

Foresail-1 Prime: Early In-Orbit Results and Platform Performance

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Abstract—Foresail-1 Prime (FS1P) is a rebuilt 3U science CubeSat developed at Aalto University within the FORESAIL program to investigate the near-Earth space environment while demonstrating sustainable-space technologies. Following the loss of the original Foresail-1 spacecraft in 2022, the Prime mission preserves the scientific objectives and platform architecture while integrating targeted improvements in system robustness, verification, and operations.

FS1P was launched in November 2025 and is operating nominally. The satellite carries the Particle Telescope (PATE) and the Plasma Brake (PB), alongside several secondary payloads. This paper focuses on early in-orbit results with emphasis on platform performance: communications and ground segment, electrical power and thermal behavior, attitude determination and control, timing and onboard software, autonomy and fault management, and electromagnetic compatibility (EMC). We report stable operations with fully commissioned links and automated commanding, initial PATE observations consistent with geomagnetic activity, completion of the first in-orbit software update, and readiness of the Plasma Brake for functional tests. We also discuss two early anomalies—payload-bay interference affecting UHF and magnetometer susceptibility to array-induced noise—and their operational mitigations.

Index Terms—CubeSat; platform performance; communications; electromagnetic compatibility (EMC); on-orbit commissioning

configuration management, verification, and operational practices. In this paper we prioritize early in-orbit platform results and performance characterization, complemented by initial payload health-check results.

I. INTRODUCTION

University-led CubeSat programs provide high scientific value at low cost but operate under tight resource and schedule constraints, making platform performance and operational discipline decisive for mission success[2]. The FORESAIL initiative integrates science and sustainability goals by flying targeted instruments on custom platforms developed primarily at Aalto University[13].

The first spacecraft, Foresail-1 (FS1), a fully custom 3U CubeSat, launched in May 2022 but was lost during commissioning due to a communication misconfiguration[11, 16]. The follow-on spacecraft, Foresail-1 Prime (FS1P), retains the original architecture and payloads while introducing improved

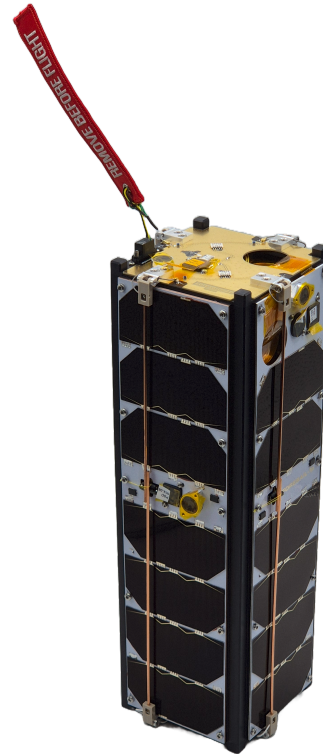


Fig. 1. Foresail-1 Prime satellite

II. MISSION OVERVIEW AND PAYLOADS

FS1P targets two primary objectives: (1) measure particle populations and precipitation in LEO, and (2) demonstrate propellantless deorbit technology via an electrostatic tether. The science payload, the Particle Telescope (PATE), developed at the University of Turku, measures energy and angular distributions of precipitating electrons and solar energetic neutral atoms using orthogonally mounted scintillator telescopes with coincidence and energy discrimination[12].

The Plasma Brake (PB), by the Finnish Meteorological Institute, deploys a negatively biased tether to generate Coulomb drag with the ionospheric flow for sustainable deorbiting and plasma interaction studies[5, 18].

III. PLATFORM ARCHITECTURE

FS1P is a fully custom platform based on the FS1 heritage[15, 14]. The avionics stack integrates dual cold-redundant TI Hercules onboard computers, with an arbiter that manages role selection and recovery, a custom UHF communications subsystem operating at 437.125 MHz using the open-source Skylink protocol[10, 9], and an electrical power subsystem (EPS) built around 2P2S 18650 cells with in-house MPPT charging, protected rails, and point-of-load distribution[3].

Attitude determination and control is provided by a magnetorquer-based system that uses sun sensors and magnetometers[1]. The structure, deployables, and key interfaces were also developed in-house[11, 8].

The FS1P rebuild emphasized verification depth rather than architectural change, preserving payload interfaces and software where appropriate while strengthening system engineering practices[6, 17, 7].

IV. LAUNCH, DEPLOYMENT AND LEOP SUMMARY

FS1P (Figure 1) was integrated into a D-Orbit ION vehicle and launched on 28 November 2025 aboard a Falcon 9 (Transporter-15). After separation from the ION ten days later, beacon frames confirmed nominal health and a staged LEOP was executed, including precise time synchronization and controlled activation of subsystems.

