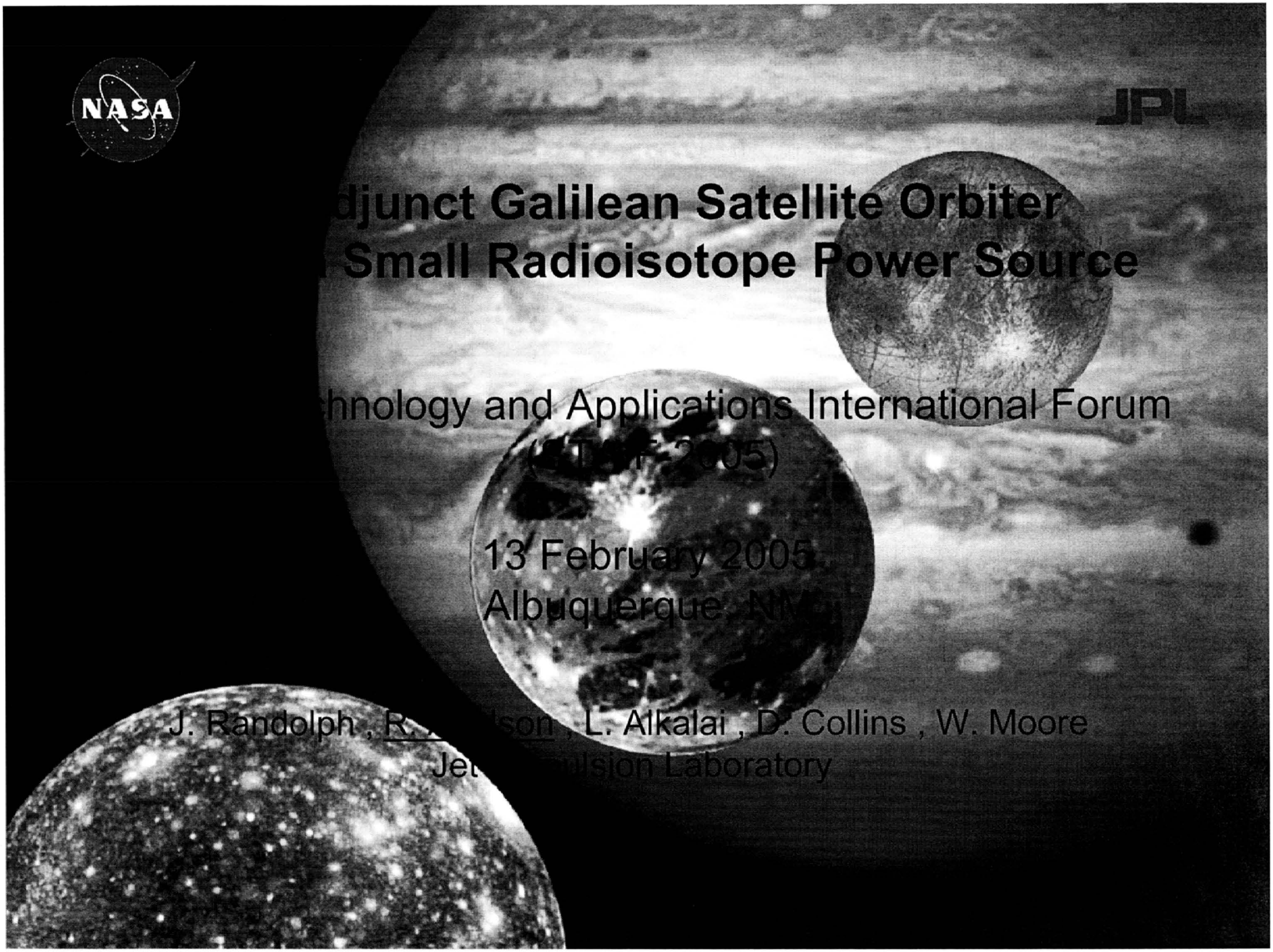

djunct Galilean Satellite Orbiter
Small Radioisotope Power Source
hnology and Applications International Forum
13 February 2005
Albuquerque, NM
J. Randolph, R. A, L. Alkalai, D. Collins, W. Moore
Jet Laboratory

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 authors wish to acknowledgement the follows persons for their contributions to this concept study.

