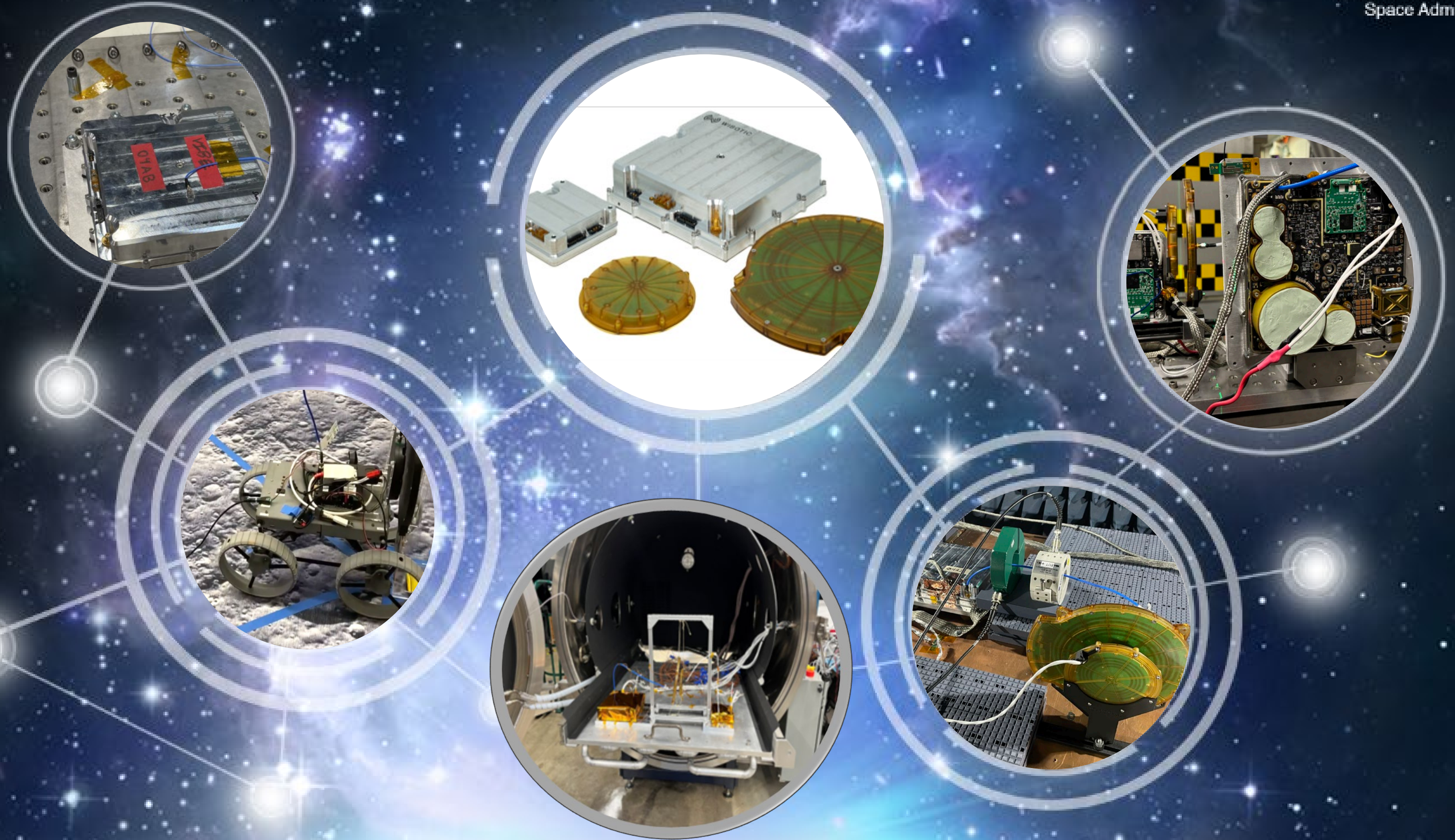
National Aeronautics and Space Administration



Space Technology Mission Directorate

Game Changing Development Program

Ultra Fast Proximity Charging for Critical Space Application / Tim Painter, Astrobotic | Annual Program Review | September 10-12, 2024

Project Overview

Timer

Technology Development Needs Addressed by Project	
Stakeholder	The Ultra Fast Proximity Charger will advance from TRL 4 to TRL 6 critical technologies needed to fully commercialize wireless charging systems, including a transmitter (TR), transmitter coil (TC), onboard charger (OC), and receiver coil (RC).
Stakeholder	A space-qualified charging system capable of near field wireless power transfer.

