North Polar Mars Ice Caps- Primarily water ice. Lower altitude/warmer. Residual cap = water ice (3km thick). Seasonal cap = summer. Mars Global Surveyor. Chasma Boreale – large valley running through (bigger than Grand Canyon) – 1100 km diam.Part of the northern ice cap consists of dry ice, solid carbon dioxide. Each winter the ice cap grows by adding 1.5 to 2 m of dry ice. In summer, the dry ice sublimates (goes directly from a solid to a gas) into the atmosphere. Mars has seasons that are similar to Earth's, because its rotational axis has a tilt close to our own Earth's (25.19° for Mars, 23.44° for Earth) During each year on Mars as much as a third of Mars' thin carbon dioxide (CO2) atmosphere "freezes out" during the winter in the northern and southern hemispheres. Scientists have even measured tiny changes in the gravity field of Mars due to the movement of carbon dioxide. The ice cap in the north is of a lower altitude than the one in the south. It is also warmer, so all the frozen carbon dioxide goes away each summer.[18] The part of the cap that survives the summer is called the north residual cap and is made of water ice. This water ice is believed to be as much as three kilometers thick. The much thinner seasonal cap starts to form in the late summer to early fall when a variety of clouds form. Called the polar hood, the clouds drop precipitation which thickens the cap. The north polar cap is symmetrical around the pole and covers the surface down to about 60 degrees latitude. High resolution images taken with NASA's Mars Global Surveyor show that north polar cap is covered mainly by pits, cracks, small bumps and knobs that give it a cottage cheese look. The pits are spaced close together relative to the very different depressions in the south polar cap.

South Polar Mars Ice Caps- 400 km diam. Residual cap = misplaced. More snow on one side than another. Consists of dry ice. The south polar permanent cap is much smaller than the one in the north. It is 400 km in diameter, as compared to the 1100 km diameter of the northern cap. Each southern winter, the ice cap covers the surface to a latitude of 50°. Part of the ice cap consists of dry ice, solid carbon dioxide. Each winter the ice cap grows by adding 1.5 to 2 meters of dry ice from precipitation from a polar-hood of clouds. In summer, the dry ice sublimates (goes directly from a solid to a gas) into the atmosphere. During each year on Mars as much as a third of Mars' thin carbon dioxide (CO2) atmosphere "freezes out" during the winter in the northern and southern hemispheres. Scientists have even measured tiny changes in the gravity field of Mars due to the movement of carbon dioxide. In other words, the winter build up of ice changes the gravity of the planet. Mars has seasons that are similar to Earth's because its rotational axis has a tilt close to our own Earth's (25.19° for Mars, 23.45° for Earth). The south polar cap is higher in altitude and colder than the one in the north. The residual southern ice cap is misplaced. That is, it is not centered on the south pole. However, the south seasonal cap is centered near the geographic pole. Studies have shown that the off center cap is caused by much more snow falling on one side than the other. On the western hemisphere side of the south pole a low pressure system forms because the winds are changed by the Hellas Basin. This system produces more snow

Mars Glaciers: Vast Martian glaciers of water ice under protective blankets of rocky debris persist today at much lower latitudes than any ice previously identified on Mars, says new research using ground-penetrating radar on NASA's Mars Reconnaissance Orbiter.

Mars: Lake deltas found—North pole looks like a butt ._. **Voyager Mission:** July 21, 1976 High Resolution Imaging Science Experiment is a camera on board the Mars Reconnaissance Orbiter. The Mars Ocean Hypothesis proposes that the Vastitas Borealis basin was the site of an ocean of liquid water at least once,[13] and presents evidence that nearly a third of thesurface of

Thrace Macula/Thera Macula Europa - Ridge system on Europa. Theoretically made by volcanic activity (water resurfacing to carve ridges) <long lava flow>

Conamara Chaos Europa - A landscape produced by the disruption of the icy crust of Europa. The region consists of rafts of ice that have moved around and rotated. Surrounding these plates is a lower matrix of jumbled ice blocks which may have been formed as water, slush, or warm ice rose up from below the surface. The region is cited as evidence for a liquid ocean below Europa's icy surface.

Ridges Europa- . These ridges are narrow, linear features, up to a few hundred kilometers in length and 100-300 m in height. Many ridge-formation scenarios have been suggested, including tidal squeezing, linear diapir, up-warping by compression, linear volcanic activity buildup, shear heating along faults, or incremental ice-wedging. (wedging is most probable on Europa's atmosphere)

Cycloids Europa- Galileo images have revealed that cycloidal ridges are in fact double ridges. Cycloidal features may be formed as tensile cracks responding to Europa's tides. When the tensile strength of ice is reached a crack begins to form perpendicular to the local direction of the tensile stress. Because diurnal tidal stress changes, cracks propagate across an ever changing stress field (in both amplitude and orientation).

Oceans Europa- Magnetometer surveys done by the Galileo spacecraft discovered an induced magnetic field near Europa's surface. This suggest that a large body of conductive material (salty water) at a depth of 30 kilometers (about 20 miles) or less The surface of Europa has bands, ridges, fractures and multi-ringed impact structures that suggest the presence of mobile material below. The surface of Europa has large -scale fractures and ridges similar to those that bound Earth's tectonic plates. These suggest a mobile layer below Europa's crust that supports it and allows it to move.
Plains Europa - Plains material is the most widespread surface type and is subdivided into ridged plains, smooth plains or simply, undifferentiated. The multiple ridges that make up the ridged plains have a variety of sizes, orientations, and crosscutting relationships. Smooth plains are generally dark and occur in circular to irregularly shaped areas. At global resolutions plains material is described

Europa: Galileo Galilei, 8 January 1610.Jupiter. Silicate rock/iron core

Kuiper Belt/Oort Cloud: In 1950, Dutch astronomer Jan Oort proposed that certain comets come from a vast, extremely distant, spherical shell of icy bodies surrounding the solar system. This giant swarm of objects is now named the Oort Cloud, occupying space at a distance between 5,000 and 100,000 astronomical units. (One astronomical unit, or AU, is the mean distance of Earth from the sun: about 150 million km or 93 million miles.) The outer extent of the Oort Cloud is believed to be in the region of space where the sun's gravitational influence is weaker than the influence of nearby stars. The Oort Cloud probably contains 0.1 to 2 trillion icy bodies in solar orbit. Occasionally, giant molecular clouds, stars passing nearby, or tidal interactions with the Milky Way's disc disturb the orbits of some of these bodies in the outer region of the Oort Cloud, causing the object to fall into the inner solar system as a so-called long-period comet. These comets have very large, eccentric orbits and take thousands of years to circle the sun (>200 years at least). In recorded history, they are observed in the inner solar system only once. In contrast, short-period comets take less than 200 years to orbit the sun and they travel approximately in the plane in which most of the planets orbit. They are presumed to come from a disc-shaped region beyond Neptune called the Kuiper Belt, named for astronomer Gerard Kuiper. (It is sometimes called the Edgeworth-Kuiper Belt, recognizing the independent and earlier discussion by Kenneth Edgeworth.) The objects in the Oort Cloud and in the Kuiper Belt are presumed to be remnants from the formation of the solar system about 4.6 billion years ago. The Kuiper Belt extends from about 30 to 55 AU and is probably populated with hundreds of thousands of icy bodies larger than 100 km (62 miles) across and an estimated trillion or more comets. In 1992, astronomers detected a faint speck of light from an object about 42 AU from the sun -- the first time a Kuiper Belt object (or KBO for short) had been sighted. More than 1,300 KBOs have been identified since 1992. (They are sometimes called Edgeworth-Kuiper Belt objects, and they are sometimes called transneptunian objects or TNOs for short.) Because KBOs are so distant, their sizes are difficult to measure. The calculated diameter of a KBO depends on assumptions about how reflective the object's surface is. With infrared observations by the Spitzer Space Telescope, most of the largest KBOs have known sizes.

Enceladus Plumes - "The discovery by instruments aboard the Cassini orbiter that there's a currently active plume of icy dust and vapour from Enceladus has revolutionized planetary science," says Schenk. "Earlier this year, we published work that showed material from Enceladus's plumes coats the surfaces of Saturn's icy moons. Now, we've uncovered two lines of evidence that point to thick deposits of plume material coating the surface of Enceladus itself." Adds to Saturn's E-ring.

Enceladus Jets- The intensity of the jets of water ice and organic particles that shoot out from Saturn's moon Enceladus depends on the moon's proximity to the ringed planet, according to data obtained by NASA's Cassini spacecraft. "The jets of Enceladus apparently work like adjustable garden hose nozzles," said Matt Hedman, the paper's lead author and a Cassini team scientist based at Cornell University in Ithaca, N.Y. "The nozzles are almost closed when Enceladus is closer to Saturn and are most open when the moon is farthest away. We think this has to do with how Saturn squeezes and releases the moon with its gravity."

Enceladus Tiger Stripes- Observations from the Composite Infrared Spectrometer (CIRS) instrument showed the tiger stripes to have elevated surface temperatures, indicative of present-day cryovolcanism on Enceladus centered on the tiger stripes. Plumes/Jets come out from here (they're about 130 km long fractures in the ground)

Enceladus- Willliam Herschel. 1789. Saturn's E- Ring. 99% Albedo

Iapetus- Discovered by Cassini. Saturn's satellite. Tidally locked. Mostly composed of ice. HEAVILY cratered. Highest albedo (.03-.05). Dark region = Cassini Regio. Light = Roncevaux Terra/Saragossa Terra. Dark area lag from warmer areas (sublimation-darkened from exposure to sun). Contains organic compounds. Initial residue = debris from meteors and the such.

Triton- Neptune, William Lassell, retrograde orbit. Geologically active (cryovolcanism, tectonic plates), geysers erupting nitrogen, N atmosphere w/ methane and CO1. Solar heating, but very weak. W. Hem. = cantaloupe terrain, southern region = nitrogen.

Ceres-Guiseppe Piazzi, Ast. Belt, - Dawn mission – 2015 – More water than freshwater on Earth, But Ceres has more in common with Earth and Mars than its

Rocky neighbors. There are signs that Ceres contains large amounts of pure water ice beneath its surface. Scientists using the Herschel Space Observatory found evidence for water vapor on Ceres: plumes of water vapor are thought to shoot up periodically from Ceres when portions of its icy surface are warmed by the sun during the course of its orbit. This proves that Ceres has a icy surface and an atmosphere as well. Astronomers estimate that if Ceres were composed of 25 percent water, it may have more water than all the fresh water on Earth. Ceres' water, unlike Earth's, would be in the form of water ice and locatedp in the mantle, which wraps around the asteroid's solid core. Also, observations by NASA's Hubble Space Telescope show that Ceres shares characteristics of the rocky, terrestrial planets of our inner solar system. Computer models show that nearly round objects such as Ceres have a differentiated interior, with denser material at the core and lighter minerals near the surface. All the terrestrial planets -- including Earth -- have differentiated interiors. This sets Ceres apart from its asteroid neighbors.

