including development, operation, and disposal. 10

IEEE Std 29119-1:™-2022
: A standard to define terminology, concepts, and a framework for software testing. 10

IEEE Std 29119-4:™-2021
: Provides standardized test design techniques to support effective software testing. 10

IL
: **Integrity level** is a value given based on the project's unique characteristics (complexity, criticality, risk, safety, etc.) that represents the importance of the system and software to the user. *(Taken from the standard IEEE 1012-2024 [1]).* 7

protocol
: The results and evidence from completed verification/validation activities. 5, 13

QCM
: Quality & Configuration Manager. 11

RM
: Requirements Manager. 11

SM
: Safety Manager. 11

SRS
: System Requirements Specification. 12

UAV
: Unmanned Aerial Vehicle. 4

V&V
: Validation & Verification. 4, 5

validation
: Refers to ”Am I building the ***right*** product?”, meaning that the product is according to what stakeholders expect and want the product to be. 4

verification
: Refers to ”Am I building the product ***right***?”, meaning that the product is according to given requirements. 4

VVM
: Validation & Verification Manager. 11

WBS
: Work Breakdown Structure. 8

1 Introduction

This document outlines the main objective of verifying and validating the project ***Intelligent Replanning Drone Swarm*** to ensure that it meets the desired objectives and maintains high quality. This document will detail the specific plan and process for achieving the main objective of the project with the aim of creating an intelligent planning protocol. Furthermore, V&V directly support the project dependability goals, ensuring that the system remains reliable and tolerant of faults, even under degraded dynamic mission conditions.

1.1 Purpose

The purpose of this plan is to cooperate in the validation and verification of the intelligent planning protocol, confirming that the distributed swarm coordination logic and task re-allocation for degraded Unmanned Aerial Vehicle (UAV) satisfy all defined requirements.

1.2 Related Documents

The following documents are directly related to this Validation & Verification (V&V) management plan:

Document ID	**Document Title**	**Ref nr**
PP-01	Project Plan	[2]
IEEE Std 1012™-2024	IEEE Standard for System, Software, and Hardware Verification and Validation	[1]
IEEE Std 29119-1:™-2022	IEEE Standard for the Software testing Part 1:General concepts	[3]
IEEE Std 29119-4:™-2021	IEEE Standard for the Software testing Part 4: Test techniques	[4]
IEEE Std 15288:™-2023	IEEE Standard for the System life cycle processes	[5]

Table 1: Table on the related documents.

For more information on related documents, see section 2.2 Deliverables.

2 Scope

The scope defines the deliverables of V&V, the assumptions made, the constraints in place, and the main activities in V&V to be carried out.

2.1 Objectives

The objectives of this V&V plan are to:

- Demonstrate compliance with applicable standards.
- Ensure and verify that all elicited requirements are correctly implemented and tested.
- Detect defects as early as possible in the project lifecycle.
- Validate that the replanning protocol fulfills the stakeholder needs.

2.2 Deliverables

V&V Activities	Deliverable	Associated IDs
Requirements	Checklist	VV-02
	Verification protocol	VV-03 – VV-07
	Traceability Matrix	VV-08
	Risk Assessment	VV-09
Design	Network Diagram	VV-10
	Test Case	VV-11
	Design Verification & Validation protocol	VV-12
Implementation and Test	Test Case	VV-11
Reporting	Test Specification	VV-12
	Final Report	VV-13

Table 2: Table of the deliverables.

2.2.1 Traceability Management

Traceability is a central part of the V&V process and is continuously ensured throughout the project lifecycle. Traceability is managed through the project database, where relationships between requirements, design artifacts, implementation, and test results are documented and updated continuously. This enables each requirement to be followed from its origin to the corresponding verification and validation activities that meet standard transparency requirements. Because traceability is integrated into multiple artifacts, V&V activities can be carried out efficiently even under time constraints. This structure ensures that nothing is lost and that changes can be quickly tracked and that all roles work from the same updated source of information. That is why a separate document for traceability (VV-08) technically does not exist. Instead, VV-08 represents the continuous traceability that is present in all activities and artifacts of the project. For this reason, it is shown in the WBS structure, since its function is present throughout the entire process.

