SSERVI FORUM

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Design of Lander PODS for Addressing Small Bodies Strategic Knowledge Gaps

The Boeing Company

Robert V. Frampton
Leora Peltz
James M. Ball

Description of the Strategic Knowledge Gaps (SKGs)

Strategic Knowledge Gaps, or SKGs, represent gaps in knowledge or information required to reduce risk, increase effectiveness, and improve the design of robotic and human space exploration missions. NASA uses SKGs to help inform research and investment strategies, and prioritize technology development for human and robotic exploration.

NASA enlisted the expertise of three analysis groups —
the Lunar Exploration Analysis Group (LEAG),
the Mars Exploration Program Analysis Group (MEPAG), and
the Small Bodies Assessment Group (SBAG).

We will focus on the SKGs being developed by SBAG, in a team led by Andrew Rivkin of JHU/APL and Mark Sykes of PSI.

The lists of SKGs will remain living documents, being updated as needed based on ongoing efforts by the analysis/assessment groups requested by NASA.

Description of SBAG SKG Themes

The Small Body Analysis Group (SBAG) conducted a Study in 2012 to identify critical SKGs for Exploration of Small Bodies, primarily Near-Earth Objects (NEO), and Phobos and Deimos. This SBAG study was motivated by the NASA Global Exploration Roadmap, which focuses on the "Asteroid First" scenario in the context of enabling Human Mars Exploration.

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Small Body (SB) SKGs were divided into four categories:

I. Human mission target identification (NEOs, or Phobos and Deimos)

II. Understand how to work on the surface and interact with the surface of the Small Body

III. Understand the Small Body environment and its potential risk and benefit to crew, systems, and operational assets

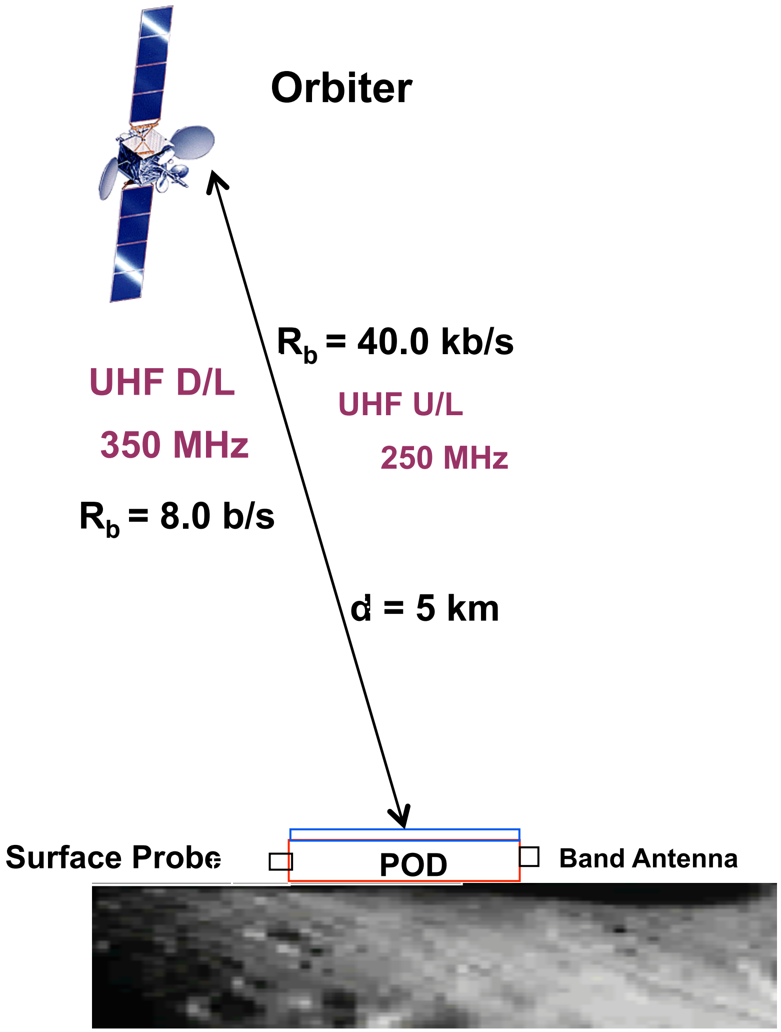
IV. Understand the Small Body resource potential

We present a mission design for *in situ* exploration of small bodies that can address the majority of these SBAG SKGs.

