



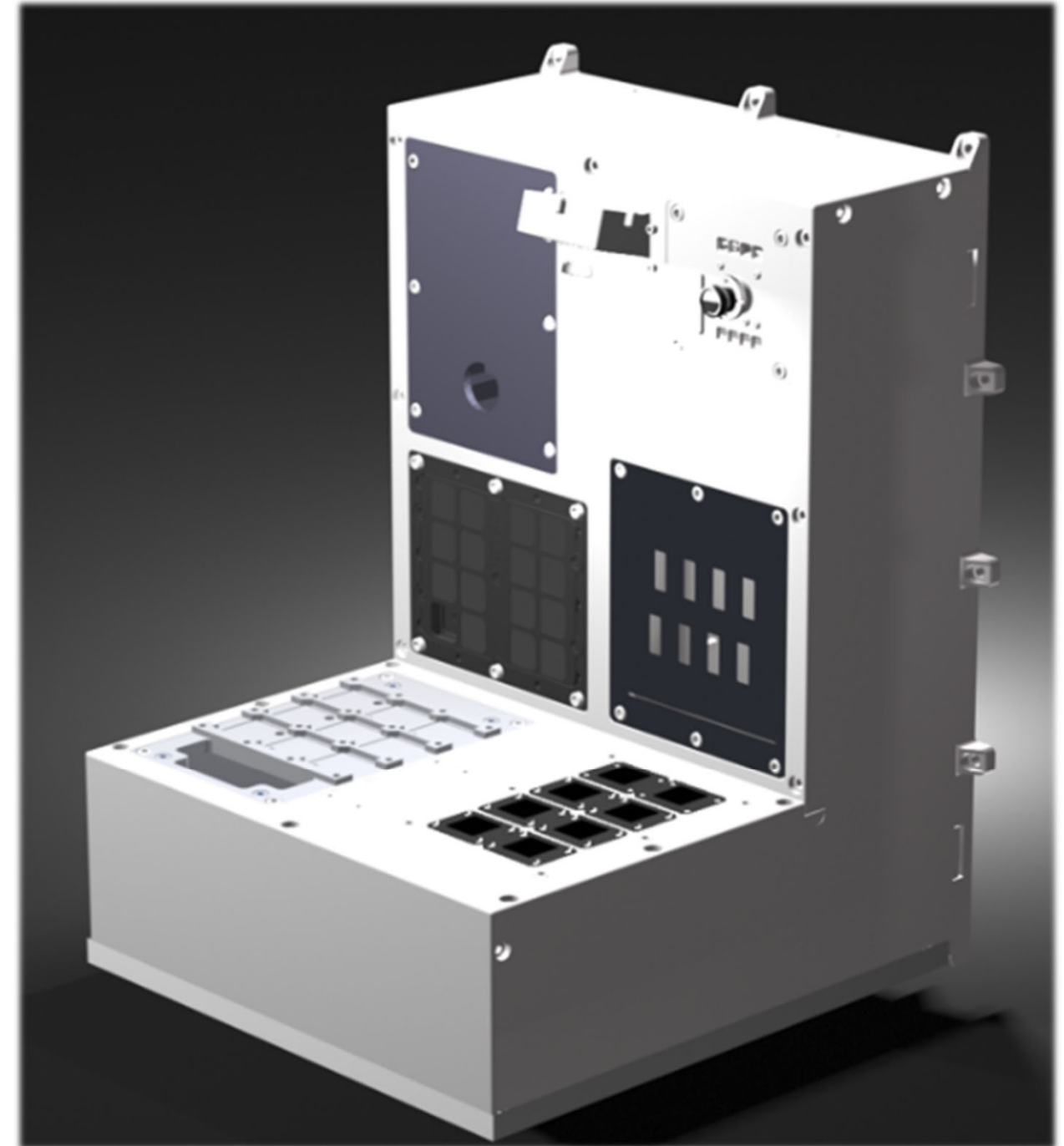
SPACE ENVIRONMENT TESTING BEYOND LEO

FINAL PROJECT REVIEW PRESENTATION (PHASE I)

DEVELOPMENT REPORT

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Space Environment Testing beyond LEO



- Materials testing and Technology Demonstration Experiments (TDEs) have been accomplished in LEO utilizing Multi-purpose ISS Experiment (MISSE)
- Beginning with MISSE-9, the MISSE Flight Facility was commissioned to improve the MISSE capabilities and reduce costs
- Space Science & Technology Evaluation Facility – First Flight (SSTEF-1) was originated by identifying the need to develop, test and deploy testing technology beyond LEO, starting with the Moon, to achieve TRL 9
- NASA Game Changing Development Tipping Point program has funded the Aegis Aerospace, Inc. SSTEF-1 project to accomplish this goal
- Phase I to develop, build and test a qualification unit and build and test a flight unit are now completed.
- Phase II will integrate the flight unit on a Lunar lander, launch, transit, land and operate on the Moon in early 2026.

SSTEF-1 Concept of Operations



1. Testing and Integration
Communication with
Experiments, Lander and
Control Center

2. Launch and Landing 4-8 days

Launch
Transit to Lunar Orbit
In-transit Health and Status
Landing on Moon

3. Payload Commissioning
Lander post Landing Ops
SSTEF-1 Power On
Experiment Power On

4. Operations (up to 14 days)

Daily Payload Power Cycles
Operations Monitoring
Command SSTEF-1 and Payloads
Data Collection and Transmission

