

## Pushing the Boundaries with the ThinSat and TROOP Platforms: F2 Flight Results and Testing New Systems

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### ABSTRACT

NearSpace Launch Inc. (NSL) has been pushing the boundaries of small satellite systems through Train Rapid on Orbit Payload (TROOP) missions and ThinSat constellations. Most recently, the TROOP-F2 mission, a 6U launched on a SpaceX rocket in August 2024, has provided a variety of payload and bus sensor results. In particular, the EyeStar-S4 on the Iridium L-band link received the first packet 15 minutes after turn on, followed by the next 15 packets without any dropouts demonstrating impressive Launch and Early Operations (LEOP) performance.

The TROOP-F2 satellite includes 1) three NSL Iridium S4 transceivers with different antennas and pointing, 2) several NASA Space Weather NSL-SWAP-E Lite sensors (Low energy particle detector, medium energy particle spectrometers, a total integral dose particle detector and a Plasma Probe), 3) several NSL new Bus systems (new Mosaic-X5 GPS, new ADCS, EPS, rad hard solar cells, and flight processors). The 6U SWAP-E (Space Weather Array Prompt Experiment) four-satellite constellation is currently being manifested for launch. The F2 bus and subsystems all worked very well in Orbit. The rad-hard solar cells, all Bus and instrument loads, the differential GPS worked well. When the GPS was compared to the TLEs the match overlapped but no GPS was received over Europe and Russia. The differential GPS pitch and yaw attitude positions and rates of rotation are consistent with the new NSL ADCS system. All the EyeStar 24/7 radio links worked well, producing uniform global maps. The LEOP turn on data was extremely remarkable with the first packet sent 4 min after turn on followed by the next 15 sequential packets without any link dropouts. All of the four advanced energetic particle ( $20\text{keV} < E < 2\text{MeV}$ ) detectors performed with good low noise resolution and mapping the earth's radiation belts.

The TROOP-F2 mission required very specific attitude control solutions. The ADCS system onboard is a low-SWaP-C magnetorquer-only system that NSL is developing towards achieving basic magnetic, sun, nadir, and velocity vector pointing with minimal or no inputs from the OBC, ground control, or GPS. Additionally, the system is optimized for efficiency, requiring minimally sized data packets for ground commands and spacecraft telemetry. The new F2 ADCS successfully completed the de-spin function and demonstrated pointing capabilities.

RAPSat-1 (Rapid Satellite Launch) is a constellation of three ThinSats that fit inside a 6U dispenser (the center satellite is 3U x 2U x 1/2U and the other two are 3U x 2U x 1/4U). RAPSat-1 was released in orbit but was delayed in its secondary deployment, so it has not released the three ThinSats yet. We hope to report this year on the RAPSat-1 release and operation based on the calculated erosion of the burn wire in orbit by intense UV and atomic Oxygen exposure.

To date NSL has 100% success of all flight S3 and S4 radios released in orbit, where verification permits. NSL also provides a time-ordered database available on a secured console, ideal for data transmission directly from the satellites. The web console is accessible from desktop or mobile, and allows users to check incoming packets, send uplink commands, or receive SMS notifications.