Landing PODS and Orbiter for Small Body

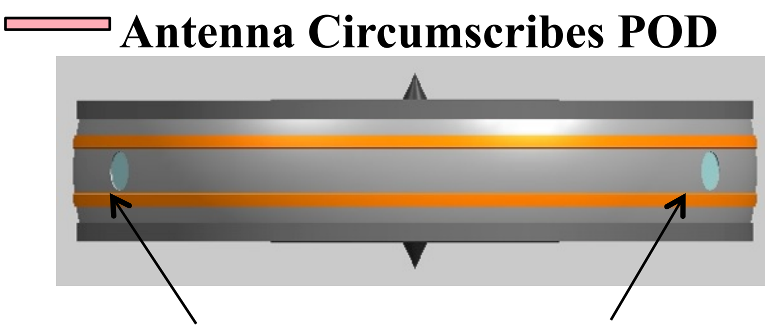
Many of the SBAG Strategic Knowledge Gaps (SKG) may be addressed by orbiting the small body (either NEO or Phobos/ Deimos) and deploying small surface landing "PODS").

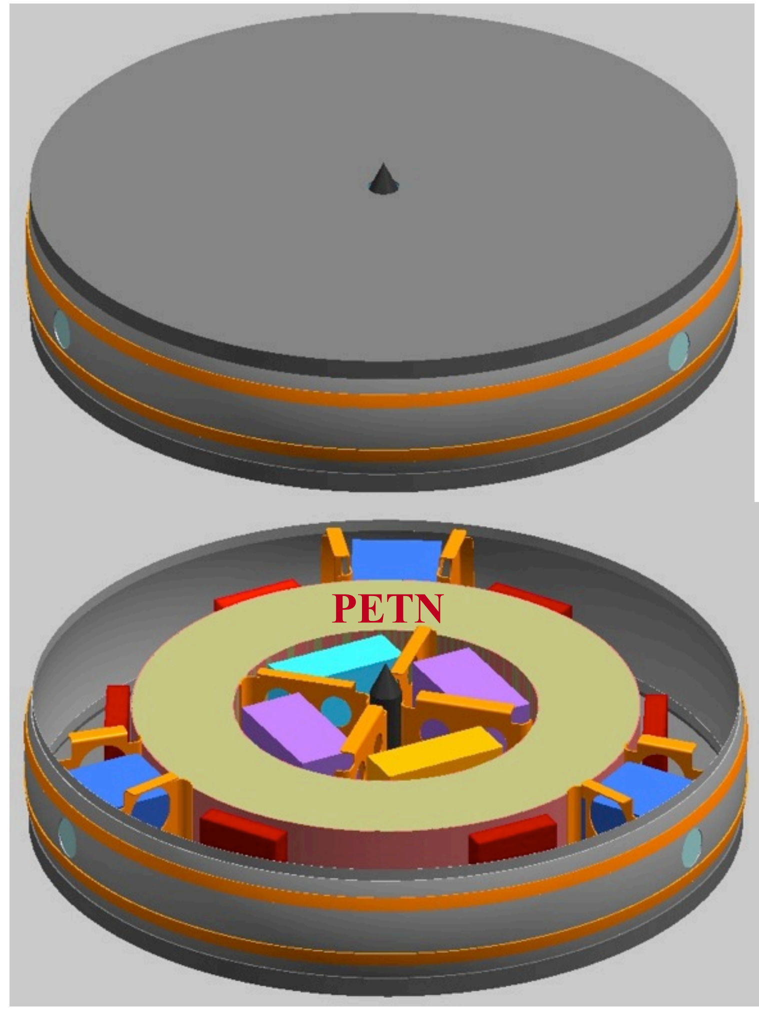
These PODS would not have an active propulsion system, but rather would be deployed by springs to cancel the orbital velocity of the spacecraft. Several PODS, each of ~20 kg mass, would then slowly descend to the surface over a period of a couple of hours. The impact velocity is small, about equivalent to a laptop computer sliding off its owner's lap; the PODS would be ruggedized to withstand such an impact. PODS would be flat, pancake shaped, and symmetrical, so that it does not matter which side is facing up. The Orbiter would provide relay of POD data back to Earth.