2.2.2 Mitigation Strategies

Since several V&V deliverables depend on other roles in the project, there is a risk of delays. To manage this, priority is always given to activities that form the basis of all following V&V, such as review of requirements, verification protocols and central test cases. By ensuring that these are started and driven early, waiting times are reduced and continuity in the V&V work is maintained.

To further reduce the risk of bottlenecks, regular reconciliations are established between V&V and the roles of the Requirements Manager, Chief Engineer and Safety Manager. Early and continuous communication clarifies which artifacts are needed at which times, allowing rapid rescheduling and effective management of any delays.

In the event of time constraints, some V&V activities can be carried out with a reduced scope without compromising the integrity of the project. For example, less critical test cases can be simplified and some analyses can be performed at a higher level of abstraction.

2.2.3 V&V Reporting requirements

The final V&V Report (VV-13 $\rightarrow$ CE-04) shall be issued at the end of the V&V process. The end report shall include the following:

- Summary of the V&V activities, task and result, including status and handling of all anomalies
- Provide an assessment of the overall quality
- Document identified opportunities for process improvements

2.2.4 V&V Test Specification documentation requirements

For the test specification documentation, the following will be included:

- Test Cases
- Test Result

2.3 Integrity Level

This Verification and Validation (V&V) Plan has been developed according to IEEE Std 1012TM-2024 Integrity Level 3 (IL 3). The choice of IL 3 is based on two factors:

- System criticality.
- Probability of faults.

Regarding criticality: Potential failures could lead to mission failure, loss of resources, or reduced rescue efficiency, but do not pose a direct risk to human life under normal conditions. Also, it should be noted that areas related Search and Rescue missions are in general sparsely populated or unpopulated, which further reduces the risk of harm. Concerning fault likelihood: The UAV swarm system includes partially degraded UAVs, task reallocation logic, and secure consensus mechanisms, all of which increase the risk of logical errors. IL 3 provides sufficient structure and discipline to manage these risks through traceability, review activities, and formal V&V activities, while IL 4 would impose significantly higher effort that is not justified given the risk assessed. Therefore, IL 3 has been chosen as the appropriate integrity level for this project.

Integrity Level	**Consequence of error**	**V&V-rigor**
IL-1	Minimal consequences. Errors lead to insignificant effects.	Very low – basic verification only.
IL-2	Low impact. Errors may cause financial damage or affect service, but no safety risk.	Low – some testing and documentation.
IL-3	Serious consequences. Errors can have significant economic impact or risk to people on a limited scale.	Medium – extensive testing, traceability and analysis.
IL-4	Catastrophic consequences. Errors can cause death, serious injury, or failure of life-critical missions.	High – strict V&V, extensive verification, traceability and independent review.

Table 3: Integrity Level schema according to IEEE Std 1012-2024 [1].

2.4 Work Breakdown Structure

This WBS further breaks down V&V activities from the WBS found in the Project Plan [2].