### INTRODUCTION

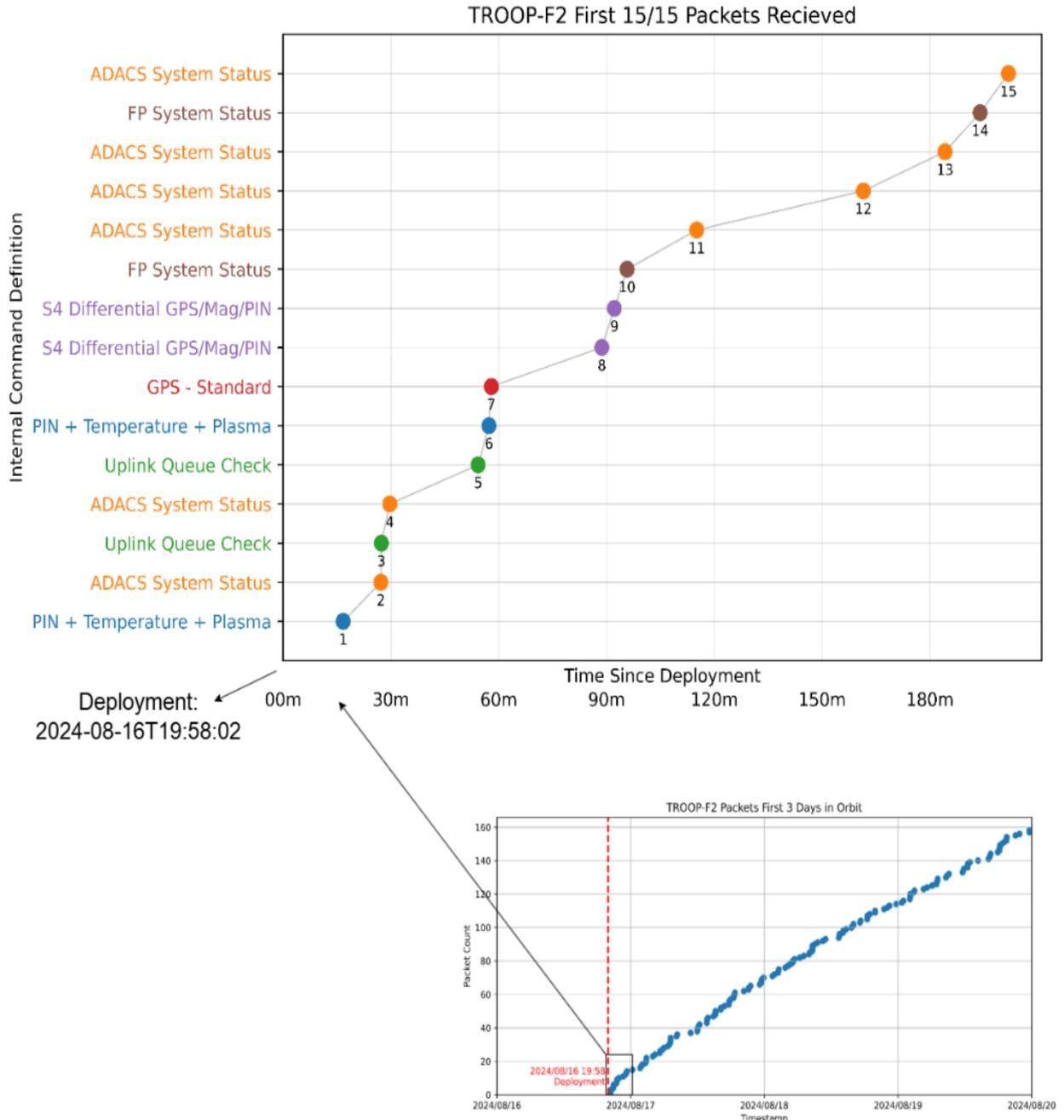
NearSpace Launch Inc. (NSL) has been pushing the boundaries of small satellite systems through Train Rapid on Orbit Payload (TROOP) missions and

ThinSat constellations. Most recently, the TROOP-F2 mission, a 6U launched on a SpaceX rocket in August 2024, has provided a variety of payload and bus sensor results. The DoD's RAPSat-1, a ThinSat Constellation

was also recently launched in March 2025, and contains three “3x2U Slice” ThinSats.

The TROOP-F2 mission required very specific attitude control solutions. The ADCS system onboard both spacecraft is a low-SWaP-C magnetorquer-only system that NSL is developing towards achieving basic magnetic, sun, nadir, and velocity vector

pointing with minimal or no inputs from the OBC, ground control, or GPS. Additionally, the system is optimized for efficiency, requiring minimally sized data packets for ground commands and spacecraft telemetry. The new F2 ADCS successfully completed the de-spin function and demonstrated pointing capabilities.



