Solar System Sites that might support life!

Jupiter and its Satellites Juno, Io & Europa

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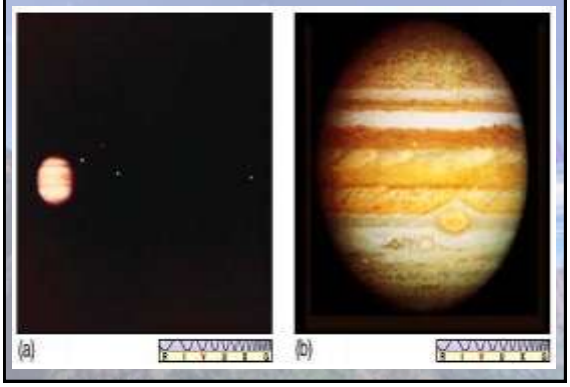
Jupiter



- Named after the most powerful god of the Roman pantheon, Jupiter is by far the largest planet in the solar system.
- Ancient astronomers could not have known the planet's true size, but their choice of names was very appropriate.
- Jupiter is the third-brightest object in the night sky (after the Moon and Venus), making it very easy to locate and study

- As massive as Jupiter is, though, it is still some 1000 times less massive than the Sun.
- This makes studies of Jupiter all the more important, for here we have an object intermediate in size between the Sun and the terrestrial planets.
- It is 1.9×10^{27}kg, or 318 Earth masses.
- Jupiter has more than twice the mass of all the other planets combined.

- Knowing Jupiter's distance and angular size, we can easily determine its radius.
- It is 71,400 km, or 11.2 Earth radii.
- From the size and mass, we derive an average density of 1300 kg/m^3 (1.3 g/cm^3) for the planet.

- Studies of the planet's internal structure indicate that Jupiter must be composed primarily of hydrogen and helium.
- Doppler-shifted spectral lines prove that the equatorial zones rotate a little faster (9^h50^m period) than the higher latitudes (9^h56^m period).
- Thus, Jupiter exhibits differential rotation

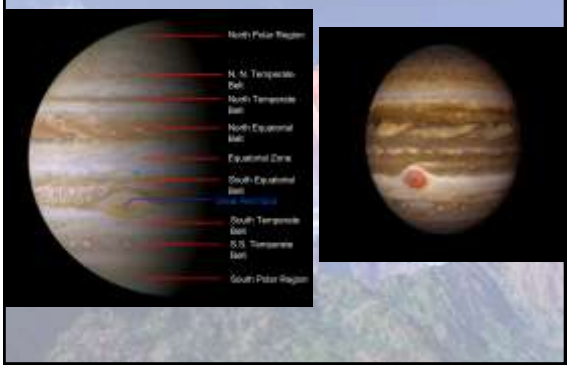
- Jupiter has the fastest rotation rate of *any* planet in the solar system, and this rapid spin has altered Jupiter's shape.
- A spinning object tends to develop a bulge around its midsection.
- Jupiter's equatorial radius-71,400 km exceeds its polar radius -66,800 km by about 6.5 percent.

Atmosphere of the Jupiter

- Jupiter is visually dominated by two features.
- 1. A series of ever-changing atmospheric bands arranged parallel to the equator.
- 2. An oval atmospheric blob called the Great Red Spot, or often just the "Red Spot.
- The cloud bands display many colors--pale yellows, light blues, deep browns, drab/dull tans, and vivid/bright reds among others.

Bands Feature

Great Red Spot



- Scientists believe that chemical compounds in Jupiter's atmosphere create these different colors
- But the detailed chemistry is still not completely understood.
- The Red Spot is one of many features associated with Jupiter's weather.
- It seems to be an Earth-sized hurricane that has persisted for hundreds of years.

ATMOSPHERIC COMPOSITION

- Spectroscopic studies of sunlight reflected from Jupiter gave scientists their first look at the planet's atmospheric composition.
- Radio, infrared, and ultraviolet observations later provided more details.
- The most abundant gas is molecular hydrogen (86.1%), followed by helium (13.8 percent).

- Together they make up over 99% of Jupiter's atmosphere.
- Scientists generally accept that these two gases also make up the bulk of the planet's interior.
- Small amounts of atmospheric methane, ammonia, and water vapor are also found.

Internal Energy Source of Jupiter

- Jupiter actually emits about twice as much energy as it receives from the Sun.
- Thus, unlike any of the terrestrial planets, Jupiter must have its own internal heat source.
- What is responsible for Jupiter's extra energy?

- It is not the decay of radioactive elements within the planet--that must be occurring, but not at nearly the rate necessary to produce the temperature we record.
- Nor is it the process that generates energy in the Sun, nuclear fusion--the temperature in Jupiter's interior, high as it is, is far too low for that.

