National Aeronautics and
Space Administration

RADIOISOTOPE POWER SYSTEMS PROGRAM

Presentation to
Planetary Advisory Committee
March 5, 2024

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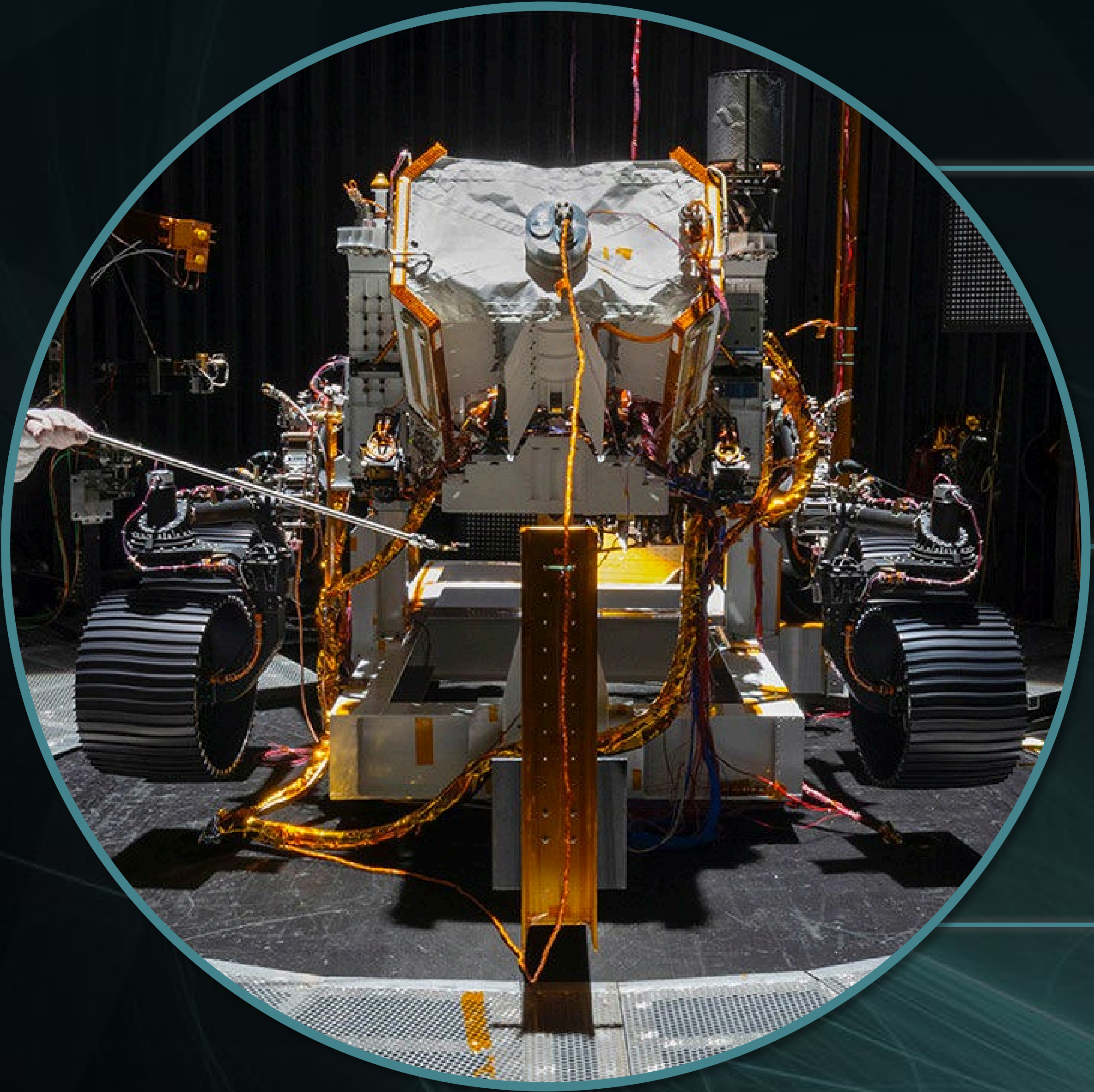
NASA Headquarters, Planetary Science Division

