



National Aeronautics and
Space Administration



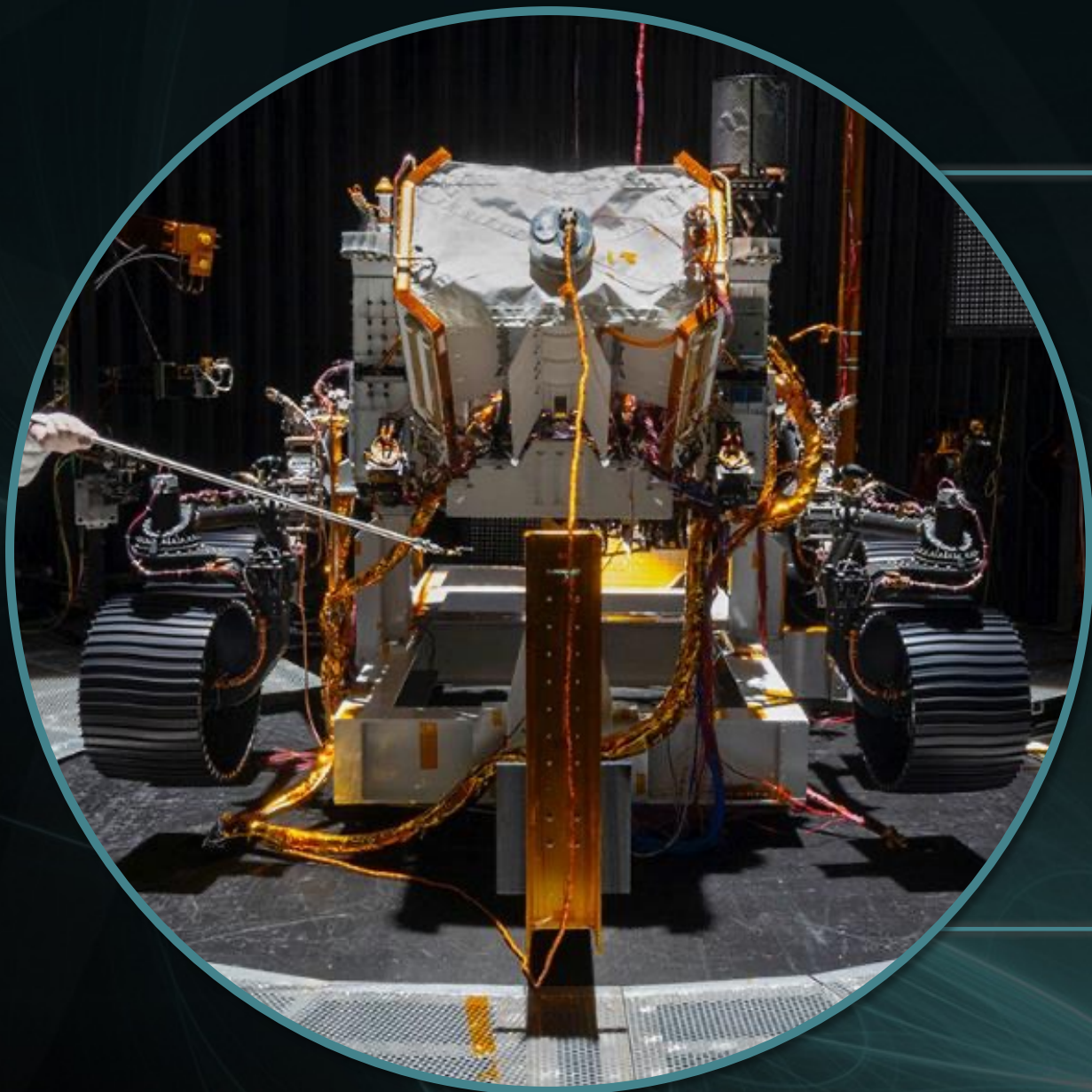
RADIOISOTOPE POWER SYSTEMS PROGRAM

NETS 2024 – Powering the Final Frontier

May 7, 2024

Carl E. Sandifer II
RPS Program Manager

Power to...