- Instead, astronomers theorize that the source of Jupiter's excess energy is the slow escape of gravitational energy released during the planet's formation.
- As the planet took shape, some of its energy was converted into heat in the interior.
- That heat is still slowly leaking out through the planet's heavy atmospheric blanket, resulting in the excess emission we observe.

- Despite the huge amounts of energy involved--Jupiter's energy emission is about 4×10^{17} watts more than it receives from the Sun--the energy loss is quite slight compared with the planet's total energy.
- A simple calculation indicates that the average temperature of the interior of Jupiter falls by only about a millionth of a kelvin per year

Moons of the Jupiter—79 (2019)

- In many ways, the entire Jupiter system resembles a miniature solar system.
- Jupiter has 53 named moons and another 26 awaiting official names. Combined, scientists now think Jupiter has 79 moons.
- Its four largest moons--the Galilean satellites--are each comparable in size to Earth's Moon.

- Moving outward from Jupiter, the four are named Io, Europa, Ganymede, and Callisto, after the mythical attendants of the Roman God Jupiter.
- Galilean moons correspond to the terrestrial planets. Their orbits are direct (i.e., in the same sense as Jupiter's rotation), roughly circular, & lie close to Jupiter's equatorial plane.

- They range in size from slightly smaller than Earth's Moon (Europa) to slightly larger than Mercury (Ganymede).
- The parallel with the inner solar system continues with the realization that their densities decrease with increasing distance from Jupiter.
- It is quite likely that the inner two Galilean moons, Io and Europa, have a rocky composition, possibly similar to the crusts of the terrestrial planets.

- Many astronomers think that the formation of Jupiter and the Galilean satellites may in fact have mimicked on a small scale the formation of the Sun and the inner planets.
- For that reason, studies of the Galilean moon system may provide us with valuable insight into the processes that created our own world.

Atmosphere of Jupiter

- Jupiter's upper atmosphere is about 88–92% hydrogen and 8–12% helium by percent volume of gas molecules.
- **The atmosphere contains trace amounts:** of methane, water vapor, ammonia, and silicon-based compounds. There are also traces of carbon, ethane, hydrogen sulfide, neon, oxygen, phosphine, and sulfur.
- The outermost layer of the atmosphere contains crystals of frozen ammonia.
- Through infrared and ultraviolet measurement, trace amounts of benzene and other hydrocarbons have also been found.

- Jupiter is much larger than Earth and considerably less dense: its volume is that of about 1,321 Earths, but it is only 318 times as massive.
- Jupiter has the largest planetary atmosphere in the Solar System, spanning over 5,000 km in altitude.
- Is there water on Jupiter?" has been asked many times.
- The answer is yes, there is a small amount of water, but it is not "on" Jupiter. It is in the form of water vapor in the cloud tops.

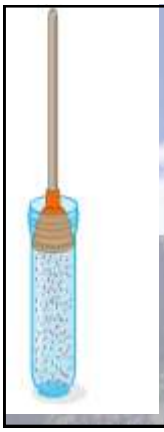
- Jupiter should have more oxygen than the Sun for water
- The oxygen would have combined with the more than abundant hydrogen in the Jovian atmosphere, thus making water a significant component.
- The trouble is that the Galileo space craft found that Jupiter's atmosphere contains less oxygen than the Sun; therefore, water is a minor trace element in the atmosphere.
- That does not mean that there is not significant amounts of water elsewhere in the Jovian system.
- A few of Jupiter's moons have been found to have water or water ice in their atmosphere or on their surface.

What's It Like Inside Jupiter?

- It's really hot inside Jupiter! No one knows exactly how hot, but scientists think it could be about 43,000°F (24,000°C) near Jupiter's center, or core.
- Jupiter is made up almost entirely of hydrogen and helium. On the surface of Jupiter–and on Earth–those elements are gases. However inside Jupiter, hydrogen can be a liquid, or even a kind of metal.
- These changes happen because of the tremendous temperatures and pressures found at the core.

What is pressure?

- Have you ever gone swimming at the deep end of a pool? Did you notice that your ears started to hurt a little bit when you were under water? The deeper you dive, the more water there is on top of you. All of that water presses on your body–and that's pressure.
- The same type of pressure happens in Jupiter's core. Under low pressure, particles of hydrogen and helium, called molecules, have lots of room to bounce around. This is when hydrogen and helium are gases.
- However, the weight of all this hydrogen and helium is really heavy. This weight presses down toward the planet's core, creating high pressure. The molecules run out of room to bounce around, so instead, they slow down and crowd together. This creates a liquid.



How much pressure would you find at the center of Jupiter?

Imagine if you swam to the bottom of the Pacific Ocean. You would feel more than 16,000 pounds of force pressing down on every square inch of your body. That is approximately the weight of four cars!

The pressure at the center of Jupiter is much higher. At Jupiter's core, you would feel as much as 650 million pounds of pressure pressing down on every square inch of your body. That would be like having approximately 160,000 cars stacked up in every direction all over your body!

