



NASA Glenn Research Center Energy Storage & Power Needs Overview

Military Power Sources Committee
Lithium Sulfur Battery Symposium
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Outline



- **NASA's Unique Requirements**
- **Battery Needs**
 - Space battery development
 - Aeronautics battery development
- **Areas of Interest**



NASA's Unique Requirements



Unique Environmental & Operating Requirements

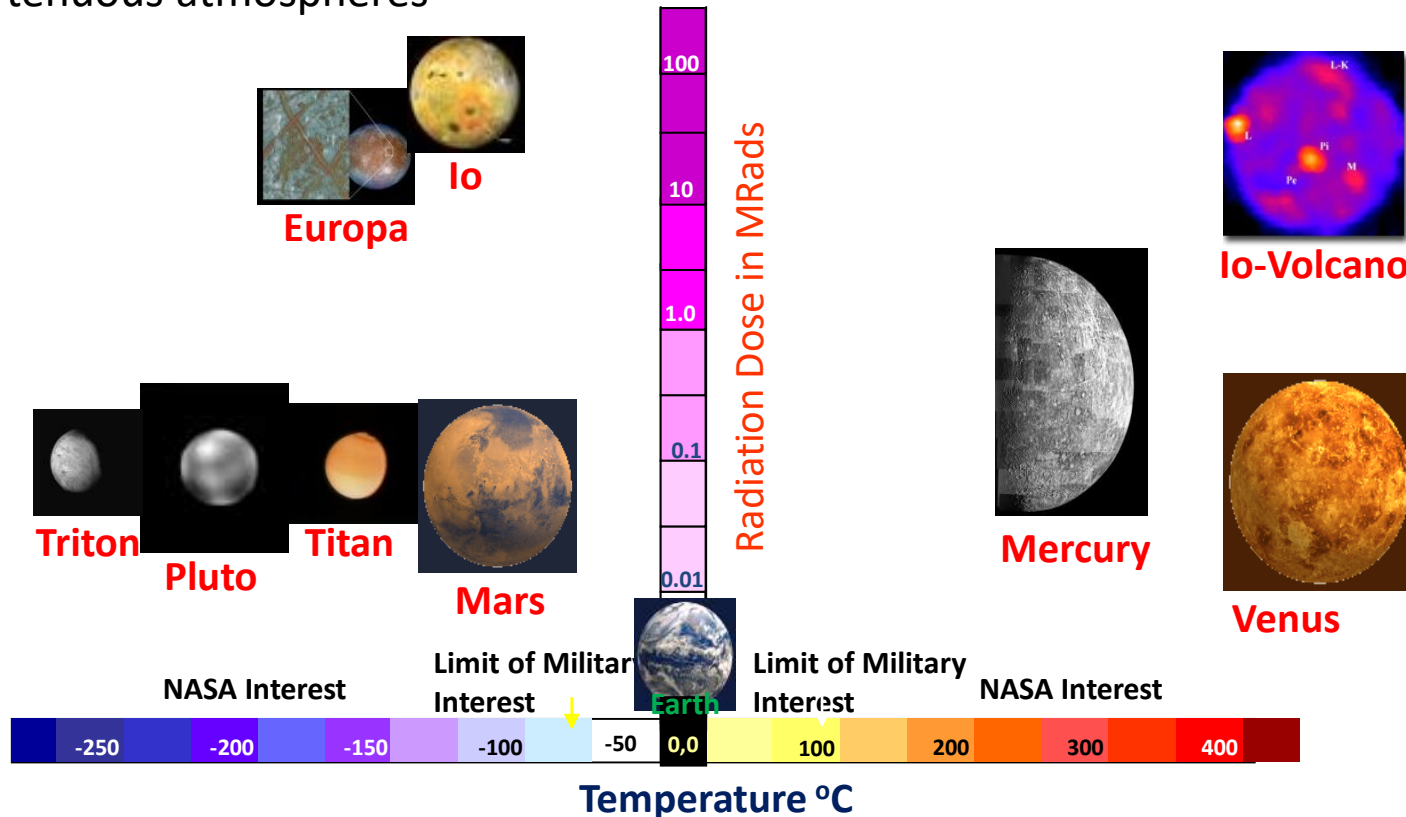


- **NASA has unique requirements for power & energy storage that reach beyond typical environmental or cycle requirements**
 - High temperature (Venus)
 - Low temperature (Lunar/outer planetary)
 - Radiation tolerance
 - Mass/volume restrictions
 - High specific energy (>500 Wh/kg)
- **High levels of safety & reliability for both manned & unmanned missions**

Extreme Environments for Planetary Missions



- Some missions require high radiation resistant power systems
- Inner planetary missions require power systems that can operate at very high temperatures
- Outer planetary surface missions require low temperature power systems
 - Some outer planetary missions must operate in deep space and in dense or tenuous atmospheres





Space Energy Storage System Needs



