Small RPS Enabled Deployable Mini-Payload Missions

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This information is pre-decisional and for discussion purposes only.

This is a conceptual mission study intended to demonstrate the range of possible missions and applications that could be enabled were a new generation of Small Radioisotope Power Systems to be developed by NASA and DOE. While such systems are currently being considered by NASA and DOE, they do not currently exist.

This study is one of several small RPS-enabled mission concepts that were studied and presented in the NASA/JPL document "Enabling Exploration with Small Radioisotope Power Systems" available at:

http://solarsystem.nasa.gov/multimedia/download-detail.cfm?DL_ID=82

Acknowledgements

- The following persons provided helpful information used in the formulation of these mission concepts:
  - Sal DiStefano -- Power Subsystem
  - Jan Tarsala -- Telecommunications Subsystem
  - Mike Newell -- Command & Data Handling Subsystem
  - Bruce Banerdt -- Micro-Seismometer
  - David Collins -- Multimission Space and Solar Physics Microspacecraft

What are Deployable Mini-Payloads?

- Deployable mini-payloads would be small, standalone instruments with low power requirements (tens of milliwatts to a few watts).
- Could take scientific measurements of a localized area or an entire region depending on how many units were deployed.
- Could be non-scientific applications such as positional beacons dropped off by rovers or aerobots for precise positional marking or transponders to extend the communications range of rovers, cryobots, aerobots or spacecraft.
- Using a conceptual small radioisotope power system (RPS), the range of operation of these instruments could be extended throughout the solar system and the mission duration could be measured in years or decades.

Why Use Small RPS Technology?

- Small RPS power systems could be enabling for small, low-power missions which:
  - Take place beyond ~5 AU from the sun, and hence cannot use conventional solar power.
  - Require a long-duration presence which cannot be supported by batteries.

- They could also be enabling for missions in the inner solar system in environments where solar power is not available (inside craters, polar regions, sub-surface, etc.)

Mission Concepts Studied

- Two Mission Concepts were selected for this initial study:
  - Seismic Monitoring Stations
  - Distributed Fields and Particles Network

