Air and Space this Week

Item of the Week

THE EUROPA CLIPPER MISSION

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KEY WORDS: Galileo Jupiter Europa Clipper

The Item of the Week in the previous installment of "Air and Space this Week" dealt with the highly-successful Galileo orbital mission and the valuable data it returned about Jupiter and its four large satellites. This week's installment is a continuation of that topic, a closer look at Europa, arguably Jupiter's most important object.

On October 14, 2024, NASA successfully launched its latest exploration mission to Jupiter, the Europa Clipper*. Its mission is to examine Europa during a total 49 close fly-bys, looking at its unusual surface features and acquiring other data that address the hypothesis formed from previous studies: Does Europa have sub-surface conditions conducive to life?*

EARLIER STUDIES OF JUPITER AND ITS MOONS

The study of Jupiter and its Moons from the time of Galileo through the completion of NASA's Galileo mission was covered in the previous Item of the Week.

Little was learned of the four Galilean satellites, Io, Europa, Ganymede, and Callisto, prior to spacecraft observations. But in 1972, astronomers at Kitt Peak were able to acquire spectra of Europa that showed conclusively the presence of water ice, and lots of it, which could explain Europa's bright white color. Neither *Pioneer 10* nor *11* got close enough during their fly-bys to be able to image the surface at high enough resolution to determine any details.

But that all changed on March 4, 1979, when *Voyager 1*'s better cameras acquired images from 1.2 million miles away. They showed that the surface of Europa was mottled, with bright and dark patches similar in appearance to the highlands and maria of the Moon. The amazing "Called Shot" discovery of active volcanoes on Io grabbed the headlines, but the interest of planetologists was collectively piqued by the presence of dark lines criss-crossing Europa's surface. Shades of Lowell's canals! The arrival at Jupiter of *Voyager 2* was eagerly awaited, for its trajectory would take it much closer to Europa and its enigmatic surface.

And they were not disappointed.

On July 9, 1979, *Voyager 2* flew by Jupiter and acquired pictures that were somewhat better than those of *Voyager 1*. The pictures showed that the dark lines were fractures, many of which had separately slightly. They were eerily similar to the cracks formed in sea ice, familiar

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to pilots in polar regions!   What's more (or less, actually), the images showed that there were almost no impact craters visible anywhere on Europa. It is certainly getting peppered by impactors, so seeing so few meant that the smooth, icy surface had to be very young. Something had to be erasing craters, either by burial or erosion, relatively quickly.

The calculations of the heating of Io by internal tides raised in it by the gravitational pulls of Jupiter and Europa were proved correct dramatically with the confirmation of the prediction that Io would have to be volcanically active. The same calculations, when applied to Europa, show that the gravitational pull of Jupiter, Io, and Ganymede would cause significant internal heating, but less than that of Io, but high enough to facilitate the differentiation of Europa, with it forming a rocky core mantled by lighter materials, including water. The heating would be enough to keep the water layer liquid, even if its surface would freeze. Internal movement of water, driven by thermal currents in the ocean, could cause the observed fracture patterns, and periodic eruptions of liquid water would bury any craters formed on a geologically-short timescale. The internal heat flow at the bottom of a Europan ocean would likely not be fully-uniform, there would be hot spots, likely akin to deep-ocean hot springs seen on Earth. On Earth, almost every deep-water hot spring cluster is the host of a great variety of living things!

Could it be possible that Europa has all of the ingredients necessary for life to arise and flourish?

GALILEO

The *Galileo* spacecraft, over the course of its mission, made twelve close fly-bys of Europa. Images returned confirmed initial impressions. Further, the magnetometer aboard *Galileo* showed that Europa distorted Jupiter's magnetic field in a manner consistent with Europa having a deep layer of some electrically-conductive fluid beneath its surface. The most likely candidate for the layer is that it is salty water! Measurements of Europa's mass, size, and angular momentum suggest that the watery layer on Europa would be on the order of tens of miles deep, capped by an icy crust 10-15 miles thick.

We have since learned that Saturn's moon, Enceladus, has a similar internal heating mechanism and similar surface features. Plumes of water were seen blasting from some of the cracks there, and the *Cassini* spacecraft was actually sent into one near the end of its mission. Its instruments showed water with a chemical composition similar to that of hot springs!

No such geyser plumes were seen at Europa initially, but ground-based observations, a re-analysis of *Galileo* data, and observations by the Hubble Space Telescope showed that Europa is releasing water from its subsurface, too. All of the ingredients of life, liquid water, the right chemistry, an energy source, and time, seem to be present at Europa, and it's easier to reach than Enceladus.

A QUICK REVIEW OF THE DRAKE EQUATION

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Frank Drake is widely regarded as the Father of the Search for Extraterrestrial Intelligence, a topic I covered in a previous Item of the Week. He created a sieve-like process to assess the abundance of potential civilizations in the Milky Way, starting with the number of stars in the Milky Way, then multiplying by a series of percentages, to arrive at the number of places where technologically-advanced life might have arisen. Leaving the technological capability aside, the same process can assess the likelihood of life arising elsewhere.

