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Test Specification

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DOCUMENT APPROVAL

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Version	Date	Reason for Change	Pages / Sections Affected
0.1	2025-11-30	First draft	
1.0	2025-12-05	Version for public release	All

Contents

Glossary

Black-box testing
A software testing method where the tester evaluates functionality without knowing the internal code or structure.. 6

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

Test Case
A set of inputs, execution conditions, and expected results used to verify a specific function.. 7

UAV
Unmanned Aerial Vehicle. 5

UPPAAL
A verification tool used for modeling, simulating, and verifying real-time systems based on timed automata.. 6

1 Introduction

1.1 Purpose

The purpose of this test specification is to describe the test cases and results used to verify the highest-priority requirements of the project, with a focus on Drone Swarm Requirements. The document defines the test methodology, test environment, and traceability to ensure that the replanning protocol meets the core requirements. The tests are designed to support the overall V&V process as outlined in the V&V Plan (VV-01) and adhere to the relevant principles from IEEE Std 29119-4:™-2021 regarding test techniques and documentation structure.

1.2 References

The following documents are directly related to this Test Specification Report:

ID	**Title**	**Ref nr**
VVP-01	Test Case Drone Swarm Requirements Matrix	According to the Google Sheets document created by Zainali (2025)
VV-01	Validation & Verification Management Plan	[1]
RM-03	Requirements Specification Guide	[2]
IEEE Std 29119-4:™-2021	IEEE Standard for the Software testing Part 4: Test techniques	[3]
MDU-C2	Project database (Github)	[4]

Table 1: Table on the related documents.

2 Scope

This test specification only includes test cases for the overall Drone Swarm Requirements, as these represent the highest level of functionality and form the basis for the system and subsystem requirements. Due to the time constraints of the project, individual test cases for system and subsystem requirements have not been included. These requirements are addressed indirectly by being derived from the overall drone swarm requirements. Verifying these core requirements ensures that the central replanning logic fulfills its primary purpose.

2.1 The following is included in the testing:

- Functionality related to Unmanned Aerial Vehicle (UAV) degradation.
- Replanning and task allocation.
- Mission behavior in simulated scenarios.

2.2 The following are not included:

- Low-level control of UAV hardware.
- Stress and performance testing outside of replanning.
- Physical testing (simulation only).

3 Methodology

The testing is based on a combination of scenario-based simulation and formal model checking. These methods were chosen to effectively verify the highest priority Drone Swarm Requirements and to evaluate the system's replanning logic under various operational conditions.

3.1 Test Methodology

The tests are primarily conducted as black-box tests where the system's behavior is evaluated based on defined requirements, without directly inspecting the implementation. The following test techniques are used:

- **Scenario-based testing**: Simulation of operational missions where one or more UAVs are degraded and the system must reallocate tasks.
- **Black-box testing**: Evaluation of system response based on test input and expected outcomes.
- **Model checking**: Used to verify that the replanning protocol is robust against a Byzantine fault, if one of the drones behaves unpredictably or sends inconsistent messages.

The methodology is chosen to be time and resource efficient while addressing the most critical functions of the replanning protocol. Since the project uses hierarchical requirements, it is sufficient to focus on overall drone swarm requirements, as these drive the underlying system and subsystem requirements.

3.2 Test Environment

All tests are performed in a controlled simulation environment, which enables reproducible and safe testing of swarm behaviors without physical UAVs. The test environment consists of:

3.2.1 Simulation platform

- **gym-pybullet-drones**: Used to simulate swarm flight behavior, degradation of individual UAVs, and replanning scenarios.
- Modified Python scripts to configure and create test scenarios.

3.2.2 Formal verification

- **UPPAAL**: Used to verify state transitions and correct consensus behavior in the replanning logic for byzantine faults.

4 Test Case

The Test Case themselves are collected in the test case matrix VVP-01, which is the primary artifact. VVP-01 contains each test case ID, associated requirements, description, test environment, test steps, expected results, and evidence. This matrix serves as a reference for all test cases described below.

Test Case TC-SW01:

Objective	That when a task can be performed by multiple agents, the agent that has the optimal (closed one with the highest budget) available capacity is selected.
Related Requirement	SW-01
Expected Test Result	The task is assigned to the agent that meets the requirement and has the highest available capacity within range.
Procedure	1. Chose number of agents. 2. Chose the desired grid size. 3. Run simulation. 4. Press Start Search button.
Pass/Fail Criteria	If it satisfy the expected test result → Pass. If it does no satisfy the expected test result → Fail.

