Countdown for Cassini Mission to Saturn Begins, as Protests over Plutonium in Space Heat Up

Sometime this month, a Titan IV rocket will lift off from launch area 40 at Cape Canaveral, soar into the upper atmosphere and set aloft its precious payload, thus beginning the long journey of the Cassini probe to Saturn. That at least is the plan.

Last-minute technical glitches could of course delay the launch. Indeed, as PHYSICS TODAY went to press, workers at the Kennedy Space Center were repairing an air conditioning malfunction, and NASA had pushed back the original 6 October launch date by at least a week. Meanwhile, antinuclear activists, who condemn the spacecraft's use of plutonium-fueled generators, continued to press their case for cancellation or postponement of the Saturn mission.

A saturnalia of science

A joint project of NASA, the European Space Agency (ESA) and the Italian Space Agency, the $3.4 billion Cassini mission is "the last of the era of the big spacecraft," says the project's science and mission design manager, Charles Kohlhase of the Jet Propulsion Lab (JPL). The six-ton, two-and-a-half-story-tall craft carries 18 scientific instruments: 12 on the Cassini orbiter that will circle throughout the Saturnian system, and the remainder aboard the ESA-supplied Huygens probe to be dropped off on Titan, the planet's largest moon. (The orbiter and probe are named for a pair of 17th-century astronomers: Jean Dominique Cassini, first director of the Paris Observatory, observed the 4000 km gap in Saturn's rings, known as Cassini's division; Christiaan Huygens was the first to spot Titan and gave it its name.)

Much of what is known about Saturn comes from the flybys of Voyager 1 and 2, which, brief as they were, did whet the appetite of planetary scientists. By comparison, Cassini's four-year tour of the planet promises to be a feast. As just one example, the radio and plasma wave science (RPWS) instrument built by University of Iowa physicist Donald Gurnett and his 21-person team will be used to study Saturn's magnetosphere, lightning storms, dust particles, and electron densities in Titan's ionosphere, among many other things. "One big puzzle is that

The last of the big planetary missions, Cassini promises to enormously increase our understanding of the Saturnian system.

the planet's magnetic moment is lined up almost parallel to its rotation axis—the difference is less than 1°, compared to Earth's 12°," Gurnett says. "So what is the origin of the rotation modulation of Saturn's radio emissions?"

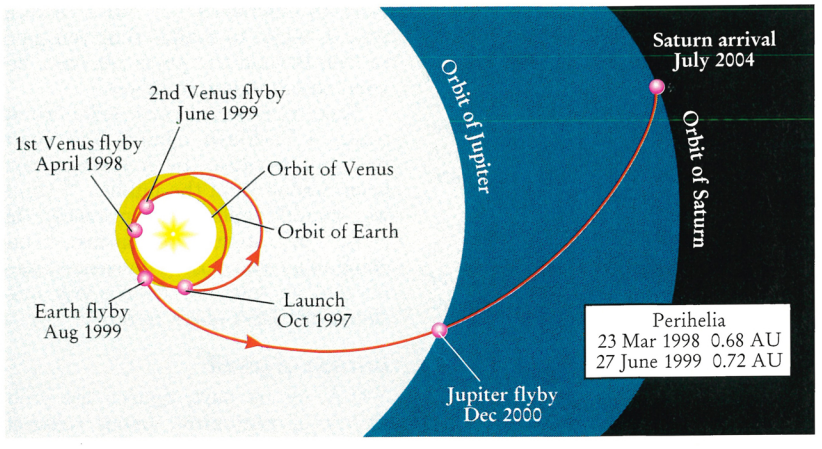
Of particular interest is Titan, whose atmosphere is laced with hydrocarbons like those thought to have given rise to life on Earth. Titan expert Jonathan Lunine of the University of Arizona calls it "one of the dark horses of the Solar System. It has a lot to teach us about how planets evolve with time and perhaps how life forms from nonbiological organic chemistry."

Because of cost concerns, no scientific data will be taken during the seven years before Cassini reaches Saturn. "It's really a wasted opportunity," laments University of Arizona professor Carolyn Porco, who led the team that built the orbiter's Imaging Science Subsystem. Like other mission scientists, she has devoted much of the past seven years to the project; compared to other space missions, she says, "everything on [Cassini] has gone very smoothly. It's really an exemplary mission."

Between the launch and Cassini's arrival at Saturn, researchers will have to plot out the actual tour through the planet's system, ideally one that will give each team ample opportunity to gather data. Unlike earlier spacecraft, which had their instruments mounted on a scan platform that could point independently, Cassini has its instruments fixed to the craft itself, Porco explains. That means "we have to take turns pointing. It makes the sequencing [of the data collection] much more contentious and complicated."

'We are not antispace'

Given their enthusiasm, Cassini scientists wince at the negative publicity their project is drawing. The controversy stems from the spacecraft's three radioisotope thermoelectric generators (RTGs), which will use the decay heat from plutonium-238 to generate about 900 watts of electricity needed to power the instruments. ^{238}Pu is an alpha emitter that is toxic when inhaled in trace amounts. Antinuclear activists charge that an accident during launch or, worse yet, during the gravity-assisted flyby of Earth in August 1999 could vaporize the plutonium and send



CASSINI'S FLIGHT will include two gravity-assisted flybys of Venus, one of Earth and one of Jupiter; in July 2004, the craft is set to reach Saturn, where it will remain for at least four years. During each flyby, the planet will slightly deflect the spacecraft's trajectory; the craft will gain velocity, while the planet will slow down infinitesimally. Delaying the launch beyond 15 November would mean altering the flight path, adding at least two years to the voyage (at a cost of $60 million per year) and reducing the scientific payback.

