

OPAG EUROPA SUBGROUP

Ron Greeley

June 9, 2005

The goal: Develop science rationale for Europa Orbiter (taking into account previous studies, etc.)

The people:

Ron Greeley (*Chair*)

Bruce Campbell

Kris Khurana

Nick Makris

Chris McKay

Bill Moore

Bob Pappalardo

Louise Prockter

Hunter Waite

ex officio

Curt Niebur

Torrence Johnson

Fran Bagenal

JPL Team

Jackie Green (*lead*)

Rob Abelson

Bill Smythe

Soren Madsen

Rob Staehl

Jim Shirley

Tom Spilker

The process: Weekly telecoms and frequent e-mail exchanges

EUROPA ORBITER SCIENCE OBJECTIVES

OPAG EUROPA SUBGROUP

*(No prioritization intended for objectives; numbered sub-objectives are in priority order)**

Confirm the presence of a subsurface ocean 1

1. Determine the amplitude and phase of the gravitational tide 1.1
2. Determine the amplitude and phase of the induced magnetic field at several frequencies 1.2
3. Determine the amplitude and phase of the surface motion during a tidal cycle 1.3
4. Determine the amplitude of libration 1.4
5. Search for active, tidally-induced crustal deformation features 4.1 + 4.2

Characterize the 3-dimensional configuration of the icy crust, including possible zones of liquid 2

1. Search for shallow subsurface liquids 2.1
2. Determine possible correlation of surface features to subsurface structure 2.3
3. Characterize the physical properties of the regolith and possible links to the interior 2.4
added: 2.2 Search for an ice-ocean interface

Map organic and inorganic surface compositions, especially as related to astrobiology 3 *added: 3.1 Characterize surface organic and inorganic chemistry.*

1. Relate compositions to geological processes, especially with regard to possible "communication" with the interior 3.2
2. Characterize past and present "habitability" ⇒ *incorporated into overall goal & 3.1*
3. Search for indicators/constraints of past or present life 3.6

**It might not be possible to meet all of the sub-objectives, but they should be addressed by priority*

OPAG ORBITER SCIENCE OBJECTIVES (CONT.)

*(No prioritization intended for objectives; numbered sub-objectives are in priority order)**

Characterize surface features and identify candidate sites for future exploration 4

1. Characterize magmatic and tectonic features **4.1**
2. Search for areas indicative of surface-subsurface exchange *incorporated into 2 & 2.3*
3. Search for areas of recent or current geological activity **4.2**
4. Assess erosion and deposition processes (impact gardening, mass wasting, micrometeoroid mass flux and composition in Europa's orbit, etc.) **4.5**
5. Investigate local and global heat flow **4.3**
6. Assess surface ages and subsurface structure using impact craters **4.4**

Characterize the magnetic field and radiation environment 5

added: 5.1 Characterize the magnetic environment at multiple frequencies

1. Characterize perturbations to the magnetic field from plasma **5.3**
2. Determine the radiation effects on surface ice redox chemistry **3.3**
3. Characterize exogenic material derived from the Jovian plasma **3.4**
4. Characterize magnetospheric sputtering interactions with the surface **3.5**
5. Determine the structure and dynamics of the ionosphere and neutral atmosphere **5.2**
6. Characterize the deep interior of Europa **5.4**

added: 5.4 Characterize the radiation environment

Understand the heat source(s) and time history of Europa *expanded to become 6*

1. Determine the nature and history of the internal heat source(s) *expanded to become 6.1*
2. Characterize the age of the surface via the cratering history of the Galilean satellites *incorporated into 6.2*

Level 2 – not part of science floor

1. Study Jupiter's atmosphere as input to the magnetosphere and its role in Europa's evolution *incorporated into 6.3*
2. Investigate Jovian aurora processes and links to the interplanetary solar wind and field-aligned current flows around the moons *incorporated into 6.3*
3. Characterize the Jovian rings and the relations to collisions with the moons *incorporated into 6.3*
4. Europa's initial bulk composition and evolution (salts, water) *incorporated into 6.1 & 6.2*

**It might not be possible to meet all of the sub-objectives, but they should be addressed by priority*

NAI Europa Focus Group

Bob Pappalardo

March 10, 2006

The goal: Consider OPAG Europa Orbiter objectives, and suggest modifications from the perspective of the Europa astrobiological community, including an overall mission goal and a write-up of justifications for the goal and objectives.

The people:

Ron Greeley (ASU) (*Europa Focus group chair*) +

Torrence Johnson (JPL) (*meeting co-chair*) +

~50 break-out group participants +

Bob Pappalardo (Univ. Colorado) (*Break-out group lead*)

Don Blankenship (UTIG)

Amanda Hendrix (JPL)

Krishan Khurana (UCLA)

Bill Moore (UCLA)

Louise Prockter (APL)

The process: Group discussion with follow up by leads assigned to each major objective.