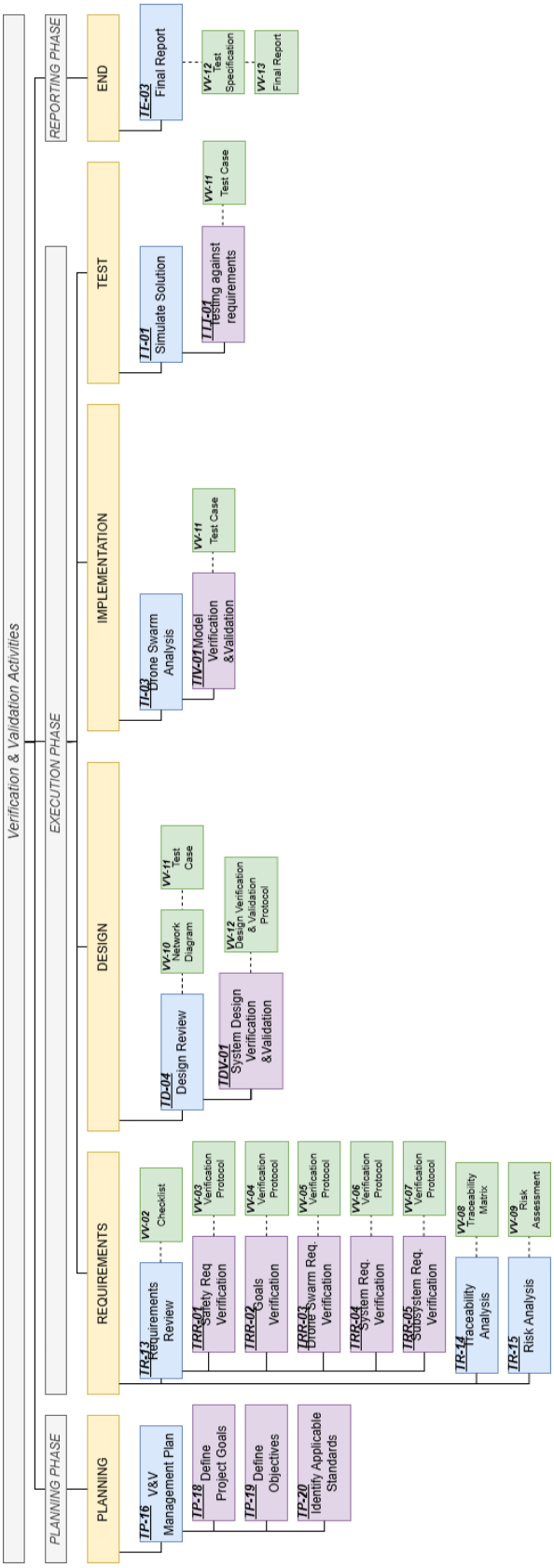

Figure 1: Work Breakdown Structure.

3 Methodology

The approach for this V&V plan is based on:

- Verification methods.
- Validation methods.
- Demonstration of how V&V activities will be distributed.

During the execution phase of the project, activities will be organised according to a modified version of ARP4754A's V-model.