Project Goals	
Goal #1	Develop a rover with integrated power receiver, and a base station, both capable of operating in a lunar environment.
Goal #2	Demonstrate wireless charging as a feasible means of power transfer for lunar missions.
Goal #3	Demonstrate that the system can enable lunar night survival.

Project Objectives	
Objective #1	The program shall develop an integrated OC, and a TR, both capable of flight qualification.
Objective #2	The program shall demonstrate wireless charging as a feasible means of power transfer for lunar missions.
Objective #3	The program shall demonstrate wireless charging as a feasible means of night survival for lunar surface assets.

TRL DEVELOPMENT TIMELINE

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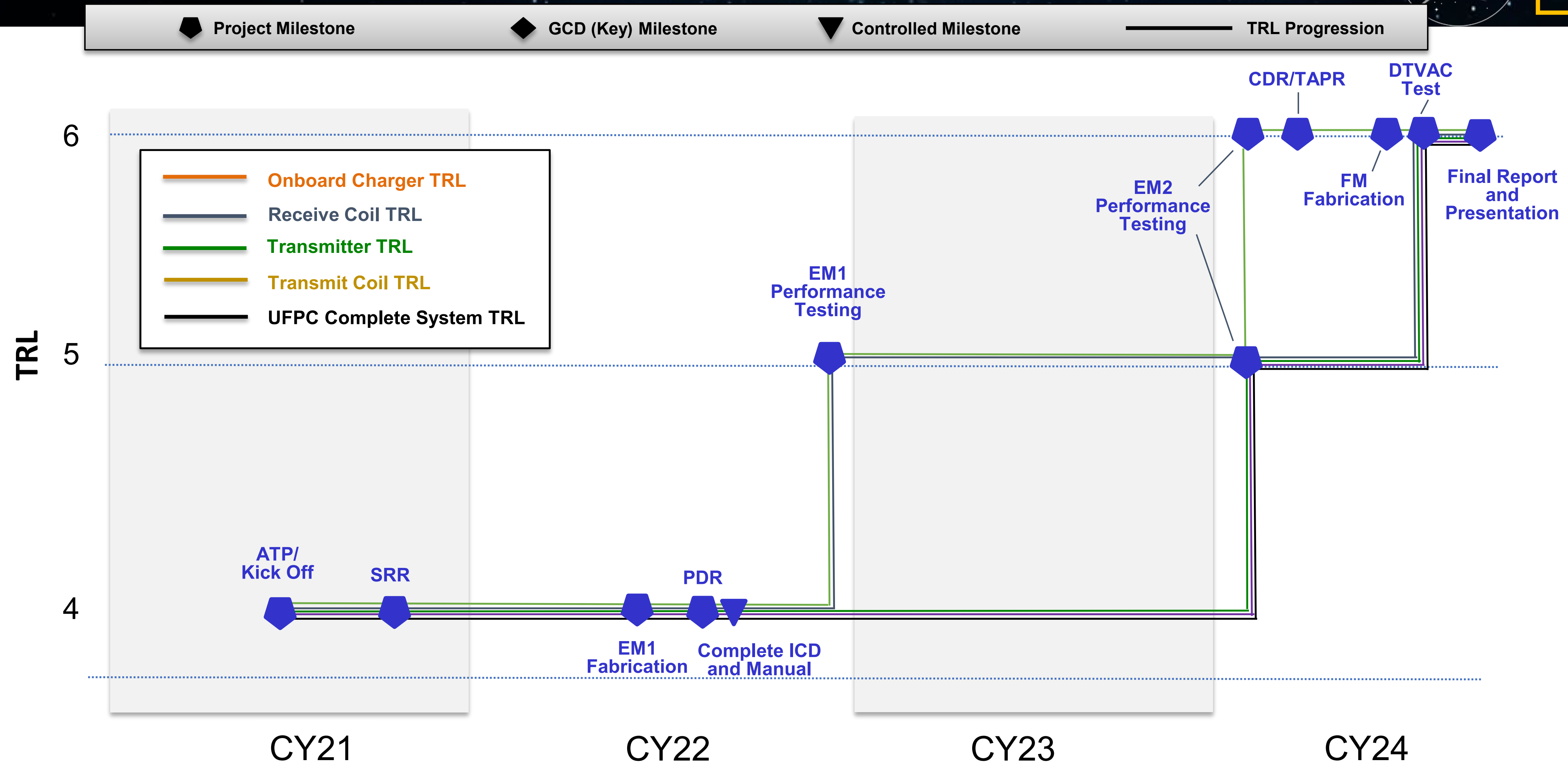