Ceres-Guiseppe Piazzi, Ast. Belt, - Dawn mission – 2015 – More water than freshwater on Earth, But Ceres has more in common with Earth and Mars than its rocky neighbors. There are signs that Ceres contains large amounts of pure water ice beneath its surface. Scientists using the Herschel Space Observatory found evidence for water vapor on Ceres: plumes of water vapor are thought to shoot up periodically from Ceres when portions of its icy surface are warmed by the sun during the course of its orbit. This proves that Ceres has a icy surface and an atmosphere as well. Astronomers estimate that if Ceres were composed of 25 percent water, it may have more water than all the fresh water on Earth. Ceres' water, unlike Earth's, would be in the form of water ice and located in the mantle, which wraps around the asteroid's solid core. Also, observations by NASA's Hubble Space Telescope show that Ceres shares characteristics of the rocky, terrestrial planets of our inner solar system. Computer models show that nearly round objects such as Ceres have a differentiated interior, with denser material at the core and lighter minerals near the surface. *All the terrestrial planets -- including Earth -- have subsurface) and robust nitrogen atmosphere, Titan's methane cycle is viewed as an analogy to Earth's water cycle, although at a much lower* temperature. Titan is the only known moon with more than a trace of atmosphere. Its atmosphere is the only nitrogen-rich dense atmosphere in the Solar System aside from Earth's. Observations of its atmosphere made in 2004 by Cassini suggest that Titan is a "super rotator", like Venus, with an atmosphere that rotates much faster than its surface. Observations from the Voyager space probes have shown that Titan's atmosphere is denser than Earth's, with a surface pressure about 1.45 times that of Earth's. Titan's atmosphere is about 1.19 times as massive as Earth's overall, or about 7.3 times more massive on a per surface area basis. It supports opaque haze layers that block most visible light from the Sun and other sources and renders Titan's surface features obscure. Titan's lower gravity means that its atmosphere is far more extended than Earth's. The atmosphere of Titan is opaque at many wavelengths and a complete reflectance spectrum of the surface is impossible to acquire from orbit.[32] It was not until the arrival of the Cassini–Huygens mission in 2004 that the first direct images of Titan's surface were obtained.[33] Titan's atmospheric composition in the stratosphere is 98.4% nitrogen with the remaining 1.6% composed mostly of methane (1.4%) and hydrogen (0.1–0.2%).[8] There are trace amounts of other hydrocarbons, such as ethane, diacetylene, methylacetylene, acetylene and propane, and of other gases, such as cyanoacetylene, hydrogen cyanide, carbon dioxide, carbon monoxide, cyanogen, argon and helium. The hydrocarbons are thought to form in Titan's upper atmosphere in reactions resulting from the

breakup of methane by the Sun's ultraviolet light, producing a thick orange smog. Titan spends 95% of its time within Saturn's magnetosphere, which may help shield Titan from the solar wind. Energy from the Sun should have converted all traces of methane in Titan's atmosphere into more complex hydrocarbons within 50 million years — a short time compared to the age of the Solar System. This suggests that methane must be somehow replenished by a reservoir on or within Titan itself. The ultimate origin of the methane in Titan's atmosphere may be its interior, released via eruptions from cryovolcanoes. On April 3, 2013, NASA reported that complex organic chemicals could arise on Titan based on studies simulating the atmosphere of Titan.On June 6, 2013, scientists at the IAA-CSIC reported the detection of polycyclic aromatic hydrocarbons in the upper atmosphere of Titan. On September 30, 2013, propylene was detected in the atmosphere of Titan by NASA's Cassini–Huygens spacecraft, using its composite infrared spectrometer (CIRS). This is the first time propylene has been found on any moon or planet other than Earth and is the first chemical found by the CIRS. The detection of propylene fills a mysterious gap in observations that date back to NASA's Voyager spacecraft's first close flyby of the moon in 1980, during which it was discovered that many of the gases that make up Titan's hazy brown colored haze were hydrocarbons, theoretically formed via the recombination of radicals formed by the ultraviolet photolysis of methane, the second-most common gas in Titan's atmosphere. Composition Variable Stratosphere: 98.4% nitrogen (N2), 1.4% methane (CH4); Lower troposphere: 95.0% N2, 4.9% CH4

Iapetus: In the 17th century, Giovanni Cassini observed that he could see Iapetus only on the west side of Saturn and never on the east. He correctly deduced that Iapetus is locked in synchronous rotation about Saturn and that one side of Iapetus is darker than the other, conclusions later confirmed by larger telescopes. The difference in colouring between the two Iapetian hemispheres is striking. The leading hemisphere and sides are dark (albedo 0.03–0.05) with a slight reddish-brown coloring, while most of the trailing hemisphere and poles are bright (albedo 0.5–0.6, almost as bright as Europa). Thus, the apparent magnitude of the trailing hemisphere is around 10.2, whereas that of the leading hemisphere is around 11.9 – beyond the capacity of the best telescopes in the 17th century. The pattern of coloration is analogous to a spherical yin-yang symbol or the two sections of a tennis ball. The dark region is named Cassini Regio, and the bright region is divided into Roncevaux Terra north of the equator, and Saragossa Terra south of it. The original dark material is believed to have come from outside Iapetus, but now it consists principally of lag from the sublimation of ice from the warmer areas of Iapetus's surface.[16][17][18] It contains organic compounds similar to the substances found in primitive meteorites or on the surfaces of comets; Earth-based observations have shown it to be carbonaceous, and it probably includes cyano-compounds such as frozen hydrogen cyanide polymers. NASA scientists now believe that the dark material is lag (residue) from the sublimation (evaporation) of water ice on the surface of Iapetus,[17][21] possibly darkened further upon exposure to sunlight. Because of its slow rotation of 79 days (equal to its revolution and the longest in the Saturnian system), Iapetus would have had the warmest daytime surface temperature and coldest nighttime temperature in the

Saturnian system even before the development of the color contrast; near the equator, heat absorption by the dark material results in a daytime temperatures of 129 K in the dark Cassini Regio compared to 113 K in the bright regions.[18] [22] The difference in temperature means that ice preferentially sublimates from Cassini Regio, and deposits in the bright areas and especially at the even colder poles. Over geologic time scales, this would further darken Cassini Regio and brighten the rest of Iapetus, creating a positive feedback thermal runaway process of ever greater contrast in albedo, ending with all exposed ice being lost from Cassini Regio.[18] It is estimated that over a period of one billion years at current temperatures, dark areas of Iapetus would lose about 20 meters of ice to sublimation, while the bright regions would lose only 10 centimeters, not considering the ice transferred from the dark regions. Scientists have long wondered why one hemisphere of Iapetus is so dark in comparison to its other hemisphere, and in comparison to other surfaces in the Saturn system. Iapetus may be sweeping up particles from the more-distant dark moon, Phoebe. If that is the darkening mechanism, it should be steadily renewing the dark surface because very few fresh bright craters are detected within the dark terrain. An alternate theory is that there might be ice volcanism distributing darker material to the surface. Volcano-like eruptions of hydrocarbons might form the dark surfaces, particularly after chemical reactions caused by solar radiation. The September 2007 Cassini flyby of Iapetus showed that a third process, thermal segregation, is probably the most responsible for Iapetus' dark hemisphere. Iapetus has a very slow rotation, longer than 79 days. Such a slow rotation means that the daily temperature cycle is very long, so long that the dark material can absorb heat from the sun and warm up. (The dark material absorbs more heat than the bright icy material.) This heating will cause any volatile, or icy, species within the dark material to sublime out, and retreat to colder regions on Iapetus. This sublimation of volatiles causes the dark material to become even darker -- and causes neighboring bright, cold regions to become even brighter. Iapetus may have experienced a (possibly small) influx of dark material from an external source, which could have warmed up and triggered this thermal segregation process. The second most notable feature of Iapetus is its "equatorial ridge," a chain of 10-km (6-mile) high mountains girdling the moon's equator. On the anti-Saturnian side of Iapetus, the ridge appears to break up and distinct, partially bright mountains are observed. The Voyager I and Voyager II encounters provided the first knowledge of these mountains, and they are informally referred to as the Voyager Mountains. There are two theories on how the ridge formed. Some scientists think the ridge was formed at an earlier time when Iapetus rotated much faster than it does today; others think the ridge is made of material left from the collapse of a ring.

Random Missions

Rosetta: The Rosetta orbiter will rendezvous with Comet 67P/Churyumov-Gerasimenko and remain in close proximity to the icy nucleus as it plunges towards the warmer inner reaches of the Sun's domain. At the same time, a small lander will be released onto the surface of this mysterious cosmic iceberg. December 2015

Mars Express: The flyby on 29 December will be so close and fast that Mars Express will not be able to take any images, but instead it will yield the most accurate details yet of the moon's gravitational field and, in turn, provide new details of its internal structure. As the spacecraft passes close to Phobos, it will be pulled slightly off course by the moon's gravity, changing the spacecraft's velocity by no more than a few centimetres per second. These small deviations will be reflected in the spacecraft's radio signals as they are beamed back to Earth, and scientists can then translate them into measurements of the mass and density structure inside the moon.

NASA's Mars Reconnaissance Orbiter, launched August 12, 2005, is on a search for evidence that water persisted on the surface of Mars for a long period of time. While other Mars missions have shown that water flowed across the surface in Mars' history, it remains a mystery whether water was ever around long enough to provide a habitat for life.

Galileo plunged into Jupiter's crushing atmosphere on Sept. 21, 2003. The spacecraft was deliberately destroyed to protect one of its own discoveries - a possible ocean beneath the icy crust of the moon Europa. Galileo changed the way we look at our solar system. The spacecraft was the first to fly past an asteroid and the first to discover a moon of an asteroid. It provided the only direct observations of a comet colliding with a planet. Launch: 10.18.8 End of Mission: 9.21.03

NASA'S LCROSS found ice water on the moon

Comets named for: year, discoverer, or instrument (or orbit calculator)

A comet is an icy small Solar System body that, when passing close to the Sun, heats up and begins to outgas, displaying a visible atmosphere or coma, and sometimes also a tail. These phenomena are due to the effects of solar radiation and the solar wind upon the nucleus of the comet. Comet nuclei range from a few hundred metres to tens of kilometres across and are composed of loose collections of ice, dust, and small rocky particles. The coma and tail are much larger, and if sufficiently bright may be seen from the Earth without the aid of a telescope. Comets have been observed and recorded since ancient times by many different cultures. Comets have a wide range of orbital periods, ranging from several years to several millions of years. Short-period comets originate in the Kuiper belt or its associated scattered disc, which lie beyond the orbit of Neptune. Longer-period comets are thought to originate in the Oort cloud, a spherical cloud of icy bodies extending from outside the Kuiper Belt to halfway to the next nearest star. Long-period comets are directed towards the Sun from the Oort cloud by gravitational perturbations caused by passing stars and the galactic tide. Hyperbolic comets may pass once through the inner Solar System before being flung out to interstellar space along hyperbolic trajectories. The coma is generally made of H2O and dust, with water making up to 90% of the volatiles that outflow from the nucleus when the comet is within 3 to 4 astronomical units (450,000,000 to 600,000,000 km; 280,000,000 to 370,000,000 mi) of the Sun.[36] The H2O parent molecule is destroyed primarily throughphotodissociation and to a much smaller extent photoionization, with the solar wind playing a minor role in the destruction of water compared to photochemistry.[36]Larger dust particles are left along the comet's orbital path whereas smaller particles are pushed away from the Sun into the comet's tail by light pressure. Periodic comets or short-period comets are generally defined as having orbital periods of less than 200 years.[60] They usually orbit more-or-less in the ecliptic plane in the same direction as the planets.[61] Their orbits typically take them out to the region of the outer planets (Jupiter and beyond) at aphelion; for example, the aphelion of Halley's Comet is a little beyond the orbit of Neptune. Comets whose aphelia are near a major planet's orbit are called its "family". [62] Such families are thought to arise from the planet capturing formerly long-period comets into shorter orbits. the shorter extreme, Encke's Comet has an orbit that does not reach the orbit of Jupiter, and is known as an Encke-type comet. Short-period comets with orbital periods shorter than 20 years and low inclinations (up to 30 degrees) are called "Jupiter-family comets".[64][65] Those like Halley, with orbital periods of between 20 and 200 years and inclinations extending from zero to

more than 90 degrees, are called "Halley-type comets".[66][67] As of 2013, only 72 Halley-type comets have been observed, compared with 470 identified Jupiter-family comets . Long-period comets have highly eccentric orbits and periods ranging from 200 years to thousands of years.[77] An eccentricity greater than 1 when near perihelion does not necessarily mean that a comet will leave the Solar System.[78] For example, Comet McNaught had a heliocentric osculating eccentricity of 1.000019 near its perihelion passage epoch in January 2007 but is bound to the Sun with roughly a 92,600-year orbit because the eccentricity drops below 1 as it moves further from the Sun. The future orbit of a long-period comet is properly obtained when the osculating orbit is computed at an epoch after leaving the planetary region and is calculated with respect to the center of mass of the Solar System. By definition long-period comets remain gravitationally bound to the Sun; those comets that are ejected from the Solar System due to close passes by major planets are no longer properly considered as having "periods". The orbits of long-period comets take them far beyond the outer planets at aphelia, and the plane of their orbits need not lie near the ecliptic. Long-period comets such as Comet West and C/1999 F1 can have apoapsis distances of nearly 70,000 AU with orbital periods estimated around 6 million years. Sungrazing comet is a comet that passes extremely close to the Sun at perihelion, generally within a few million kilometres.[147] Although small sungrazers can be completely evaporated during such a close approach to the Sun, larger sungrazers can survive many perihelion passages. However, the strong tidal forces they experience often lead to their fragmentation.

