The ICE Plan Cometh

Half a year before an international cluster of spacecraft visits Comet Halley, a little probe borrowed from a totally different kind of mission is about to become the first man-made object ever to visit a comet

By JONATHAN EBERHART

The international fleet of spacecraft now heading for encounters next March with Comet Halley is doing so to the accompaniment of an array of T-shirts, trinkets, talk shows, shipboard "observing tours," books and other cometobilia the like of which has not attended another space event since the Apollo program headed for the moon 16 years ago.

Yet in less than two weeks, on Sept. 11, a far less publicized probe will beat the whole Halley armada to the honor of being the first man-made object ever to visit a comet.

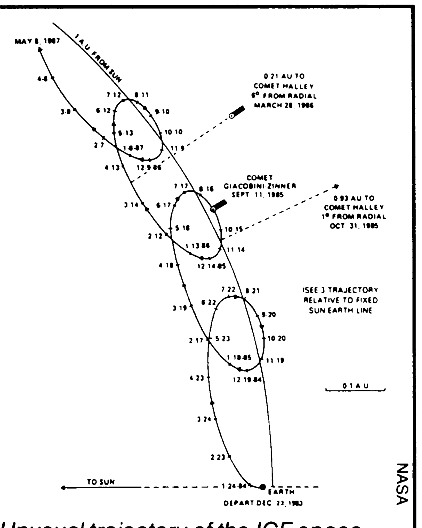
Comet Giacobini-Zinner is not exactly a household name, and the International Cometary Explorer (ICE) spacecraft was not even designed to study comets in the first place. It was launched in 1978 as ISEE-3, the third in a family of satellites called the International Sun-Earth Explorers, and sent to a bizarre orbit around an imaginary point between the earth and sun. Its purpose was to monitor the solar wind from about a million miles sunward of the planet, providing data about the "wind" from outside earth's magnetic field for comparison with data taken within the magnetosphere by ISEE-1 and -2.

It stayed at its post until June 10, 1982, when its rocket engine was fired to send it off on a nine-month study trip down the magnetic field's "tail." This was step one in a complex mission devised by Robert Farquhar of the NASA Goddard Space Flight Center in Greenbelt, Md., who had been thinking about sending the craft to a comet even before it was launched to its solar-wind-watching site. He had at first considered Comet Halley, and there was even a possible trajectory by which ISEE-3 could get there, but it turned out that the resultant encounter would take place too far from the earth for the craft's transmitter to send the data back.

Another candidate, however, was Comet Giacobini-Zinner, first observed in 1900 by Michel Giacobini and rediscovered 13 years later by Ernst Zinner. Sending ISEE-3 there would not be easy: The craft's rocket had plenty of fuel, but to achieve his goal, Farquhar had to work out an intricate trajectory involving five close trips past the moon (for gravitational assistance), four major firings of the rocket engine and 11 more minor navigational corrections. If everything worked, the craft would pass the comet about 70 million kilometers from earth, less than half the distance of the Halley encounter and well within radio range.

The comet trip was not a unanimous choice. Some of the ISEE researchers were reluctant to have their solar-wind monitor sent away on a different mission, but the consensus favored the plan, as did the National Academy of Sciences' Space Science Board, which recommended that NASA go ahead with it. NASA gave its approval, and on Dec. 22, 1983, the newly named International Cometary Explorer made the key lunar swing-around that would direct it to the comet.

Again, ICE was not built for comet studies, but during the Sept. 11 encounter with Giacobini-Zinner, representatives from the Soviet Union, Europe and Japan will be out at NASA Goddard to see what can be learned that may bear on their own probes' later visits to Comet Halley.



Unusual trajectory of the ICE spacecraft, which will encounter Comet Giacobini-Zinner on Sept. 11. (The apparent loops are because the trajectory is shown with respect to a fixed line between the earth and sun.) Next March 28, ICE will also be in position to monitor the solar wind "upstream" from Comet Halley.

Even apart from providing advance warnings for the Halley crowd, however, ICE's major contribution, in a sense, is the fact that its target comet is *not* Halley. Comets come in all shapes, sizes and unusual behaviors, and no spacecraft has been to any of them. If the entire file of close-up scientific data about comets were focused on a single example, it would be difficult to determine what can be said about comets in general, versus what applies only to Halley. Some meteor showers believed to be associated with debris left behind Giacobini-Zinner in its orbit, for example, appear to include many meteorites whose tails (as they burn up in earth's atmosphere) are atypically short, says ICE project scientist Tycho von Rosenvinge of NASA Goddard. This could mean that the trailing pieces of Giacobini-Zinner are unusually low in density — striking evidence of comets' diversity even from a mere pair of examples. ICE's target, in other words, is anything but second-best. More to the point, it is *different*.

ICE does not even have a camera. Yet if it did, says von Rosenvinge, "we probably wouldn't be going to the comet." With no pictures to take, there has been no need to worry about the requirements of photography, including flying past Giacobini-Zinner's nucleus on its sunlit side. Instead, the craft is free to go by on the side *away* from the sun, which is also the direction in which the comet's tail streams away into space.

ICE's limitation thus becomes the key to an important asset: As a member of the overall armada of spacecraft bound for comets over the next six months, ICE will "merely" be the first. But in facing unknown hazards of flying through the huge dust storm of a comet's tail, it will be the only one. Europe's Giotto spacecraft will face a far greater dust hazard, coming within only 500 kilometers of the nucleus of Comet Halley (SN: 7/13/85, p. 20), while ICE will be about 10,000 km from the nucleus of Giacobini-Zinner. But Giotto, like the two Soviet VEGA craft, will pass sunward of Halley, leaving ICE alone as a "tail probe."

