National Aeronautics and Space Administration

Department of Energy

RADIOISOTOPE POWER SYSTEMS PROGRAM

RPS MISSION PLANNING CONSIDERING THE US Pu-238 SUPPLY

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Small Bodies Assessment Group
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Radioisotope Power Systems

- Radioisotope Power Systems (RPS) are ideally suited for missions that need autonomous, long-duration power
  - Proven record of operation in the most extreme cold, dusty, dark, and high-radiation environments, both in space and on planetary surfaces.
- RPS provide long-lived power solutions for future Planetary Decadal Science missions
  - Mars 2020 (sample return precursor)
  - Uranus Orbiter/Probe
  - New Frontiers (Ocean-Worlds, Saturn, Lunar)
- RPS technologies offer potential to serve a wide range of missions from SmallSat/CubeSat to Flagship-class Science (1-1000 W_e)
  - Thermoelectric (Pb-Te/TAGS; Skutterudite)
  - Dynamic (Stirling)
  - Radioisotope Heater Units
- RPS Program has an established relationship with DOE and has processes in place to work effectively

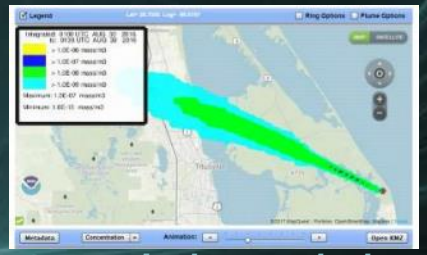
RPS have successfully powered NASA Missions for over 40 years and continues to serve the needs of NASA in its exploration of the Solar System

Radioisotope Power Systems Program

- Develops new power conversion technologies and qualified systems
- In partnership with the Department of Energy
  - Produces new plutonium 238 and heat source material for integration into flight RPS
  - Maintains the infrastructure necessary to produce flight RPS
- Conducts mission and systems studies to ensure technologies are relevant to mission requirements
- Manages mission nuclear launch approval activities

Newly produce $HS\text{-}PuO_2$

MMRTG unit F2



Launch site analysis

The RPS Program provides a one-stop point of contact for the acquisition and integration of RPS for NASA Missions

DOE RPS Supply Chain

Pu-238 Isotope Production
- Oak Ridge National Laboratory
- Idaho National Laboratory

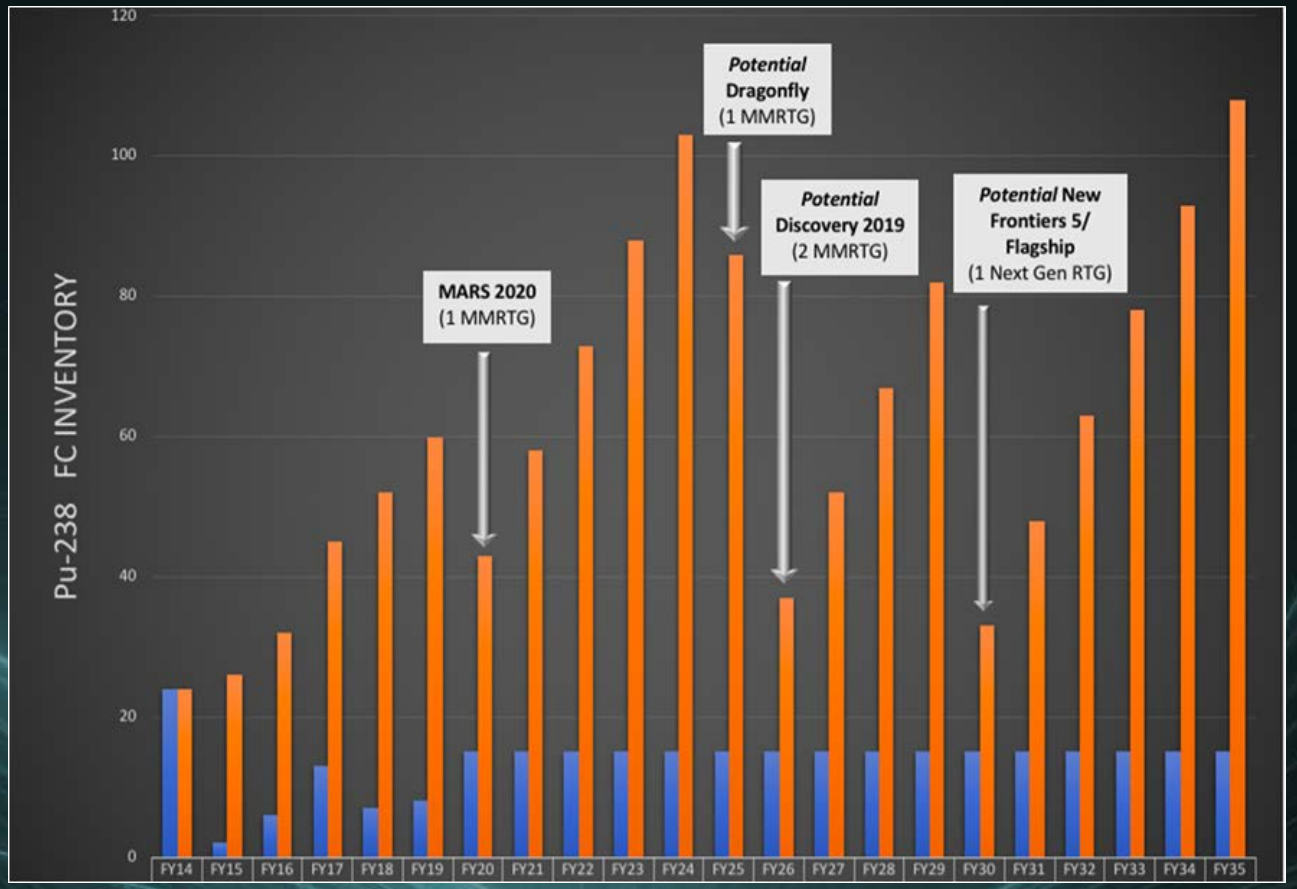
Fueled Clad Manufacturing
- Oak Ridge National Laboratory
- Los Alamos National Laboratory