5. End of Life

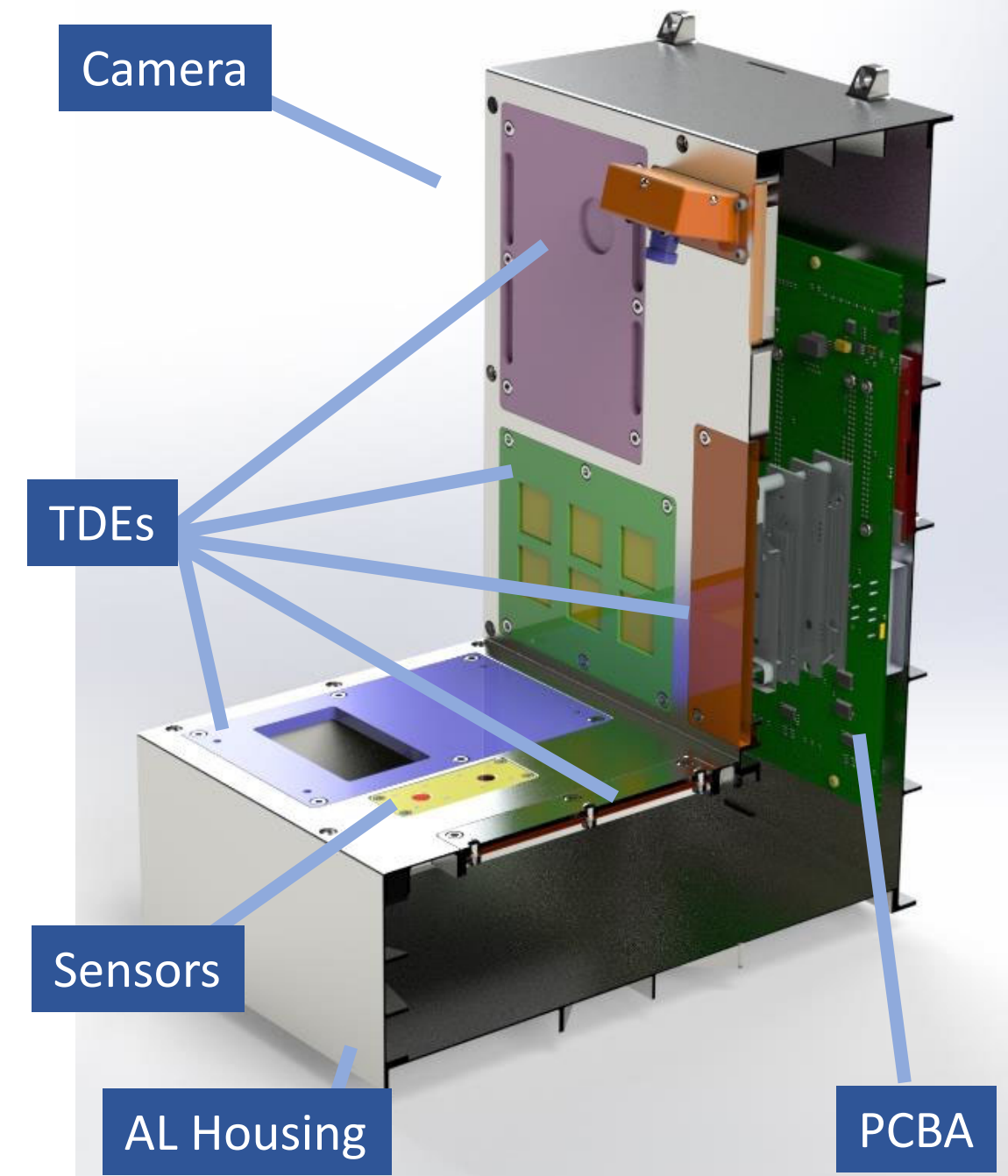
Shutdown Ops
Abandon in Place



SSTEF-1 Features



- SSTEF CPU – Power In, Ethernet and RS-422 communications with lander
- Accommodates six (6) TDEs
 - Solar Cell Test Bed
- Up to two (2) onboard cameras
- Sensors
 - TDE voltage and current (power measurement)
 - Irradiance sensors – total and UV
 - Temperature sensors
- Survival Heaters



SSTEF-1 Features



CPU Experiment

Radiation Shielding Experiment

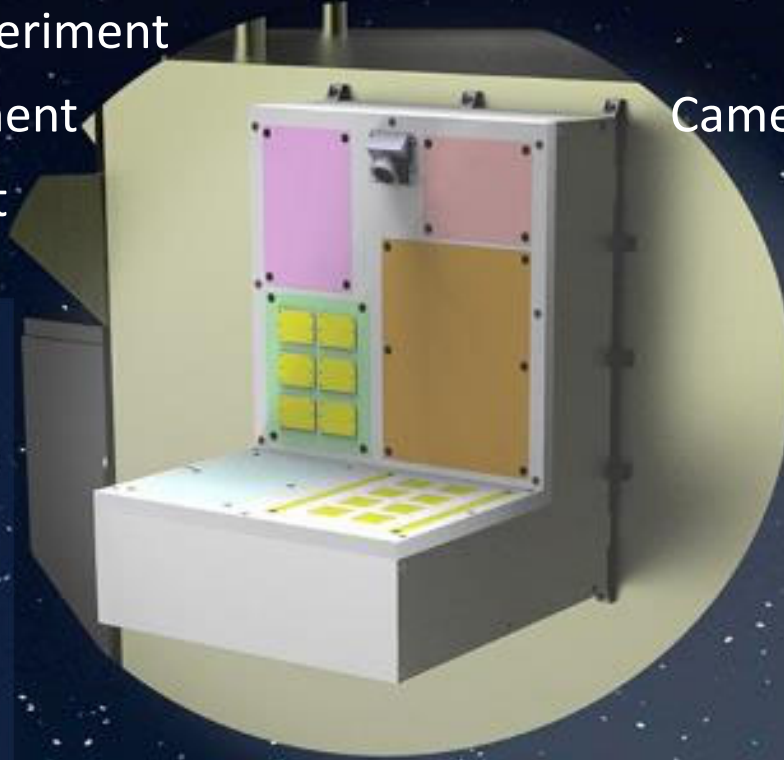
3D printed Antennas Experiment

Material evaluation Experiment

Camera

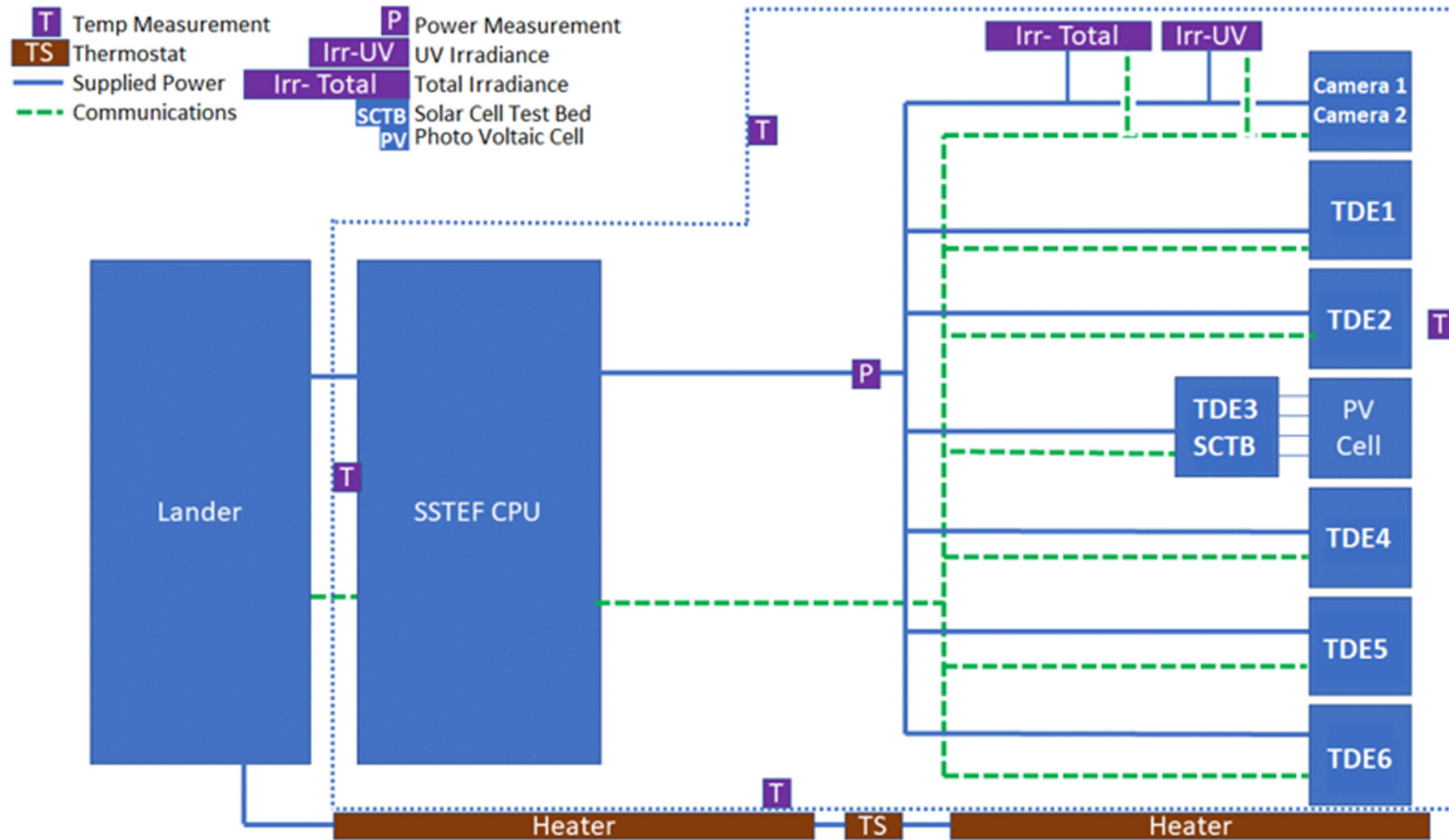
Electrodynamic Dust Shield

Solar Cell Test Bed



- SSTEF-1 occupies a footprint of 30.2 cm x 27.1 cm x 40.0 cm
- 6 kg cumulative TDE mass. The total SSTEF mass may be up to 10kg.
- TDE power available
 - 28V: +6/-4 volts 0.21 amps/5 watts
 - 12V: +/-10% 0.50 amps/6 watts
 - 5V: +/-10% 0.40 amps/2 watts
- TDEs may operate continuously on minimal power (<1 W)
- All TDEs may operate separately for 1 hour per Earth Day
 - High power mode available to specific TDEs
 - Power available may be increased depending on the lander power availability and TDE requirements
- SSTEF-1 was configured for ~45 W total heater power
- Camera imagery available of the lower deck
- UV and total irradiance sensor data collection
- Eight temperature sensors allow monitoring of the SSTEF housing temperatures
- Sixteen GPIO are available for discrete inputs from TDEs or outputs to TDEs
- Fourteen 12-bit ADC channels are available
- Flight and ground software created, maintained, and operated by Aegis Aerospace, Inc.
- 25 kbps average total experiment data via RS-422, which can increase or decrease subject to vehicle link budget available
- Redundant communications with lander (Primary: Ethernet, Backup: RS-422)
- Two processors in each SSTEF printed circuit board (PCB), providing redundancy if there is a fault
- Experiment power monitoring can detect off nominal events and move SSTEF operations into troubleshooting fault modes
- Asynchronous commanding from control center