Leon Alkalai, JPL
David Collins, JPL
Faramaz Davarian, JPL
David Hansen, JPL
Bill Imbriale, JPL
Alex Konopliv, JPL
Jerry Langmaier, JPL
Bob Miyake, JPL
Bill Moore, JPL
Bill Nesmith, JPL
Jon Sims, JPL
Rao Surampudi, JPL
Paul Timmerman, JPL
Brian Wilcox, JPL
Daniel Winterhalter, JPL

What is the GSO?

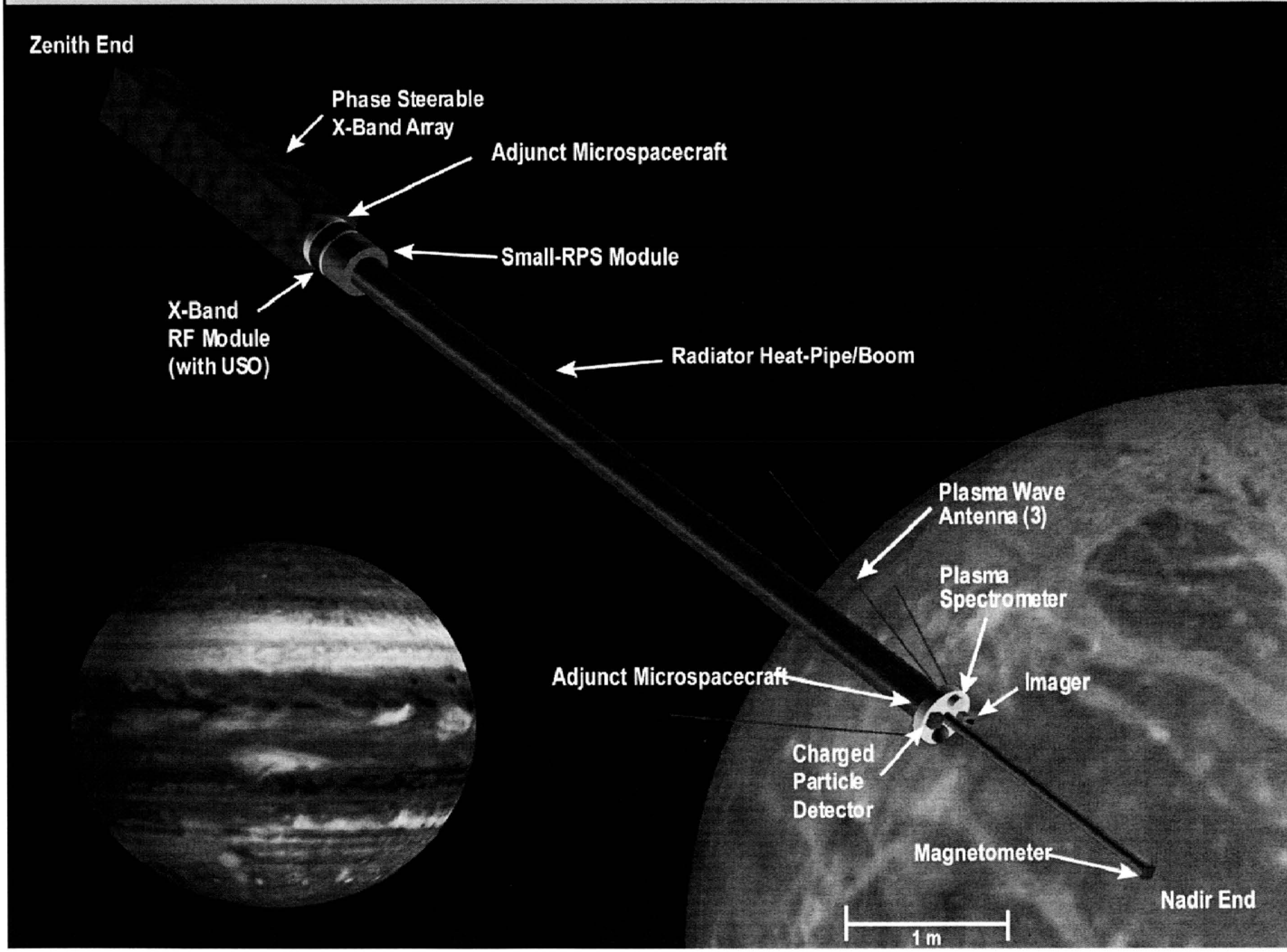
- The Galilean Satellite Orbiter (GSO) was conceived to illustrate a potential new class of low-powered, low-mass, scientifically-rich missions.