Technical Progress and Results

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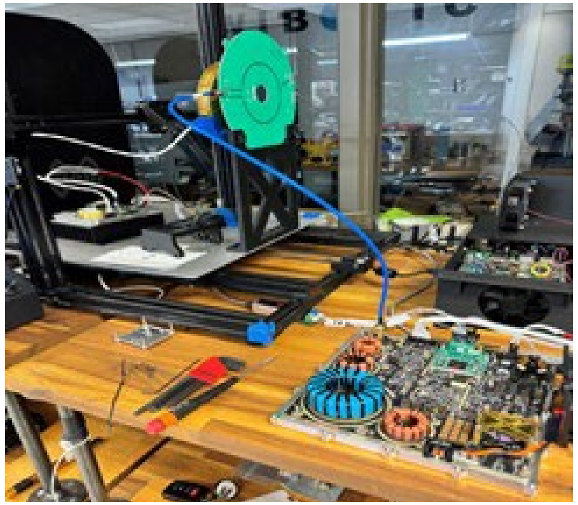
- Wibotic
  - Wibotic finalized the design of the EM2 build for the UFPC system.
  - Systems underwent endurance testing on Wibotics 'coilbot' test fixture to ensure functionality for long durations and to test misalignment.
  - 6 complete systems were built in order to support the vigorous testing campaign

EM2 Build

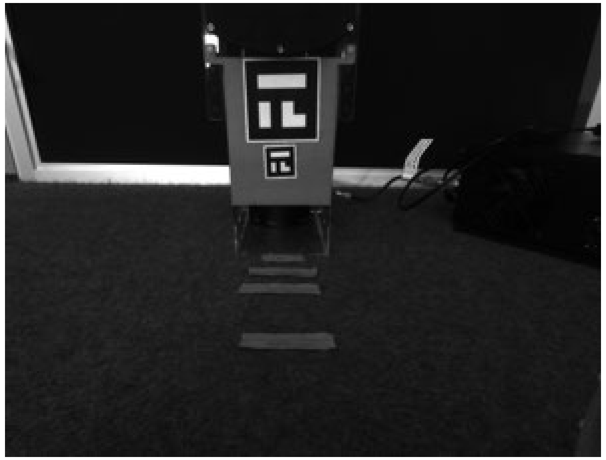


Endurance Testing

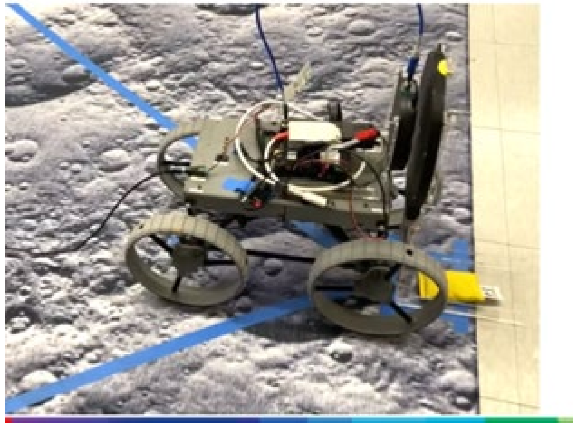
Technical Progress and Results

Timer

- Bosch
  - A study was performed to understand the impacts of using different size and types of fiducials and their ability to be detected effectively given the CubeRover hardware.
  - Nesting fiducials with progressively smaller fiducials allows the rover to approach the target and remain aligned.
  - Several path planning exercises were performed concluding with the teams first successful docking demonstration on a CubeRover surrogate.