EXPLORE

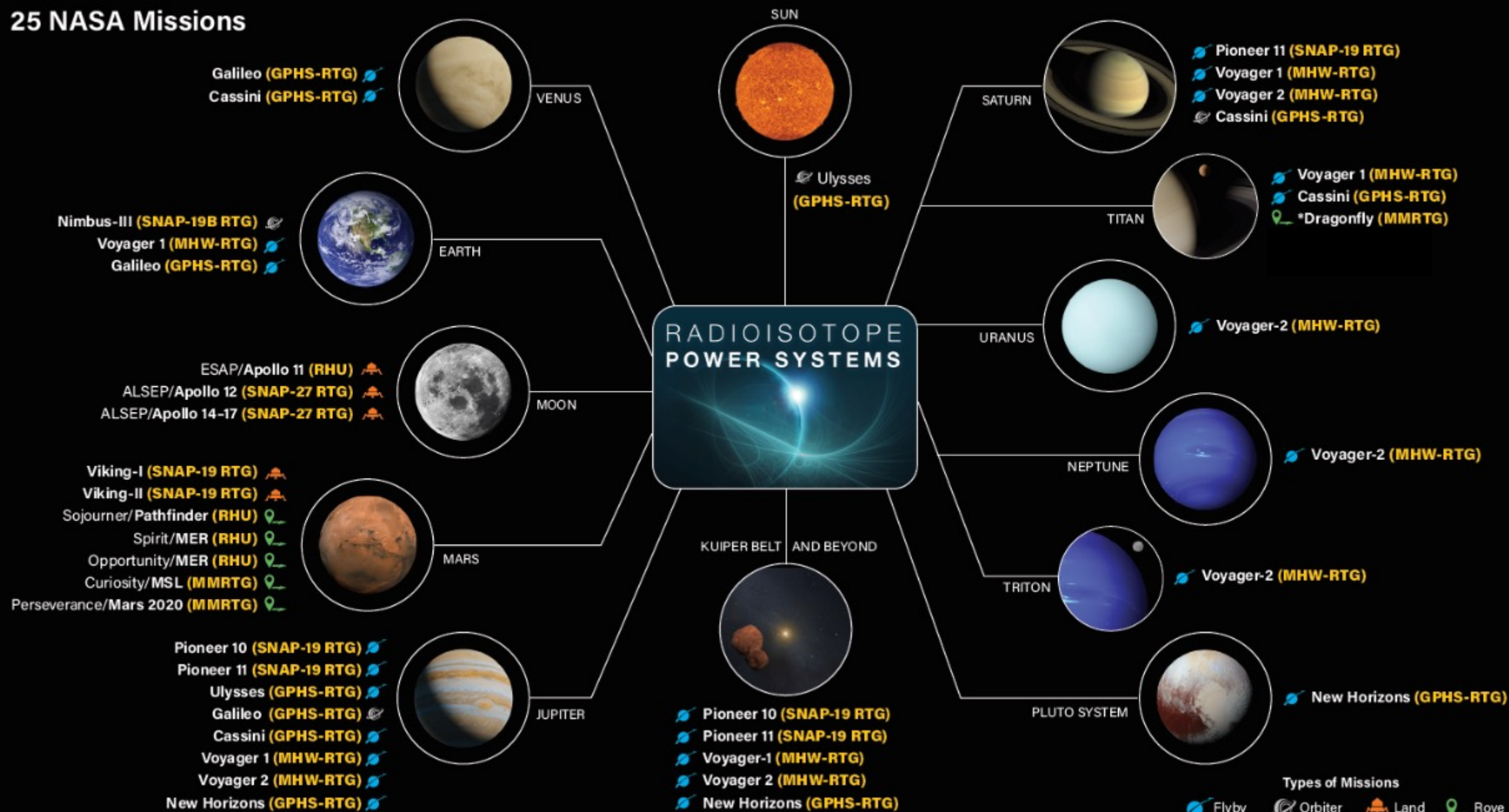


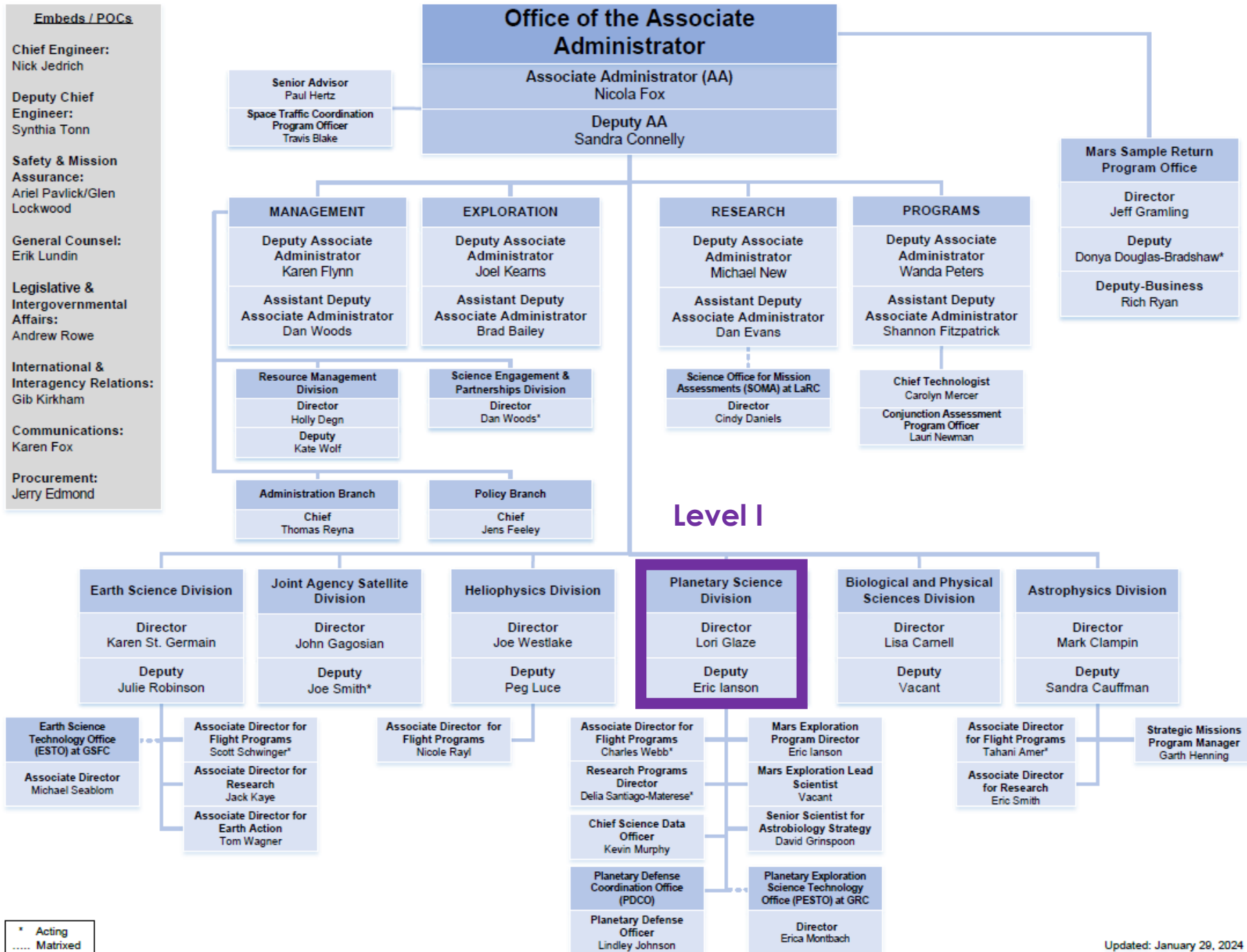
DISCOVER



UNDERSTAND

25 NASA Missions







RPS Program Functionality



Department of Energy (DOE)

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

- APL
- GRC
- JPL

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
- 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, RFM)
- AO Formulation and Support
- MMRTG Builds, Users Guides
- Decadal Support
- Modeling and Testing

Systems Engineering & Integration

- SE&I Technical Mgmt.
- Requirements & Studies
- Surrogate Mission Team
- Tech Assessment
- Product Realization

Level II Program Office Residing at NASA GRC

Level III

NG RTG Mod 1 Project

Mod 0 Task

HEPGT

GRC Space Science Project Office

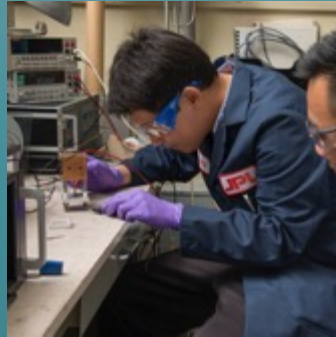
RPS Program Elements

- 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)



