

Enabling Secure Maritime Connectivity: MAIV of the MICE-1 CubeSat Mission

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Abstract— The increasing reliance of Maritime Internet of Things and Internet of Vessels applications on satellite connectivity places stringent requirements not only on system architecture and communications performance, but also on the robustness, manufacturability, and verification of spaceborne platforms operating in demanding environments. In this context, nanosatellite missions targeting maritime services must balance tight mass, volume, and cost constraints with high reliability, secure data handling, and rapid development cycles. The present work presents the Manufacturing, Assembly, Integration, and Verification approach adopted for MICE-1, a commercial CubeSat mission developed by Prisma Electronics to provide private, secure vessel-to-space communications integrated with the company’s LAROS remote monitoring platform. The work details the end-to-end MAIV flow, from subsystem manufacturing and acceptance through spacecraft-level integration, functional testing, and environmental qualification, tailored to support maritime-oriented mission requirements.

Keywords—nanosatellites, CubeSats, MICE-1, MAIV, Maritime IoT, Internet of Vessels (IoV)

I. INTRODUCTION

The maritime industry heavily relies on satellite communications for communication between vessel and shore, ship-to-ship coordination and the continuous exchange of operational, navigational, and safety-critical information [1]. As the sector undergoes rapid digital transformation—driven by remote monitoring, fleet optimization, and emerging Internet of Vessels (IoV) applications—the reliance on robust and dependable satellite links has become increasingly critical [2].

However, existing satellite communication solutions continue to face significant challenges, including limited bandwidth, high operational costs, and inconsistent global coverage, particularly in remote maritime regions [1]. Alternative communication technologies, such as terrestrial and 5G networks, are often unsuitable for open-sea operations or constrained in terms of capacity [3], [4]. In addition, latency and intermittent connectivity can negatively impact data transmission reliability and decision-support systems [5]. The maritime propagation environment introduces further challenges that may degrade link performance and create communication blind spots [6]. These technical limitations are compounded by growing cybersecurity concerns, as maritime communication systems are increasingly exposed to threats

such as interception, spoofing, and unauthorized access, necessitating robust end-to-end security mechanisms [7].

A number of CubeSat missions have been developed to support maritime applications, primarily focusing on Automatic Identification System (AIS) data collection, including ESAIL [8], M3MSat [9], and the AISat/NorSat missions [10]. While effective for vessel tracking, these missions provide limited flexibility for broader maritime services. Similarly, satellite-based IoT missions such as LacunaSat [11] and Sateliot [12] offer generic connectivity solutions, while initiatives like the MARIOT project aim to enable dedicated maritime IoT services [13]. Nevertheless, these approaches do not fully address the need for secure, mission-specific, and tightly integrated communication architectures.

In this context, this work presents MICE-1, a CubeSat-based solution developed by Prisma Electronics to provide private, secure, and globally accessible maritime communications through an S-band link. The paper focuses on the Manufacturing, Assembly, Integration, and Verification (MAIV) phase of the mission, which plays a critical role in ensuring that the spacecraft meets its functional, environmental, and operational requirements. The presented work highlights key implementation aspects of the MAIV campaign and provides lessons learned that contribute to reducing development risk and improving the reliability of future maritime CubeSat missions.

II. LAROS IoT/IoV SYSTEM DESCRIPTION

LAROS is an integrated Internet of Things (IoT) and Internet of Vessels (IoV) platform developed by Prisma Electronics S.A. for the remote monitoring and analysis of vessel operational parameters. The system comprises in-house developed hardware, embedded software, and application-level software that enable onboard data acquisition, transmission to the shipping company’s headquarters, as well as data storage, visualization, and analysis. LAROS has been widely adopted by numerous shipping companies worldwide as a versatile solution offering diagnostic, prognostic, and early warning capabilities through the analysis of key vessel parameters. By leveraging these capabilities, it supports improved safety and operational efficiency at both fleet and individual vessel levels [14]. The overall architecture of LAROS is illustrated in Fig. 1.