What lies at the very center of Jupiter?

- At the moment, scientists aren't 100% sure.
- It may be that the planet has a solid core that is bigger than Earth. But some scientists think it could be more like a thick, boiling-hot soup.

Is it possible for life on Jupiter?

- **There is no way that life as we understand it could exist on the gas giant.**
- **The possibility of life within the Jovian system is still being explored. Some debate exists about Europa.**
- **NASA's Jupiter Icy Moons Orbiter was set to answer those questions before it was canceled.**

Can a person survive on Jupiter?

- **It would be impossible for humans or any other life to live on Jupiter, as the planet is made up primarily of gases almost the all the way to its core.**
- **NASA speculates that it might be possible for a very secure spacecraft to visit Jupiter, but it couldn't land, as the planet does not have any solid surfaces.**

Possibility of life on planets

- As of 2014, it would also take an incredibly long time for a spacecraft to even visit the planet considering the current technology that is available.
- Due to a number of different factors, Mars is considered to be the next most habitable planet in the solar system.
- One of the reasons is its distance from the sun, which makes it fall within the temperature range that could possibly support life.

- The rest of the planets in the solar system are either far too hot or far too cold.
- For instance, despite the fact that Venus is the next closest planet to Earth after Mars, the temperature on its surface surpasses 400 F.
- The pressure on Venus is also too much for a human to sustain, as it is the equivalent of being 900 meters below the ocean on Earth, whereas the gravity on Mars is only 38 percent of that on Earth.

Space missions

Present:

- Juno
- New Horizons
- Cassini
- Voyager1 & 2

Past:

Ulessys
Pioneer 10 & 11
Galilio

Missions to Jupiter Mission

Missions	Country	Launch Date
Pioneer 11	USA	April 6, 1973
Voyager 1	USA	September 5, 1977
Voyager 2	USA	August 20, 1977
Galileo	USA & Europe	October18, 1989

Missions to Jupiter

Mission	Country	Launch Date	Arrival Date	Type	Encounter Characteristics
Pioneer 11	USA	April 6, 1973	September 1, 1979	Flyby	Returned detailed pictures of Jupiter and Jupiter's Great Red Spot.
Voyager 1	USA	September 5, 1977	November 13, 1980	Flyby	Returned photographs and information on Jupiter's many moons.
Voyager 2	USA	August 20, 1977	August 26, 1981	Flyby	Showed that Jupiter's Great Red Spot is really a complex storm, and that Io, one of Jupiter's moons, has active volcanism.
Galileo	USA & Europe	October18, 1989	February 10, 1990	Orbiter/ Probe	The Galileo Probe successfully descended into Jupiter's atmosphere on December 7,1995. Galileo Orbiter successfully entered orbit well above the cloud tops of Jupiter on December 7, 1995 and is currently observing the Jupiter system.

Juno

Juno Will Show Jupiter's True Nature

- Juno is a NASA spacecraft to help scientists learn more about Jupiter. Juno launched August 5, 2011, and it went into orbit around Jupiter on July 4, 2016.
- The slowly spinning spacecraft orbits around Jupiter's poles instead of around its middle.
- It swings far away, then back toward Jupiter, coming as close as 5,000 kms above the cloud tops.
- During the parts of each orbit when it is closest to Jupiter, Juno takes measurements to find out whether Jupiter has a solid planetary core.
- Juno is also mapping Jupiter's intense magnetic field, measuring the amount of water and ammonia in the deep atmosphere, and observing the planet's auroras.

Juno accomplished a close flyby over Jupiter's churning atmosphere on Wednesday, Feb. 7, successfully completing its tenth science orbit. The closest approach was at 6:36 a.m. PST (9:36 a.m. PST) Earth-received time. At the time of perijove (the point in Juno's orbit when it is closest to the planet's center), the spacecraft will be about 3,500 kms above the planet's cloud tops.

This flyby was a gravity science orientation pass. During orbits that highlight gravity experiments, Juno is in an Earth-pointed orientation that allows both the X-band and Ka-Band transmitter to downlink data in real-time to one of the antennas of NASA's Deep Space Network in Goldstone, California. All of Juno's science instruments and the spacecraft's JunoCam were in operation during the flyby, collecting data that is now being returned to Earth.

Io –The Volcanic Moon

- Jupiter's moon Io is the most volcanically active world in the Solar System, with hundreds of volcanoes, some erupting lava fountains dozens of miles (or kilometers) high.
- Io is caught in a tug-of-war between Jupiter's massive gravity and the smaller but precisely timed pulls from two neighboring moons that orbit further from Jupiter - Europa and Ganymede.

