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ICE Second Halley Radial: TDA Mission Support and DSN Operations

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TDA Mission Support and DSN Operations

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This article documents the operations encompassing the International Cometary Explorer (ICE) second Halley radial experiment centered around March 28, 1986. The support was provided by the Deep Space Network (DSN) 64-meter subnetwork. Near continuous support was provided the last two weeks of March and the first two weeks of April to insure the collection of adequate background data for the Halley radial experiment. During the last week of March, plasma wave measurements indicate that ICE was within the Halley heavy ion pick-up region.

I. Introduction

The International Sun Earth Explorer (ISEE-3) was launched in 1978. Five years were spent in Earth orbit, measuring particles and fields; first monitoring the solar wind upstream of the Earth and later in the geomagnetic tail region. During this period, support of ISEE-3 was provided by the 26-m antennas operated by the Ground Spaceflight Tracking and Data Network (GSTDN). In December 1983, using a 119-km-altitude, lunar-gravity-assist swingby, the spacecraft was sent on a new mission to intercept Comet Giacobini-Zinner (G-Z). At perihelion, the spacecraft was renamed the International Cometary Explorer (ICE).

Mission Trajectory acrobatics and navigation from launch through comet encounter are covered in detail in Reference 1. The Comet G-Z Encounter operations are covered in References 2-7.

While in Earth orbit, the geocentric range to ISEE-3 had been on the order of 0.01 AU (1.5×10^6 km) or less. While enroute to encounter with G-Z the geocentric range to ICE grew to 0.51 AU. In January 1984, ICE went out of range of the 26-m antennas and required support from the DSN 64-m antennas for the remainder of the mission.

The primary mission goal was to make the first *in situ* measurement of a comet. This was achieved on September 11, 1985 when the spacecraft passed unscathed through the G-Z tail 7800 km downstream of the nucleus.

A secondary mission goal was to obtain measurements in the solar wind upstream of Halley's Comet for possible correlation with Earth- and space-based observations of that celestial visitor during the same time frame. Twice during interplanetary cruise the ICE orbit placed the spacecraft in near

radial alignment between the sun and Halley's Comet. This occurred first in October–November 1985 and again late in March 1986. This is illustrated in Fig. 1. The second Halley radial alignment occurred when ICE approached within 30×10^6 km of the comet. Around this time, the plasma wave instrument aboard ICE made measurements indicative of ions produced by heavy neutrals emitted by Halley's Comet. Hence, ICE can lay claim to being the sixth member of the Halley Armada, behind Sakigake, Suisei, Giotto, Vega 1 and Vega 2.

II. Spacecraft Systems

The ICE spacecraft is a 16-sided cylinder which is 1.61 meters tall and 1.74 meters wide. Spacecraft mass at launch was 479 kg which included 104 kg of instruments and 89 kg of hydrazine propellant. There are two solar arrays, above and below an equipment platform where most of its payload of scientific instruments is mounted (Fig. 2). The solar array provides for all of the power requirements of the spacecraft.

The propulsion system is arranged in two independent and redundant systems consisting of 12 jet thrusters and 8 fuel tanks. This system is used for all spin-rate-change trajectory correction, and attitude control maneuvers. The spacecraft rotates around the central axis of the cylinder at a rate of approximately 20 revolutions per minute.

The spacecraft carries 13 scientific instruments. Several of these utilize appendages to measure conditions near the spacecraft without spacecraft interference. Magnetic fields are measured by two search coils located at the end of two 3-meter-long booms that extend in opposite directions out from the cylinder. Also, long wires, acting as radio mapping antennas, extend 92 meters tip-to-tip in the radial direction and 14 meters in the axial direction. The experiments aboard the spacecraft have directly affected the strategy for targeting the spacecraft for its Comet G-Z intercept and Halley radial experiment.

III. Operations

The DSN utilized the 64-meter subnetwork with stations located at Goldstone, California; Madrid, Spain; and Canberra, Australia. The 64-meter subnetwork provided nearly continuous support from March 15, 1986 to April 15, 1986. The subnetwork was used to collect spacecraft telemetry data, send commands to spacecraft, and generate radiometric data. Two-way range and range rate data over a 6-week time span were utilized by the JPL Multimission Navigation Team in determining the spacecraft orbit relative to Halley's Comet. The data arc covered the period between spacecraft trajectory

correction maneuvers performed on February 27, 1986 and April 7, 1986.

High quality *in situ* Halley Comet data was obtained via the 64-meter subnetwork and sent to the ICE Project located at the Goddard Space Flight Center (GSFC) where the data was processed and provided to the science investigators. The ICE Project was very pleased with the high quality data that was provided by the DSN and as a direct result were able to obtain excellent day-to-day data correlation for the Halley radial encounter period.

IV. Surprising Results

Solar plasma flowing radially outward from a rotating sun, carries along with it the interplanetary magnetic field (IMF). This results in a pinwheel-like structure to the solar wind. For a plasma flowing radially outward at 450 km/sec, Fig. 3 schematically illustrates the heliocentric orbits of the Earth, ICE and Halley relative to IMF field lines at 45° intervals during the six month period from 1 January 1986 through 1 July 1986. Figure 4 provides three orthogonal projections of the ICE orbit in a Halley-centered reference frame. Figure 4a shows a projection for an observer above the Halley orbit plane, 4b for an observer looking toward the Sun along the Halley-Sun line, and 4c for an observer in the Halley orbit plane looking toward the Sun-Halley line. In each view the circle is the projection of a sphere of radius 35×10^6 km centered at Halley. Due to the negligible gravity potential and weak bow shock associated with comets, neutral heavy particles emitted from the nucleus are able to travel great distances in all directions before they are ionized by the Sun's ultraviolet radiation. Once ionized, they are picked up by the plasma and begin to gyrate around the field lines.

