RIT
NanoPower Research Laboratories

Radioisotope Thermoradiative Cell Power Generator

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NIAC NASA Innovative Advanced Concepts
Phase I: 80NSSC23K0593
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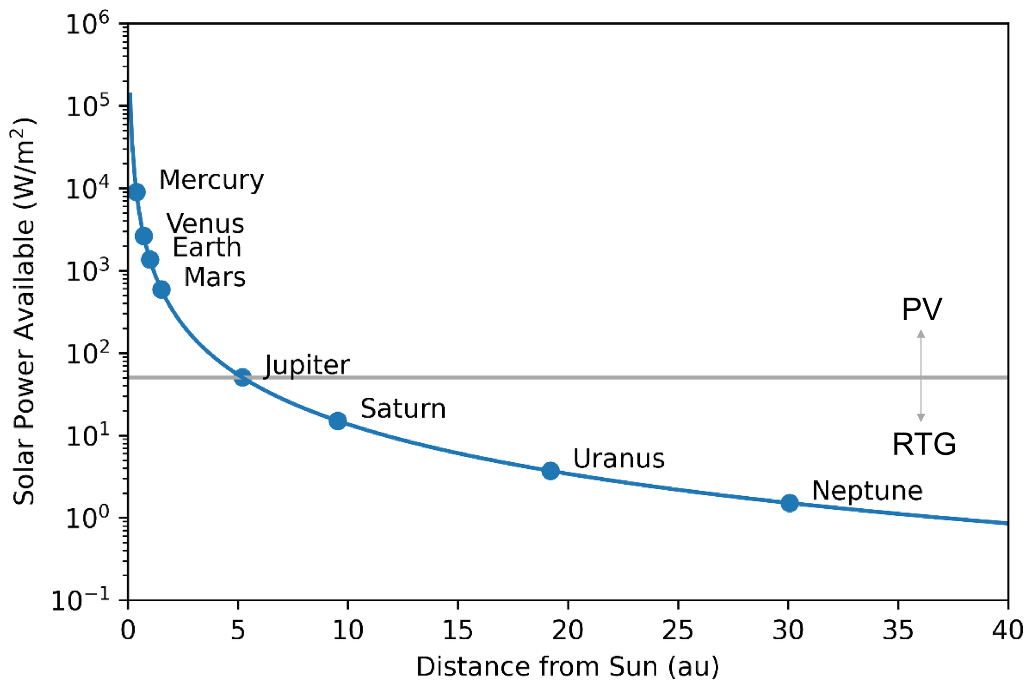
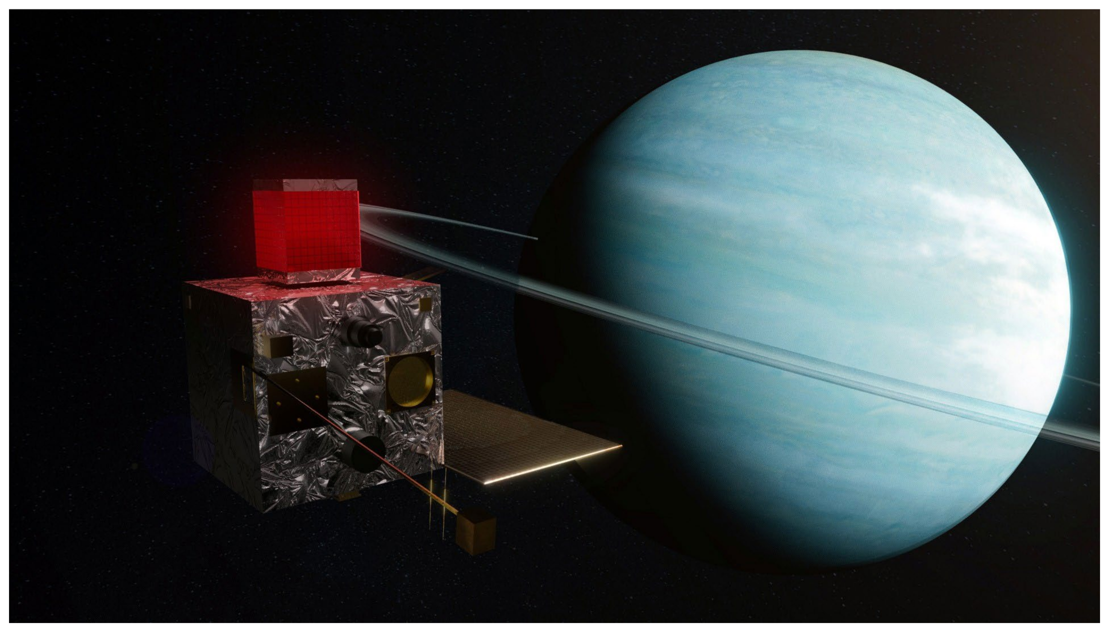
Overview