- Although Io always points the same side toward Jupiter in its orbit around the giant planet, the large moons Europa and Ganymede perturb Io's orbit into an irregularly elliptical one.
- Thus, in its widely varying distances from Jupiter, Io is subjected to tremendous tidal forces.
- These forces cause Io's surface to bulge up and down (or in and out) by as much as 100 m (330 feet)! Compare these tides on Io's solid surface to the tides on Earth's oceans.
- On Earth, in the place where tides are highest, the difference between low and high tides is only 18 m (60 feet), and this is for water, not solid ground!

Io

Io is slightly larger than the Moon

Diameter:	**3,643.2 km**
Mass:	**8.93 x 1022 kg (1.2 Moons)**
Orbits:	**Jupiter**
Orbit Distance:	**421,800 km**
Orbit Period:	**1.77 days**
Surface Temperature:	**-163 °C**
Discovery Date:	**Jan 8, 1610**
Discovered By:	**Galileo Galilei**

- Io has more than 400 active volcanoes on its surface.
- They make this little moon the most actively volcanic world in the solar system.
- The volcanism on Io is due to tidal heating, as the moon is stretched by Jupiter's strong gravitational pull and by the lesser gravitational effects of the other satellites.
- The volcanoes of Io are constantly erupting, creating plumes that rise above the surface and lakes that cover vast areas of the landscape.

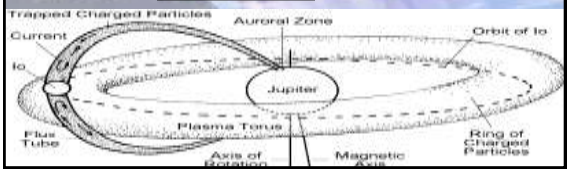
- The volcanic plumes of Io rise up as high as 200 km, showering the terrain with sulfur, sulfur dioxide particles, and rocky ash.
- Io has a very thin atmosphere that contains mostly sulfur dioxide (emitted from its volcanoes).
- Gases from the atmosphere escape to space at the rate of about a ton per second.
- Some of the material becomes part of a ring of charged particles around Jupiter called the Io plasma torus.

- Io has a number of mountains, some of which rise up as high as Mount Everest on Earth.
- The average height of Io's peaks are around 6 km.
- Io is made mostly of silicate rocks, and its surface is painted with sulfur particles from the volcanoes and frosts that are created as the atmospheric gases freeze out and fall to the ground.
- Robotic missions to Io could study its volcanism in closer detail.
- No human missions are planned as yet, due to the extreme radiation environment and highly toxic atmosphere and surface.

Interior

- The interior of Io is composed of an iron or iron sulfide core and a brown silicate outer layer, giving the planet a splotchy orange, yellow, black, red, and white appearance.
- Most distinctive features are its volcanoes.
- Because of the volcanic activity, Io's atmosphere contains mostly sulfer dioxide.
- Io's orbit cuts across Jupiter's powerful magnetic lines of force, turning Io into an electric generator.

- As Jupiter rotates, the magnetic forces strip away about a ton (1,000 kg) of Io's material every second.
- The material becomes ionized and forms a doughnut-shaped cloud of radiation called a plasma torus.



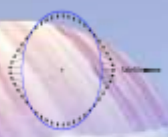
What causes such amazing volcanic activity on Io?

- Surely that moon is too small to have geological activity like the Earth.
- Io should be long dead, like our own Moon.
- At one time, some scientists suggested that Jupiter's magnetosphere might be the offender- perhaps the (then-unknown) processes creating the plasma torus were somehow also stressing the moon.
- We now know that this is not the case.

- The real source of Io's energy is gravity--Jupiter's gravity.
- Io orbits very close to Jupiter--only 422,000 km, or 5.9 Jupiter radii, from the center of the planet.
- As a result, Jupiter's huge gravitational field produces strong tidal forces on the moon.

Tidal Forces

- The tidal force is a force that is the secondary effect of the force of gravity; it is responsible for the phenomenon of tides.



It arises because the gravitational force exerted by one body on another is not constant across it: the nearest side is attracted more strongly than the farthest side.

- If Io were the only satellite in the Jupiter system, it would long ago have come into a state of synchronous rotation with the planet, just like our own Moon.
- In that case, Io would move in a perfectly circular orbit, with one face permanently turned toward Jupiter.
- The tidal bulge would be stationary with respect to the moon, and there would be no internal stresses and hence no volcanism.

- But Io is not alone.
- As it orbits, it is constantly tugged by the gravity of its nearest large neighbor, Europa.
- These tugs are small and not enough to cause any great tidal effect in and of themselves, but they are sufficient to make Io's orbit slightly noncircular, preventing the moon from settling into a precisely synchronous state.
- The reason for this effect is exactly the same as in the case of Mercury.

- In a noncircular orbit, the moon's speed varies from place to place as it revolves around its planet, but its rate of rotation on its axis remains constant.
- Thus it cannot keep one face always turned toward Jupiter. Instead, as seen from Jupiter, Io rocks or "wobbles"(vibrate) slightly from side to side as it moves.
- The large tidal bulge, however, always points directly toward Jupiter, so it moves back and forth across Io's surface as the moon wobbles.
- These conflicting forces result in enormous tidal stresses that continually flex and squeeze Io's interior.