First definitive evidence of ice on comets: Deep Impact Probe

Introduction: Ice is the name given to any one of the 15 known crystalline solid phases of water. In non-scientific contexts, it usually describes ice Ih, which is the most abundant of these phases. It can appear transparent or an opaque bluish-white color depending on the presence of impurities such as air. The addition of other materials such as soil may further alter appearance.The most common phase transition to ice Ih occurs when liquid water is cooled below 0 °C (273.15 K, 32 °F) at standard atmospheric pressure. It can also deposit from a vapor with no intervening liquidphase, such as in the formation of frost. Ice appears in nature in varied forms such as hail and glaciers. Amorphous ice is more common in outer space whereas hexagonal crystalline ice is extremely rare, which is predominant on Earth. Phase properties of Earth's Water Ice: The main physical nature and phases of water ice are given in the table 1. The figure 1 a) and b) shows the phase diagram of water and different ice types.

Space Ice: The solid-vapor curve becomes very low (fig. 1a) as pressures and temperatures decreases and by -90oC the vapor pressure of ice is about 10-4 mb. At the temperatures of the outer solar system, the vapor pressure of ice is so low that ice remains for geologically long times even in a vacuum. In Space, instead of pure water ice, we find Clathrate Hydrates, which were first discovered in 1810 by Sir Humphrey Davy, they are crystalline water based solids physically resembling ice, in which small non polar molecules are trapped inside cages of hydrogen bonded water molecules. These gases includes O2, H2, N2, CO2, CH4, H2S, Ar, Kr, and Xe as well as some higher hydrocarbons and freons which forms hydrates at suitable temperatures and pressures. **Remote Sensing of Water Ice and Space Ice:** The ice in space may occurs in form of dry ice at Mars polar caps [2] [7], clathrate hydrate, Earth moon poles, Europa, and Triton are other examples where ice is found and has been studied using remote sensing based observations. The CO2, SO2, and H2S, other than the water ice, have been detected on the surface of Europa by spectroscopic sensors. These substances might occur as pure crystalline ices, as vitreous mixtures, or as clathrate hydrate phases, depending on the system conditions and the history of the material [4]. Similar ice types are found on the Saturn's icy moons by Cassini Team [8].Space Ice: Vapour pressure is extremely low. In space instead of pure water ice, we find Clathrate Hydrates. They were found by Sir Humphrey Davy in 1810. They are crystalline water based solids physically resembling ice, in which small non polar molecules are trapped inside cages of hydrogen bonded water molecules. These gases include O2 H2 N2 CO2 CH4 H2S Ar Kr and Xe as well as some higher hydrocarbons and freons which forms hydrates at suitable temperatures and pressures. Use spectroscopic sensors to detect forms of ice in space. Most common: Amorphous Least Common: Hexagonal

Mars: Many lines of evidence indicate that water is abundant on Mars and has played a significant role in the planet's geologic history.[27][28] The present-day inventory of water on Mars can be estimated from spacecraft imagery, remote sensing techniques (spectroscopic measurements,[29][30] radar,[31] etc.,), and surface investigations from landers and rovers.[32][33] Geologic evidence of past water includes enormous outflow channels carved by floods; ancient river valley networks,[34][35] deltas, and lakebeds;[36][37][38][39] and the detection of rocks and minerals on the surface that could only have formed in liquid water.[40] Numerous geomorphic features suggest the presence of ground ice (permafrost) [41] and the movement of ice in glaciers, both in the recent past[42][43][44][45][46][47] and present.[48] Gullies and slope lineaealong cliffs and crater walls suggest that flowing water continues to shape the surface of Mars, although to a far lesser degree than in the ancient past. Although the surface of Mars was periodically wet and could have been hospitable to microbial life billions of years ago,[49] the current environment at the surface is dry and subfreezing, probably presenting an insurmountable obstacle for living organisms. In addition, Mars lacks a thick atmosphere, ozone layer, and magnetic field, allowing solar and cosmic radiation to strike the surface unimpeded. The damaging effects of ionizing radiation on cellular structure is another one of the prime limiting factors on the survival of life on the surface.[50][51] Therefore, the best potential locations for discovering life on Mars may be in subsurface environments. Aqueous minerals can also form in the subsurface by hydrothermal fluids migrating through pores and fissures. The heat source driving a hydrothermal system may be nearby magma bodies or residual heat from large impacts.[78] One important type of hydrothermal alteration in the Earth's oceanic crust is serpentinization, which occurs when seawater migrates through ultramafic and basaltic rocks. The water-rock reactions result in the oxidation of ferrous iron in olivine and pyroxene to produce ferric iron (as the mineral magnetite) yielding molecular hydrogen (H2) as a byproduct. The process creates a highly alkaline and reducing (low Eh) environment favoring the formation of certain phyllosilicates (serpentine minerals) and various carbonate minerals, which together form a rock called serpentinite.[79] The hydrogen gas produced can be an important energy source for chemosynthtetic organisms or it can react with CO2 to produce methane gas, a process that has been considered as a non-biological source for the trace amounts of methane reported in the Martian atmosphere. [80] Serpentine minerals can also store a lot of water (as hydroxyl) in their crystal structure.

The objects present wide range of spectra, differing in reflectivity in visible red and near infrared. Neutral objects present a flat spectrum, reflecting as much red and infrared as visible spectrum.[21] Very red objects present a steep slope, reflecting much more in red and infrared. A recent attempt at classification (common with centaurs) uses the total of four classes fromBB (blue, average B-V=0.70, V-R=0.39 e.g. Orcus) to RR (very red, B-V=1.08, V-R=0.71, e.g. Sedna) with BR and IR as intermediate classes. BR and IR differ mostly in the infrared bands I, J and H.

Typical models of the surface include water ice, amorphous carbon, silicates and organic macromolecules, named tholins, created by intense radiation. Four major tholins are used to fit the reddening slope:

Titan tholin, believed to be produced from a mixture of 90% N2 and 10% CH4 (gaseous methane)

Triton tholin, as above but with very low (0.1%) methane content

(ethane) Ice tholin I, believed to be produced from a mixture of 86% H2O and 14% C2H6 (ethane)

(methanol) Ice tholin II, 80% H2O, 16% CH3OH (methanol) and 3% CO2

As an illustration of the two extreme classes BB and RR, the following compositions have been suggested

for Sedna (RR very red): 24% Triton tholin, 7% carbon, 10% N2, 26% methanol, and 33% methane

for Orcus (BB, grey/blue): 85% amorphous carbon, +4% titan tholin, and 11% H2O ice

Enceladus: Enceladus was discovered by Fredrick William Herschel on August 28, 1789, during the first use of his new 1.2 m telescope, then the largest in the world. [26][27]Herschel first observed Enceladus in 1787, but in his smaller, 16.5 cm telescope, the moon was not recognized.[28] Its faint apparent magnitude (+11.7m) and its proximity to much brighter Saturn and its rings make Enceladus difficult to observe from Earth, requiring a telescope with a mirror of 15–30 cm in diameter, depending on atmospherical conditions and light pollution. Like many Saturnian satellites discovered prior to the Space Age, Enceladus was first observed during a Saturnian equinox, when Earth is within the ring plane; at such times, the reduction in glare from the rings makes the moons easier to observe. The two Voyager spacecraft obtained the first close-up images of Enceladus. Voyager 1 was the first to fly past Enceladus, at a distance of 202,000 km on November 12, 1980.[29] Images acquired from this distance had very poor spatial resolution, but revealed a highly reflective surface devoid of impact craters, indicating a youthful surface.[30] Voyager 1 also confirmed that Enceladus was embedded in the densest part of Saturn's diffuse E-ring. Combined with the apparent youthful appearance of the surface, Voyager scientists suggested that the E-ring consisted of particles vented from Enceladus's surface Voyager 2 passed closer to Enceladus (87,010 km) on August 26, 1981, allowing much higher-resolution images of this satellite.[29] These images showed a youngsurface.[31] They also revealed a surface with different regions with vastly different surface ages, with a heavily cratered mid- to high-northern latitude region, and a lightly cratered region closer to the equator. This geologic diversity contrasts with the ancient, heavily cratered surface of Mimas, another moon of Saturn slightly smaller than Enceladus. The geologically youthful terrains came as a great surprise to the scientific community, because no theory was then able to predict that such a small (and cold, compared to Jupiter's highly active moon Io) celestial body could bear signs of such activity. However, Voyager 2 failed to determine whether Enceladus was currently active or whether it was the source of the E-ring. Voyager 2 found several types of tectonic features on Enceladus, including troughs, scarps, and belts of grooves and ridges.[31] Recent results from Cassini suggest that tectonism is the dominant deformation style on Enceladus. One of the more dramatic types of tectonic features found on Enceladus are rifts. These canyons can be up to 200 km long, 5–10 km wide, and 1 km deep. Such features appear relatively young, as they cut across other

Thanks to data from a number of instruments on the Cassini spacecraft in 2005, cryovolcanism, where water and other volatiles are the materials erupted instead of silicate rock, has been discovered on Enceladus. The first Cassini sighting of a plume of icy particles above Enceladus's south pole came from the Imaging Science Subsystem (ISS) images taken in January and February 2005,[2] though the possibility of the plume being a camera artifact stalled an official announcement. Data from themagnetometer instrument during the February 17, 2005 encounter provided a hint that the feature might be real when it found evidence for an atmosphere at Enceladus. The magnetometer observed an increase in the power of ion cyclotron waves near Enceladus. These waves are produced by the interaction of ionized particles and magnetic fields, and the frequency of the waves can be used to identify the composition, in this case ionized water vapor.[10] During the next two encounters, the magnetometer team determined that gases in Enceladus's atmosphere are concentrated over the south polar region, with atmospheric density away from the pole being much lower.[10] TheUltraviolet Imaging Spectrograph (UVIS) confirmed this result by observing two stellar occultations during the February 17 and July 14 encounters. Unlike the magnetometer, UVIS failed to detect an atmosphere above Enceladus during the February encounter when it looked for evidence for an atmosphere over the equatorial region, but did detect water vapor during an occultation over the south polar region during the July encounter. Composition 91% Water vapor 4% Nitrogen 3.2% Carbon dioxide 1.7% Methane [9]