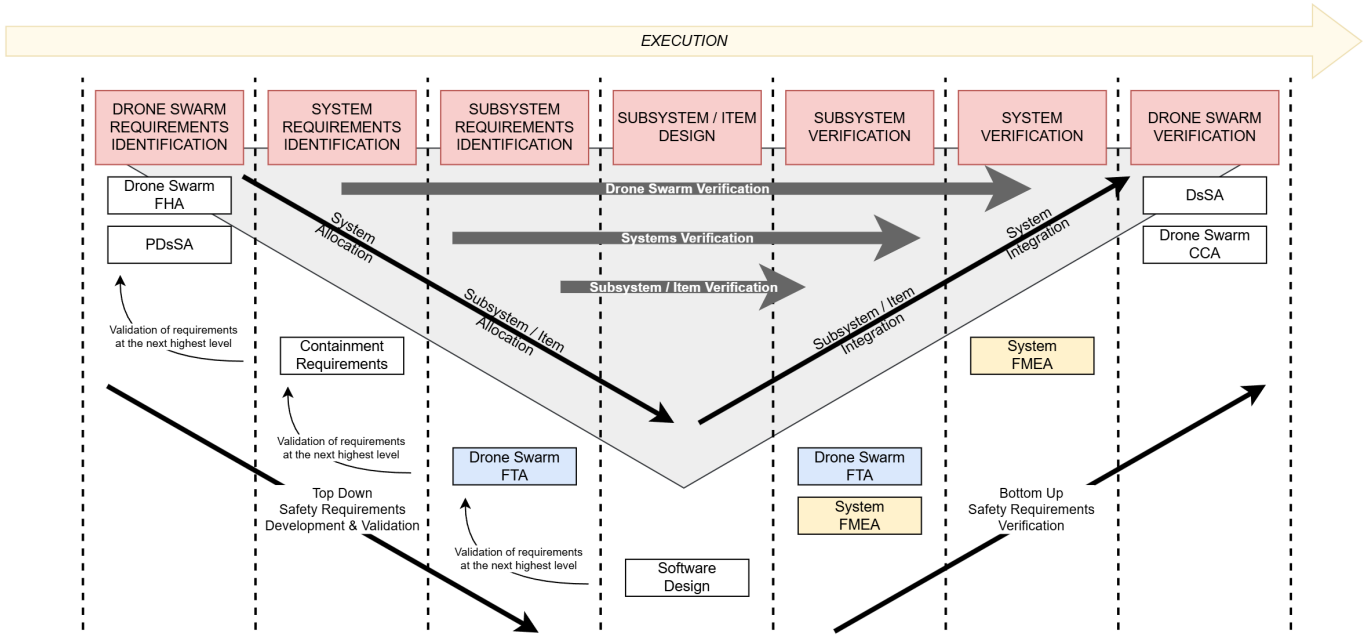

Figure 2: V-model based on ARP4754A.

3.1 Tools & Techniques

The methods and techniques that will be used include analysis, such as interface and traceability analysis, inspection, such as review of system design, and tests that will cover areas such as abnormal criteria, various scenarios, and boundary conditions. The main tool for validating the UAV swarm will be a simulation software, provided by the project owner, called gym-pybullet-drones and the tool called UPPAAL . This open-source software will be modified and then used to simulate the UAV swarm's behaviour to support the development and evaluation of the Replanning Protocol.

The validation and verification methods are the following:

Verification

- Checklists
- Simulations
- Model checking
- Traceability analysis
- Requirements review

Validation

- Simulations
- Design review
- Testing against requirements

3.2 Application of Standard

IEEE Std 1012™-2024 is the chosen standard V&V for this project because it is an internationally recognised standard for planning and implementing verification and validation activities. The standard provides a clear structure for how the V&V activities should be conducted during different phases of system and software development. It also ensures traceability and quality assurance, which increases the credibility of this V&V management plan. The standard has been tailored to this project since the standard itself is very general and is intended for projects of different sizes and criticality. Therefore, the content of the standard has been tailored by excluding certain phases and processes that have been deemed not relevant, because this project is mainly focused on requirements elicitation, system design and implementation, and testing. Some examples of this tailoring are the following:

- Disposal V&V is not relevant, as the project does not include the decommissioning of the system.
- Maintenance V&V, as the project does not include upgrades.

The use of IEEE Std 15288:™-2023 is to give an overall view of how the entire cycle works and is interconnected. This helps to outline and plan how and when V&V activities should be performed. Provides information on what is expected and what activities should be performed to meet the requirement. For IEEE Std 29119-1:™-2022, and IEEE Std 29119-4:™-2021, it has become necessary to provide a tool on how to perform the tests and which methods should be used. These standards are also tailored to this project.

4 Activities

4.1 Organisation

4.1.1 Roles and Responsibilities

The V&V process is divided into different stages, and each stage produces specific deliverables. Each deliverable is further divided into tasks that are assigned to different roles. These deliverables will be part of the overall verification and validation activities. Different roles will be responsible for executing the tasks that make up each deliverable, while the V&V management role will have the overall responsibility of ensuring that the deliverables are properly verified and validated.

The following table illustrates project roles and their corresponding colors, where the colors will be used to indicate which roles will be involved in the execution of a given task. Deliverables and the order of activities can be found in Figure 2 in the Appendix.

Role	**Color**
Requirements Manager (RM)	Blue
Chief Engineer (CE)	Yellow
Safety Manager (SM)	Red
Validation & Verification Manager (VVM)	Green
Quality & Configuration Manager (QCM)	Purple

Table 4: Shows the color coding for each role.