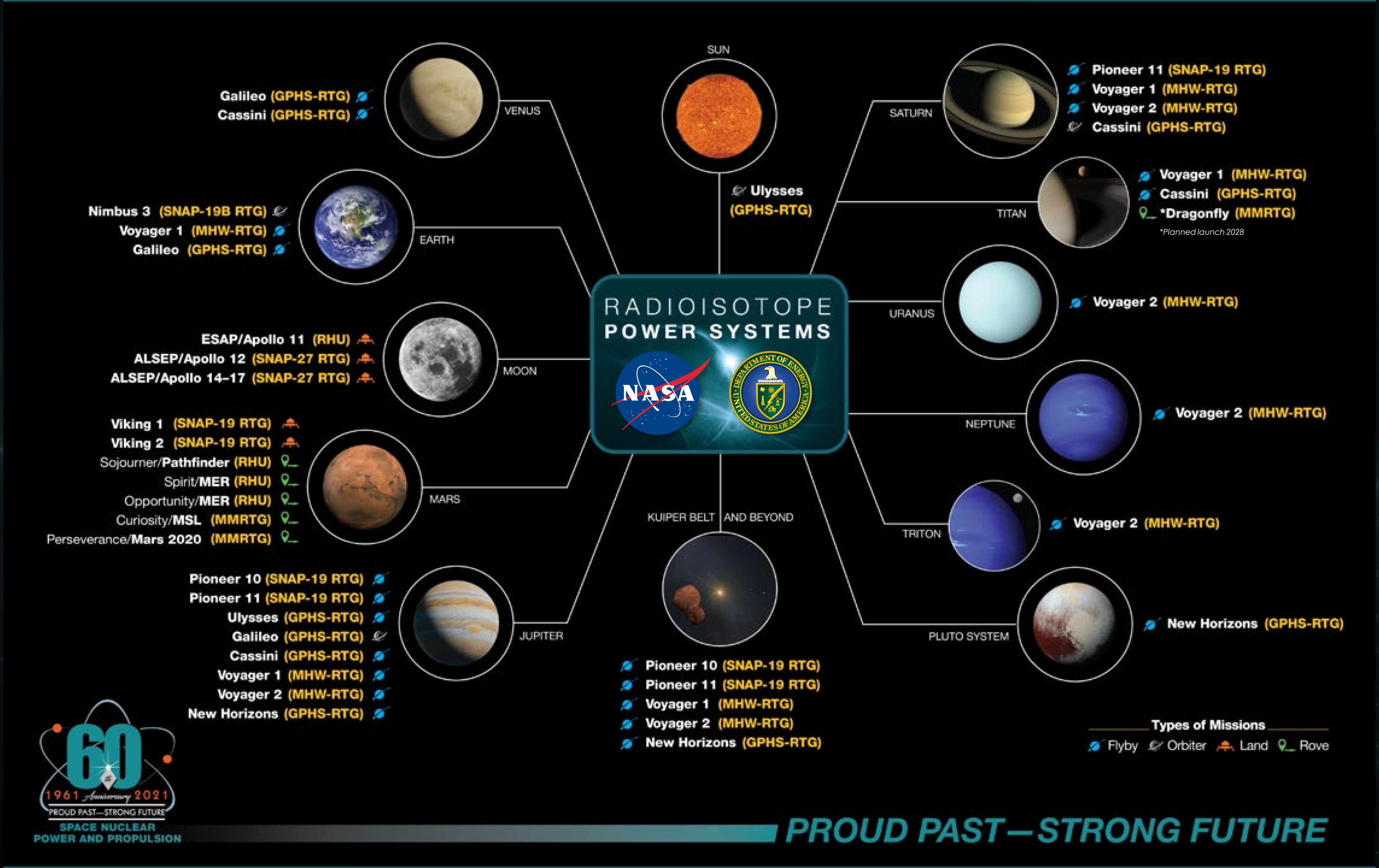
Power to…



EXPLORE

DISCOVER

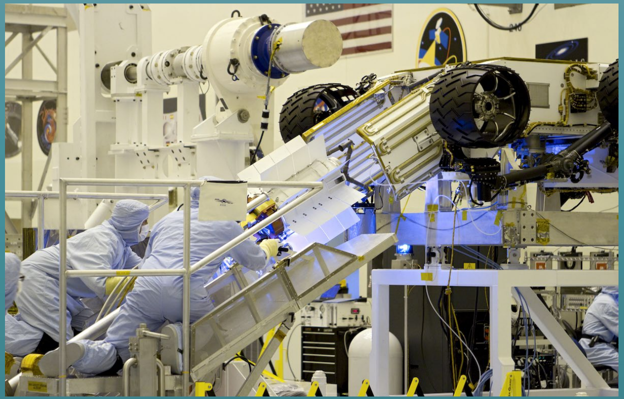
UNDERSTAND


RADIOISOTOPE POWER SYSTEMS
NASA
DEPARTMENT OF ENERGY UNITED STATES OF AMERICA
SUN
Ulysses (GPHS-RTG)
VENUS
Galileo (GPHS-RTG)
Cassini (GPHS-RTG)
EARTH
Nimbus 3 (SNAP-19B RTG)
Voyager 1 (MHW-RTG)
Galileo (GPHS-RTG)
MOON
ESAP/Apollo 11 (RHU)
ALSEP/Apollo 12 (SNAP-27 RTG)
ALSEP/Apollo 14–17 (SNAP-27 RTG)
MARS
Viking 1 (SNAP-19 RTG)
Viking 2 (SNAP-19 RTG)
Sojourner/Pathfinder (RHU)
Spirit/MER (RHU)
Opportunity/MER (RHU)
Curiosity/MSL (MMRTG)
Perseverance/Mars 2020 (MMRTG)
JUPITER
Pioneer 10 (SNAP-19 RTG)
Pioneer 11 (SNAP-19 RTG)
Ulysses (GPHS-RTG)
Galileo (GPHS-RTG)
Cassini (GPHS-RTG)
Voyager 1 (MHW-RTG)
Voyager 2 (MHW-RTG)
New Horizons (GPHS-RTG)
SATURN
Pioneer 11 (SNAP-19 RTG)
Voyager 1 (MHW-RTG)
Voyager 2 (MHW-RTG)
Cassini (GPHS-RTG)
TITAN
Voyager 1 (MHW-RTG)
Cassini (GPHS-RTG)
*Dragonfly (MMRTG)
*Planned launch 2028
URANUS
Voyager 2 (MHW-RTG)
NEPTUNE
Voyager 2 (MHW-RTG)
TRITON
Voyager 2 (MHW-RTG)
PLUTO SYSTEM
New Horizons (GPHS-RTG)
KUIPER BELT AND BEYOND
Pioneer 10 (SNAP-19 RTG)
Pioneer 11 (SNAP-19 RTG)
Voyager 1 (MHW-RTG)
Voyager 2 (MHW-RTG)
New Horizons (GPHS-RTG)
Types of Missions
Flyby Orbiter Land Rove
60
1961 Anniversary 2021
PROUD PAST—STRONG FUTURE
SPACE NUCLEAR POWER AND PROPULSION
PROUD PAST—STRONG FUTURE

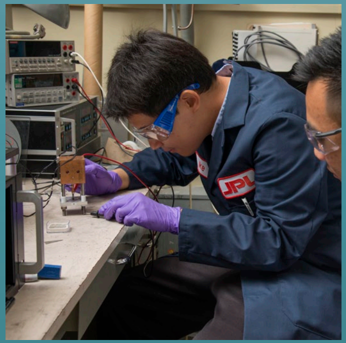
RPS Program Elements

- Deliver reliable radioisotope power systems to enable science and exploration missions resulting in the following tangible outcomes over time