- Just as repeated back-and-forth bending of a piece of wire can produce heat through friction, Io is constantly energized by the ever-changing distortion of its interior.
- This generation of large amounts of heat within Io ultimately causes huge jets of gas and molten rock to squirt/spray out of the surface.
- It is likely that much of Io's interior is soft or molten, with only a relatively thin solid crust overlying it.
- In fact, Io's volcanoes are probably more like geysers on the Earth, but the term volcano has stuck.

- A geyser is a spring characterized by intermittent discharge of water ejected turbulently and accompanied by steam
- Geysers are temporary geological features.
- Geysers are generally associated with volcanic areas.
- As the water boils, the resulting pressure forces a superheated column of steam and water to the surface through the geyser's internal plumbing.

- Researchers estimate that the total amount of heat generated in Io.
- As a result of tidal flexing is about 100 million megawatts.
- This phenomenon makes Io one of the most fascinating objects in our solar system.

Space missions

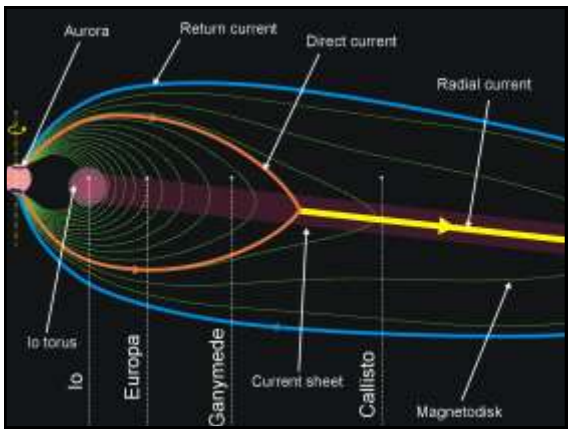
- *Pioneer 10* and *Pioneer 11* on March 3, 1972 and April 6, 1973, respectively.
- *Voyager 1* and *Voyager 2*, launched on September 5 and August 20, 1977, respectively.
- *Galileo* arrived at Jupiter on December 7, 1995, after a six-year journey from Earth during which it used gravity assists with Venus and Earth to boost its orbit out to Jupiter.

- *New Horizons* spacecraft, en route to Pluto and the Kuiper belt, flew by the Jupiter system on February 28, 2007 to explore Io
- *Io Volcano Observer* (*IVO*) is proposed for future

Europa

It's possible actually that the chances of life today are better on Europa than on Mars."
UK Space Agency -Dr Lewis Dartnell

- Europa was one of the four moons of Jupiter. Smallest moon discovered by Galileo Galilei in 1610. orbital radius of about 670,900 km.
- Orbital period 3.5 days. Europa is slightly smaller than the Moon.
- At just over 3,100 kilometres in diameter, it is the sixth-largest moon and fifteenth-largest object in the Solar System.
- Europa's surface is a near vacuum, with an atmosphere so thin it is called an exosphere.
- Europa has a very weak magnetic field, so radiation at its surface is strong enough to sicken.



- Europa is a very different world from Io.
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- Lying outside Io's orbit, 670,000 km (9.4 Jupiter radii) from Jupiter, it has relatively few craters on its surface, suggesting geologic youth.
- Recent activity must have erased the scars/marks of ancient meteoritic impacts.

Europa's surface does display a vast network of lines crisscrossing bright, clear fields of water ice.

- Some of these linear "bands," or fractures, appear to extend halfway around the satellite and resemble in some ways the pressure ridge(Crust) that develop in ice floes/glaciers on the Earth's polar oceans.
- Some researchers have theorized that Europa is covered completely by an ocean of liquid water whose top is frozen at the low temperatures that prevail so far from the Sun.
- The cracks are attributed to the tidal influence of Jupiter and the gravitational pulls of the other Galilean satellites, although these forces are weaker than those powering Io's volcanic activity.

- Other planetary scientists suggest that Europa's fractured surface is instead related to some form of tectonic activity, one involving ice rather than rock.
- If the markings truly are fault lines of ice, then this moon is probably still quite active.
- If Europa does have a liquid ocean below the ice, it opens up many interesting avenues of speculation into the possible development of life there

- The surface of Europa averages -170°C.
- Europa was the first moon proposed to have an underground ocean.
  - The underground ocean theory is attractive because it would provide another habitat for life somewhere else in the solar system.
- Life on Europa would live in the ocean, fed by geothermal heat like life on the bottom of Earth's oceans fed by "black" vent/emit that put out a constant stream of methane and hydrocarbons.
- Life on Europa would not need or use sunlight, since it never reaches the icy depths.

