



# Radioisotope Power Systems Program

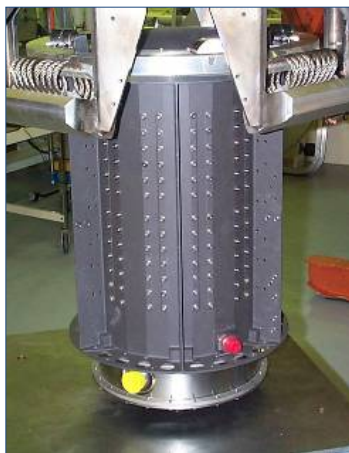
## RPS Looking Forward – Not Back

*(A Next Radioisotope Thermoelectric Generator Study)*

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Presentation to OPAG August 12, 2016



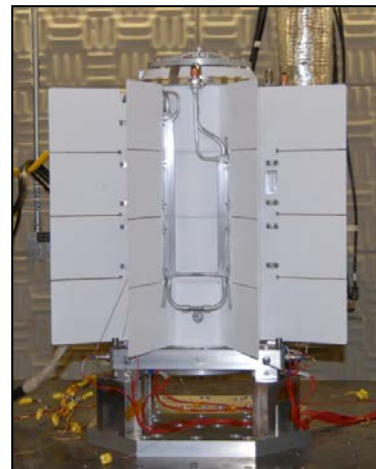
# RTG Systems



Multi-Hundred Watt -  
Radioisotope  
Thermoelectric  
Generator (MHW-RTG)



General Purpose Heat  
Source - Radioisotope  
Thermoelectric  
Generator (GP-  
RTG)



Multi-Mission  
Radioisotope  
Thermoelectric  
Generator  
(MMRTG) &  
enhanced  
MMRTG  
(eMMRTG)



Next RTG



# Study Objectives

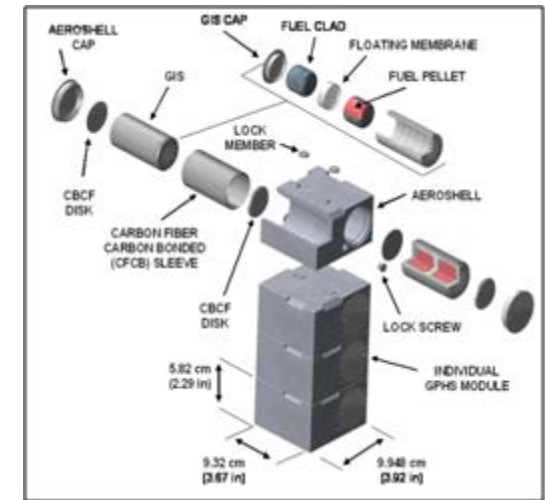
Determine the characteristics of a next-generation RTG that would “best” fulfill Planetary Science Division (PSD) mission needs. “Best” is defined as a confluence of the following factors:

- An RTG that would be useful across the solar system
- An RTG that maximizes the types of potential missions: flyby, orbit, land, rove, boats, submersibles, balloons
- An RTG that has reasonable development risks and timeline
- An RTG that has value (importance, worth and usefulness) returned to PSD that warrants the investment, as compared with retaining existing baseline systems



# Assumptions

- This study is limited to systems that convert heat to electricity using thermoelectric couples.
- Mission concepts that impose “outlying” requirements will be identified and evaluated for their burden on PSD missions.
- The notional RPS will be GPHS based and compatible with current or planned DOE facilities and associated capabilities.
- This study will be performed by NASA and DOE and will not include industry. It will include participants from APL, GSFC, GRC, JPL, UDRI and DOE.





# Approach (1/2)

## **Mission Set Evaluation:**

- Evaluate the database of mission concepts currently collected and destinations across the solar system to assess Power, Size, and Environments.
- Draft RTG key requirements for each solar system destination, considering trajectories, mass and flight times.
- Perform 2-3 mission assessment studies with notional RTG concepts to understand mission impacts to the notional RTG concepts and key requirements. Update key requirements.





# Approach (2/3)

- **RTG Evaluation:**

- Work with the mission community to assess the perceived needs of a next-generation RTG
  - Collect information from RTG-powered missions managed at JPL and APL
  - Collect information on pros and cons from mission concepts that have considered or are considering flying an RTG
- Develop RTG notional concepts to test confluence of technology benefits and RTG key requirements and generator concept drawings. Update key requirements.
- Assess and trade single RTG vs modular RTG vs multiple RTG designs.
- How does sustainment factor in the long-term availability and costs?





