

Development and In-Orbit Demonstration of CubeSats with Optical Communication Terminals and Upgrades of Optical Ground Stations for the Greek National Satellite Space Project

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ABSTRACT

Five in-orbit demonstration (IoD) CubeSat missions featuring optical communications and imaging capabilities have been designed, integrated, qualified and launched by small and medium-sized companies and universities across Greece. Three of these also carry compact imagers for Earth observation or resilience applications. The missions form part of the Greek National Satellites Space Project, initiated by the Greek Ministry of Digital Governance, funded by the European Commission via the Recovery and Resilience Facility (RRF), and implemented by ESA's Directorate of Connectivity and Secure Communications (D/CSC). This paper describes the missions, some assembly, integration and verification (AIV) activities carried out with ESA support, pre-launch optical alignment procedures, and selected post-launch results for the OptiSat and ERMIS-3 missions. In parallel, ESA is supporting the upgrade of three Greek observatories into optical ground stations (OGS) to perform optical communication tests with the satellites.

Keywords: optical communications, CubeSat, in-orbit demonstration, free-space optical links, optical ground station, optical alignment, Greek National Satellites Space Project

1. INTRODUCTION

The proliferation of small satellite platforms has opened new possibilities for demonstrating optical free-space communications technology at low cost and with rapid iteration cycles. CubeSats offer compelling platforms for in-orbit demonstrations (IoD) of optical communication terminals, provided that their integration, pointing and verification challenges are adequately addressed.

The Greek National Satellites Space Project represents a programmatic framework of some breadth: seven CubeSat missions, spanning 3U to 8U form factors, developed by Greek universities and industry, each carrying one or more advanced payloads including optical communication terminals, compact imagers, and hyperspectral sensors. The programme is initiated and funded by the Greek Ministry of Digital Governance through the European Commission's Recovery and Resilience Facility and implemented by ESA's Directorate of Connectivity and Secure Communications (D/CSC). ESA's role spans program management, design and development support, AIV assistance, and coordination with optical ground stations.

This paper describes the five missions carrying imagers and optical communication terminals, and ESA-supported AIV activities such as pre-launch optical alignment measurement, and post-launch performance results for ERMIS-3 and OptiSat. A description of the parallel upgrade of three Greek observatories into optical ground stations is also provided.

2. PROGRAMME OVERVIEW

The Greek National Satellites Space Project encompasses seven CubeSat missions. Five carry optical communication terminals; three carry compact imagers. Table 1 summarises the five OCT-bearing missions discussed in this paper.^{6,7}

Table 1. Greek National Satellites Space Project — OCT missions summary.

Mission	Size	Prime Contractor	Payload(s)	Launch
OptiSat	6U	Planetek Hellas	SCOT20 OCT (Tesat)	Transporter 16
PeakSat	3U	Aristotle University Thessaloniki	ATLAS-1 OCT (Astrolight)	Transporter 16
DUTHSat-2	6U	Democritus University Thrace	Dual Band Imager for monitoring of soil moisture and marine pollution	Transporter 14
ERMIS	6U/8U	National & Kapodistrian University of Athens	ATLAS-1 OCT (Astrolight) on ERMIS-3 satellite High resolution (5m GSD) hyperspectral camera	Transporter 16
Hellenic Space Dawn	8U ×2	EMTECH	CubeCat OCT (AAC Clyde Space) on SELENE and HELIOS satellites High resolution (16m GSD) Earth observation cameras	Transporter 16.5

3. MISSION DESCRIPTIONS

3.1 OptiSat

OptiSat is a 6U CubeSat led by Planetek Hellas. Its primary objective is the demonstration of secure optical free-space communication and space-based data processing. The spacecraft carries the SCOT20 optical communications terminal provided by Tesat, a compact terminal designed for LEO-to-ground optical links with heritage from Tesat's larger LEO and GEO programmes. OptiSat was launched on SpaceX Transporter 16.^{2,3}

3.2 PeakSat

PeakSat is a 3U CubeSat led by Aristotle University of Thessaloniki. It is intended to demonstrate laser-optical links with ground stations in Greece and carries the ATLAS-1 optical communications terminal from Astrolight. The 3U form factor imposes stringent volume and mass constraints on integration of both the platform and the optical communication terminal.