- Europa is the most important source of water in the system.
- Europa is thought to have an iron core, a rocky mantle and a surface ocean of salty water.
- Unlike oceans on Earth, this ocean is deep enough to cover the whole surface of Europa, and being far from the sun, the ocean surface is globally frozen over.

- Europa's orbit is eccentric, so when it is close to Jupiter the tide is much higher than when it is at aphelion.
- Tidal forces raise and lower the sea beneath the ice, most likely causing the cracks seen in images of Europa's surface.
- The tidal forces cause Europa to be warmer than it would otherwise be.
- The warmth of Europa's liquid ocean could prove critical to the survival of simple organisms within the ocean, if they exist.

Europa's Liquid Water

- The surface of Europa is very cold and covered with ice. This ice forms a "crust" on the moon that is thought to be several kilometers thick.
- Beneath the crust, a subsurface ocean of liquid water up to 100 kilometers deep is thought to exist.
- Investigators believe that the ocean is rich in dissolved ions, particularly magnesium, sodium, potassium, and chlorine.
- Organisms on Earth live in ion-rich solutions, so there is a good chance that they live in them on Europa.

Europa's Building Blocks of Life

- Spacecraft observations determined that the surface of Europa is covered with water ice.
- That ice and other materials on Europa's surface are bombarded with radiation from Jupiter that could alter them into some of the chemical building blocks of life.
- These include: free oxygen (O_2), hydrogen peroxide (H_2O_2), carbon dioxide (CO_2), and sulfur dioxide (SO_2).
- If these compounds reach the subsurface ocean, they can be valuable nutrients to start and sustain life.
- The ocean water can react with the rocks and minerals of the subsurface ocean's floor to liberate other nutrients to support life.

Life on Europa Might be Easy to Find

- **The presence of magnesium compounds on the surface of Europa suggests that water from the subsurface ocean reaches the surface through springs or vents.**
- If this occurs these eruptions would deliver up ions and microbes from the ocean below.

- So, if there is life in Europa's subsurface ocean, it could be scattered about the surface of the planet where landers or rovers might find it.
- A mission to the surface of the Europa might easily find evidence of life or even some of the microbes by sampling surface materials.
- This makes Europa a very interesting target in the search for extraterrestrial life.
- **Some researchers believe that it is a much better target than Mars.**

- **Europa Explorer**
- **Europa Jupiter System Mission (2020)**
- **Europa Lander** Europa Lander is a proposed astrobiology **mission concept** by NASA to Europa, a moon of Jupiter. If**selected** and developed, it would be launched separately in 2025 to complement the studies by the Europa Clipper orbiter mission.
- **Europa Mission**
- **Europa Clipper** (***Europa Clipper*** is an interplanetary mission in development by NASA comprising an orbiter. Set for a launch in June of 2023)

Europa Multiple Flyby missions

- The mission plan calls for a spacecraft to be launched to Jupiter in the 2020s, arriving in the distant planet's orbit after a journey of several years.
- The spacecraft would orbit the giant planet about every two weeks, providing many opportunities for close flybys of Europa.
- The mission plan includes 45 flybys, during which the spacecraft would image the moon's icy surface at high resolution and investigate its composition and the structure of its interior and icy shell.
- NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, has been assigned the responsibility of managing the project.

- NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, has been assigned the responsibility of managing the project.
- JPL has been studying the multiple-flyby mission concept, in collaboration with the Johns Hopkins University Applied Physics Laboratory (APL) in Laurel, Maryland, since 2011.
- "It's a great day for science," said Joan Salute, Europa program executive at NASA Headquarters in Washington. "We are thrilled to pass the first major milestone in the lifecycle of a mission that will ultimately inform us on the habitability of Europa."

- The multiple flyby mission will investigate Europa's habitability by mapping its composition, determining the characteristics of the ocean and ice shell, and increasing our understanding of its geology.
- The mission also will lay the foundation for a future landing by performing detailed reconnaissance using its powerful cameras.

Europa Lander Concept

- In early 2016, NASA's Planetary Science Division began a pre-Phase -A study to assess the science value and engineering design of a future Europa lander mission.
- NASA routinely conducts such studies -- known as Science Definition Team (SDT) reports -- long before the beginning of any mission to gain an understanding of the challenges, feasibility and science value of the potential mission.

- In June 2016, NASA convened a 21-member team of scientists for the SDT.
- Since then, the team has deliberated to define a workable and worthy set of science objectives and measurements for the mission concept, submitting a report to NASA on Feb. 7,2017.
- The report lists three science goals for the mission.
- The primary goal is to search for evidence of life on Europa.
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- The other goals are: To assess the habitability of Europa by directly analyzing material from the surface, and to characterize the surface and subsurface to support future robotic exploration of Europa and its ocean.
- The report also describes some of the notional instruments that could be expected to perform measurements in support of these goals.
- Scientists agree that the evidence is quite strong that Europa, which is slightly smaller than Earth's moon, has a global saltwater ocean beneath its icy crust.

