EUROPA EXPLORATION: CHALLENGES AND SOLUTIONS. T. V. Johnson[1], K. B. Clark[1], R. Greeley[2], and R. T. Pappalardo[3], [1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109, Torrence.V.Johnson@jpl.nasa.gov, Karla.B.Clark@jpl.nasa.gov, [2]Arizona State University, Tempe, AZ 85287, greeley@asu.edu, [3]University of Colorado, Boulder, CO 80309, robert.pappalardo@colorado.edu

Introduction: Europa, Jupiter's second Galilean satellite, is among the most interesting targets for planetary exploration in the solar system. Telescopic data in the early 1970's showed that it has a surface of predominately water ice; the Voyager mission reconnaissance at the end of that decade revealed a geologically youthful, fractured surface; and the Galileo mission discovered strong evidence for the presence of a deep water ocean beneath its icy surface. These findings have affirmed the astrobiological potential of Europa, and have made further in-depth exploration of Europa a high priority for the science community.

The NRC's Decadal Survey of Solar System Exploration [1] ranked a Europa orbital mission as the highest priority large ("flagship") mission for solar system exploration in the near term. The NRC's Committee on Planetary and Lunar Exploration (COMPLEX) concluded that Europa exploration should be assigned a priority equal to that of Mars exploration [2]. Numerous other advisory bodies, including NASA's Solar System Exploration Committee and NASA's recent Roadmap Committee for Solar System Exploration have made strong recommendations to initiate the next stage of Europa exploration, including orbital studies and possible landed payloads, as soon as possible.

All of these scientific studies have highlighted the high priority scientific objectives required to make major advances over our current understanding of Europa: confirmation of an ocean, study of the ice crustal structure, geologic history of exchange between the ocean and surface and the chemical composition of the non-water materials on the surface, including organics if present.

Europa Exploration Background: Post-Galileo exploration of Europa presents a number of major technical challenges. Accomplishing the science objectives outlined above requires a more complex mission than a repeat of Voyager or Galileo-style flybys. In turn, this translates to a requirement to not only get into Jupiter orbit, but to orbit Europa itself and survive and operate within Jupiter's trapped radiation environment for long enough to achieve the major objectives.

Two major mission concepts for Europa exploration have been studied in the last decade: 1. Europa Orbiter (EO), which was cancelled in 2001 (in Phase B) due to a combination of the perceived lack of readiness of radiation-tolerant electronics, limited scientific payload capability (~ 20 kg), short data-taking mission (~30 days in orbit) and high cost (~1.2 B$). 2. Jupiter Icy Moons Orbiter (JIMO), which involved development of nuclear-electric propulsion to orbit each of the icy Galilean satellites, ending with Europa. Significantly more ambitious and scientifically capable than EO, JIMO was abandoned in 2005, primarily due to the large initial investment in space nuclear propulsion infrastructure required for a purely scientific mission, combined with NASA's new direction toward human exploration of the Moon and Mars.

Solutions: In this paper, we argue that the investments in technology and research for these past mission concepts, particularly in the areas of radiation tolerant electronics and complex mission design, have now put us in a position to develop a Europa exploration concept in the flagship mission class that relies on demonstrated technologies and achieves the high level science objectives. We believe that solutions now exist in each of the major areas which challenge Europa exploration, briefly outlined below.

Mass and Trip Time: The key to enabling reasonable, conventional propulsion, Europa exploration is accepting increased trip time to at least double the delivered spacecraft mass at Europa, and increasing the science payload nearly 10-fold, compared with EO**.** The small science payload and short orbit stay time of EO resulted primarily from a decision to fly a direct trajectory. Due to the large wet mass fraction required to get into orbit at Europa, the resultant spacecraft dry mass was ~ 1000 kg.

Utilizing indirect, Earth gravity assist, trajectories increases the available dry mass to ~ 2000 kg (for delta-V EGA) - ~3000 kg (for Venus EEGA). Trips times range from 4.5 to 8 yrs to Jupiter (comparable to Galileo, Cassini, Rosetta, and Messenger flight times). The mass made available can be used to increase the science payload (~150 - 200 kg), increase available power, increase data taking lifetime, and enable the use of existing radiation hard electronic technologies.

Radiation Tolerant Electronics: A significant program of radiation hard technology development was begun by NASA at the same time as EO. (NASA investments leveraged those made by the Department of Defense.) Originally driven by EO requirements, much of this development was completed or continued as part of the Prometheus (JIMO) program.

Key radiation areas include:

- *Flight Computer* - A reliable, powerful, radiation tolerant flight computer (RAD750) has now been demonstrated in flight (e.g. Deep Impact and MRO), with over 100 ordered by a number of other customers.
- *Electronics* – ASIC design and development are complete and are ready for flight qualification, and many new radiation tolerant electronic parts have been developed and are now available for use
- *Memory and Communication* – A remaining problem in the radiation area is the development of radiation hard memory for science data. However, existing radiation hard SRAM technologies can be used to provide sufficient science capability when combined with operational scenarios and high rate downlink capabilities (< 300 kbps) made possible by the increased mass and power margins.

Orbital Science Mission: With more radiation tolerant parts, increased mass for radiation shielding, and a better understanding of the Jupiter radiation environment following Galileo, we believe that we can take a probabilistic approach to the data taking lifetime of an orbital mission. Current assessments suggest that a 60 - 90 day nominal mission is reasonable, with some significant probability of functioning much longer.

Planetary Protection: The ultimate fate of an orbiter will be impact with Europa. Planetary protection requirements will be met following the approach developed for JIMO: Radiation sterilization during the primary mission for most external and unshielded internal surfaces, combined with pre-launch sterilization of shielded components.

Summary: We conclude that a flagship class Europa mission can now be developed relying on existing technologies, having significantly more capability and returning considerably more science data than previous conventional propulsion mission concepts.

References: [1] Solar System Exploration Survey, Space Studies Board, National Research Council, *New Frontiers in the Solar System: An Integrated Exploration Strategy*, National Academy Press, Washington, D.C., 2003. [2] Committee on Planetary and Lunar Exploration, National Research Council, *A Science Strategy for the Exploration of Europa*, National Academy Press, Washington, D.C., 1999.

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