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Radioisotope Power Systems (RPS) Overview





Radioisotope Power Systems (RPS) Program

RPS Programmatic Mission

Fuel, test and deliver radioisotope power systems (RPS) and related technologies for use in remote, harsh environments, such as space.

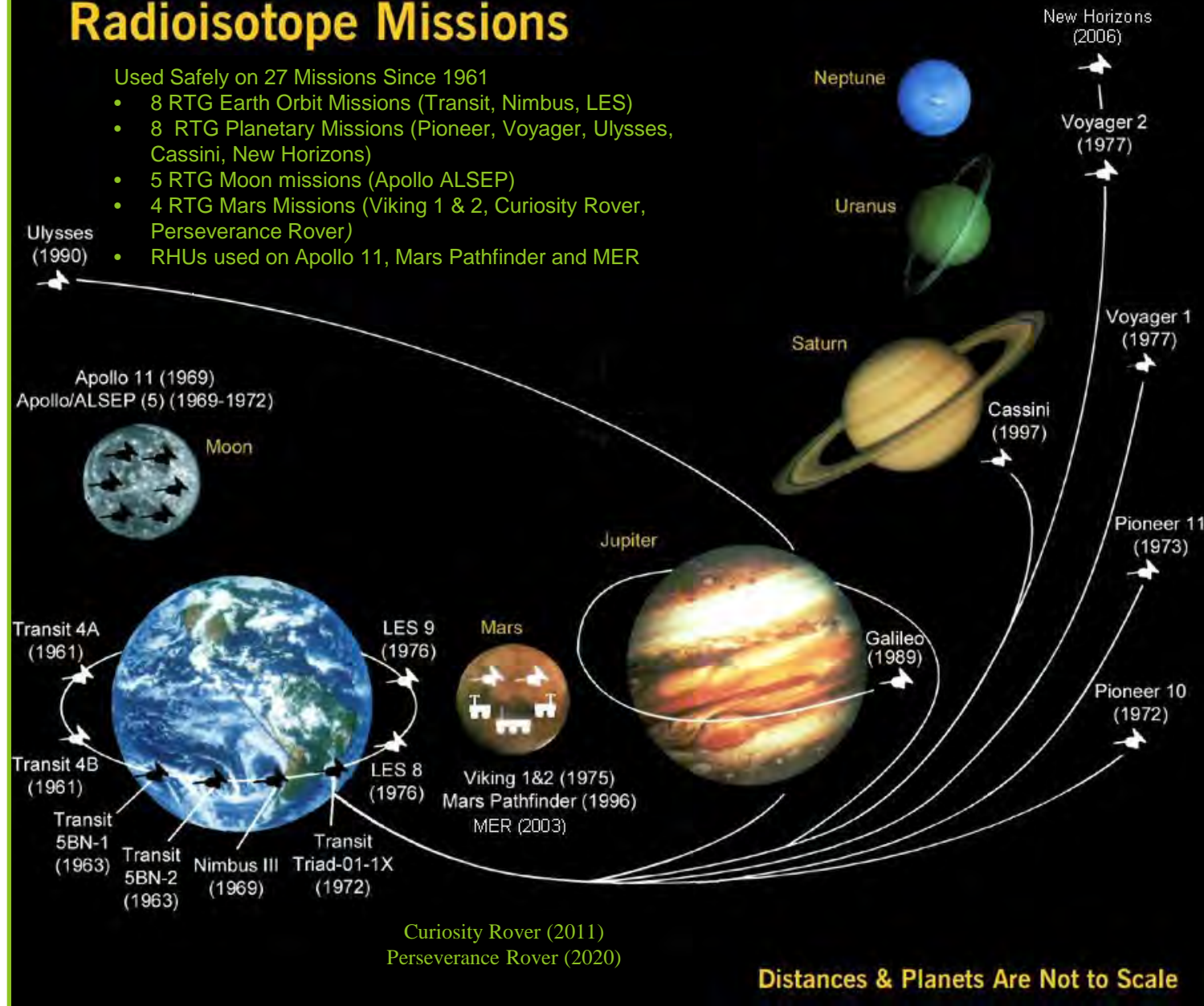
Radioisotope Thermoelectric Generators (RTG)

Electrical generator that converts heat generated from the radioactive decay of Plutonium Oxide into electrical energy using thermoelectric devices.

Radioisotope Missions

Used Safely on 27 Missions Since 1961

- 8 RTG Earth Orbit Missions (Transit, Nimbus, LES)
- 8 RTG Planetary Missions (Pioneer, Voyager, Ulysses, Cassini, New Horizons)
- 5 RTG Moon missions (Apollo ALSEP)
- 4 RTG Mars Missions (Viking 1 & 2, Curiosity Rover, Perseverance Rover)
- RHUs used on Apollo 11, Mars Pathfinder and MER

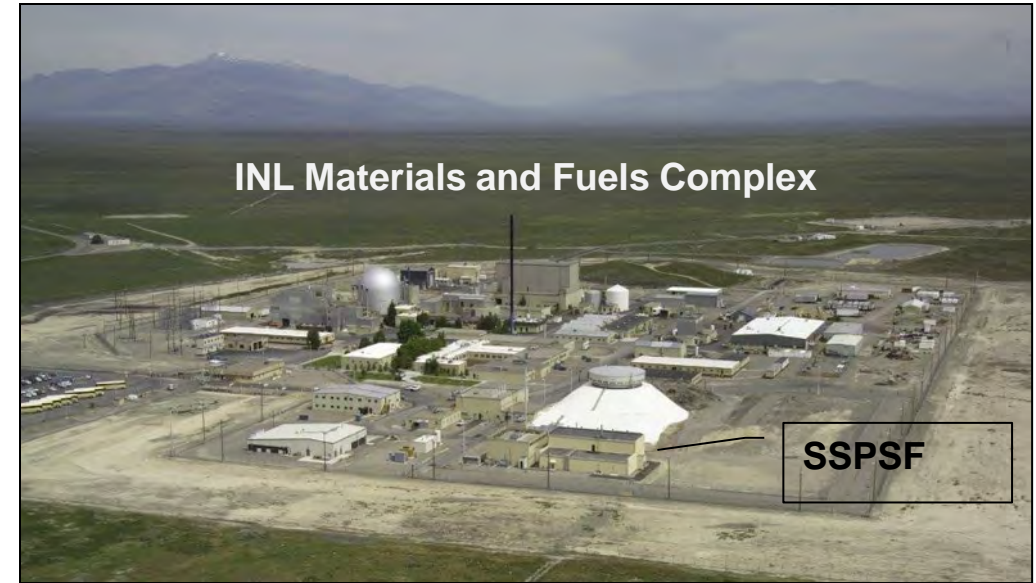


Curiosity Rover (2011)
Perseverance Rover (2020)