Two of the factors needed are the percentage of stars that have planets capable of supporting life, and the percentage of those planets where life has actually arisen. Neither were known when Drake formulated the Equation, but we've made a lot of progress since then.

I devote an entire section of the News: Astronomy section of this newsletter to exoplanets. Since Drake, we've found over 5500 of them in our small section of the Milky Way. There must be millions and millions more, and that's just in one galaxy of the billions and billions around us.

The key factor, then, is "What percentage of planets capable of supporting life did life actually arise?" It could be that the percentage is totally miniscule, meaning that we are alone in our section of the Universe. But…

There are four places in our own Solar System where we think conditions needed for life presently, or once, existed: Earth, Mars, Europa, and Enceladus. If Earth is the only one where life developed, we could be alone. BUT, if any one of the others either has or had life, the implications are astounding! We could be unique, but if TWO places where life arose just happen to be in one tiny solar system out of billions, it would be quite ridiculous to assume that the only two ever just happened to be here. We are unique, or life is abundant.

And figuring out Europa is the key to resolving the issue, hence NASA's launch last week of the spacecraft designed to help planetologists out, the…

EUROPA CLIPPER

The scientific objectives of the Europa Clipper mission are:

Determine the Thickness of Europa's Icy Shell & How the Ocean Interacts with the Surface	Scientists aim to determine the thickness of Europa's icy shell – the moon's outer layer that includes its surface. They will discover whether there's liquid water within and beneath the shell. Researchers will estimate the size, saltiness and other qualities of Europa's ocean. They also will determine how the ocean interacts with the surface: Does anything in the ocean rise up through the shell to the top? Does any material from the surface work its way down into the ocean?
Investigate Europa's Composition	Scientists will investigate the composition of Europa's ocean to determine if it has the ingredients to permit and sustain life.

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Characterize the Geology of Europa	Scientists will study how Europa's surface features formed and locate any signs of recent activity such as sliding crust plates or plumes that are venting water into space.

Table from: https://europa.nasa.gov/mission/science

INSTRUMENTAION

Europa Clipper will carry instruments designed to help scientists meet the above objectives.

Four imaging systems will be used, covering a wide range of the EM spectrum:

> Thermal IR: The Europa Thermal Imaging System (E-THEMIS) will determine surface temperatures to assess if there have been any recent eruptions of water. A version of the THEMIS camera has been in use on the Mars Odyssey spacecraft for almost 25 years, producing valuable data on the thermal and physical properties of surface materials. Imagine what the improvements in technology in the E-THEMIS will show us!
>
> Near IR: The Mapping Imaging Spectrometer for Europa (MISE) will map the distribution and composition of surface materials, many of which have diagnostic spectral signatures in the near IR part of the spectrum.
>
> Visible: The Europa Imaging System (EIS) comprises two visible light cameras, one wide angle, and one narrow angle, providing high-resolution color images, with an imaging rate that will allow the creation of stereoscopic images, which will be a boon for the study of geologic processes.
>
> UV: Europa Ultraviolet Spectrograph (Europa-UVS) will help determine the chemical composition of the surface and any atmospheric plume/gases, many of which have diagnostic spectral signatures in the UV parr of the spectrum.

Other Instruments:

> Europa Clipper Magnetometer (ECM) data will build on the observations made by the magnetometer on *Galileo* decades before, which led to the recognition that Europa has a liquid sub-surface ocean.
>
> Plasma Instrument for Magnetic Sounding (PIMS): Jupiter's intense magnetic field induces a magnetic field at Europa, the nature of which can reveal information about the depth of and conductivity of Europa's ocean, and the thickness of its icy shell.
>
> Gravity/Radar Science: Europa's gravity field will make subtle but measurable changes in the wavelength of radio signals going to/from the spacecraft, allowing detailed measurement of Europa's gravity field to be measured, which in turn will reveal details of Europa's internal structure.
>
> Radar for Europa Assessment and Sounding: Ocean to Near-Surface (REASON): Radar signals from REASON can penetrate Europa's icy shell about 18 miles, revealing the

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internal structure of the shell and probably show its thickness. Radar reflections from Europa's surface will reveal topographic, compositional, and roughness characteristics. Lastly, REASON radar can detect plume activity.

MAss Spectrometer for Planetary EXploration (MASPEX): Jupiter's radiation, vented plumes, or impacts all litter the near-surface environment of Europa. The composition of material collected by MASPEX can be determined with great precision. Such data will help assess the (potential for) internal chemical processes potentially conducive for life.

MISSION PROFILE

The *Europa Clipper* spacecraft, built by the Jet Propulsion Laboratory, is the largest ever used for a planetary exploration mission, 100 feet long and 58 feet wide when its solar panels and radar antennae are fully-deployed. It's heavy too; its launch weight was 6067 kg (13,371 pounds), of which 2750 kg (6060 pounds) was propellant, half of which is needed for entering Jupiter orbit. The spacecraft's payload weight is 352 kg (776 pounds).