- **Extreme environments**

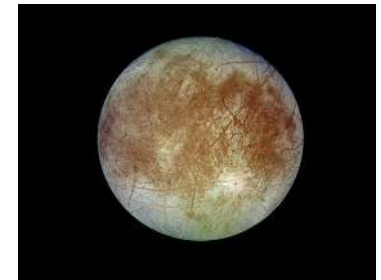
- Extreme heat – primary & secondary up to 500° C
- Extreme cold – below -200° C
- Lunar surface ranges -230 to $+120^{\circ}$ C

- **Application-specific**

- Lunar Gateway
- Landers
- Rovers
- Extravehicular Activity suit and tools



Venus



Europa



Lunar Gateway



Space Battery Development

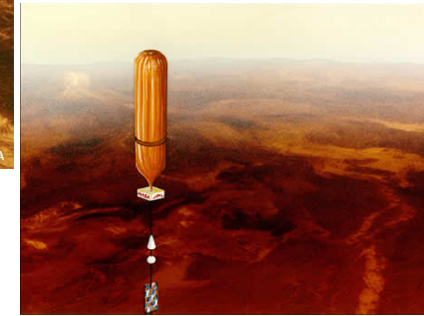


Energy Storage System Needs for Inner Planetary Missions



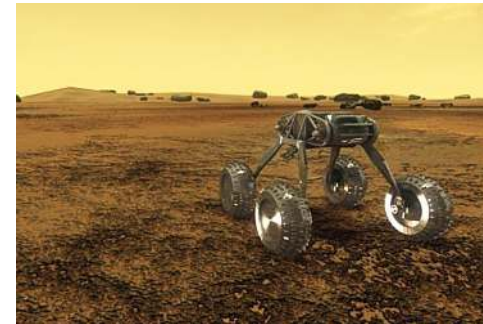
- **Primary Batteries/Fuel Cells for Surface Probes**

- High Temperature Operation ($> 465\text{C}$)
- High Specific Energy ($>400 \text{ Wh/kg}$)
- Operation in Corrosive Environments



- **Rechargeable Batteries for Aerial Platforms**

- High Temperature Operation ($300\text{-}465\text{C}$)
- Operation in Corrosive Environments
- Low-Medium Cycle Life
- High Specific Energy ($>200 \text{ Wh/kg}$)
- Operation in High Pressures



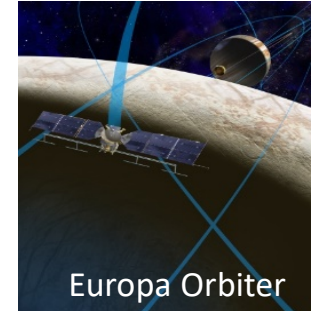


Energy Storage System Needs for Outer Planetary Missions



- **Primary Batteries/Fuel cells for planetary landers/probes**

- High Specific Energy (> 500 Wh/kg)
- Long Life (> 15 years)
- Radiation Tolerance & Sterilizable by heat or radiation