Nested Fiducials



Autonomous Docking

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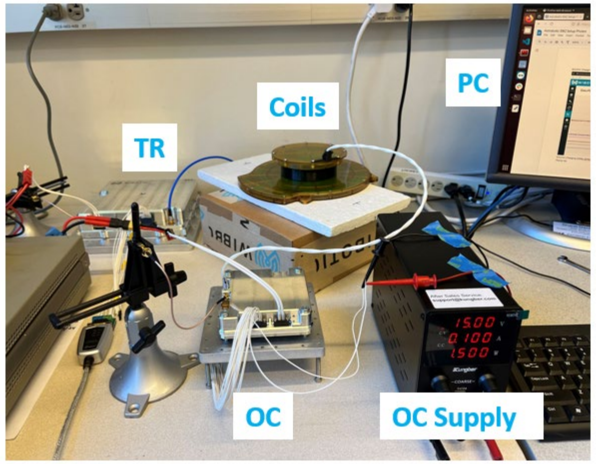
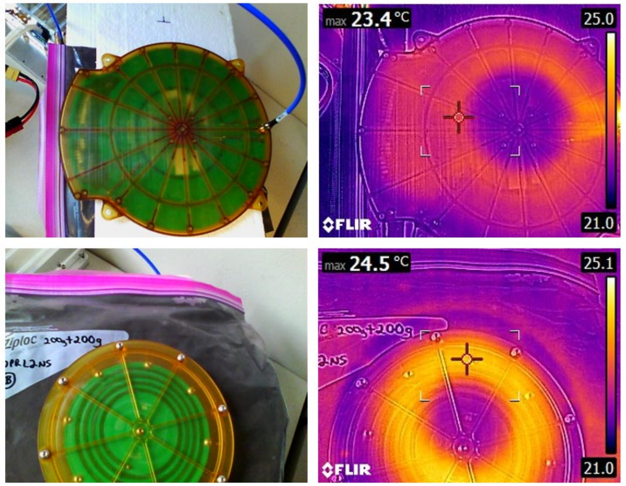
- University of Washington
  - Dust adhesion testing is done on the wireless charger to characterize the effect regolith buildup have on charging.
  - Controlled variable for the experiment are:
    - Coil distance.
    - Coil misalignment.
    - Type of regolith simulant present.
  - Data analyzed:
    - Efficiency.
    - Coil temperature.
  - Preliminary testing shows the EM2 model functions the same as the previous EM1 version with respect to interference caused by regolith



Test Fixture

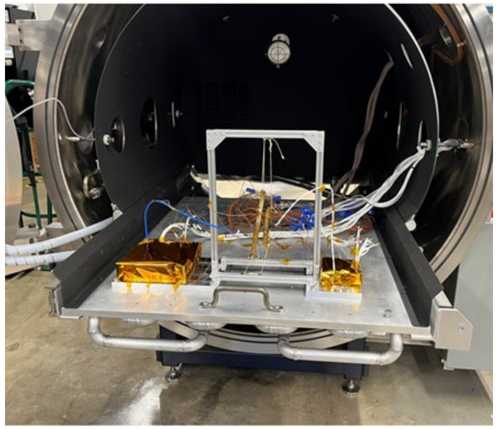
With Simulant



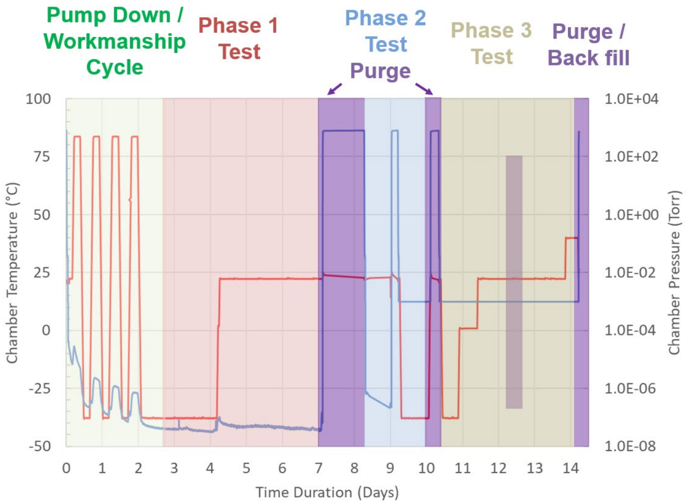
Coil Heating

Timer

- TVAC Testing
  - Thermal vacuum tests were conducted to verify device workmanship, demonstrate power transmission in extreme cold and hot conditions, and to evaluate system performance under desired vacuum and thermal conditions
  - Units performed well under workmanship cycles.
  - Units demonstrated successful power transmission in both hot and cold conditions in vacuum.
  - Units showed transmission occasional interruption in vacuum.
  - Investigations are underway to root cause transmission interruptions during testing.