Seismic Monitoring Stations

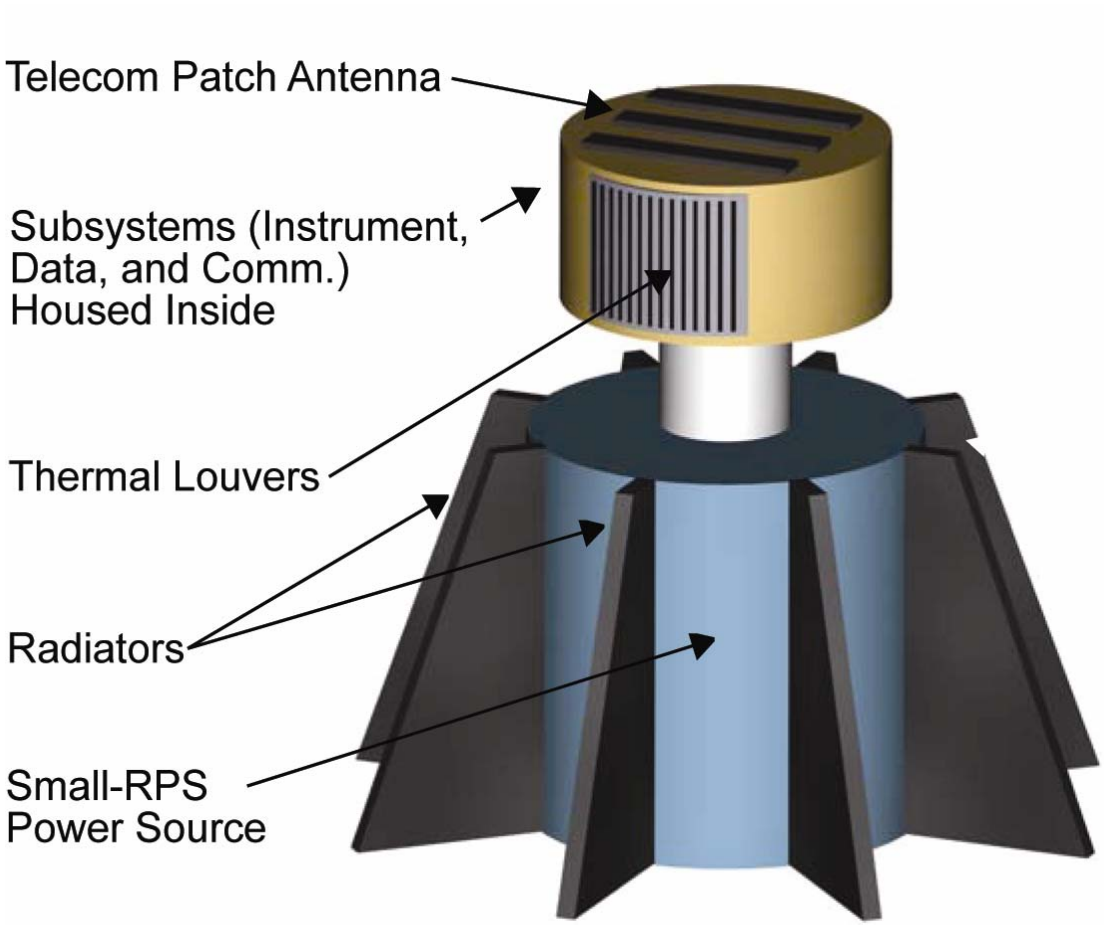
Mission Architecture Overview

- Seismic monitoring stations could be used to detect and measure a target body's seismic activity to determine its interior structure, composition, and physical state
- A network of miniaturized seismic monitoring stations could be dropped-off by a rover or (where there is an atmosphere) an aerobot.
- They would provide long-term monitoring of seismic activity, particularly on icy-moons where scientists are interested in crustal motion.
- Their data would be relayed periodically to either a central base or to an orbiter. Monitoring could continue for years, conceivably limited only by the lifetime of the relay element.

Mission Objectives

- A distributed array of miniaturized seismic monitoring stations would provide long-term monitoring of seismic activity on bodies in the outer solar system.

Conceptual Seismic Monitoring Station



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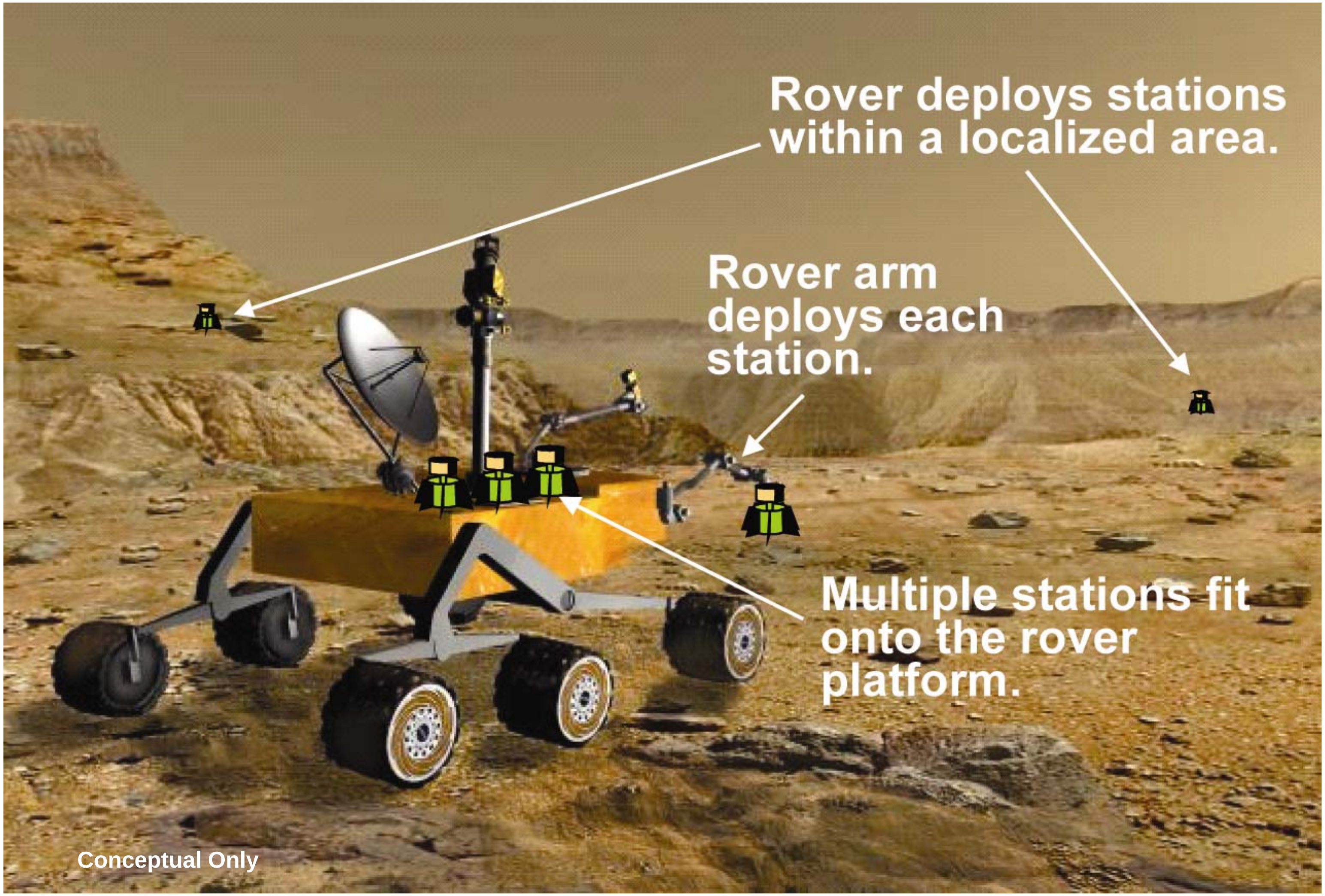
Seismic Station being deployed by a Rover