3.3 DUTHSat-2

DUTHSat-2 is a 6U CubeSat led by Democritus University of Thrace. It carries a visible and near-infrared imager for oil spill detection and soil moisture monitoring and was launched on SpaceX Transporter 14.

3.4 ERMIS Constellation

The ERMIS constellation, led by the National and Kapodistrian University of Athens, consists of three CubeSats: two 6U units (ERMIS-1, ERMIS-2) and one 8U unit (ERMIS-3). The constellation targets IoT applications, inter-satellite radio communications, hyperspectral imaging for precision agriculture, and optical communications. ERMIS-3 carries an ATLAS-1 optical communication terminal and a hyperspectral imager and is described in further detail in Section 4.2.

3.5 Hellenic Space Dawn

Hellenic Space Dawn, led by EM Tech, comprises two 8U CubeSats (SELENE and HELIOS) supporting in-space data processing hardware validation, Earth observation, and demonstration of inter-satellite links and secure optical communications. Both platforms carry a CubeCat optical communication terminal from AAC Clyde Space, and an optical imager consisting of an imager from by ScanWay.

4. SELECTED MISSIONS IN DETAIL

4.1 OptiSat

OptiSat carries the Tesat SCOT20 terminal, designed to establish optical downlinks to a ground station receiver, with the spacecraft attitude control system providing coarse pointing and the terminal's internal beam-steering mechanism providing fine pointing. The 6U platform provides sufficient volume to accommodate the SCOT20 alongside the spacecraft bus subsystems, though integration required careful management of the thermal dissipation requirements of the terminal.³

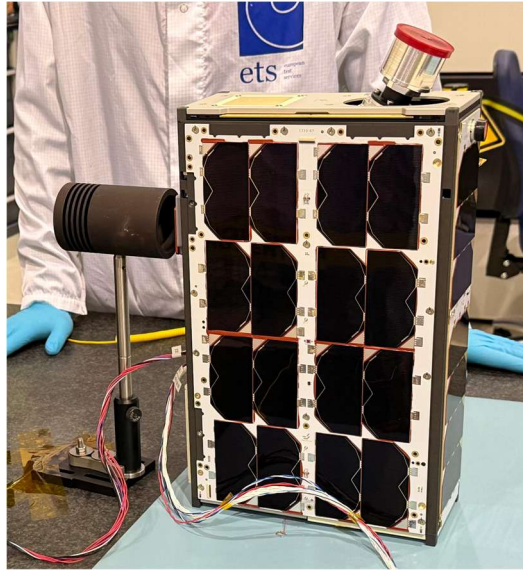


Figure 1. OptiSat spacecraft with the SCOT20 optical communications terminal (Tesat).

4.2 ERMIS-3

ERMIS-3 is an 8U cubesat of the ERMIS constellation. It combines two optical payloads: a hyperspectral imager from SimeraSense for land monitoring, and the ATLAS-1 optical communications terminal from Astrolight operating at 1550 nm. The ATLAS-1 terminal receives an acquisition beacon at 808 nm and transmits a data downlink at 1.25 Gbps.

The co-location of the hyperspectral imager and the ATLAS-1 terminal on a single platform poses a pointing challenge: the spacecraft attitude must be reconciled between Earth-pointing for imaging and ground-station-pointing for optical communications. The mission addresses this through separate, non-overlapping observation windows for each payload.

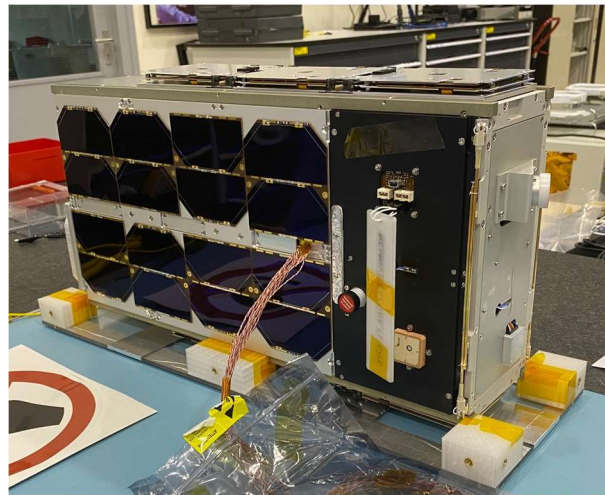


Figure 2. ERMIS-3 spacecraft with the ATLAS optical communications terminal and hyperspectral imager.