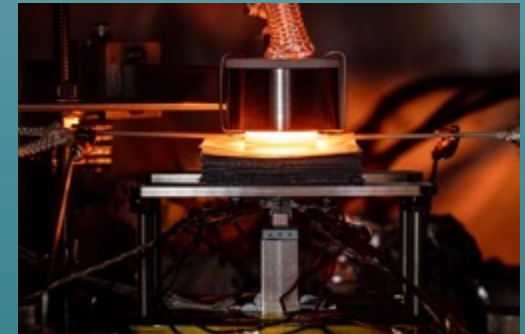
- ✓ Efficient and cost effective NEPA and launch authorization



- ✓ Develop a new vacuum rated RPS for future missions



- ✓ Develop technologies for future flight systems



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

Vacuum-Rated Radioisotope
Power System



Next Gen RTG

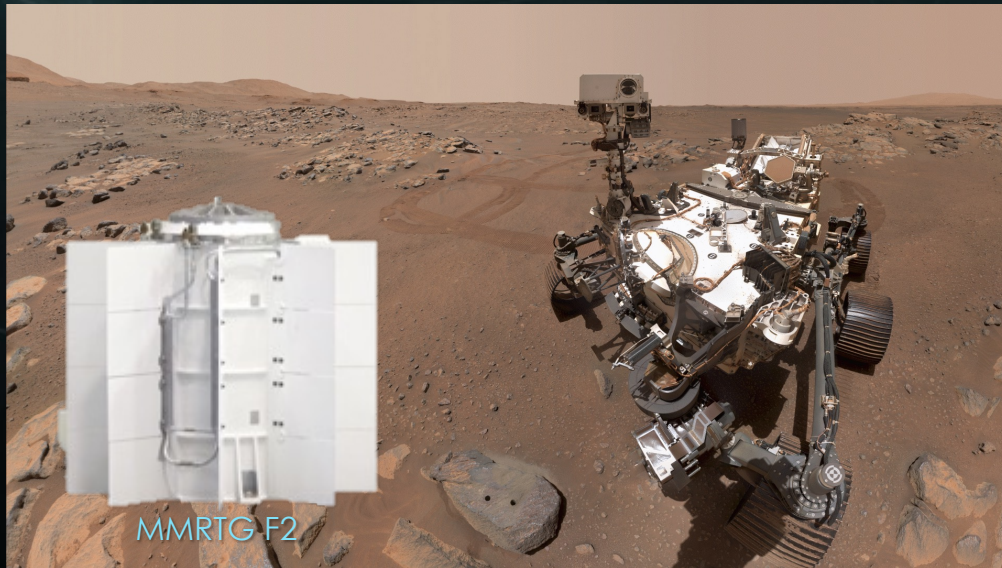
Next Generation
Radioisotope
Thermoelectric Generator

Current Flight Systems

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

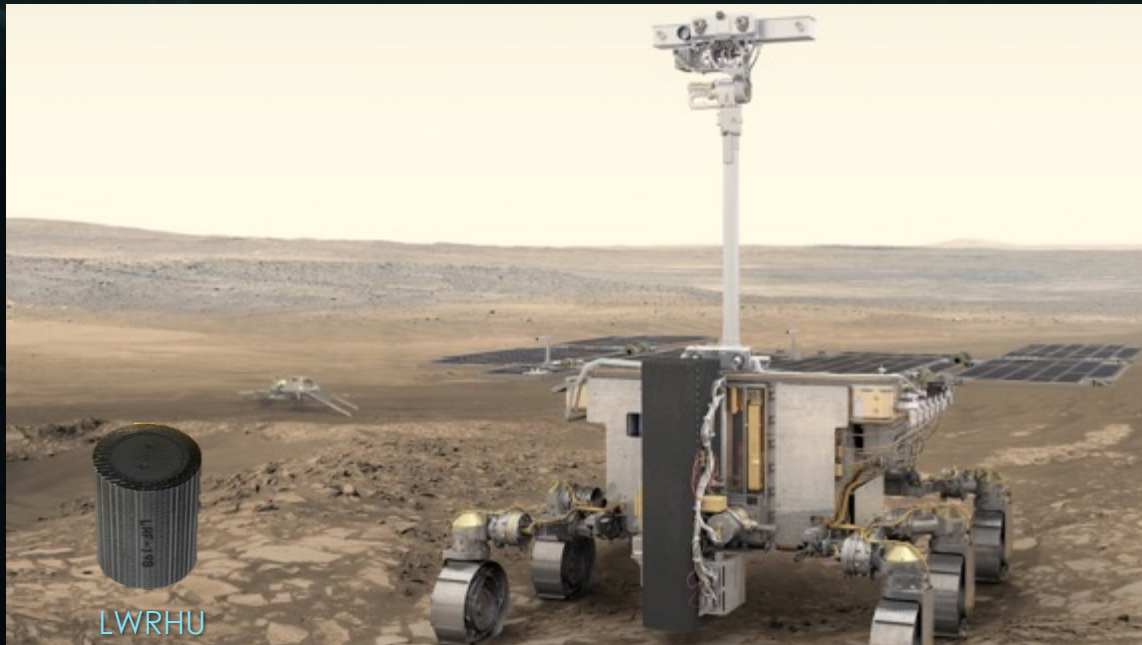
- Flights to explore Saturn's moon Titan, an organic-rich ocean world
- Planned launch no earlier than 2028
- A Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) will enable Dragonfly to explore beneath the thick, hazy atmosphere of Titan