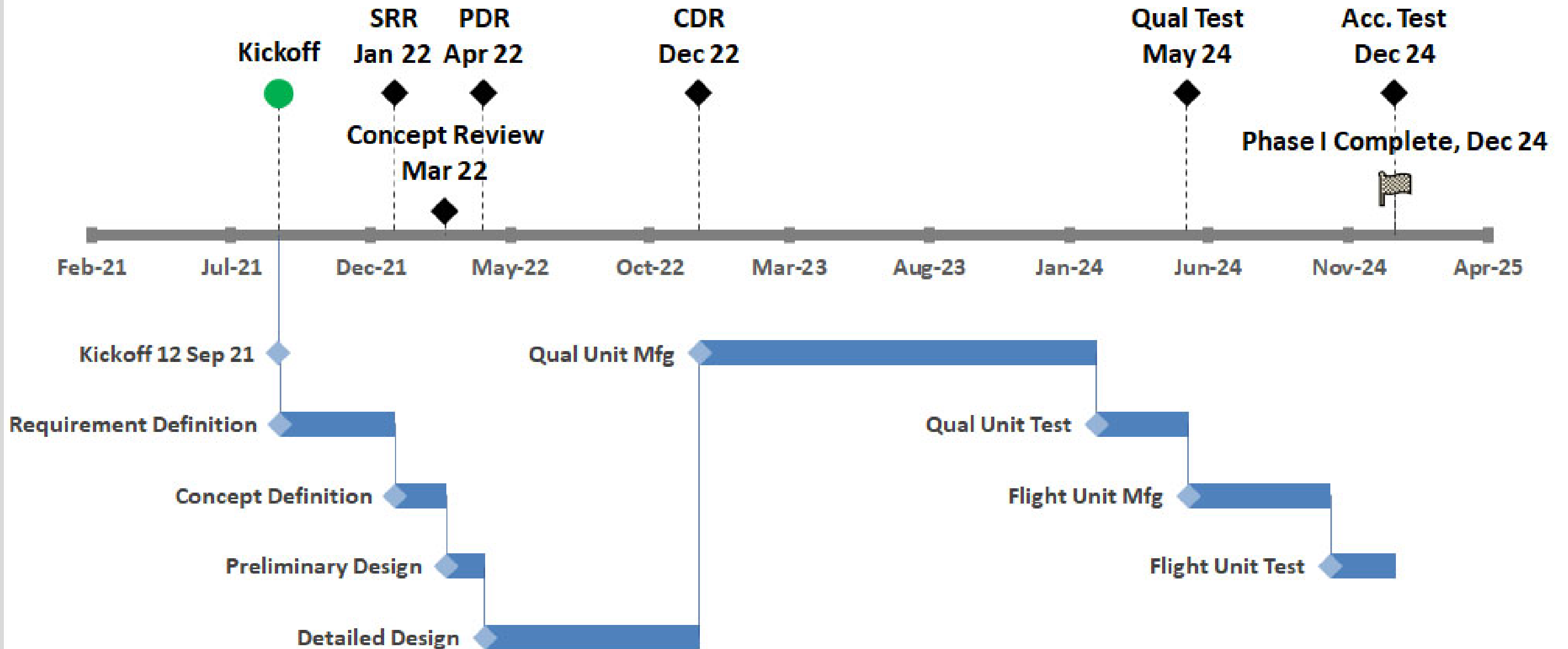
SSTEF Functional Diagram



Schedule



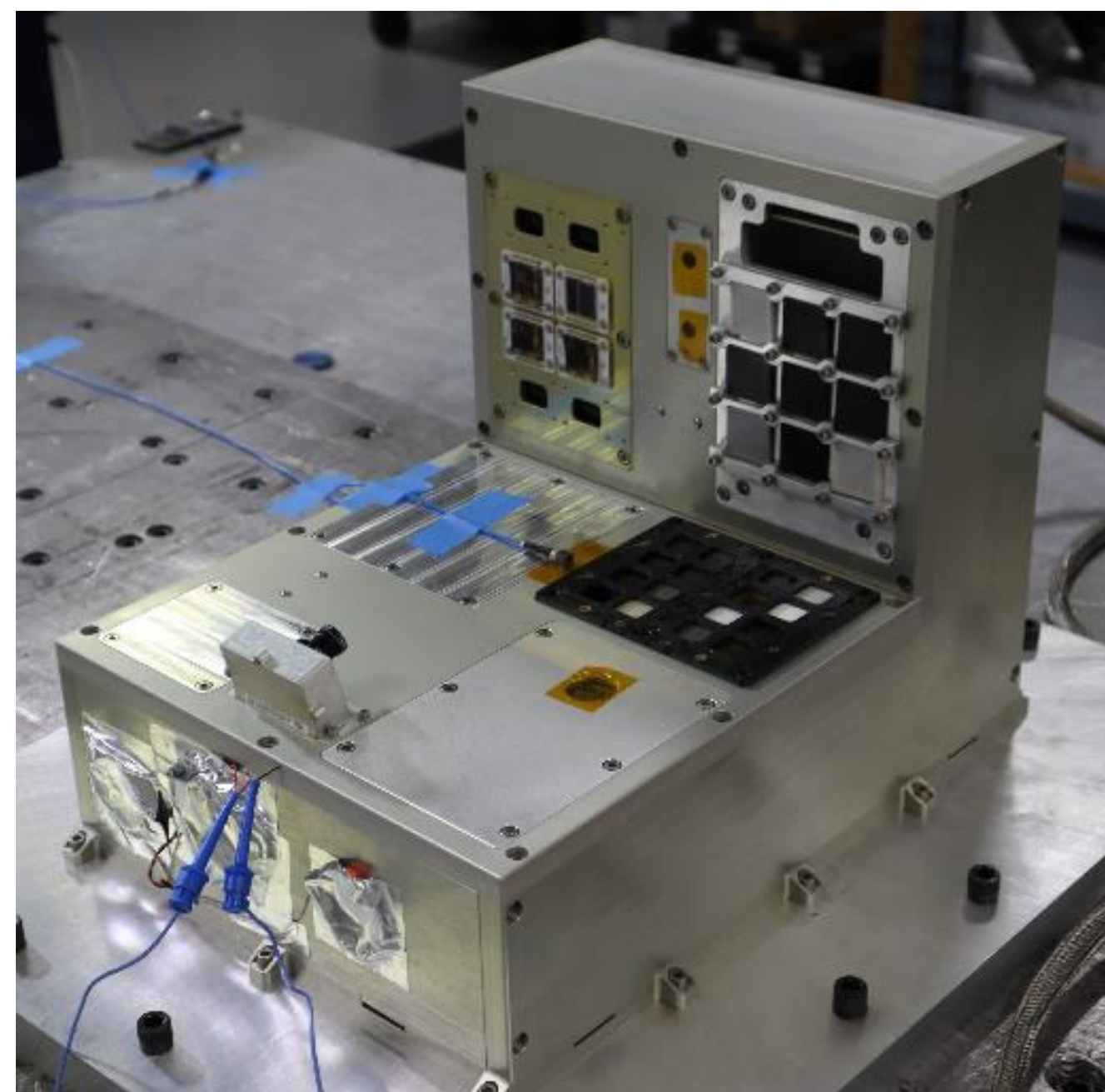
SSTEF Project Schedule



Project Images

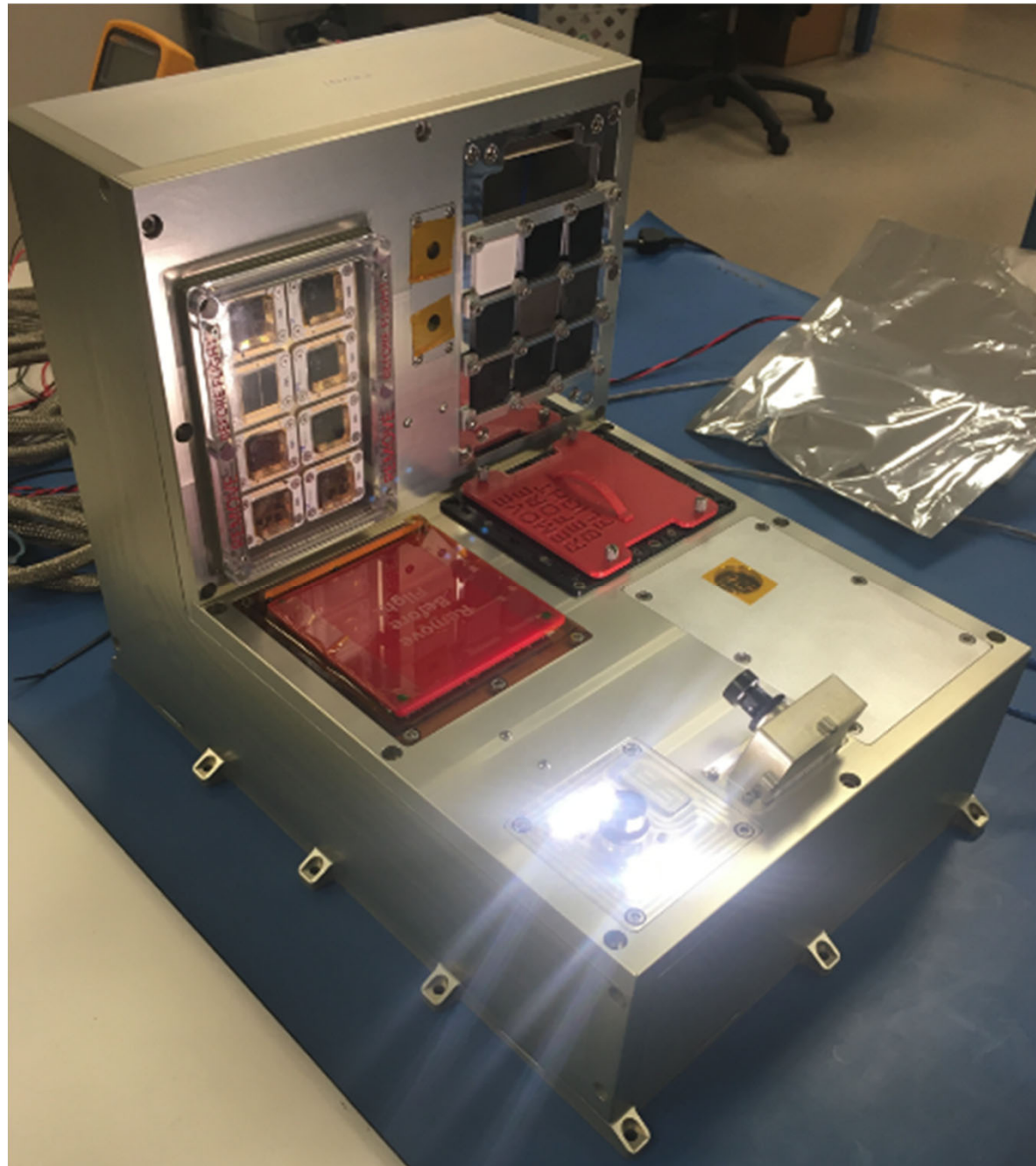


Qualification Assembly Completed



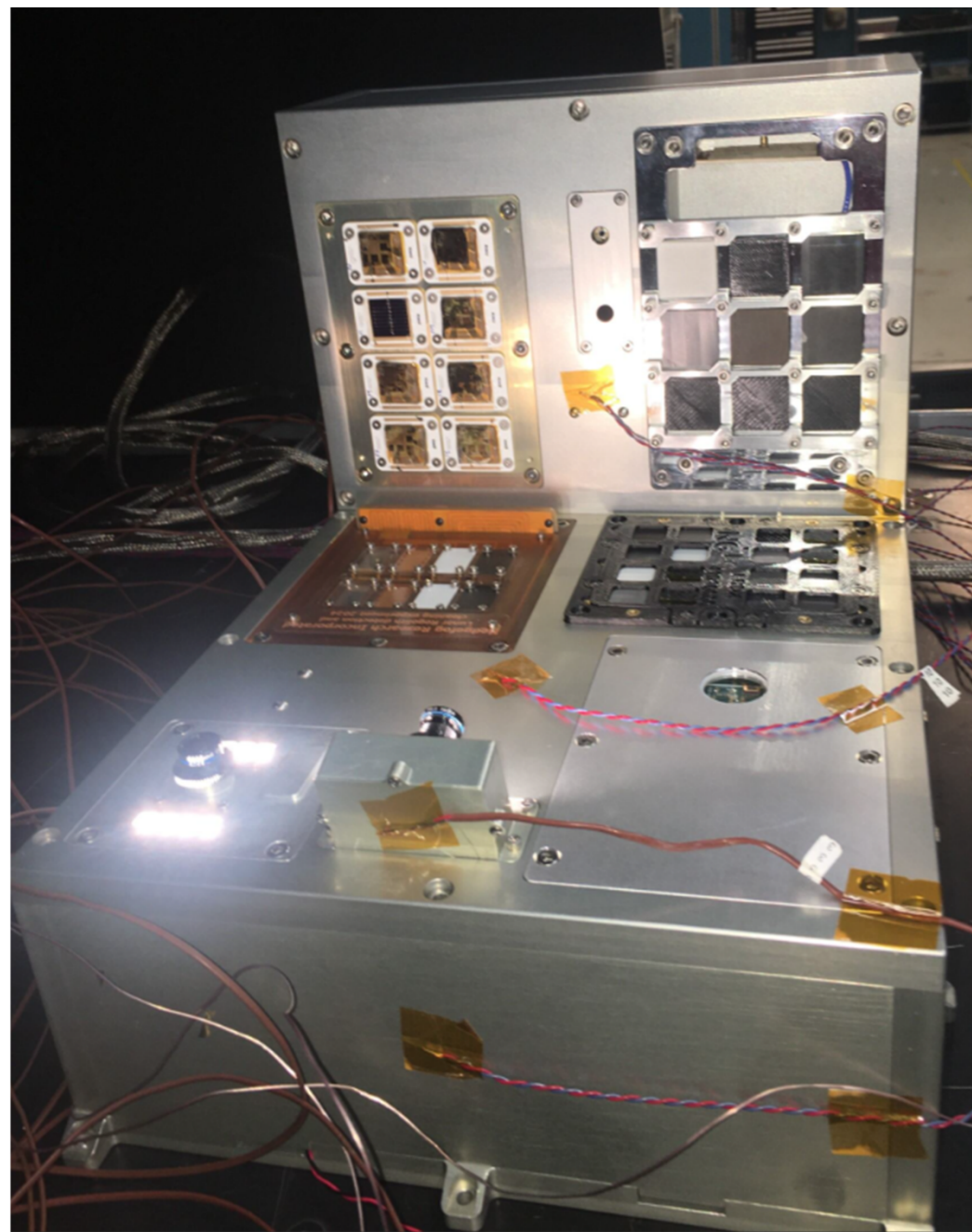
Qualification Vibration Testing

Project Images

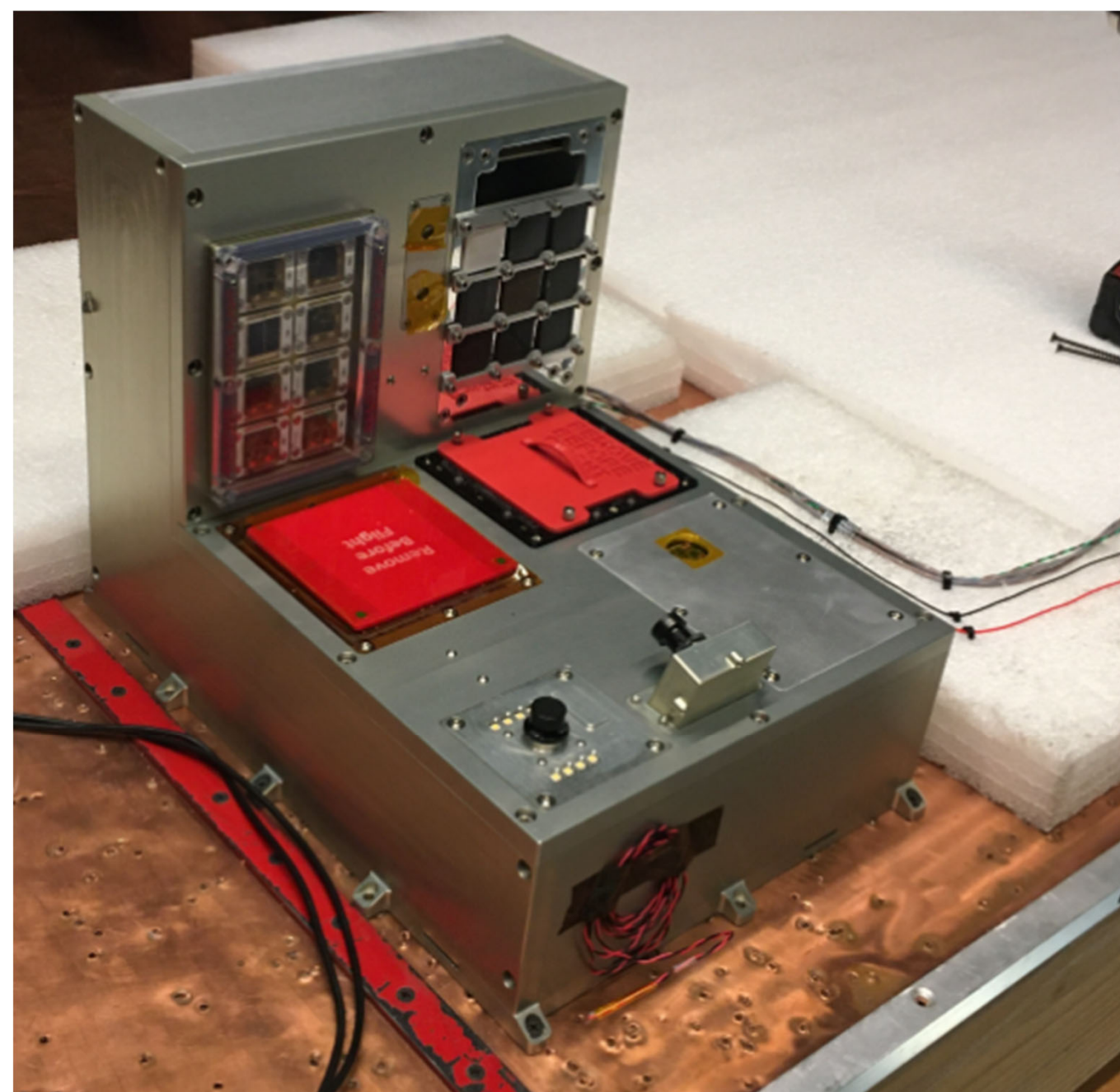


Flight Assembly Ongoing – Electrical checkout complete

Project Images

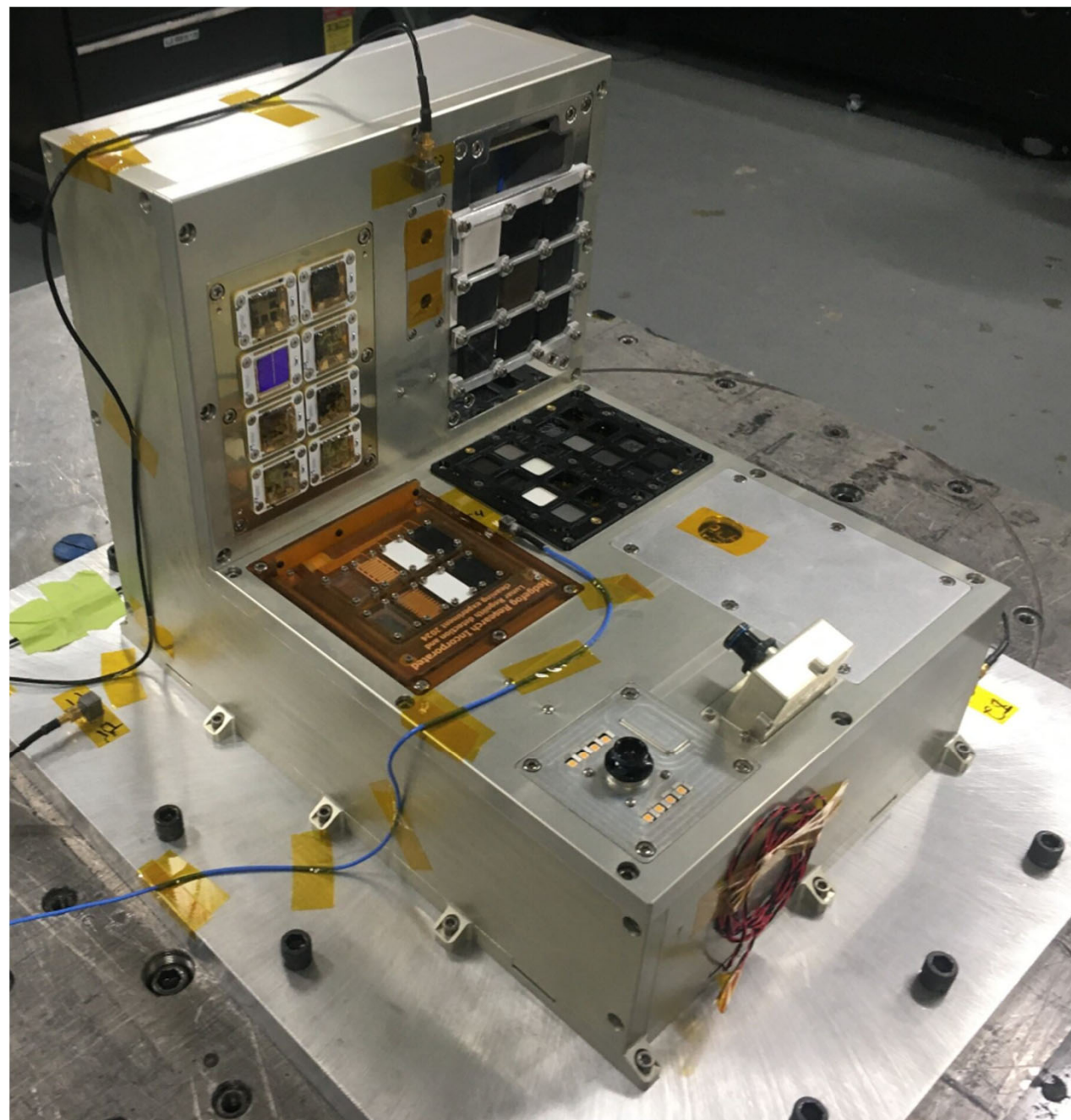


