The fascinating surface of Jupiter’s icy moon Europa looms large in this newly-reprocessed color view, made from images taken by NASA’s Galileo spacecraft in the late 1990s. This is the color view of Europa from Galileo that shows the largest portion of the moon’s surface at the highest resolution. Credits: NASA/JPL-Caltech/SETI Institute

This artist’s rendering shows a concept for a future NASA mission to Europa in which a spacecraft would make multiple close flybys of the icy Jovian moon, thought to contain a global subsurface ocean. Credits: NASA/JPL-Caltech

**Europa Multiple Flyby Mission: In Depth**

**Goals:** The Europa Multiple Flyby Mission will conduct detailed reconnaissance of Jupiter’s moon Europa to see whether the icy moon could harbor conditions suitable for life. The mission will carry a highly capable, radiation-tolerant spacecraft that would perform repeated close flybys of the icy moon from a long, looping orbit around Jupiter.

The payload of selected science instruments includes cameras and spectrometers to produce high-resolution images of Europa’s surface and determine its composition. An ice penetrating radar will determine the thickness of the moon’s icy shell and search for subsurface lakes similar to those beneath
Antarctica. The mission also will carry a magnetometer to measure strength and direction of the moon's magnetic field, which will allow scientists to determine the depth and salinity of its ocean.

A thermal instrument will scour Europa's frozen surface in search of recent eruptions of warmer water, while additional instruments will search for evidence of water and tiny particles in the moon's thin atmosphere. NASA's Hubble Space Telescope observed water vapor above the south polar region of Europa in 2012, providing the first strong evidence of water plumes. If the plumes' existence is confirmed - and they're linked to a subsurface ocean - it will help scientists investigate the chemical makeup of Europa's potentially habitable environment while minimizing the need to drill through layers of ice.

**Accomplishments:**

The Europa Multiple Flyby Mission concept, currently under development and refinement by a NASA mission team, would send a spacecraft to the Jupiter system to perform repeated close flybys of the giant planet's large moon Europa to investigate its potential habitability. The spacecraft would collect information on Europa's ice shell thickness, composition and surface geomorphology. The notional science payload consists of four instruments: a Shortwave Infrared Spectrometer (SWIRS), an Ice-Penetrating Radar (IPR), a stereo Topographical Imager (TI), and an Ion and Neutral Mass Spectrometer (INMS).

The nominal Europa mission would include 45 flybys of Europa at altitudes varying from 1675 miles to 16 miles (2700 km to 25 km). In the course of performing these flybys, the mission would also fly by the Jovian moons Ganymede and Callisto, although these flybys are solely to shape the orbit and would not drive science priorities.

The notional mission would launch from Cape Canaveral in the early 2020s and spend 6.5 years traveling to Jupiter. During this time, the spacecraft performs gravity assist flybys, first of Venus and then two of Earth, before swinging out to Jupiter. Upon arrival at Jupiter, the spacecraft would perform a nearly 2-hour main engine burn to allow capture into Jovian orbit. The spacecraft then performs four Ganymede flybys over the course of three months to reduce orbital energy and align its trajectory with Europa.

The mission would minimize the hazards posed by Jupiter's intense particle radiation environment in a manner similar to the Juno mission. The spacecraft would spend most of its time well outside the most intense regions of radiation, only diving in close to Europa for brief periods to collect precious science data during flyby encounters. The radiation hazard would be further minimized by placing the spacecraft's most sensitive electronics into a shielded vault. The vault would be placed in an area surrounded by propellant tanks for additional radiation shielding.

The Europa flyby campaign would be comprised of four segments each designed to provide good coverage of a wide region on Europa with consistent lighting conditions. During each flyby, a preset sequence of science observations would be executed. On approach the spacecraft would perform low-resolution global scans with its IR spectrometer ("nodding" the spacecraft's field of view back and forth across the moon, much like the Cassini spacecraft does during its moon flybys), followed by high-
resolution scans with that instrument. At 1,000 km the ice-penetrating radar, topographic imager and ion and neutral mass spectrometer (INMS) would power up. The radar pass would occur from 250 miles (400-km) inbound altitude to 250 miles (400-km) outbound altitude, during which stereo imaging and INMS data are acquired continuously. During departure, the IR spectrometer would conduct additional high- and low-resolution scans as the spacecraft moves away from Europa.