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



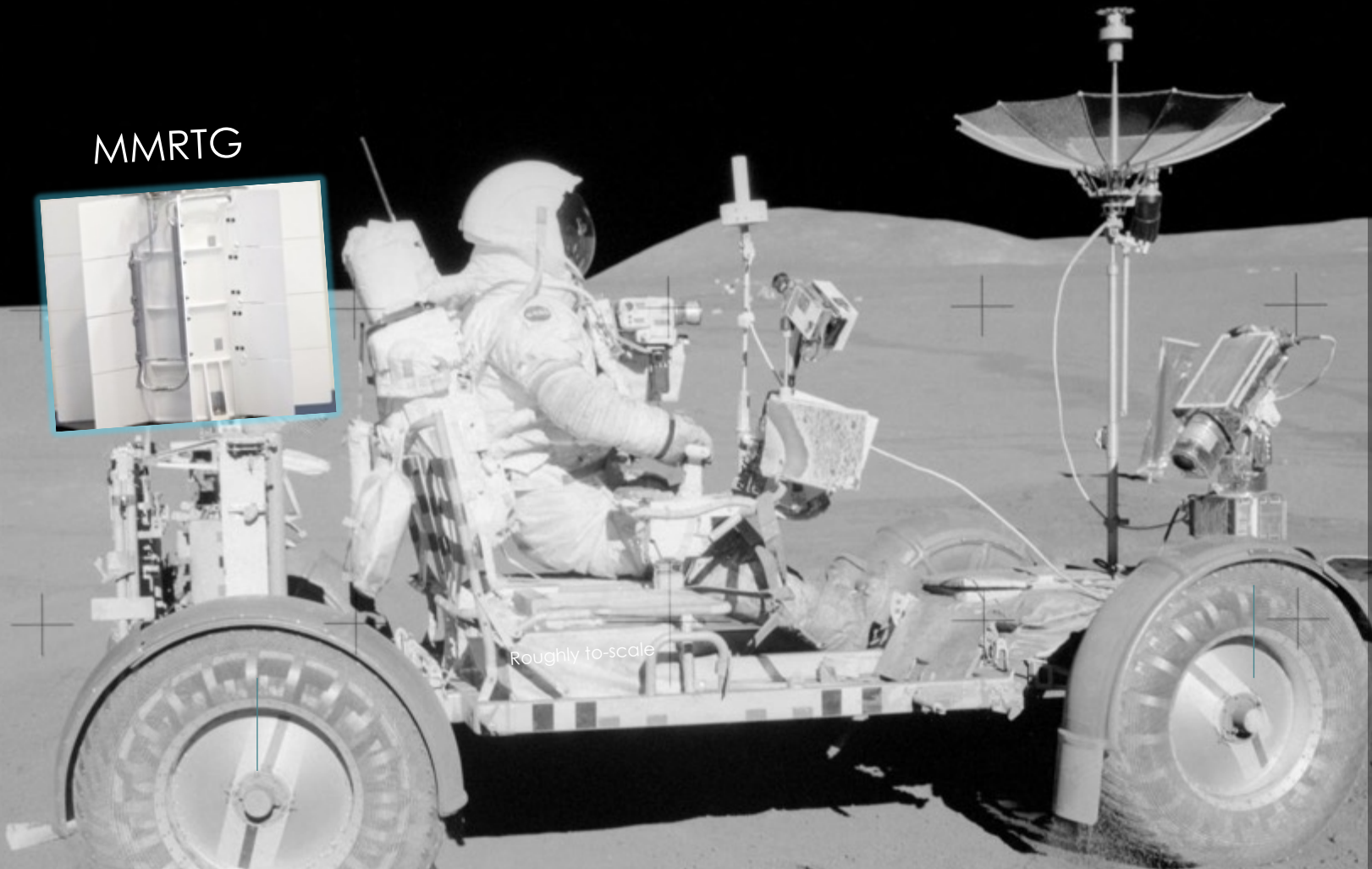
- Potential New Frontiers Mission

- Up to 2 MMRTGs and up to 20 LWRHU
- AO release no earlier than 2026

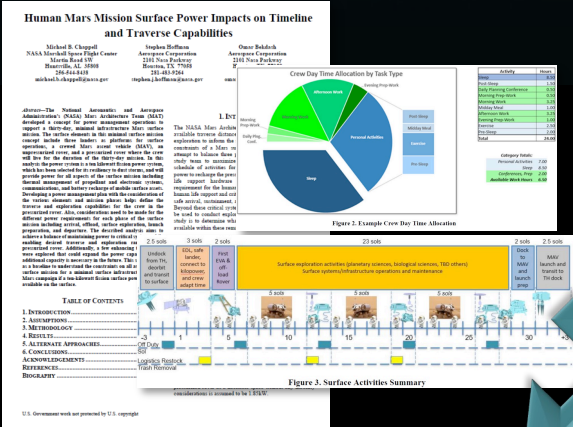


RPS Can Support Human Spaceflight Missions

MMRTG



Roughly to-scale

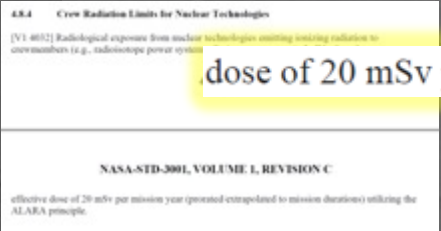


Reference Mars Architecture Team (MAT) ConOps:
23-day Mars surf mission: 15 EVA days & 6.5 work-hr/day

Strawman case for illustration/discussion

Activity	Activity Time-Split	Distance from MMRTG Endcap	Mission Total NO SHIELDING
Driving the Rover	25%	0.5 m	13.5 mSv
Working Close to Rover	25%	2 m	1 mSv
Working Far from Rover	50%	5 m	0.5 mSv
TOTAL			15 mSv

NASA-STD-3001 on RPS Radiation limit for crew:



Prospect is high for meeting RPS radiation limits for human spaceflight missions

NLAM: Three Elements: Independent and Interrelated

- NEPA – **INFORM** the Public of a planned action
 - RPSPO supports Missions in ensuring NEPA (nuclear) compliance
- Launch Authorization – **ENSURE** Approval Authority is informed and approves
 - RPSPO supports Missions in ensuring (nuclear) Launch Authorization is achieved
- Radiological Contingency Planning – **RECOVER** if there's a 'bad day'
 - RPSPO supports Mission & Launch Site in preparedness in event of nuclear release

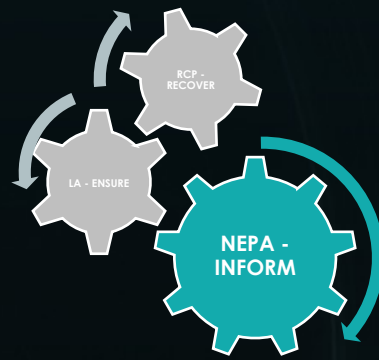


Commonality: Simplify Mission actions required for use of RPS & RHU

NEPA Overview

- Council on Environmental Quality (CEQ) “Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act”

- Requires all federal agencies to consider alternatives to their proposals before action is taken
- NEPA does not require a particular result; it does not require that the best alternative from an environmental perspective be selected.
- Requires public review and comment of agency actions