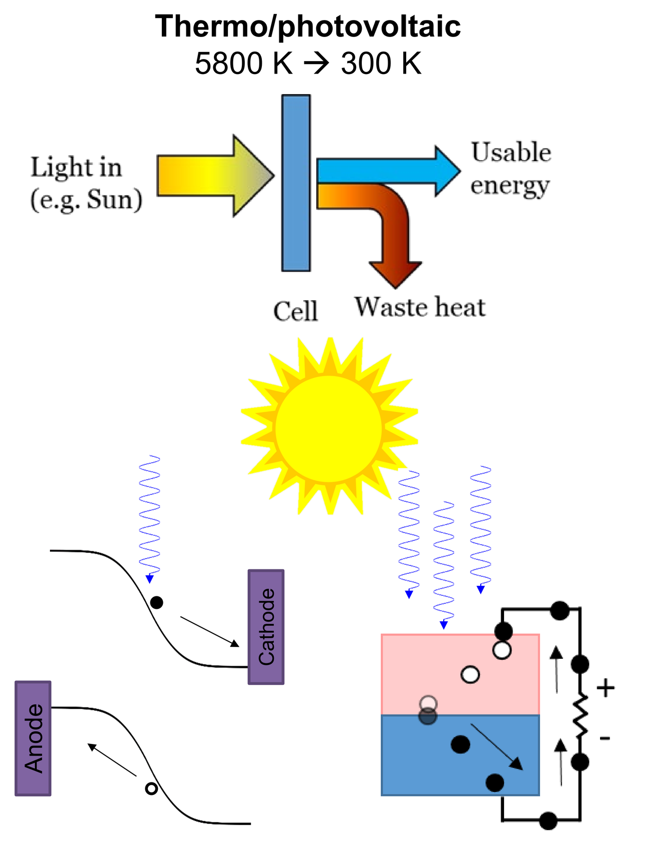
In this project we demonstrate the feasibility of a revolutionary power source for missions to the outer planets utilizing a new paradigm in thermal power conversion, the thermoradiative cell (TRC). We predict this technology will enable a significant increase in mass specific power density possible from radioisotope heat sources which currently utilize thermoelectric generators. This new small, lightweight, and efficient power source will enable system power on small platforms currently dependent on photovoltaic power, allowing the proliferation of small, nimble craft to environments where solar power is prohibitive.