- The GSO is a small adjunct spacecraft that would ride with a mother ship to a target destination, be left behind to take long-duration fields and particles measurements, and relay the data to the mothership for transmission to Earth.

- The GSO would orbit one or more of the Galilean Satellites (Europa, Ganymede, or Callisto) carrying a full fields and particles payload to measure the local magnetospheric characteristics of these moons.

- GSO would also measure the interaction between these moons and Jupiter's magnetosphere, perform surface imaging, and measure each moon's gravity field characteristics.

Small RPS-Enabled GSO Mission

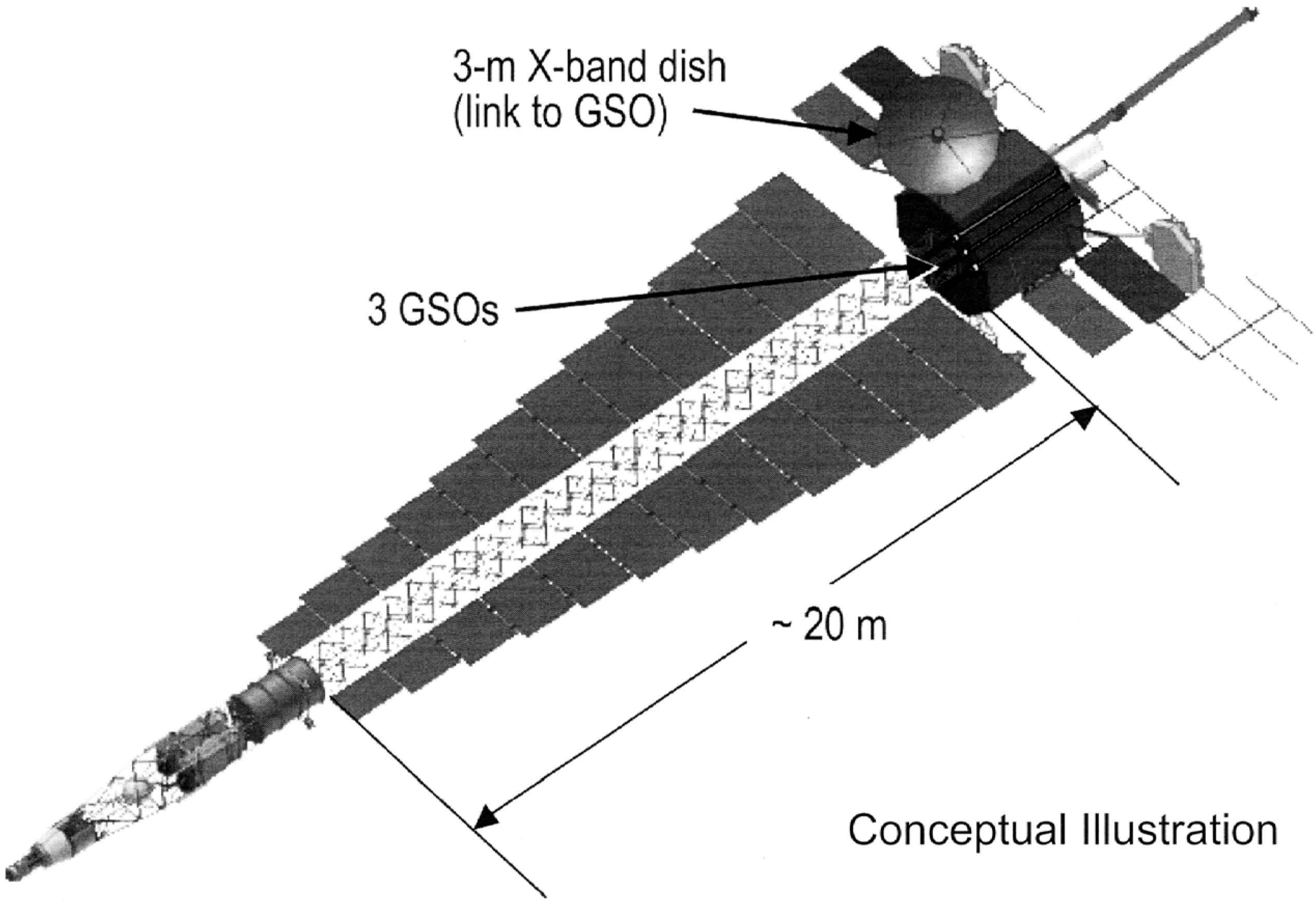


Solar System Exploration

MISSION ARCHITECTURE

- The GSO spacecraft would notionally be delivered to the Jupiter System by the proposed Jupiter Icy Moons Orbiter (JIMO).
- Delivery sequence of GSO to the Jupiter System
  - JIMO would achieve low altitude orbit about Callisto.
  - JIMO would release the Callisto GSO vehicle in that orbit.
  - JIMO would leave Callisto and travel to Ganymede, achieving low altitude orbit there.