Flight Assembly Thermal Vacuum Test



Flight Assembly EMI Testing

Project Images



Flight Assembly Vibration Test

Test Plan



Test Type	Qualification Testing	Acceptance Testing	Source
Random Vibration	14.1 Grms	10.0 Grms	GSFC-STD-7000B table 2.4.3
Shock	Max 250Gs and 500Gs	None	GSFC-STD-7000B Figure 2.4-1
Thermal Vacuum	Minimum of 12 cycles, 15 deg C beyond AFT	Minimum of 12 cycles, 5 deg C beyond AFT	GSFC-STD-7000B section 2.6.1, section 2.6.3.2.2.1
EMI	MIL-STD-461G CE101, CE102, RE101, RE102, RS103	MIL-STD-461G CE101, CE102, RE101, RE102, RS103	SSTEF-1 Requirements Definition Document
SSTEF-1 Assembly Level Functional	Full test of all SSTEF-1 and TDE functions after all other testing completed	Full test of all SSTEF-1 and TDE functions after all other testing completed	SSTEF-1 Requirements Definition Document

TDE: AEGIS AEROSPACE, INC. – ANGSTROM DESIGNS, INC. – SOLAR CELL TEST BED



Solar Cell Test Bed (SCTB) performs electrical characterization of photovoltaic (PV) cells on the Moon.

