THERMO-OPTICAL CHARACTERIZATION AND QUALIFICATION OF A SPACE SITUATIONAL AWARENESS (SSA) PAYLOAD

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1. INTRODUCTION AND MOTIVATION

Context: Low Earth Orbit (LEO) is increasingly congested, competitive and contested making Space Situational Awareness (SSA) a global priority for monitoring resident space objects (RSOs).
Problem: Heritage space-grade hardware is costly with long development timelines.
Our Solution: Utilizing Commercial Off-The-Shelf (COTS) star tracker-class cameras as a cost-effective augmentation for SSA.
Objective: Perform environmental qualification and optical characterization of a COTS-based Wide Field-of-View (WFOV) system for the upcoming UPMSAT-4 mission.

By demonstrating a dual-use star tracker for SSA, we incentivize the modification of current star trackers to implement RSO detection.

3. METHODOLOGY

Test Facility: Tests were conducted at the Canadian Planetary Simulator (CAPS) at York University. The Simulator is a 1.7m^3 TVAC chamber capable of pressures as low as 10^{-7} torr, and temperatures ranging from 70 to 400K.
Test profile: A single cycle including cold survival, cold operational, hot operational and finally, hot survival.
Optical Testing: In-situ characterization of a 1951 USAF test chart at 70 cm working distance. As seen in figure 8.
Dark Current Testing: Capture images in complete darkness to quantify the thermal noise floor at different temperatures.