Fueling/Testing/Delivery
- Idaho National Laboratory

Launch Support
- Kennedy Space Center

RPS Production for Notional Mission Sequence

- PSD potential mission requirements over next decade can be met by adjusting Pu-238 clad production capabilities
  - Ability to tune production rate based on mission needs
- A steady state 1.5 kg/y of HS-PuO_2, with 1:1 blending, yields:
  - 3+ kg/yr for clads
  - Have produced 350 g of new PuO_2 to date; Last Campaign produced 250 g
  - Potential higher yield (blend ratio improves)
- Constant Rate Production decreases mission costs and mission risks



Possible Future RPS

- enhanced Multi-Mission Radioisotope Thermoelectric Generator (eMMRTG)
  - Retrofit the MMRTG with higher efficient thermoelectric (TE) couples
  - Midway through Technology Maturation Phase
- Next Generation RTG (Next Gen)
  - In-house TE maturation efforts
  - RFI followed by RFP for system concept and technology maturation long-pole plan
  - Initial planning phase
- Dynamic RPS (DRPS)
  - SOA assessment - complete
  - Requirements definition - complete
  - Multiple industry, multiple conversion technology contracts – imminent

Parameter	GPHS-RTG	MMRTG	eMMRTG	Next Gen	DRPS
P_0 - BOL (We)	291	110	148	400-500	200-500
Efficiency - $P_0/Q*100$ (%)	6.60%	5.50%	7.40%	10-14%	20-25%
Specific Power - P_0/m (We/Kg)	#DIV/0!	2.4	3.3	6-8	TBD
Q - BOL (Wth)	4410	2000	2000	4000	500-2000
Maximum Average annual power degradation, r (%/yr)	1.54	4.8	2.5	1.9	1.3
P_{BOM} - $P=P_0*e^{-rt}$ (We)	NA	95	137	378-472	194-485
Fueled storage life, t (years)	2	3	3	3	3
P_{EODL} - $P=P_0*e^{-rt}$ (We)	NA	49	80	290-362	169-422
Flight Design Life, t (yrs)	16	14	14	14	14
Design Life, t (yrs)	18	17	17	17	17
Allowable Flight Voltage Envelope (V)	22-36	22-36	22-34	22-34	22-34
Planetary Atmospheres (Y/N)	N	Y	Y	N	Y

Next Gen RTG

- Final Report of Next-Gen RTG Study team and more can be found at:
  - https://rps.nasa.gov/galleries/reports/
- Level I requirement:
  - *The RPS Program shall develop and qualify a new vacuum-rated RPS by 2028.*
- *Goals*
  - Vacuum-only
  - Modular
  - 16 GPHSs (largest RTG variant)
  - P_{BOM} = 400-500 W_e (largest RTG variant)
  - Mass goal of < 60 kg (largest RTG variant)
  - Degradation rate < 1.9 %

- Planning Stage
  - System concept driven TE technology plan
  - Technology Phases with Gates
  - Flight System design with unfueled qualification hardware
  - Beginning with Sources Sought and Industry day(s)

RPS Program Summary

- RPS Program and DOE working together to provide NASA a robust, end-to-end program capability
  - Strong NASA & DOE partnership
  - NASA's RPS Program is
    - Planning for, baselining and implementing exploration missions using radioisotope power
    - Investing in systems and capabilities to support a wide class of missions, including modular capabilities that may be of interest to SBAG missions
    - Established singular point of contact to DOE, and provides necessary support for all nuclear missions
  - Constant Rate Production
    - Mitigates risks, and provides significant cost reductions, already realized for missions
    - Plutonium Production
      - End-to-End demonstration complete
      - Successfully scaling up – 50 g, 53 g, 250 g, next campaign 300 g
      - NASA is no longer fuel limited!

Power to Explore

https:// rps.nasa.gov