**Figure 1 TROOP F2 Launch and Early Operations (LEOP) flight results for first 200 min after canister deployment. Each of the first 15 packet transmissions were successfully recorded giving critical Bus and Instrument diagnostic data within a few minutes of each.**

**Table 1 Results of 5 most recent NSL missions.**

Spec	S4-Crossover	TROOP-3	S4-A (T-10)	S4-LN	S4-F2 (T-11)
Launch Date UTC	3/15/2022 16:31:00	5/25/2022 19:31:42	3/4/2024 2330 UTC	3/4/2024 TBD UTC	8/16/2024 TBD UTC
Rocket	Astra Rocket 3	SpaceX Falcon-9	SpaceX Falcon-9	Nanoracks ISS	SpaceX Falcon-9
Orbit	SSO, 550x498, 97.5°	SSO, 534x539, 97.5°	SSO, 534x539, 97.5°	430 km orbit, 51.6° inclination	SSO, 534x539, 97.5°
Tip off	< 60 RPM	< 8 RPM	Unknown	Unknown	< 2.5 RPM
NSL Radios	S3, S4, GPS	S3, S4, GPS	5x S4s	S4	4x S4s, GPS
Sensors	Solar Temp, Bat, Mag	Bat V/Q, PIN	NA	NA	Particles, Plasma, Mag, ADCS
Uplink	Yes	Yes	Yes	Yes	Yes
Downlink	Yes	Yes	Yes	Yes	Yes

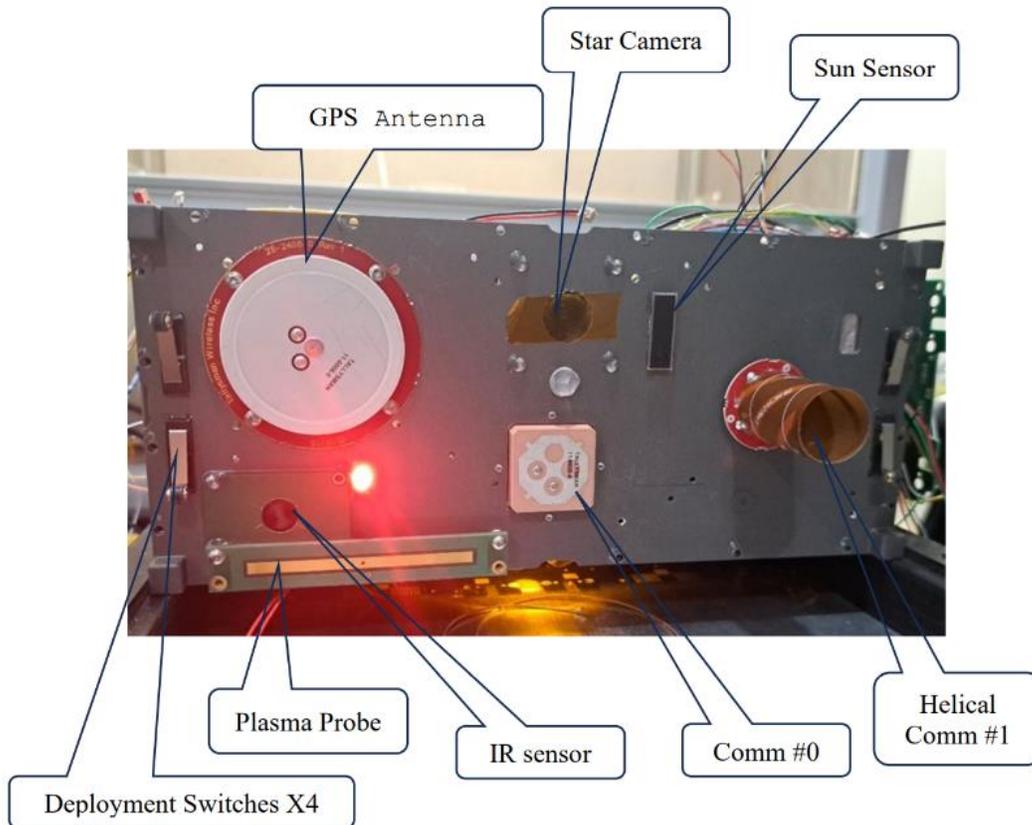
**LAUNCH AND EARLY OPERATIONS (LEOP)**

Early flight results are shown in Figure 3 of the S4 Iridium links from TROOP-F2. Even during the initial tumble, the spacecraft sent “first light” packets of data within a few seconds of cold start first transmitter turn-on to the NSL console via Iridium.

The first packet was received within 15 minutes of deployment, with 15 consecutive packets received

immediately afterwards. This enabled quick IDing of the spacecraft and commissioning of various bus subsystems before passing over any ground stations.

Additional recent NSL launches and their summaries can be found in Table 1.