  - JIMO would releases the Ganymede GSO vehicle in that orbit.
  - JIMO would leave Ganymede and travel to Europa, achieving low altitude orbit there.
  - JIMO would release the Europa GSO vehicle in that orbit.
- Following the release of a GSO into a low satellite orbit
  - JIMO would then act as a relay satellite for the GSO telemetry downlink.
  - JIMO would also act as a communications uplink for gravitational experiments

JIMO SPACECRAFT CONFIGURATION WITH GSOs



NOTIONAL GSO SCIENCE GOALS AND INSTRUMENTS

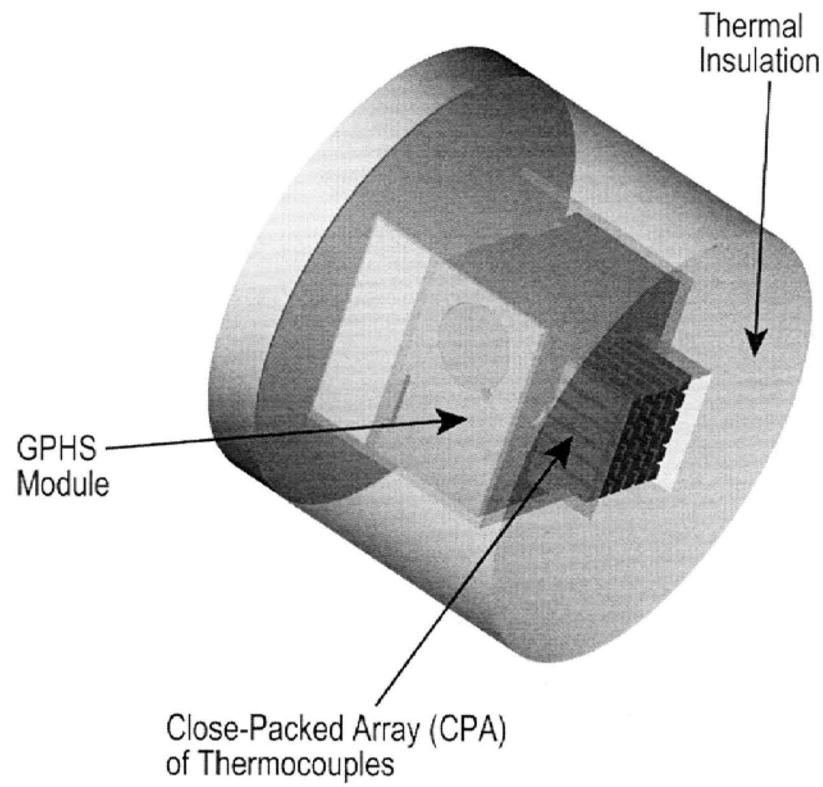
Science Goal	Instrument
Detect Evidence of Subsurface Water	Magnetometer (MAG)
Determine Satellite Interaction with Jovian Magnetosphere	MAG, Plasma Spectrometer (PLS), Plasma Wave Detector (PWD), Particle Detector
Determine Local Radiation Environment	Particle Detector
Quantify Satellite Magnetosphere	MAG, PLS, PWD, Particle Detector
Identify Plasma/Particle Interaction	MAG, PLS, PWD, Particle Detector
Determine Variations in Magnetic Field	Magnetometer
Map Gravity Field and Mascons	Doppler Extractor
Monitor Global Surface Processes	Imaging