Based on Aerospace Corp. 'Aerospace Measurement Unit' (AMU)

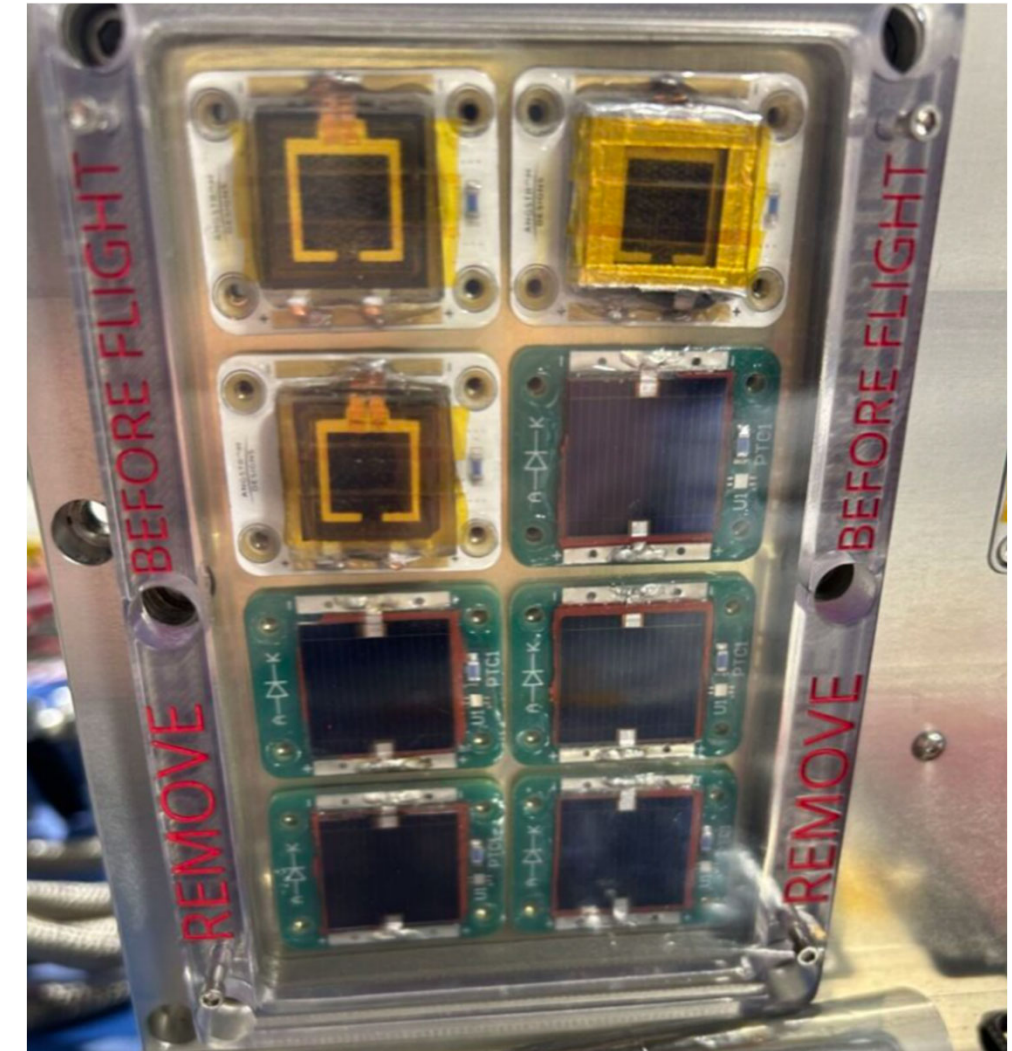
TDE designed on subcontract to Angstrom Designs, Inc.

Accommodates eight (8) PV cells.

Georgia Tech provided solar cells which utilize perovskite-based photoabsorbers, offering key insights into solar resilience and composition in space. This will be the first emplacement of perovskite-based solar cells on the lunar surface.

MicroLink Devices, Inc. supplied high-efficiency photovoltaic (PV) cells for the SCTB. These inverted metamorphic multijunction (IMM) solar cells were specifically designed for space applications and manufactured using MicroLink's proprietary epitaxial liftoff (ELO) process.

Martin Materials Solutions LLC (MMS) provided the specialized coverglasses used in the construction of the MicroLink PV cell assemblies.



Solar Cell Test Bed

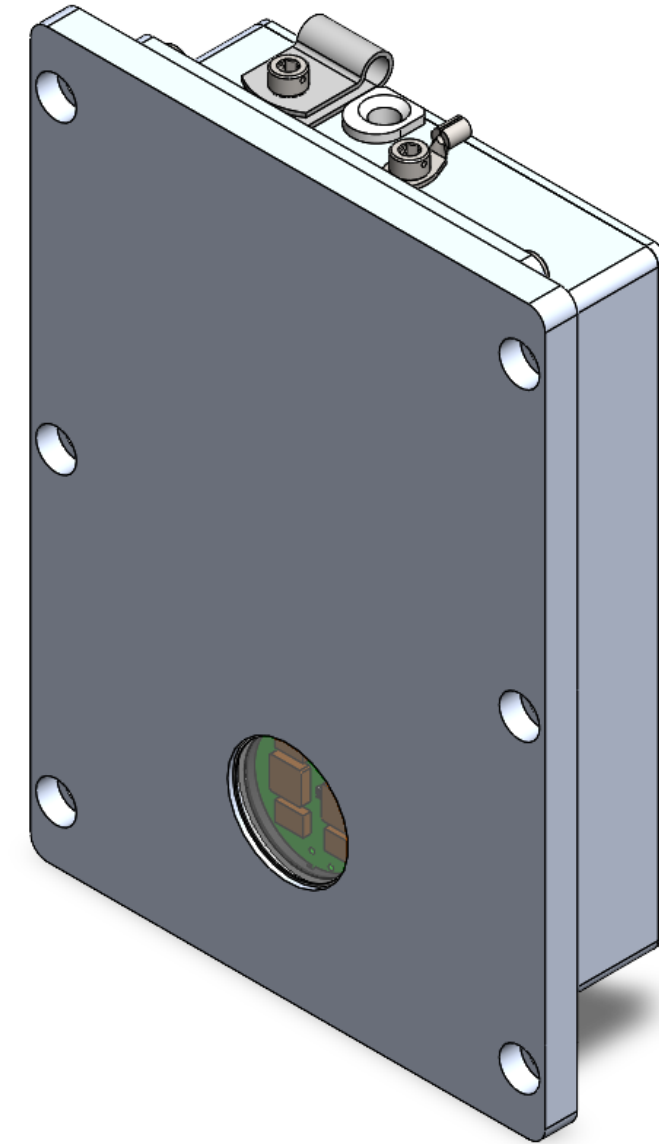
TDE: OZARK INTEGRATED CIRCUITS, INC. – XNODE SAMPLE EVALUATION SYSTEM



The Ozark IC XNode™ Sample Evaluation System utilizes the AQ200 extreme environment XNode computing product and a custom, SiC, high response, UV sensor to provide a sample read-out platform for materials evaluation in the lunar/space environment.

This has the ability to measure the voltage vs. current relationship of any material, from a dielectric, a conductor, or semiconductor device.

