National Aeronautics and
Space Administration

RADIOISOTOPE POWER SYSTEMS PROGRAM

Lunar Surface Innovation Consortium : Surface Power Focus Group
January 28 Group Telecon
Lunar Design Reference Mission using a Dynamic RPS

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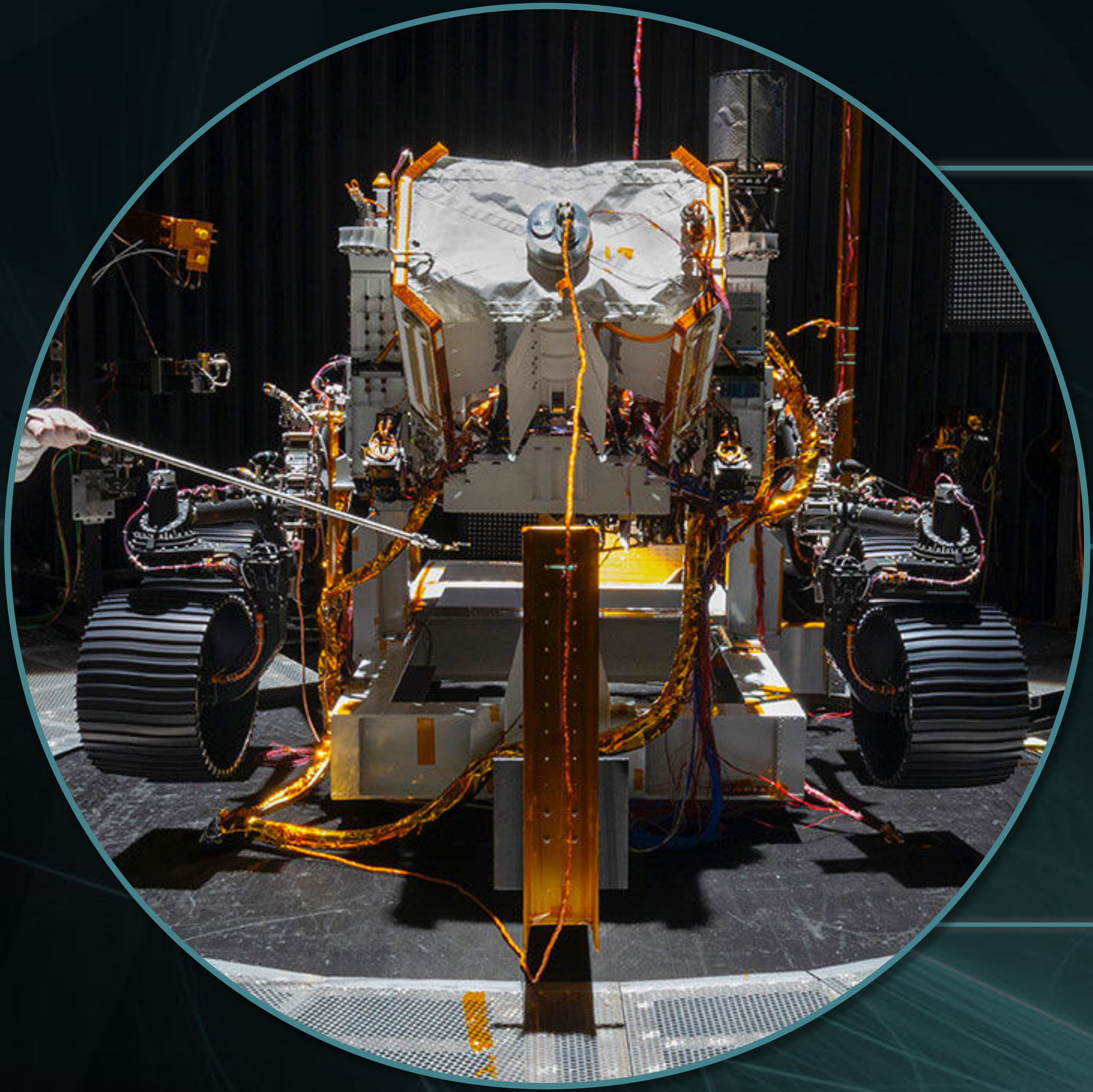
Power to...