5. AIV AND PRE-LAUNCH OPTICAL ALIGNMENT

ESA provided AIV support throughout the integration and test campaigns. A key requirement across all missions is knowledge of the relative as-built orientation of the star tracker and the optical communication terminal with sufficient accuracy for the terminal to be correctly pointed toward the optical ground station using the spacecraft attitude solution. A boresight alignment accuracy target of 100 μ rad was aimed at for this programme.^{4,5}

Two complementary methods were proposed and applied across the missions. Both were carried out at initial spacecraft AIV and repeated after mechanical and after thermal-vacuum environment testing,¹ consistent with standard optical alignment practice.

5.1 3D Measurement Arm Method

This method relies on physical measurement of accessible reference surfaces on the star tracker and the OCT using a coordinate measuring arm. Reference surfaces are defined on both units prior to integration. Where the star tracker optical prism is not directly accessible from the spacecraft exterior, the manufacturer-provided alignment data between the prism and the external housing reference surface is used to propagate the boresight. After integration, the 3D arm measures the relative orientation of the two surfaces; the procedure is repeated after each environmental test stage. This method is accessible with standard AIV metrology equipment and does not require the spacecraft to be powered.

5.2 Optical (Theodolite) Method

The optical method directly measures the relative boresights of the star tracker and the OCT beacon using two theodolites. Each theodolite is first autocollimated to its respective optical reference surface to establish normal incidence. The theodolites are then pointed toward each other, and the angular difference between the two autocollimated normals yields the relative boresight misalignment. This method provides a direct boresight measurement but requires operational access to the star tracker prism, and to the beacon optical surface.

5.3 Alignment Measurement Results

Table 2 summarises the as-built (design) and measured pitch and roll misalignment angles between the star tracker and optical communication terminal boresights for OptiSat and ERMIS-3, obtained using the methods described in Sections 5.1 and 5.2.^{4,5}

Table 2. Star tracker to OCT boresight misalignment: as-designed vs. measured values.

Mission	Method	Measurement	Designed Pitch [degrees]	Designed Roll [degrees]	Measured Pitch [degrees]	Measured Roll [degrees]
OptiSat	3D arm	Post-TVAC	90	65	89.946	65.071
ERMIS-3	Theodolite	Pre-TVAC	104	14	104.273721	14.272326
		Post-TVAC	104	14	104.274105	14.274686

6. POST-LAUNCH RESULTS

OptiSat and ERMIS-3 were launched and commissioned ahead of this paper. The following subsections outline in-orbit demonstration results.

6.1 OptiSat — SCOT20 In-Orbit Performance

OptiSat was launched on SpaceX Transporter-16 on 30 March 2026 and is currently in its commissioning phase. Following successful deployment and initial contact, the satellite bus was verified nominal, and the SCOT20 optical communication terminal was powered on. The optical power amplifier (OPA) was activated and its output characterised across multiple commissioning passes, confirming stable operation at the 10 dBm design setpoint, as shown in Figure 3.

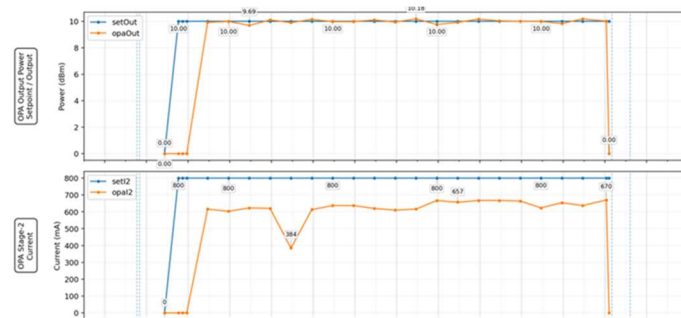


Figure 3. OptiSat optical power amplifier (OPA) commissioning sequence. Top: OPA output power setpoint and measured output, stabilising at 10 dBm. Bottom: OPA stage 2 current setpoint and measured current (~600–800 mA) X-axis: time in minutes.