GSO SCIENCE INSTRUMENT CHARACTERISTICS

Instrument	Instrument Performance	Telemetry Rate (bits/s)	Mass (kg)	Power (W)
Magnetometer	± 200 nT @ 0.05 nT	20	1	1
Plasma Spectrometer	0.001 to 20 keV	50	1	1
Plasma Wave	5 to 1000 kHz	10	1	1
Charged Particles	5 to 100 MeV	10	1	1
Imaging	Wide angle FOV (~60°) 1024 × 1024 pixels	10 frames/day	1	2
Doppler Extractor	~0.01 mm/s	100	1	2

SMALL RPS CONFIGURATION - CONCEPTUAL

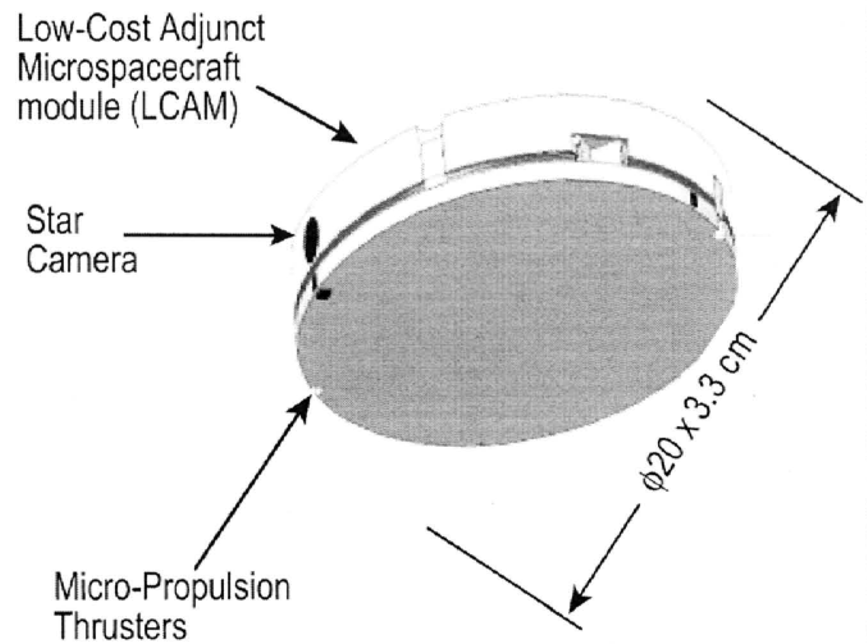
- RPS based on a single GPHS module with thermal output of 250W (BOM)
- Assumes a conversion efficiency of 7% at BOM.
  - Believed conservative –OSC has studied small-RPSs with predicted conversion efficiencies >9%.
- Power output: ~ 14 We at EOM (13 yrs)
  - Assumes Pu-238 degradation of 0.8%/year and TE degradation of 0.8%/year.
- Small RPS mass estimated at ~5 kg
  - Consistent with mass estimates generated by DOE/OSC during their detailed studies.
- Assumes an end mounted close packed array (CPA) configuration.
  - Facilitates the use of a long-end mounted boom as thermal radiator
- Batteries used to supplement the RPS for peak power loads (telecom)
  - RPS recharges batteries during lower-power operations.