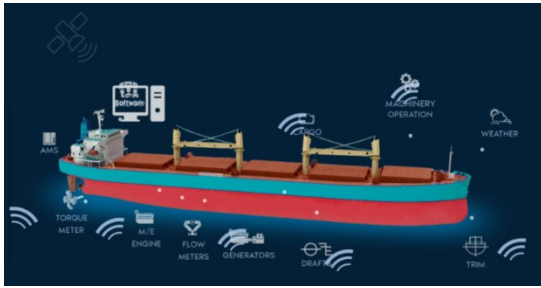


Fig. 1. MICE-1 MAIV plan Overview

Prisma Electronics S.A.’s extensive experience in the maritime sector is closely aligned with its expertise in the satellite communication challenges outlined in the Introduction. This stems from the fact that LAROS relies on existing vessel satellite communication channels to transmit operational data to shore. Building on this experience, the concept emerged to develop a private and secure satellite communication channel tailored to the maritime industry which, if extended into a constellation, could also address connectivity gaps in coverage of “blind spots.” Furthermore, this approach presents an opportunity to enable global vessel monitoring while enriching the already extensive LAROS dataset with additional information sources, such as Automatic Identification System (AIS) data collected worldwide. In [15], the mission and spacecraft design has been presented. The present work, being a follow-up to this, presents the MAIV process followed for MICE-1.

III. MICE-1 MAIV OVERVIEW

A. MAIV Plan

Fig. 2 provides an overview of the MAIV activities performed for the MICE-1 mission. The tests are color-coded according to their category, while every other operation on the spacecraft is represented by a white background box.

Even though each MAIV phase can be presented in great detail, with several sub-activities for each one of the presented activities, a very detailed plan presentation exceeds the scope of the present work.

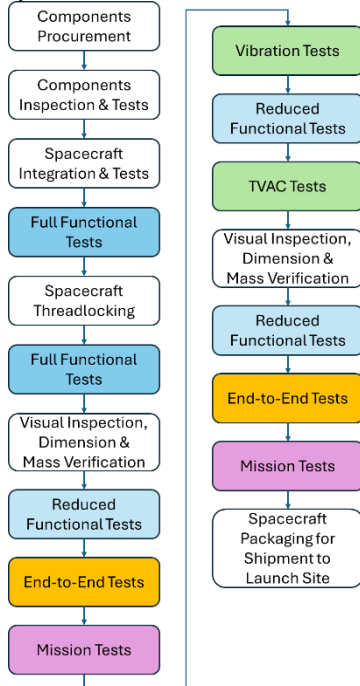


Fig. 2. MICE-1 MAIV plan Overview

The tests performed on the spacecraft are presented in more detail in the following sub-section.

B. Test Overview

The following categories of tests have been performed for the mission as part of its MAIV campaign. They are divided into five (5) general categories, with each one further divided into several sub-categories. In the present work, a more general, yet complete overview of the tests performed is presented.

- Full Functional Tests (FFT). These tests aim at testing the entire set of functionalities of the spacecraft, from the simplest ones involving each spacecraft component individually to more complicated ones involving the entire spacecraft. FFTs have been performed during the following MAIV campaign major internal milestones: after spacecraft integration and during the TVAC testing during both on the hot and cold operational plateaus.
- Reduced Functional Tests (RFT). The Reduced Functional tests are a subset of the FFT and aim at testing the core functionalities of the spacecraft. They are often performed when limited time is available for testing or when a full set of functional tests is not necessary, such as prior to and after each individual environmental test.
- End-to-End Tests (E2ET). They are designed to test the communication between the spacecraft and any ground equipment that is going to be employed for the mission.
- Mission Tests. The purpose of the Mission Tests is to verify that the spacecraft is going to perform nominally during all phases of its mission and transition seamlessly between them. They also involve the ground station equipment of the mission but they are mostly oriented towards testing the functionalities at each mission stage and the effective transition between the different mission phases.
- Environmental Tests (EVT). The purpose of the EVT is to verify that the spacecraft is going to survive in the harsh launch and space environments and is going to function properly at all phases of the mission.

C. Standards Compliance

The mandatory ECSS and ISO standards associated with any MAIV campaign were also followed during the MICE-1 MAIV campaign and are presented in Table I.