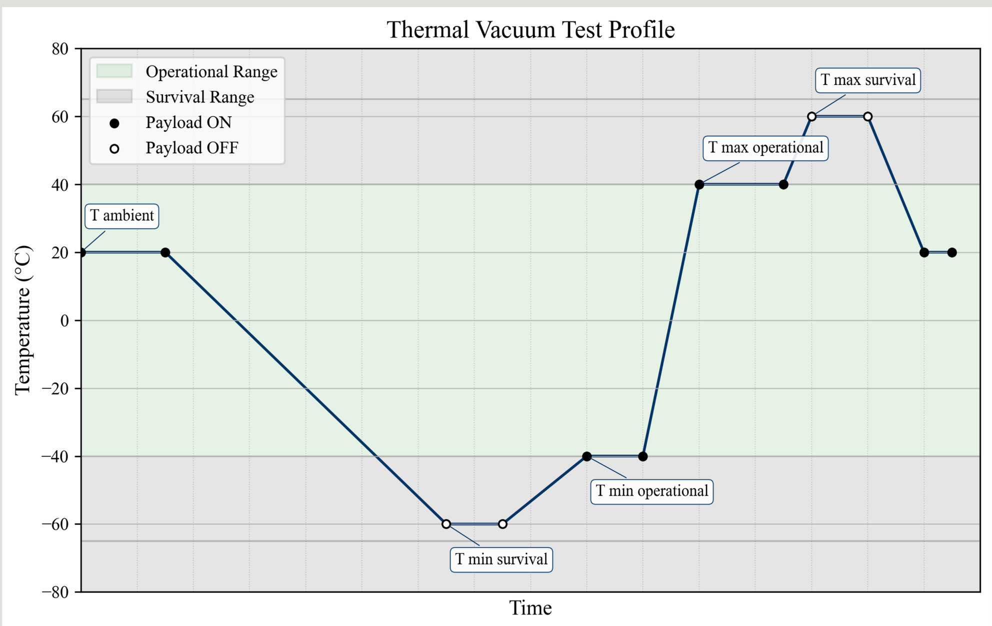


Figure 1: Thermal Vacuum Test Profile with Payload Operational State

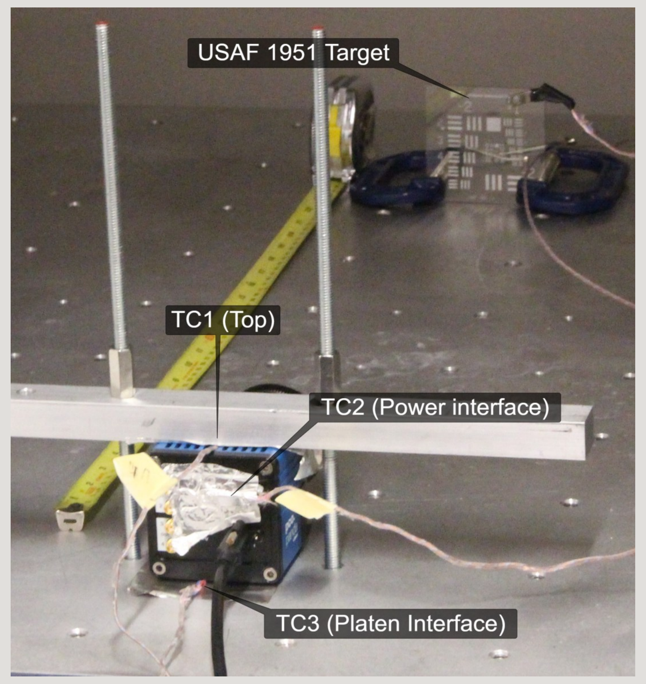


Figure 2: Payload Setup Within TVAC

Temperature Acquisition: The temperature was acquired at six different points of the camera. Three external type-T thermocouples were used to capture the temperature of the chassis of the camera. They were placed on the top (TC1), the power interface / back (TC2) and the platen interface / bottom (TC3). There are also three internal thermocouples, one at the sensor, one at the FPGA of the camera, and one at the internal power interface, these internal thermocouples were however limited to collecting data only when the camera was powered.

4. KEY RESULTS

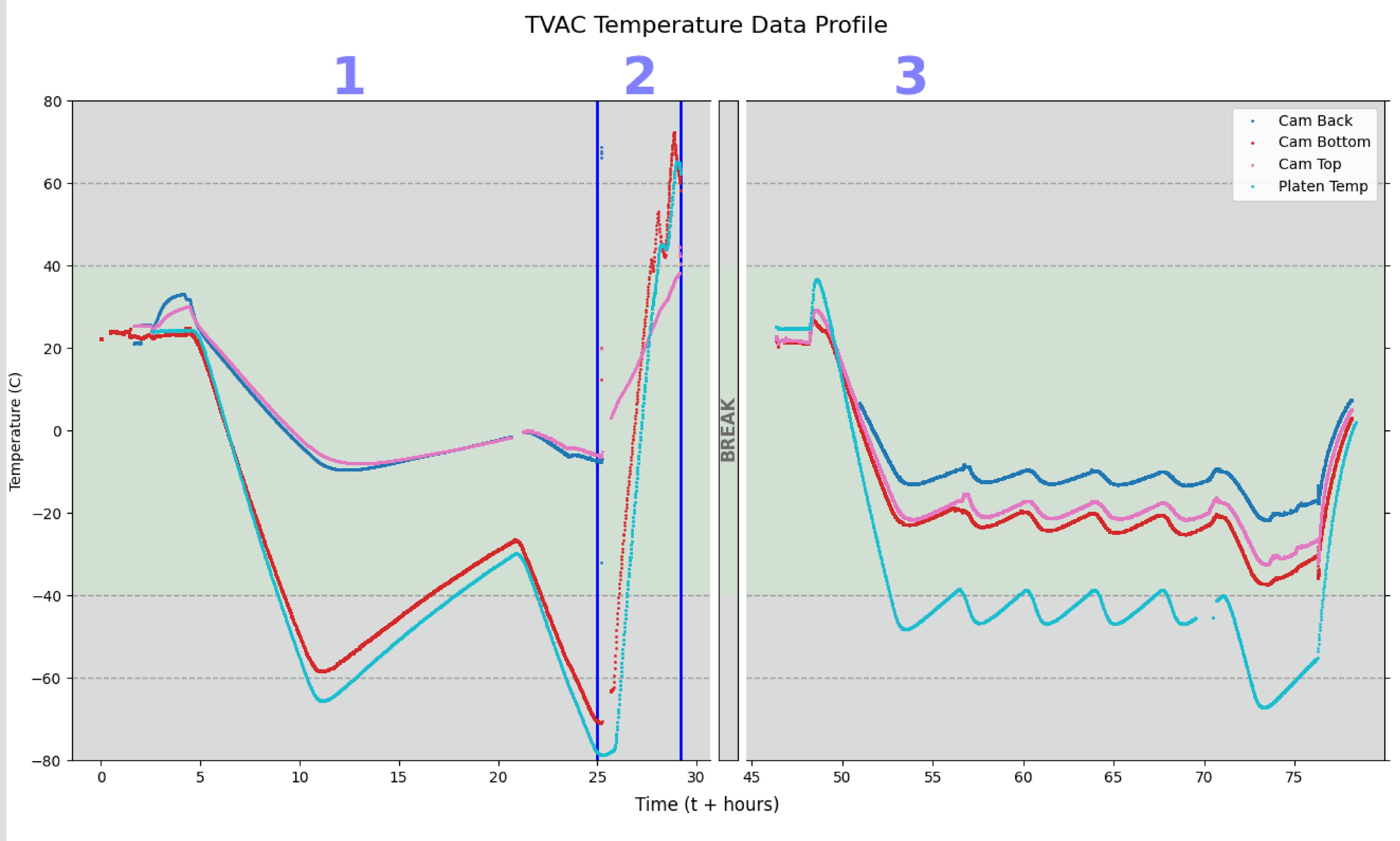


Figure 5: Measured Thermal Profile, Showing: Initial Cold Attempt (Phase 1), the Hot Cycle (Phase 2), and final Successful Cold Soak (Phase 3)