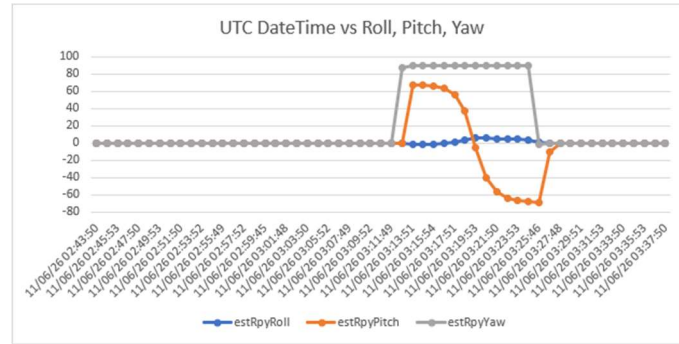


Figure 3b. OptiSat estimated roll, pitch and yaw angles during a commanded slew executed at ~03:12 UTC on 6 November 2026, targeting Almeria optical ground station. Pitch reaches ~65° and yaw steps to ~90° during the slew, before returning to nominal attitude. Roll remains near zero throughout. Optisat data is provided by Planetek Hellas.

Attitude control and target-pointing capabilities were validated through a commanded slew to the Almeria optical ground station at approximately 03:12 UTC on 11 June 2026. The manoeuvre, shown in Figure 3b, demonstrated the pitch and yaw slew required to point the SCOT20 terminal toward the ground station, with pitch reaching approximately 65° and yaw stepping to 90° before returning to the nominal attitude. Roll remained near zero throughout, consistent with a single-axis target-pointing sequence. Comparison of the in-orbit execution with the pre-planned simulation confirmed that the commanded sequence was executed as designed. Optical link acquisition tests will start soon.

6.2 ERMIS-3 — ATLAS Terminal In-Orbit Performance

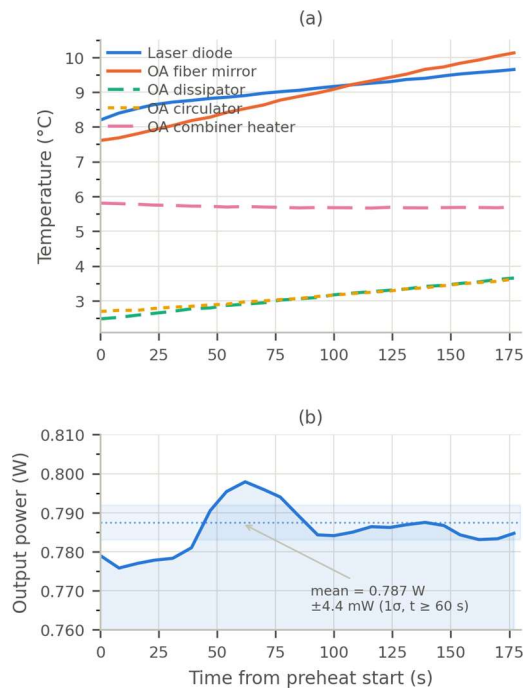


Figure 4. ATLAS-1 terminal preheat sequence on ERMIS-3 (2026-07-21). (a) Component temperature evolution during the 177 s preheat period. (b) Optical amplifier output power, stabilising at $0.787\text{ W} \pm 4.4\text{ mW}$ (1σ) for $t \geq 60\text{ s}$. ERMIS-3 data is provided by the National and Kapodistrian University of Athens

ERMIS-3 was also launched on SpaceX Transporter-16 on 30 March 2026 and is currently in its commissioning phase. Following deployment and initial contact, the spacecraft bus was confirmed nominal, and the ATLAS-1 optical communication terminal was powered on. The terminal’s pre-heat sequence was validated in orbit, with component

temperatures and optical amplifier output power evolving as expected, as shown in Figure 5. The optical amplifier output stabilised at $0.787 \text{ W} \pm 4.4 \text{ mW}$ (1σ) once thermal equilibrium was reached, consistent with ground characterisation results.

Attitude control and beacon acquisition sequences are under validation. The pre-launch optical alignment measurements — establishing the relative boresight between the star tracker and the ATLAS-1 terminal to within the $100 \mu\text{rad}$ programme requirement — provide the pointing knowledge base for the in-orbit acquisition campaign. Optical link acquisition attempts with the upgraded Greek optical ground stations will start soon.