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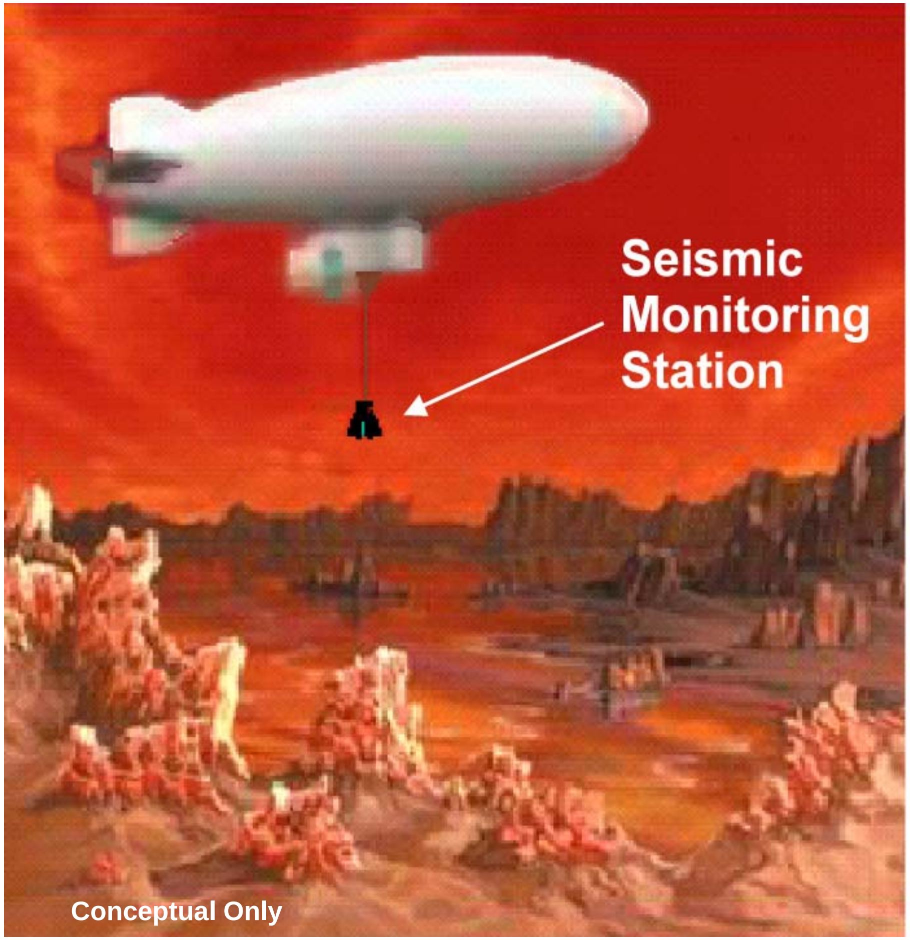
Seismic Station being deployed by an Aerobot