- This ocean has at least twice as much water as Earth's oceans.
- While recent discoveries have shown that many bodies in the solar system either have subsurface oceans now, or may have in the past, Europa is one of only two places where the ocean is understood to be in contact with a rocky seafloor (the other being Saturn's moon Enceladus).
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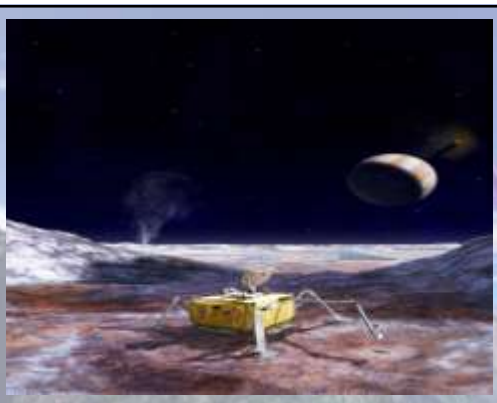
- This rare circumstance makes Europa one of the highest priority targets in the search for present-day life beyond Earth.

- The SDT was tasked with developing a life-detection strategy, a first for a NASA mission since the Mars Viking mission era more than four decades ago.
- The report makes recommendations on the number and type of science instruments that would be required to confirm if signs of life are present in samples collected from the icy moon's surface.
- The team also worked closely with engineers to design a system capable of landing on a surface about which very little is known.

- Given that Europa has no atmosphere, the team developed a concept that could deliver its science payload to the icy surface without the benefit of technologies like a heat shield or parachutes.
- The concept lander is separate from the solar-powered Europa multiple flyby mission, now in development for launch in the early 2020s.
- The spacecraft will arrive at Jupiter after a multi-year journey, orbiting the gas giant every two weeks for a series of 45 close flybys of Europa



Europa Clipper.

- NASA's upcoming mission to investigate the habitability of Jupiter's icy moon Europa now has a formal name: Europa Clipper.
- Europa has long been a high priority for exploration because it holds a salty liquid water ocean beneath its icy crust.
- The ultimate aim of Europa Clipper is to determine if Europa is habitable, possessing all three of the ingredients necessary for life: liquid water, chemical ingredients, and energy sources sufficient to enable biology.

- NASA's Europa Clipper will conduct detailed investigation of Jupiter's moon Europa and investigate whether the icy moon could harbor conditions suitable for life.
- The mission will place a spacecraft in orbit around Jupiter in order to perform a detailed investigation of Europa -- a world that shows strong evidence for an ocean of liquid water beneath its icy crust and which could host conditions favorable for life.
- The mission will send a highly capable, radiation-tolerant spacecraft into a long, looping orbit around Jupiter to perform repeated close flybys of the icy moon.

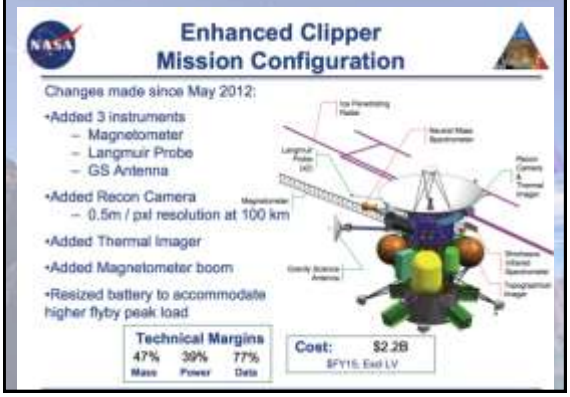
- NASA has selected nine science instruments for the mission.
- The selected payload includes cameras and spectrometers to produce high-resolution images of Europa's surface and determine its composition.
- An ice penetrating radar will determine the thickness of the moon's icy shell and search for subsurface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

- Gravity measurements will also help confirm the existence of Europa's subsurface ocean.

  A thermal instrument will survey Europa's frozen surface in search of recent eruptions of warmer water at or near the surface, 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 potential evidence of water plumes/trails. If the plumes' existence is confirmed -- and they're linked to a subsurface ocean -- studying their composition will help scientists investigate the chemical makeup of Europa's potentially habitable environment while minimizing the need to drill through layers of ice.

Scientific Instruments

- Plasma Instrument for Magnetic Sounding (PIMS)
- Interior Characterization of Europa using MAGnetometry (ICEMAG)
- Mapping Imaging Spectrometer for Europa (MISE)
- Europa Imaging System (EIS)
- Radar for Europa Assessment and Sounding: Ocean to Near-surface (REASON)
- Europa THermal Emission Imaging System (E-THEMIS)
- MAss SPectrometer for Planetary EXploration/Europa (MASPEX)
- Ultraviolet Spectrograph/Europa (UVS)
- SUrface Dust Mass Analyzer (SUDA)



Ingredients for Life?

