

# Request for Proposal: A Self-Sustaining System for Global Terrain Exploration and Environmental Sampling on Titan

## I. OPPORTUNITY DESCRIPTION

The same planetary bodies that were so intriguing to Copernicus, Galileo, Newton and other natural philosophers more than five centuries ago are even more intriguing today. It seems that with every telescopic image or planetary probe, with every step toward greater understanding, comes a mystery even more profound. Among the greatest enigmas of our solar system are the bodies with dense atmospheres, such as the planet Venus and Saturn's moon Titan. With their thick atmospheres, these bodies host physical processes that could better inform our understanding of Earth. Volcanic activity on Venus, masked by its dense carbon dioxide atmosphere, may hold clues about geophysics. The chemistry of Titan's atmosphere, surface, and subsurface may provide clues to the pre-biotic processes which led to the emergence of life on Earth. The same atmospheres which make these planets so interesting also obscure the underlying surfaces from high-resolution imaging systems, making it difficult to target probes for safe or interesting landing sites.

As NASA increases its focus on space exploration, it is necessary to reconsider the various approaches which have been used or proposed for planetary exploration. Recently, NASA outlined a number of visionary challenges in the enterprise strategies of its various divisions. Among the near-term challenges (sooner than 2025) pertaining to "Surface Exploration and Expeditions" are (quoting from [1]):

- Mobile Surface Systems. Highly robust, intelligent and long-range Mobile Systems to enable safe/reliable, affordable and effective human and robotic research, discovery and exploration in lunar, planetary and other venues.
- Flying and Swimming Systems. Highly effective and affordable Flying and Swimming systems to enable ambitious scientific (e.g., remotely operated sub-surface swimmers) and operational (e.g., regional overflight) goals to be realized by future human/robotic missions in lunar, planetary and other venues.
- Sustained Surface Exploration & Expedition Campaign Architectures. Novel and robust architectures that best enable Sustained Surface Expeditions and Exploration Campaigns to be undertaken to enable ambitious goals for future human/robotic research, discovery and exploration.

Dramatically improved "Surface Mobility and Access" is a longer-term challenge (after 2025), which includes "regional

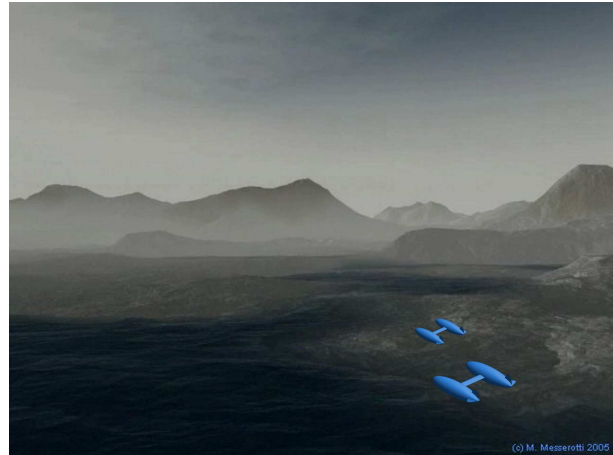


Fig. 1. Buoyancy gliders explore Titan.

and global mobility in accessible planetary venues, with access at various depths below – and altitudes above – planetary surfaces." Taken together, these challenges suggest the development of complete system architectures for autonomous or semi-autonomous exploration, architectures which include high-mobility agents and energy renewal mechanisms.

Limitations on energy storage restrict the range of conventionally powered vehicles, but self-contained energy harvesting devices (such as solar cells) increase the cost, weight, and complexity of individual vehicles. Added weight is a particularly serious impediment for atmospheric flight vehicles and added complexity generally reduces vehicle reliability. Moreover, in many of the most interesting environments, conventional energy regeneration technologies like solar cells are of questionable use. Titan, for example, is more than nine astronomical units from the sun. The relatively small amount of radiant solar energy that reaches Titan is further diminished by the dense, smoggy atmosphere.

NASA is considering a new system concept for exploring Titan. The system is self-sustaining, extracting energy from the planetary boundary layer for both energy renewal and efficient locomotion. The system comprises three components:

- 1) A fleet of rechargeable, autonomous, buoyancy driven gliders, actuated through internal shape control.
- 2) A tethered, buoyant vehicle to harvest wind energy in the upper planetary boundary layer.
- 3) A fixed anchor and docking station. The docking station must store energy generated by the energy

harvester and must serve as a recharging node for the gliders.

Results of a preliminary study described in [2] and [3] may provide some structure for the proposed investigation, but should not define or limit the investigation's scope.

## II. PROJECT OBJECTIVE

The objective of this project is to design each component of the system described above, with a view toward deploying the system in the 2040 time frame. Before designing the various components, the investigators must define a feasible science mission and identify available sensors for the mission, including details about mass, volume, and power requirements for these sensors. This preliminary investigation will be well-informed by a review of the sensors carried by *Cassini/Huygens*.

Additional topics for consideration include requirements and possible solutions for

- power generation, storage, and transfer,
- communication (between vehicles and between the system and Earth scientists/engineers),
- guidance and navigation (including positioning technology),
- packaging and delivery to Titan's surface, and
- launch and interplanetary transfer devices.

Preference will be given to proposals which include a dynamic modeling and simulation component for the buoyancy gliders and the tethered wind energy harvester.

Finally, the investigators must compare this concept to alternative concepts for exploring Titan. The comparison should be based on expected mission duration, available science data products, and total cost in 2005 dollars. Concepts should also be compared based on risk; the final report should include a comprehensive list of failure modes for the competing concepts.

## III. REQUIREMENTS & CONSTRAINTS

The system must be capable of operating continuously for at least ten Earth years. It must be capable of generating global visual, gravity gradiometric, and magnetometric maps of Titan. Although not a requirement, a surface chemistry sampling capability would also be quite valuable.

This effort focuses on viability, so there is no specific cost constraint. However, the total mission cost must be commensurate with the cost of similar planetary exploration missions currently being considered by NASA and its international partners.

## IV. DATA REQUIREMENTS

The proposal should

- describe the system architecture;
- explain the concept of operation from first principles;
- explain the launch vehicle selection process;
- describe how the system will be deployed, including any deployment mechanisms to be used;
- describe the power requirements and the power system design;
- describe how a typical planetary exploration mission would proceed;
- describe how vehicles dock, recharge, and communicate with Earth scientists/engineers
- describe the command and data handling system, including telemetry and data storage requirements;
- include performance predictions, including potential failure modes.
- include cost estimates for production, deployment, and operation.

## REFERENCES

- [1] Visionary challenges of NASA strategic enterprises for the NASA Institute for Advanced Concepts. Technical report, NASA, January 2004.
- [2] M. T. Morrow. A self-sustaining, boundary-layer-adapted system for terrain exploration and environmental sampling. Master's thesis, Virginia Polytechnic Institute and State University, 2005.
- [3] C. Woolsey, G. Hagerman, and M. Morrow. A self-sustaining, boundary-layer-adapted system for terrain exploration and environmental sampling. Technical report, NASA Institute for Advanced Concepts, 2005. Report available at <http://www.niac.usra.edu/studies/studies.jsp>.