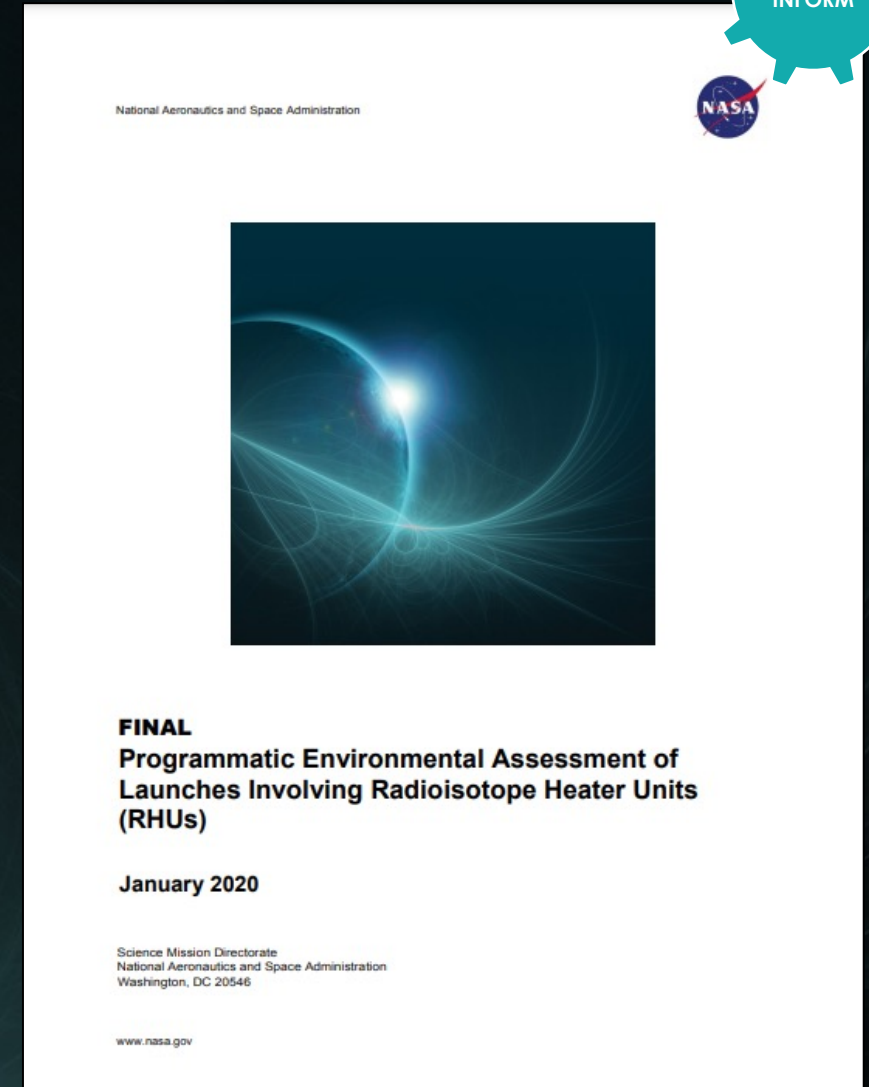


Levels of NEPA Analysis

Analysis	Decision Document
Categorical Exclusion (CatEx)	Record of Environmental Consideration (REC)
Environmental Assessment (EA)	Finding of No Significant Impact (FONSI)
Environmental Impact Statement (EIS)	Record of Decision (ROD)

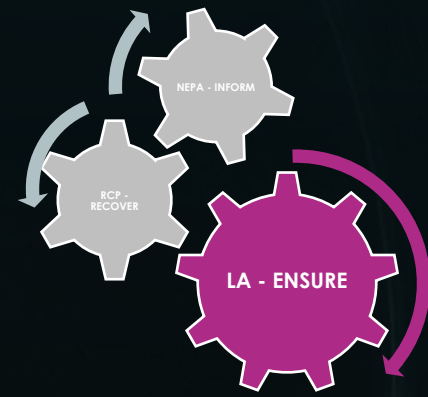
RPS Programmatic NEPA Documents

- LWRHU Programmatic Environmental Assessment (PEA) (2020)
 - The programmatic document will be applied each time an RHU is used in a space mission, as long as the parameters listed below are met
 - ✓ Up to 130 RHUs for a maximum combined 351 grams of plutonium-238 oxide (Pu-238)
 - ✓ Covers launches from the KSC and CCSFS launch complexes
 - ✓ Launch vehicles that have been fully analyzed through the NASA NEPA process and have undergone the NASA launch approval process are included in this analysis



National Security Presidential Memorandum 20 - Presidential Memorandum on Launch of Spacecraft Containing Space Nuclear Systems

- NSPM-20 replaces the prior standard employed (PD/NSC-25) for US Launch Authorization (8/2019)
- NSPM-20 major changes
 - Guidelines vary with quantity and form of material planned for use, as well as, with potential radiological risk
 - NASA Procedural Requirement (NPR) 8715.26 “Nuclear Flight Safety” published February 2022 to be compliant with NSPM-20:
 - Interagency Nuclear Safety Review Board (INSRB)
 - Reporting levels and launch authorization vary based on Tier
 - RPS missions utilize the DOE Safety Analysis Report



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

Head of
Sponsoring
Agency
Authorizes
Launch

- 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 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:

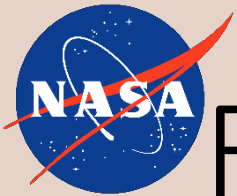
- Safety analysis finds that there is a credible accident scenario (greater than or equal to 1 in a million chance) that might result in radiation exposure greater than 25 rem TED to any member of the public; or
- The system is a nuclear reactor using any nuclear fuel other than low-enriched uranium.

POTUS or
Delegate
Authorizes
Launch

Alternative Isotopes and RPS Commercialization

- In addition of plutonium-238, research and development in alternative fuels are underway across the industry, both domestic and international
 - 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