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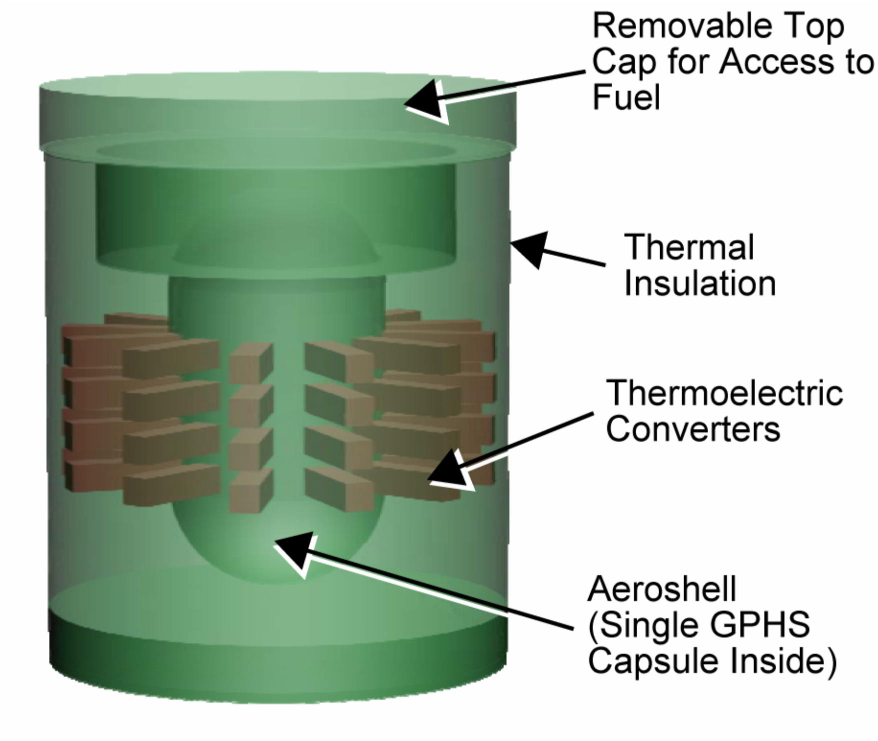
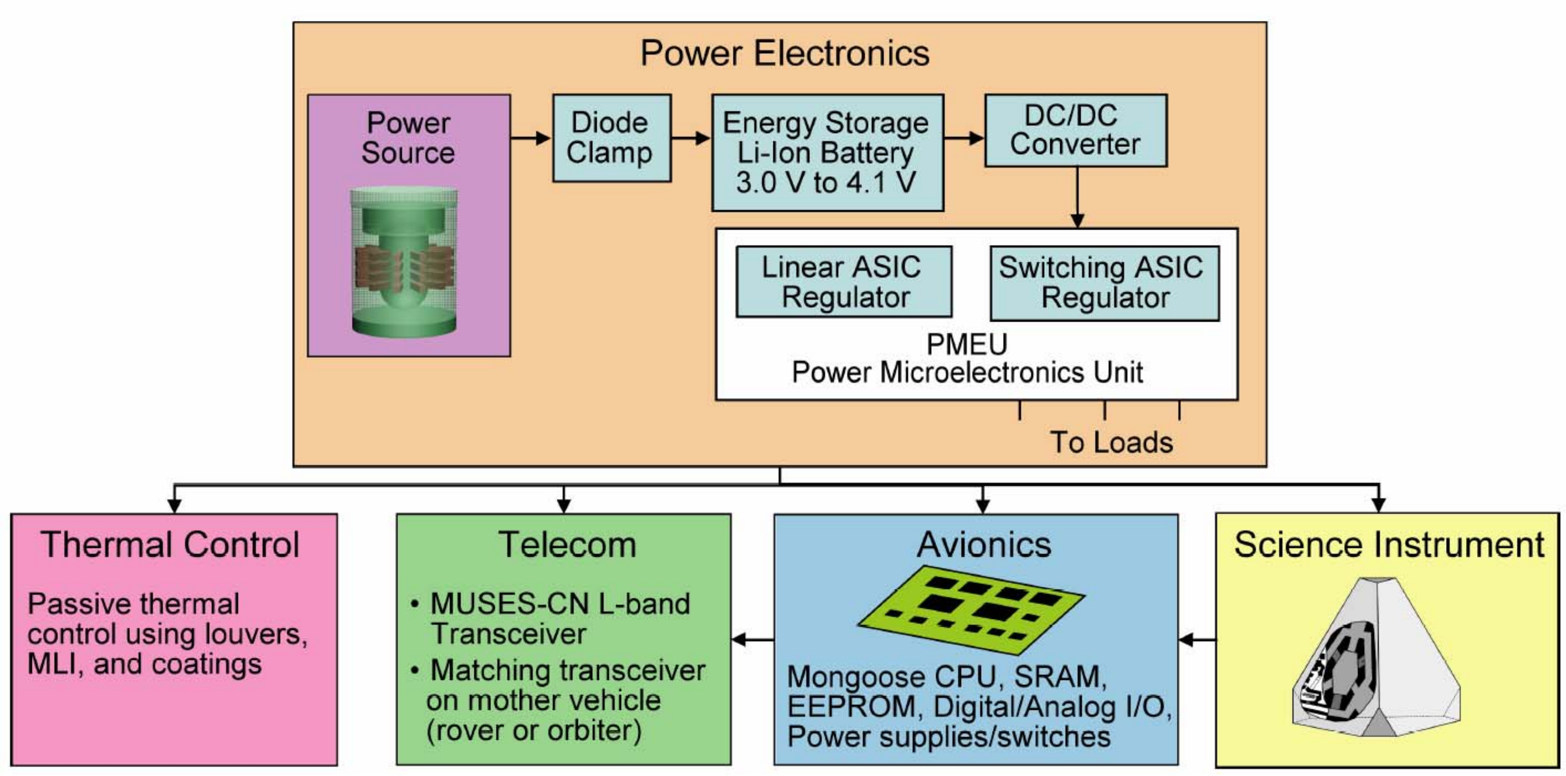
Conceptual Small RPS Characteristics