Layout of the Landing PODS

Cratering experiment uses 12 kg of PETN per POD (Pentaerythritol tetranitrate), placed in the torus of the POD. Seismic waves travelling through the SB would be measured by Endevco 7290A-2 Low Level Accelerometers in the other PODs. We desire to measure to 250 Hz and detect variations of 10^{-4} g (0.2 mv). So A-to-D Conversion is 16 bits, with 24 Kbps R/T data rate.





Experiments and Instrumentation to Address SBAG SKGs

One of the main science goals from the seismic experiment is to determine the interior structure of the asteroid, whether as a solid body or a "rubble pile." Another goal is to expose fresh unweathered regolith from the cratering for spectrographic mineralogical mapping. The third goal is to characterize surface dust and plasma. The orbiting spacecraft would provide radio relay for 40 kbps signal from PODS.

The PODs would have instrumentation to investigate both the interior structure and the regolith of these asteroids. Three cameras with micro-lens would obtain microscopic images of the regolith particles; a Langmuir Probe would investigate the electric field and plasma environment at the surface, and the mechanism of electrostatic charging and levitation of dust particles. Each POD could carry ~12 kg of PETN explosive material. The detonation would send seismic signals through the interior of the asteroid, to be recorded by sensitive accelerometers on the other PODS. The orbiting spacecraft would then observe the resulting crater for spectroscopic images of the freshly exposed regolith.

On Orbiter

- NA and WA Imaging Camera
- IR Imaging Spectrometry (mineralogy)
- S-Band Carrier for Radio Science
- Transponder for Data Relay of POD Data

On PODS

- Three Micro-lens Cameras per POD
- Langmuir Probe (electric field, electron density, and dust levitation)
- PETN Explosive (create small crater)
- Accelerometers for Seismic Mapping of Interior of Small Body

Category I. Human Mission Target Identification for Small Bodies

SKG Addressed by PODS and Orbiter	Description of SKG	Instruments to address the SKG
C-1: Small Body Size	Knowledge of SB size	Imaging by orbiter camera on approach to the SB
C-2: SB Albedo	Albedo in both visible and IR regions is desired	Imaging by orbiter camera and IR Imaging Spectrometer
C-3: SB Rotation State	Rotation rate provides information on interior structure and accessibility for human access to surface	Imaging by orbiter camera on approach to the SB

Category II. Understanding How To Work On Or Interact With the SB Surface

SKG Addressed by PODS and Orbiter	Description of SKG	Instruments to address the SKG
B-1: Mechanical and Electrical Effects of SB Surface Particles	Surface dust may create challenges for astronauts and hamper their surface experiment packages	Mechanical properties observed by PODS micro-lens cameras (three cameras give 360-degree view, focusing within a few meters of the POD). Electrical field is measured by the Langmuir Probe
C-1: Macro-porosity of SB Interior	Requires *in situ* measurement using ground-penetrating radar or seismic studies	POD "cratering experiment," exploding PETN and measuring seismic waves by accelerometers on the other PODS
C-2: Geotechnical properties of SB Surfaces	Requires *in situ* measurement of porosity, gravity, cohesion, shear strength, etc. to design optimal crew surface activities and recognize potentially hazardous crew activities	This diverse set of surface properties may be measured by orbital dynamics (gravity), micro-lens imaging, and orbital observation of crater after PETN detonation

Category II. Understanding How To Work On Or Interact With the SB Surface (Continued)

SKG Addressed by PODS and Orbiter	Description of SKG	Instruments to address the SKG
D-1: Anchoring for tethered activities	Design of anchoring mechanisms requires knowledge of surface and subsurface morphology	Regolith morphology properties determined by micro-lenses and cratering experiment
D-2: Non-contact close-proximity operations for detailed surface exploration and surveys	*In situ* experiments and observations for study of particle levitation and reaction to disturbances	Orbital imaging of regolith disturbance by POD landing; Langmuir Probe for particle levitation mechanisms
E-1: Expanding habitat volume to SB Interior for shielding and human factors	Shielding would require knowledge of specific asteroid composition, internal fractures, porosity, etc.	SB interior structure determined by seismic sensors on other PODS during "cratering experiment"