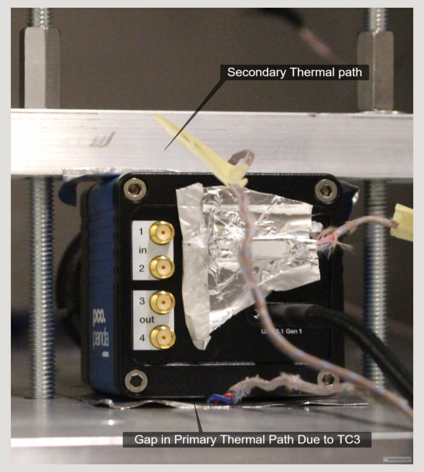


Figure 6: Gap in Thermal Path Caused by TC3

Temperature Profile: The characterization occurred in three phases. Phase 1 failed due to a gap caused by a Thermocouple, as shown in Figure 6. Phase 2 and 3 successfully reached hot and cold operational and survival temperatures.

Optical Focus: Figure 8 Shows a sample of the optical focus degradation that occurs at low temperatures.

Dark Current Characterization: Figure 7 Shows a brightened master dark image confirmed the absence of hot pixels but showed faint column-wise banding typical of SCMOS architectures

Dark Noise Stability: remained relatively constant throughout the test. Shown in Table 2.

Temperature Range (°C)	Samples	Mean DN	Std. Dev
-60 to -40	24	95.27	0.33
-40 to -20	130	96.89	0.20
-20 to 0	103	97.34	0.13
0 to 20	29	97.40	0.14
20 to 40	120	97.99	0.33
40 to 60	175	98.42	0.15

Table 2: Dark Current Statistics vs. Temperature

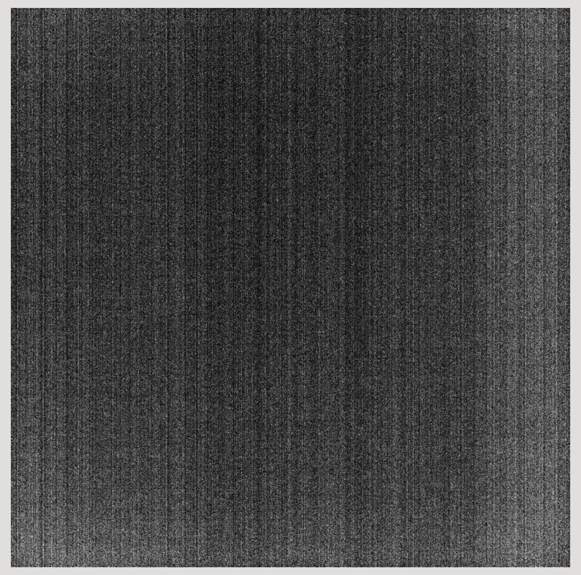
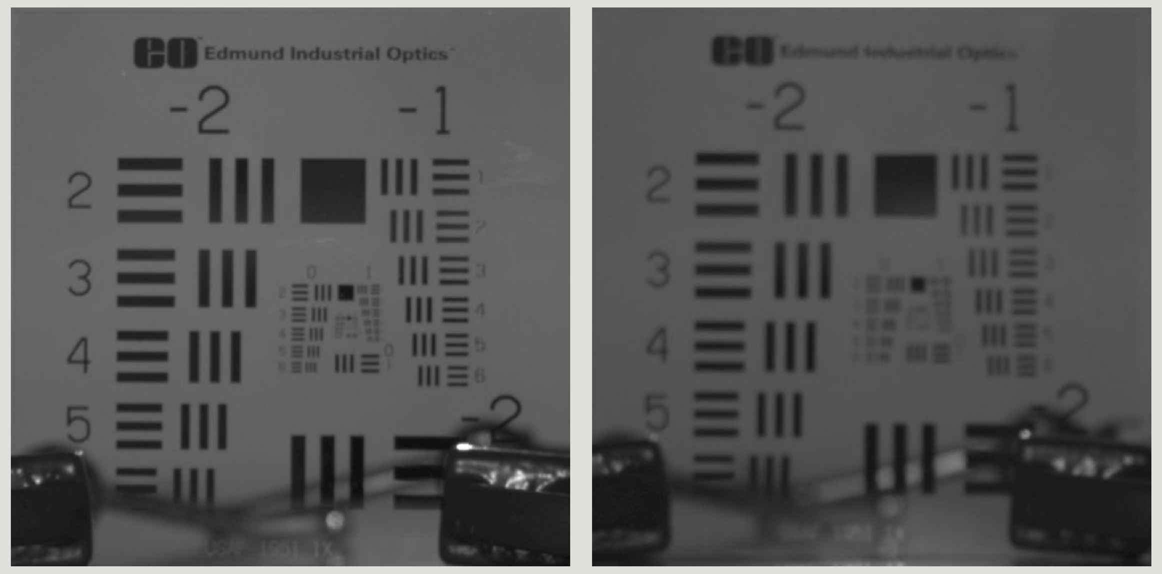