Still, ICE was designed to study ionized and neutral atoms and molecules in the

Comet Giacobini-Zinner, photographed Oct. 21, 1959, by Elizabeth Roemer at the U.S. Naval Observatory, Flagstaff, Ariz.

solar wind, not an onslaught of solid particles. Besides lacking a camera, it also lacks a dust detector. Or does it? Though none of its 13 sensors actually has "dust" in its name, three of them may be reporting on dust after all, providing valuable information not only for studies of Giacobini-Zinner, but also to the scientists and engineers wondering about the fate of their own probes at Halley.

One such instrument was essentially "born" to its new role on Aug. 25, 1981, as the Voyager 2 spacecraft flew through the plane of the rings of Saturn. At that moment, one of the Voyager sensors recorded what Frederick L. Scarf of TRW in Redondo Beach, Calif., calls "the most intense noise we've ever detected with such an instrument in space." The device was a plasma-wave detector, measuring electromagnetic radiation, not solid chunks of anything. But according to Donald A. Gurnett of the University of Iowa in Iowa City, together with Scarf and other colleagues, the "noise" — essentially static — was apparently produced by "impact ionization of particles striking the spacecraft body, thereby releasing a cloud of charged particles, some of which were collected by the plasma-wave antenna." Adds Gurnett, "There just isn't any conceivable explanation other than impacts." In other words, dust. ICE, too, has a plasma-wave detector, its antennas stretching 100 meters from tip to tip. Unlike Voyager 2, ICE's sensor cannot count "hits" by individual particles, but it can provide a "noise spectrum" that is proportional to the total number and mass of particles that strike the antennas each second. Each such spectrum will represent the sum of the impact energy contributing to it, potentially yielding what amounts to a dust hazard map of ICE's trip through Giacobini-Zinner's tail.

Also perhaps playing a role in the dust watch will be a low-energy charged-particle detector, for which "particles" usually means electrons and ions rather than solid grains. The device includes a number of gas-filled pressure cells, however, and Dieter Hovestadt of the Max Planck Institute in Munich has studied the cells to see just how big and fast an impact from a dust grain would puncture one, signaling its presence by letting out the gas.

A more improbable-sounding sensor for dust studies is ICE's radio astronomy instrument, featuring another 100-meter antenna array. It works over a frequency range that may show up the "impact pulses" less clearly than does the plasma-wave detector, but it also has a different sampling rate and other differences, and none of these ad hoc dust analyses, notes Scarf, will be easy.

The radio instrument, however, is also conducting another unusual quest: For weeks, says Joseph Fainberg of NASA Goddard, he and his colleagues have been looking for signals from the comet in advance of the actual trip through the trail. If enough ions from the comet are trapped on the lines of the interplanetary magnetic field, Fainberg says, the resulting "mass loading" may cause the field lines separated by the comet to recombine behind it, producing radio emissions. Radar waves have been bounced off comets and received back at their earth-based antennas, but ICE represents the first chance to detect cometary radio emissions from a spacecraft's close-up viewpoint. To facilitate the search, Fainberg has been receiving his data from ICE at the end of every week, rather than in 4-to-6-week batches like the experiments for which no such remote sensing is anticipated.

Another of ICE's instruments being used in a way far more ambitious than that for which it was originally intended is its plasma-composition experiment, looking to see just what ions have in fact been picked up from Giacobini-Zinner's nucleus by the solar wind.

Designed primarily to study hydrogen, helium and other lightweight ions, the instrument was built around a microprocessor whose programming was inalterable, envisioned only for ions with mass-to-charge ratios of 6 or less. Late in 1981, however, Keith Ogilve of NASA Goddard and co-investigator Michael A. Coplan of the University of Maryland in College Park were contemplating ICE's then-forthcoming long excursion down earth's magnetic tail when they noted that although the program was locked in, certain parameters could indeed be changed by radioed instructions from the ground. These were the parameters used to determine the specific ions for which the instrument would search, and it was realized that by allowing some of these parameters to exceed their originally planned range, the device could accommodate not only lightweight ions at high speeds, but also heavier ions moving more slowly.

"We worked out a set of numbers," says Ogilve, "and sent them up, and lo and behold, it worked." The result is that Ogilve's team is now able to measure singly charged ions with masses as high as 34, including such presumably important cometary species as water (H_2O^+), nitrogen (N_2^+) and several others (O^+, OH^+, HCO^+, NH^+, etc.).

Though ICE is expected to spend from 1½ to 3 hours in the comet's conspicuous dust tail, according to von Rosenvinge, the trip through its much subtler ion tail is likely to last only about 5 minutes. Because the plasma-composition instrument takes 22 minutes to cycle through its new mass range, says Ogilve, "we have essentially written off the tail," but there will be plenty of time to concentrate on ions picked up by the solar wind from the comet's huge coma. The instrument will be operated from about a day before the encounter until about a day afterward.

(A limitation on the instrument's performance is that any ions entering it must do so through an opening which is pointed at a large angle away from the ionic flow direction. The angle is a consequence of the fact that ICE's solar panels must remain pointed at the sun, while its communications antenna points at earth. To save power for key instruments during the encounter, in fact, a gamma ray experiment, three cosmic ray experiments and the heater for ICE's hydrazine propellant all will be turned off.)

Sometime in 1988, according to Farquhar, ICE will get so far from earth that its transmitters will no longer be detectable even by NASA's largest ground antennas. "However," he says, "this may not be the end of the ICE mission. ICE will return to the vicinity of the earth in July 2012. At that time, it is planned to use a lunar gravity-assist maneuver to place the spacecraft into a high-apogee earth orbit. From this location, it would be possible to recover ICE and eventually put it on display in the National Air and Space Museum." □