Once the nominal mission (45 flybys) has been completed, the mission could continue to execute Europa flybys during an extended mission. The spacecraft would eventually be decommissioned via targeted impact on Ganymede before its propellant runs out or radiation damage compromises its electronics.

Science Package
The payload of selected science instruments includes cameras and spectrometers to produce high-resolution images of Europa's surface and determine its composition. An ice penetrating radar will determine the thickness of the moon's icy shell and search for subsurface lakes similar to those beneath Antarctica. The mission also will carry a magnetometer to measure strength and direction of the moon's magnetic field, which will allow scientists to determine the depth and salinity of its ocean.

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Last year, NASA invited researchers to submit proposals for instruments to study Europa. Thirty-three were reviewed and, of those, nine were selected in 2015 for a mission that will launch in the 2020s.

"This is a giant step in our search for oases that could support life in our own celestial backyard," said CurtNiebur, Europa program scientist at NASA Headquarters in Washington. "We're confident that this versatile set of science instruments will produce exciting discoveries on a much-anticipated mission."

The NASA selectees are:

- **Plasma Instrument for Magnetic Sounding (PIMS)** -- principal investigator Dr. Joseph Westlake of Johns Hopkins Applied Physics Laboratory (APL), Laurel, Maryland. This instrument works in conjunction with a magnetometer and is key to determining Europa's ice shell thickness, ocean depth, and salinity by correcting the magnetic induction signal for plasma currents around Europa.

- **Interior Characterization of Europa using Magnetometry (ICEMAG)** -- principal investigator Dr. Carol Raymond of NASA's Jet Propulsion Laboratory (JPL), Pasadena, California. This magnetometer will measure the magnetic field near Europa and - in conjunction with the PIMS
instrument - infer the location, thickness and salinity of Europa's subsurface ocean using multi-frequency electromagnetic sounding.

- **Mapping Imaging Spectrometer for Europa (MISE)** -- principal investigator Dr. Diana Blaney of JPL. This instrument will probe the composition of Europa, identifying and mapping the distributions of organics, salts, acid hydrates, water ice phases, and other materials to determine the habitability of Europa's ocean.

- **Europa Imaging System (EIS)** -- principal investigator Dr. Elizabeth Turtle of APL. The wide and narrow angle cameras on this instrument will map most of Europa at 50 meter (164 foot) resolution, and will provide images of areas of Europa's surface at up to 100 times higher resolution.

- **Radar for Europa Assessment and Sounding: Ocean to Near-surface (REASON)** -- principal investigator Dr. Donald Blankenship of the University of Texas, Austin. This dual-frequency ice penetrating radar instrument is designed to characterize and sound Europa's icy crust from the near-surface to the ocean, revealing the hidden structure of Europa's ice shell and potential water within.

- **Europa Thermal Emission Imaging System (E-THEMIS)** -- principal investigator Dr. Philip Christensen of Arizona State University, Tempe. This "heat detector" will provide high spatial resolution, multi-spectral thermal imaging of Europa to help detect active sites, such as potential vents erupting plumes of water into space.

- **MAss SPectrometer for Planetary EXploration/Europa (MASPEX)** -- principal investigator Dr. Jack (Hunter) Waite of the Southwest Research Institute (SwRI), San Antonio. This instrument will determine the composition of the surface and subsurface ocean by measuring Europa's extremely tenuous atmosphere and any surface material ejected into space.

- **Ultraviolet Spectrograph/Europa (UVS)** -- principal investigator Dr. Kurt Retherford of SwRI. This instrument will adopt the same technique used by the Hubble Space Telescope to detect the likely presence of water plumes erupting from Europa's surface. UVS will be able to detect small plumes and will provide valuable data about the composition and dynamics of the moon's rarefied atmosphere.

- **SUrface Dust Mass Analyzer (SUDA)** -- principal investigator Dr. Sascha Kempf of the University of Colorado, Boulder. This instrument will measure the composition of small, solid particles ejected from Europa, providing the opportunity to directly sample the surface and potential plumes on low-altitude flybys.

Separate from the selectees listed above, the SPace Environmental and Composition Investigation near the Europan Surface (SPECIES) instrument has been chosen for further technology development. Led by principal investigator Dr. Mehdi Benna at NASA's Goddard Space Flight Center in Greenbelt, Maryland,
The combined neutral mass spectrometer and gas chromatograph will be developed for other mission opportunities.