Distances & Planets Are Not to Scale

INL Role in Radioisotope Power System (RPS) Program

- Component Fabrication
- RPS Assembly
- RPS Acceptance Testing
- RPS Delivery to NASA
- RPS NASA Ground Operations

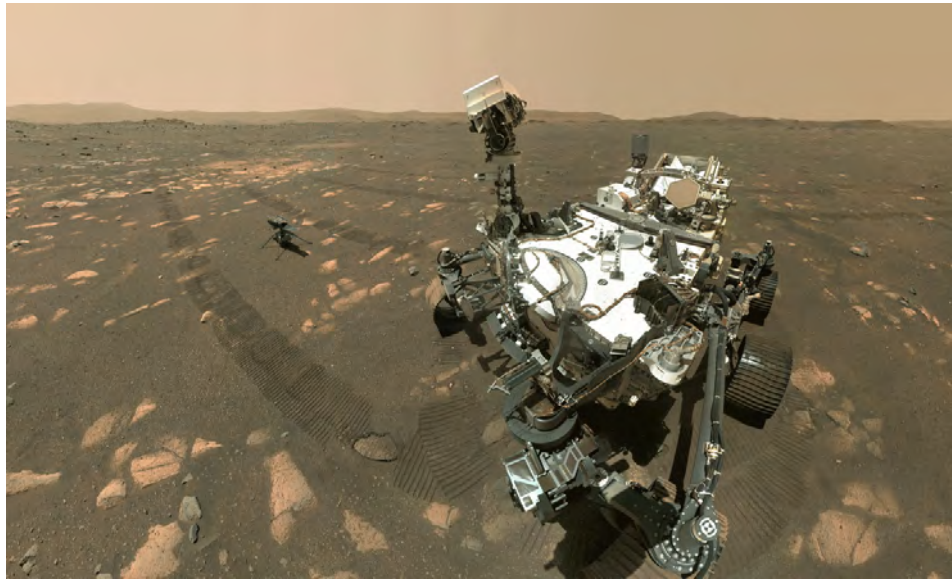
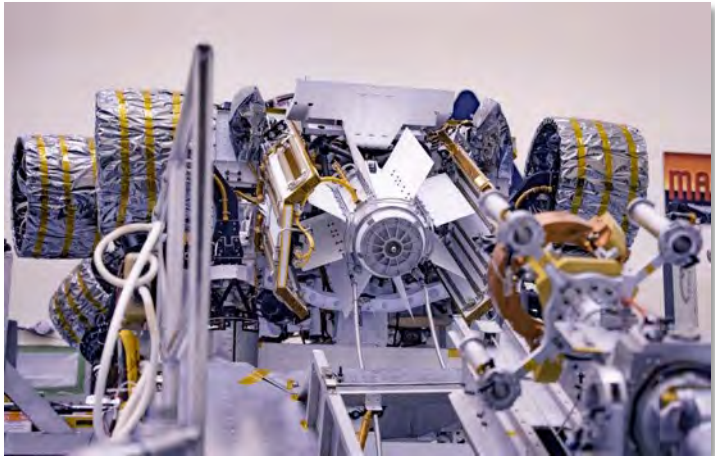
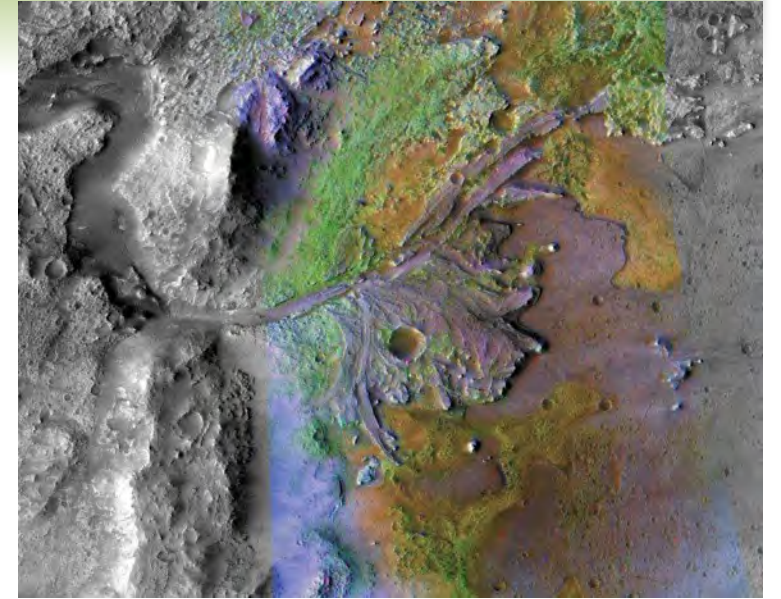


NASA Missions that utilized RPS Systems that were assembled and tested at SSPSF:

NASA Mission	RPS System	Launch Date
Pluto New Horizons	GPHS RTG	January 19, 2006
Curiosity	MMRTG	November 26, 2011
Mars 2020	MMRTG	July 30, 2020