✓ Flights of RPS powered science missions

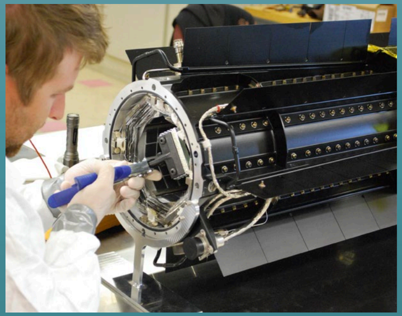


✓ Sustaining RPS capabilities for future missions (talent, infrastructure, and production)

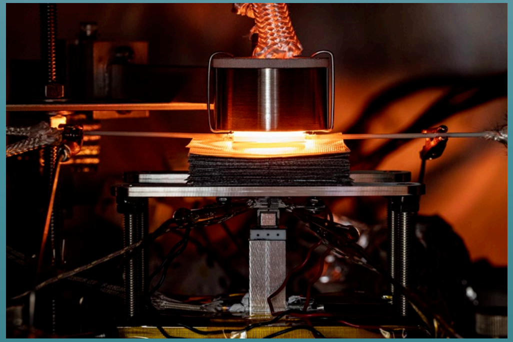


✓ Efficient and cost effective NEPA and launch authorization

✓ Develop a new vacuum rated RPS for future missions



✓ Develop technologies for future flight systems



HQ Program Commitment Agreement (PCA) update includes focus on commercial and international RPS development opportunities

RPS Program Functionality

Department of Energy
Constant Rate Production and Mission Support

Radioisotope Power Systems Program Office
Program Manager (PM)
Deputy Program Manager (DPM)
Chief Engineer (CE)
Chief Safety Officer (CSO)
Administrative

Key Technical Support
- JPL
- APL
- Support Service
- Contractors

Level II

Program Integration
- Scheduling
- Risk Management
- Acquisitions and Contract Management
- Budget Analysis/ Planning/Forecasting
- Export Control
- CM/DM

Stakeholder Engagement
- Strategic Comm
- Public Engagement
- STEM
- Website Design
- Messaging/Branding/ Marketing
- Nuclear Community Coordination

NEPA & Launch Authorization
- NEPA Coordination
- Launch Authorization
- Multi-Mission Databooks (MMDB)
- Radiological Contingency Mission Coord w/DOE, KSC
- Policy Support

Mission Integration
- RPS/RHU Missions (M2020, Dragonfly)
- AO Formulation and Support
- MMRTG Builds, Users Guides
- Decadal Support
- Modeling and Testing

Systems Engineering & Integration
- Technical management
- Product Realization
- Surrogate Mission Function
- Project IRB Mgt.