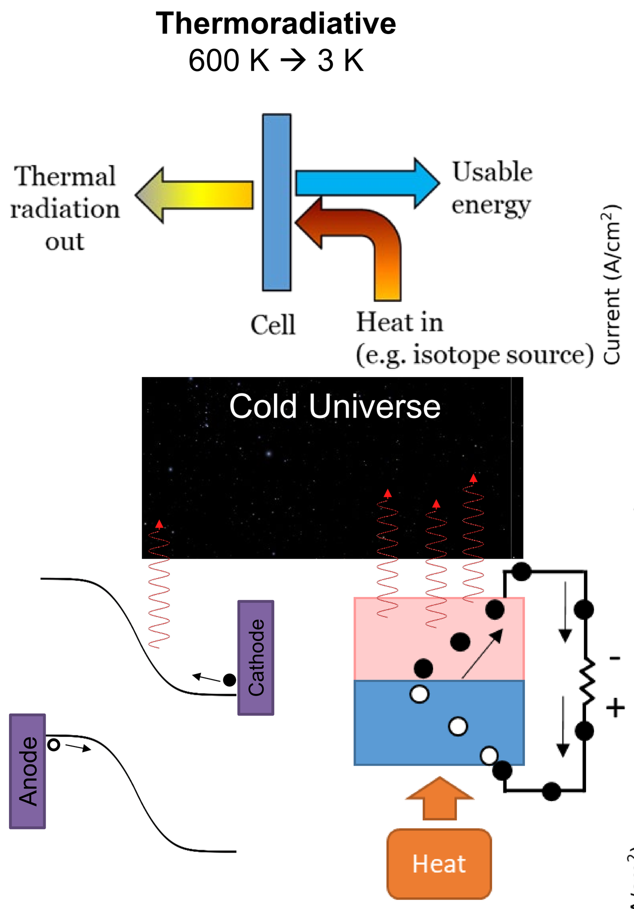
In particular, NASA is interested in micro-satellites for solar system exploration, but small lightweight power systems for the outer solar system remains an unsolved problem. We investigate the feasibility of the TRC to solve this problem, and open the outer solar system to exploration by radically smaller spacecraft.