- Single-pellet GPHS-derivative
- TE Power conversion
- PbTe-TAGS Assumed
  - Existing Technology
- Performance assumptions:
  - ~5% conversion efficiency
  - 3W electrical output (BOM)
  - ~60 W thermal output (BOM)
  - ~2 kg mass
- TE operating temperatures:
  - Hot Side: 550C
  - Cold Side: 155C

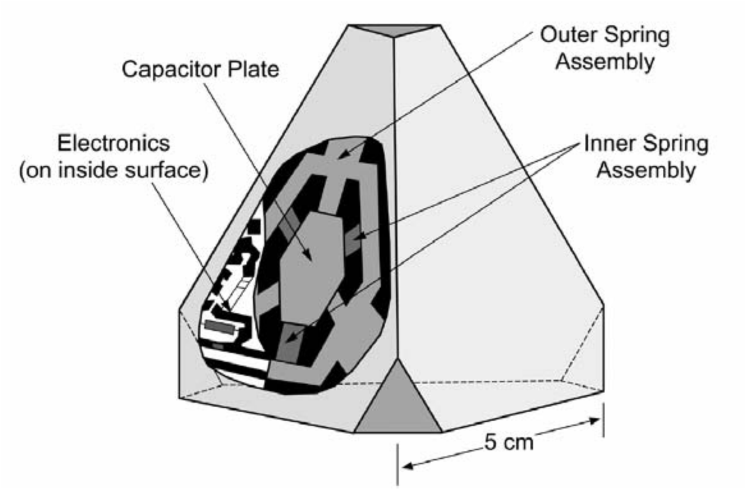


Conceptual Only

Seismic Monitoring Station Block Diagram



Baseline Payload - JPL Microseismometer



Suspension:	Micro-machined Silicon, 10 Hz Resonance, 6 x 10^{-9} m/sec^2/_Hz Noise Floor
	UHF Capacitive Displacement, 5 x 10^{-13} m/_Hz Sensitivity
Transducer:	Tetrahedral (3 components of acceleration plus 1 redundant)
Mass:	< 0.1 kg
Power Consumption:	100 mW
Size:	5 cm on Edge
Acceleration Sensitivity:	Better than 10^{-8} m/sec^2
Frequency Range:	0.01 - 100 Hz
Data Rate:	Depends on sampling rate which depends on frequency range of interest. Sampling at 5 Hz with 16-bit samples (each of three axes) yields a data rate ~ 240 bps. Compression not yet assessed.