# Approach (3/3)

- **Technology Evaluation:**

- Develop a risk assessment of the potential next-generation RTG technologies. The technologies considered must be “in-hand”: SKD, SKD/Zintl/LaTe, BiTe, PbTe/TAGS, or SiGe.

“In-hand” technologies	Current generators	Recent generators	Production status of technology
BiTe	NA	NA	Commercial and military uses
PbTe/TAGS	MMRTG (MSL, M2020)	SNAP-19 (VKG)	Sustainment of production on-going
SiGe	GPHS RTG (CAS, GLL, ULS, PNH)	MHW-RTG (VGR)	Production halted 10+ years
SKD	eMMRTG	NA	Technology transfer to industry beginning 4 <sup>th</sup> of 6 years
SKD/Zintl/LaTe	Conceptual	NA	5 yr technology transfer to industry to start in FY19

- **Final integration and concepts:**

- Complete concepts and integrate information to finish final out-brief.



# Schedule Overview

## Schedule Outline:

- Study initiated – 7/19/16
- Pros & Cons of MMRTG/eMMRTG from flight centers – 8/10/16
- Mission set identified – August 31, 2016
- DRAFT RTG requirements developed – September 23, 2016
- Assess technology risks – October 10, 2016
- DRAFT RTG Concepts around technologies – October 27, 2016
- NASA mission assessment of top RTG concepts – November 2016
- Finalize presentation – December 2016
- Out Brief – January 2017





# Study Deliverables

- Power point briefing on:
  - Key requirements for next-generation RTG(s) concepts
  - RTG notional concept(s) that addresses the requirements and maximizes value (importance, worth, and usefulness)
  - Risks associated with development of enabling technologies
  - Risks imposed by minimizing RTG concepts while maximizing destinations
  - Next steps to developing next generation RTG

# Thermoelectrics in Space: A Success Story

## RTG-Powered, U.S. Missions



Mission	RTG type (number)	TE	Destination	Launch Year	Mission Length	Power Level***
Transit 4A	SNAP-3B7(1)	PbTe	Earth Orbit	1961	15	2.7
Transit 4B	SNAP-3B8 (1)	PbTe	Earth Orbit	1962	9	2.7
Nimbus 3	SNAP-19 RTG (2)	PbTe	Earth Orbit	1969	> 2.5	~ 56
Apollo 12*	SNAP-27 RTG (1)	PbTe	Lunar Surface	1969	8	~ 70
Pioneer 10	SNAP-19 RTG (4)	PbTe	Outer Planets	1972	34	~ 160
Triad-01-1X	SNAP-9A (1)	PbTe	Earth Orbit	1972	15	~ 35
Pioneer 11	SNAP-19 RTG (4)	PbTe	Outer Planets	1973	35	~ 160
Viking 1	SNAP-19 RTG (2)	PbTe	Mars Surface	1975	> 6	~ 84
Viking 2	SNAP-19 RTG (2)	PbTe	Mars Surface	1975	> 4	~ 84
LES 8	MHW-RTG (2)	Si-Ge	Earth Orbit	1976	15	~ 308
LES 9	MHW-RTG (2)	Si-Ge	Earth Orbit	1976	15	~ 308
Voyager 1	MHW-RTG (3)	Si-Ge	Outer Planets	1977	37	~475
Voyager 2	MHW-RTG (3)	Si-Ge	Outer Planets	1977	37	~475
Galileo	GPHS-RTG (2)	Si-Ge	Outer Planets	1989	14	~ 574
Ulysses	GPHS-RTG (1)	Si-Ge	Outer Planets/Sun	1990	18	~ 283
Cassini	GPHS-RTG (3)	Si-Ge	Outer Planets	1997	19	~ 885
New Horizons	GPHS-RTG (1)	Si-Ge	Outer Planets	2005	9 (17)	~ 246
MSL	MMRTG (1)	PbTe	Mars Surface	2011	4 (to date)	~ 115
<i>Mars 2020**</i>	<i>MMRTG (1 baselined)</i>	<i>PbTe</i>	<i>Mars Surface</i>	<i>2020</i>	<i>(5)</i>	<i>&gt; 110</i>

\*Apollo 12, 14, 15, 16, and 17

\*\*Planned

\*\*\*Total power at Beginning of Mission (W)

From a few watts up to ~ 900 W, up to 37 years of operation (and counting)



# Questions?

Please Contact June or Dave with any  
Comments, Questions or Input

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