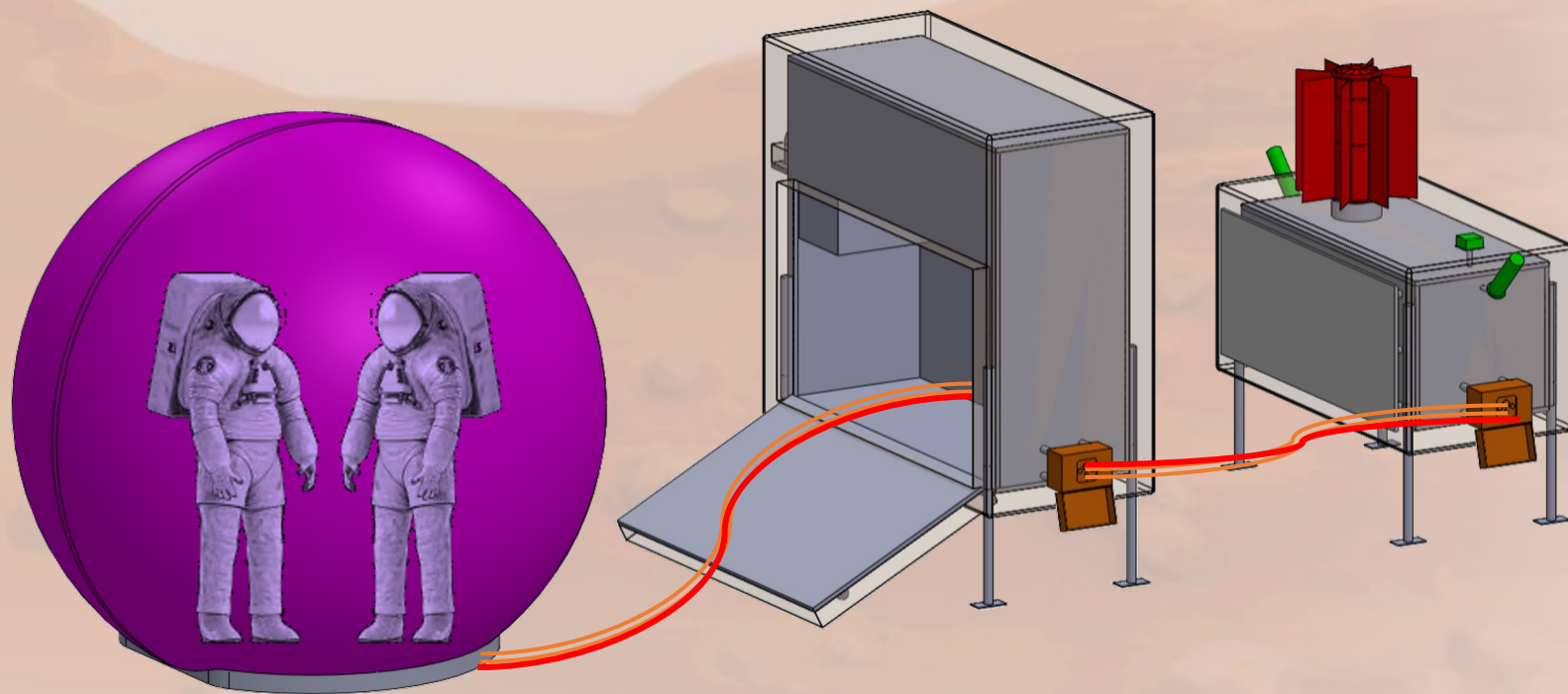
HQ Program Commitment Agreement (PCA) update includes focus on commercial and international RPS development opportunities