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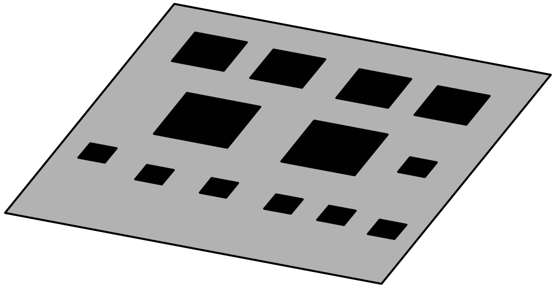
Command & Data Handling (C&DH)

- Based on MUSES CN Nanorover:
  - The flight electronics are based on the Synova R3000 32-bit flight processor.
    - Fabricated on the Honeywell Rad-Hard Foundry production line
  - Includes a radiation hard custom gate-array.
  - 2 MB of rad-hard RAM and 1 MB of rad-hard EEPROM are provided.
  - Mass: 154 grams
  - Power: ~0.81 Watts
  - Volume: 6U card (~ 17 x 11 x 2 cm)



Mongoose CPU, SRAM, EEPROM, Digital/Analog I/O, Power supplies/switches

Telecommunications

- MUSES CN L-Band (1900 MHz PCS) Transceiver with matching transceiver on the parent rover (or aerobot)
- Range of ~ 20 km at 9.6 Kbaud at up to 1 radian off-axis of station normal.
- Should provide ~96 Baud to an orbiter 200 km away
  - Assuming data rate scales as 1/R^2.
- Commercial rad-hard GaAs packaged parts
- Clock recovery and Manchester decoding implemented in a radiation hard FPGA
- Mass: 53 grams
- Power: Input power 0.75 Watts max at +5 V dc

  Receive power 0.2 Watts max
- Volume: ~ 12 cm x 6 cm x 2 cm (single board)

Position and Attitude Knowledge

- Position information provided by parent rover
- Attitude knowledge provided by parent rover

(Allows monitoring stations to be as simple as possible)

Thermal Control

- Passive thermal control using MLI, low thermal conductance materials, louvers, thermal coatings
- RPS waste heat utilized to keep station electronics warm
- Preliminary calculations indicate that 25 Wt of RPS waste heat would be sufficient to maintain internal operating temperatures on the seismic station on the surface of Titan (T~94K).
- Excess heat radiated (or conducted) to environment utilizing radiator fins.