The system contains 4 channels at 16 bits of resolution and includes onboard housekeeping/monitoring capability including temperature and power supply.



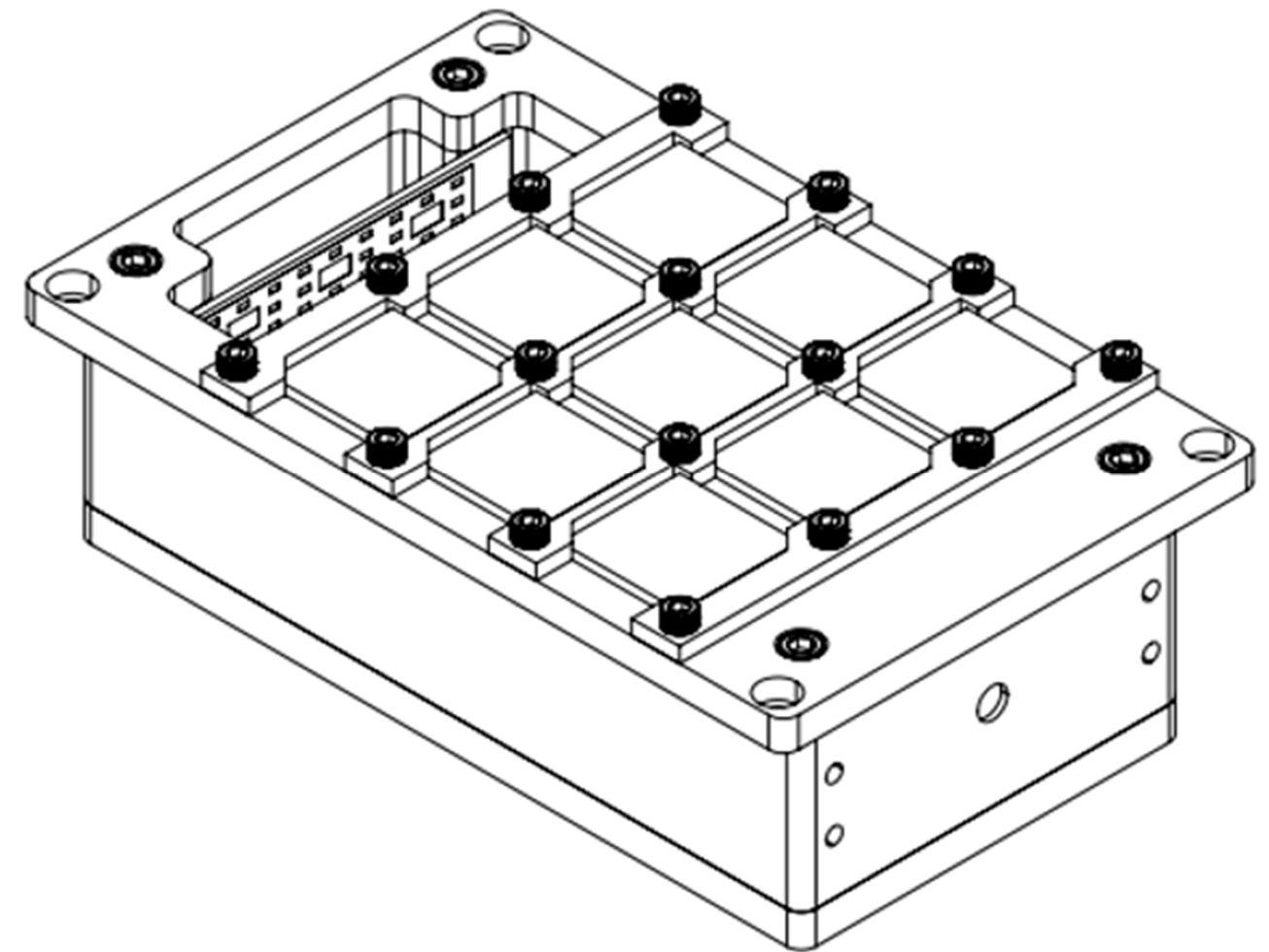
*Sample Evaluation System
(image used with OzarkICs permission)*

TDE: 3D PRINTED ANTENNAS



3D printed antenna testing TDE

Material samples are mounted to the top surface and pictures are taken periodically