Early weeks focused on tuning Skylink parameters and stabilizing ground-segment SDR performance[10]. Two initial issues were identified and managed operationally: (1) intermittent UHF degradation linked to a Raspberry Pi-based secondary payload bay during specific memory-read activities, and (2) magnetometer susceptibility to array- and panel-induced field variations. Both were mitigated by operating constraints and calibration work, enabling completion of commissioning.

V. COMMUNICATIONS AND GROUND SEGMENT PERFORMANCE

The custom Skylink stack was refined in orbit to achieve robust uplink and downlink performance with predictable command-stack latency. We co-tuned the ground SDR chain and onboard modem using scripted passes and repeatable

profiles; following this tuning campaign, packet loss and frame retries stabilized within the expected design margins for nominal pass geometries. Routine operations now rely on automated commanding and command stacks, which both reduce operator workload and standardize the transition from LEOP to nominal operations. We also investigated and mitigated intermittent UHF degradation that correlated with activity in the payload bay. The issue was reproduced and resolved operationally through pass scheduling and mode constraints, without structural changes to the system. Skylink remains open-source and shareable for missions requiring a single-frequency UHF link with error control and virtual channels[10, 9].

With a UHF downlink at 437.125 MHz, free space path loss of 148.78 dB, and a 15 dBi ground antenna, predicted C/N_0 was 9.57 dB under nominal polarization loss of 3 dB. Preliminary results showed lower performance in orbit. After Skylink parameter tuning we were able to improve the performance slightly. Especially the window length between TX and RX needed to be significantly increased in order to avoid frame collisions. The interference case linked to the Raspberry Pi-based payload increased EMI as seen in Figure 2.

VI. ELECTRICAL POWER AND THERMAL BEHAVIOR

The EPS and solar power path performed within design intent throughout early operations. Panel power, battery charge-discharge profiles, and regulated-rail loading matched pre-flight analyses under nominal pointing, while rail current limits provided the intended protection; no destructive latch-up events were observed.

MPPT tracking functioned as designed, and the boot sequence, including antenna deployment prior to OBC activation, executed nominally [3]. The recorder current draw of the subsystems directly after deployment can be seen in Figure 3.

Thermal behavior also remained within qualification ranges across both eclipse and sunlight conditions for the observed beta-angle evolution, and no heater-driven contingency actions were required during the initial weeks on orbit.

VII. ADCS AND SENSORS

The magnetorquer-based ADCS met early commissioning goals. However, due to heavy EMI on the onboard magnetometer in sunlight we needed to change the magnetometer source to build in magnetometers of PATE. This was done via a software update of the OBC. Unfortunately, PATE magnetometer only provides information in Y and Z. Therefore further optimization to the attitude determination algorithms had to be done.

Sun-sensor performance matched ground characterization [1], and in combination with the magnetometers. We will report absolute pointing performance after completing the extended calibration campaign.

VIII. ONBOARD SOFTWARE, TIMING, AND FAULT MANAGEMENT

The first in-orbit software update completed successfully, validating our reprogrammability concept, image integrity

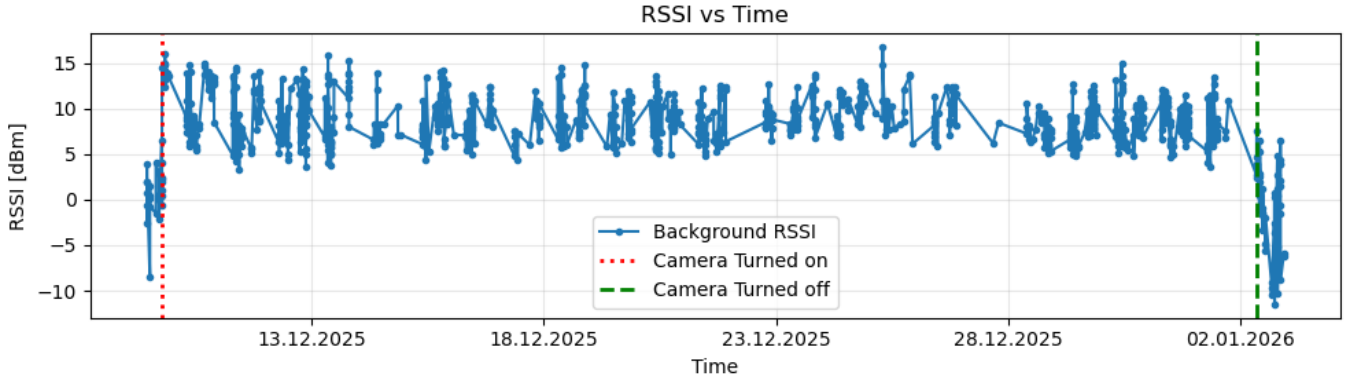


Fig. 2. Link RSSI with marked camera power events.

checks, and rollback preparedness. Ground-to-space time synchronization established a stable onboard timescale, enabling deterministic execution of command stacks and accurate payload timing.