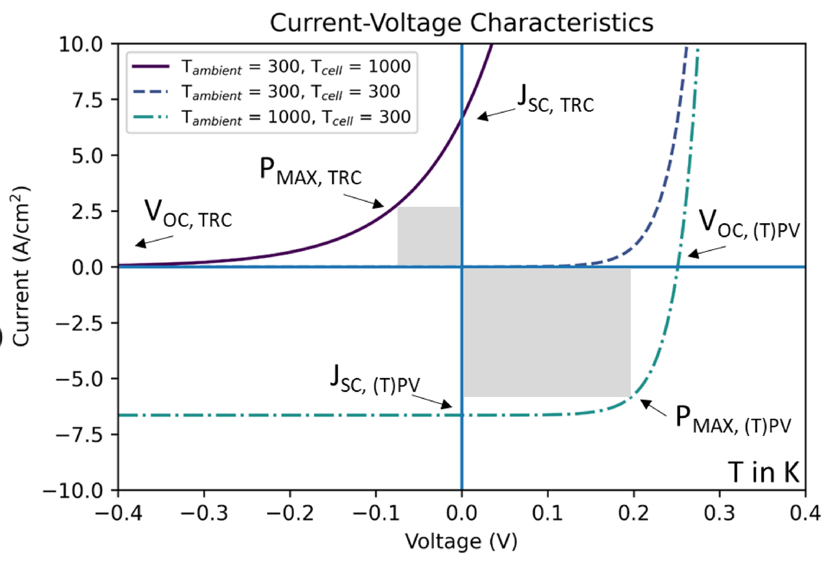


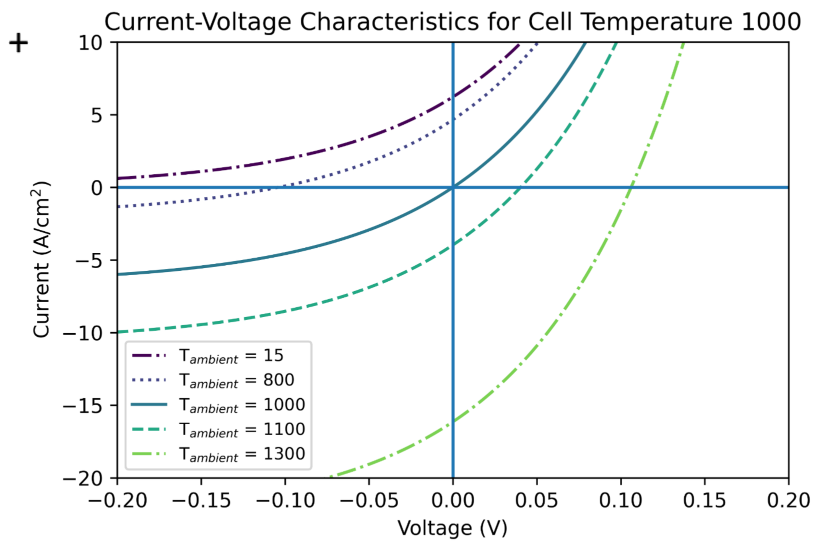


Technology Concept





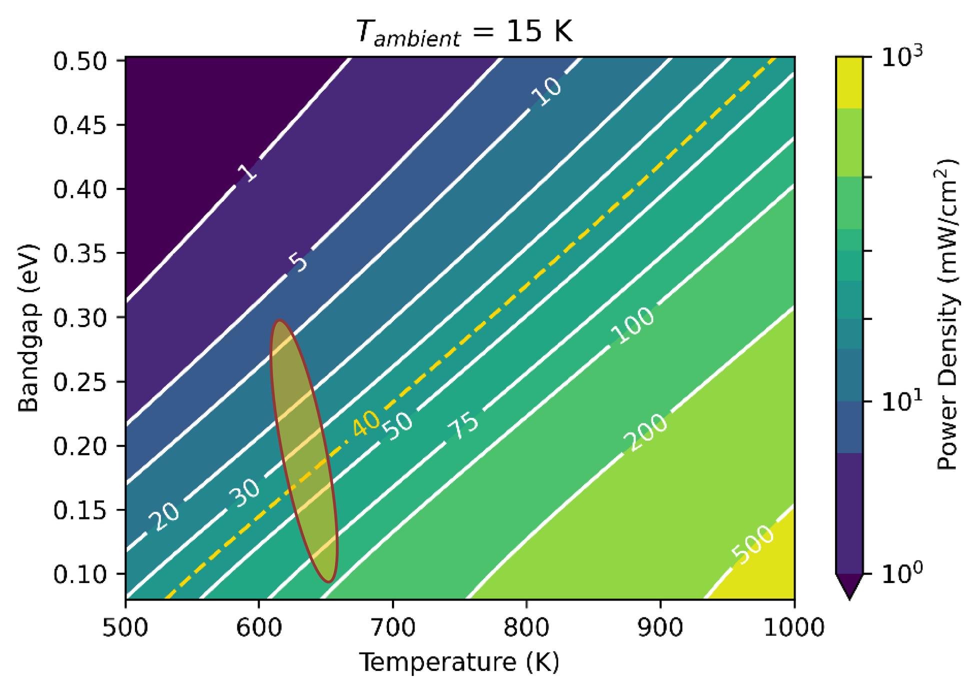


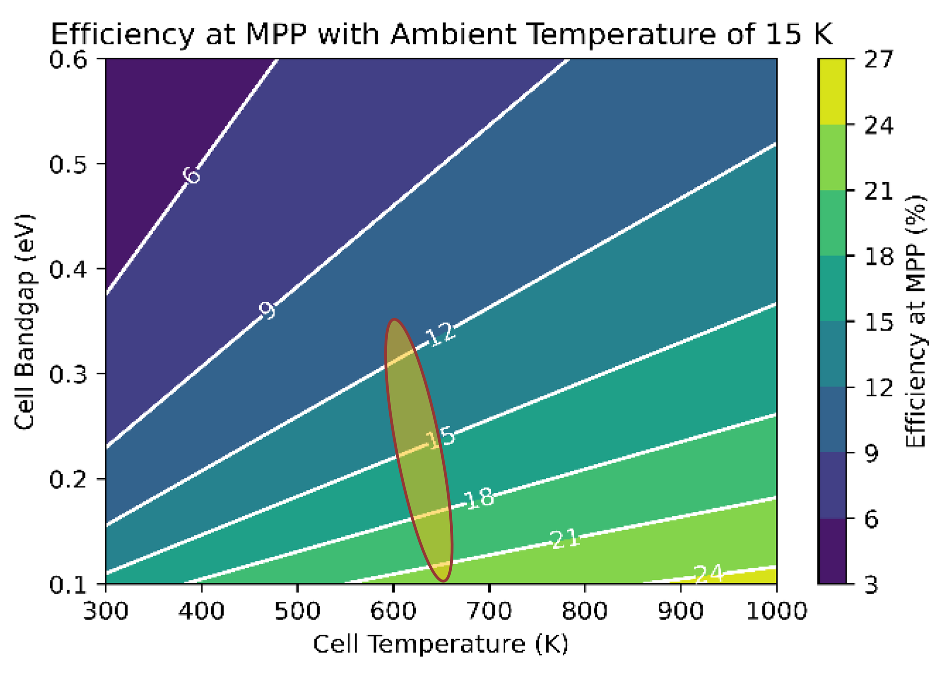


PV devices absorb photons from the hot sun, generating electron-hole pairs which are separated and collected generating a negative current at positive voltage to perform work in an external load.

TRC devices emit photons to a cold environment from recombination of electrons and holes, which cools the TRC. Heat is supplied to maintain temperature, so these electrons are replenished from an external load, generating a positive current at negative voltage to perform work.