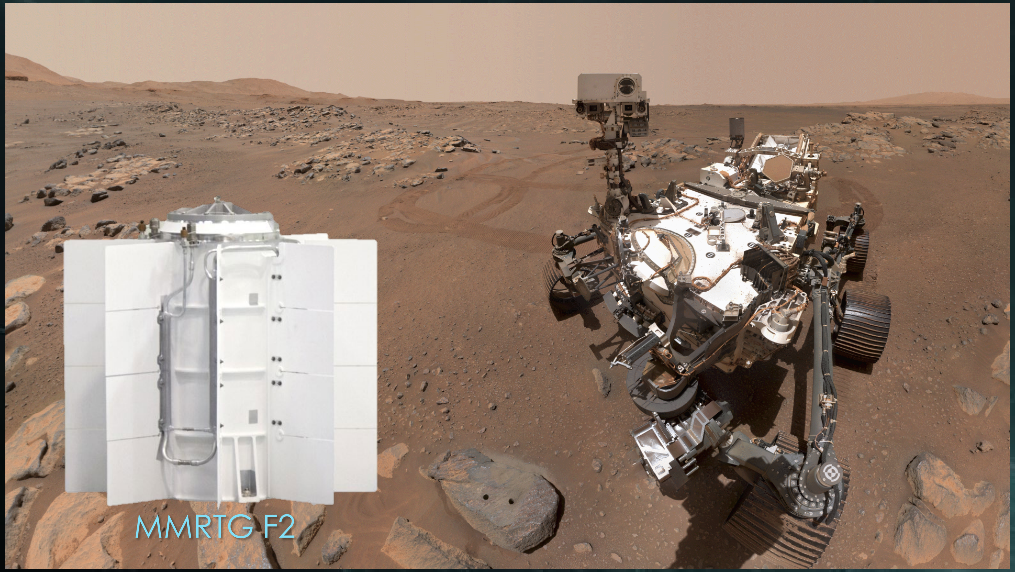
Level III

NG RTG Project

HEPGT

NASA Current RPS Missions: The Power to Explore

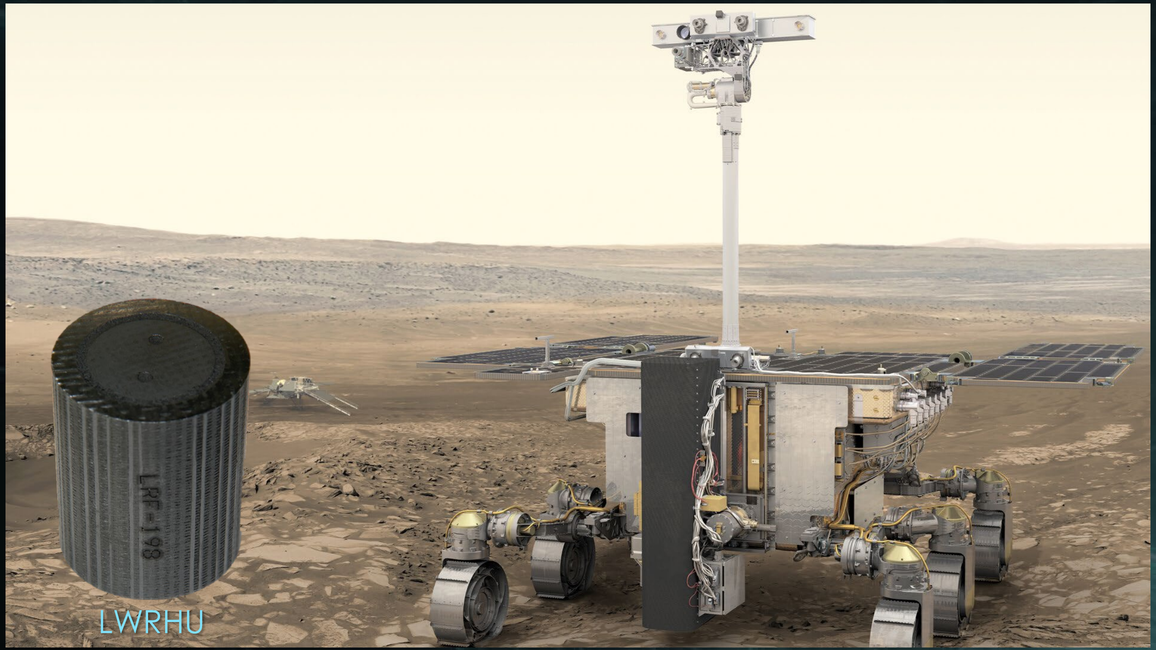
- Perseverance
  - Launched in July 2020
  - Seeking signs of ancient life and collecting rock and soil sample
  - Provided an MMRTG under budget, ahead of schedule, above power, during the COVID-19 pandemic