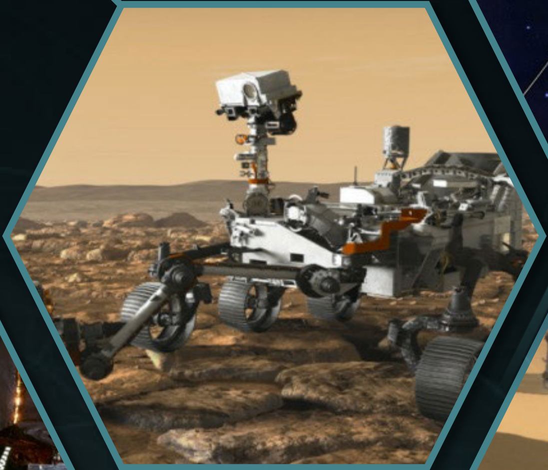


EXPLORE

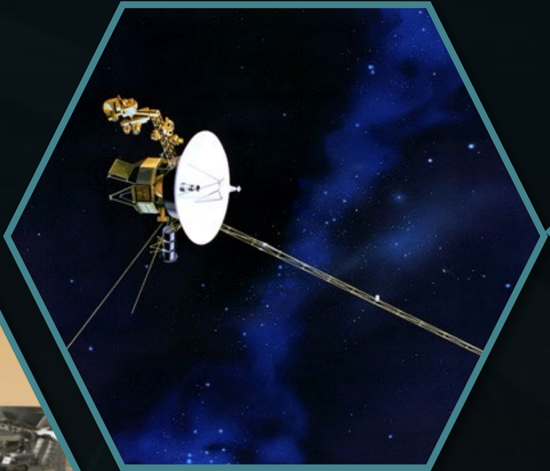
DISCOVER

UNDERSTAND

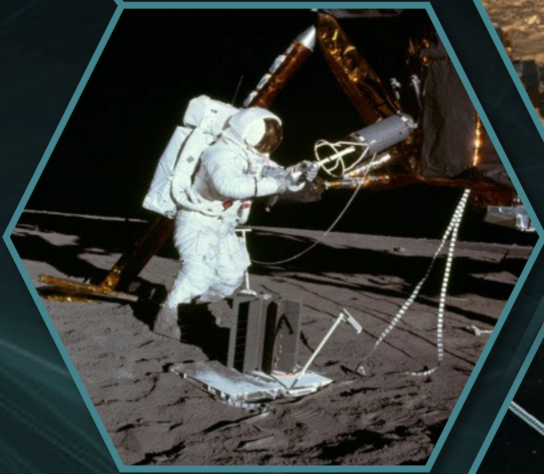
PERSEVERANCE



Voyager 1 & 2



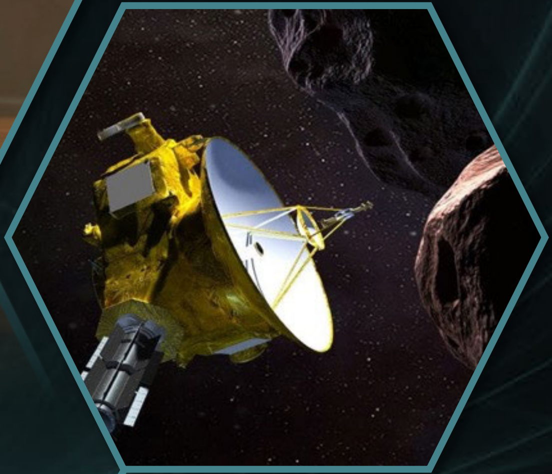
APOLLO LUNAR SURFACE EXPERIMENTS PACKAGE (ALSEP)