PHYSICIST MICHIO KAKU speaks during a rally at Cape Canaveral in July. Protests are expected to culminate in demonstrations there and in Germany on 4 October.

it raining down on the planet. NASA has used RTGs without mishap on more than 20 previous space missions, including Galileo and Ulysses, and intends to use them on future missions to Mars, Jupiter and Pluto; but Cassini carries the largest amount of plutonium—about 50 pounds—to date.

Calling for an end to the "nuclearization of space," protesters have staged candlelight vigils at the White House, circulated petitions and organized rallies and press conferences. Using e-mail and the World Wide Web, they have been able to spread their message quickly, cheaply and globally. Indeed, the campaign has far eclipsed protests of Galileo or Ulysses. "It's unbelievable," JPL's Kohlhase says. "I've never seen it at such a level before." Like his colleagues, he views the attacks as "alarmist" and "totally misplaced."

"We are not antispace," stresses Jan Smiley of the Florida Coalition for Peace and Justice, one of the main groups opposing Cassini. "If they put solar panels on Cassini, we'll all come back and cheer when it lifts off." But, like other antinuclear activists, she doesn't trust the official numbers.

Adding credibility to the opposition's arguments have been medical, technical and scientific experts such as Helen Caldicott, founder of Physicians for Social Responsibility; Alan Kohn, who worked on NASA's emergency preparedness plans for the Galileo and Ulysses missions; and Michio Kaku, the Henry Semat Professor of Theoretical Physics at the City University of New York.

Kaku says his criticisms are based on a careful review of the final environmental impact statement (FEIS) for Cassini and other NASA documents (his review is posted on the Web at http://www.animatedsoftware.com/cassini/mk9708so.htm). The FEIS, he says, "uses optimistic risk probabilities and underestimates the degree of land contamination and plutonium dispersal" that would occur in an accident. He also faults the agency's reliance on computer programs to estimate risk probabilities. "A chain is not stronger than its weakest link, and the weak link is human failure and design flaws," he argues. "You cannot simulate stupidity."

Until the 1986 Challenger explosion, Kaku says, he never thought to question NASA's methods. "The turning point was when I read the article by Richard Feynman in PHYSICS TODAY [see February 1988, page 26] about his study of the Challenger explosion. He approached his analysis from a physicist's point of view, not a manager's or even an engineer's. . . . After reading that, I began to realize that you have to look beyond the press releases, beyond the fantastic numbers."

Kaku worries that an accident could cause a backlash against the space program, because the real risks have been hidden from the public. "I think we should explore outer space," he says. "My attitude is, Saturn is not going to go away. Let's downsize Cassini and go solar for deep space missions, like ESA plans to do."

Burden of proof

NASA, for its part, figures the probability of plutonium being released during a flyby accident to be less than 1 in a million, and during a launch accident, 1 in 1400. And in no case, the agency says, would the kind of radioactive catastrophe depicted by activists occur.

Exhaustive tests have been conducted on the RTGs, which were built by Lockheed Martin for the Department of Energy, and the results are summarized in a two-foot-thick report, says Beverly Cook, who oversees DOE's manufacture and safety analysis of the generators. The plutonium is in ceramic pellet form and cannot be easily pulverized, she explains; the pellets are further shielded by iridium and layers of graphite. "My 13-year-old daughter will be coming to the launch," she adds. "I wouldn't have her there if I didn't think it was completely safe."

To help counter the criticisms, NASA has posted fact sheets about nuclear safety and RTGs on its Cassini home page (http://www.jpl.nasa.gov/cassini/). The agency could do more, says John Pike of the Federation of American Scientists. "NASA needs to provide a readily understood and consistent set of paperwork justifying this mission to the tax-paying, voting, radiation-fearing public." For starters, he suggests, it should explain fully how it conducted the risk assessment and why it opted for nuclear power over other energy sources.

He mentions the FEIS estimate that 2300 cancer fatalities could result from the worst-case flyby accident; that figure was lowered to 120 in a supplemental report released in June. DOE's Cook explains that the larger number was preliminary, calculated before the detailed safety analysis had been completed; in addition, JPL revised the flyby trajectory to further minimize the risk. And even if an accident like this were to occur, adds Arizona's Porco, "scientists, say, in the 22nd century looking over the record of cancer deaths for the late 20th century would not be able to tell that there had been such an accident. It would be lost in the noise." To skeptical protesters, however, the falling numbers seem merely convenient.

Pike doesn't oppose the use of RTGs in deep space *per se*, nor does he want to argue over the numbers. In his opinion, the main problem is one of openness. "The public is allergic to the idea of radioactive spacecraft falling in their backyards," he observes. "So there's a very high burden of proof on the people proposing to fly such spacecraft. NASA hasn't met that burden of proof."

While their differences continue to defy resolution, Cassini's critics and supporters at least agree on one thing: A launch will, in all likelihood, go off without a hitch. And seven years from now, scientists may begin poring over the first bits of Saturn data as they come streaming back to Earth. Meanwhile, the debate over nuclear power in space appears likely to continue too.

JEAN KUMAGAI