Figure 7: Master Dark Image (Brightened)



(A) (B)
Figure 8: Visual Comparison of the USAF 1951 Test Chart Showing Focus Stability at (A) Ambient Temperature and (B) -20°C

2. THE PAYLOAD

Sensor: COTS PCO Edge Panda 4.2 scientific CMOS (4.2-megapixel)
Optics: Zeiss Dimension 2/25 High speed lens (f/2, 25mm focal length)

Parameter	Value
Aperture Diameter	12.5 mm
Field of View	29.7° x 29.7°
Resolution (max)	2048 x 2048
Bit Depth	16
Exposure time	10 ms
Effective QE at 55nm	78%

Table 1: Optical Characteristics of the Payload


Figure 3: The Payload Flown on RSONAR 1,2 and 3

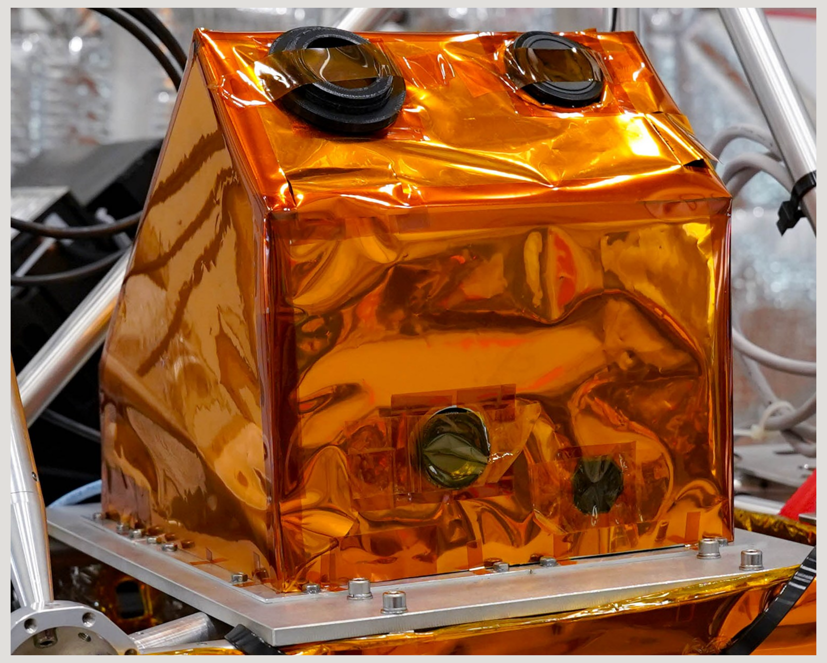


Figure 4: RSONAR 2 Onboard the CSA & CNES STRATOS 2023 Mission

Flight Heritage: This payload has flight heritage from the RSONAR 1 – 3 missions raising it to a TRL 7 in terms of a Space flight, with the goal of these test to raise it once more to TRL 8 before launch.

This Payload was chosen due to it's similar characteristics to commercial Star Trackers.

5. CONCLUSION

Interface Sensitivity: To ensure that the payload is dumping it's heat to the satellite, we must ensure that the interface is well mounted to the Satellite body.
Focus Degradation: While focus degrades at colder temperatures, this is mainly an issue that affects fine details, and can be mitigated by having strong thermal controls.
Dark Noise: Remained relatively constant, and with it showing no significant noise, it is unlikely to generate phantom RSOs.
TRL Advancement: This test advances the Payload's TRL from 7 to 8 meaning that it is ready for integration onto the satellite
Future Work: We will now begin integration with the UPMSAT-4 bus at Universidad Politécnica de Madrid and development of a master-dark calibration library with the flight camera to ensure accurate on-orbit noise removal.

The Payload is mission-ready: TVAC results confirm TRL 8 advancement with verified thermal-optical stability for the space environment.

MORE INFO

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