PLANNING FOR THE LAST PLANET

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Spacecraft from Caltech's and NASA's Jet Propulsion Laboratory (JPL) in La Canada Flintridge have visited all the planets in the solar system except Pluto. To complete the job of studying all the planets from less expensive robotic space.cratl, a small team of mission, trajectory, and spacecraft designers has been working for several years to develop an affordable plan to send a spacecraft to that most distant planet. JPL spacecraft began exploring all the planets of our sun thirty-five years ago when Mariner 2 was launched to study Venus. Mariner 4 sent back the first pictures of another world as it flew by Mars in 1964, and initial exploration of the inner rocky planets was completed in 1973 and 1974 as Mariner 10 flew by Venus and Mercury. The giant gas outer planets were first visited by the spinning spacecraft Pioneers 10 and 11, bui It by NASA's Ames Research Center, when they flew by Jupiter and Saturn in 1973, 1974 and 1979. JPL's Voyagers 1 and 2 sent back images with much greater detail as both passed Jupiter in 1979, Saturn in 1981, and as Voyager 2 passed Uranus in 1986 and Neptune in 1989. Each generation of spacecraft has added even more detail to our knowledge of the planets they visit. For example, after Mariner 4's initial brief fly-by in 1964, Mariner 9 went into orbit and mapped all of Mars in 1969; and Vikings 1 and 2 got as close as possible by landing on the red planet in 1976. Similarly, after Mariners 2, 5 and 10 made quick fly-by studies of Venus, the Magellan mission was able to go into orbit around the planet and use radar to penetrate Venus' thick sulfuric acid clouds and make a detailed map of the planet's entire surface in the early 1990s. Even now the Galileo spacecraft is building on the Voyagers' fly-by successes by orbiting Jupiter and repeatedly studying the planet and its moons from much closer than Voyager could approach. Galileo even carried a probe which sent information for an hour in December 1995 from inside Jupiter's stormy clouds and atmosphere before it was crushed by the planet's high pressure deep in its atmosphere. The most expensive of all these more ambitious missions will be launched in five months when JPL's Cassini spacecraft is launched to go into orbit around Saturn in 2004 and to send the Huygens probe into the hazy atmosphere of Saturn's largest moon Titan for a possible landing on the moon's surface, if it finds a liquid or solid surface.

But all these past studies of the eight planets closer to the sun than Pluto, while they discovered more detailed information about each planet they studied, cost much more to build, launch and fly with each mission and with each passing year. Planning for a Pluto mission started in this earlier time when designers could think of carrying many instruments on a large spacecraft lifted by a very powerful rocket, which was required for traveling from Earth to Pluto's 3.7 billion mile distance from the sun. During the mid-1 990s, however, the discretionary part of the federal budget, including NASA's funding for space science and planetary exploration, began to shrink as health and welfare entitlements continued their

rapid growth and as eliminating the federal deficit became a higher priority. The work on a Pluto mission has therefore slowed as the team has tried to reduce total mission costs by designing smaller and less expensive spacecraft which would require smaller and less expensive launch rockets. Today, the mission is called the Pluto-Kuiper Express to indicate that it is less expensive and that it will continue long past its encounter with Pluto to explore the Kuiper Belt of comet-like iey and rocky bodies billions of miles beyond the nine planets known to humans. Pluto-Kuiper Express is one of three missions called "Fire and Ice" which, in addition to the Pluto mission, include a plan to explore Jupiter's moon Europa to study whether it might have a liquid water ocean which could contain life, and a mission to explore the hot and dangerous neighborhood of the sun. The advanced and miniaturized technologies required to fly these ambitious missions are being developed under a JPL program called "X2000," which will be run like a normal intense, schedule-driven flight project, and will provide new technical capabilities every couple of years, which ean be used on the Pluto-Kuiper Express, but which ean be used on any future planetary or deep space missions that require smaller, less expensive, but more capable equipment. For instance, although the Galileo orbiter now orbiting Jupiter is twenty-two times larger than any possible Pluto spacecraft, the Pluto spacecraft computer must be twenty to fifty times smaller than the Galileo computer.