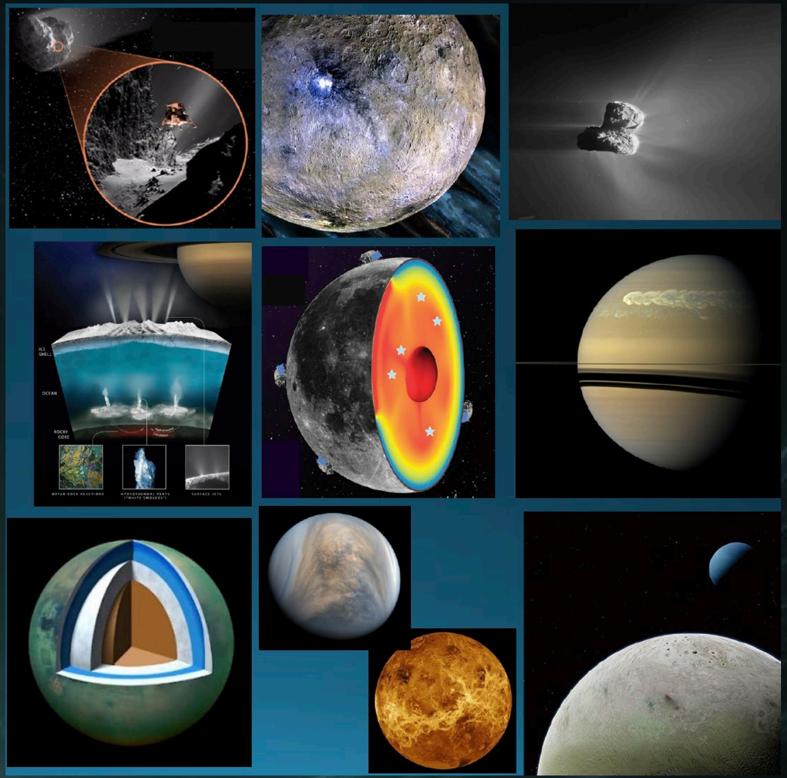
- Dragonfly
  - Flights to explore Saturn's moon Titan, an organic-rich ocean world
  - Planned launch no earlier than 2028
  - A Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) will enable Dragonfly to explore beneath the thick, hazy atmosphere of Titan

NASA Near Future RPS Missions: The Power to Explore

- NASA Rosalind Franklin Project
  - ESA Mars robotic rover mission with NASA contributions
  - NASA-ESA MOU final iterations underway with NASA/DOE
  - Up to 40 LWRHU, and potential to include one Am-241 RHU from UKSA



- Potential New Frontiers Mission
  - Up to 2 MMRTGs and up to 20 LWRHU
  - AO release no earlier than 2026