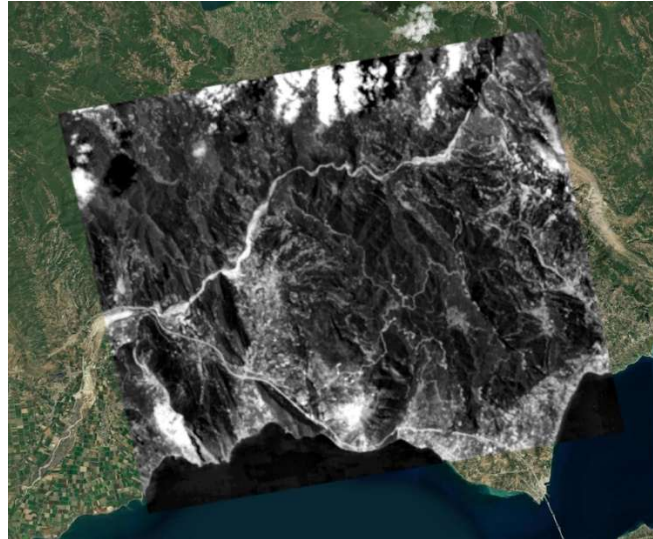


Figure 5. An image of the Antirrio region, Greece, captured by the ERMIS-3 hyperspectral imager on 27 June 2026 at 12:53:53 UTC. The image is overlaid on a reference map for georeferencing context. Satellite position at time of capture: 38.444°N , 21.877°E ; image centre: 38.409°N , 21.671°E ; off-nadir angle: 2.1° . The Gulf of Corinth and the coastal plain west of Antirrio are visible in the lower portion of the frame

7. GREEK OBSERVATORY UPGRADES TO OPTICAL GROUND STATIONS

In parallel with the CubeSat missions, ESA supported Greek companies (Raymetrics) and universities in the upgrade of three observatories to optical ground stations (OGS). The requirement was to support both optical and quantum communications. The three sites (Holomondas, Helmos and Skinakas) provide geographic diversity across Greece and enable multi-pass contact opportunities with the LEO constellation. The location of the OGS' is shown in Figure 6.

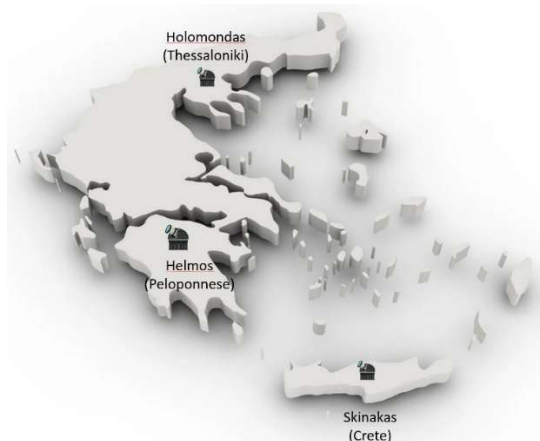


Figure 6. Locations of the three optical ground stations in Greece.

All three OGS are compatible with optical communication standards published by the space development agency (SDA) and the Consultative Committee on Space Data Systems (CCSDS). While the optical systems installed in the OGS' are transparent to any communication data rate, modulators, detectors and modems are limited to 2.5 Gbps.

The OGS design was initially driven by the requirement to be compatible with the optical and quantum communication terminal (SCOT80 from Tesat Spacecom) onboard the Eagle-1 satellite. The terminal provides a bi-directional data rate of 314 Mbps (according to SDA standard 2.1.2) and transmits a phase encoded quantum signal. The Eagle-1 satellite and its quantum transmitter development are managed by SES (Luxembourg) and supported by ESA.

The expected launch date of the Eagle-1 satellite is in 2028.

The optical and quantum communication receive equipment installed in all three OGS is based on Tilba-ATMO (Cailabs, France), an adaptive optics alternative to couple the signal received from a satellite into a Single-Mode Fiber (SMF). SMF coupling is mandatory for the reception of the quantum signal from Eagle-1 and for optical communication exceeding data rates of ~10 Gbps.