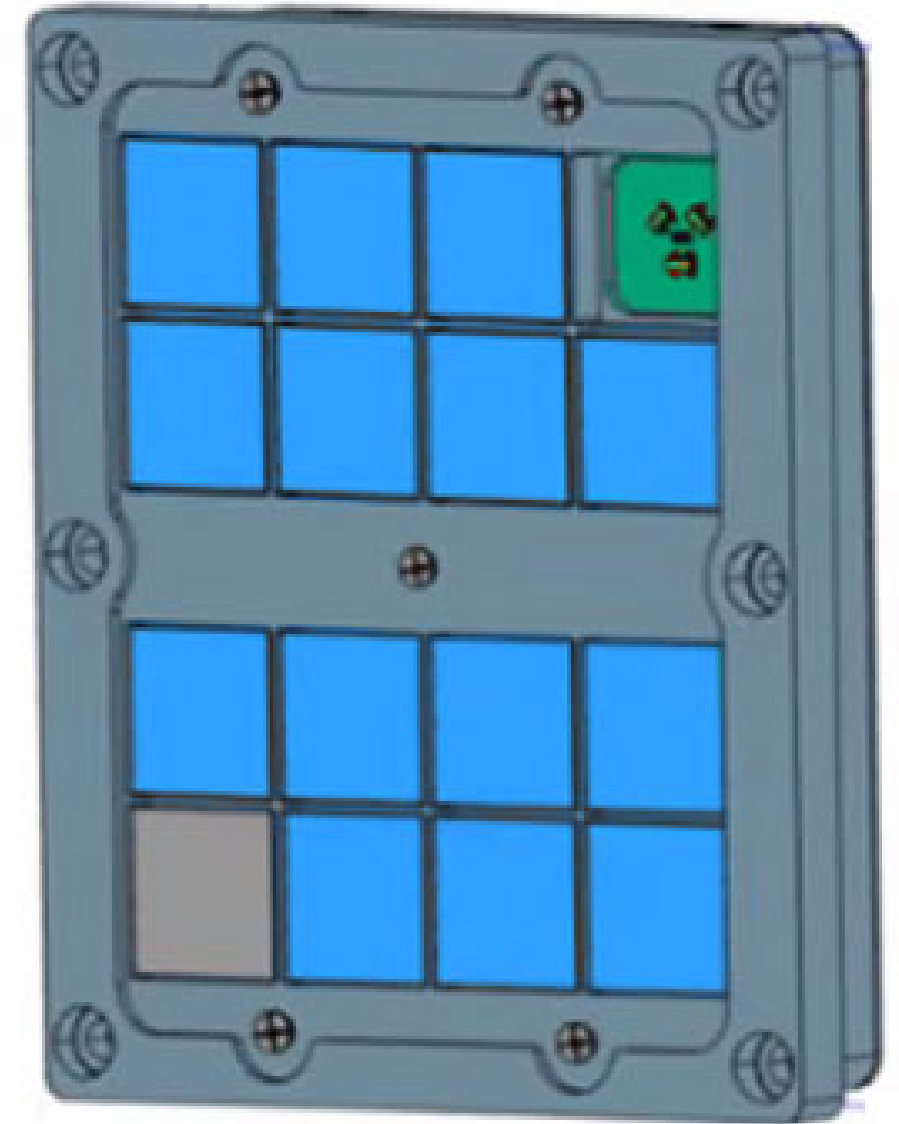


3D printed antennas with Material Samples

TDE: MATERIALS TESTING



Materials testing TDE



TDE: HEDGEFOG RESEARCH, INC. ELECTRODYNAMIC DUST SHIELD



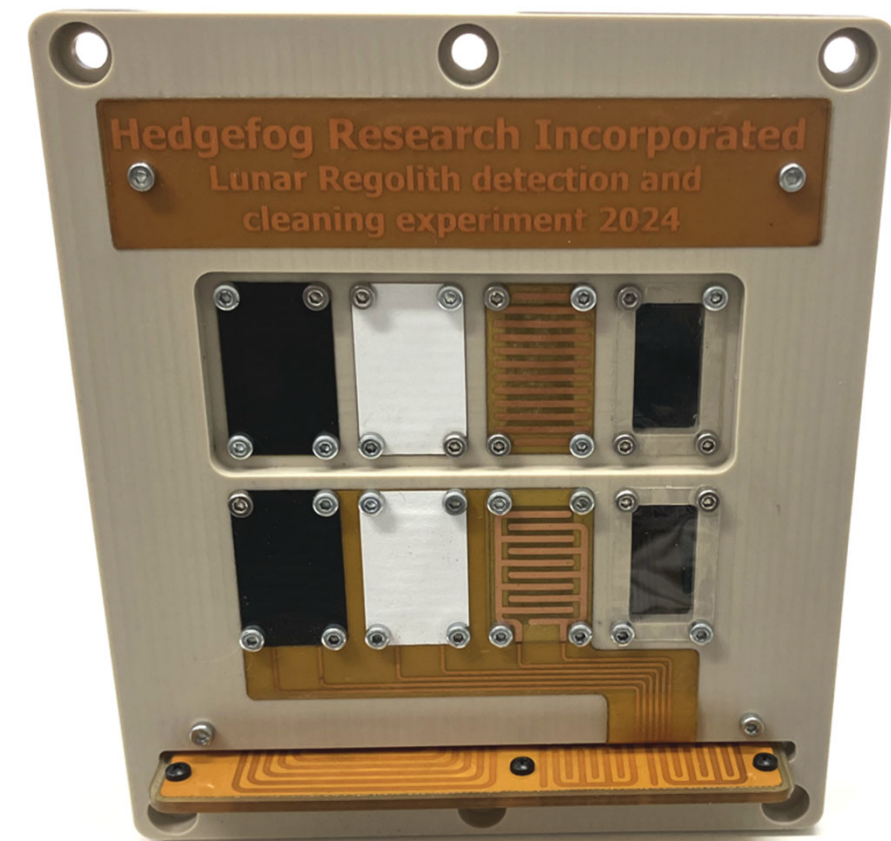
Hedgefog Research (HFR) will deliver an electrodynamic dust shield (EDS) for testing removal of lunar regolith from its surface in the Lunar environment.

It is anticipated that surface interaction will cause a cloud of dust to rise above the SSTEF-1 platform such that some dust will fall back to the surface and land on the horizontally mounted EDS grid.

During the first 10 seconds of power up, the overhead SSTEF-1 camera will take still images of the EDS device every second to record any dust that has landed on the grid.

During the next 10 seconds, the EDS will be switched on to remove the dust, while still being photographed each second.

For the remaining part of the 1-hour experiment, HFR will monitor the presence of dust on thin film detectors.



*Electrodynamic Dust Shield
(image used with Hedgefog Research permission)*

Software Operations



Aegis Aerospace Operations are performed from the Payload Operations Control Center (POCC)

Operator can monitor telemetry from user interface (shown): Temperatures, irradiance sensors, TDE current, SSTEf total current, etc.

Software performs automated scheduling of experiment power on/off, camera image taking

Operator can transmit commands to the SSTEf payload via the user interface, e.g. power on/off experiments, camera image, camera lights, scheduler on/off

Software monitors experiment current and can shutoff power bus in case of overcurrent

The screenshot displays the SSTEf software interface with the following sections:

- Primary System Power:**

	Voltage	Amps	Watts
Lander:	29.23	0.09	2.70
Heater:	31.24	1.12	35.1
SSTEf:	26.99	0.10	2.70
- Heartbeat:**
 - BB-1 ← BB-2 (Green)
 - BB-2 ← BB-1 (Green)
- Power:**
 - 5V (Grey)
 - 12V (Green)
 - 28V (Green)
- Cameras:**
 - Power (Green)
 - Lights (Green)
 - Camera 1 (Green)
 - Camera 2 (Grey)
- SSTEf Temperature Sensors:**

	Count	Voltage	Value
Back Plate - Bottom	3,002		27.05 °C
Back Plate - Top	3,025		29.35 °C
Vertical Deck - Middle	971		-176.05 °C
Vertical Deck - Bottom	3,001		26.95 °C
Horizontal Deck	2,991		25.95 °C
Top Plate	3,016		28.45 °C
Front Plate	2,980		24.85 °C
Camera	3,008		27.65 °C
PCB - Top	1,429	0.63	28.50 °C
PCB - Bottom	1,440	0.63	29.10 °C
RTD - Back Plate			32.10 °C
- Network:**

	BB-1	BB-2
sstef-bb1	Green	Green
sstef-bb2	Green	Green
sstef-ppp	Grey	Grey
im-lander	Green	Green
im-lander-ppp	Grey	Grey
- Experiments:**

	5V	12V	28V	TX	RX
1. TDE 1	Grey	Grey	Grey	Grey	Grey
2. Hedgefog EDS	Grey	Grey	Grey	Grey	Grey
3. Solar Cell TB	Grey	Grey	Green	Orange	Grey
5. Ozark IC	Grey	Grey	Grey	Grey	Grey
6. TDE 6	Grey	Grey	Grey	Grey	Grey
7. TDE 7	Grey	Green	Grey	Green	Grey
8. Irradiance Sensors	Grey	Grey	Grey	Grey	Grey
- IM Lander:**

	Primary	Backup	RS-422
Command-Forward:	0	0	0
Store-Forward:	0	0	0
Stream:	0	0	0
Ping:	0	0	0
- Message Counts:**

	Primary	Backup	RS-422
Command-Forward:	257	45	0
Store-Forward:	0	0	0
Stream:	5221	225937	0
Ping:	1122254	1121257	0
- Scheduler:**
 - Enabled (Green)
 - Running (Grey)
 - Filename: LunarOps 01
 - Description: LunarOps Schedule 01
 - Midnight: 18:22:40
- SSTEf Analog Inputs:**

	Count	Voltage	Value
UV Irradiance	0		W/m ²
Total Irradiance	0		W/m ²
LRDX	0		
- GPIO Status:** (Button)
- Host:** sstef-bb1
- Time:** 2025-04-24 18:38:46
- Uptime:** 04:55:20
- Flight Mode:** Lunar Ops
- TDE Current Draw:** 0.21 A
- Buttons:** Command, Exit
- Footer:** 2025-04-24 18:38:49 UTC

Lessons Learned



Electromagnetic Susceptibility of Temperature Sensors

During MIL-STD-461 RS103 EMI/EMC test, it was found that the SSTEf housing temperature sensors read erroneously while testing in the 30 – 1000MHz range at 20V/m intensity.

Troubleshooting was completed to isolate the problem to the actual temperature sensor and not the measurement circuit

Other onboard temperature sensors did not exhibit the issue

Troubleshooting with a non-flight unit showed that an alternative temperature sensor does not exhibit the behavior

Two learnings came from this issue:

1. As described in MIL-STD-461, troubleshooting of RS103 testing anomalies should include determining the energy threshold and frequencies at which the anomalous behavior occurs
2. On future SSTEf hardware, consider using the alternative sensor that was unaffected

Lessons Learned



Backup Plans

One of the greatest risks identified to the SSTEF-1 program was the number of contributions, specifically the TDEs, by third parties.

Originally there were seven (7) third parties identified in the SSTEF proposal

Only four (4) of the original third parties completed the program and are flying hardware

Backup plans were put in place and identified two (2) new third parties to provide TDE hardware

One TDE slot was filled by another Aegis Aerospace, Inc. camera, which had to be rapidly designed due to the different form factor

TDE Testing Program

The original TDE acceptance test program for the flight unit was to perform integrated testing of the TDEs for Vibration, Thermal Vacuum and EMI

The drawback to this approach is that any TDE issues that are uncovered could quickly become the critical path for the entire SSTEF payload

Delays in the lander launch allowed these issues to be handled due to corresponding delay in the payload delivery date

The lesson learned is for the TDE to perform vibration, some thermal vacuum cycles and EMI emissions prior to integration and testing with SSTEF