Conceptual Only

LOW COST ADJUNCT MICROSPACECRAFT (LCAM) – CORE MODULE

- Low power avionics module for spacecraft control and data handling.
- Contains inertial and celestial sensors
- High throughput and computational capability
  - Central spacecraft sequencing and control
  - Data handling of celestial sensors
  - Data handling and storage of science telemetry
- LCAM capability allows cross strapped redundancy
- LCAM currently being studied and developed at JPL by L. Alkalai.



SPACECRAFT REQUIREMENTS

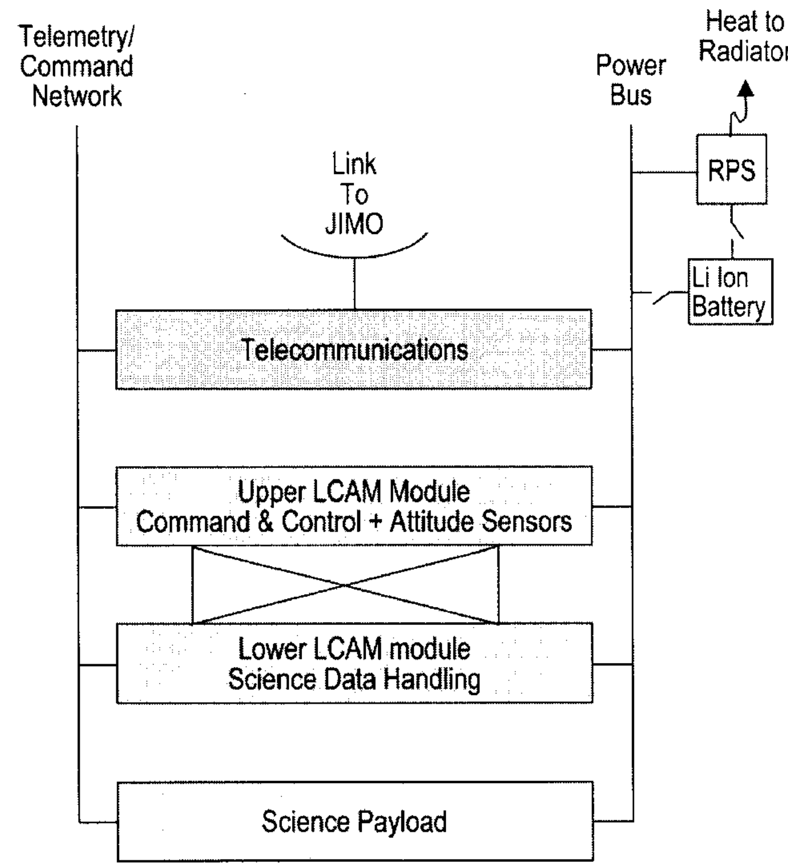
- RPS accommodation with long cylindrical boom/radiator
- Long radiator / boom allows gravity gradient attitude control
  - Accommodation of LCAM and RPS at the zenith end
  - Accommodation of other LCAM and Science Payload at the nadir end
- LCAM Modules (2) for spacecraft control and data handling
  - Zenith LCAM supporting central control and attitude control
  - Nadir LCAM supporting science payload telemetry data
  - Cross strapped LCAMs for increased reliability in hostile environment

SPACECRAFT BLOCK DIAGRAM

Three key functioning modules:

1. Telecommunications -
   - Transponder
   - Amplifier
   - Phase steerable antenna
2. LCAMs
   - Zenith (Avionics)
   - Nadir (Science data handling)
3. Science payload