TVAC Testing



Environment Profile

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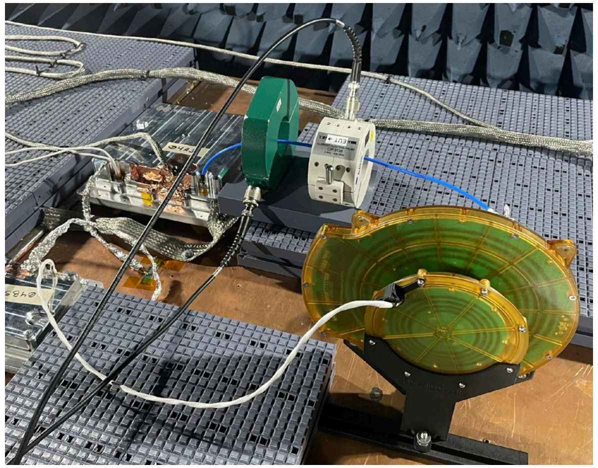
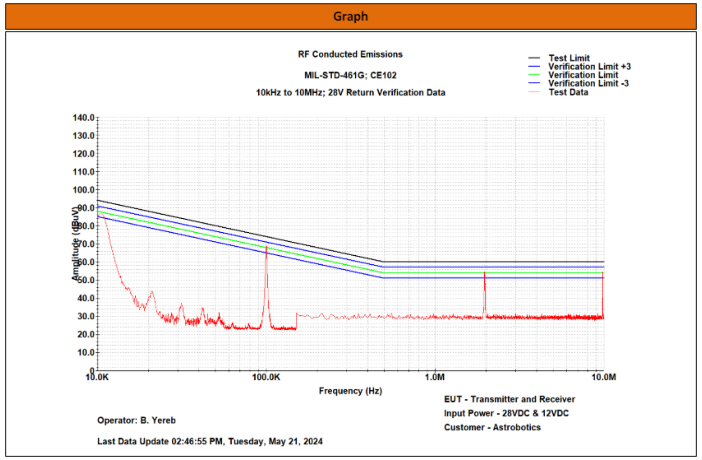
- EMI Testing
  - Testing was conducted to test how the wireless charger responds to electromagnetic sources, as well as the emissions of the wireless charger itself.
  - All testing was done to MIL-STD-461G:
    - CE102 – Conducted emissions
    - CS101, CS114, CS115, CS116 – Conducted susceptibility
    - RS102 – Radiated emissions
    - RS103 – Radiated susceptibility
  - Unit performed well overall.
  - No failures of test article.
  - Some susceptibilities detected, but not of grave concern.
  - Some emissions over the MIL standard observed, but not of grave concern.



EMI Testing

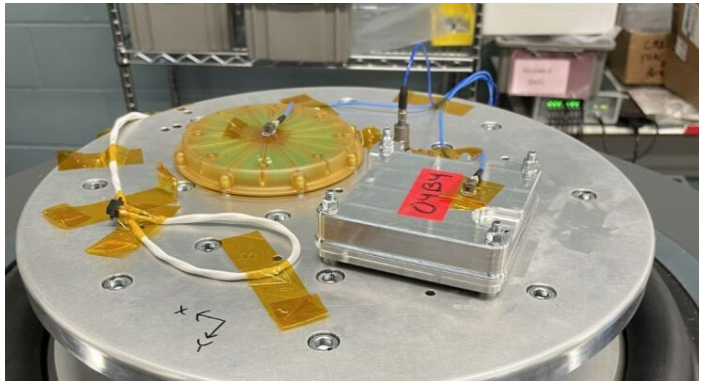


Conductive Emission Results

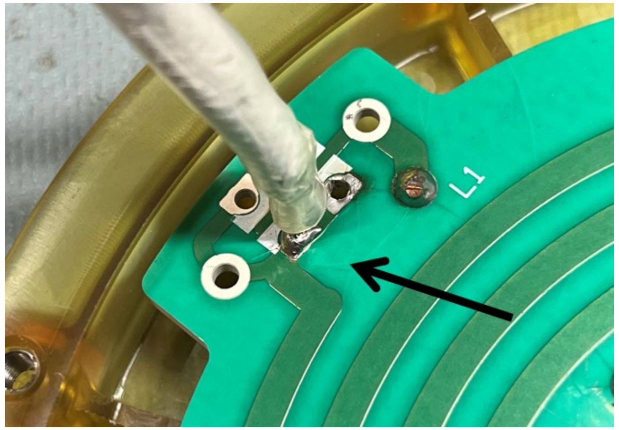
Ultra Fast Proximity Charging for Critical Space Application
Technical Progress and Results

Timer

- Vibration Testing
  - Vibration testing was conducted to assess workmanship, demonstrate survivability during launch loads, and provide any necessary feedback for flight models.
  - Testing included GEVS qual random vibration levels, Astrobotic Griffin lander qual sine levels, and a generic shock profile within the capabilities of the Astrobotic owned shaker table.
  - Minimal shifts in natural frequencies between pre and post major tests.
  - It was noted that the TC had around a 5% shift in modes post random vibration testing. A functional checkout was performed to show that the component was still operating as expected and testing was continued.
  - In addition, functional checkouts were performed before and after test. All functional checkouts showed the components to still be fully operations post vibration testing except for the RC.
  - Upon inspection of the RC and TC, cracking was observed.