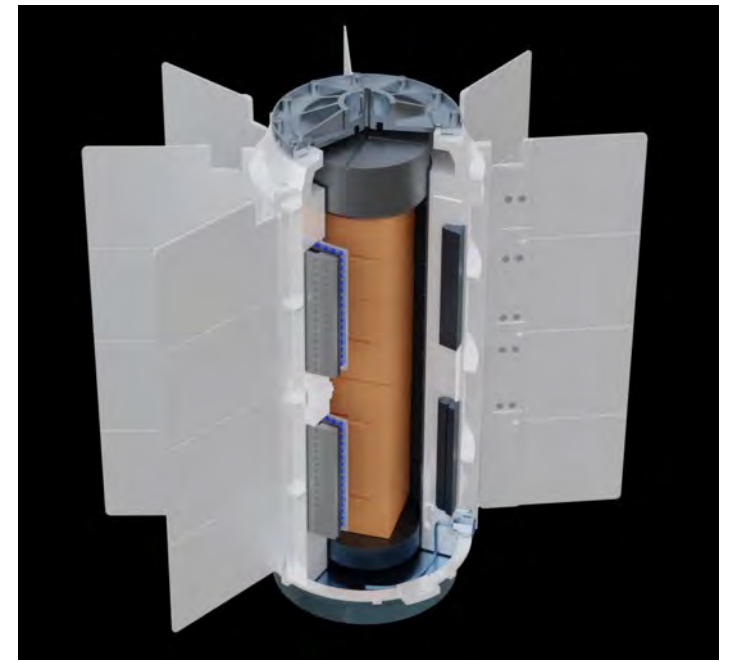


Mars 2020 | Perseverance Rover

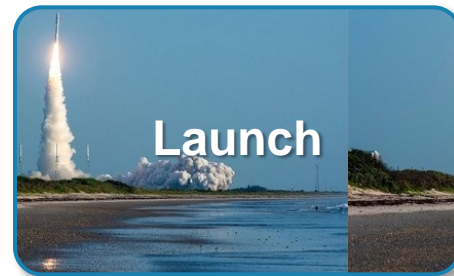
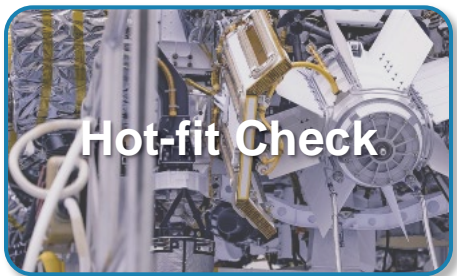
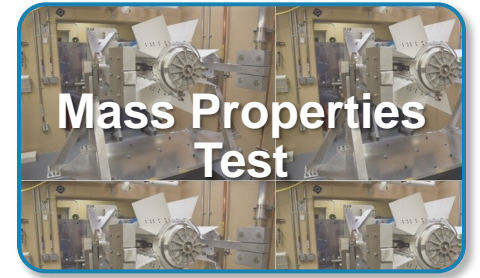
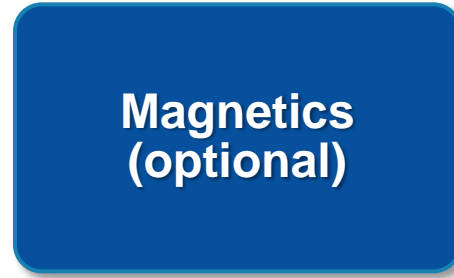
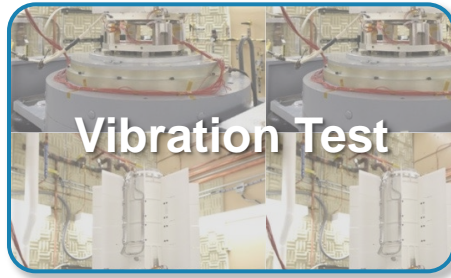
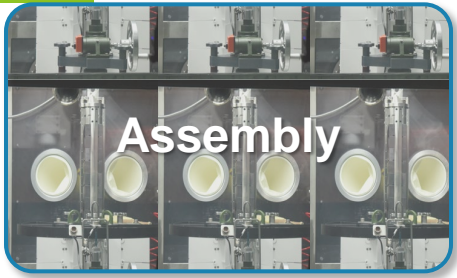


MMRTG Overview

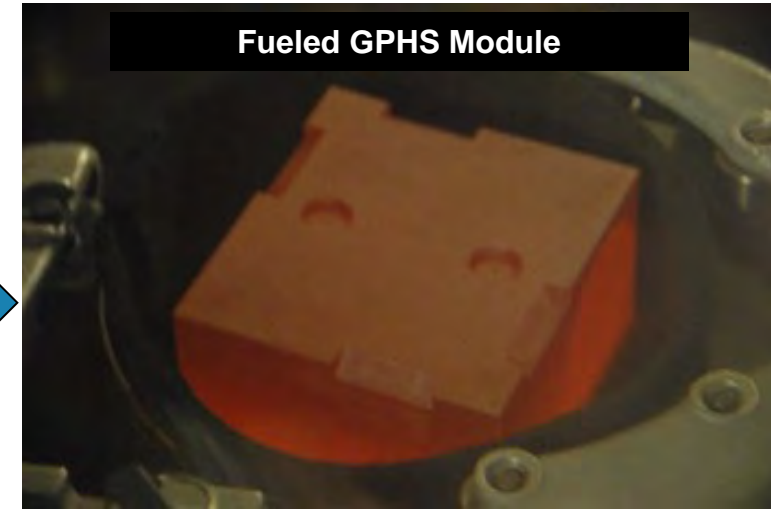
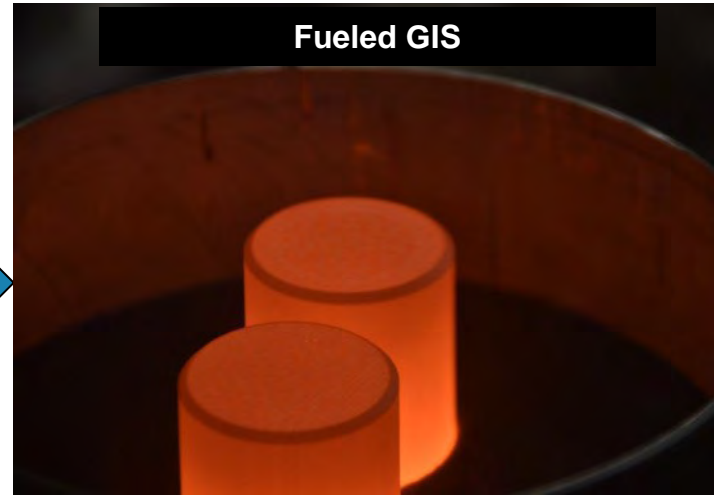
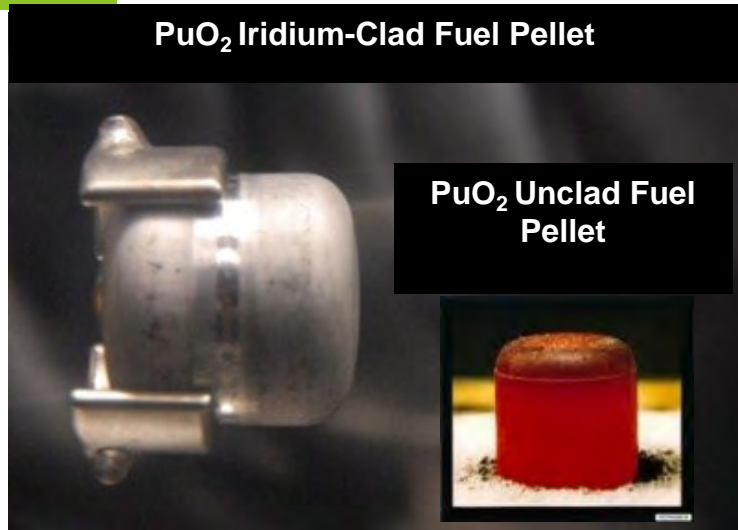
- 8 General Purpose Heat Source (GPHS) modules
- 110 W_e Beginning of Mission (BOM) power
- Load voltage (30 V)
- Mass (46.5 kg)
- DOE national laboratory collaboration between INL, ORNL, & LANL
- Industry partners – Aerojet Rocketdyne & Teledyne Energy Systems