TABLE I. MAIV CAMPAIGN STANDARDS

MICE-1 MAIV Standards	Standard Followed	Standard Scope
1	IPC-A-600	Acceptability of printed boards
2	IPC-A-610E	Acceptability of Electronic Assemblies
3	J-STD-001	Requirements for Soldered Electrical and Electronic Assemblies
4	J-STD-020	Moisture/Reflow Sensitivity Classification of Plastic Surface Mount Devices

MICE-1 MAIV Standards	Standard Followed	Standard Scope
5	IPC-7530	Guidelines for Temperature Profiling for Mass Soldering (Wave and Reflow) Processes
6	J-STD-033	Packaging and Handling of Moisture Sensitive Non-Hermetic Solid State Surface Mount Devices
7	ISO 14644	Cleanrooms and associated controlled environments
8	IEC 61340	Electrostatics ESD: Protection of electronic devices from electrostatic phenomena
9	IPC-7525B	Stencil Design Guidelines
10	ECSS-E-ST-20-08C	Photovoltaic assemblies and components

IV. ASSEMBLY AND INTEGRATION

As presented in Fig. 2, after the procurement of all spacecraft components, the spacecraft integration commenced, alongside the integration testing that follows each integration stage and each component that is added to it. After the spacecraft was fully integrated and tested by performing a full set of FFT, it was threadlocked and then tested again by performing another set of functional tests. Pictures of the finalized spacecraft are presented in Fig. 3.

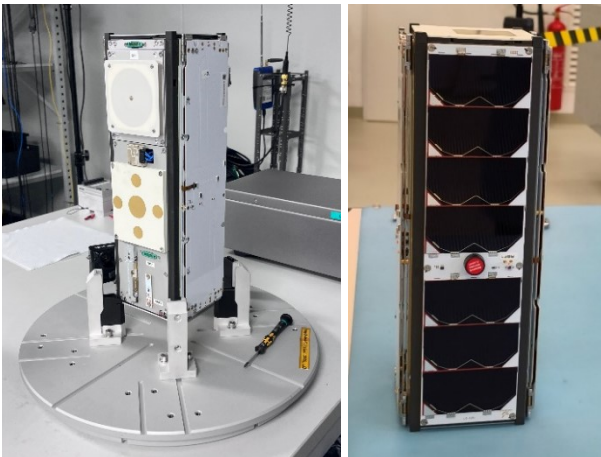


Fig. 3. Fully Integrated MICE-1 Spacecraft

A. Mass and Dimensions Verification

The Mass and Dimensions Verification was performed after the final spacecraft integration and threadlocking. The results are shown in Table II:

TABLE II. RESULTS OF MASS AND DIMENSIONS VERIFICATION

Mass and Dimensions Verification Results	Requirement (based on deployer)	Result
Confirm that the external dimensions of the satellite are within the requirements	X: 100 mm \pm 0.1 mm	Confirmed satellite external dimensions are within the requirements
Make sure the protrusion of the roller switches from the structure makes good contact with the rails of the TestPod/Deployer Measure the protrusion	Protrusion Measurement: min. +1.5 mm	Roller switches protrusion presents a good degree of freedom with no observable blockages. Protrusion measured: RSW1: 2.3 mm \times 1.5 mm RSW2: 2.1 mm \times 1.5 mm
Measure the satellite mass and compare with the requirements	Mass: 8 kg	Mass: 4875 grams

V. FUNCTIONAL TESTING

The functional tests, either full or reduced, can be further divided into the following sub-categories:

- Bus-Level Tests, which verify that the bus is assembled correctly and every module is properly connected and performing as expected.
- ADCS Functional Tests is an important category of bus-level tests, that verify that the Attitude Determination and Control System (ADCS) performs as expected and will effectively be able to control the spacecraft orientation when in orbit.
- Payload Level Tests that verify the proper functionality of the spacecraft payloads while functioning either as standalone units or as part of the entire spacecraft system and they are interacting with the other spacecraft components.
- Stability Tests, which is the repetition of the functional tests several times to verify the repeatability of the test results and the spacecraft behavior while performing all its functionalities. It also helps with the detection of faults and bugs associated with the long-term operation of the spacecraft.
- Encryption Tests, focusing on data encryption and decryption to ensure secure data transfer between satellite and ground segment

VI. ENVIRONMENTAL TESTING

The environmental tests performed for the mission were divided into two types: Vibration tests and Thermal Vacuum Chamber (TVAC) tests. The EVT levels were dictated by the launch provider, i.e.: SpaceX. Since the spacecraft would be encapsulated in a launch pod, it was considered to be fully containerized [16]. The EVTs are presented in detail in the following sub-sections:

A. Vibration Tests

The Vibration test campaign was performed at ESA's facilities, at ESTEC, the Netherlands and followed the same process for each of the three axes of the spacecraft: an initial resonance search was conducted before the random vibration to determine the resonant frequencies of the spacecraft. Then, the random vibration testing was conducted, followed by another resonance search to prove that the random vibration testing had not affected the resonant frequencies of the spacecraft and/or that no structural defect occurred during the testing. Table III presents the resonance search test requirements.