All five Greek CubeSats (PeakSat, OptiSat, ERMIS-3, SELENE, HELIOS) are baselined to demonstrate operational communication performance with the three OGS before the Eagle-1 satellite is launched.

General OGS System Architecture

The OGS design relies on a number of modules (performing different tasks) which are common to all three observatories. The description of the various modules of the station is as follows:

- **Acquire & Emit Laser with the Satellite (LAE):** This module exchanges laser telecommunication signals with a satellite.
- **Communicate With the Customer Data Network (COM):** This module digitizes the received (Rx) signal and provides it to the Customer Data Network, while also retrieving the transmitted (Tx) digital data.
- **Manage The Station (MCM):** This module monitors and controls the station in accordance with client requests coming from the Station Manager.
- **Generate Tx Optical Signal (TxG):** This module generates emission laser towards the satellite.
- **Monitor & Assess the Environment (EMA):** This module determines atmospheric parameters and the seeing conditions.
- **Interface With the Customer Infrastructure & Installation's Site (CAI):** This module is the man-machine interface to the OGS.

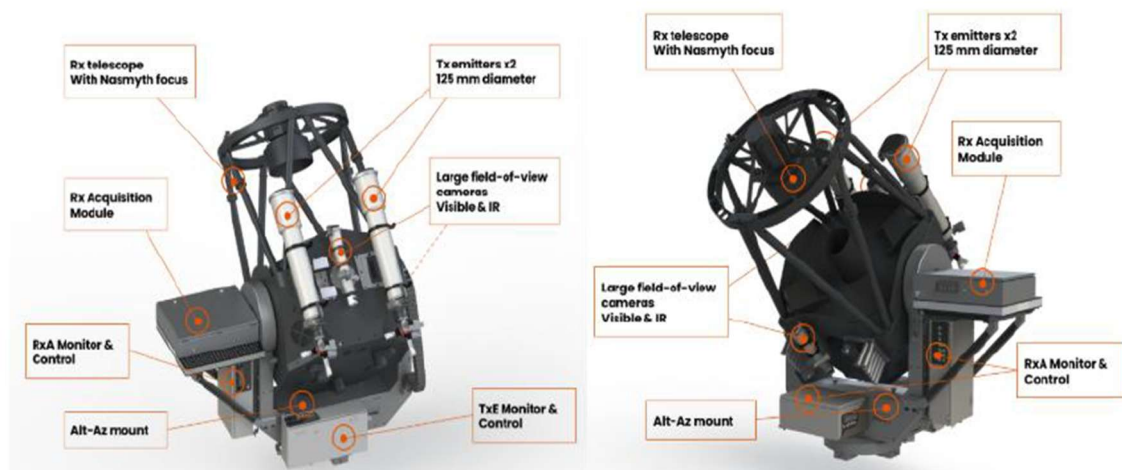


Figure 7. Locations of transmitter and receiver modules on the telescopes.

7.1 Helmos:

The Helmos observatory is operated by the National Observatory of Athens (NOA).

Latitude: 37.9844° North
Longitude: 22.1916° East
Altitude: 2300 m



Figure 8. Helmos observatory (left) and two transmit and (in between) one receive module attached to the telescope (right).

The Helmos OGS is developed as an upgrade of the Helmos observatory located ~150 km west of Athens on a mountain top on the northern Peloponnese. It houses the Aristarchos telescope (Zeiss, Germany) with an aperture diameter of 2.2 m. To enable tracking of LEO satellites the telescope control system was upgraded (ProjectSoft, Czechia).

Due to limited optical beam coupling capabilities of the Tilba-ATMO system when telescope apertures exceed ~1 meter, an off-axis sub-aperture is used at Helmos (unobscured ~0.7 m diameter avoiding the secondary mirror) for reception of optical and quantum communication signals.

Helmos OGS will verify the accuracy of an automatic alignment procedure (Cailabs, France) between transmit modules and the telescope in changing elevation angles. It will also analyse the far-field pattern of the transmission. The verification is done by moving a motorized retroreflector into the (highly attenuated) transmit beam from an off-axis telescope. The retroreflector laterally offsets the beam and sends it back into the aperture of the main telescope.

An 808 nm beacon laser system is additionally installed for uplink compatibility with optical communication terminals (ATLAS-1) onboard PeakSat and ERMIS-3.