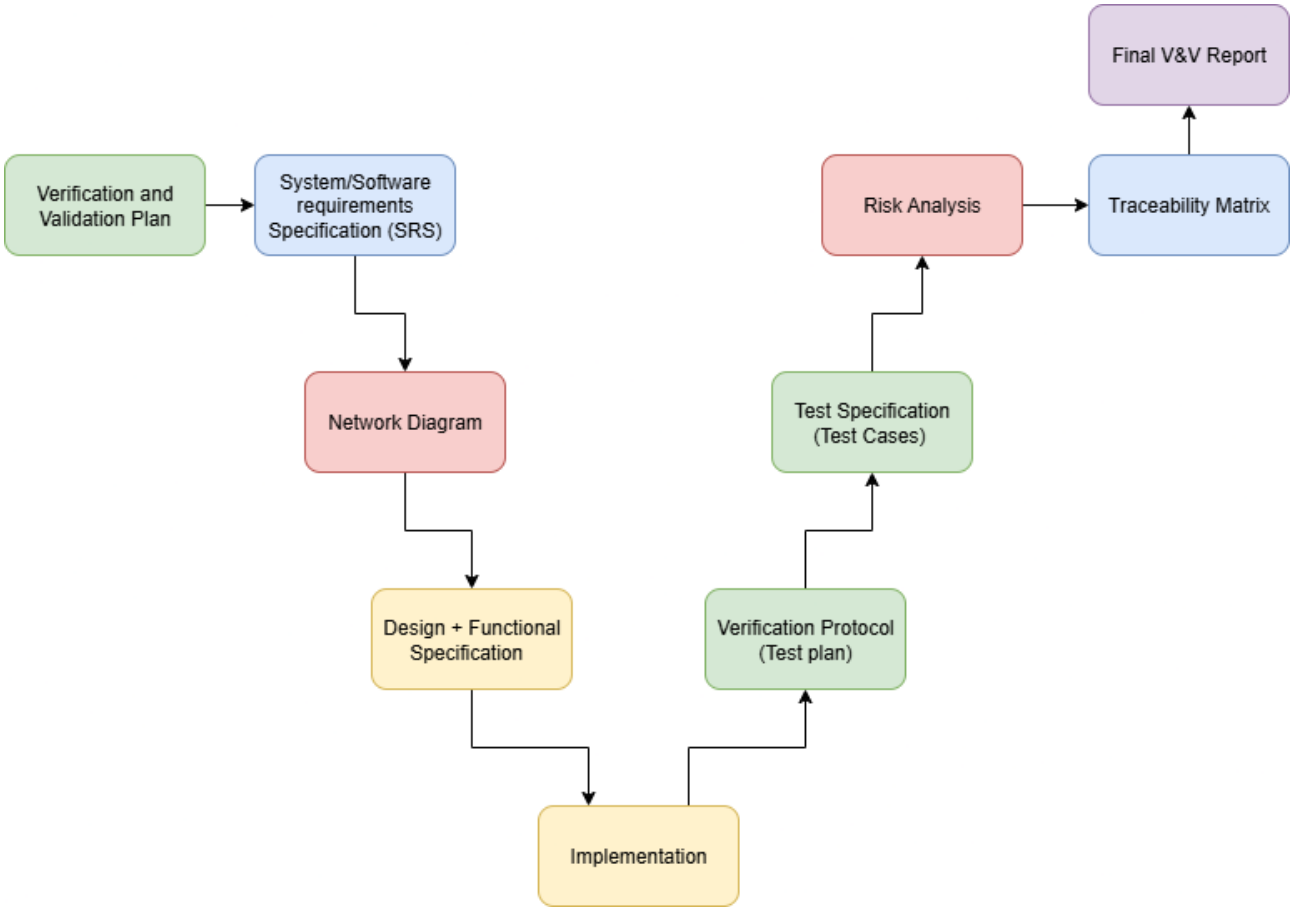

Figure 3: Shows how the roles are assigned in the process.*It is **important** to note that, although the traceability matrix is shown as the last item in the figure, this is not the case. It will be created in an early state, but it will be continuously updated throughout all the phases.*

4.2 Planning Phase

4.2.1 Planning

The planning phase establishes the foundation for the V&V process. During this phase, strategies and responsibilities are well defined to ensure that V&V activities are aligned with project objectives.

