SCIENCE RATIONALE FOR AN *IO VOLCANO OBSERVER (IVO)* MISSION. A. McEwen[1], E. Turtle[2], L. Keszthelyi[3], J. Spencer[4], N. Thomas[5], P. Wurz[5], P. Christensen[6], K. Khurana[7], K.-H. Glassmeier[8], U. Auster[8], R. Furfaro[1], A. Davies[9], F. Nimmo[10], J. Moses[11], F. Bagenal[12], R. Kirk[3], M. Wieser[13], S. Barabash[13], C. Paranicus[2], R. Lorenz[2], B. Anderson[2], A. Showman[1], B. Sandel[1]. [1]University of Arizona (Tucson, mcewen@lpl.arizona.edu), [2]APL, [3]USGS, [4]SwRI/Boulder, [5]U. Bern, [6]ASU, [7]UCLA, [8]IGEP, [9]JPL, [10]UCSC, [11]LPI, [12]CU, [13]IRF.

Introduction: Io presents a rich array of interconnected orbital, geophysical, atmospheric, and plasma phenomena [1-2]. 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.

In early FY2008, NASA solicited study concepts for Discovery/Scout-class missions that would be uniquely enabled by use of 2 government-furnished Advanced Stirling Radioisotope Generators (ASRGs) [3-4]. Each ASRG can provide ~140 W electric from just 0.8 kg Pu^{238}. Given the extreme scarcity of Pu^{238} the ASRGs have great potential value to future exploration, providing ~6x power per kg of Pu^{238}, but NASA wants the first flight to be on a relatively low-cost mission. One of these studies was for an *Io Volcano Observer* (*IVO*) concept [5]. An *Io Observer* mission is a high priority to the NASA science community as a candidate New Frontiers mission [6-7], but we think the top science priorities could be achievable in Discovery 12 capped at $425M, not including launch and the ASRG power system.

Mission Strategy: Io is always inside the intense trapped radiation belt of Jupiter, so a radiation strategy is key. An inclined orbit that passes Io at high velocity (~19 km/s) near perijove keeps the total ionizing dose to ~10 krad (behind 100 mils Al) per flyby, compared to 85 krad/flyby from the slower equatorial orbit envisioned for *Jupiter Europa Orbiter (JEO)* [8]. *IVO's* orbit and the need for high-resolution remote sensing data means that the spacecraft (S/C) must be quite nimble -- able to turn, stop, and settle very quickly; this would be impossible with large solar arrays, so radioisotope power is enabling.

The inclined orbit provides nearly pole-to-pole flybys of Io, which not only minimizes radiation dose but is essential to 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) in Io's mantle [9].

Science Objectives: The 2002 Decadal survey [6] 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. The mission can also contribute significantly to theme (1) as current volcanism on Io is analogous to ancient volcanism on the terrestrial planets, 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.

The NRC study [5] 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.

Technology (Future Science) Objectives: We expect *IVO's* nominal mission to provide a 7- to 8-year flight test of the ASRGs, with the final 18 months in the Jupiter system. Given the shortage of Pu^{238}, *JEO* may need to use ASRGs to avoid becoming the last mission for a decade to use radioisotope power. *IVO* would provide experience building and launching an ASRG powered S/C for a high-radiation environment, and provide flight experience in that environment several years before *JEO* would arrive at Jupiter.

One extended mission concept is to pump the orbital period out to ~1 year to enable a long-term life test of the ASRGs (essential to future missions beyond Saturn) and enabling longer-term Io and Jupiter system monitoring (concurrent with *EJSM*). An alternative extended mission concept is to pump the orbit down to a shorter period to more rapidly test performance of the ASRG with increasing total dose, prior to the arrival of *JEO*.

***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 for key Io measurement requirements. Furthermore the failed high-gain antennae resulted in limited data return for a world that is extremely 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 *JEO*:** Given an Io priority for *IVO*, the S/C design, orbit, and payload are all driven to very different attributes than is the case for *JEO*. The S/C must not have flexible appendages or gimballed structures to keep it highly stable. 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., 10]. *JEO*, on the other hand, will contribute other useful Io observations and *IVO* can add to Jupiter system science so the missions are complementary.

Primitive Bodies: Although the mission is driven by Io objectives, we expect to encounter a main-belt asteroid en route to Jupiter, to serve as a dress rehearsal for the Io flybys. In addition, if we pump the orbit out to a 1-year period for an extended mission, it will be possible to encounter an outer irregular satellite, which could be a captured KBO [11].

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Table 1. IVO Science Goals, Objectives, and Key Measurements

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 and at global scales, thermal mapping, movies of dynamic phenomena, measurement of 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, measure lava eruption temperatures, map global pattern of heat flow, measure the shape of Io, place tighter constraints on nonsynchronous rotation.
B1. Understand the processes that form mountains and paterae 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 over decades, acquire color imaging for relations between volatiles and tectonic structures.
B2. Understand how Io affects the Jovian system, and implications for the study of other planetary systems.	B2. Understand Io's surface chemistry, atmosphere, and ionosphere, the dominant mechanisms of mass loss, the connections to Io's volcanism and differentiation	Measure abundances of neutral and ionized species in Io's environment; remotely observe Na-D, OI, and other emissions; map surface compositions; monitor SO_2 atmosphere and passive surface temperatures.
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 potential internal magnetic field.	Measure magnetic field strength and variability and plasma effects.