EUROPA'S PRIORITY IN NASA, NRC, AND COMMUNITY DOCUMENTS

Outer Planets Assessment Group (OPAG), 2006. *Scientific Goals and Pathways for Exploration of the Outer Solar System*. <http://www.lpi.usra.edu/opag>

OPAG affirms the findings of the Decadal Survey, COMPLEX, and SSES, that Europa is the top-priority science destination in the outer solar system.

OPAG makes the following findings:
• Europa remains the consensus priority target of the OPAG community, as it is in the NRC Decadal Survey, in reports to NASA from both COMPLEX and SSES.
• OPAG encourages NASA to undertake a comprehensive Phase A mission study to assess the feasibility of a Europa mission that can achieve the priority science (as stated in the Decadal Survey and by the OPAG Europa Working Group) within an accurate and realistic cost-cap and, most importantly, complete the primary mission by a timeframe of 2020-2022. OPAG reiterates the concern that SSES has stated about delays in starting a Europa mission.... A comprehensive study would allow a decision to be made about implementation of a Europa mission.

Solar System Exploration Roadmap Committee, 2006. *Solar System Exploration*. NASA, Washington, DC, in press.

The program outlined here includes a set of five Flagship missions over 25 years to a variety of destinations in the inner and Outer Solar System.... Among these, Europa should be the next target for a Flagship mission.

Considered at least a theoretical possibility for nearly three decades, the existence of global liquid layers under the icy crusts of the larger moons has received major support from the Galileo mission's exploration of the Jovian system. Although the evidence for its existence is as yet indirect, there is wide acceptance that Europa does today possess a subsurface global ocean of liquid water. While there are many uncertainties regarding the geology and chemistry of this environment and potential life-supporting energy sources within it, confirmation of the existence and determination of the characteristics of Europa's ocean will allow us to conclude whether it is or ever has been a habitable environment. A positive finding would provide tremendous impetus for future surface and subsurface chemical and geophysical Europa exploration. Both Ganymede and Callisto also show evidence for subsurface oceans similar to that of Europa. If the formation of oceans is found to be a common phenomenon, the implications for life in the cosmos could be stunning. Comparative intensive studies of Callisto, Ganymede, and Europa could therefore prove to be one of the most important contributions we can make to the understanding of habitability in the solar system.

If the sub-surface waters of this Galilean moon are found to contain life, the discovery would spawn a revolution in our understanding of life in the universe. An orbiter mission would explore Europa and determine its potential for life, including characterizing the ocean and ice shell through geophysical measurements and locating potential habitable

zones within or beneath Europa's ice shell, the critical first steps in determining Europa's potential habitability.

The top priority (non-Mars) Flagship mission objective is intensive exploration of potential subsurface oceans on Jupiter's large icy satellites. The Galileo mission provided strong evidence that a liquid water ocean may exist beneath the ice crust of Europa, and perhaps beneath the surfaces of Ganymede and Callisto as well. This possibility makes these Galilean satellites among the most fascinating bodies in the Solar System from an astrobiological perspective. Verification of the presence of significant amounts of liquid water on one or more of these satellites, study of their surface and subsurface chemistries, and determination of the thicknesses of the ice crusts would allow us to understand the history and biological potential of the Galilean satellites and lay the groundwork for future missions. Studies of Europa Explorer mission concepts have been undertaken for the past decade. Recent advances in technology and engineering developments have made such a mission feasible with today's technology. Such a mission would achieve the top-priority Decadal Survey objective of focused Europa geophysical exploration.

The fundamental objectives of any Europa mission will be to determine the existence of a subsurface water ocean and to characterize the composition and physical properties of the overlying ice. Mission concepts vary in relation to the extent to which they define, meet and exceed these two fundamental science objectives. Europa's sibling moons Ganymede and Callisto likely also contain subsurface watery layers, though much deeper beneath the surface than Europa's. Moreover, long-term variability in Io's heating may intimately affect the evolution and habitability of Europa. It is critical to determine how the components of the Jovian system operate and interact, leading to potentially habitable environments within icy moons. By studying the Jupiter system as a whole, we can better understand the type example for habitable planetary systems within and beyond our Solar System.

Solar System Exploration Roadmap Committee, 2003. *SRM3 – The Solar System Exploration Strategic Roadmap*. NASA, Washington, DC.

The first key decision point occurs in the 2006/2007 timeframe for the start of the Europa Geophysical Orbiter. The stunning discovery of a young icy surface, perhaps covering an ocean with a potentially habitable environment in Europa, made this mission one of the highest priorities for a new start flagship mission in the NRC decadal survey. The technology and capabilities are ripe for a new start. The Vision for Space Exploration, supported by the objectives of the Solar System Exploration roadmap and its emphasis on habitability, clearly reinforce this recommendation.

Solar System Exploration ["Decadal"] Survey (2003). *New Frontiers in the Solar System: An Integrated Exploration Strategy.* National Academies Press, Washington, DC.

Europa Geophysical Exploration mission is the first priority in large-cost class.

[T]he EGE mission ... seeks primarily to define a possible habitat for life by vastly expanding our current knowledge of a subsurface ocean.

One Flagship mission is recommended for this decade, the Europa Geophysical Explorer.

Europa Geophysical Explorer

Europa holds the most promise for understanding the biological potential of icy satellites. There is convincing evidence for the presence of liquid water within just tens of kilometers of the surface, and there is evidence for recent transfer of material between the surface and the water layer. Europa's ocean is probably in direct contact with a rocky mantle below and potentially endowed with hydrothermal systems, so chemical disequilibrium may be able to nourish oceanic organisms. The first step in understanding the potential for icy satellites as abodes for life is a Europa mission with the goal of confirming the presence of an interior ocean, characterizing the satellite's ice shell, and understanding its geological history. Europa is important for addressing the issue of how far organic chemistry goes toward life in extreme environments and the question of how tidal heating can affect the evolution of worlds. Europa is key to understanding the origin and evolution of water-rich environments in icy satellites. **The SSE Survey endorses the current recommendations for a mission to orbit Europa. However, given the high cost of the EGE mission we consider it essential that the mission address both Group1 and Group 2 science objectives described by the Europa Orbiter Science Definition Team.**

Committee on Planetary and Lunar Exploration (COMPLEX), Space Studies Board, National Research Council, 1999. *A Science Strategy for the Exploration of Europa*. National Academies Press, Washington, DC.

Priority Status of Europa Exploration

With the likelihood that it has vast quantities of liquid water beneath its icy surface, Europa is one of the places in our solar system with the greatest potential for the existence of life. Along with Mars, it appears to possess all of the environmental conditions necessary to support the origin and the continued existence of biota. As a result, finding evidence that might indicate whether life had existed on either Mars or Europa would help us to understand whether our theories for the origin of life on Earth are correct and would help us to understand whether life might be widespread outside our solar system.

Thus, **COMPLEX concludes that Europa is an exciting object for additional study following the completion of the Galileo mission. It offers the potential for major new discoveries in planetary geology and geophysics, planetary atmospheres, and, possibly, studies of extraterrestrial life. In light of these possibilities and the equal priority given to the exploration of Mars and the Jupiter system by COMPLEX's *Integrated Strategy,* COMPLEX feels justified in assigning the future exploration of Europa a priority equal to that for the future exploration of Mars. This equality must, however, be tempered by the uncertainty as to whether liquid water is actually present and the technological challenges posed by the exploration of Europa.**