Europa Orbiter

- **Rechargeable Batteries for flyby/orbital missions**

- High Specific Energy (> 250 Wh/kg)
- Long Life (> 15 years)
- Radiation Tolerance & Sterilizable by heat or radiation



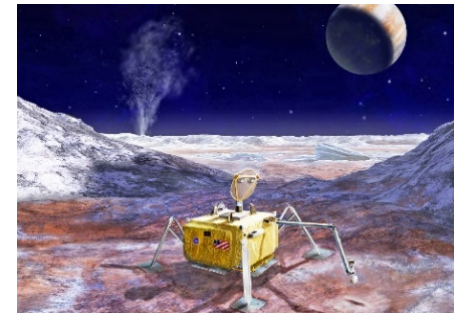
Icy Giants

Uranus/Neptune missions

- **Low temperature Batteries for Probes and Landers**

- Low Temperature Primary batteries (< -80 C)
- Low Temperature Rechargeable Batteries (< -60 C)

Europa Lander
(artist's concept)





Energy Storage System Needs for Lunar Applications



- **14-day eclipse Lunar Night survivability and operability beyond -40° C, increased reliability & decreased system complexity**
- **Cislunar Space**
 - Lunar Gateway Power & Propulsion Element
 - 15 year on-orbit operational life
 - 50 kW class spacecraft with 40 kW EP system
- **Lunar Surface**
 - Landers
 - Rovers (> 500 Wh/kg)
 - Permanent habitat power
 - Permanently Shadowed Regions (PSR)
- **EVA suits (> 400 Wh/kg, > 100 cycles)**



Lunar Gateway



Lunar Landers



Lunar Rovers



Aeronautics Battery Development



Representative Examples of Aeronautics Mission Requirements



Mission	Number of Passengers	Typical Range	Power Level	Specific Energy	EAP Configurations
Urban Mobility	<=4	<50 miles	200-500kW	250 – 400 Wh/kg	<ul style="list-style-type: none"> • All electric • Hybrid Electric
Thin Haul	<=9	<600 miles	200-500kW	300 – 600 Wh/kg	<ul style="list-style-type: none"> • Hybrid Electric
Short Haul Aircraft	40-80	<600 miles	500-1500kW	300 – 600 Wh/kg	<ul style="list-style-type: none"> • Hybrid Electric
Single Aisle	150-190	900 mile typical mission, 3500 mile maximum range	1000-5000kW	750 – 1000 Wh/kg minimum	<ul style="list-style-type: none"> • Hybrid Electric • Turbo Electric



Battery Needs for Electric Aircraft Propulsion



- **> 400 Wh/kg required at the system level**
- **1000's of cycles**
- **Extremely high power requirements (C-rates) during takeoff and landing**
- **Cruise power for long range flights**
- **High reliability, limited maintenance**
- **Improved safety for thermal runaway events**



Areas of Interest



Past, Present & Future R&D Areas



- **Increased Wh/kg through system-level weight reduction**
 - Multifunctional thermal management/packaging
 - Reduced parasitic mass
 - Improved low-temperature cell operability & survivability
- **Multi-functionality & integration of energy storage within spacecraft/aircraft structures**
- **Integrated sensors for improved safety & enhanced operability**
- **Hybrid chemistry concepts to balance high power and high energy demands**
- **Hybrid battery/fuel cell/turbine engine concepts**
- **Modeling efforts to combine battery models with aircraft system-level models to optimize thermal management & mechanical loading**



Adoption of Lithium-Sulfur



- **> 400 Wh/kg at the cell level**
- **100s of cycle may be acceptable for space applications with lower requirements, but would require Wh/kg and other gains over SOA Li-ion**
- **Safety on par or better than Li-ion systems**
- **Reliable BMS**
- **Flexibility in charge/discharge rates for aeronautics applications**



THANK YOU FOR YOUR ATTENTION

Questions/Comments -

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