Electrical power for the spacecraft was an issue; only two power sources were available, radioisotope thermal generators or solar. Plutonium for RTGs is very expensive, and an Earth gravity assist for a spacecraft with an RTG power system causes public protests. However, the solar energy available at Jupiter is only 4% of what it is at Earth, and the systems of the spacecraft require 600 watts of power. Going solar would mean that four large solar panels would be needed, each with a surface area of 18 square meters, and that the solar panels would need to be able to withstand the intense radiation near Jupiter for an extended period. The panels are heavier than an RTG system, too. The weight issue was not decisive, and the solar panel system was chosen.

A large high-gain antenna was required to be able to communicate with Earth from the distance of Jupiter. It is 3.1 meters in diameter. REASON's antenna is big, too; 16 meters long.

Europa Clipper will use two gravity assists on its way to Jupiter, one of Mars on March 1, 2025, and one of Earth on December 3, 2026. Jupiter Orbit Insertion is planned for April 11, 2030. The orbit will be quite elliptical, to help minimize radiation damage risk to the spacecraft. Forty-nine close passes of Europa are planned, and at the end of its operational lifetime, the spacecraft will be crashed into Ganymede as a planetary protection measure, which will also assist ESA's *JUICE* spacecraft's goal of determining the composition of Ganymede's surface (The *Jupiter Icy Moons Explorer* spacecraft, the subject of a future Item of the Week, is now *en route* to Jupiter).

Jupiter's magnetic field is ~20,000 times stronger that of Earth. It captures and accelerates solar wind charged particles and other materials from its surroundings, producing damaging radiation. *Europa Clipper*'s instruments are shielded somewhat, and trajectory planners will guide the Europa approaches to keep radiation exposure at a minimum, but even so, the spacecraft will be exposed to the equivalent of several million chest X-rays on each flyby.

There had been some concern a few months before launch that the transistors built into the *Europa Clipper*'s electronic infrastructure might not be as resistant to radiation as designers

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thought. An exhaustive review immediately followed, with the end result that the mission was cleared for launch. Engineers found that heating the electronics to room temperature after a fly-by would cause the transistor materials to "anneal," a process that would eliminate (heal) the damage received.

Europa Clipper Intern Program: The first group of interns for the Europa Clipper program have been selected; an intern group will be selected each year for the duration of the mission (2034). For more information, see: https://www.jpl.nasa.gov/news/nasa-selects-students-for-europa-clipper-intern-program.

Prediction: Jim Green was the head of NASA's Planetary Science Division when I was there on detail. He was convinced that evidence of extra-terrestrial life, or at least the conditions favorable to the development of life, would be found in our Solar System in his lifetime. May we all live long enough, *Europa Clipper* included, to find out that he was right!

RESOURCES

EUROPA

NASA Facts: https://science.nasa.gov/jupiter/moons/europa/europa-facts

NASA Europa Up Close: https://europa.nasa.gov/why-europa/europa-up-close

NASA: https://europa.nasa.gov/news/33/europa-a-world-of-ice-with-potential-for-life

NASA In Depth: https://solarsystem.nasa.gov/moons/jupiter-moons/europa/in-depth.amp

Nature: Life on Europa? https://www.nature.com/articles/d41586-024-03225-4

Juno's first picture of Europa: https://www.nasa.gov/missions/europa-clipper/nasas-juno-shares-first-image-from-flyby-of-jupiters-moon-europa

EUROPA CLIPPER

NSSDC: https://nssdc.gsfc.nasa.gov/nmc/spacecraft/display.action?id=EUROPA-CL

NASA Science: https://science.nasa.gov/mission/europa-clipper

JPL: https://www.jpl.nasa.gov/missions/europa-clipper

Mission: https://europa.nasa.gov/spacecraft/meet-europa-clipper

Press Kit: https://www.jpl.nasa.gov/press-kits/europa-clipper

Wikipedia: https://en.wikipedia.org/wiki/Europa_Clipper

EUROPA CLIPPER INSTRUMENTS

Europa Imaging System (EIS): https://europa.nasa.gov/spacecraft/instruments/eis

Europa Thermal Imaging System (E-THEMIS):

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Europa Ultraviolet Spectrograph (Europa-UVS):
https://europa.nasa.gov/spacecraft/instruments/europa-uvs

Mapping Imaging Spectrometer for Europa (MISE):
https://europa.nasa.gov/spacecraft/instruments/mise

Europa Clipper Magnetometer (ECM): https://europa.nasa.gov/spacecraft/instruments/ecm

Plasma Instrument for Magnetic Sounding (PIMS):
https://europa.nasa.gov/spacecraft/instruments/pims

Gravity/Radar Science: https://europa.nasa.gov/spacecraft/instruments/gravity-radio-science

Radar for Europa Assessment and Sounding: Ocean to Near-Surface (REASON):
https://europa.nasa.gov/spacecraft/instruments/reason; see also:
https://en.wikipedia.org/wiki/Radar_for_Europa_Assessment_and_Sounding:_Ocean_to_Near-surface and https://www.lpi.usra.edu/opag/meetings/aug2015/presentations/day-1/8_f_REASON.pdf

MAss Spectrometer for Planetary EXploration (MASPEX):
https://europa.nasa.gov/spacecraft/instruments/maspex

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