7.2 Holomondas:

The Holomondas observatory is operated by the Aristotle University of Thessaloniki (AUTH).

Latitude: 40.4595° North
Longitude: 23.2502° East
Altitude: 900 m



Figure 9. Holomondas observatory (left) and transmit module attached to the telescope (right).

For the Holomondas OGS a new location was selected on a hilltop ~60 km East of Thessaloniki. It houses an ASA800 telescope (Astro-Systeme Austria) with an aperture diameter of 0.8m under a Baader dome (Germany).

Holomondas is the only OGS with a quantum receiver installed, because its development exceeded the available budget required for three units. The quantum receiver is intended to be verified at Holomondas first and will be tested in the two other Greek OGS on a later date. The quantum receiver was developed by Xairos (United Kingdom) and ThinkQuantum (Italy) using phase-detection interferometers and Super-conducting Nano-wire Single Photon Detectors (SNSPD).

The block diagram of the Quantum Receiver along with the receiver installation rack is shown below:

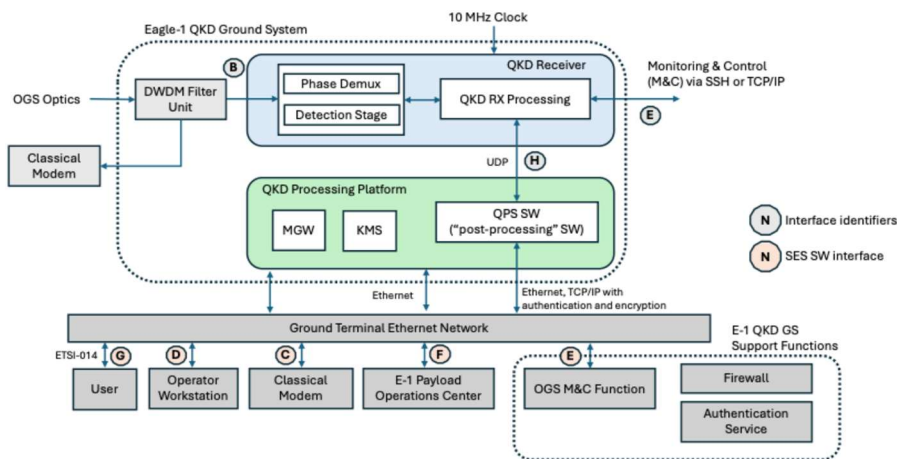


Figure 10. Block diagram of the quantum receiver (left) and quantum equipment rack with helium compressor (right).

7.3 Skinakas:

The Skinakas observatory is operated by the Foundation for Research and Technology Hellas (FORTH).

Latitude: 35.2115° North

Longitude: 24.8946° East

Altitude: 1750 m



Figure 11. Skinakas observatory and transmit and receive modules attached to the telescope..

The Skinakas OGS is located South of Heraklion on mount Idi in central Crete. It houses an ASA1000 telescope (Astro-Systeme Austria) with an aperture diameter of 1.0 m under a Baader dome (Germany).

Being equatorially mounted, keeping alignment between the 1.0 m telescope and the transmit and receive modules attached to its side is more challenging (compared to Helmos and Holomodas whose telescopes are horizontally mounted) due to the gravity vector changing with movement of both telescope axes.

An 808 nm beacon laser system is additionally installed for uplink compatibility with optical communication terminals (ATLAS-1) onboard PeakSat and ERMIS-3.

8. CONCLUSIONS

The Greek National Satellites Space Project has produced a diverse fleet of CubeSat missions demonstrating optical free-space communications at small satellite scale. Five missions carrying optical communication terminals from three different manufacturers — Tesat, Astrolight, and AAC Clyde Space — were developed, integrated, and tested by Greek universities and SMEs with ESA support.

Pre-launch optical alignment of the star tracker and OCT boresights, using both 3D measurement arm and optical theodolite methods, formed a critical element of the AIV campaigns and established the pointing knowledge required for successful in-orbit link acquisition. The satellites are in various stages of post-launch commissioning. Post-launch data from OptiSat and ERMIS-3 confirm their readiness to attempt optical links.

The concurrent upgrade of three Greek observatories to optical ground stations completes the end-to-end demonstration infrastructure and provides a replicable model for national optical communications IoD programmes.

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