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Science Rationale for the *Io Volcano Observer (IVO)*

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1. Introduction

The *Io Volcano Observer* mission can explore the rich array of interconnected orbital, geophysical, atmospheric, and plasma phenomena surrounding the most volcanically active world in the Solar System. It is the only place in the Solar System (including Earth) where we can watch very large-scale silicate volcanic processes in action, and it provides unique insight into high-temperature and high effusion-rate volcanic processes that were important in the early histories of the terrestrial planets. Io is the best place to study tidal heating, which greatly expands the habitable zones of planetary systems. The coupled orbital-tidal evolution is key to understanding the histories of Europa and Ganymede as well as Io.

2. Mission Strategy

Io is always inside the intense radiation belt of Jupiter, so a radiation strategy is needed. An inclined orbit that passes Io at high velocity (~19 km/s) near spacecraft perijove keeps the total ionizing dose to ~10 krad (behind 2.5 mm or 100 mils Al) per flyby, compared to 85 krad/flyby from the slower equatorial orbit envisioned for Jupiter Europa Orbiter (JEO) [1]. The electron radiation maximizes at the planet's magnetic equator and IVO will cross this equator at a high incidence angle and at high velocity, thus minimizing total dose. The inclined orbit provides nearly pole-to-pole flybys of Io, which enables some of the highest-priority science such as understanding the polar heat flow and electrical conductivity of Io's mantle (which may contain a magma ocean) [2]. Key science instruments include a camera, magnetometer, thermal mapper, neutral mass spectrometer, and plasma ion analyzer.

3. Science Objectives

NASA's 2002 Decadal survey [3] identified 4 broad themes: (1) The first billion years of Solar System history, (2) Volatiles and organics: The stuff of life, (3) The origin and evolution of habitable worlds, and (4) Processes: How planetary systems work. A mission dedicated to Io most directly addresses theme (4), as we can watch geologic and geophysical processes in action at Io and relate them to processes in Io's torus and Jupiter's magnetosphere. The ESA Cosmic Vision also includes the high-level scientific question "How does the Solar System work?" IVO can also contribute significantly to theme (1) as current volcanism on Io is analogous to ancient volcanism on the terrestrial planets; theme (2) as Io provides a prime example of how worlds can lose volatiles through magnetospheric interactions; and to theme (3) as tidal heating, best studied at Io, could significantly expand the habitability zone(s) of outer planet satellites and extra-solar planetary systems.

A more recent NRC study [4] listed 7 science goals/objectives for a New Frontiers class Io Observer, derived from the Decadal Survey goals. For IVO we have embraced essentially the same goals and objectives, but have combined some interrelated objectives and prioritized them into groups A and B (Table 1). Better understanding magnetospheric interactions and Jupiter system science are group C objectives.

4. Comparison to Other Missions

IVO and GLL: The Galileo (GLL) mission and payload were designed prior to the Voyager 1 flyby and discovery of active volcanism, so they were not designed to meet key Io measurement requirements. Furthermore the failed high-gain antennae resulted in severely limited data return for a world that is highly variable in space, time, and wavelength. IVO will be designed to address Io science as currently understood and will return, on every orbit, ~100x the total Io data return of GLL over 8 years.

IVO and EJSM: Given that Io is the priority for IVO, the S/C design, orbit, and payload are all driven to very different attributes than is the case for JEO or JGO. The IVO S/C must be agile enough (without flexible appendages) for high-stability observations during close encounters. High-inclination (pole-to-pole) flybys are essential for mapping polar heat flow, for electromagnetic sounding of mantle melt, and to get closer to Io while outside the intense radiation for observing faint emissions. The science instruments need special design considerations to address challenges unique to Io [e.g., 5]. IVO and EJSM are complementary: JEO and JGO will contribute Io observations from instrument types not carried by IVO, and IVO will add to Jupiter system science.

References

[1] Clark, K. et al., 2008, JEO study, http://opfm.jpl.nasa.gov/

[2] Khurana, K. et al., 2009, Fall AGU P53B-05.

[3] NRC (2003) New Frontiers in the Solar System.

[4] NRC (2008) New Opportunities for Solar System Exploration.

[5] Keszthelyi, L. et al. (2009) LPSC 40, #1943.

Table 1. IVO Science Goals, Objectives, and Measurement Requirements

Science Goals	Science Objectives	Key Measurements
A1. Understand Io's currently active volcanism and implications for volcanic processes on other planetary bodies throughout geologic time.	A1. Understand the eruption and emplacement of Io's currently active lavas and plumes.	Repeat imaging at <10 m/pixel to global scales, thermal mapping, movies of dynamic phenomena, measure plume and atmospheric species.
A2. Understand Io's interior structure and tidal heating mechanisms and implications for the coupled orbital-thermal evolution of satellites and extrasolar planets.	A2. Determine the melt state of Io's mantle and map heat flow patterns to distinguish between asthenospheric and deep mantle tidal heating.	Electromagnetic sounding of mantle lava, measure peak lava temperatures, map global pattern of heat flow.
B1. Understand tectonic processes on Io and the implications for tectonics under high-heat-flow conditions that may have existed early in the history of other planetary bodies.	B1. Test models for the formation of mountains and paterae on Io.	Map topography of a variety of rugged landforms, compare IVO to Voyager and GLL images to document topographic changes.
B2. Understand Io's surface-atmosphere interactions and impact on the Jovian system (i.e., relate to chemistry and processes in Io's torus and the Jovian magnetosphere).	B2. Understand the chemistry of Io's surface, atmosphere, and ionosphere, the dominant mechanisms of mass loss, and the connections to Io's volcanism and differentiation.	Measure abundances of neutral and ionized species in Io's environment, remotely observe Na-D, SII, SO_2, OI, and other emissions, map surface compositions, monitor SO_2 atmosphere.
B3. Seek evidence for activity in Io's deep interior and understand the generation of internal magnetic fields	B3. Characterize the magnetic environment to better constrain the nature of Io's permanent and induced magnetic fields.	Measure magnetic field strength and variability and plasma effects.