**Figure 2 End panel of the 6U TROOP-F2 / SWAP-E Lite showing the array of antennas and sensors. Details of F2 systems are referenced in SSC**

## TROOP-F2 CONFIGURATION AND SENSOR LOCATIONS

The TROOP-F2 satellite (6U) was launched on a SpaceX launch in August 2024. The satellite includes 1) three NSL-Iridium S4 transceivers with different antennas and pointing, 2) several Space Weather NSL-SWAP-E Lite sensors (Low Energy particle detector, Medium Energy Particle spectrometers, a total integral dose particle detector and a Plasma Probe), 3) several NSL Bus systems (new Mosaic-X5 GPS, new ADCS, EPS, rad hard solar cells, 900 MHz link for Sat-Sat or Sat-Ground transceiver, processors) and 4) a primary rendezvous experiment payload. In addition, 5) NSL has added two more GPS antennas to test the differential GPS capability (high-position accuracy and attitude determination required for science, rendezvous, and lower cross section for orbital debris mitigation).

In addition to the primary mission of TROOP-F2, the satellite also contains the SWAP-E Lite package, which reduces risk for the SWAP-E mission by testing

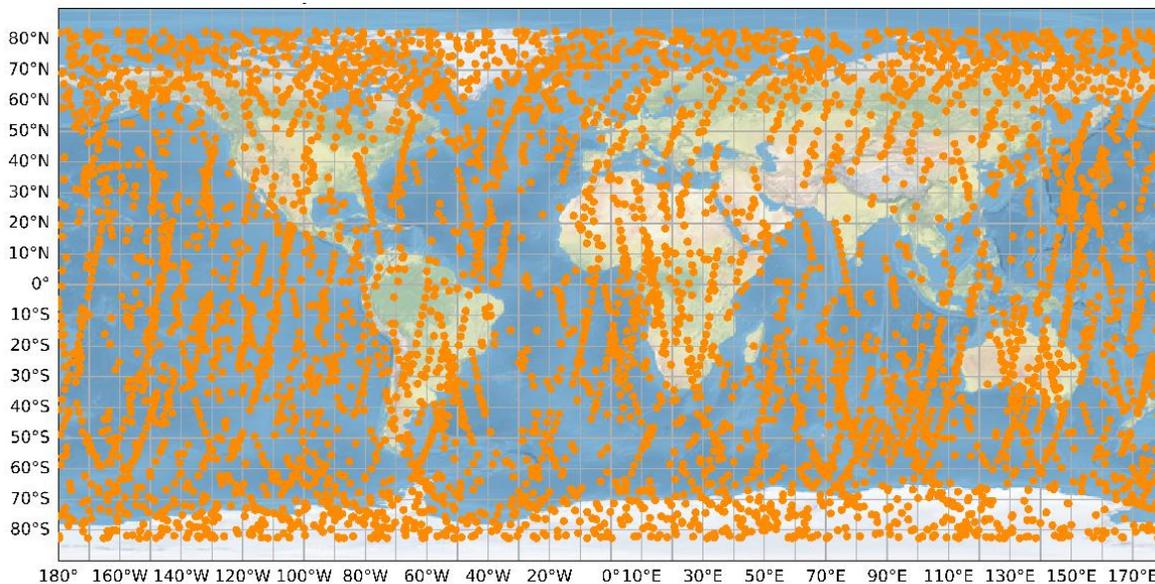
- Multiple S4 radio and antenna configurations to maximize connectivity on orbit.
- Direct comparison of different S4 antennas on orbit.
- ARMAS particle detector payload.
- SES particle detector payload.
- New S4 firmware and analysis techniques for improving and characterizing on orbit performance.

Some of these systems can be seen in Figure 2.

## IRIDIUM LINK THROUGH TROOP-F2

The EyeStar-S4 is 24/7 seamlessly connected to a secure internet within a few seconds or minutes to the client's server. The EyeStar is designed for constellations of satellites or for multiple EyeStar units per spacecraft.