Activities (IEEE 1012-2024) [1]:

- Identify scope and objectives of V&V activities.
- Define V&V methods, techniques, and tools.
- Establish roles, and responsibilities.

Artifacts:

- Requirements *(to be defined in the SRS during the execution phase).*

Deliverables:

- V&V Management Plan.

NOTE: During the planning phase, references will be made to the System Requirements Specification (SRS). It is important to note that during the planning phase, the SRS does not yet exist, as the requirements will be defined in the execution phase. Once the requirements have been determined and documented in the SRS, they will be subject to verification and validation according to this V&V plan, and the SRS will serve as the basis for test planning, traceability, and all subsequent verification and validation activities. It is also important to remember that V&V activities are performed in parallel with all activities in the project, not just at their conclusion.

4.3 Execution Phase

4.3.1 Requirements

In the requirements phase, V&V activities are carried out to ensure that all the system requirements are complete, correct, and verifiable.

Activities (IEEE 1012-2024) [1]:

- Traceability analysis.
- Risk analysis.
- Requirements Review.
- Stakeholder needs and requirements evaluation.

Artifacts:

- Requirements specification (TI-02, TI-03, TI-05 [2]).

Deliverables:

- Verification protocol.
- Traceability Matrix.
- Risk Assessment.

4.3.2 Design

The design phase ensures that the system architecture meets the requirements and is feasible.

Activities (IEEE 1012-2024) [1]:

- Interface Analysis.
- Design Review.

Artifacts:

- Design Models.

Deliverables:

- Test Case.
- Network Diagram.
- System Design Verification protocol.

4.3.3 Implementation

During the implementation phase, it is verified that the code meets the design requirements.

Activities (IEEE 1012-2024) [1]:

- Drone Swarm (System) Analysis.

Artifacts:

- Test Cases.

Deliverables:

- Traceability Matrix.

4.3.4 Test

The testing phase ensures that the integrated system meets the requirements and functions correctly.

Activities (IEEE 1012-2024) [1]:

- Drone Swarm System V&V.

Artifacts:

- Simulations.

Deliverables:

- Test Case.

4.4 Reporting Phase

The final phase concludes the verification and validation (V&V) activities by finalizing all planned activities, reviewing results, and documenting the overall results. The results of this phase provide evidence that the V&V process has been successfully executed and serve as a formal basis for the closing of the project.

Activities (IEEE 1012-2024) [1]:

- Final Report.

Artifacts:

- All from previous phases.

Deliverables:

- Test Specification.
- Final Report.

References

[1] "Ieee standard for system, software, and hardware verification and validation," *IEEE Std 1012-2024 (Revision of IEEE Std 1012-2016)*, pp. 1–309, 2025.

[2] A. Haglund, *Project Plan*, Intelligent Replanning Drone Swarm, Sep. 30 2025, Version 1.0.

[3] "Iso/iec/ieee international standard - software and systems engineering –software testing –part 1:general concepts," *ISO/IEC/IEEE 29119-1:2022(E)*, pp. 1–60, 2022.

[4] "Ieee/iso/iec international standard - software and systems engineering–software testing–part 4: Test techniques," *ISO/IEC/IEEE 29119-4:2021(E)*, pp. 1–286, 2021.

[5] "Systems and software engineering — system life cycle processes," *ISO/IEC/IEEE 15288, May 2023*, pp. 1–77, 2023.