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Introduction: The following is a mission concept study conducted at the NASA Jet propulsion Laboratory, California Institute of Technology, Pasadena, California, under a contract with the National Aeronautics and Space Administration during NASA's 20th Annual Planetary Science Summer School.

Presented here is a scientific proposal based on a study of a New Frontiers class mission to Io that has been named Argus. The Argus mission would enable breakthrough level science advances through investigation of the innermost Galilean moon, Io, as outlined in the 2008 National Academies Report on choices for the next New Frontiers Announcement of Opportunity.

Background: Io is the most volcanically active planetary body in the solar system and is an ideal body for studying fundamental planetary process. The orbit of Io has a 2:1 orbital resonance with next Galilean moon, Europa, and a 4:1 resonance with Ganymede. This resonance causes Io to maintain a 0.0041 orbital eccentricity, causing tidal heating of the interior. In addition to interior perturbations, Io is strongly coupled to Jupiter's magnetosphere, which surrounds Io in high radiation levels around Jupiter's equatorial plane, leading to a significant mass flux from Io's atmosphere. The Argus mission to Io will evaluate these properties and study the moon to achieve significant advances in fundamental planetary science questions.

Interplanetary Trajectory Options

#	Itinerary	Launch Date	TOF (Yrs)	Launch C3 (km^2/s^2)	DSM ΔV	JOI ΔV w/ Io flyby	Max S/C Dry Mass (kg)
1	VEE	04/10/2018	6.03	14.1	0	1240	2320
2	VVE	09/12/2018	5.01	11.6	200	1250	2270
3	VE	12/26/2019	4.93	18.9	280	751	2167

- VVEGA trajectory (2) selected.
  - Selected primarily based on TOF, launch dates
  - Design allows launch on VEEGA (1) if needed (ΔV, C3)
- Arrival at Io with V_∞ 16.6 km/s (17.0 km/s relative velocity)

Event	ΔV (m/s)
Launch	30
DSM	205
Earth flyby	55
Statistical	*[20]*
JOI	1250
PRM	190
Orbit adjustment	280
De-orbit burn	10
Total	**2030**

Science: Io lends insight into key questions related to the origin and evolution of satellite systems and dynamic planetary processes. Through the study of the internal processes of Io, the volcanic history of early Earth and its evolution can be critically investigated. Io's volcanism is driven by tidal heating related to its orbital eccentricity, and is an important topic for understanding the range of volcanic processes and styles found on solar system bodies. In addition, due to the orbital resonance of Europa and Ganymede, it is likely these moons have experienced, or currently have; internal heating that may provide habitable zones under a surface icy layer.

Additional questions the Argus mission can investigate concern the interior structure of Io, which has implications for the possibility of past surface water. Surface temperatures on Io (as determined from data returned by the Galileo spacecraft) are unexpectedly low, and can be studied to determine if and how they are related to tidal heating characteristics. Finally, investigating Io's atmosphere can provide data to assist in our understanding planetary atmospheres and atmospheric evolution, in addition to the important coupling of the atmosphere to Io's interior and the Jovian magnetosphere. Results from Io investigations will provide insight into not only the Jovian satellites, but also early Earth and all planetary body processes.

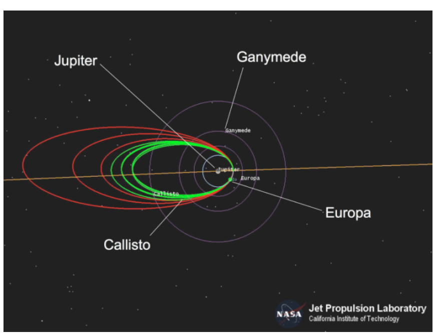
The four principal areas of investigation defined by the team include: (1) geology, (2) geochemistry, (3) atmosphere and (4) tidal heating. The features related to geological processes of continuous crustal recycling at the surface, mountain building, and erosion, are fresh and evident and can be investigated easily. Understanding the relationships between volcanic activity and composition, tidal heating, atmospheric compositions, and interactions with the magnetosphere of Jupiter and mass wasting, can further our understanding of critical and dynamic planetary processes.

Instruments: Five instruments were designed or chosen to obtain data related to these processes. First is a visible-wavelength imager designed to obtain high-resolution images of the surface, intended to analyze the morphology of surface features and its implications for surface geologic processes. A second instrument, a thermal infrared imager, obtains thermal emission spectra to investigate surface heat flux, which has important implications for internal structure and heating. The third instrument, a visible to near-infrared imaging spectrometer, obtains high-resolution reflectance spectra that would be used to constrain surface mineralogy and the composition of surface volatiles. A fourth instrument is a point UV spectrometer that would be used to investigate the composition of Io's atmosphere and large volcanic plumes. The last instrument, a low-energy ion and neutral mass spectrometer experiment, will gather in-situ data for low-energy ion and neutral species in Io's atmosphere and volcanic plumes.

Instrument Coverage with Required Storage

Instrument	Data Volume/orbit Mb (floor)	Nominal Coverage/Orbit
I-SPI Visible Imager	2700 (1000)	Full Disk @ 1 km/pix, 3 colors 617 target images 10-100 m/pix res
TIRIMISU Thermal Imager	50 (10)	2 Global maps of Io each Orbit, distant observations daily outside close encounter
CheESE Near IR Spectrometer	2800 (1000)	~30 image cube, 2.9 km across at 10,000 km
LIME Ion and neutral mass spectrometer	50 (30)	83000 mass spectra, continuous during encounter at 1 second interval.
SUSHI UV Spectrometer	1200 (440)	Up to 4 plumes mapped at ~2km/pixel and 1 map of torus

Mission Design: To reduce radiation exposure, Argus will be placed into an inclined resonance orbit with Jupiter, which minimizes time spent in the intense radiation environment surrounding Io in Jupiter's equatorial plane. The orbital period will be ~10.6 days, allowing the requisite 40 flybys in the 2-year mission lifetime at Io. This design leads to a relatively short time during closest approach to Io, so data collection strategies were optimized to collect data quickly and downlink during the rest of the orbit rather than in real-time.



Data Acquisition and Downlink: Data volume requirements and spacecraft downlink capability were strong drivers for each instrument's design in the planning stage for the mission. Storage capability for the Argus mission is 6.8 Gb. Data will be downloaded in ten 4-hour downlink periods over the 9 days following each Io encounter. Downlink periods alternate with safe mode periods to recharge batteries.

Considerations/Risks: An important consideration for instrument design is the high-level of radiation Argus would be exposed to during fly-bys of the planet Jupiter. All instruments were designed or chosen for a radiation level of 1.5 Mrad. Heritage in radiation shielding from the 2015 Europa flagship mission was assumed for all instruments except the thermal infrared imager. This allowed significant cost savings in instrument development for the Argus mission.

Conclusion: The Argus mission will help answer breakthrough level science questions in the areas of geology, geochemistry, atmospheres, and tidal heating of Io. Through investigations of the dynamic processes of Io, insight into other planetary processes such as those on the early Earth and other Galilean satellites will be obtained. Additionally, Argus will help further the understanding of habitable environment formation and evolution.

Acknowledgements: "We would like to thank Charles Budney, Anita Sohus, Amber Norton, Gene Tattini, Brent Sherwood, Bernie Bienstock, Rosaly Lopes, John Crawford, Ashley Davies, Greg Garner, Satish Khanna, Steve Matousek, Bob Nelson, Team X, and NASA/JPL for their support, encouragement, and feedback."

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