Test Case TC-SW02:

Objective	The system's error shall be able to handle when an agent's tasks cannot be allocated.
Related Requirement	SW-02
Expected Test Result	The system shall detects that the agent is not performing the task, so it is assigned to the another agent.
Procedure	1. Chose number of agents. 2. Chose the desired grid size. 3. Run simulation. 4. Start Search 5. Navigate to the Injection Agent Fault display. 6. Chose the desired drone to be degraded. 7. In Health Code chose nr 6 MOTOR_FAILURE. 8. Press Inject Fault button.
Pass/Fail Criteria	If it satisfy the expected test result → Pass. If it does no satisfy the expected test result → Fail.

Test Case TC-SW03.1:

Objective	That the agent is prioritizing down to a defined "less critical" task.
Related Requirement	SW-03
Expected Test Result	The agent will become a Communication relay.
Procedure	1. Chose number of agents. 2. Chose the desired grid size. 3. Run simulation. 4. Start Search 5. Navigate to the Injection Agent Fault display. 6. Chose the desired drone to be degraded. 7. In Health Code chose nr 3 SENSOR_FAILURE. 8. Press Inject Fault button.
Pass/Fail Criteria	If it satisfy the expected test result → Pass. If it does no satisfy the expected test result → Fail.

Test Case TC-SW03.2:

Objective	That proper handling when demotion renders the agent incapable of performing any task, including the less critical one.
Related Requirement	SW-03
Expected Test Result	It shall emergency land.
Procedure	1. Chose number of agents. 2. Chose the desired grid size. 3. Run simulation. 4. Start Search 5. Navigate to the Injection Agent Fault display. 6. Chose the desired drone to be degraded. 7. In Health Code chose nr 6 MOTOR_FAILURE. 8. Press Inject Fault button.
Pass/Fail Criteria	If it satisfy the expected test result $\rightarrow$ Pass. If it does no satisfy the expected test result $\rightarrow$ Fail.

Test Case TC-SW04:

Objective	That the system can handle one Byzantine fault, when one agent give one incorrect data to one agent.
Related Requirement	SW-04
Expected Test Result	It shall be able to handle one Byzantine fault.
Procedure	1. Send a error message.
Pass/Fail Criteria	If it satisfy the expected test result $\rightarrow$ Pass. If it does no satisfy the expected test result $\rightarrow$ Fail.

Test Case TC-SW05.1:

Objective	That the swarm reaches a unanimous consensus for a new task.
Related Requirement	SW-05
Expected Test Result	All agents shall be able to receive information about the new task and process the information and participate in the consensus protocol.
Procedure	1. Chose number of agents. 2. Chose the desired grid size. 3. Run simulation. 4. Press Start Search.
Pass/Fail Criteria	If it satisfy the expected test result $\rightarrow$ Pass. If it does no satisfy the expected test result $\rightarrow$ Fail.

Test Case TC-SW05.2:

Objective	That the swarm reaches a unanimous consensus when abort mission occurs.
Related Requirement	SW-05
Expected Test Result	All agents shall be able to receive the information and abort the mission.
Procedure	1. Chose number of agents. 2. Chose the desired grid size. 3. Run simulation. 4. Press Start Search. 5. Press Abort mission.
Pass/Fail Criteria	If it satisfy the expected test result $\rightarrow$ Pass. If it does no satisfy the expected test result $\rightarrow$ Fail.

Test Case TC-SW06.1:

Objective	That a swarm of N agents can partition a defined search region.
Related Requirement	SW-06
Expected Test Result	Each agent gets their own area (without overlap).
Procedure	1. Chose number of agents. 2. Chose the desired grid size. 3. Run simulation. 4. Press Start Search.
Pass/Fail Criteria	If it satisfy the expected test result → Pass. If it does no satisfy the expected test result → Fail.

Test Case TC-SW06.2:

Objective	That the swarm can successfully reconfigure the area division after an agent is lost.
Related Requirement	SW-06
Expected Test Result	The swarm shall start redistributing the area. The lost area is divided between the remaining agents.
Procedure	1. 1. Chose number of agents. 2. Chose the desired grid size. 3. Run simulation. 4. Start Search 5. Crash one drone.
Pass/Fail Criteria	If it satisfy the expected test result → Pass. If it does no satisfy the expected test result → Fail.

Test Case TC-SW07.1:

Objective	That a agent is allowed to make the independent decision to abort the mission and initiate an emergency landing.
Related Requirement	SW-07
Expected Test Result	The agent shall make an independent assessment that continuing is unsafe and decides to abort the mission by making an emergency landing.
Procedure	1. Chose number of agents. 2. Chose the desired grid size. 3. Run simulation. 4. Start Search 5. Navigate to the Injection Agent Fault display. 6. Chose the desired drone to be degraded. 7. In Health Code chose nr 6 MOTOR_FAILURE. 8. Press Inject Fault button.
Pass/Fail Criteria	If it satisfy the expected test result → Pass. If it does no satisfy the expected test result → Fail.