TRC Feasibility



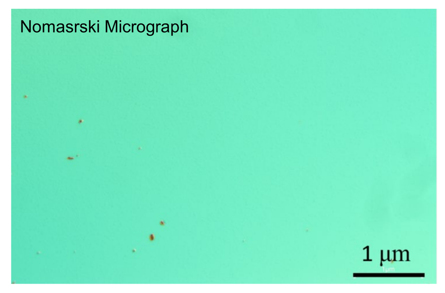


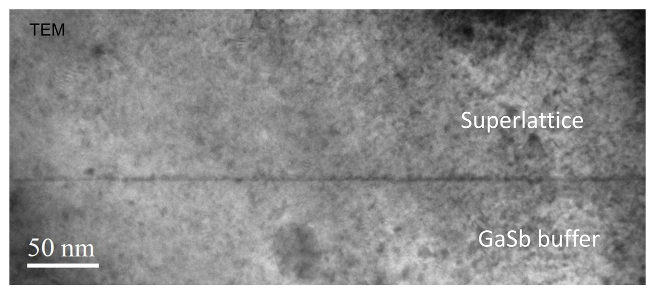
Power output levels > 6 mW/cm² at a power conversion efficiency of 12.3 % are possible in low bandgap systems

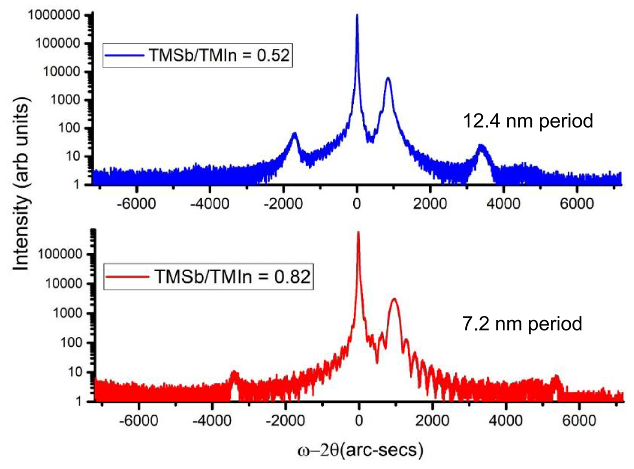
The dashed yellow line shows approximate power density of state-of-the-art multijunction solar cells operating at Earth's orbit.

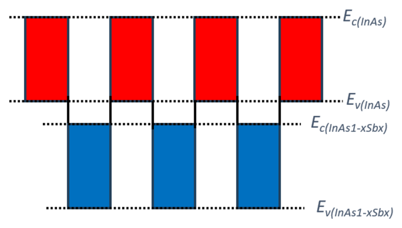
These results show the capability of the TRC can provide a feasible solution to deep space power systems.