Slightly smaller than the Moon, Europa is primarily made of silicate rock and probably has an iron core. It has a tenuous atmosphere composed primarily ofoxygen. Its surface is composed of water ice and is one of the smoothest in the Solar System.[10] This surface is striated by cracks and streaks, whereas craters are relatively rare. The apparent youth and smoothness of the surface have led to the hypothesis that a water ocean exists beneath it, which could conceivably serve as an abode for extraterrestrial life.[11] This hypothesis proposes that heat from tidal flexing causes the ocean to remain liquid and drives geological activity similar to plate tectonics. The Galileo mission, launched in 1989, provided the bulk of current data on Europa. No spacecraft has yet landed on Europa, but its intriguing characteristics have led to several ambitious exploration proposals. The European Space Agency's Jupiter Icy Moon Explorer (JUICE) is a mission to Europa that is due to launch in 2022. [15] NASA is planning a robotic mission that would be launched in the "mid-2020s". Europa's most striking surface features are a series of dark streaks crisscrossing the entire globe, called lineae (English: lines). Close examination shows that the edges of Europa's crust on either side of the cracks have moved relative to each other. The larger bands are more than 20 km (12 mi) across, often with dark, diffuse outer edges, regular striations, and a central band of lighter material. [36] The most likely hypothesis states that these lineae may have been produced by a series of eruptions of warm ice as the Europan crust spread open to expose warmer layers beneath.[37] The effect would have been similar to that seen in Earth's oceanic ridges. These various fractures are thought to have been caused in large part by the tidal flexing exerted by Jupiter. Because Europa is tidally locked to Jupiter, and therefore always maintains the same approximate orientation towards Jupiter, the stress patterns should form a distinctive and predictable pattern. However, only the youngest of Europa's fractures conform to the predicted pattern; other fractures appear to occur at increasingly different orientations the older they are. This could be explained if Europa's surface rotates slightly faster than its interior, an effect that is possible due to the subsurface ocean mechanically decoupling Europa's surface from its rocky mantle and the effects of Jupiter's gravity tugging on Europa's outer ice crust.[38] Comparisons of Voyager andGalileo spacecraft photos serve to put an upper limit on this hypothetical slippage. The full revolution of the outer rigid shell relative to the interior of Europa occurs over a minimum of 12,000 years. Scientists' consensus is that a layer of liquid water exists beneath Europa's surface, and that heat energy from tidal flexing allows the subsurface ocean to remain liquid.[12][46] Europa's surface temperature averages about 110 K (−160 °C; −260 °F) at the equator and only 50 K (−220 °C; −370 °F) at the poles, keeping Europa's icy crust as hard as granite.[7] The first hints of a subsurface ocean came from theoretical considerations of tidal heating (a consequence of Europa's slightly eccentric orbit and orbital resonance with the other Galilean moons). Galileo imaging team members argue for the existence of a subsurface ocean from analysis of Voyager and Galileo images.[46] The most dramatic example is "chaos terrain", a common feature on Europa's surface that some interpret as a region where the ubsurface ocean has melted through the icy crust. This interpretation is extremely controversial. Most geologists who have studied Europa favor what is commonly called the "thick ice" model, in which the ocean has rarely, if ever, directly interacted with the present surface.[47] The different models for the estimation of the ice shell thickness give values between a few kilometers and tens of kilometers . The best evidence for the thick-ice model is a study of Europa's large craters. The largest impact structures are surrounded by concentric rings and appear to be filled with relatively flat, fresh ice; based on this and on the calculated amount of heat generated by Europan tides, it is predicted that the outer crust of solid ice is approximately 10–30 km (6–19 mi) thick, including a ductile "warm ice" layer, which could mean that the liquid ocean underneath may be about 100 km (60 mi) deep.[32][49] This leads to a volume of Europa's oceans of 3 × 1018 m3, slightly more than two times the volume of Earth's oceans . The thin-ice model suggests that Europa's ice shell may be only a few kilometers thick. However, most planetary scientists conclude that this model considers only those topmost layers of Europa's crust that behave elastically when affected by Jupiter's tides. One example is flexure analysis, in which Europa's crust is modeled as a plane or sphere weighted and flexed by a heavy load. Models such as this suggest the outer elastic portion of the ice crust could be as thin as 200 metres (660 ft). If the ice shell of Europa is really only a few kilometers thick, this "thin ice" model would mean that regular contact of the liquid interior with the surface could occur through open ridges, causing the formation of areas of chaotic terrain. In late 2008, it was suggested Jupiter may keep Europa's oceans warm by generating large planetary tidal waves on Europa because of its small but non-zero obliquity. This previously unconsidered kind of tidal force generates so-called Rossby waves that travel quite slowly, at just a few kilometers per day, but can generate significant kinetic energy. For the current axial tilt estimate of 0.1 degree, the resonance from Rossby waves would store 7.3×1017 J of kinetic energy, which is two thousand times larger than that of the flow excited by the dominant tidal forces.[50][51] Dissipation of this energy could be the principal heat source of Europa's ocean. he Galileo orbiter found that Europa has a weak magnetic moment, which is induced by the varying part of the Jovian magnetic field. The field strength at the magnetic equator (about 120 nT) created by this magnetic moment is about one-sixth the strength of Ganymede's field and six times the value of Callisto's.[52] The existence of the induced moment requires a layer of a highly electrically conductive material in Europa's interior. The most plausible candidate for this role is a large subsurface ocean of liquid saltwater. [28] Spectrographic evidence suggests that the dark, reddish streaks and features on Europa's surface may be rich in salts such as magnesium sulfate, deposited by evaporating water that emerged from within.[53] Sulfuric acid hydrate is another possible explanation for the contaminant observed spectroscopically.[54] In either case, because these materials are colorless or white when pure, some other material must also be present to account for the reddish color, and sulfur compounds are suspected

Moon/ Object	Density	Grav/Pressure
Titan	1.8798±0.0044 g/cm3	146.7 kPa /1.352 m/s2 (
Triton	2.061 g/cm3	1.4–1.9 Pa /0.779 m/s2
Iapetus	1.088±0.013 g/cm³	0.224 m/s²
Europa	3.01 g/cm3	/1.314 m/s2
Mars	3.9335±0.0004g/cm³	3.711 m/s² /0.636 (0.4–0.87) kPa
Ceres	2.077±0.036 g/cm3	0.27 m/s2 /
Enceladus	1.609±0.005 g/cm³	0.114 m/s² /Trace pressure

Acidophile: An organism with optimal growth at pH levels of 3 or below

Alkaliphile: An organism with optimal growth at pH levels of 9 or above

Anaerobe: An organism that does not require oxygen for growth such as Spinoloricus Cinzia. Two sub-types exist: facultative anaerobe and obligate anaerobe. Facultative anaerobe can tolerate anaerobic and aerobic condition; however, an obligate anaerobe would die in presence of even trace levels of oxygen.

Cryptoendolith: An organism that lives in microscopic spaces within rocks, such as pores between aggregate grains; these may also be called Endolith, a term that also includes organisms populating fissures, aquifers, and faults filled with groundwater in the deep subsurface.

Halophile: An organism requiring at least 0.2M concentrations of salt (NaCl) for growth[10]

Hyperthermophile: An organism that can thrive at temperatures between 80–122 °C, such as those found in hydrothermal systems

Hypolith: An organism that lives underneath rocks in cold deserts

Lithoautotroph: An organism (usually bacteria) whose sole source of carbon is carbon dioxide and exergonic inorganic oxidation (chemolithotrophs) such as Nitrosomonas europaea; these organisms are capable of deriving energy from reduced mineral compounds like pyrites, and are active in geochemical cycling and the weathering of parent bedrock to form soil

Metallotolerant: capable of tolerating high levels of dissolved heavy metals in solution, such as copper, cadmium, arsenic, and zinc; examples include Ferroplasma sp., Cupriavidus metallidurans and GFAJ-1.[11][12][13]

Oligotroph: An organism capable of growth in nutritionally limited environments

MARS CON'T..

Mars was covered by a liquid ocean early in the planet's geologic history.[118] [147] This ocean, dubbed Oceanus Borealis,[13] would have filled the Vastitas Borealis basin in the northern hemisphere, a region which lies 4–5 km (2.5–3 miles) below the mean planetary elevation. Two major putative shorelines have been suggested: a higher one, dating to a time period of approximately 3.8 billion years ago and concurrent with the formation of the valley networks in the Highlands, and a lower one, perhaps correlated with the younger outflow channels. The higher one, the 'Arabia shoreline', can be traced all around Mars except through the Tharsis volcanic region. The lower, the 'Deuteronilus', follows the Vastitas Borealis formation.[120]

A study in June 2010 concluded that the more ancient ocean would have covered 36% of Mars.[20][21] Data from the Mars Orbiter Laser Altimeter (MOLA), which measures the altitude of all terrain on Mars, was used in 1999 to determine that the watershed for such an ocean would have covered about 75% of the planet. [148] Early Mars would have required a warmer climate and denser atmosphere to allow liquid water to exist at the surface.[149][150] In addition, the large number of valley networks strongly supports the possibility of a hydrological cycle on the planet in the past.[140][151]

However, the existence of a primordial Martian ocean remains controversial among scientists, and the interpretations of some features as 'ancient shorelines' has been challenged.[152][153] One problem with the conjectured 2 billion years old (2 Ga) shoreline is that it is not flat — i.e. does not follow a line of constant gravitational potential. This could be due to a change in distribution in Mars' mass, perhaps due to volcanic eruption or meteor impact;[154] the Elysium volcanic province or the massive Utopia basin that is buried beneath the northern plains have been put forward as the most likely causes.

Osmophile: An organism capable of growth in environments with a high sugar concentration

Piezophile: (Also referred to as barophile). An organism that lives optimally at high pressures such as those deep in the ocean or underground;[14] common in the deep terrestrial subsurface, as well as in oceanic trenches

Polyextremophile: A polyextremophile (faux Ancient Latin/Greek for 'affection for many extremes') is an organism that qualifies as an extremophile under more than one category.

Psychrophile/Cryophile: An organism capable of survival, growth or reproduction at temperatures of -15 °C or lower for extended periods; common in cold soils, permafrost, polar ice, cold ocean water, and in or under alpine snowpack

Radioresistant: Organisms resistant to high levels of ionizing radiation, most commonly ultraviolet radiation, but also including organisms capable of resisting nuclear radiation

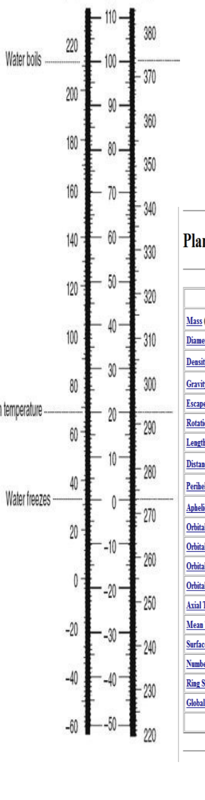
Thermophile: An organism that can thrive at temperatures between 45–122 °C

Thermoacidophile: Combination of thermophile and acidophile that prefer temperatures of 70–80 °C and pH between 2 and 3

Xerophile: An organism that can grow in extremely dry, desiccating conditions; this type is exemplified by the soil microbes of the Atacama Desert

Barophile: Thrives at high pressure

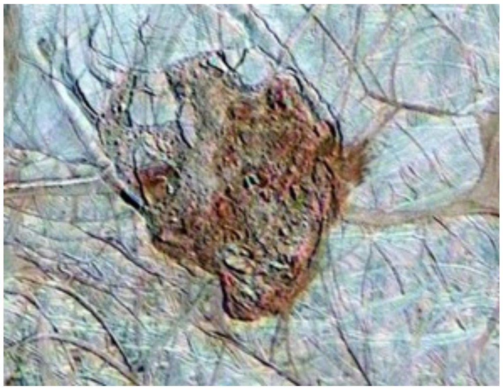
Endolith: Lives inside rock, coral animal shells, or in pores in the mineral grains of a rock Many are extremophiles.

