The High Priority and Relevance of Europa Exploration

Galileo Galilei's discovery of moons of Jupiter in 1610 advanced the Copernican Revolution. Now nearly 400 years later, one of these moons–Europa–has the potential for discoveries just as profound. Europa's icy surface is believed to hide a global subsurface ocean with volume nearly three times that of Earth's oceans[1]. The moon's surface is young, with a nominal age of 50 million years, implying that it is most likely geologically active today[2]. The primitive materials that nourish life have rained onto Europa throughout solar system history, are created by radiation chemistry at its surface, and may pour from vents at the ocean's deep bottom[3]. On Earth, microbial extremophiles take advantage of environmental niches arguably as harsh as within Europa's subsurface ocean[4]. If the subsurface waters of this Galilean moon were found to contain life, the discovery would spawn another revolution, this time in our understanding of life in the universe.

The astrobiological potential of Europa has been revealed in recent years through spectacular data from the Galileo spacecraft. The existence of liquid water in the outer solar system was once thought a remote possibility, but the combination of geological, gravitational, and magnetic field observations and theory make it appear quite possible–even likely–that liquid water exists beneath Europa's icy surface[1]. It is now recognized that oceans may exist within many large icy satellites, but Europa's inferred thin ice shell and potentially active surface-ocean exchange elevate its priority for astrobiological exploration. A Europa mission is the first step in understanding the potential for icy satellites as abodes for life.

The high priority and relevance of Europa to scientific advancement has been recognized by several national committees. In 1994, the Space Studies Board of the National Research Council recognized that Europa's geology and geophysics along with its potential for extraterrestrial life assigned Jupiter system exploration a priority equal to that of the exploration of Mars[5]. In 1999, the Committee on Planetary and Lunar Exploration of the National Research Council (NRC), while acknowledging the technological challenges involved in Europa exploration, reaffirmed that Europa exploration should be assigned a priority equal to that of Mars exploration[6]. In 2003, the decadal Solar System Exploration Survey[7] of the NRC called for a Europa orbiting spacecraft as the single highest priority large "flagship class" exploration mission for the decade 2003-2013. Such a spacecraft mission would confirm the existence of Europa's subsurface ocean, characterize in detail the moon's surface and icy shell, and conduct reconnaissance vital for future landed exploration.

Much of NASA's current planetary exploration focus, and that planned for the future in NASA's exploration vision[8], is placed on the astrobiological potential of Mars, which likely once had liquid water on its surface and may have water underground today. Given that Europa appears to currently possess the three main criteria for the existence of life as we know it (liquid water, sufficient energy sources, and organic building blocks)[3], Europa is equally as promising a place to look for extant life in our solar system. Moreover, the proximity of Mars to Earth means that the two planets could have exchanged biological materials over solar system history, transferred in meteorites like those found on Earth[9]. Thus, life originating on one planet could have spread to its neighbor, plausibly resulting in a single tree of life with a common ancestor at some point early in biological history. On the other hand, transfer of biological materials between Earth and distant Europa is quite unlikely, so any life on Europa would probably have a completely independent origin. If organisms exist there, Europa would provide essential evidence for a distinct origin, and perhaps a distinct chemistry, of life.

To fully understand the planetary context and origin(s) of life in the solar system, a systematic program of astrobiological exploration is necessary for both Mars and Europa. Europa is a challenging exploration target because of significant travel times, a severe radiation environment, and the lack of a substantial atmosphere for aerobraking. Moreover, planetary protection is a vital issue because any forward contamination of Europa's ocean at one location could enable global access for contaminants[10]. Nonetheless, Europa's priority as an exploration target requires that technology hurdles be addressed with sufficient near-term investment. Technology sharing and complementarity between Europa and

Mars exploration should be encouraged, most notably in life detection experiments and planetary protection.

The extremely high priority of Europa exploration calls for concomitant attention and dedication to Europa exploration not only in the distant future but in the present decade, and with priority equal to that of Mars. Europa exploration, which has the potential for finding extant life in our solar system, must be central not only to NASA's exploration vision, but to its exploration implementation.

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[1] Greeley, R., C. Chyba, J. W. Head, T. McCord, W. B. McKinnon, R. T. Pappalardo, and P. Figueredo, Geology of Europa, in *Jupiter: The Planet, Satellites & Magnetosphere* (F. Bagenal et al., eds.), pp. 329-362, 2004.
[2] Zahnle, K., P. Schenk, H. Levison, and L. Dones, Cratering rates in the outer Solar System, *Icarus*, *163*, 263–289, 2003.
[3] Chyba, C. F. and C. B. Phillips, Possible ecosystems and the search for life on Europa, *Proc. Nat. Acad. Sci.*, *98*, 801-804, 2001.
[4] Horikoshi, K. and W.D. Grant (eds.), *Extremophiles: Microbial Life in Extreme Environments*, Wiley-Liss: New York, 1998.
[5] Space Studies Board, National Research Council, *An Integrated Strategy for the Planetary Sciences: 1995-2010*, National Academy Press, Washington, D.C., 1994.
[6] Committee on Planetary and Lunar Exploration, National Research Council, *A Science Strategy for the Exploration of Europa*, National Academy Press, Washington, D.C., 1999.
[7] 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.
[8] President's Commission on Implementation of United Spates Space Exploration Policy, *A Journey to Inspire, Innovate, and Discover*, Washington D.C., 2004.
[9] Mileikowsky, C., F. Cucinotta, J.W. Wilson, G. Horneck, L. Lindgrin, H.J. Melosh, H. Rickman, and M. Valtonen, Natural transfer of viable microbes in space: 1. From Mars to Earth and Earth to Mars, *Icarus*, *145*, 391-427, 2000.
[10] Space Studies Board, National Research Council, *Preventing the Forward Contamination of Europa*, National Academy Press, Washington, D.C., 2000.