Material Development

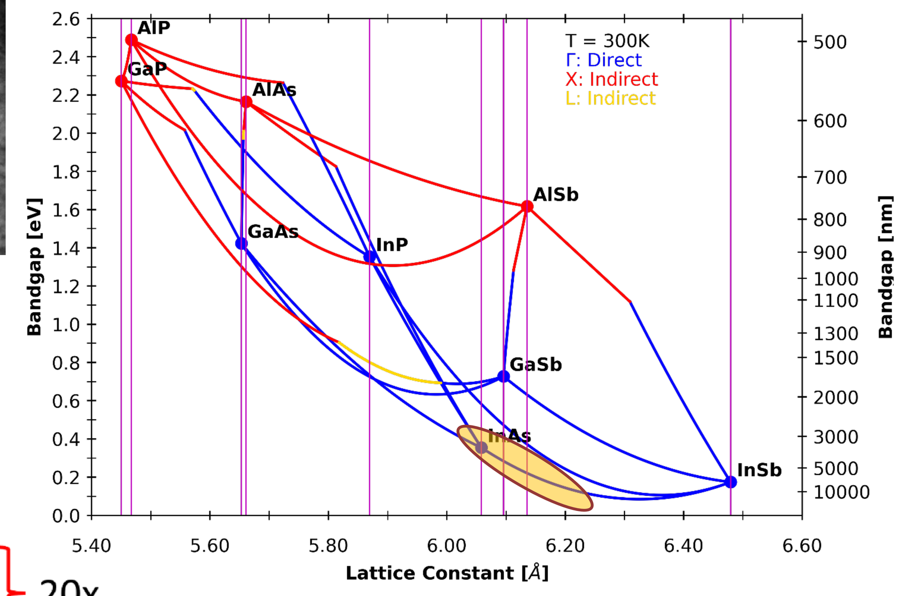








50 nm InAs: Te (1.0e19) contact
30 nm AlGaSb: Te (1.14e18) window
125 nm GaSb: Te (7.5e17) emitter
50 nm intrinsic GaSb
5.8 nm intrinsic InAs (20x)
3.7nm intrinsic InAsSb (20x)
50 nm intrinsic GaSb
1000nm GaSb: Zn (8.5e16) base
30 nm GaSb: Zn (1.34e18) BSF
200 nm GaSb : Zn (6.7e17) buffer
p type GaSb substrate



Significant improvements of InAsSb materials development using metalorganic vapor phase epitaxy at RIT. High quality type-II superlattice demonstrated. Prototype TRC device grown. Currently investigating high temperature contacts to use for fabrication and testing ot TRC operation.

Technology Innovation Thermoradiative Uranus Smallsat (TITUS)

Uranus has a unique magnetosphere and radiation belt that has never been closely observed. The only observations we have of Uranus come from the Voyager 2 flyby leaving fundamental questions about Uranus's formation and evolution. Study of the magnetosphere offered a compelling use case for the thermoradiative power system to shine.

- **Mission**: Smallsat delivered by UOP to Uranus orbit to demonstrate novel thermoradiative cell (TRC) power system. Provide corroborative science to the UOP mission.
- **Launch**: 2036/2038, Falcon H with UOP, C_3 of ~27 km²/s², EVEEU, 13.4 yr transit
- **Science**: Investigate Uranus's magnetosphere and radiation belt, providing better understanding of its temporal and spatial variations
- **Power**: 33 We TRC power system using 1 GPHS brick. PMAD for 3V, 5V, and 12V outputs, battery to support communications and science modes.
- **Propulsion**: Cold gas thrusters for RCS, 1.4 kg useable propellant available.
- **Thermal**: Thermal paint to provide appropriate emissivity and absorptivity characteristics, heat pipes to spread heat, insulation to protect bus from TRC heat, and Heaters
- **Mechanical**: A-286 Iron base alloy, Al 7075-T6, Ti-6Al-4V, thermally isolated pressure vessel, lightband separation system
- **Communications, C&DH**: X-Band- up to 47 kbps data rate to UOP, reflectarray antenna, X-band patch backup comm, 1.5 GB storage
- **AD&C**: 2 Star Trackers, 2 IMUs, 4 reaction wheels, cold gas RCS
- **Cost**: 45$M FY25 (excluding GPHS, nuclear launch costs, TRL<6)