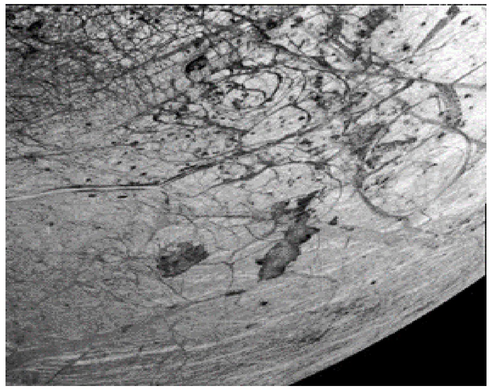


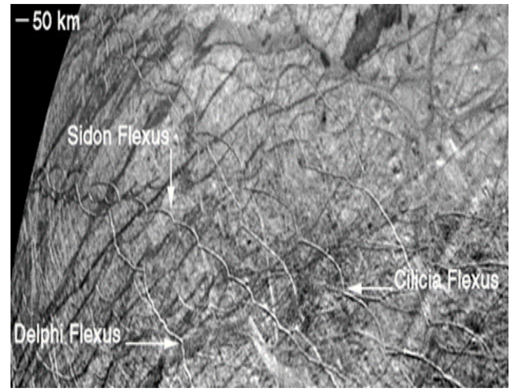
Triton's guttae (drop, lat.), (Fig 1.) originally named 'mushrooms' [1] and now named maculae in the IAU nomenclature, have been photographed by Voyager 2. They are found in groups between 5S and 45S, on or near the edge of the south polar cap [2], on bright smooth terrain (albedo: 0.85) [3]. They are irregular spots with an albedo lower than the surrounding terrain (albedo: 0.7), with brighter (albedo: 0.9) annular aureoles around them whose materials are visually similar to the opaque bright material on the south polar cap [2].Now named maculae :O Guttae have been interpreted as residual deposits of a pre-existing, thicker and more extensive polar cap [2]. They are proposed to have been formed as the low albedo interior is sublimating N2 at high rate, which rises local N2 pressure that radiates outwards, where under the locally increased partial pressure, condensation temperature is higher and consequently N2 re-condensates as frost (or sublimates at slower rate), resulting in the bright annulus [3]. They have been compared to outliers of the permanent Martian cap shaped by ablation [2] or CO2 frost halos on the south polar residual cap, where frost accumulation occurs due to higher sublimation rates on sun-facing slopes [3]. That guttae have similar origin to seasonally formed inliers on the Martian polar seasonal frost cover that form over dark dunes. DDS's have been proposed to form by defrosting, sublimation of CO2 frost, exposing the underlying dark surface. Defrosting occurs as low albedo polar sand heats beneath an optically thin layer of frost, causing the frost to evaporate. This vapor is re- precipitated in the colder outer zones forming a bright halo. As the core evolves, the bright halo narrows and disappears, but the spot develops a dark interior and a grey exterior zone. [7]. On Triton only a dark interior and a bright outer zone have been observed, both with sharp boundaries, composed of N2 frost. On Mars, DDS's have a prominent dark core with a temporary grey outer zone with a diffuse bright halo, composed of CO2 frost. The Tritonian example may be a temporal state in seasonal guttae deveopment.

Planetary Fact Sheet - Metric

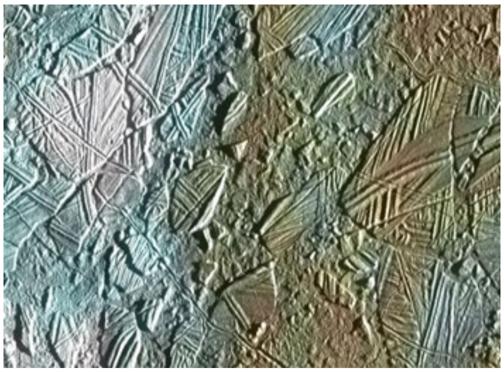
	MERCURY	VENUS	EARTH	MOON	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Mass (10^{24}kg)	0.330	4.87	5.97	0.073	0.642	1898	568	86.8	102	0.0131
Diameter (km)	4879	12,104	12,756	3475	6792	142,984	120,536	51,118	49,528	2390
Density (kg/m^3)	5427	5243	5514	3340	3933	1326	687	1271	1638	1830
Gravity (m/s^2)	3.7	8.9	9.8	1.6	3.7	23.1	9.0	8.7	11.0	0.6
Escape Velocity (km/s)	4.3	10.4	11.2	2.4	5.0	59.5	35.5	21.3	23.5	1.1
Rotation Period (hours)	1407.6	-5832.5	23.9	655.7	24.6	9.9	10.7	-17.2	16.1	-153.3
Length of Day (hours)	4222.6	2802.0	24.0	708.7	24.7	9.9	10.7	17.2	16.1	153.3
Distance from Sun (10^6 km)	57.9	108.2	149.6	0.384*	227.9	778.6	1433.5	2872.5	4495.1	5870.0
Perihelion (10^6 km)	46.0	107.5	147.1	0.363*	206.6	740.5	1352.6	2741.3	4444.5	4435.0
Aphelion (10^6 km)	69.8	108.9	152.1	0.406*	249.2	816.6	1514.5	3003.6	4545.7	7304.3
Orbital Period (days)	88.0	224.7	365.2	27.3	687.0	4331	10,747	30,589	59,800	90,588
Orbital Velocity (km/s)	47.9	35.0	29.8	1.0	24.1	13.1	9.7	6.8	5.4	4.7
Orbital Inclination (degrees)	7.0	3.4	0.0	5.1	1.9	1.3	2.5	0.8	1.8	17.2
Orbital Eccentricity	0.205	0.007	0.017	0.055	0.094	0.049	0.057	0.046	0.011	0.244
Axial Tilt (degrees)	0.01	177.4	23.4	6.7	25.2	3.1	26.7	97.8	28.3	122.5
Mean Temperature (C)	167	464	15	-20	-65	-110	-140	-195	-200	-225
Surface Pressure (bars)	0	92	1	0	0.01	Unknown*	Unknown*	Unknown*	Unknown*	0
Number of Moons	0	0	1	0	2	67	62	27	14	5
Ring System?	No	No	No	No	No	Yes	Yes	Yes	Yes	No
Global Magnetic Field?	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Unknown
	MERCURY	VENUS	EARTH	MOON	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO

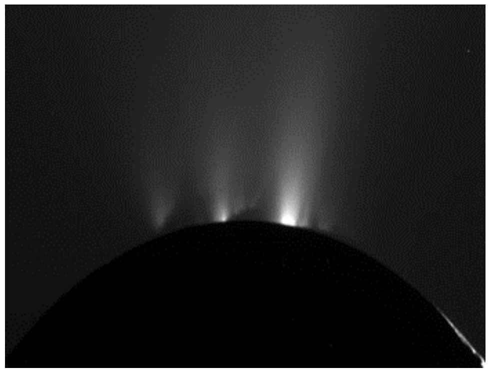


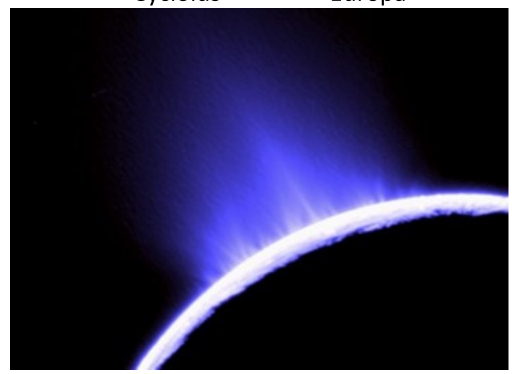




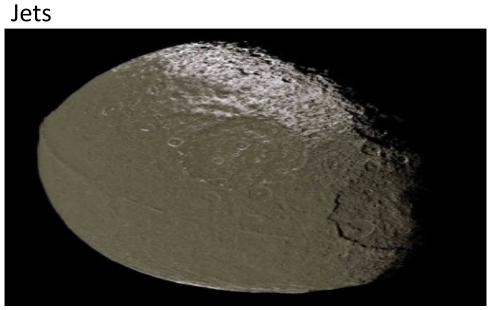
Thera Macula   Thrace Macula   Cycloids   Europa

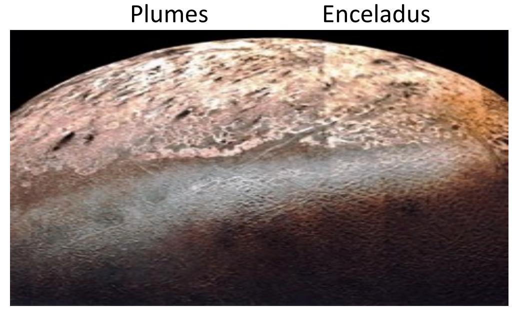




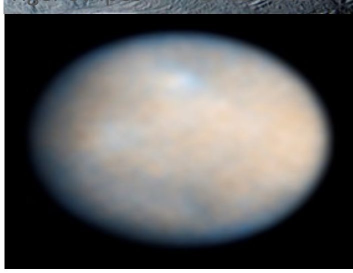


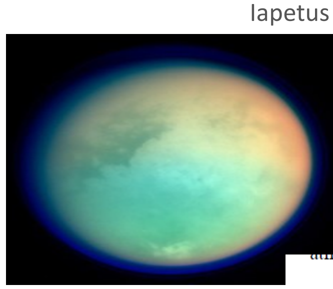
Conamara Chaos <Europa>   Jets   Plumes   Enceladus

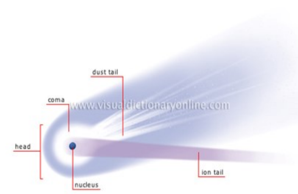




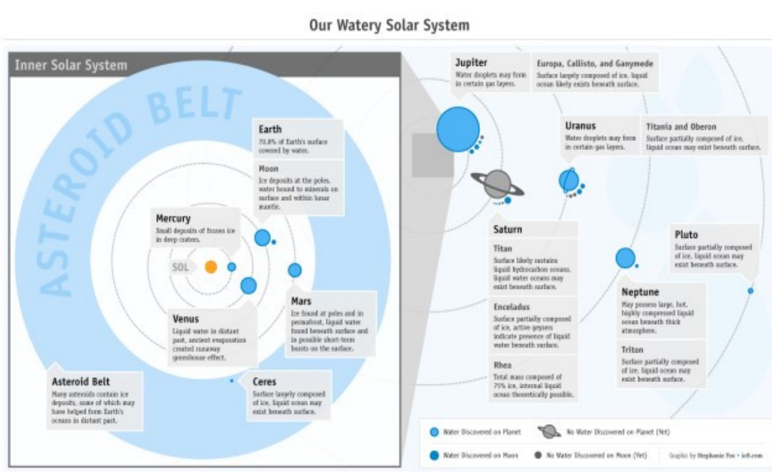
Tiger Stripes   Enceladus   Iapetus   Triton







