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SmallSat Spinning Lander with a Raman Spectrometer Payload for Future Ocean Worlds Exploration Missions

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Abstract

We describe an Evolved Expendable Launch Vehicle Secondary Payload Adapter (ESPA)-class SmallSat spinning lander concept for the exploration of Europa or other Ocean World surfaces to ascertain the potential for life. The spinning lander will be ejected from an ESPA ring from an orbiting or flyby spacecraft and will carry on-board a standoff remote Spatial Heterodyne Raman spectrometer (SHRS) and a time resolved laser induced fluorescence spectrograph (TR-LIFS), and once landed and stationary the instruments will make surface chemical measurements. The SHRS and TR-LIFS have no moving parts have minimal mass and power requirements and will be able to characterize the surface and near-surface chemistry, including complex organic chemistry to constrain the ocean composition.

1. Introduction

The spinning lander concept is a novel adaption of a classic dual-spin spacecraft architecture. A spinning module provides robust gyroscopic attitude stability, a relatively benign thermal environment (by evenly distributing heat loads) and centripetal acceleration (for effective propellant settling and flow control); it is connected to a despun module *via* a rotor/bearing assembly, and this despun module also accommodates a landing leg system. Most subsystems for a spinning lander—power, telemetry and command, RF telecommunications, attitude control, despun rotor control, propulsion, etc.—are nearly identical functionally to those included on over a hundred successful dual-spin spacecraft missions in the past [1-3]. What converts this proven, robust, scalable spacecraft architecture into an effective small lander [4, 5] is the addition of landing legs to the despun section, a landing radar and dedicated science instrument payloads that are commensurate with CubeSat volumes, *e.g.*, spatial heterodyne Raman spectrometer [6, 7]. It is envisaged that a constellation of spinning landers (each spinning lander carrying a dedicated payload) would be ejected and deployed from an ESPA. Fig. 1 shows an ESPA-class spinning lander concept with a 1U CubeSat avionics enclosure volume.

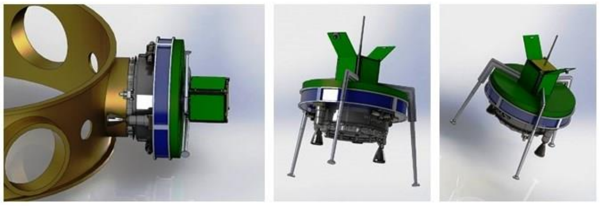

Figure 1: ESPA-class spinning lander concept (only one spinning lander shown). There is an 8” Lightband interface with the ESPA ring port and ~1U CubeSat-sized avionics electronics enclosure on the despun side.

Fig. 2 shows a notional spinning lander mission concept. Control of spacecraft velocity, spin rate and attitude is accomplished *via* relatively simple and independent sets of thrusters: axial (parallel to spin axis), radial (normal to spin axis) and tangential (to spinning section rim). In free space, bulk spin rate of the spacecraft is controlled with the tangential thrusters, while relative spin rate and azimuth phase control between the despun and spun sections is accomplished with the rotor/bearing assembly, which also passes power and signals across the interface *via* a series of slip rings. Telecom antennas, scaled to meet mission objectives, can be mounted to both sections, though the higher gain antenna(s) are almost always on the despun section.

During the terminal landing phase, with despun section and legs set at zero spin, the spinning portion of the lander continues to spin until touchdown, providing significant gyroscopic stability to the entire landed system. Importantly, this system essentially can't tip over during landing, but will rather 'bounce' or 'stick' depending on the leg system design. Depending on mission goals, once on the surface the spacecraft's spinning section can either be stopped or left to spin at any desired rate *via* rotor/bearing control. In the spinning mode, the entire lander becomes an excellent hopper as well, providing extended range/coverage options, onboard propellant permitting. Selected instruments on the despun section can be controlled independently in azimuth and elevation during all mission phases using typical pan-tilt assemblies. Instruments and components on the spun side can be positioned in azimuth by rotation of the entire spun module.

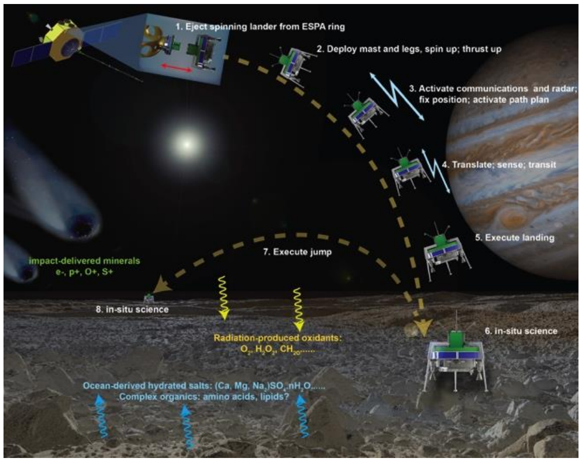

Figure 2: Cartoon of stowed spinning lander in an ESPA ring and subsequent ejection and concept of operations. For example a dedicated Raman spectrometer science payload on a Europa Mission will provide surface and near-surface spectroscopy while the lander is stationary or hovering. Europa's surface composition is derived from a mixture of processes, which must be unraveled to understand the ocean below.

The mass-efficient, cost-effective spinning lander system designs can, for relatively low total mission costs, address mission objectives for planetary exploration, resource utilization and commercialization at various solar system destinations. Solar system mission capability is enabled primarily by how much onboard Δv capability is incorporated (*via* some combination of liquid monopropellant and/or bipropellant and/or solid kick motor systems) and available power (*via* spun- and despun-mounted solar arrays, batteries).

2. Future Work

Apart from issues of landing leg design, spun-despun bearing design, lander dynamics and control system design and analyses, propulsion subsystem design, *etc.*, adapting the small spinning lander concept to Ocean World exploration missions brings into play some additional challenges not yet addressed [8]:

- Lander Δv requirements will be different for specific missions. These differences will likely drive propulsion subsystem sizing and technologies in significant ways, and perhaps other subsystems.
- Communication relay operations will be much more challenging.
- Landing targeting will inherently come with significant uncertainties.
- Miniaturized RTG's and primary batteries are anticipated to be far superior for longer mission duration. However focused science objectives must be accomplished in hours to days.
- Outer planet and moon surface environments are extremely cold, and subject to extreme radiation so temperature-control and radiation hard subsystem designs need to be addressed.
- Two-way light times from Earth to target and back combined with a short mission duration will likely lead to the requirement that all lander operations be conducted in a fully autonomous mode.

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