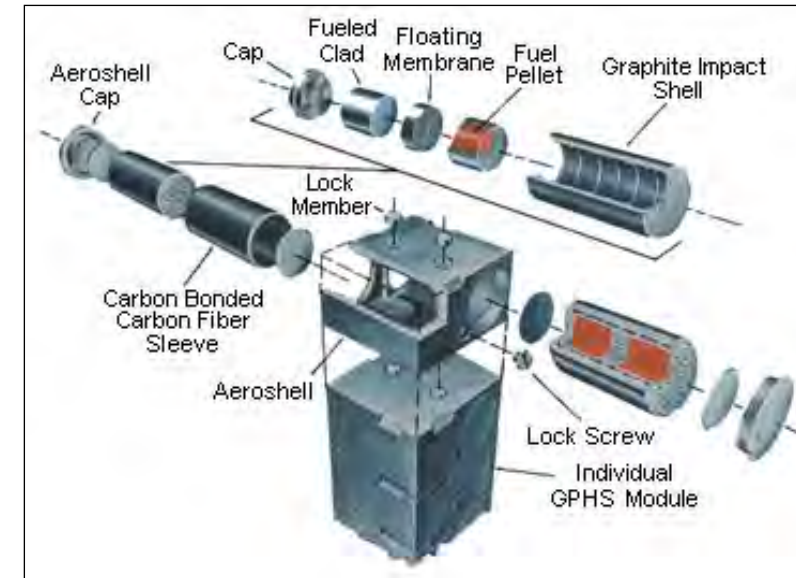
MMRTG / ATLO Flow



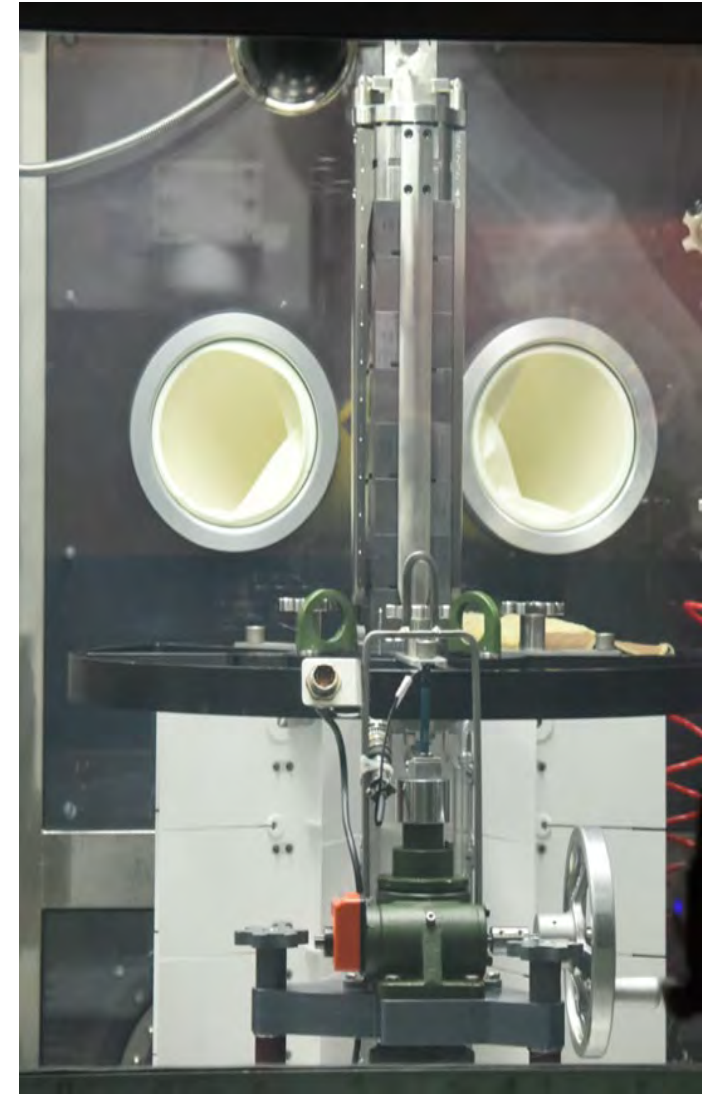
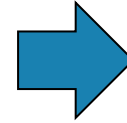
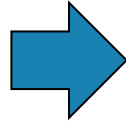
Fuel Assembly and Preparation