Ceres   Titan



atmospheric pressure. It can also deposit

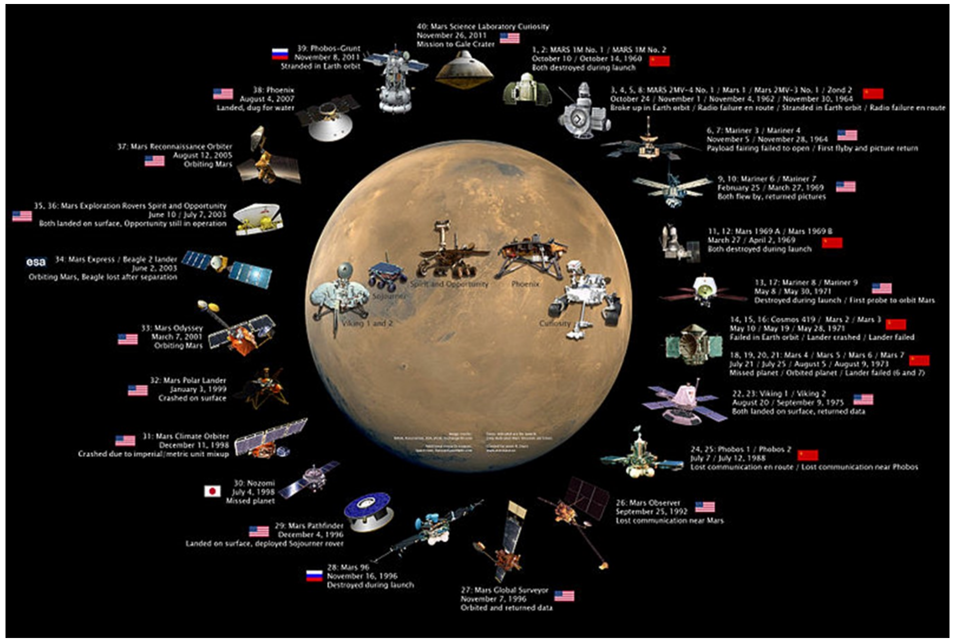
Table 1: Phases and characteristics of Water Ice [6]

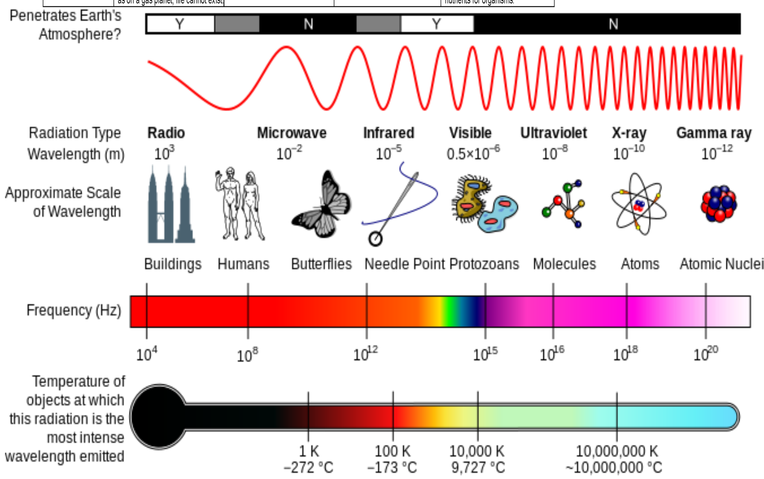
Phase	Characteristics
Amorphous ice	Amorphous ice as an ice which does not have crystal structure. This ice occurs in three forms; low density (LDA) formed at atmospheric pressure, or below, high density (HDA) and very high density amorphous ice (VHDA), forming at higher pressures. LDA forms by extremely quick cooling of liquid water ("hyperquenched glassy water", HGW), by depositing water vapour on very cold substrates ("amorphous solid water", ASW) or by heating high density forms of ice at ambient pressure.
Ice I_h	Normal hexagonal crystalline ice. Almost all ice in the Earth's biosphere is ice I_h with small amount of I_c
Ice I_c	Metastable cubic crystalline variant of ice. The oxygen atoms are arranged in a diamond structure, made at 130-150 K, and is stable upto 200K, when it transform to ice I_h. It is sometimes present in the upper atmosphere.
Ice 2	A rhombohedral crystalline form with highly ordered structure. Formed from ice I_h by compressing it at temperature of 190-210 K. When heated it undergoes transformation to ice 3.
Ice 3	A tetragonal crystalline ice, formed by cooling water down to 250 K a 300 MPa, least dense of the high pressure phases and denser than the water.
Ice 4	Metastable rhombohedral phase. Does not easily form without a nucleating agent.
Ice 5	A monoclinic crystalline phase, formed by cooling water to 253 K at 500 MPa. Most complicated structure of all.
Ice 6	A tetragonal crystalline phase, formed by cooling water to 270 K at 1.1 GPa, shows Debye relaxation.
Ice 7	A cubic phase. The hydrogen atom's position is disordered, the material shows Debye relaxation. The hydrogen bonds from two interpenetrating lattices.
Ice 8	A more ordered version of Ice 7, where the hydrogen atoms assume fixed positions, formed from ice 7 by cooling it beyond 5°C.
Ice 9	A tetragonal metastable phase, formed gradually from ice 3 by cooling it from 208 K to 165 K, stable below 140 K and pressures between 200 and 400 MPa. It has density of 1.16 g/cm^3, slightly higher than ordinary ice.
Ice 10	Proton ordered symmetric ice, forms at about 70 GPa.
Ice 11	An orthorhombic low temperature equilibrium form of hexagonal ice, which is ferroelectric.
Ice 12	A tetragonal metastable dense crystalline phase. it is observed in the phase space of ice V and ice VI. It can be prepared by heating high-density amorphous ice from 77 K to about 183 K at 810 MPa
Ice 13	A monoclinic crystalline phase, formed by cooling water below 130 K at 500 MPa. The proton-ordered from of ice 5.
Ice 14	An orthorhombic crystalline phase, formed below 118 K at 1.2 GPa. The proton-ordered from of ice 12.
Ice 15	The predicted but no proven proton ordered form of ice 6, thought to be formed by cooling water to around 108-80 K at 1.1 Gpa

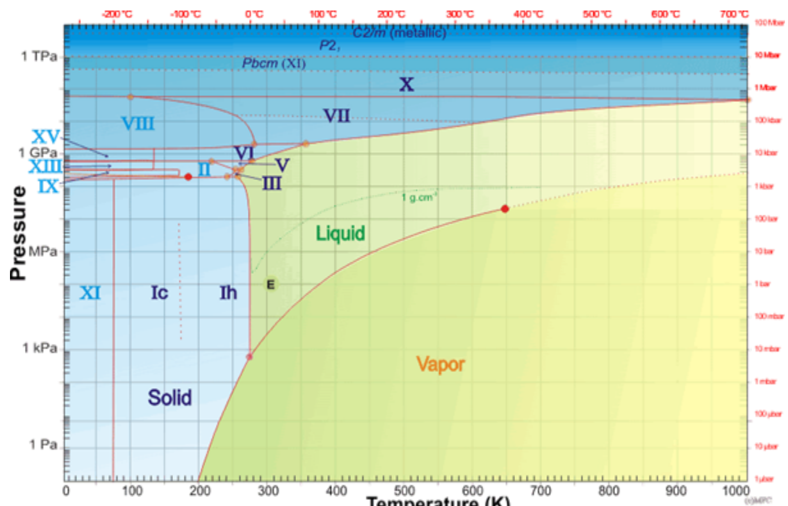
What Makes a World Habitable?

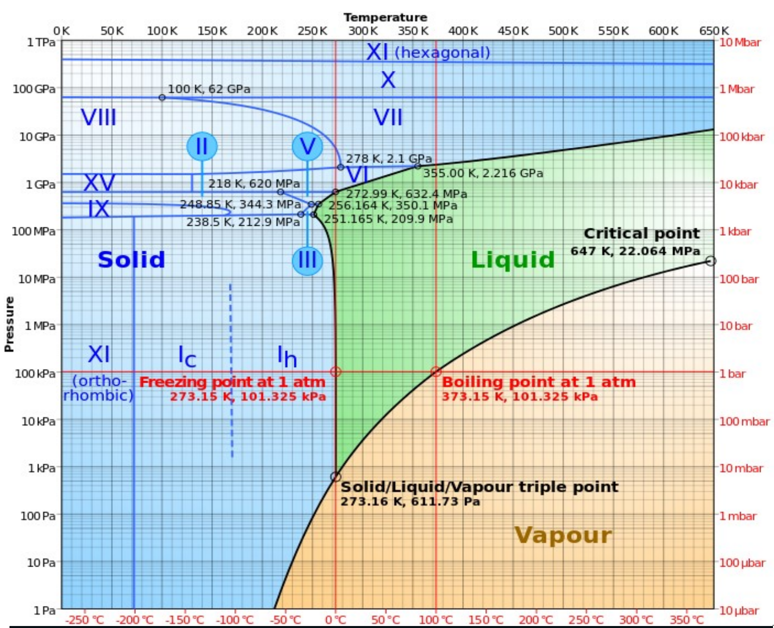
Use this table to identify the factors (and the appropriate levels) that will enable you to design your habitable worlds.

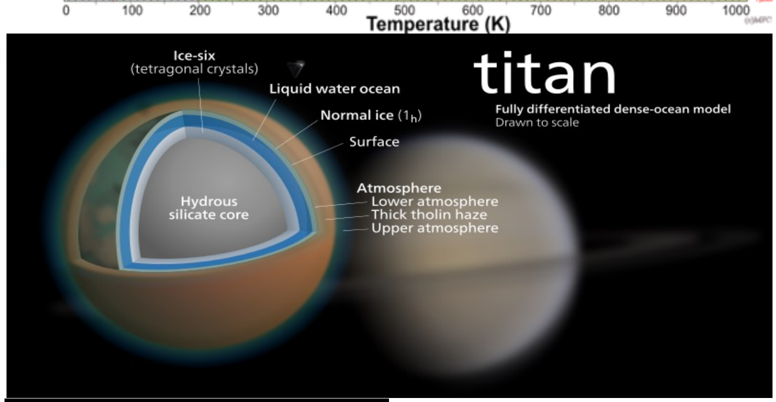
Factors that make a Planet Habitable	Not Enough of the Factor	Just Right	Too Much of the Factor	Situation in the Solar System
Temperature *Influences how quickly atoms & molecules move*	Low temperatures cause chemicals to react slowly, which interferes with the reactions necessary for life. Also low temperatures freeze water, making liquid water unavailable.	Life seems limited to a temperature range of minus 15°C to 115°C. In this range, liquid water can still exist under certain conditions.	At about 125°C, protein and carbohydrate molecules and genetic material (e.g., DNA and RNA) start to break apart. Also, high temperatures quickly evaporate water.	**Surface:** Only Earth's surface is in this temperature range. **Sub-surface**: The interior of the solid planets & moons may be in this temperature range.
Water *Dissolves & transports chemicals within and to and from a cell*	The chemicals a cell needs for energy & growth are not dissolved or transported to the cell	Water is regularly available. Life can go dormant between wet periods, but, eventually, water needs to be available.	Too much water is not a problem, as long as it is not so toxic that it interferes with the chemistry of life	**Surface:** Only Earth's surface has water, though Mars once had surface water and still has water ice in its polar ice caps. Saturn's moon, Titan, seems to be covered with liquid methane. **Sub-surface:** Mars & some moons have deposits of underground ice, which might melt to produce water. Europa, has a vast oceans beneath its outer shell if ice.
Atmosphere *Traps heat, shields the surface from harmful radiation, and provides chemicals needed for life, such as nitrogen and carbon dioxide.*	Small planets and moons have insufficient gravity to hold an atmosphere. The gas molecules escape to space, leaving the planet or moon without an insulating blanket or a protective shield.	Earth & Venus are the right size to hold a sufficient-sized atmosphere. Earth's atmosphere is about 100 miles thick. It keeps the surface warm & protects it from radiation & small- to medium-sized meteorites.	Venus's atmosphere is 100 times thicker than Earth's. It is made almost entirely of greenhouse gasses, making the surface too hot for life. The four giant planets are completely made of gas.	Of the solid planets & moons, only Earth, Venus, & Titan have significant atmospheres. Mars' atmosphere is about 1/100th that of Earth's, too small for significant insulation or shielding.
Energy *Organisms use light or chemical energy to run their life processes.*	When there is too little sunlight or too few of the chemicals that provide energy to cells, such as iron or sulfur, organisms die.	With a steady input of either light or chemical energy, cells can run the chemical reactions necessary for life.	Light energy is a problem if it makes a planet too hot or if there are too many harmful rays, such as ultraviolet. Too many energy-rich chemicals is not a problem	**Surface:** The inner planets get too much sunlight for life. The outer planets get too little. **Sub-surface:** Most solid planets & moons have energy-rich chemicals.
Nutrients *Used to build and maintain an organism's body.*	Without chemicals to make proteins & carbohydrates, organisms cannot grow. Planets without systems to deliver nutrients to its organisms (e.g., a water cycle or volcanic activity) cannot support life. Also, when nutrients are spread so thin that they are hard to obtain, such as on a gas planet, life cannot exist.	All solid planets & moons have the same general chemical makeup, so nutrients are present. Those with a water cycle or volcanic activity can transport and replenish the chemicals required by living organisms.	Too many nutrients are not a problem. However, too active a circulation system, such as the constant volcanism on Jupiter's moon, Io, or the churning atmospheres of the gas planets, interferes with an organism's ability to get enough nutrients.	**Surface:** Earth has a water cycle, an atmosphere, and volcanoes to circulate nutrients. Venus, Titan, Io, and Mars have nutrients and ways to circulate them to organisms. **Sub-surface:** Any planet or moon with sub-surface water or molten rock can circulate and replenish nutrients for organisms.