DRAGONFLY

(PROPOSED) TRIDENT

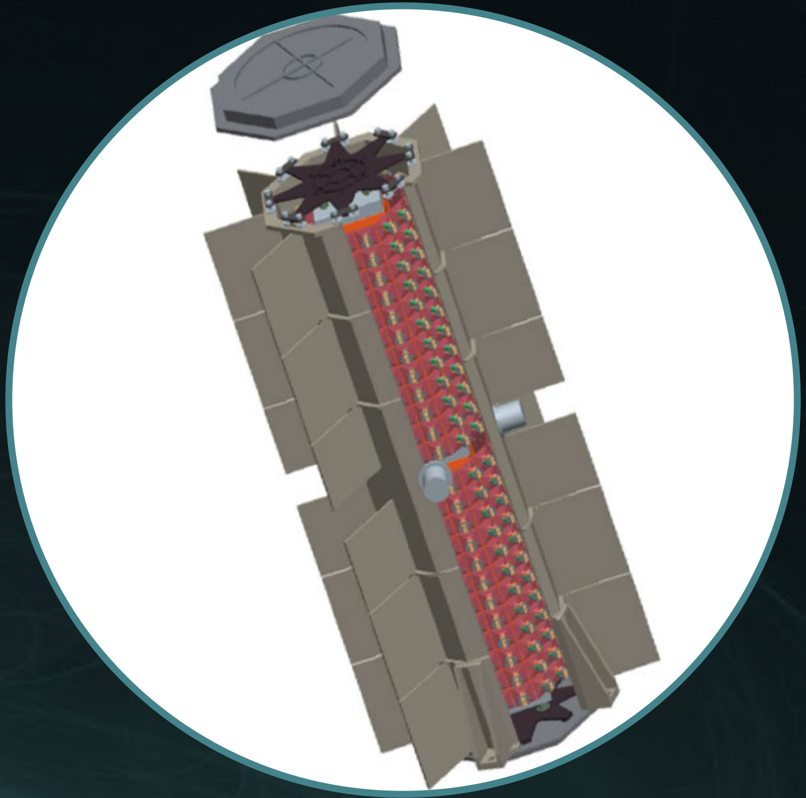
New Horizons



Technology Investments
Enable New Radioisotope Generators

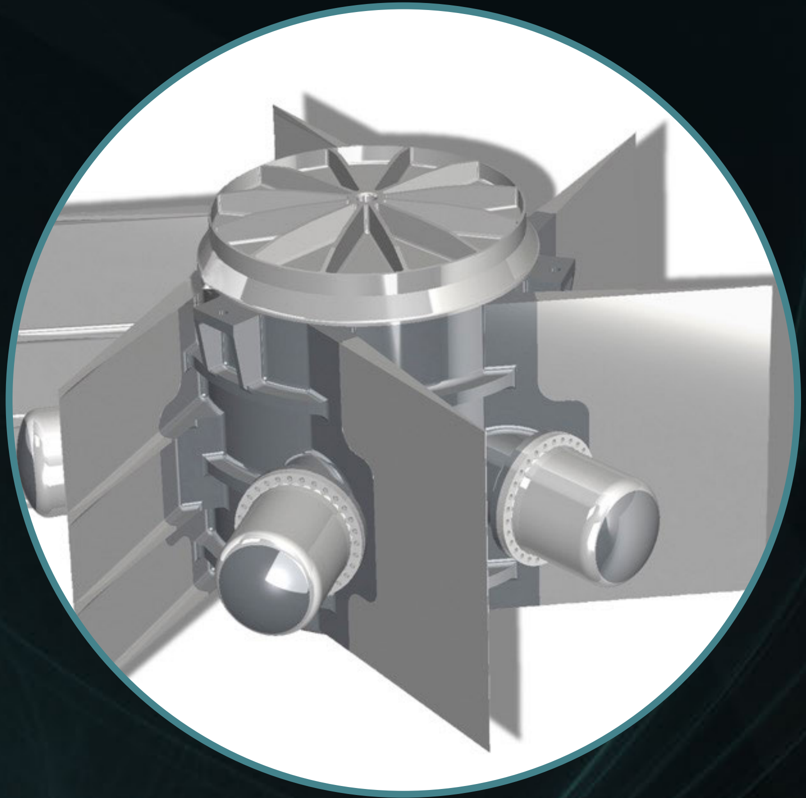
MMRTG

Multi-Mission
Radioisotope Power
System



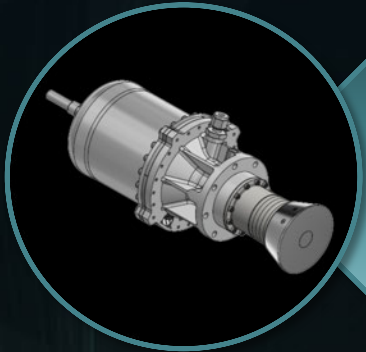
Next Gen RTG

Deep Space
Radioisotope Power
System

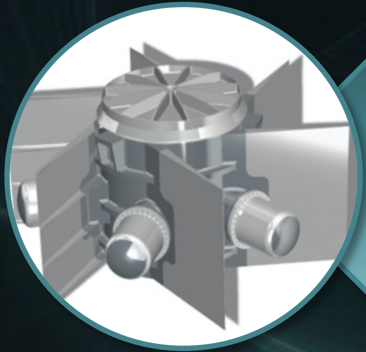


DRPS

Multi-Mission
Dynamic Radioisotope
Power System



Innovative energy conversion investments to provide power in the deep craters of the moon to **enable spacecraft to survive** the long, dark, and cold lunar night.



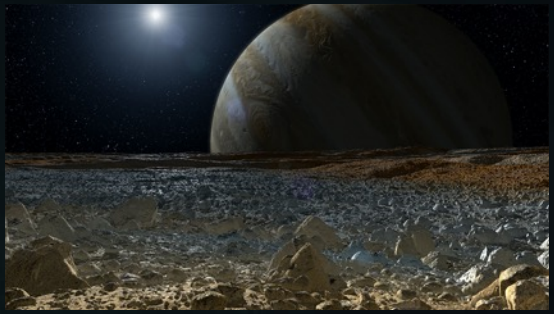
Dynamic Radioisotope Power System (DRPS) could achieve **efficiencies on the order of 3-4 times greater** than the current state of the art, Radioisotope Thermoelectric Generator (RTG).

A **demonstration unit on the moon** could prove the use of dynamic power in space, making DRPS an excellent candidate to enable specific missions that could not be achieved any other way.