- 32 Fueled Clads (FC) (nominal 62.5 W_{th}) received from LANL
- 2 FC assembled into each Graphite Impact Shell (GIS)
- 2 GIS assembled into each General Purpose Heat Source (GPHS) module (nominal 250 W_{th})
- Inert glovebox operation with remote handling tools



Generator Assembly



- Electrically heated generator received
- Generator placed in inert atmosphere assembly chamber
- Electric heater removed
- 8 GPHS modules cleaned and stacked ($2,000 W_{th}$)
- Stack slowly lowered into the MMRTG
- MMRTG sealed and leak checked

MMRTG Testing

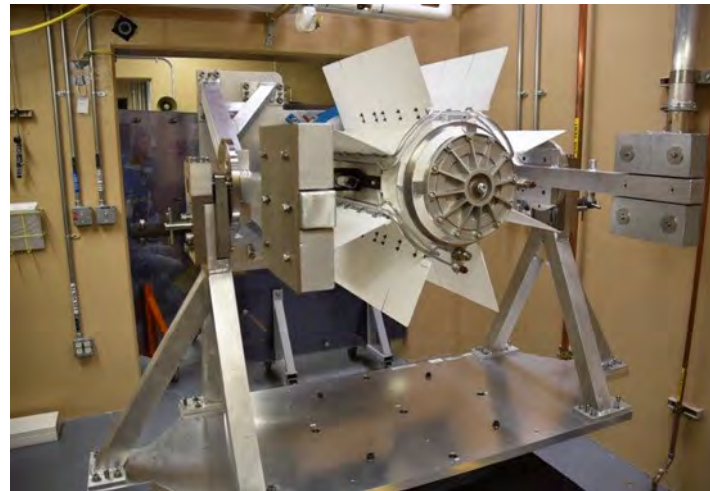
Vibration Acceptance Testing

- MMRTG was subjected to a series of vibration acceptance tests
- Vibration in 3 orientations tests X, Y, and Z-axis independently
- Health checks performed between each test



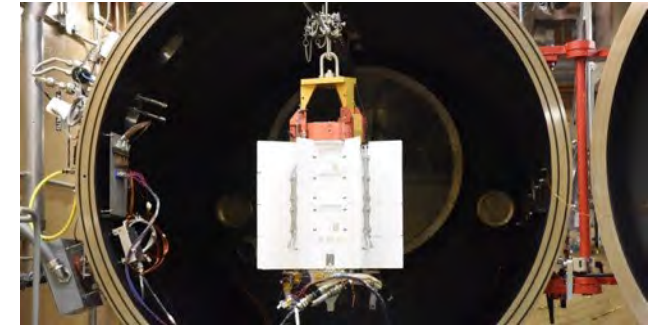
Mass Properties Measurement

- Accurately determined the weight of the MMRTG, its center of gravity (CG), and its moments of inertia (MOI)
- Cradle assembly allows MMRTG rotation horizontally for CG and MOI of all axis.
- Non flight articles (e.g. cooling tube caps) are analytically removed



Thermal Vacuum Testing

- Provide near-earth space vacuum
- Measured MMRTG electrical power output
- Tested radiant heat transfer surfaces
- Correlated power prediction



MMRTG Transportation, Receipt, Unloading, and Handling Ops

- MMRTG F2 traveled from INL to KSC in April 2020
 - Loaded into certified Department of Transportation (DOT) Type B shipping cask (9904)
 - Transported using Radioisotope Thermoelectric Generator Transportation System (RTGTS)
 - Chase Team follows convey to respond to any issues
- Arrived at building KSC, Bldg. RTGF
- INL team at KSC preparing to receive and unload the MMRTG from the RTGTS and 9904 Cask