Over the past several years, NSL has gained substantial experience and expertise with delivering and operating the Iridium connected EyeStar-S4



**Figure 3 TROOP-F2 EyeStar-S4 Transmissions from 4/11/2025 to 6/3/2025.**

some of the bus and payload systems of SWAP-E. Some of these systems include

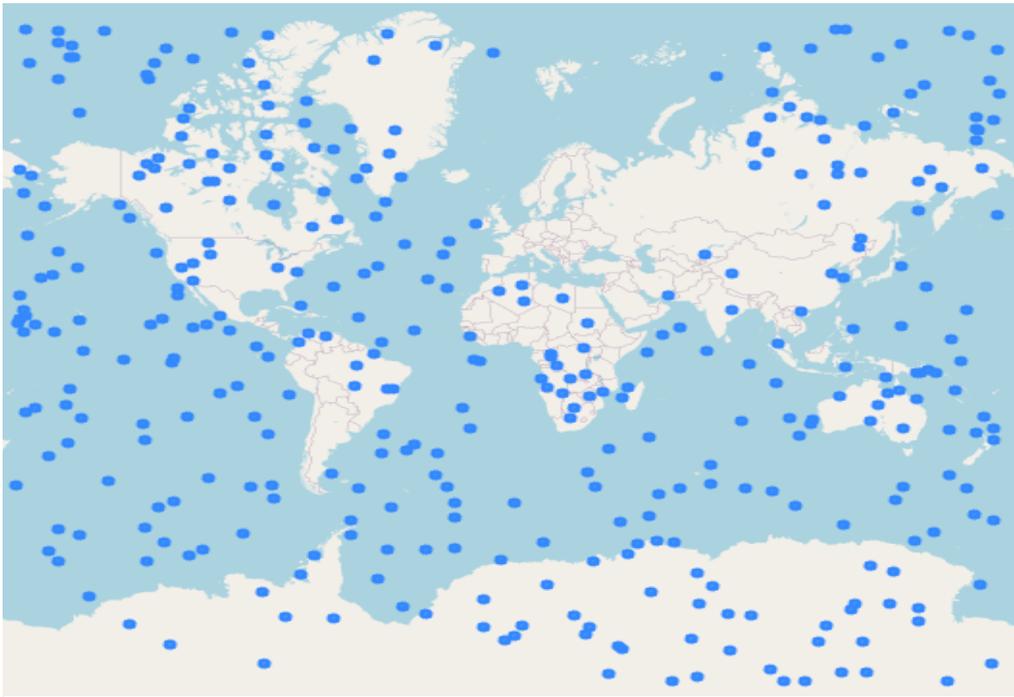
- New NSL ADCS with Horizon and Sun Pointing.
- New NSL RadStar particle detector suite.
- New NSL GPS with higher precision and faster cold start acquisition times.
- NSL Plasma Probe.
- NSL 3 axis fluxgate magnetometer.
- NSL Solar arrays.

(though we still have quite a bit to learn!). Since development started, over 120 EyeStar-S4 units have been delivered to partners. In the past year, 18 EyeStar S4 units have been launched and operated in orbit.

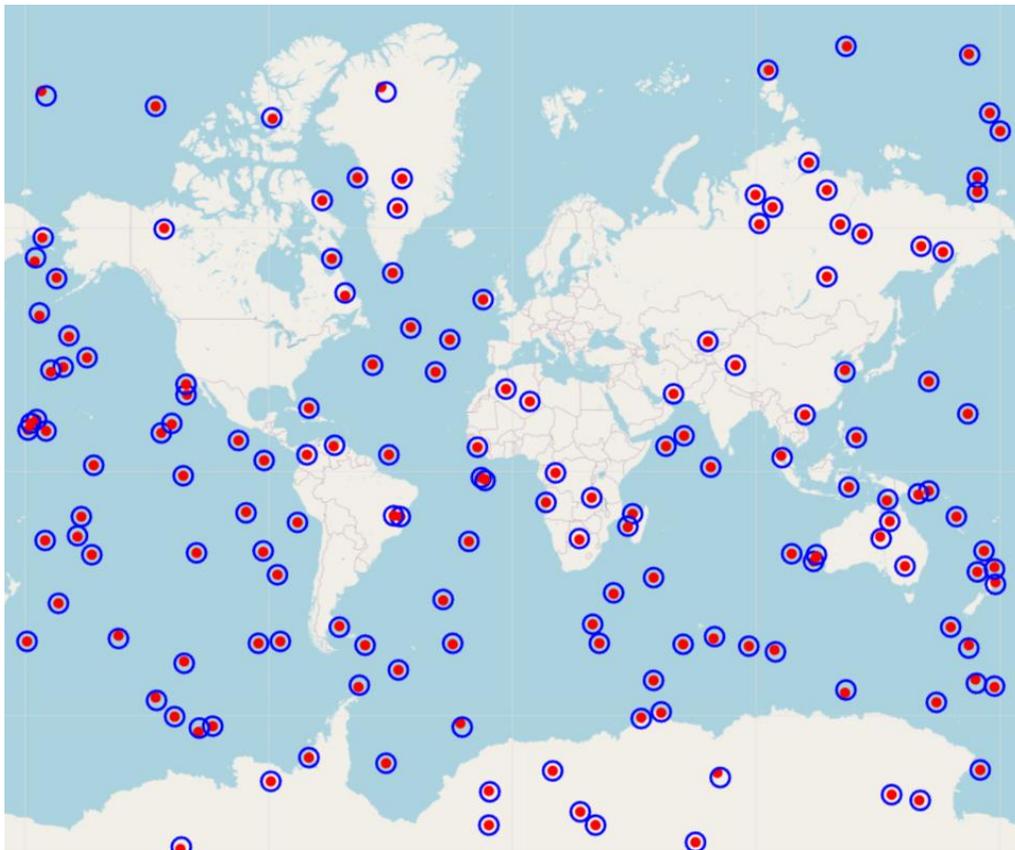
Results from TROOP-F2, showing orbit data coverage, are shown in Figure 3.