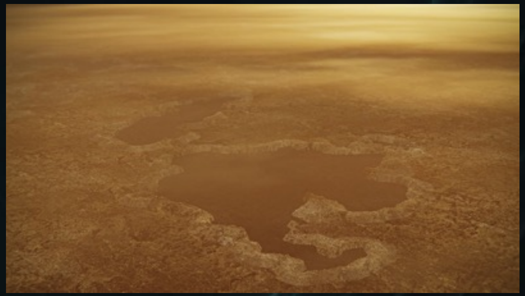
Multi-Mission DRPS Requirements

- Requirements (SRD, ERD) developed using the SMT to meet exploration mission center needs (APL, GSFC, JPL) while considering DOE specific requirements
- May be tailored for a 1st mission (i.e. Lunar application design life is only 2 years)
- On track to released procurement for Multi-Mission design verified to a Lunar Demonstration. Working to ensure requirements are complete via DRMs

Parameter	DRPS
$P_{0,}$ BOL (W_e)	300 to 400
Efficiency = P_0/Q*100 (%)	20 to 25%
BOL Specific Power = P_0/m (W_e/kg)	2 to 3
Q, BOL (W_{th})	1500
Mass (kg)	100 to 200
Annual power degradation averaged over flight design life, r (%/yr)	1.3
$P_{BOM,}$ $P=P_0*e^{-rt}$ (W_e), t=3 yrs	289 to 385
Fueled storage life, t (years)	3
$P_{EODL,}$ $P=P_0*e^{-rt}$ (W_e), t=17 yrs	241 to 321
Flight Design Life, t (yrs)	14
Design Life, t (yrs)	17
Allowable Flight Voltage Envelope (V)	22 to 36
Planetary Atmospheres (Y/N)	Y