TABLE III. RESONANCE SEARCH TEST LEVELS

Resonance Search Test Levels		Duration	Number of Applications
Frequency [Hz]	Level [g]		
5	0.2	2 oct/min	1 on each of 3 orthogonal axes before all other tests are commenced and 1 on each of 3 orthogonal axes after the remaining tests are completed
20			
50			

Resonance Search Test Levels		Duration	Number of Applications
Frequency [Hz]	Level [g]		
700			
800			
925			
2000			

Table IV summarizes the random vibration test levels.

TABLE IV. RANDOM VIBRATIONS TEST LEVELS

Random Vibrations Test Levels	ASD during the first Random Vibration Test Campaign [g ² /Hz]	ASD during the second Random Vibration Test Campaign [g ² /Hz]
Frequency [Hz]		
20	0.02	0.01
50	0.03	0.015
700	0.03	0.015
800	0.06	0.03
925	0.06	0.03
2000	0.01288	0.00644
GRMS	5.57	

The following tolerances were considered acceptable for the tests:

Sinusoidal vibration:

- Frequency (5Hz to 2000Hz): +/-2% (or +/-1Hz whichever is the greater)
- Amplitude (g): +/-10%
- Sweep rate: +/-5%

Random vibration:

- Amplitude PSD, frequency resolution better than 10Hz
 - 20Hz-100Hz: -1dB/+3dB
 - 100Hz-2000Hz: +/-3dB
- Overall amplitude RMS: +/-10%

Test duration: -0%/+10%

Fig. 4 presents the results of the random vibration test campaign:

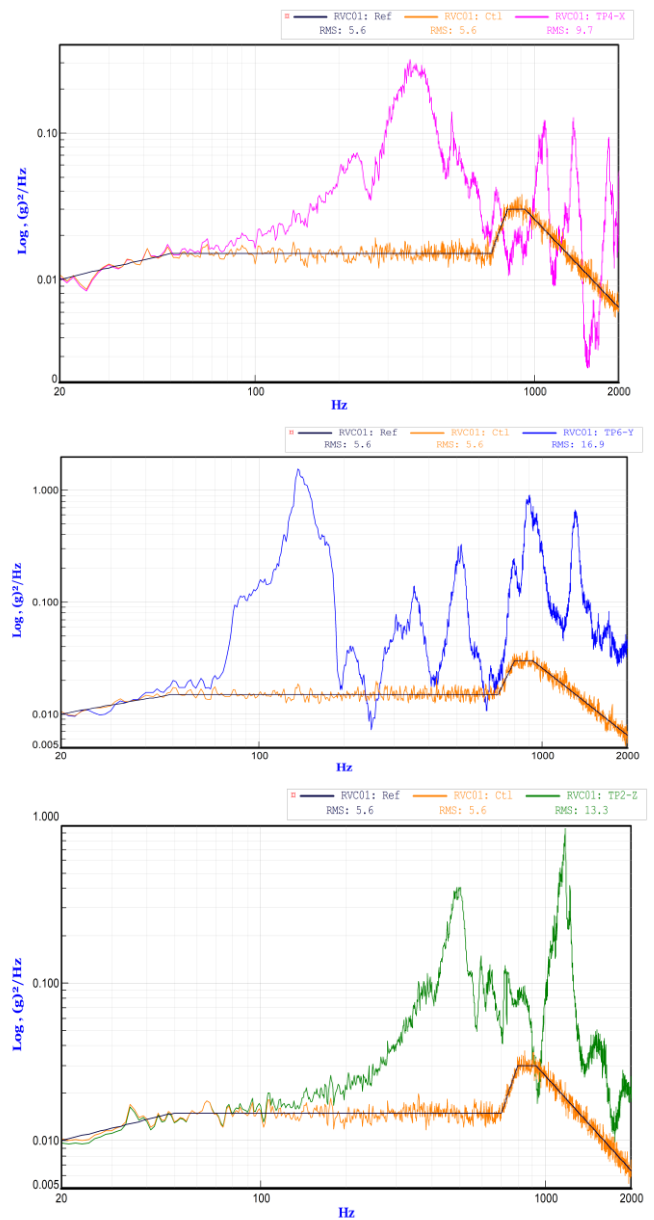
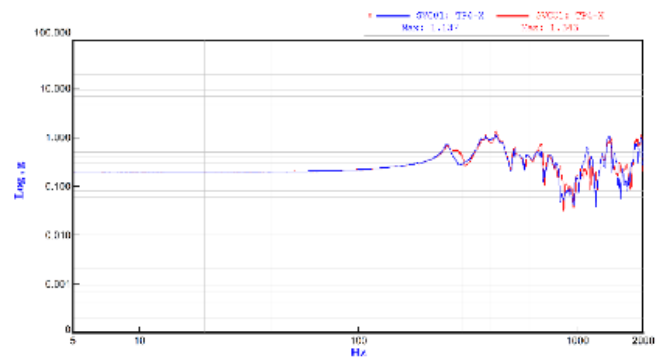