Radioisotope Power System (RPS)- Enabled Mars Crew Shelter Kit

RPS Office, Mars
Architecture Team (MAT)
and Compass Team

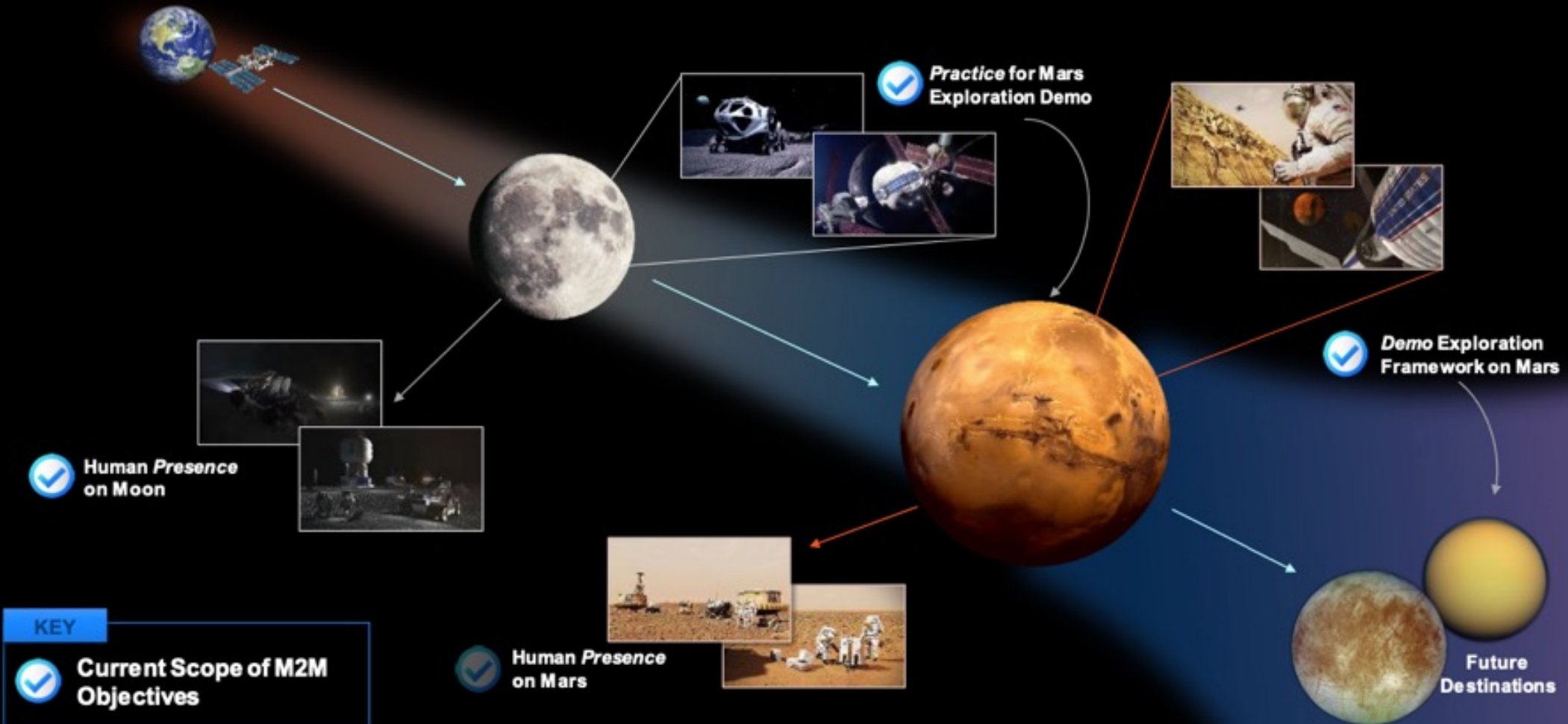
Dec. 2023



Pre-decisional: For Planning and Discussion Only

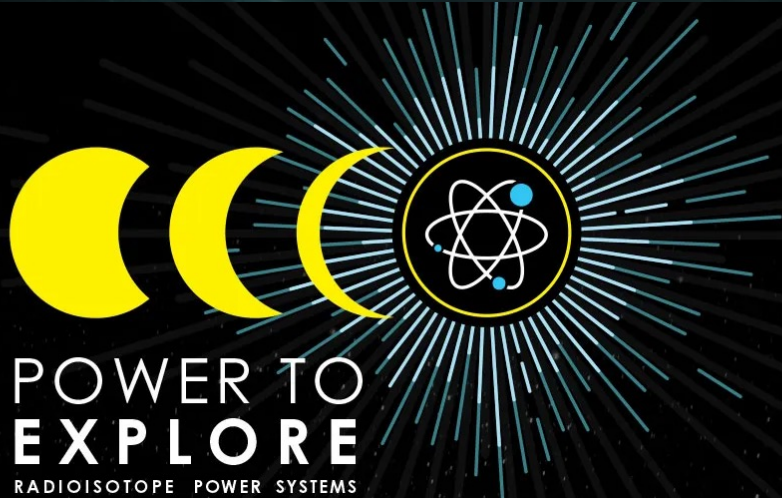
Supporting Various Mission Applications Utilizing Alternative Isotopes

Current Moon to Mars Scope

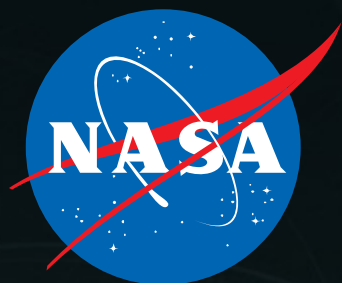


RPS Program: Stakeholder Engagement

- RPS Program Power to Explore Student Challenge winners announced.
 - Semi-Finalists were invited to discuss their radioisotope-powered mission concepts with NASA scientists and engineers, including SMD Director Dr. Nicky Fox, during the virtual event
 - Finalists announced by astronaut Stephen Bowen during Total Eclipse Fest 2024 on April 8th.
 - Winners will visit GRC later this summer
- Workforce development with effort with Shasta High School
 - Interactive AR mission planning program simulating NASA processes



The winners of NASA's 2024 Power to Explore Student Challenge are: 9-year-old Raine Lin, left, 12-year-old Aadya Karthik, and 18-year-old Thomas Liu.



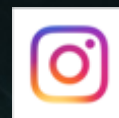
NASA



NASA



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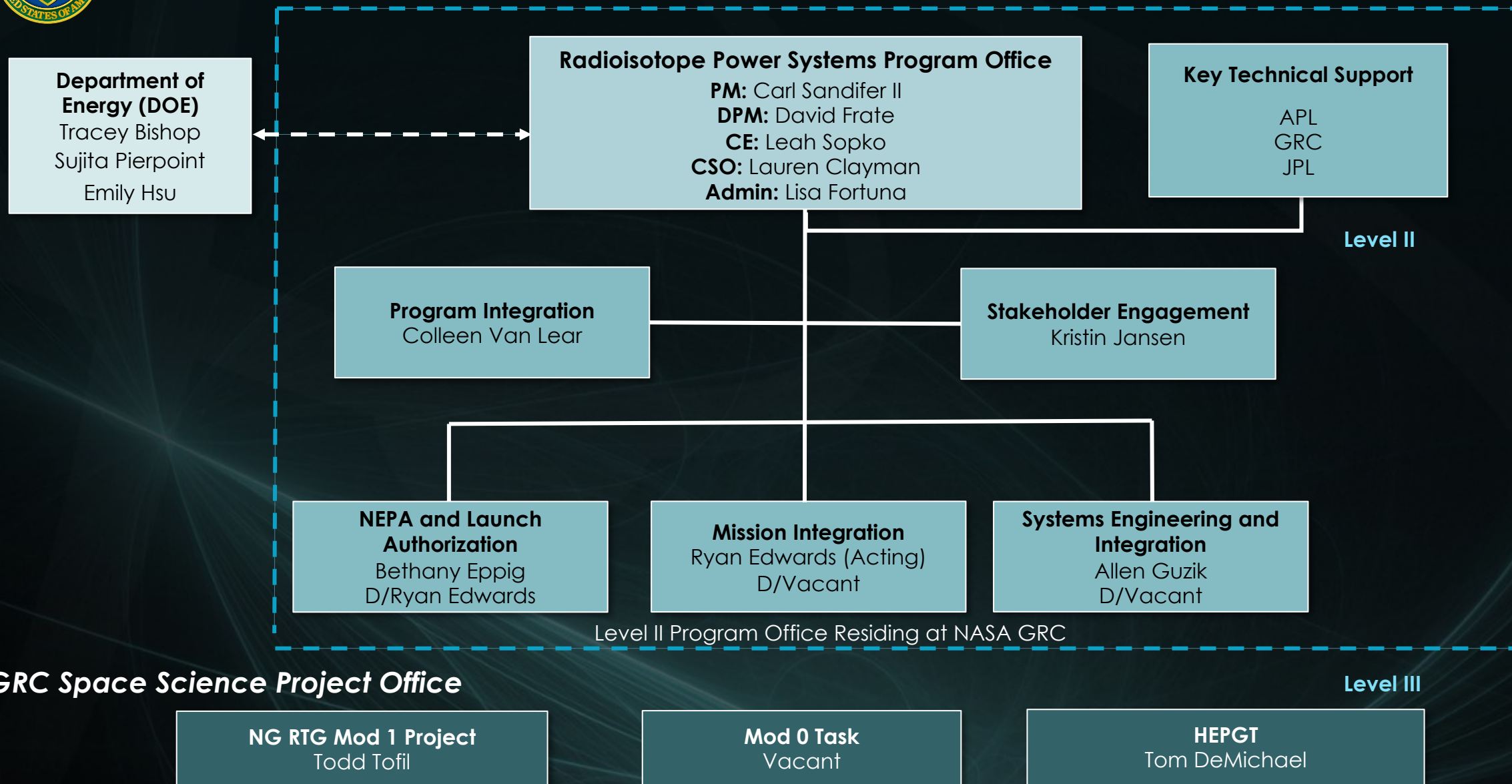
POWER TO EXPLORE