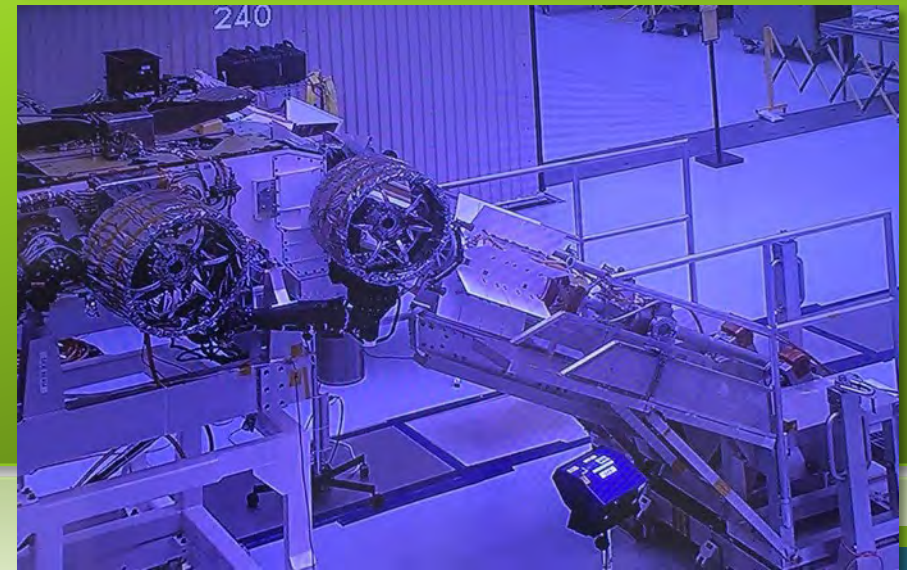
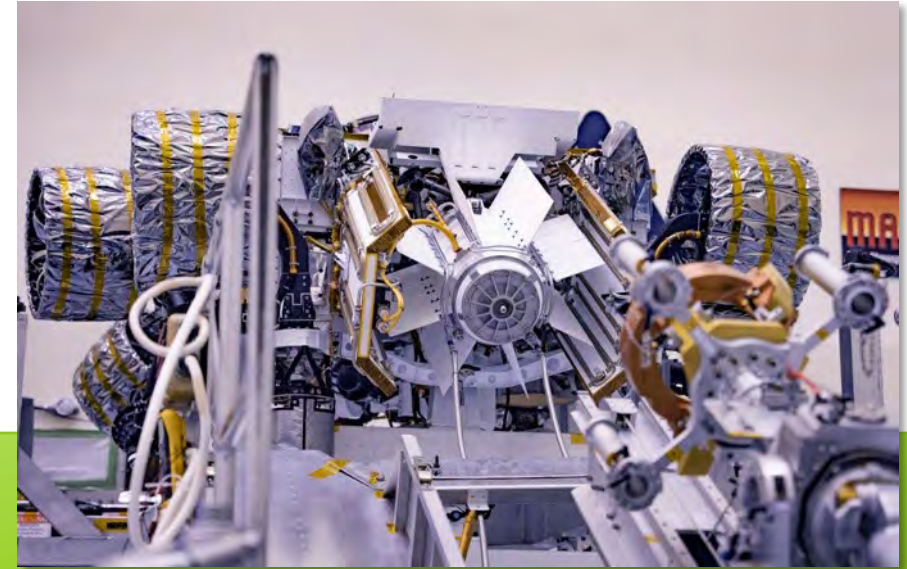
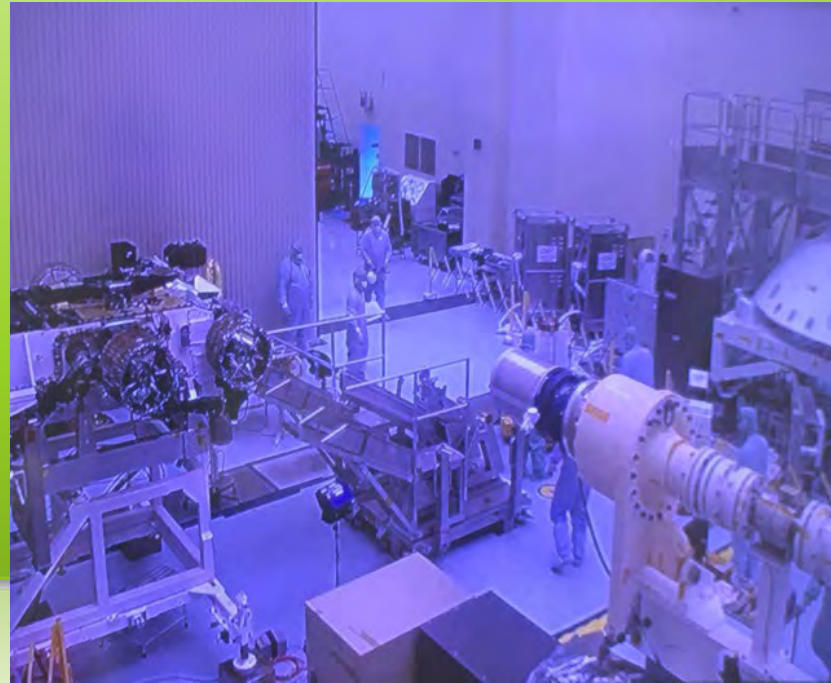
MMRTG Integrated Operations with Jet Propulsion Laboratory (JPL)

- JPL performs receipt inspection of the MMRTG
- JPL Flight Cable and Adapter Installation operations
 - Handoffs between INL and JPL procedures to complete operations
- MMRTG is shipped to PHSF utilizing the RTGTS in a Converter Shipping Assembly (CSC)

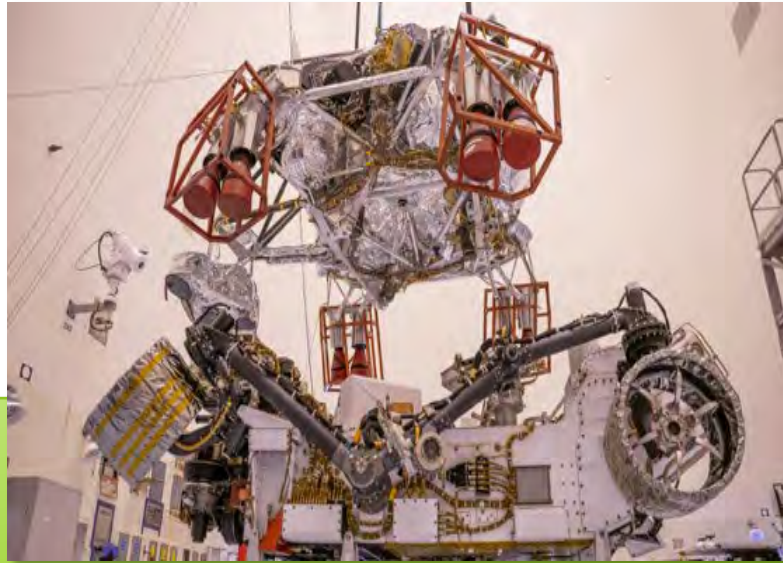
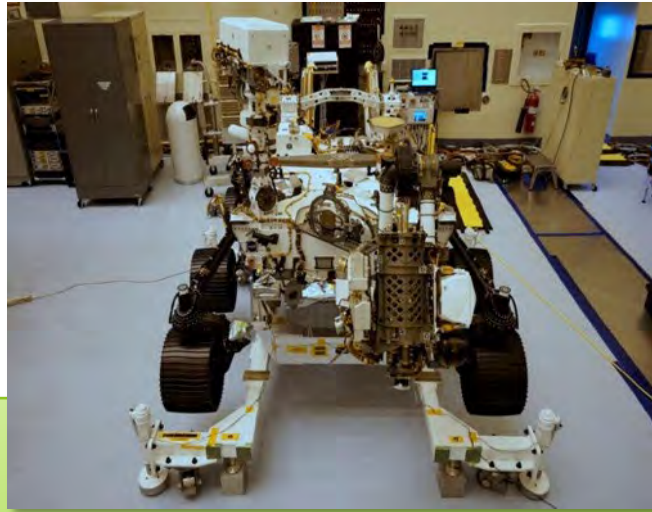