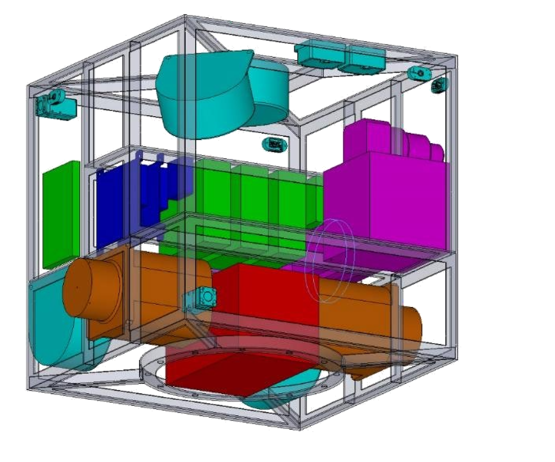
Science: Magnetometer Electronics, Camera and Electronics, Langmuir Probe Electronics, Low Energy Module, and Suprathermal Ion Spectrograph

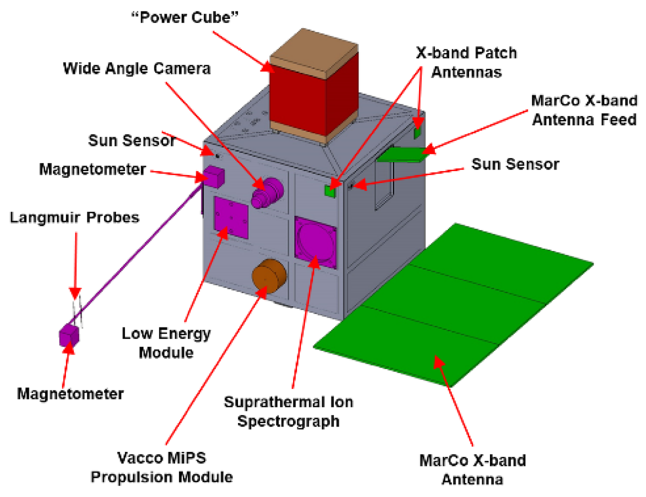
Attitude Determination and Control: 4 Reaction Wheels, 2 IMUs, 4 Sun Sensors, and 2 Star Trackers

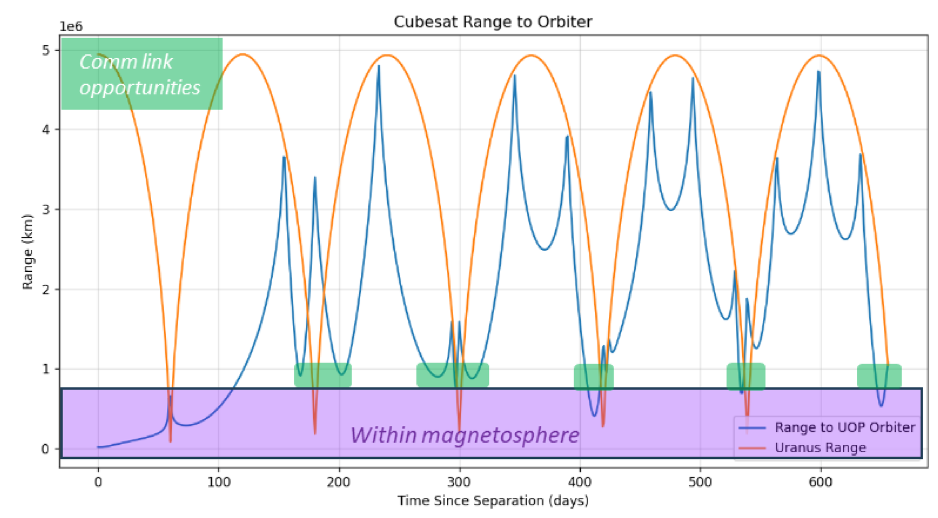
Command and Data Handling: Atomic clocks, On-Board Computers, External Storage, and External Watchdog Timers