<https://rps.nasa.gov>

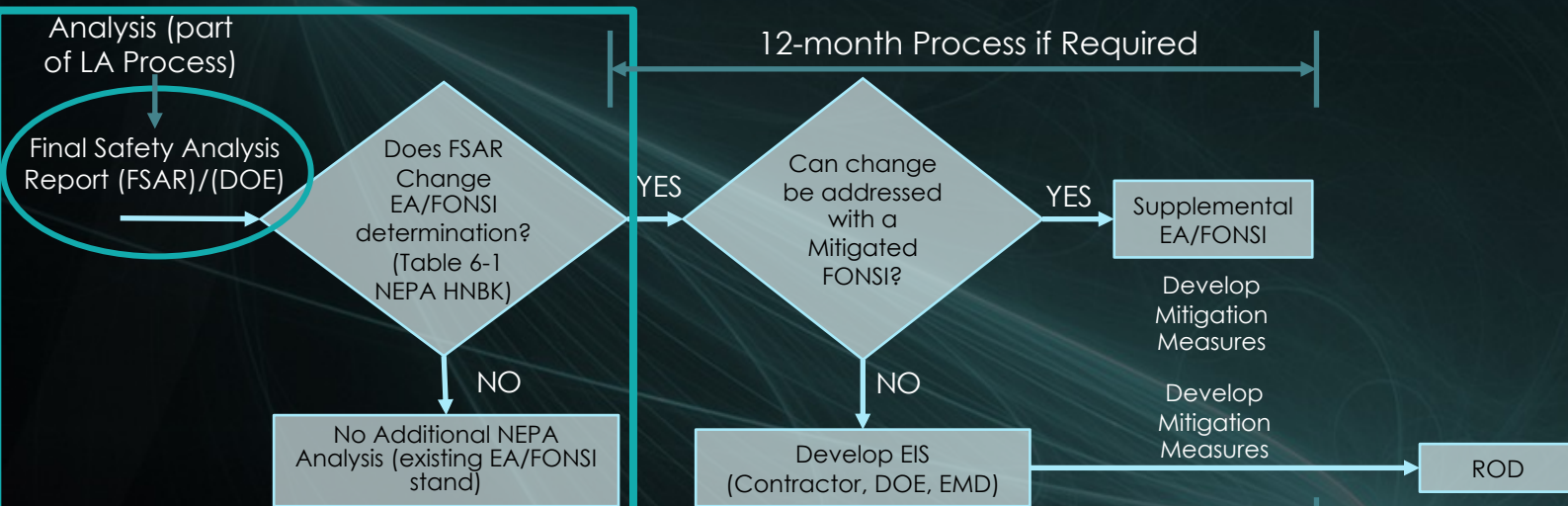
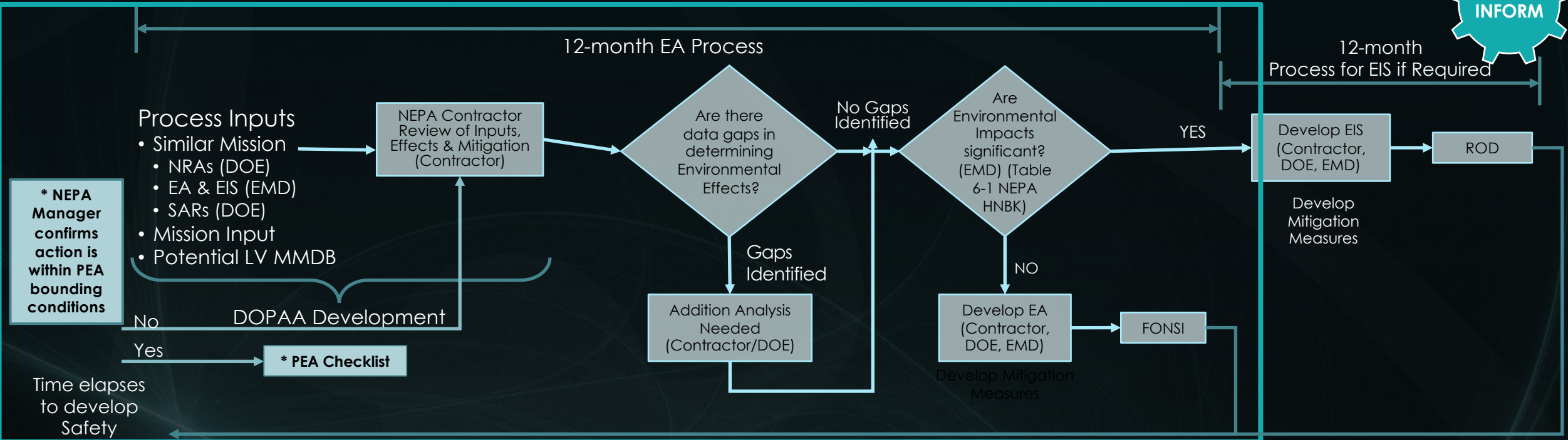
nasa-rps@mail.nasa.gov



RPS Program Organization



NEPA Process for RPS Missions



Key:

6-1 – Review Impact Assessment
 DOE – Department of Energy
 DOPAA – Description of Proposed Actions and Alternatives
 EA – Environmental Assessment
 EIS – Environmental Impact Statements
 EMD – Environmental Management Division (NASA)
 FONSI – Finding of No Significant Impact
 LV – Launch Vehicle
 MMDB – Multi-Mission Databook
 NC – NEPA contractor
 NEPA – National Environmental Policy Act
 NRAs – Nuclear Risk Assessments
 ROD – Record of Decision
 SARs – Safety Analysis Report

* For NEPA reviews that may fall within the bound of existing programmatic NEPA documents only

NSPM-20 Tiering Criteria & Safety Guidelines

Tier	Authorizing Official (USG Mission)	Tiering Criteria			Reference Dose Range	Safety Guidelines
		A2 value	Reactor Fuel Type (if applicable)	Probability of Accident Resulting in Exposure at Specified Level		Probability of Accident Resulting in Exposure at Specified Level
Tier 1	Head of Sponsoring Agency	>1,000X* & <100,000X	not a nuclear reactor	N/A	25 mrem** to 5 rem***	< 1 in 100 at
Tier II <i>Mars 2020 Perseverance</i>	Head of Sponsoring Agency	>100,000X	a nuclear reactor using low-enriched uranium fuel	≥ 1 in 1,000,000 at	5 rem to 25 rem	< 1 in 10,000 at
Tier III	POTUS or Delegate Authorizes Launch	N/A	a nuclear reactor using any nuclear fuel other than low-enriched uranium fuel	≥ 1 in 1,000,000 at	> 25 rem	< 1 in 100,000 at

*this “floor” reflects the implementation of NSPM-20 in NASA NPR 8715.26

**if at or above 0.025 rem (equivalent to approximately one month exposure to natural background radiation)

***5 rem is approximately equivalent to 5 full body CT scans, and is the annual allowable limit for nuclear workers