Test Case TC-SW07.2:

Objective	That a agent is allowed to make the independent decision to abort the mission and initiate an emergency safe state.
Related Requirement	SW-07
Expected Test Result	The agent shall make an independent assessment that continuing is unsafe and decides to abort the mission by going home.
Procedure	1. Chose number of agents. 2. Chose the desired grid size. 3. Run simulation. 4. Start Search 5. Navigate to the Injection Agent Fault display. 6. Chose the desired drone to be degraded. 7. In Health Code chose nr 1 LOW_BATTERY. 8. Press Inject Fault button.
Pass/Fail Criteria	If it satisfy the expected test result → Pass. If it does no satisfy the expected test result → Fail.

5 Test Results

The results of each test case are presented according to the test plan.

Test Result TC-SW01:

Execution date	2025-11-13
Actual Test Result	As Expected
V&V Method used	Simulation (dynamic testing)
Pass/Fail	Pass
Evidence ID	E-03

Test Result TC-SW02:

Execution date	2025-11-13
Actual Test Result	As Expected
V&V Method used	Simulation (dynamic testing)
Pass/Fail	Pass
Evidence ID	E-03

Test Result TC-SW03.1:

Execution date	2025-11-13
Actual Test Result	As Expected
V&V Method used	Simulation (dynamic testing)
Pass/Fail	Pass
Evidence ID	E-04

Test Result TC-SW03.2:

Execution date	2025-11-13
Actual Test Result	As Expected
V&V Method used	Simulation (dynamic testing)
Pass/Fail	Pass
Evidence ID	E-05

Test Result TC-SW04:

Execution date	2025-11-13
Actual Test Result	As Expected
V&V Method used	Model checking
Pass/Fail	Pass
Evidence ID	E-06 & E-07

Test Result TC-SW05.1:

Execution date	2025-11-13
Actual Test Result	As Expected
V&V Method used	Simulation (dynamic testing)
Pass/Fail	Pass
Evidence ID	E-08

Test Result TC-SW05.2:

Execution date	2025-11-13
Actual Test Result	As Expected
V&V Method used	Simulation (dynamic testing)
Pass/Fail	Pass
Evidence ID	E-09 & E-10

Test Result TC-SW06.1:

Execution date	2025-11-13
Actual Test Result	As Expected
V&V Method used	Simulation (dynamic testing)
Pass/Fail	Pass
Evidence ID	E-11

Test Result TC-SW06.2:

Execution date	2025-11-13
Actual Test Result	As Expected
V&V Method used	Simulation (dynamic testing)
Pass/Fail	Pass
Evidence ID	E-12

Test Result TC-SW07.1:

Execution date	2025-11-13
Actual Test Result	As Expected
V&V Method used	Simulation (dynamic testing)
Pass/Fail	Pass
Evidence ID	E-13

Test Result TC-SW07.2:

Execution date	2025-11-13
Actual Test Result	As Expected
V&V Method used	Simulation (dynamic testing)
Pass/Fail	Pass
Evidence ID	E-14

6 Traceability

Since traceability is managed in the project's database [4], the table below is a summary of the central links.

Requirement ID	**Test Case ID**	**Result**
SW-01	TC-SW01	Passed
SW-02	TC-SW02	Passed
SW-03	TC-SW03.1	Passed
SW-03	TC-SW03.2	Passed
SW-05	TC-SW05.1	Passed
SW-05	TC-SW05.2	Passed
SW-06	TC-SW06.1	Passed
SW-06	TC-SW06.2	Passed
SW-07	TC-SW07.1	Passed
SW-07	TC-SW07.2	Passed

7 Conclusion

The tests performed show that the highest priority Drone Swarm Requirements are met. The replanning function works according to specification, and the system exhibits correct behavior when degrading UAVs. All performed test cases have passed without deviations. System and subsystem requirements have not been tested individually within this test specification, but are indirectly covered by their derivation from the overall drone swarm requirements. Based on the results, it can be concluded that the system meets the central goals set for this phase of the project.

References

[1] E. Zainali, *VV Management Plan*, Intelligent Replanning Drone Swarm, Dec. 05 2025, Version 1.2.

[2] C. Namatovu, *Requirements Specification Guide*, Intelligent Replanning Drone Swarm, Nov. 28 2025, Version 1.1.

[3] "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.

[4] A. Haglund, C. Namatovu, E. Målqvist, E. Zainali, and Y. M. Beyene, *MDU-C2/Intelligent-Drone-Swarm, github.com*, Intelligent Replanning Drone Swarm, Nov. 3 2025, [Online]. Available: https://github.com/MDU-C2/Intelligent-Drone-Swarm.