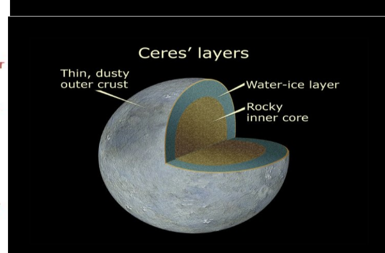


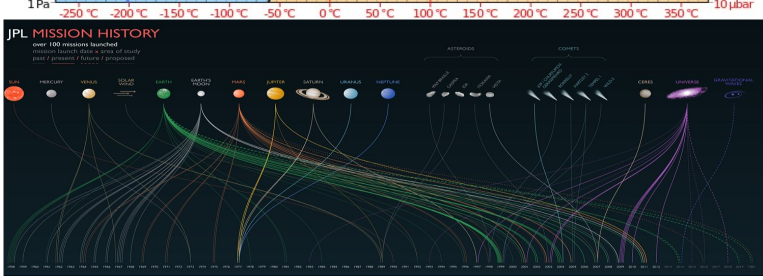












Name of Satellite/Rover	Date commissioned	Instruments/What they do	Where it's been
Mars Reconnaissance Orbiter	10 March 2006, 21:24:00 UTC	**HiRISE**: The High Resolution Imaging Science Experiment camera is a 0.5 m reflecting telescope, the largest ever carried on a deep space mission, and has a resolution of 1microradian (μrad), or 0.3 m from an altitude of 300 km. Takes really nice pictures.**CTX:** The Context Camera (CTX) provides grayscale images (500 to 800 nm) with a pixel resolution up to about 6 m. CTX is designed to provide context maps for the targeted observations of HiRISE and CRISM, and is also used to mosaic large areas of Mars, monitor a number of locations for changes over time, and to acquire stereo (3D) coverage of key regions and potential future landing sites **MARCI:** The Mars Color Imager (MARCI) is a wide-angle, relatively low-resolution camera that views the surface of Mars in five visible and two ultraviolet bands. Each day, MARCI collects about 84 images and produces a global map with pixel resolutions of 1 to 10 km. **CRISM:** The Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) instrument is a visible and near infrared (VNIR) spectrometer that is used to produce detailed maps of the surface mineralogy of Mars. **MCS:** The Mars Climate Sounder (MCS) is a spectrometer with one visible/near infrared channel (0.3 to 3.0 μm) and eight far infrared (12 to 50 μm) channels. These channels were selected to measure temperature, pressure, water vapor and dust levels. MCS observes the atmosphere on the horizon of Mars (as viewed from MRO) by breaking it up into vertical slices and taking measurements within each slice in 5 km (3 mi) increments. **SHARAD:** MRO's Shallow Subsurface Radar (SHARAD) experiment is designed to probe the internal structure of the Martian polar ice caps. It also gathers planet-wide information about underground layers of ice, rock and possibly liquid water that might be accessible from the surface. SHARAD uses HF radio waves between 15 and 25 MHz,	Mars
Mars Global Surveyor	7 November 1996, 17:00 UTC // November 2, 2006	Five scientific instruments fly onboard Mars Global Surveyor:[4] **MOC** – the Mars Orbiter Camera, operated by Malin Space Science Systems[5] **MOLA –** the Mars Orbiter Laser Altimeter **TES** – the Thermal Emission Spectrometer **MAG/ER –** a Magnetometer and electron reflectometer **USO/RS** Ultrastable Oscillator for Doppler measurements	Mars
Opportunity	July 7, 2003	**Panoramic Camera (Pancam)** – examines the texture, color, mineralogy, and structure of the local terrain. **Navigation Camera (Navcam)** – monochrome with a higher field of view but lower resolution, for navigation and driving. **Miniature Thermal Emission Spectrometer (Mini-TES)** – identifies promising rocks and soils for closer examination, and determines the processes that formed them. **Hazcams**, two B&W cameras with 120 degree field of view, that provide additional data about the rover's surroundings.**Mössbauer spectrometer (MB) MIMOS II** – used for close-up investigations of the mineralogy of iron-bearing rocks and soils. **Alpha particle X-ray spectrometer (APXS)** – close-up analysis of the abundances of elements that make up rocks and soils. **Magnets –** for collecting magnetic dust particles **Microscopic Imager (MI) –** obtains close-up, high-resolution images of rocks and soils. **Rock Abrasion Tool (RAT)** – exposes fresh material for examination by instruments on board.	Mars
Spirit	June 10, 2003—22 March 2010	Everything on Opportunity	Mars
Curiosity	26 November 2011	Mast Camera (MastCam)-The MastCam system provides multiple spectra and true-color imaging with two cameras.[56] The cameras can take true-color images at 1600×1200pixels and up to 10 frames per second hardware-compressed, video at 720p **ChemCam-**ChemCam is a suite of remote sensing instruments, and as the name implies, ChemCam is actually two different instruments combined as one: a laser-induced breakdown spectroscopy (LIBS) and a Remote Micro Imager (RMI) telescope. NavCam, HazCam, **REMs-** REMS comprises instruments to measure the Mars environment: humidity, pressure, temperatures, wind speeds, and ultraviolet radiation.[76] It is a meteorological package that includes an ultraviolet sensor provided by the Spanish Ministry of Education and Science. **MAHLI—** MAHLI is a camera on the rover's robotic arm, and acquires microscopic images of rock and soil. MAHLI can take true-color images at 1600×1200 pixels with a resolution as high as 14.5micrometers per pixel. **APXS CheMin-** CheMin is the Chemistry and Mineralogy X-ray powder diffraction and fluorescence instrument.[86] CheMin is one of four spectrometers. It can identify and quantify the abundance of the minerals on Mars. **SAM**—The SAM instrument suite analyzes organics and gases from both atmospheric and solid **DRT–** DUST REMOVER TOOL **RAD–** This instrument was the first of ten MSL instruments to be turned on. Its first role was to characterize the broad spectrum of radiation environment found inside the spacecraft during the cruise phase **DAN**—A pulsed sealed-tube neutron source[95] and detector for measuring hydrogen or ice and water at or near the Martian surface **MARDI**—During the descent to the Martian surface, MARDI took color images at 1600×1200 pixels with a 1.3-millisecond exposure time starting at distances of about 3.7 km (2.3 mi) to near 5 m (16 ft) from the ground, at a rate of four frames per second for about two minutes.	Mars
Phoenix	May 25, 2008[1] – November 2, 2008 (lost communication); November 10, 2008	The Surface Stereo Imager (SSI) was the primary camera on the spacecraft . The Thermal and Evolved Gas Analyzer (TEGA) is a combination of a high-temperature furnace with a mass spectrometer. It was used to bake samples of Martian dust and determine its content.	Mars
Juice <Jupiter Icy Moons Explorer)	2022	JANUS MAJIS UVS SWI GALA RIME JMAG PEP RPWI 3GM PRIDE	Jupiter
Mars Express	2 June 2003,	Visible and Infrared Mineralogical Mapping Spectrometer (OMEGA)(Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité) - France - Determines mineral composition of the surface up to 100 m resolution. Is mounted inside pointing out the top face.[14] Instrument mass: 28.6 kg[15] Ultraviolet and Infrared Atmospheric Spectrometer (SPICAM) - France - Assesses elemental composition of the atmosphere. Is mounted inside pointing out the top face. Instrument mass: 4.7 kg [15] Sub-Surface Sounding Radar Altimeter (MARSIS) - Italy - A radar altimeter used to assess composition of sub-surface aimed at search for frozen water. Is mounted in the body and is nadir pointing, and also incorporates the two 20 m antennas. Instrument mass: 13.7 kg[15] Planetary Fourier Spectrometer (PFS) - Italy - Makes observations of atmospheric temperature and pressure (observations suspended in September 2005). Is mounted inside pointing out the top face.,[16] currently working. Instrument mass: 30.8 kg[15] Analyzer of Space Plasmas and Energetic Atoms (ASPERA) - Sweden - Investigates interactions between upper atmosphere and solar wind. Is mounted on the top face. Instrument mass: 7.9 kg [15] High Resolution Stereo Camera (HRSC)- Germany - Produces color images with up to 2 m resolution. Is mounted inside the spacecraft body, aimed through the top face of the spacecraft, which is nadir pointing during Mars operations. Instrument mass: 20.4 kg[15] Mars Express Lander Communications (MELACOM) - UK - Allows Mars Express to act as a communication relay for landers on the Martian surface. (Has been tested with Mars Exploration Rovers, and was used to support the landing of NASA's Phoenix mission) Mars Radio Science Experiment (MaRS) - Uses radio signals to investigate atmosphere, surface, subsurface, gravity and solar corona density during solar conjunctions. It uses the communications subsystem itself.	Mars
Galileo	October 18, 1989, September 21, 2003	Solid State Imager (SSI)[edit] = The SSI was an 800-by-800-pixel solid state camera consisting of an array of silicon sensors called a "charge coupled device" (CCD). Galileo was one of the first spacecraft to be equipped with a CCD camera. [citation needed] The optical portion of the camera was built as aCassegrain telescope. Light was collected by the primary mirror and directed to a smaller secondary mirror that channeled it through a hole in the center of the primary mirror and onto the CCD. The CCD sensor was shielded from radiation, a particular problem within the harsh Jovian magnetosphere. The shielding was accomplished by means of a 10 mm thick layer of tantalum surrounding the CCD except where the light enters the system. An eight-position filter wheel was used to obtain images at specific wavelengths. The images were then combined electronically on Earth to produce color images. The spectral response of the SSI ranged from about 0.4 to 1.1 micrometres. The SSI weighed 29.7 kilograms and consumed, on average, 15 watts of power.[11][12]**Near-Infrared Mapping Spectrometer** (NIMS)[edit]The NIMS instrument was sensitive to 0.7-to-5.2-micrometre wavelength IR light, overlapping the wavelength range of the SSI. The telescope associated with NIMS was all reflective (using only mirrors and no lenses) with an aperture of 229 mm. The spectrometer of NIMS used a grating to disperse the light collected by the telescope. The dispersed spectrum of light was focused on detectors of indium antimonide and silicon. The NIMS weighed 18 kilograms and used 12 watts of power on average.[13][14]**Ultraviolet Spectrometer / Extreme Ultraviolet Spectrometer (UVS/EUV)[edit]** The Cassegrain telescope of the UVS had a 250 mm aperture and collected light from the observation target. Both the UVS and EUV instruments used a ruled grating to disperse this light for spectral analysis. This light then passed through an exit slit into photomultiplier tubes that produced pulses or "sprays" of electrons. These electron pulses were counted, and these count numbers constituted the data that were sent to Earth. The UVS was mounted on Galileo's scan platform and could be pointed to an object in inertial space. The EUV was mounted on the spun section. As Galileo rotated, EUV observed a narrow ribbon of space perpendicular to the spin axis. The two instruments combined weighed about 9.7 kilograms and used 5.9 watts of power.[15][16]Photo**polarimeter-Radiometer (PPR)[edit]**The PPR had seven radiometry bands. One of these used no filters and observed all incoming radiation, both solar and thermal. Another band allowed only solar radiation through. The difference between the solar-plus-thermal and the solar-only channels gave the total thermal radiation emitted. The PPR also measured in five broadband channels that spanned the spectral range from 17 to 110 micrometres. The radiometer provided data on the temperatures of Jupiter's atmosphere and satellites. The design of the instrument was based on that of an instrument flown on the Pioneer Venus spacecraft. A 100 mm aperture reflecting telescope collected light and directed it to a series of filters, and, from there, measurements were performed by the detectors of the PPR. The PPR weighed 5.0 kilograms and consumed about 5 watts of power.[17][18]**Spun section[edit] Dust Detector Subsystem (DDS)[edit]** The Dust Detector Subsystem (DDS) was used to measure the mass, electric charge, and velocity of incoming particles. The masses of dust particles that the DDS could detect go from 10^{-16} to 10^{-7} grams. The speed of these small particles could be measured over the range of 1 to 70 kilometers per second. The instrument could measure impact rates from 1 particle per 115 days (10 megaseconds) to 100 particles per second. Such data was used to help determine dust origin and dynamics within the magnetosphere. The DDS weighed 4.2 kilograms and used an average of 5.4 watts of power.