Technology Investments
Enable New Radioisotope Generators

Radioisotope Power System Heat Source

LWRHU

Light Weight Radioisotope Heater Units

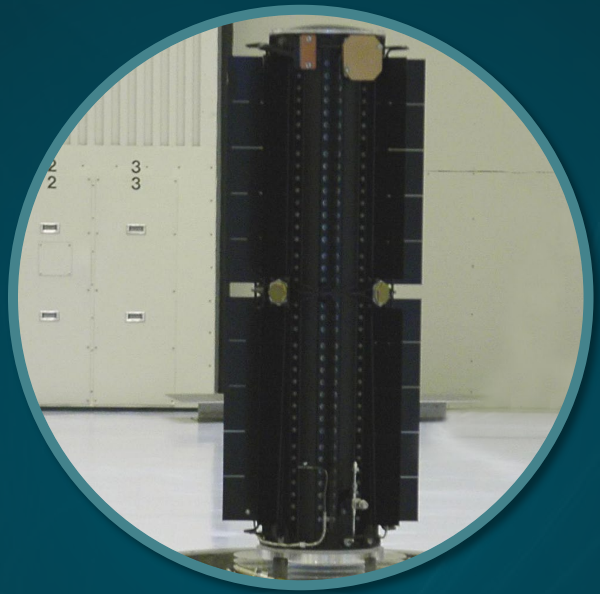
Multi-Mission Radioisotope Power System

MMRTG

Multi-Mission Radioisotope Thermoelectric Generator

Current Flight Systems

Vacuum-Rated Radioisotope Power System



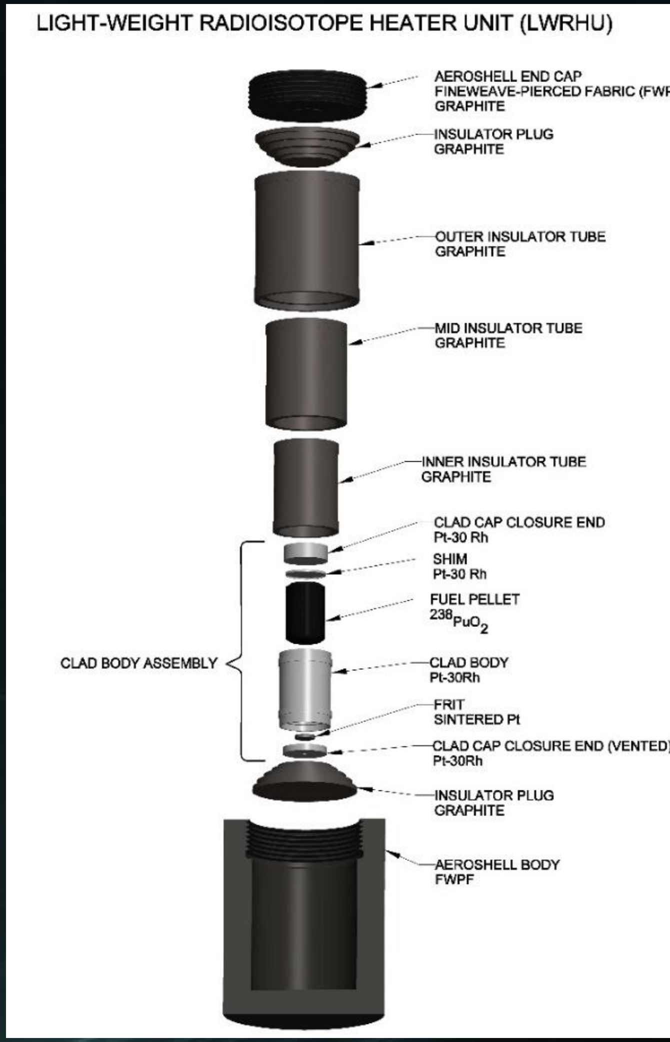
Next Gen RTG

Next Generation Radioisotope Thermoelectric Generator

Lightweight Radioisotope Heater Units (LWRHU)

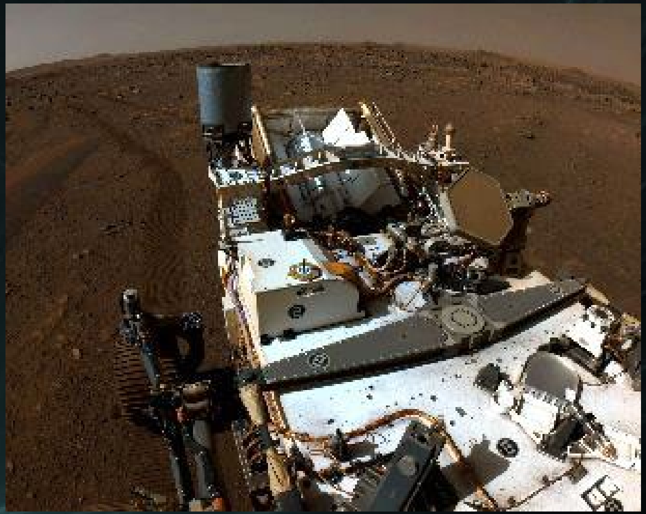
- Current Cassini-era LWRHUs available (~.8 W_{th})
- DOE reconstituting approximately 1 W_{th} LWRHU production capability
  - Capability completed at ORNL
  - Capability at INL and LANL to be completed by 2026
  - Dedicated run is planned for 2027
- Documentation
  - LWRHU Programmatic Environmental Assessment completed (cost savings to missions)
  - LWRHU System-Specific Documented Safety Analysis completed and in DOE approval cycle
  - LWRHU User Guide is available for request

RHU User Guide



Multi-Mission Radioisotope Thermoelectric Generator (MMRTG)

- **F1** on Mars on Curiosity
  - Current Power 77.2 W_e
- **F2** on Mars on Perseverance
  - Current Power 101.9 W_e
- **F3** at INL ready for a mission
  - Completed 1–MMRTG 48-couple module
- **F4** slated for Dragonfly
  - Machined, inspected, cooling tube fatigue analysis



* Current as of December 2023

Next Gen Mod 1 = ~GPHS-RTG

- A revectored design of the **heritage GPHS-RTG** was the results of a DOE Phase 1 industry effort for a new technology-based system
- Built by Aerojet Rocketdyne under INL letter contract
- Reestablish GPHS RTG production capability
  - Use of proven heritage design with proven long life and low degradation
  - Cost effective
  - Low risk
- 90% heritage design, but lower heat; lower power; 2 trades going on to consider change to stretch the housing; more efficiency of the couples; EODL~177-210 W_e
- Maintains opportunity for enhancements providing increased performance & greater efficiency (Mod 2)