## GPS Results From TROOP-F2

Results from the NSL GPS onboard TROOP-F2 are shown in Figure 4. It is noteworthy to observe the lack of connections over eastern Europe and Russia. Given



**Figure 5 Global Distribution of Mosaic GPS locks. Note the absence of locks over Europe and Russia.**



**Figure 4 Coverage map showing the position offset of TLE data (Blue) to onboard GPS data (Red). The two data sets showed very good agreement.**

the current state of international political affairs, one

could understand this as a somewhat expected result. It's worth comparing this coverage map to the total Iridium connections coverage map in Figure 3. This shows a much more homogenous connection distribution, with no disruptions observed over Europe and Russia.

The differential GPS pitch and yaw attitude positions and rates of rotation showed general consistency with the new NSL ADCS system. With very little on-orbit data currently to analyze, performing and displaying quantitative data analysis on this will be left for future work.

**GPS versus TLE locations over Globe**

Shown in Figure 5 is a comparison of the position data from propagated TLE data vs position data from the onboard NSL GPS. This correlation demonstrates the consistent accuracy of the NSL GPS, as it almost precisely lines up with the TLE orbit propagation.

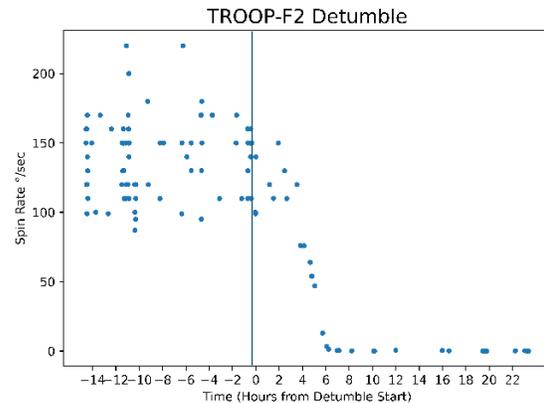
**RAPSAT-1 RESULTS**

RAPSat-1 was launched on 3/14/2025, as part of the Tranporter-13 rideshare mission onboard a SpaceX Falcon 9. After a successful initial deployment from the CubeSat Dispenser, it experienced a delay in the secondary deployment, causing a prolonged delay in the commissioning phase. RAPSat-1 is still currently awaiting the secondary deployment, with expected initial operations occurring around Q4 2025.