[19][20]**Energetic Particles Detector (EPD)[edit]** The Energetic Particles Detector (EPD) was designed to measure the numbers and energies of ions and electrons whose energies exceeded about 20 keV (3.2 fJ). The EPD could also measure the direction of travel of such particles and, in the case of ions, could determine their composition (whether the ion is oxygen or sulfur, for example). The EPD used silicon solid state detectors and a time-of-flight detector system to measure changes in the energetic particle population at Jupiter as a function of position and time. These measurements helped determine how the particles got their energy and how they were transported through Jupiter's magnetosphere. The EPD weighed 10.5 kilograms and used 10.1 watts of power on average.[21][22] **Heavy Ion Counter (HIC)[edit]** The HIC was in effect a repackaged and updated version of some parts of the flight spare of the Voyager Cosmic Ray System. The HIC detected heavy ions using stacks of single crystal silicon wafers. The HIC could measure heavy ions with energies as low as 6 MeV (1 pJ) and as high as 200 MeV (32 pJ) per nucleon. This range included all atomic substances between carbon and nickel. The HIC and the EUV shared a communications link and, therefore, had to share observing time. The HIC weighed 8 kilograms and used an average of 2.8 watts of power.[23][24]**Magnetometer (MAG)[edit]**The magnetometer (MAG) used two sets of three sensors. The three sensors allowed the three orthogonal components of the magnetic field section to be measured. One set was located at the end of the magnetometer boom and, in that position, was about 11 m from the spin axis of the spacecraft. The second set, designed to detect stronger fields, was 6.7 m from the spin axis. The boom was used to remove the MAG from the immediate vicinity of Galileo to minimize magnetic effects from the spacecraft. However, not all these effects could be eliminated by distancing the instrument. The rotation of the spacecraft was used to separate natural magnetic fields from engineering-induced fields. Another source of potential error in measurement came from the bending and twisting of the long magnetometer boom. To account for these motions, a calibration coil was mounted rigidly on the spacecraft to generate a reference magnetic field during calibrations. The magnetic field at the surface of the Earth has a strength of about 50,000 nT. At Jupiter, the outboard (11 m) set of sensors could measure magnetic field strengths in the range from ±32 to ±512 nT, while the inboard (6.7 m) set was active in the range from ±512 to ±16,384 nT. The MAG experiment weighed 7 kilograms and used 3.9 watts of power.[25][26]**Plasma Subsystem (PLS)[edit]**The PLS used seven fields of view to collect charged particles for energy and mass analysis. These fields of view covered most angles from 0 to 180 degrees, fanning out from the spin axis. The rotation of the spacecraft carried each field of view through a full circle. The PLS measured particles in the energy range from 0.9 eV to 52 keV (0.1 aJ to 8.3 fJ). The PLS weighed 13.2 kilograms and used an average of 10.7 watts of power.[27][28]**Plasma Wave Subsystem (PWS)[edit]**An electric dipole antenna was used to study the electric fields of plasmas, while two search coil magnetic antennas studied the magnetic fields. The electric dipole antenna was mounted at the tip of the magnetometer boom. The search coil magnetic antennas were mounted on the high-gain antenna feed. Nearly simultaneous measurements of the electric and magnetic field spectrum allowed electrostatic waves to be distinguished from electromagnetic waves. The PWS weighed 7.1 kilograms and used an average of 9.8 watts.[29][30]	Jupiter
Cassini-Huygens	October 15, 1997,	**Cassini Plasma Spectrometer (CAPS)**The CAPS is a direct sensing instrument that measures the energy and electrical charge of particles that the instrument encounters, (the number of electrons and protons in the particle). CAPS will measure the molecules originating from Saturn's ionosphere and also determine the configuration of Saturn's magnetic field. CAPS will also investigate plasma in these areas as well as the solar wind within Saturn's magnetosphere.[19][20] CAPS has been turned off since June 2011 because of an electrical short circuit that occurred in the instrument. The instrument was powered on in March 2012; after 78 days a second short circuit forced the instrument to be shutdown again.[21]**Cosmic Dust Analyzer (CDA)**The CDA is a direct sensing instrument that measures the size, speed, and direction of tiny dust grains near Saturn. Some of these particles are orbiting Saturn, while others may come from other star systems. The CDA on the orbiter is designed to learn more about these mysterious particles, the materials in other celestial bodies and potentially about the origins of the universe.[19]**Composite Infrared Spectrometer (CIRS)**The CIRS is a remote sensing instrument that measures the infrared waves coming from objects to learn about their temperatures, thermal properties, and compositions. Throughout the Cassini–Huygens mission, the CIRS will measure infrared emissions from atmospheres, rings and surfaces in the vast Saturn system. It will map the atmosphere of Saturn in three dimensions to determine temperature and pressure profiles with altitude, gas composition, and the distribution of aerosols and clouds. It will also measure thermal characteristics and the composition of satellite surfaces and rings.[19]**Ion and Neutral Mass Spectrometer (INMS)**The INMS is a direct sensing instrument that analyzes charged particles (like protons and heavier ions) and neutral particles (like atoms) near Titan and Saturn to learn more about their atmospheres. INMS is intended also to measure the positive ion and neutral environments of Saturn's icy satellites and rings.[19][22][23]**Imaging Science Subsystem (ISS)**The ISS is a remote sensing instrument that captures most images in visible light, and also some infrared images and ultraviolet images. The ISS has taken hundreds of thousands of images of Saturn, its rings, and its moons, for return to the Earth by radio telemetry. The ISS has a wide-angle camera (WAC) that takes pictures of large areas, and a narrow-angle camera (NAC) that takes pictures of small areas in fine detail. Each of these cameras uses a sensitive charge-coupled device (CCD) as itselectromagnetic wave detector. Each CCD has a 1,024 square array of pixels, 12 μm on a side. Both cameras allow for many data collection modes, including on-chip data compression. Both cameras are fitted with spectral filters that rotate on a wheel—to view different bands within the electromagnetic spectrum ranging from 0.2 to 1.1 μm.[19][24]**Dual Technique Magnetometer (MAG)**The MAG is a direct sensing instrument that measures the strength and direction of the magnetic field around Saturn. The magnetic fields are generated partly by the intensely hot molten core at Saturn's center. Measuring the magnetic field is one of the ways to probe the core, even though it is far too hot and deep to visit. MAG aims to develop a three-dimensional model of Saturn's magnetosphere, and determine the magnetic state of Titan and its atmosphere, and the icy satellites and their role in the magnetosphere of Saturn.[19][25]**Magnetospheric Imaging Instrument (MIMI)**The MIMI is both a direct and remote sensing instrument that produces images and other data about the particles trapped in Saturn's huge magnetic field, or magnetosphere. This information will be used to study the overall configuration and dynamics of the magnetosphere and its interactions with the solar wind, Saturn's atmosphere, Titan, rings, and icy satellites.[19][26] MIMI includes the Ion and Neutral Camera (INCA), which captures and measures Energetic Neutral Atoms (ENAs).[27]**Radar**The onboard radar is a remote active and remote passive sensing instrument that will produce maps of Titan's surface. It measures the height of surface objects (like mountains and canyons) by sending radio signals that bounce off Titan's surface and timing their return. Radio waves can penetrate the thick veil of haze surrounding Titan. The radar will listen for radio waves that Saturn or its moons may be producing.[19]**Radio and Plasma Wave Science instrument (RPWS)**The RPWS is a direct and remote sensing instrument that receives and measures radio signals coming from Saturn, including the radio waves given off by the interaction of the solar wind with Saturn and Titan. RPWS is to measure the electric and magnetic wave fields in the interplanetary medium and planetary magnetospheres. It will also determine the electron density and temperature near Titan and in some regions of Saturn's magnetosphere. RPWS studies the configuration of Saturn's magnetic field and its relationship to Saturn Kilometric Radiation (SKR), as well as monitoring and mapping Saturn's ionosphere, plasma, and lightning from Saturn's (and possibly Titan's) atmosphere.[19] **Radio Science Subsystem (RSS)**The RSS is a remote sensing instrument that uses radio antennas on Earth to observe the way radio signals from the spacecraft change as they are sent through objects, such as Titan's atmosphere or Saturn's rings, or even behind the Sun. The RSS also studies the compositions, pressures and temperatures of atmospheres and ionospheres, radial structure and particle size distribution within rings, body and system masses and gravitational waves. The instrument uses the spacecraft X-band communication link as well as S-band downlink and Ka-band uplink and downlink.[19]**Ultraviolet Imaging Spectrograph (UVIS)**The UVIS is a remote sensing instrument that captures images of the ultraviolet light reflected off an object, such as the clouds of Saturn and/or its rings, to learn more about their structure and composition. Designed to measure ultraviolet light over wavelengths from 55.8 to 190 nm, this instrument is also a valuable tool to help determine the composition, distribution, aerosol particle content and temperatures of their atmospheres. Unlike other types of spectrometer, this sensitive instrument can take both spectral and spatial readings. It is particularly adept at determining the composition of gases. Spatial observations take a wide-by-narrow view, only one pixel tall and 64 pixels across. The spectral dimension is 1,024 pixels per spatial pixel. Also, it can take many images that create movies of the ways in which this material is moved around by other forces.[19]**Visible and Infrared Mapping Spectrometer (VIMS)**The VIMS is a remote sensing instrument that captures images using visible and infrared light to learn more about the composition of moon surfaces, the rings, and the atmospheres of Saturn and Titan. It is made up of two cameras in one: one used to measure visible light, the other infrared. VIMS measures reflected and emitted radiation from atmospheres, rings and surfaces over wavelengths from 350 to 5100 nm, to help determine their compositions, temperatures and structures. It also observes the sunlight and starlight that passes through the rings to learn more about their structure. Scientists plan to use VIMS for long-term studies of cloud movement and morphology in the Saturn system, to determine Saturn's weather patterns.[19]	Saturn/Its moons