Voyager 2
Aug. 20, 1977–Present
3 MHW RTG: @~158 W_e BOL

Voyager 1
Sept. 5, 1977–Present
3 MHW RTG: @~158 W_e BOL

New Horizons
Jan. 19, 2006–Present
GPHS RTG: 245 W_e BOL

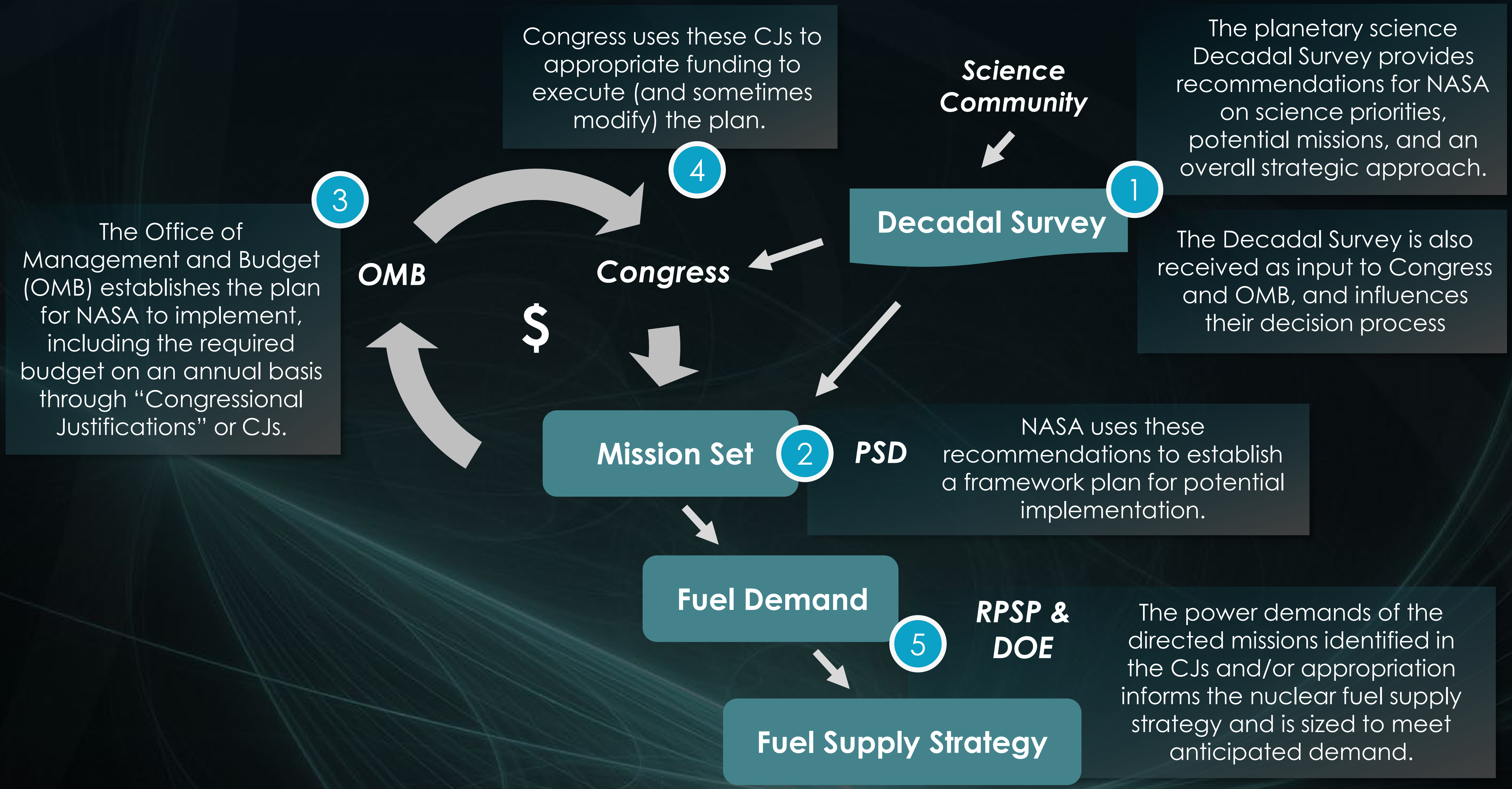
Cassini
Oct. 15, 1997–2017
3 GPHS RTG: @~292 W_e BOL

LES 9*
Mar. 14, 1976–2020
2 MHW RTG: 158 W_e BOL

LES 8*
Mar. 14, 1976–2004
2 MHW RTG: 158 W_e BOL

* U.S. Air Force Mission

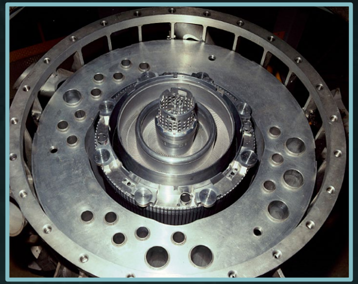
Future Radioisotope Power Systems: Heat Source Production & Rate



RPS Fuel Production and Availability

- Constant Rate Production
  - Department of Energy has reestablished the capability to domestically produce plutoninium-238 in support of RPS.
  - RPS is well positioned to enable future exploration.