Fig. 4. Results of the Random Vibration Test for x, y and z-axis

Fig. 5 presents the resonance search results of the second random vibration test campaign:



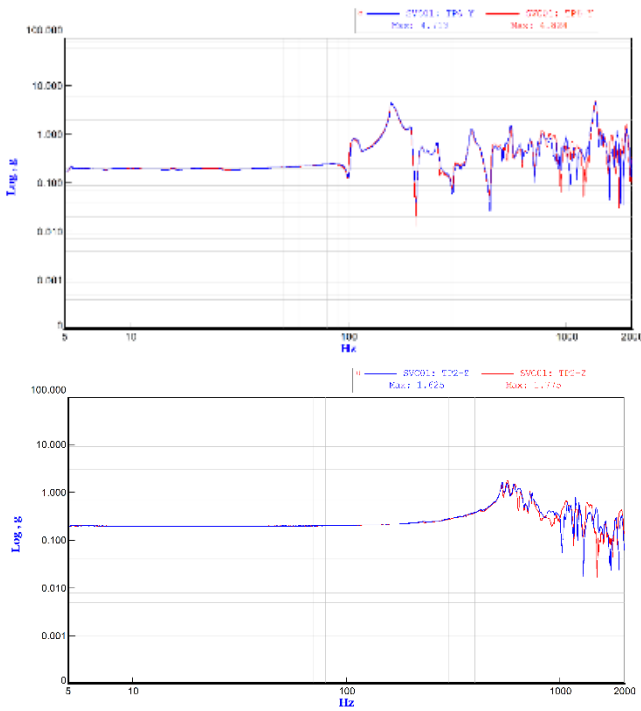


Fig. 5. Results of the Resonance Search Results for x, y and z-axis

Overall, the vibration test campaign was successful and demonstrated good structural integrity and robustness of the spacecraft. The resonant frequencies remained virtually the same before and after the random vibration tests.

B. TVAC Tests

The TVAC test campaign was performed at EnduroSat’s facilities, in Sofia, Bulgaria. Two different types of TVAC cycles were performed: non-operational cycles, corresponding to the launch phase, during which the spacecraft would be powered off and operational cycles, that correspond to the main, in-orbit mission phase, during which the spacecraft would be powered on. The TVAC test profile followed during the TVAC testing is presented in Fig. 6.

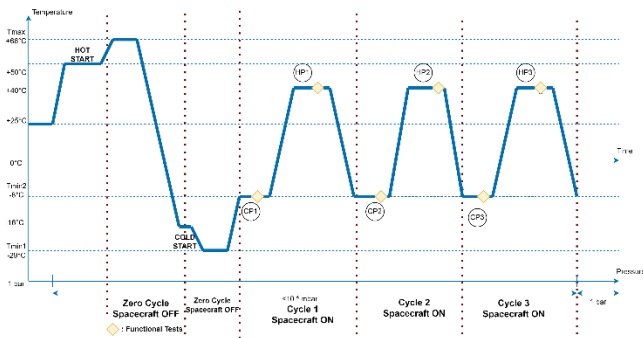


Fig. 6. Profile for the TVAC Test

The TVAC Test Profile included a single non-operational cycle, hot start and cold start, followed by three operational cycles. The non-operational cycle temperature limits were dictated by the launch provider [16]. The operational cycle temperature limits were dictated by the launch provider. The spacecraft reference temperature during TVAC was the Battery Pack temperature, as the most critical single point of failure component of the spacecraft. The operational cycle

test limits were dictated by the thermal analysis that had been performed during the spacecraft’s design phase. The following tolerances were considered tolerable for the TVAC tests:

- **Temperature:**
 - In cold temperature: $T_{min} -0^{\circ}C/+4^{\circ}C$
 - In hot temperature: $T_{max} -4^{\circ}C/+0^{\circ}C$
- **Pressure:** $\pm 80\%$
- **Test duration:** $-0\%/+10\%$

During the operational cycles, a set of RFTs was carried out to ensure proper functionality of the spacecraft during the extreme predicted hot and cold temperatures of the mission.

VII. LESSONS LEARNED

In the present section, the lessons learned associated with the mission’s MAIV campaign are presented.

Regarding the MAIV campaign, one of the key lessons learned is to define early the Environmental Verification Tests (EVTs) that will be required, preferably before the Design Review (DR) or Preliminary Design Review (PDR). It is important to consult the launch provider at this stage and ensure that all required tests are identified, including, but not limited to, Thermal Vacuum (TVAC) and magnetic tests. Even when the required tests have been identified, it is strongly recommended to reconfirm them with the launch provider to ensure completeness and correctness, as late-stage discrepancies may introduce significant risks to the mission.

In addition, it is crucial to carefully select the facilities and teams that will support the MAIV campaign, especially when external services are involved. A thorough evaluation should be performed by requesting documentation from previous missions, verification reports, and evidence of compliance with relevant standards, such as ECSS. It is also important to request detailed information regarding their MAIV processes, including indicative test flows, procedure templates, expected EVT limits, and sensor placement strategies. Ensuring that these capabilities are clearly documented helps guarantee that all necessary verification evidence can be provided to both the launch provider and the stakeholders.

Furthermore, it is advisable to ensure, preferably through contractual agreements, that the mission team retains the ability to intervene in the MAIV process, perform additional tests if required, and have full visibility over all procedures.

From an operational perspective, it is essential to define a detailed plan prior to initiating any MAIV procedure, covering all stages from assembly to functional testing and environmental verification. When multiple teams are involved, this plan should be shared among all parties or requested from the responsible entity, ensuring alignment and coordination. While flexibility is required to accommodate facility schedules, it is important to guarantee that the minimum required verification activities are always performed. If these cannot be achieved, rescheduling should be considered.

Finally, during the execution of MAIV procedures, caution should be exercised at every step. In case of uncertainty regarding any aspect of a procedure, such as sensor placement, spacecraft configuration, or test limits, it is advisable to pause and reassess rather than proceed under uncertainty. Careful evaluation, documentation of the situation, and discussion within the team can help prevent errors. Similarly, if any anomaly or unexpected behavior is observed during testing, the test should be halted immediately and all involved parties should be informed. Testing should only resume after ensuring that no risk is posed to the device under test. This cautious approach helps avoid potential damage and ensures the integrity of the verification campaign.

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VIII. CONCLUSIONS

This work presented the Manufacturing, Assembly, Integration, and Verification (MAIV) approach adopted for MICE-1, a commercial CubeSat mission developed by Prisma Electronics to enable private and secure vessel-to-space communications integrated with the LAROS remote monitoring platform. The entire MAIV process was outlined, covering subsystem manufacturing and acceptance, spacecraft-level integration, functional verification, and environmental qualification, all tailored to the specific requirements of maritime applications.

The implementation of the MAIV campaign highlighted several key challenges associated with CubeSat development under commercial constraints. Particular emphasis was placed on ensuring compliance with launch provider requirements and maintaining sufficient documentation and traceability throughout the process.

The lessons learned from the MAIV phase demonstrate the importance of a structured and proactive approach to integration and verification. Early planning of environmental testing and clear definition of operational and testing procedures were identified as critical factors for reducing risk and avoiding late-stage redesigns or delays.

Overall, the experience gained from the MICE-1 MAIV campaign provides valuable insights for future Maritime CubeSat missions, particularly those aiming to deliver secure and mission-specific communication services. The presented approach contributes to improving development efficiency, enhancing system reliability, and supporting the successful deployment of small satellite solutions in the maritime domain.

The authors aim to continue sharing their experience and even more valuable lessons learned from the entire mission in their future works, while aiming at designing, developing and successfully operating a follow-up mission to MICE-1.

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