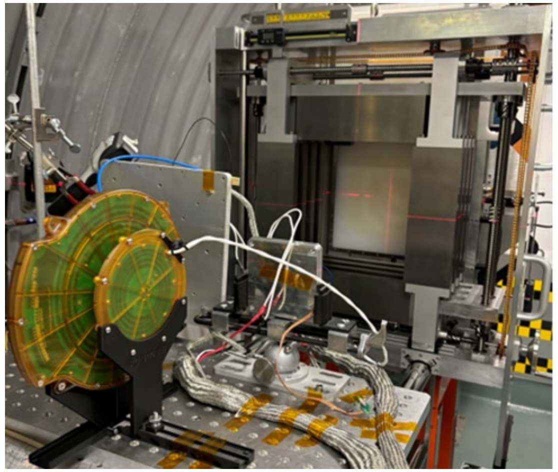


OC and RC Testing

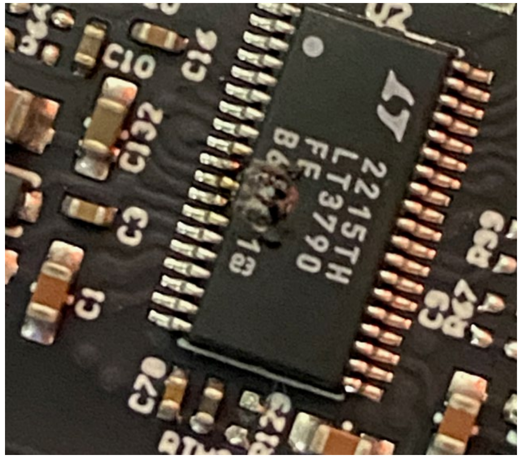


RC Cracking

- Radiation Testing
  - CO-60 irradiation was performed at 33kRad.
    - TR failed at 6 kRad.
    - OC failed at <11 kRad.
    - Specimens were returned to Astrobotic to perform root cause.
  - Heavy ion SEE testing was performed.
    - Both TR and OC experienced a DSEE at LET ~18.5
    - Imaged were taken of the failed IC’s prior to disposal of the DUT.



Radiation Testing



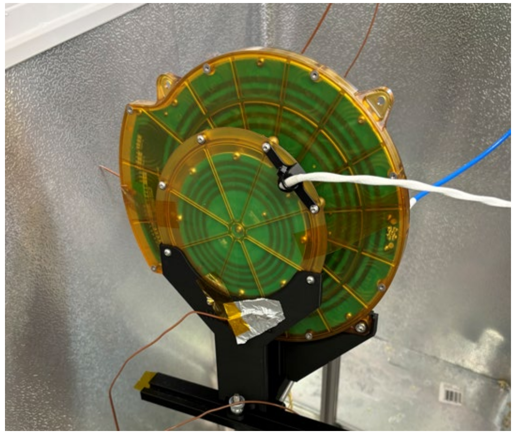
OC Component Failure

Technical Progress and Results

Timer

- Cryogenic Testing
  - Conducted cryogenic functional testing of transmit and receive coils.
  - The coils were brought down to LN2 temperatures and operated at maximum power transfer.
    - Thermocouple was placed on the receive coil fixture and temperature was controlled to that TC.
    - Power transmission was started at room temperature and continued to operate all throughout the ramp down to –180C.
    - The system was operated for another 4 hours after achieving thermal balance at –180C and then brought back up to room temperature.
  - There was no measurable impact on coil performance or efficiency.
  - Visual inspection shows no signs of damage from the cryogenic exposure.

Cryo Test Chamber



TC and RC under test

Ultra Fast Proximity Charging for Critical Space Application Transition/Infusion Status

Timer

- Astrobotic remains heavily committed to commercializing the UFPC as a product offering to other commercial space companies and NASA project teams.
- Astrobotic and WiBotic have formalized commercial agreements to define the procurement model of the jointly developed UFPC
- The UFPC remains baselined as the power system for the IPEx rover demonstration, another GCD project being lead by NASA KSC