MMRTG Hot-Fit Checks with Perseverance Rover

- First electrical and mechanical integration with Perseverance Rover
- JPL performed several integrated performance tests after MMRTG was integrated
- MMRTG was detached from rover and transported back to RTGF



Jet Propulsion Laboratory (JPL) and United Launch Alliance (ULA) Flight Ready Operations

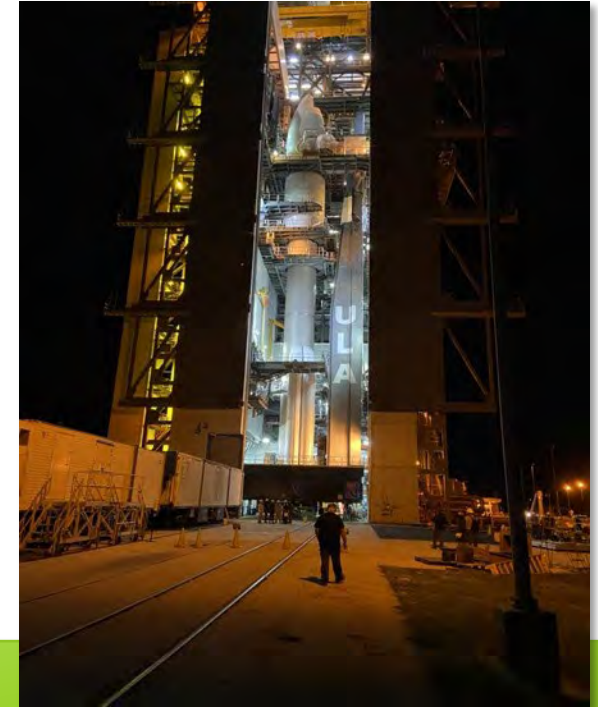


JPL and ULA Flight Ready Operations



Final MMRTG Integration at VIF

- MMRTG offloaded from RTGTS
- Hoisted to VIF 7th level using crane inside the CSC
 - ULA was responsible for all crane operations and manning of tag lines
 - INL reviewed all maintenance and certifications performed on crane prior to lift



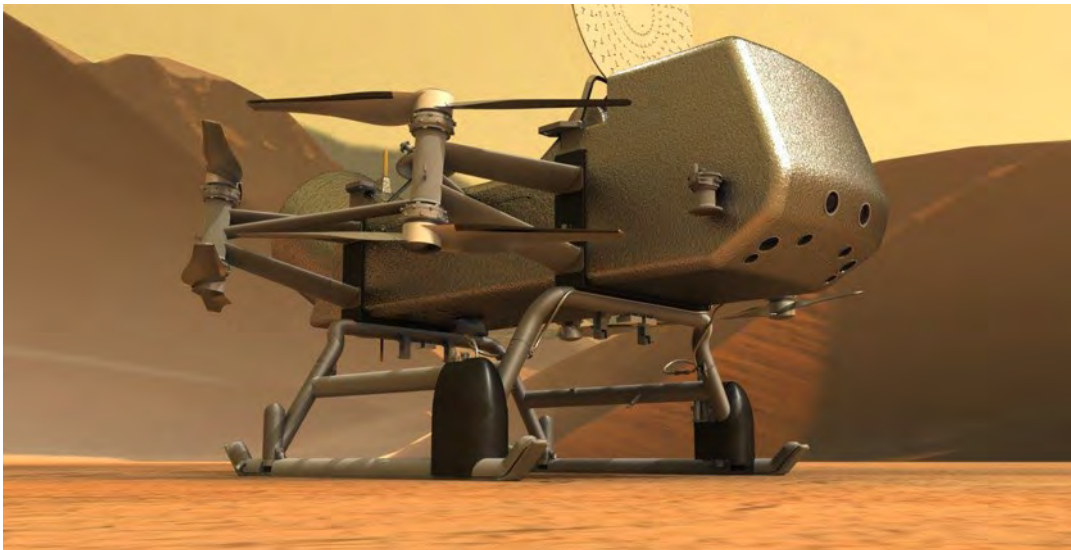
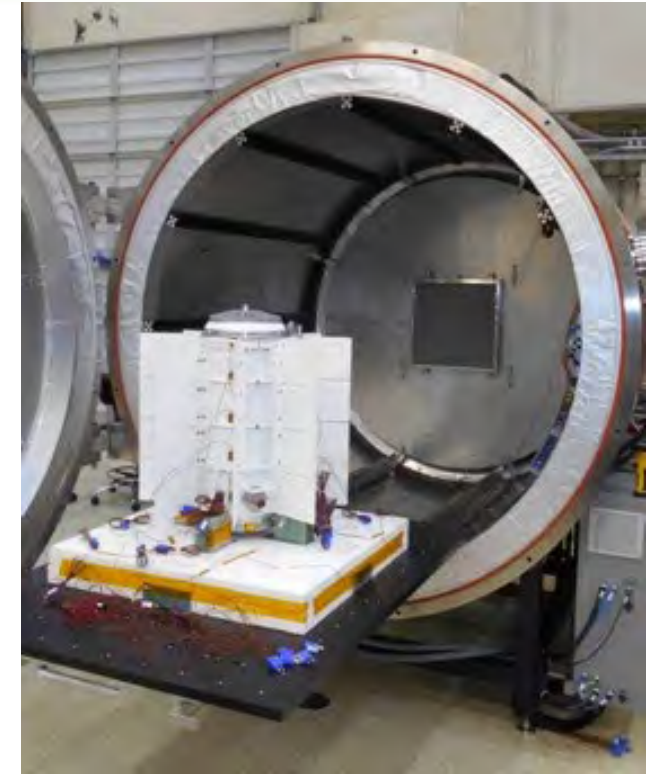
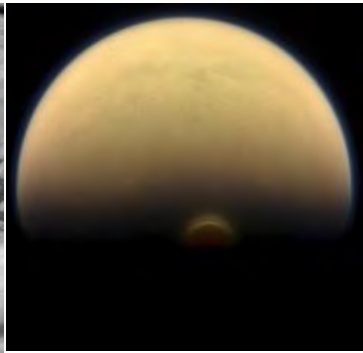
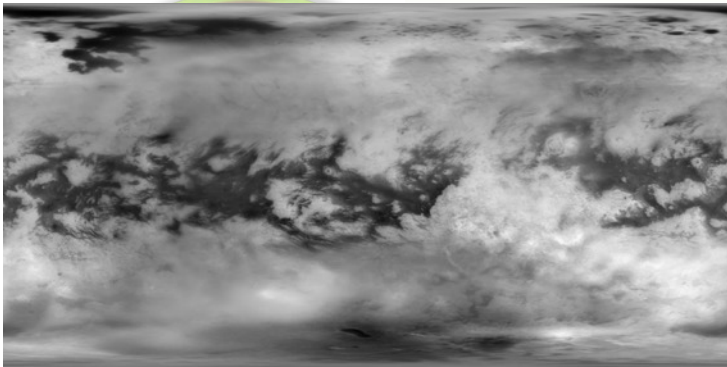
MMRTG Final Launch Integration (Continued)