**NEW MODEST DE-SPIN AND POINTING ADCS**

TROOP-F2 was the debut launch for the NSL ADCS. This new system is intended to provide out-of-the-box detumble and rough pointing with minimal commissioning and no external data feeds (no need for

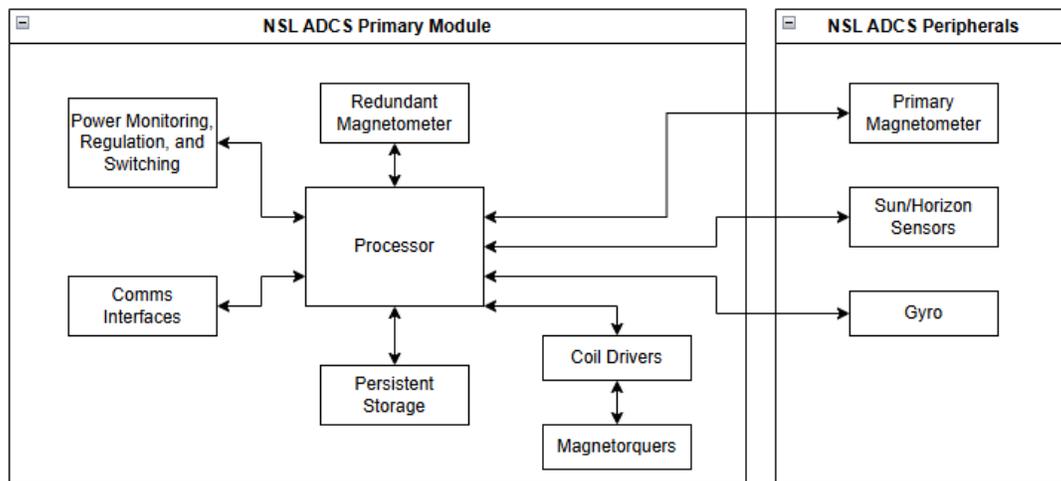
GPS locks or TLEs). It can connect directly to an EyeStar-S4 or NSL Black Box for a redundant pathway for pointing telemetry and commanding. Drawing less than 1W OAP and fitting within ¼ U of volume, its SWaP-C is promising. The rad-tolerant processor has operated without any observable degradation during the solar maximum. Figure 6 shows a block diagram. It uses a torquer-only approach. Multiple com ports allow for direct connection to TT&C radios and the flight computer.



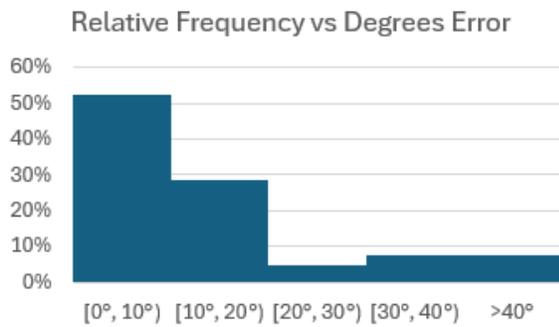
**Figure 7 – Detumble Demo from 20-30 RPM**

Figure 7 shows a detumble sequence executed from a starting tumble rate of 20-30 RPM. The volatility in spin rate readings is due to limited filter durations, a magnetometer-only data source, and the different MOIs on each spacecraft axis.

The target accuracy for this system was 10-20 degrees. Figure 8 shows the relative frequency of different error buckets during magnetic pointing, with over 80% of samples falling under the 20° threshold. Updates are



**Figure 6 – NSL ADCS Block Diagram**



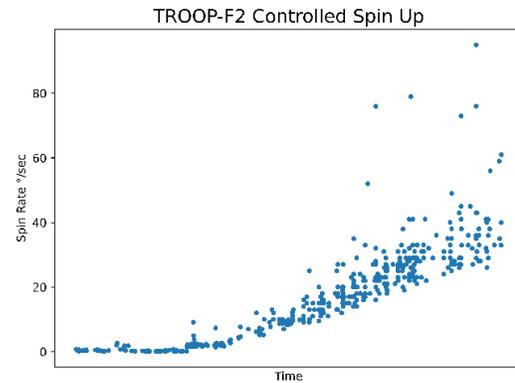
**Figure 8 – Pointing Accuracy**

being worked on for both knowledge and control, aiming to improve the accuracy with future launches.

Figure 9 demonstrates starting from a stable attitude and entering a spin mode. The initial spin was just a few degrees/second and left there for a period, then continued spinning up. The variation in spin rate readings is re-introduced as before, but the trend is clearly confirmed.