Pluto has been a puzzle to astronomers ever since it was discovered by 24-year-old Clyde Tombaugh at the Lowell Observatory in Flagstaff in 1930. Tombaugh had to find the planet strictly by careful observation since calculations of disturbances in the orbits of Uranus and Neptune thought to be caused by the gravity of a hypothetical ninth planet were wrong. Pluto was named by an eleven year old **English school girl for the Roman god of the underworld, and has a diameter only two-thirds that of** Earth's moon: 720 miles. From Earth, Pluto's physical characteristics seem to be similar to Neptune's moon Triton: a surface composed of solid nitrogen, methane (natural gas) and carbon monoxide at a temperature of almost 400 degrees Fahrenheit below zero (on the temperature scale on which absolute zero--where all atomic motion stops--is 463 degrees below zero). Only nineteen years ago astronomers discovered that Pluto was really two bodies; it had a moon half its own diameter which was named Charon after the boatman who, in Greek mythology, ferries souls across the River Styx to the underworld realm of Hades (the earlier Greek name for the Roman Pluto). The Pluto-Charon system is thought to have been formed by a collision between two independent bodies from the Oort Cloud or Kuiper Belt, two clouds of small iey bodies surrounding the solar system far beyond Pluto's orbit which arc thought to be the source of comets that we see as they occasionally fall toward the sun. Pluto and Charon are thought to have formed independently because their surface materials are so different; Pluto's surface contains methane and no water, while Charon's has frozen water but no methane. Pluto is so distant that a full revolution around the sun takes 248 years, but right now, because its orbit is so elliptical or elongated, it is closer to the sun than its next closest neighbor, Neptune. However, this condition has lasted only from 1979 through 1999 out of its entire 248-year orbital period.

After starting out as an ambitious concept requiring a very powerful military launch rocket to provide the energy required to get it to Pluto's distant orbit, the present much smaller Pluto mission envisions two 220-pound spacecraft being launched in March 2001 and arriving thirteen years later to fly by the planet and continue out of the solar system and to the Kuiper belt of small icy and rocky objects. Two spacecraft are planned, to provide redundancy for an improved chance of success, and to increase the area of Pluto and Charon that can be mapped if both survive the hazardous journey several times around the sun, which will be required so that they can flyby Venus many times and by Jupiter once to pick up energy from those planets' gravitational fields and their motions around the sun. In addition to reducing costs by shrinking the sizes of the spacecraft and launch vehicles, the project plans to enlist the help of other nations, possibly Russia and Germany, and may launch the spacecraft on Russian rockets. If Russia is able, it might provide a twenty-two pound probe to send into Pluto's thin and highly variable atmosphere as the spacecraft continues past the planet. The atmosphere was discovered nine years ago when Pluto passed in front of a star, and, like the atmospheres of Neptune's moon Trite% Saturn's largest moon Titan, and Earth, is composed mostly of nitrogen. Pluto's atmosphere is about one millionth as thick as our own atmosphere when, as now, Pluto is closest to the sun ("perihelion") but condenses out onto the cold, solid surface and disappears as Pluto moves into the more distant parts of its orbit. In addition, a German probe might be dropped off into the sulfurous atmosphere of Jupiter's volcanic moon Io as the spacecraft gets its energy kick in flying by the largest planet. Instead of carrying a dozen or more instruments like Voyager, Galileo and Cassini, Pluto Kuiper Express will carry only four: a camera, an infrared (heat waves longer than light) spectrometer to measure the infrared energy from Pluto's surface over a wide range of wavelengths, an ultraviolet (waves shorter than light) spectrometer, and a radio experiment to study any atmospheres of Pluto and Charon. The project is planning a major educational outreach program for all grades from kindergarten through university level, and will develop curriculum guides to assist teachers in explaining the spacecraft's journey and its discoveries. The Pluto Kuiper Express mission is still in the planning stages, and its concept will undoubtedly change many times over the next few years, but it is a major mission in NASA's roadmap to complete the exploration of the solar system.