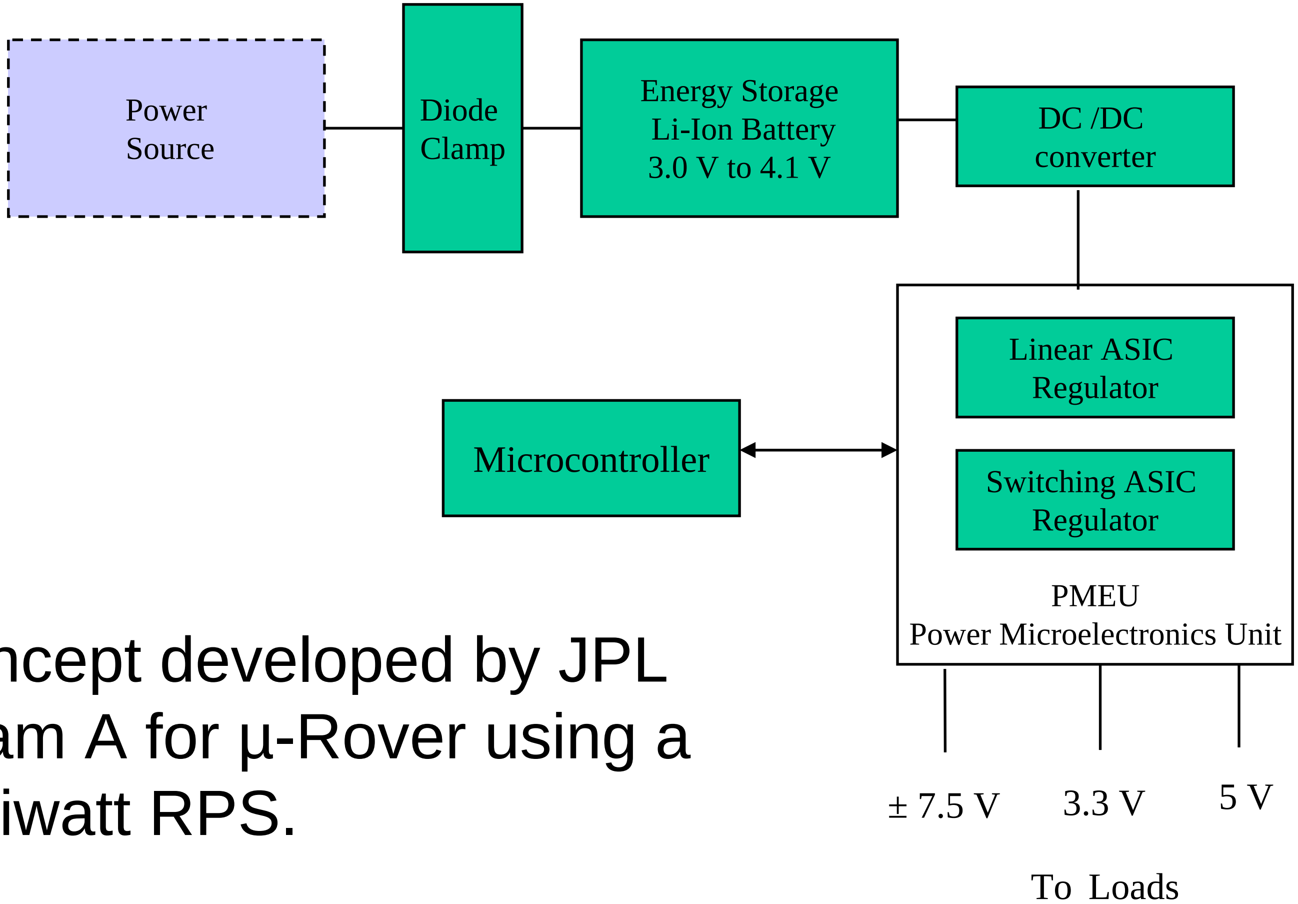
Power Modes

- Operational modes are extremely simple...
  - Science data is taken continuously.
  - Downlink is performed on demand or at pre-determined intervals.

- Power Requirements: - 1.37 W (Science Data Taking Mode)
  - 2.49 W (Science data acquisition + downlink)

Subsystem	Mode A (We)	Mode B (We)
Instrument	0.1	0.1
C&DH	0.81	0.81
Telecom	(off)	0.75
Subtotal	**0.91**	**1.67**
50% contingency	0.46	0.83
Total	**1.37**	**2.49**

Power Subsystem



- Concept developed by JPL Team A for µ-Rover using a Milliwatt RPS.

Station Mass Summary

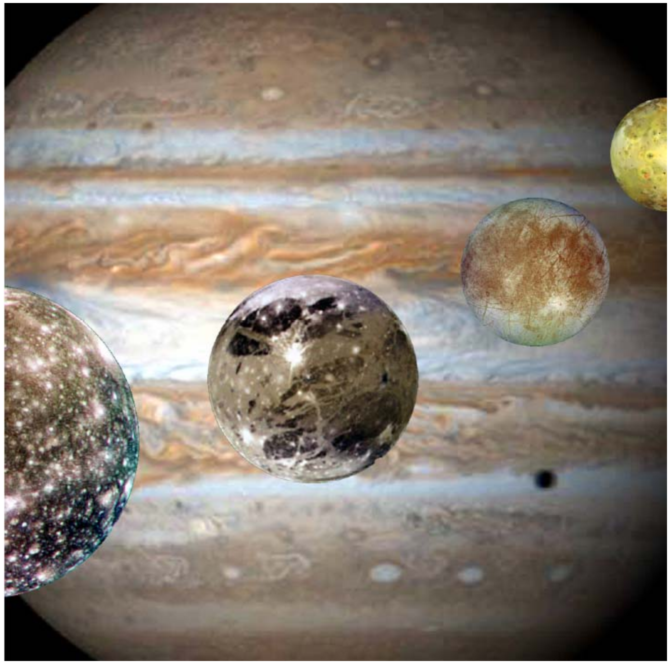
Subsystem	Mass (kg)	Margin (50%) (kg)	Mass + Margin (kg)
Instrument	0.1	0.05	0.15
Avionics	0.15	0.08	0.23
Communications	0.53	0.03	0.08
Thermal	0.3	0.15	0.45
Small RPS	2	1	3
Battery and Power Distribution	0.3	0.15	0.45
Structure	1.32	0.66	1.98
Total	**4.7**	**2.35**	**7.1**

