SCIENCE THAT CAN BE ACHIEVED FROM THE EUROPA CLIPPER MISSION CONCEPT: A MEANS TO EXPLORE EUROPA AND INVESTIGATE ITS HABITABILITY. D. Senske[1], L. Prockter[2], R. Pappalardo[1], M. Mellon[3], W. Patterson[2], S. Vance[1], B. Cooke[1], and the Europa Study Team. [1]Jet Propulsion Laboratory/California Institute of Technology, Pasadena, CA 91109, [2]Johns Hopkins Applied Physics Laboratory, Laurel, MD, 20723, [3]Southwest Research Institute, Boulder, CO 80302.

Introduction: The 2011 Planetary Science Decadal Survey, "Visions and Voyages" [1] emphasizes the importance of Europa exploration as "the first step in understanding the potential of the outer solar system as an abode for life [1]." Although the previously studied Jupiter Europa Orbiter (JEO) concept [2,3] would address science that would revolutionize the understanding of icy world habitability, it was deemed too expensive in light of current and projected NASA budgets. In response, an immediate effort was launched to find major cost reductions for the JEO concept. A Europa Science Definition Team (SDT) and Technical Study Team identified both Europa Orbiter and multiple flyby (called the Europa Clipper) options that could achieve high priority Europa science, albeit not all the key science objectives derived by the JEO SDT could be achieved by each standalone platform. The results of these studies were delivered to NASA in May of 2012 [4]. Subsequently, NASA directed the SDT and Technical Team to optimize and enhance these reduced-scope Europa missions to better achieve the science objectives within a cost target of $2.0B ($FY15, excluding launch vehicle). In this paper, we discuss the science that could be achieved by the Europa Clipper concept, a spacecraft in orbit around Jupiter that would make observations over the course of 34 flybys of Europa. The Clipper concept was endorsed by the SDT as addressing a greater breadth of science relative to a Europa Orbiter concept.

Background: Understanding Europa's habitability is intimately tied to understanding the three "ingredients" for life: water, chemistry, and energy. Starting from this foundation, the SDT identified a set of four objectives that any mission to Europa would need to address; (1) *Ocean*: confirm the existence, extent, and salinity of a subsurface ocean, (2) *Ice Shell:* assess the existence and nature of water within or beneath the ice shell and determine the nature of surface-ice-ocean exchange, (3) *Composition:* evaluate the distribution and chemistry of key compounds and the links to ocean composition, and (4) *Geology*: examine the characteristics and formation of surface features, including sites of recent or current activity.

Ocean and Ice Shell: To assess Europa's habitability, it is necessary to determine how the ingredients for life might be brought together in this environment. This includes unraveling the dynamic processes that connect Europa's underlying ocean to the surface of its ice shell. Therefore, a detailed understanding of the internal structure of Europa's ice is essential. Probing the third dimension of the shell would be key to understanding the distribution of subsurface water both within and beneath the ice shell. Understanding the processes of ice–ocean exchange would indicate whether surface oxidants can be transported to Europa's ocean, providing the chemical nutrients for life.

As it orbits Jupiter, Europa is continually flexed, tugged, and deformed by the gravity of this gas giant. Consequently, the satellite's tidal response enables the characteristics of its ocean and ice to be observed and inferred. Europa also experiences the magnetic field of Jupiter, which generates induction currents in the satellite's interior, enabling its conductivity structure to be inferred. These external influences, in addition to Europa's internal thermal and chemical properties, create the possibility that Europa's deep interior is volcanically active.

Possible means to constrain models of Europa's interior include measurements of the gravitational and magnetic fields and the rotational state of Europa, each of which includes steady state and time-dependent components. Taken together, results from measuring a range of geophysical parameters would be fundamental to characterizing the ocean and the overlying ice shell and would provide constraints on deep interior structure and processes.

Composition: The current understanding of Europa's bulk density and of solar and stellar composition suggests the presence of both water and silicates. It is likely that the differentiation of Europa resulted in mixing of water with the silicates and carbonaceous materials that formed the satellite, resulting in chemical alteration and redistribution. Interior transport processes could then have brought a variety of materials from the interior first into the ocean and from there up to the surface.