EUROPA EXPLORER SCIENCE OBJECTIVES

NAI Europa Focus Group

March 10, 2006

Goal:

- **Explore Europa and Determine its Potential for Life**

Objectives:

- **Characterize the ocean through its effects on potential fields and its dynamic relationship with the ice shell.**
- **Characterize processes operating within the ice shell, and the nature of ice-ocean exchange.**
- **Determine surface compositions and chemistry, especially as related to habitability.**
- **Understand the formation of surface features, including sites of recent or current activity, and identify candidate sites for *in situ* exploration.**
- **Characterize the magnetic environment and moon-particle interactions.**
- **Determine how the components of the Jovian system operate and interact, leading to potentially habitable environments in icy moons.**

EUROPA EXPLORER SCIENCE OBJECTIVES

NAI Europa Focus Group

*(No prioritization intended for objectives; numbered sub-objectives are in priority order)**

Characterize the ocean through its effects on potential fields and its dynamic relationship with the ice shell.

1. Determine the amplitude and phase of the gravitational tide.
2. Determine the induction response from the ocean over multiple frequencies.
3. Characterize surface motion over the tidal cycle.
4. Determine the amplitude of libration.

Characterize processes operating within the ice shell, and the nature of ice-ocean exchange.

1. Characterize the distribution of any shallow subsurface water.
2. Search for an ice-ocean interface.
3. Correlate surface features and subsurface structure.
4. Characterize the physical properties of the regolith and possible links to the interior.

Determine surface compositions and chemistry, especially as related to habitability.

1. Characterize surface organic and inorganic chemistry.
2. Relate compositions to geological processes, especially communication with the interior.
3. Determine the radiation effects on surface materials.
4. Characterize exogenic material associated with the Jovian plasma.
5. Characterize magnetospheric sputtering interactions with the surface.
6. Search for compositional indicators of past or present life.

**It might not be possible to meet all of the sub-objectives, but they should be addressed by priority.*

EUROPA EXPLORER SCIENCE OBJECTIVES (CONT.)

*(No prioritization intended for objectives; numbered sub-objectives are in priority order)**

Understand the formation of surface features, including sites of recent or current activity, and identify candidate sites for *in situ* exploration.

1. Characterize magmatic, tectonic, and impact features.
2. Search for areas of recent or current geological activity.
3. Investigate global and local heat flow.
4. Assess surface ages.
5. Assess processes of erosion and deposition.

Characterize the magnetic environment and moon-particle interactions.

1. Characterize the magnetic environment at multiple frequencies.
2. Determine the structure and dynamics of the ionosphere and neutral atmosphere.
3. Characterize relationships between the magnetic field and plasma.
4. Investigate the deep interior.
5. Characterize the radiation environment.

Determine how the components of the Jovian system operate and interact, leading to potentially habitable environments in icy moons.

1. Determine the nature and history of the internal heat sources and interior evolution of the Galilean satellite system.
2. Investigate the geological processes and surface evolution of the Galilean satellite system.
3. Study the Jovian system as a model for other potentially habitable planetary systems.

**It might not be possible to meet all of the sub-objectives, but they should be addressed by priority.*

Science Objectives from Europa Orbit

Europa Focus Group
(Modifications of OPAG Europa Subgroup Objectives)

March 28, 2006

Revised April 10, 2006

Goal:

Explore Europa and Determine its Potential for Life

Nearly 400 years after Galileo Galilei's discovery of Jupiter's moons advanced the Copernican Revolution, one of these moons, Europa, has the potential for discoveries as profound. Europa's icy surface is believed to hide a global subsurface ocean with volume nearly three times that of Earth's oceans. The moon's surface is young, with a nominal age of 60 million years, implying that it is most likely geologically active today. 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. On Earth, microbial extremophiles take advantage of environmental niches arguably as harsh as within Europa's subsurface ocean. If the subsurface waters of this Galilean moon are found to contain life, the discovery would spawn another scientific revolution, this time in our understanding of life in the universe.

The potential for habitability of Europa has been revealed in recent years through spectacular data from the Galileo spacecraft. Though an ocean beneath Europa's surface ice was once thought to be a remote possibility, the combination of geological, gravitational, and magnetic field observations made by the Galileo spacecraft make it appear quite likely that liquid water exists beneath Europa's icy surface today. However, the Galileo spacecraft was not designed to characterize Europa's ocean and ice shell. Thus, new objectives arise for the exploration of Europa, and to determine its potential to support microbial life. Although it is now recognized that water may exist within several of the solar system's icy satellites, Europa's relatively 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 following set of six science objectives are recommended as guiding a mission to explore Europa and determine its potential for life. Each is considered part of the science floor, and all are intended to be of equal importance.