Europa
Credit: NASA/JPL



Titan
Credit: NASA/JPL

Lunar (Far side & S. Aitken Basin)
Credit: NASA

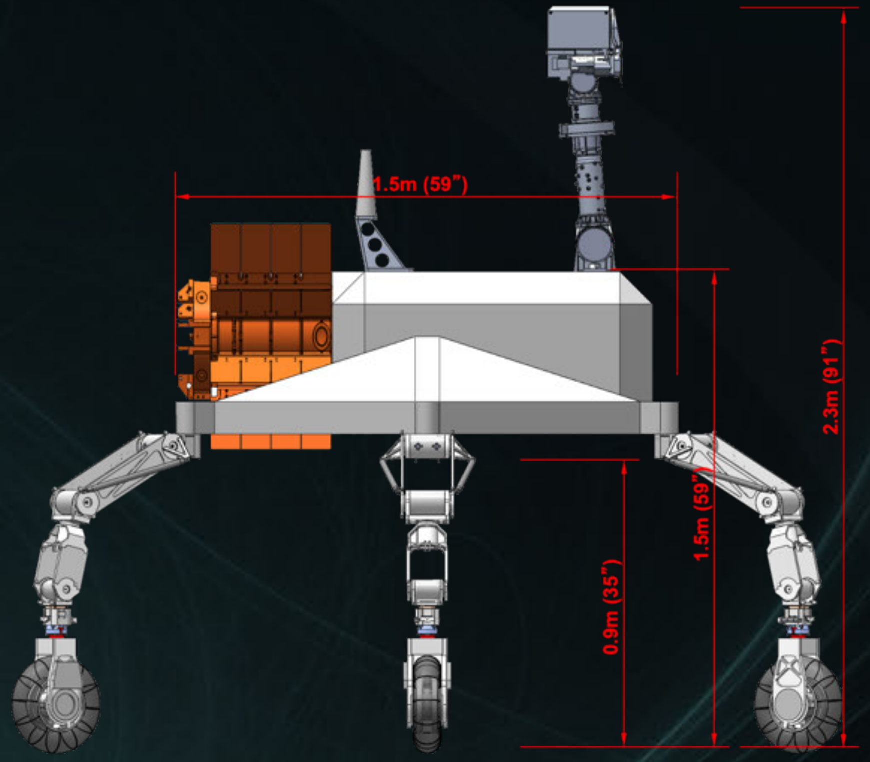
Study Charter / Guidelines

This Study is not yet finished

- Purpose – Develop an initial reference mission architecture:
  - Given: DRPS designed / built to full multi-mission requirements, but validated to lunar-specific requirements
  - Action: Outline a concept for a potential lunar demonstration mission flight of a DRPS
- Study Team: RPS Program Surrogate Mission Team (SMT) – NASA GRC & GSFC, JPL, INL, APL
- Project Risk Class: D (NPR 8705.4); tailored.
- Lunar DRM Mission Life: 20 months (1.7 yrs) post-launch, with potential for extended DRPS operation of up to 14 years.
  - Lunar DRM: 32 months (2.7 yrs), with one year of pre-launch storage after fueling.
  - Multi-mission DRPS design life per RPS-REQ-0137 (3.1.4): 14-year mission after three years of pre-launch fueled storage.
- Destination: Lunar south pole and its permanently shaded regions (PSR).
- Baseline a DRPS-enabled JPL Long Lived Lunar ATHLETE (L3) rover – 6-leg option baselined
- Science mission with drill is required – VIPER class minimum, upgrade considered
- Examine feasibility for use of CLPS Lander for delivery to lunar surface.
- Consider tentative launch opportunities in 2029

L3 Rover:
DRPS Lunar Demo DRM Accommodations and Assumptions

- Single string, Class D
- Rover does not need to offload itself from lander; ramps, lift, etc. provided by CLPS.
- 1 meter ground clearance
- 4-leg variant saves mass but sacrifices maneuverability.
- Science payload-specific accommodations [TBD] not included in design.
- Rover avionics would be capable of supporting DRPS command and telemetry interface requirements as specified in the DRPS SRD.
- Included rover navigation cameras are capable of satisfying science mapping objectives [TBR].