- Summary of Seismic Monitoring Station Concept
  - Small RPS technology could enable a simple, long-duration seismic monitoring station for use on bodies in the outer solar system (or inner solar system where solar power is infeasible).
  - A single-pellet GPHS-derived RPS concept providing ~3 We (BOL) is adequate to meet the requirements of this mission.
  - ~2.5 We power output (after 10 year cruise) still allows virtually continuous downlink
  - Seismic Monitoring Station design concept has sufficient flexibility to accommodate small changes in RPS output via
    - Slower processor clock speed
    - Data compression and reduced downlink rates and/or durations
  - The technology for these stations is at a moderately-high state of development (Engineering Models and Breadboards)

Passive Fields & Particles (PFP) Monitoring Station

Deployable Mini-Payload Missions

- The PFP is a simplified version of the Galilean Satellite Observer (GSO) concept [Randolph, JPL], except this monitoring station:
  - Has no propulsion or active attitude control (requires that parent spacecraft deliver the station to the desired orbit)
  - Utilizes passive gravity gradient stabilization and small APS star camera to provide attitude knowledge



- Payload based on Multimission Space and Solar Physics Microspacecraft (David Collins et al.), consists of:
  - Energetic Particle Detector
  - Electron and Ion Analyzer
  - Magnetometer

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RPS Power System Summary - Conceptual

- Two GPHS fuel capsules and thermoelectric power conversion technology (Schock, 1992).
- Mass of ~3 kg
- Initial conversion efficiency of 5% (Conservative Estimate)
- Power Output (BOM) ~ 125 Wt and 6.25 We
- Power Output (EOM) ~ 114 Wt and 5.2 We after 10 years.

PFP Performance Summary

- Peak Power (Science + Navigation + Telecom all operating simultaneously) ~8.6 W
- Min Power (Science + Navigation only) ~4.8 W
- Could be compatible with a 2-pellet GPHS-derivative (depending on data rates and downlink durations)
- Total Monitoring Station mass ~ 11.5 kg (with margin)

Power Modes of PFP Deployable Mini-Payload

Subsystem	Mode A (We)	Mode B (We)
Instruments	2.1	2.1
Energetic Particle Detector	0.3	0.3
Electron and Ion Analyzer	1.1	1.1
Magnetometer	0.3	0.3
Active Pixel Sensor Camera	0.4	0.4
Instrument Electronics Module	0.3	0.3
Avionics	0.8	0.8
Communications	(Off)	2.5
Subtotal	3.2	5.7
50% Margin	1.6	2.9
Total	4.8	8.6

Mass Estimates of PFP Deployable Mini-Payload

Subsystem	Mass (kg)	Margin (50%) (kg)	Mass + Margin (kg)
Instruments	1.33	0.67	2
Energetic Particle Detector	0.3	0.15	0.45
Electron and Ion Analyzer	0.68	0.34	1.02
Magnetometer	0.29	0.14	0.43
Active Pixel Sensor Camera	0.06	0.03	0.09
Instrument Electronics Module	0.1	0.05	0.15
Avionics (incl. Power Electronics)	0.15	0.08	0.23
Power Source (RPS)	3	1.5	4.5
Battery System	0.5	0.25	0.75
Communications	0.15	0.08	0.23
Thermal Control	0.3	0.15	0.45
Structure	2.16	1.08	3.24
Total	7.7	3.9	11.5

Summary and Conclusions of PFP Concept

– A two-pellet GPHS-derived RPS could provide 6 We (BOM), enough to power a simple passive fields and particles instrument suite.

  - The fuel capsules would be identical to those of the GPHS module; however, a new two-capsule aeroshell would need to be developed.

– The 5.2 We (EOM) power output would be sufficient for taking continuous science measurements.

  - The small RPS power estimates are conservative (assumed 5% conversion efficiency). May be able to achieve 7% to 9% efficiency with near-term thermoelectric materials [Noravian].

– Would require a hybrid RPS/Battery system to permit concurrent science measurements and periodic communications to a mother ship or relay satellite.

– Small RPS technology could enable a network of low-power, low-mass Fields and Particles monitoring stations, permitting significant scientific benefit in a very small package.