Power provided by Small RPS and Li ion Battery



GSO POWER ESTIMATES

Item	Power (W)	Margin (W)	Power with Margin (W)	A (W)	B (W)	C (W)	D (W)	Heritage
	Power			**Power per Mode**				
Payload								
Magnetometer	0.5	0.5	1.0	1.0				MSSPM incl. Boom
Plasma Spec.	1.5	0.5	2.0	2.0				IES
Plasma Wave	0.3	0.3	0.6	0.6				Solar Probe
Charged Particles	0.3	0.2	0.5	0.5				MSSPM
Imaging	1.5	0.5	2.0			2.0		LCAM
Doppler 5 Extractor	1.5	0.5	2.0					New
P/L Totals	5.6	2.5	8.1	4.1	2	2		
Spacecraft Bus								
AC Sensors	0.6	0.2	0.8	0.8	0.8	0.8	0.8	LCAM
C&DH	1.5	0.3	1.8	1.8	1.8	1.8	1.8	LCAM
Power	1.0	0.5	1.5	1.5	1.5	1.5	1.5	New
Profs	0.1	0.1	0.2					LCAM
Cabling								New
Structure								LCAM
Thermal Boom (Radiator)								New
JIMO Adapter								New
RF Transceiver	0.5	0.5	1.0		1.0		1.0	New
RF Amplifier	15.0	5.0	20.0				20.0	New
High Gain Antenna	0.5	0.5	1.0		1.0		1.0	New
S/C Totals	19.2	7.1	26.3	4.1	6.1	4.1	20.[illegible]	
Overall Totals	24.8	9.6	34.4	8.2	8.1	6.1	26.1	

Operating Modes

Mode	Data Activity
A	F&P Science Acquisition
B	Doppler Science Data
C	Imaging
D	Playback

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

GSO DATA RATE ESTIMATES

Data Acquisition					
Mode	Data Rate (incl. Engr.), bits/s		Duration, hr	Total bits	
A	110		72	2.85 E + 07	
B	100		72	2.59 E + 07	
C	10 frames	0.5 Mbits/ frame		1.00 E + 06	
Playback					
Downlink Rate, bits/s		5000			
Mode A Playback (worst case)					
Total Power Required, We		26			
Power from RPS, We		10			
Power from Battery, We		16			
Battery depletion duration, hr			2.1		
Playback duration, hr			1.584		
Margin, %		23			

Mode	Data Activity
A	F&P Science Acquisition
B	Doppler Science Data
C	Imaging
D	Playback

GSO Mass Estimates

Item	Mass (kg)	Margin* (kg)	Mass with Margin (kg)	Heritage
Payload	2.8	3.2	6.0	
Magnetometer (with boom)	1.0	0.6	1.6	MSSPM incl. Boom
Plasma Spectrometer	0.6	0.4	1.0	IES
Plasma Wave	0.5	0.5	1.0	Solar Probe
Charged Particles	0.3	0.6	0.9	MSSPM
Doppler Extractor	0.3	0.6	0.9	New
Imaging	0.1	0.5	0.6	LCAM
Spacecraft Bus	33.6	31.2	64.8	
AC Sensors	0.2	0.6	0.8	LCAM
Command & Data Handling	0.6	1.8	2.4	LCAM
Power	6.0	3.0	9.0	New
Propulsion	0.8	0.8	1.6	LCAM
Cabling	2.0	1.0	3.0	New
Structure	2.0	2.0	4.0	LCAM
Thermal (w/Boom Radiator)	10.0	4.0	14.0	New
JIMO Adapter	2.0	1.0	3.0	New
RF Transceiver	2.0	6.0	8.0	New
RF Amplifier	3.0	6.0	9.0	New
High Gain Antenna	5.0	5.0	10.0	New
Overall Totals	36.4	34.4	70.8	

Notes:
* Mass margin includes radiation shielding

SUMMARY and CONCLUSIONS

- The GSO is a new class of low-powered, scientifically-rich spacecraft that could be enabled by small-RPS technology.
- GSO would use a mothership (e.g., JIMO, etc.) as a delivery vehicle and a telemetry relay to Earth.
  - The GSO would be left behind, allowing the mothership to continue to new destinations.
  - Planetary protection requirements would need to be considered.
- The GSO would orbit one or more of the Galilean satellites carrying a fields and particles payload (other payloads could be used).
- The Small-RPS in conjunction with the long boom/radiator allows gravity gradient stabilization (eliminates the need for active attitude control)
- The small-RPS, LCAM, and other advanced GSO technology capabilities could potentially be available in the 2015 time frame to support a JIMO / Europa Orbiter mission.
- In conclusion, the GSO concept demonstrates the potential for a Small-RPS to enable a rich plasma science mission using a low-power, low-mass adjunct spacecraft.