- JPL responsible for final mechanical and electrical integration activities
- INL provided support
- VIF remained under nuclear facility requirements until fairing door installed
- Launched from KSC on July 30th, 2020





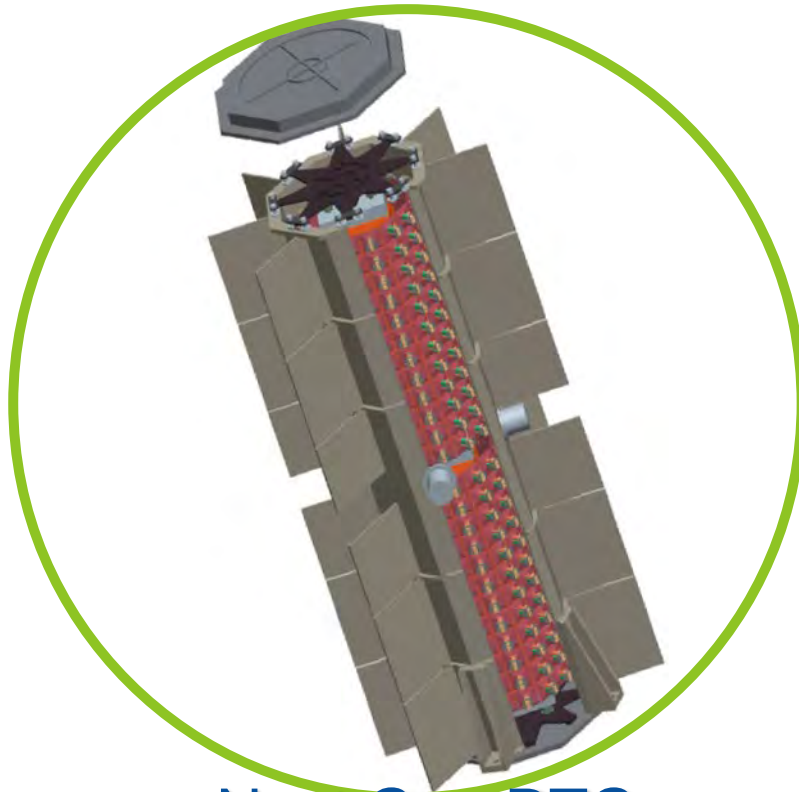
Dragonfly



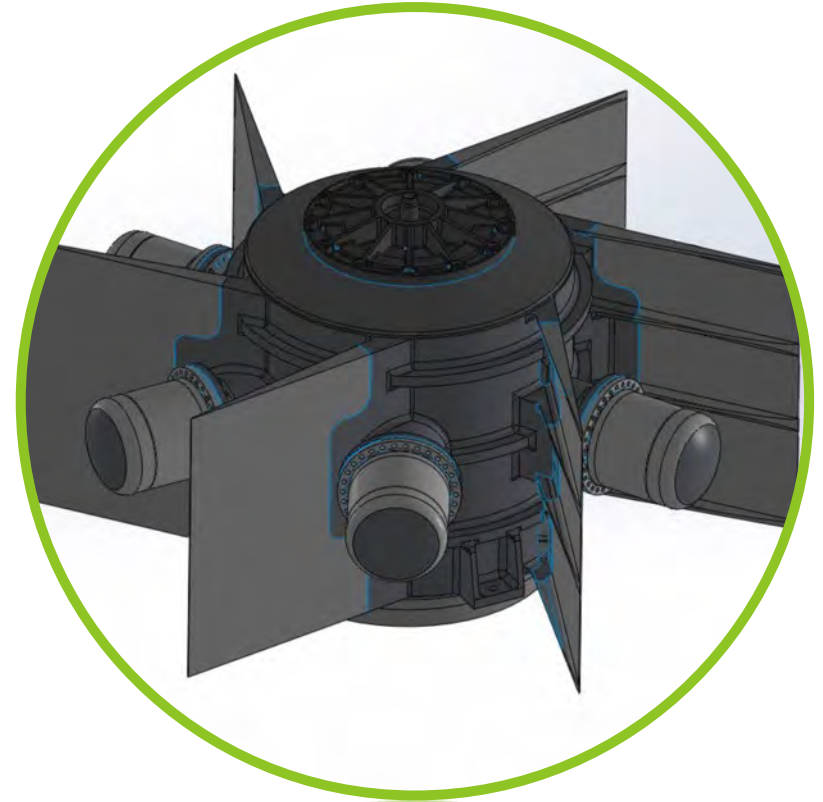
Technology Investments to Enable Innovative Science Missions



MMRTG
Multi-Mission
Radioisotope Power
System



Next Gen RTG
Vacuum Rated
Radioisotope Power
System



DRPS
Multi-Mission
Dynamic Radioisotope
Power System

Multi-Mission systems can be used in both vacuum and environments

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