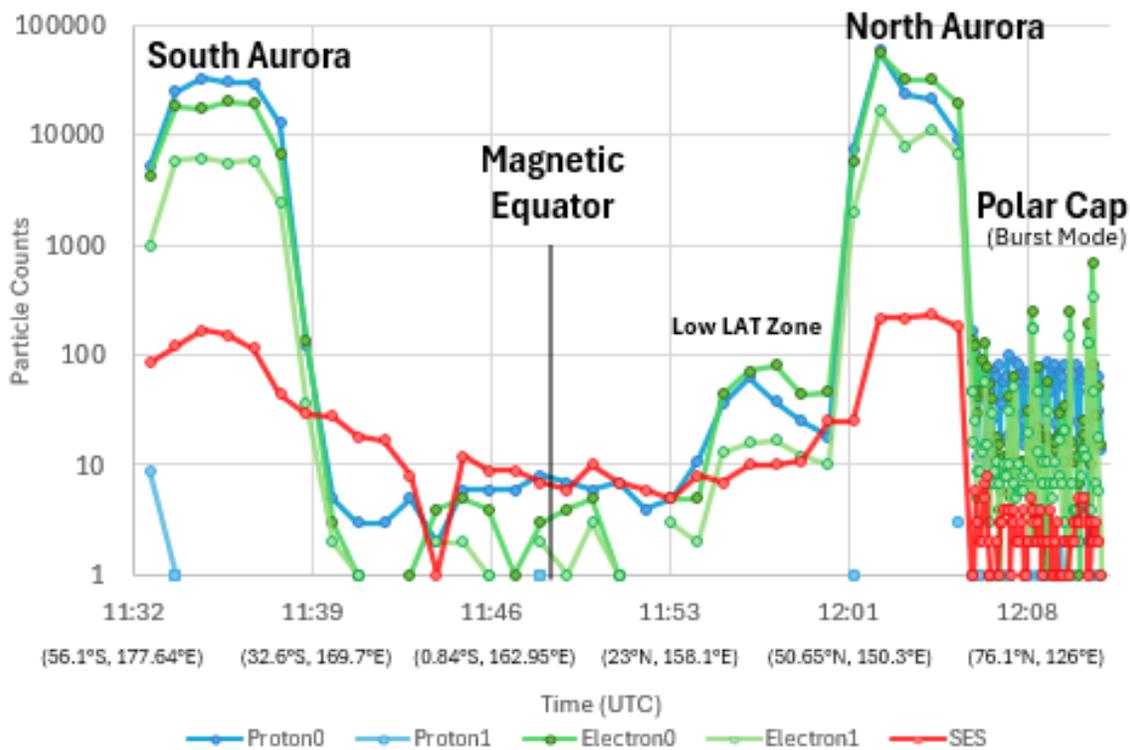
**RADSTAR ENERGETIC PARTICLE FLIGHT DATA**

See RadStar Energetic Particle Flight Data in Figure 10.



**Figure 9 - Spin-up Demo**

The RadStar energetic particle suite includes three separate telescopes for measuring electrons  $E > 15$  KeV with selectable light tight windows, measuring Protons (or ions)  $E > 50$  KeV with selectable windows, and measuring low energy electrons or x-rays. The solid-state detector areas range from  $9 \text{ mm}^2$  to  $10 \text{ mm}^2$  for supporting different geometric factors. The proton detector uses a sweeping magnet to bend the electrons away from the detector. A picture of the miniaturized RadStar sensor suite is shown in Figure 11 with dimensions of  $9 \times 4 \times 2.5 \text{ cm}$ .



**Figure 10 Energetic particle RadStar data from three sensors showing auroral zones, Polar cap precipitation in a higher data rate burst mode, and Midlatitude and equatorial trapped fluxes.**



**Figure 11 NSL RadStar Particle Detector.**

## CONCLUSIONS

NSL has been able to successfully validate and characterize several new systems onboard the TROOP-F2 spacecraft. Improvements to LEOPS operations were enabled with immediate position data collected by the new NSL GPS. Detumble and modest pointing operations were demonstrated by the experimental NSL ADCS. Energetic Particle data was collected and downlinked by the NSL RadStar. All of these flight results will continue to enable NearSpace Launch pushing the boundaries of small satellite technical capabilities.

## ACKNOWLEDGEMENTS

We would also like to give special thanks to Iridium Engineers, Managers, and Legal for their devotion and commitment to optimize their powerful constellations for real-time Sat-to-Sat links. Mike Miller, as our FCC legal consultant, did a fantastic job helping us with navigating the FCC requirements.

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