Communications: All Communication Electronics

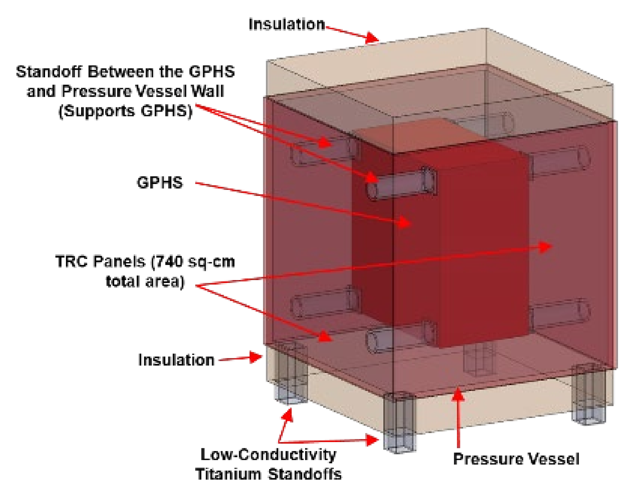
Electrical Power: PMADs and Lithium-Ion Batteries (combined into one unit)

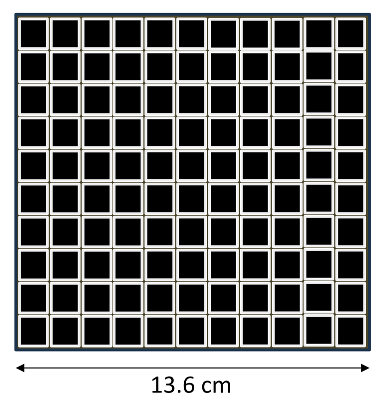






Stable orbit for communication link with UOP
Limits risk to prime mission -- 15 orbits over 5 years





110 cells per face, 4 faces
1.18 cm x 1.3 cm cell size
169 cm² total emitter area
> 90% surface coverage
2 strings at 12.1 V, 33 W out

MEL Summary: Case 1_TITUS CD-2025-225	Bus	TRC	TOTAL
Main Subsystems	Basic Mass (kg)	Basic Mass (kg)	Total Basic Mass(kg)
Science	4.3	0.0	4.3
Attitude Determination and Control	4.2	0.0	4.2
Command & Data Handling	0.4	0.0	0.4
Communications and Tracking	2.7	0.0	2.7
Electrical Power Subsystem	2.0	2.0	4.0
Thermal Control (Non-Propellant)	1.1	0.1	1.2
Propulsion (Chemical Hardware)	1.2	0.0	1.2
Propellant (Chemical) / Fluids	1.5	0.0	1.5
Structures and Mechanisms	4.5	3.8	8.2
Element Total	***21.9***	***5.9***	***27.8***
Element Dry Mass (no prop,consum)	20.4	5.9	26.3
Element Propellant	1.5	0.0	1.5
Element Mass Growth Allowance (Aggregate)	4.9	1.2	6.2
MGA Percentage	24%	21%	23%
Predicted Mass (Basic + MGA)	25.3	7.1	32.4
System Level Mass Margin	3.1	0.9	3.9
System Level Growth Percentage	15%	15%	15%
Element Dry Mass (Basic+MGA+Margin)	28.3	8.0	36.4
Element Inert Mass (Basic+MGA+Margin)	28.5	8.0	36.5
Total Wet Mass (Allowable Mass)	***29.9***	***8.0***	***37.9***

COMPASS