CAD Concept

DRM Architecture:
Lunar Surface Segment – Science Payload

Base Payload Option:

- Reflight of VIPER Payload

Instrument	Description	Mass (kg) *	Peak Power (W)
NSS	Neutron Spectrometer	2.0	10
NIRVSS	Two-channel near-IR point spectrometer	3.6	24
MSolo	Mass Spectrometer	7.5	40
TRIDENT	1-m drill for subsurface sampling	18	100

https://www1.grc.nasa.gov/space/pesto/instrument-technologies-current/nasa-provided-lunar-payloads/

*** Note**: *Reported payload masses are assumed to be CBE values for this DRM study [TBR]. Further investigation and analysis is required to more precisely define individual mass values and margins based on current TRLs for individual instruments. Assumption of CBE values provides the more conservative estimate pending further information.*

Enhanced Payload Option:

- APL PIPELiNE Decadal Concept Study

Instrument	Description	Mass (kg) *	Peak Power (W)
NS	Neutron Spec.	1.9	1.5
GCMS	Gas Chrom. Mass Spectrometer	15	60
IRS	IR Spectrometer	4	30
Drill	1-meter depth	18	175
SHS	Spatial Heterodyne Spec.	1	6
Raman	Raman Spec.	7.2	15.5
GPR	Ground Penetrating Radar	6	10
IS	Ion Spectrometer	5	9

PIPELiNE = Polar Ice Prospecting Explorer for Lunar No-Light Environments

Surface Mission Concept of Operations Overview

- Survey while roving to locate high sub-surface H areas, “cold and old” PSRs.
- Perform site analyses with drill: sample at 10cm depth increments, observe pilings with IR spectrometry.
  - Potential for ingesting sample for composition analysis with an extended payload.
- Make measurements of volatile composition, abundance, and physical form; map the distribution on meter scale; relate all measurements to environmental parameters.
- Traverse to multiple sites and conduct survey over minimum 20-month (1.7yr) period.
- DRPS provides continuous power enabling day/night operation and potential extended excursions into PSRs [max. duration TBD].
  - Extended exploration of PSRs likely limited by communications (i.e., Earth line-of-sight or availability of relay assets in 2029) and/or rover autonomous driving capability (cost and risk impacts TBD).

Conclusions:

- Mass: Beyond medium-class CLPS capability:
  - Fully margined (~43% over CBE) configuration options exceed the maximum landed mass capability for known medium-class CLPS lander options (~500 kg) available in the 2023 timeframe. It is not clear what capability is planned for 2029.
- Power: OK [TBR]
  - Preliminary conclusion: specifications are sufficient to enable this concept
- Environment: Multi-Mission specification is OK
  - Nothing expected to exceed DRPS environmental requirements / typical applications regarding deep-space operation in vacuum; however, need more detailed mission planner's information is required from CLPS providers [TBR].
  - DRPS carries less heat source, uses it more efficiently than an RTG, less "waste heat" injected into the PSR environment being studied. Some waste heat is available to warm sensitive instruments or help with ISRU.
  - DRPS enables a free-maneuver exploration strategy not tethered to a remote power generation system (solar/battery/fission)
- A follow-on study will need to examine potential options [TBR]:
  - Obtain better estimates from providers for CLPS landed mass capabilities expected in 2029.
  - Reconsider science mission requirements and extent of payload complement.
  - Refine current mass estimates for key flight system elements.

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POWER TO EXPLORE

https://rps.nasa.gov