Fabricate → Irradiate → Separate



Alternative Isotopes

- In addition of plutonium-238, research and development in alternative fuels are underway across the industry, both domestic and international
- A viable fuel alternative should have the following characteristics:
  - Exist in an insoluble form and/or otherwise not be readily absorbed into the body
  - Exist in a form such that it presents no or minimal chemical toxicity
  - Have relatively low neutron, beta, and gamma radiation emissions, so as to not adversely affect spacecraft instruments or require excessively massive shielding
  - Stability at high temperatures, to enable consistent performance over many years
  - Long half-life, so that it can generate for many years sufficient heat for transformation into electricity
  - High power density, so a small amount of it can generate a substantial amount of heat
- Example candidate alternatives:
  - Americium-241 (half-life 432.7 years)
  - Strontium-90 (half-life 28.8 years)
- Technology investments in conversion efficiency has enhanced the viability of alternative isotopes

Future Systems: NASA Partnerships in Commercial Development

- Zeno: Harmonia Tipping Point award for development of a Stirling RPS utilizing americium-241
  - Project will develop an electrically heated flight-qualification unit and an Am241 heat source

- Aerospace Corp & JPL: APPLE NIAC Phase II award to develop ~2 W_e RTG modules that can be configured in multiples on a spacecraft that also utilizes the waste heat
  - Heat source of novel design using plutonium-238 or americium-241

- USNC: Nyx NIAC Phase II award to develop an RPS utilizing a short half-life isotope along with a medium half-life isotope for a novel science mission capability

Launch Authorization Process

- NSPM-20 replaces the prior standard employed (PD/NSC-25) for U.S. Launch Authorization (8/2019)
- NSPM-20 necessitates update to NASA NPRs
  - Guidelines vary with quantity and form of material planned for use, as well as, with potential radiological risk
  - Updating NPR 8715.3D Chapter 6* "Nuclear Safety Launching of Radioactive Materials" to NPR 8715.y for compliance with NSPM-20
    - Interagency Nuclear Safety Review Board (INSRB)
    - Reporting levels and launch authorization vary based on Tier
    - RPS mission require DOE SAR

Mars 2020 Mission launching from Cape Canaveral Air Force Station, Florida on July 30, 2020

Note: Interim usage of NPI 8715.93 Impacts of NSPM-20 on NASA Nuclear Flight Safety Requirements and Practices June 2020.

NSPM-20 Risk-Based Tiered Approval

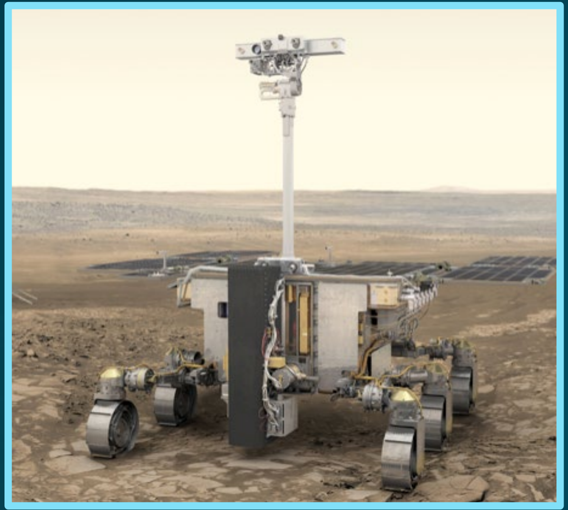
- Tier I applies when *all* of the following apply:
  - The quantity of radioactive material equals more than and including 1,000 times the "A2 value" and up to and including 100,000 times the "A2 value" established in the International Atomic Energy Agency's (IAEA) current standards for safe transport of radioactive material;
  - Safety analysis finds that there is no credible accident scenario (less than 1 in a million chance) that might result in radiation exposure of 5 rem or greater Total Effective Dose (TED) to any member of the public; and
  - The space nuclear system is not a nuclear reactor.
- Tier II applies when *any* of the following applies:
  - The quantity of radioactive material exceeds 100,000 times the "A2 value" established in the IAEA current standards for safe transport of radioactive material; or
  - Safety analysis finds that the there is a credible accident scenario (greater than or equal to 1 in a million chance) that might result in radiation exposure of 5 rem to 25 rem TED to any member of the public; or
  - The system is a nuclear reactor that uses low-enriched uranium fuel.
- Tier III applies when *either* of the following applies:
  - Safety analysis finds that there is a credible accident scenario (greater than or equal to 1 in a million chance) that might result in radiation exposure greater than 25 rem TED to any member of the public; or
  - The system is a nuclear reactor using any nuclear fuel other than low-enriched uranium.

Head of Sponsoring Agency Authorizes Launch

POTUS or Delegate Authorizes Launch

Delivering on NASA Missions!

Dragonfly



Rosalind Franklin Mission

New Frontiers 5

Currently within RPS Mission planning set

Discovery

Flagship

Under consideration based on PSD budget availability

NASA NASA @NASA NASA

POWER TO EXPLORE

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