Category III. Understand the SB Environment and Its Effect on Human Life

SKG Addressed by PODS and Orbiter	Description of SKG	Instruments to address the SKG
A-1: Expected dust environment due to ejecta from micrometeor impacts	Dust environment in near-vicinity of the SB may act as hazard or nuisance, especially given cohesive forces in low-g environment. *In situ* observations preferred	Orbital imaging of regolith disturbance by POD landing and from cratering events
A-2: Observe the population of a dust torus around the Phobos and Deimos orbits	Obtain *in situ* observations of dust in the vicinity of Phobos and Deimos, and along their orbital tori	Back-scattering observations from Orbiter camera, and possible dust impact acoustic detector
A-3: Possible dust environment in the asteroid exosphere due to charged particle levitation following surface disturbances	Obtain *in situ* observations of dust in the vicinity of the small bodies	Observation by orbiter during POD landings and during cratering events

Category III. Understand the SB Environment and Its Effect on Human Life (Continued)

SKG Addressed by PODS and Orbiter	Description of SKG	Instruments to address the SKG
B-1: Local environment effects from solar flare activity	Solar flares may lead to enhanced dust levitation due to enhanced UV intensity, producing ionization of surface material	Langmuir Probe to measure near-surface electric field and ionization products. Orbital camera observation of dust cloud around SB during flare activity, through imaging back-scatter of sunlight
B-2: Small Body surface as a source of radiation	SB may have enhanced radiation return during solar flares. Laboratory measurements have not provided good modeling, so *in situ* measurements are necessary	Langmuir Probe to measure near-surface electric field and ionization products. Also, need sensor to detect γ-ray flux from surface.
D-2: Global structural stability	Remote observations of rotation period, and changes in period provide insight, but *in situ* measurements are necessary	Seismic measurement during cratering events provides some information on the global structural stability

Category IV. Understand the SB Resource Potential

SKG Addressed by PODS and Orbiter	Description of SKG	Instruments to address the SKG
A-1: Remotely identify resource-rich SB	Low-albedo SBs are more likely than high-albedo SBs to have water/OH-bearing minerals. Laboratory work is needed to better understand how to spectroscopically identify those dark SBs that are water-rich	This mission may serve as a truth-test for laboratory modeling of spectra. IR spectral imaging from orbiter of surface regolith and of fresh material exposed by the cratering event
B-1: Do resource materials exist beneath the surface of Phobos or Deimos?	Requires a mission to Phobos/Deimos with capability of drilling and making observations beneath the surface	(Rather than drilling), IR spectral imaging from orbiter of fresh material exposed by the cratering event

SBAG SKGs Not Addressed By This Mission Concept

SBAG SKGs that are not addressed by this mission concept

I-A-1 Laboratory radiation studies on radiation risk to tissue -- could be conducted on ISS

I-A-2 Survey of reachable SB targets within planned architecture (ground-based)

I-B-1 An IR telescopic survey of long-synodic period small bodies having multi-mission opportunities

I-B-2 An IR telescopic survey of number of SB targets available at a given time -- building a database

II-A-1 Laboratory experiments to address biological effects of SB surface particles (e.g., toxicity to crew)

III-C-1 Modeling SB as shields for crewed missions against solar storms

III-D-1 Investigating local structural stabilituy

IV-A-2 Techniques tested on Earth and on ISS to provide knowledge of how to excavate and collect SB regolith material to be processed

SBAG SKGs that could be addressed by a follow-on mission with a larger lander equipped with more sophisticated *in situ* investigations (e.g., drilling, etc.)

III-D-1 Investigating local structural stability

IV-A-3 Techniques tested on Earth and then on SB mission to provide demonstrate excavation and collecting water from regolith material by heating

IV-A-4 Caching and prepositioning regolith material

IV-A-5 Refining, storing, and using H and O from regolith material

IV-B-2 Demonstrate knowledge on how to access resource material from SB at depth (e.g., from drilling)

IV-B-3 Refining, storing, and using H and O in a usable state on Phobos and Deimos

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