Characterizing the surface organic and inorganic composition and chemistry provides fundamental information about Europa's history and evolution, the composition, transport properties and habitability of the subsurface and ocean, their interaction with the surface, and the role of exogenic processes. Surface materials might be ancient, derived through time from the ocean and altered by radiation, or they might be exogenic in origin. Surface materials oxidized by the intense surface radiation are probably incorporated into the subsurface, affecting the ocean's composition and providing chemical energy essential for habitability. Sputtered materials from the surface probably form Europa's tenuous atmosphere. Low altitude spacecraft flybys could provide opportunities to sample this atmosphere, allowing direct compositional measurements.

Geology: By understanding Europa's varied and complex geology at scales of 10s to 100s of meters, it is possible to decipher the moon's past and present processes, along with implications for habitability. An area of focus for the Clipper Mission would be to identify sites of most recent geological activity.

The relative youth of Europa's surface (60 million years on average) [5] compared to most other solar system bodies is inherently linked to the ocean and the effects of gravitational tides, which trigger processes that include cracking of the ice shell, resurfacing, and possibly a release of materials from the interior. It is thus important to understand the formation processes and three-dimensional characteristics of magmatic, tectonic, and impact landforms.

Reconnaissance: Science achieved by the Clipper would provide a global characterization of Europa. It is anticipated that a next logical step to address scientific questions regarding the habitability and composition of this icy world's subcrustal ocean would be to land a spacecraft capable of *in situ* sampling and analysis. From the recent study of a lander concept [4] it became clear that additional information is needed regarding surface characteristics and properties to robustly architect a low-risk lander concept within a reasonable cost. To maximize success of a landed mission, ensuring both safe landing and access to surface material of highest scientific value, some level of reconnaissance is necessary.

The goals of obtaining reconnaissance data are twofold. The first goal is to provide information about the nature of Europa's surface to enable the design of a landed spacecraft, optimize a scientific payload, and develop a mission profile. The second goal of reconnaissance is to obtain sufficient information about the surface hazards and scientific characteristics at specific candidate landing sites. Without realizing both of these goals a landed mission will incur an unacceptably high risk. Including a reconnaissance remote-sensing package (e.g. a high resolution camera and thermal imager to map thermal inertia) on the Europa Clipper would present the most efficient way of obtaining this needed data.

The Clipper mission: To achieve the Europa science objectives, a flight system and mission design are required that can accommodate a capable science payload that will provide information on the three-dimensional structure of Europa. The notional set of science instruments identified by the SDT include, an Ice Penetrating Radar (IPR), Topographic Imager (TI), Shortwave Infrared Spectrometer (SWIRS), Neutral Mass Spectrometer (NMS), Magnetometer (MAG), Langmuir Probe (LP), and the spacecraft Radio Subsystem (RS) with an independent gimbaled antenna (separate from the spacecraft telecom antenna). In addition reconnaissance capability would include a Reconnaissance Camera (RC) and a Thermal Imager (ThI). To achieve adequate surface coverage, a mission design that incorporates 34 close flybys (32 illuminated) of Europa has been developed. The overall mission architecture would provide for radiation-shielded instruments and is optimized for the mass, power, and data rate of the payload.

Conclusions: A Jupiter-orbiting spacecraft that makes many flybys of Europa would provide an excellent platform from which to conduct measurements to investigate Europa's ocean and ice shell, composition, and geology, and thus the ingredients for life. Most of the required measurements would be achieve through remote sensing techniques that tend to be resource-intensive, in terms of data volume and data rate drivers. Such needs would be readily accommodated through implementation of the Europa Clipper concept.

References: [1] Space Studies Board, (2011) The National Academies Press, Washington, DC. [2] Clark, K., *et al.,* (2008) JPL Internal Document D-48279, 2008. [3] Pappalardo, R., *et al.,* (2010) JPL Internal Document D-67959. [4] Europa Study Team, (2012) JPL Internal Document D-71990. [5] Schenk, P., *et al.,* (2004) in Jupiter: The Planet, Satellites, and Magnetosphere, pp. 427-457.