In functional tests, the arbiter-mediated dual-computer architecture behaved as designed, and the updated recovery concept of operations produced safe-state entry and exit consistent with the mission’s fault-containment objectives.

IX. EMC OBSERVATIONS AND MITIGATIONS

Two EMC topics with operational relevance were identified during early commissioning. UHF susceptibility to a secondary payload’s memory-read activity was traced to specific modes and mitigated by constraining those activities during communication passes and adjusting pass plans; follow-on work targets root-cause isolation at board level without disrupting operations.

In addition, magnetometer susceptibility to array and panel currents was addressed via calibration updates and data-selection rules, and we are evaluating model-based compensation as the dataset expands. These observations reinforce the importance of system-level EMC considerations in compact, tightly integrated platforms and complement unit-level testing.

X. PAYLOAD HEALTH

The Particle Telescope (PATE) [12] completed on-orbit calibration and acquired initial datasets, including intervals coincident with enhanced geomagnetic activity, with channel behavior consistent with expectations. The Plasma Brake [4] performed initial self-checks and is ready for stepwise functional tests in upcoming operations windows.

The onboard camera was commissioned and produced multiple images; an example is shown in Figure 4. These images also aid illumination and attitude-assessment studies. The image sequence can give an understanding of the rotation speed and tumbling behavior.

XI. OPERATIONS AND GROUND PROCESS

End-to-end validation and automation were central to FS1P’s stable early operations. Pre-flight hardware-in-the-loop

and full-chain ground–space–ground testing reduced ambiguity in command and telemetry behavior and ensured consistent parameter handling[6, 17].

Stricter configuration management—covering software images, parameters, and interface definitions—helped minimize integration drift[7]. Commissioning was executed using playbooks built around automated sequences with guarded steps, checkpoints, and revert plans, which shortened LEOP and improved repeatability across passes and operators.

XII. DISCUSSION: PLATFORM PERFORMANCE AND RISKS

FS1P demonstrates that a custom, university-built platform can achieve stable early operations after modest in-orbit tuning. Communications robustness improved through targeted adjustments to an open protocol running on COTS radios, while EPS and thermal behavior tracked pre-flight analyses without unexpected margin erosion.

ADCS performance met design expectations once contamination sources were characterized and compensated, and practical autonomy—centered on time-managed command stacks, safe states, and recovery—enabled lean operations. The early anomalies were operationally manageable and informed updates to calibration and pass planning.

Overall, the experience highlights the need for system-level EMC considerations beyond unit testing, comprehensive end-to-end verification that includes the ground segment, and operational safeguards that limit the impact of commissioning-phase uncertainties.

XIII. CONCLUSIONS

Foresail-1 Prime has achieved a stable operational state with commissioned links, verified onboard autonomy, and first payload results. Platform subsystems—communications, EPS, thermal control, ADCS sensing, timing, and software update mechanisms—performed within design intent following targeted in-orbit tuning. Two EMC-related findings were mitigated operationally with continuing calibration and modeling work.

These early results indicate that the rebuilt platform can sustain routine operations and support the mission’s science



Fig. 3. EPS currents after deployment

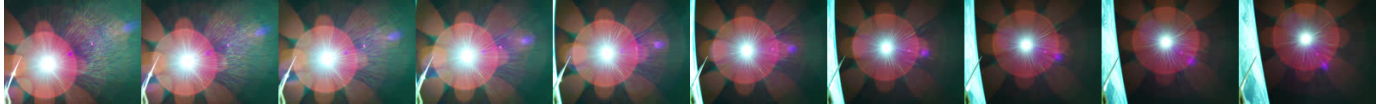


Fig. 4. Image sequence taken by Foresail-1 Prime.

and technology goals. Beyond the specific outcomes, FS1P emphasizes platform-centric practices—configuration control, end-to-end testing, and automation—that are broadly applicable to university-led CubeSat missions pursuing resilient, repeatable performance.

XIV. FUTURE WORK

Upcoming activities include completion of ADCS calibration, staged Plasma Brake activation and performance assessment. We will also release ADCS datasets.

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