- Europa could have the ingredients needed for life:
- Water
- Chemistry
- Energy

- Water is essential to life, serving as a perfect liquid medium for dissolving nutrients for ingestion or wastes for excretion, and for transporting chemicals living things can use.
- Several lines of evidence strongly suggest that the planet-sized moon contains an ocean of liquid water many tens of miles deep.
- If it does exist, the ocean lies beneath an ice shell that is at least a few miles thick, and perhaps tens of miles thick.

- At the ocean bottom lies a rocky seafloor in direct contact with the water, possibly supplying chemical nutrients into the ocean by hydrothermal activity.
- There are several important clues to the presence of an ocean within Europa.

Chemistry

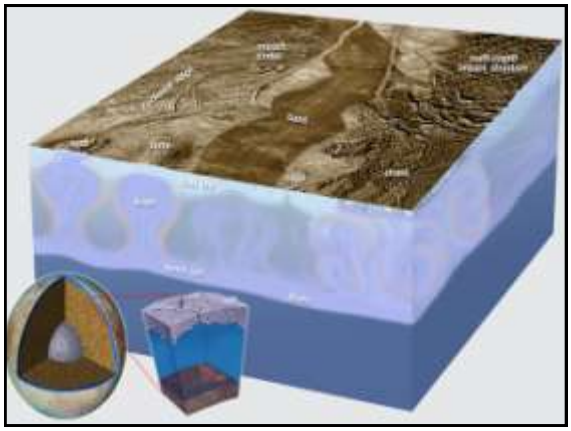
- Studying Europa's chemistry -- on the surface and within the suspected ocean -- is important for understanding its habitability because living things extract energy from their environments via chemical reactions.
- Interactions between materials from Europa's surface and those in an ocean environment beneath the ice could produce elements essential for life such as carbon, hydrogen, nitrogen, oxygen, phosphorous and sulfur.

- Europa's surface is mostly water ice (H2O), but the surface is bombarded by intense radiation from Jupiter, which can alter the chemistry of the ice.
- Through this process, the hydrogen and oxygen from water ice can combine with other materials on the surface to create a host of molecules like free oxygen (O_2), hydrogen peroxide (H_2O_2), carbon dioxide (CO_2) and sulfur dioxide (SO_2).
- If these compounds are finding their way into an ocean as part of an ongoing cycle, they could be used to power the reactions living things depend upon.
- Meanwhile, cycling of ocean water through minerals in the seafloor could replenish the water with other chemicals that are crucial for life.

- Life extracts energy from its environment in order to carry out biological processes like maintaining cellular structures, growing and reproducing.
- Most living things on Earth's surface depend (directly or indirectly) on energy supplied by the sun, but there are many organisms that extract their energy from chemical sources like those produced by hydrothermal activity.
- Europa's constant tidal flexing provides heat energy to drive chemical reactions in the rocky interior, recycling the elements and making them available for potential use by living things.

- If Europa's seafloor has volcanoes (as its sibling moon Io does) or hydrothermal vents, they may drive the chemistry of the ocean and play an important role in cycling nutrient-rich water between the ocean and the rocky interior.
- Tidal flexing of the ice shell could create slightly warmer pockets of ice that rise slowly upward to the surface, carrying material from the ocean below.
- Jupiter's intense radiation also provides a source of energy by ripping apart chemicals on the surface, where they can recombine to form new compounds.

- How material cycles between the ice, the ocean and the rocky interior is the greatest uncertainty about energy as it relates to Europa's habitability.
- The greatest uncertainty about energy as it relates to Europa's habitability is in how material cycles between the ice, the ocean and the rocky mantle on the ocean bottom.
- There are, potentially, sources of chemical energy for life being created on the surface and in the rocky interior, but their availability for use by living organisms depends on how well Europa's different layers are able to exchange material.
- In essence, the more energetic Europa is, the more energy would be available for life. Determining the balance of all these forces - Europa's energy balance - is a major hurdle toward understanding the icy moon's habitability.

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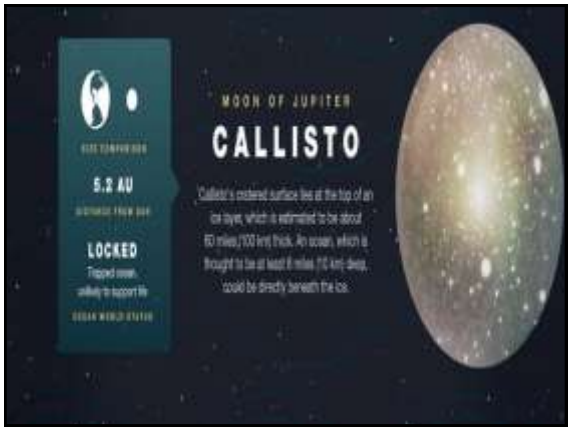
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THANK YOU!