Closest approach of ICE to Halley was at a distance of 28×10^6 km on 25 March 1986. The minimum Halley-Sun-ICE angle of about 6° occurred on 28 March 1986. From References 7 and 8, the energetic ion instrument (EPAS) measurements aboard ICE appear to be consistent with the interaction of the solar wind with heavy ions speculated to have their source in Halley's nucleus. Such an interpretation is in agreement with the ICE observations during the Comet G-Z encounter period. This implies a Halley's Comet solar wind interaction region extending perhaps $30\text{--}40 \times 10^6$ km from the comet's nucleus. Hence, when Halley is 1 AU from the Sun, its plasma interaction region extends from near the orbit of Venus out to mid-way between the orbits of Earth and Mars. The ICE mission has unexpectedly revealed that comets, despite their small nuclei, can have interaction zones near perihelion which exceed in size and volume the similar zones associated with the heliocentric motion of even the giant outer planets.

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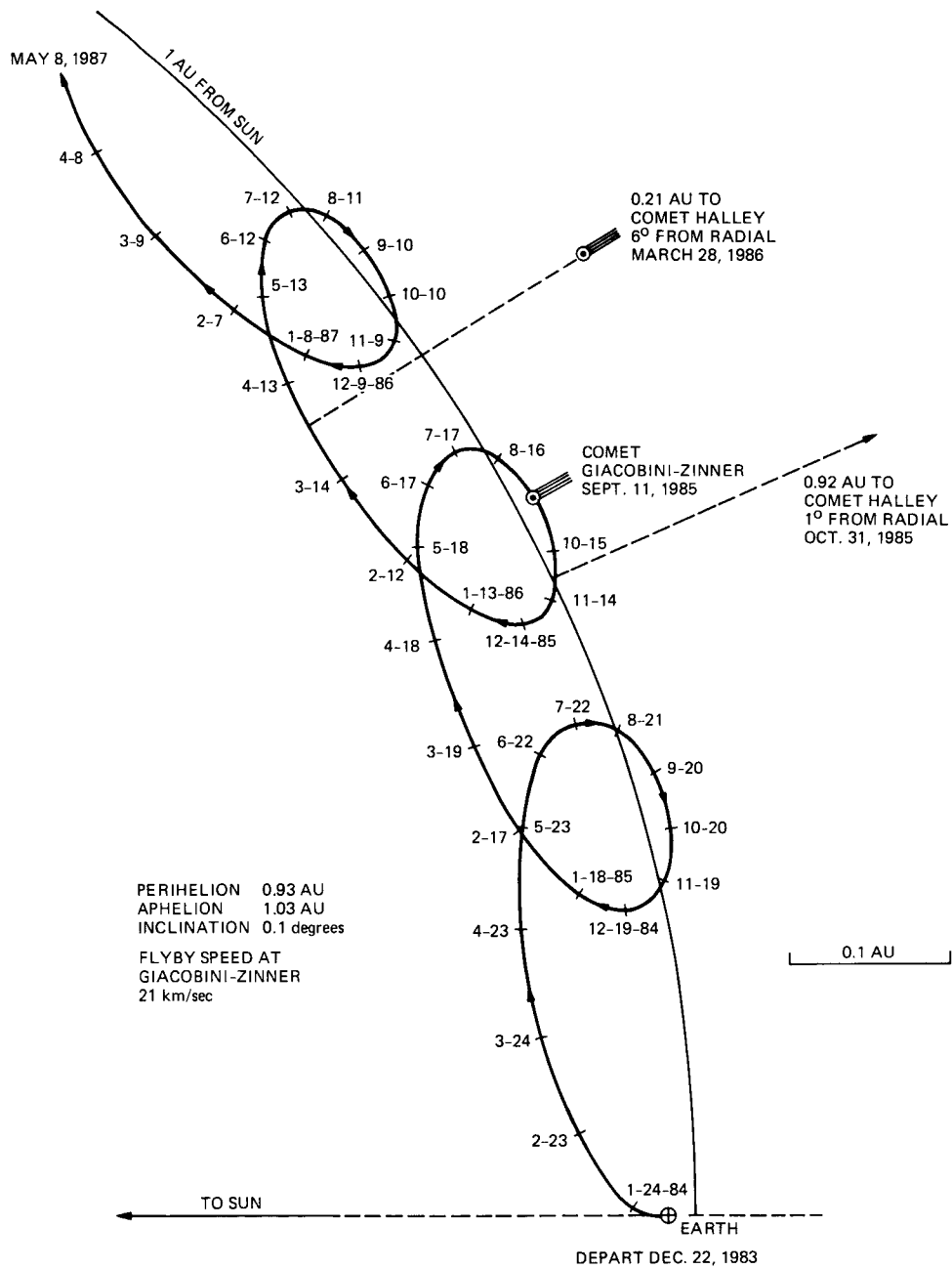


Fig. 1. ICE trajectory relative to a fixed Sun-Earth line

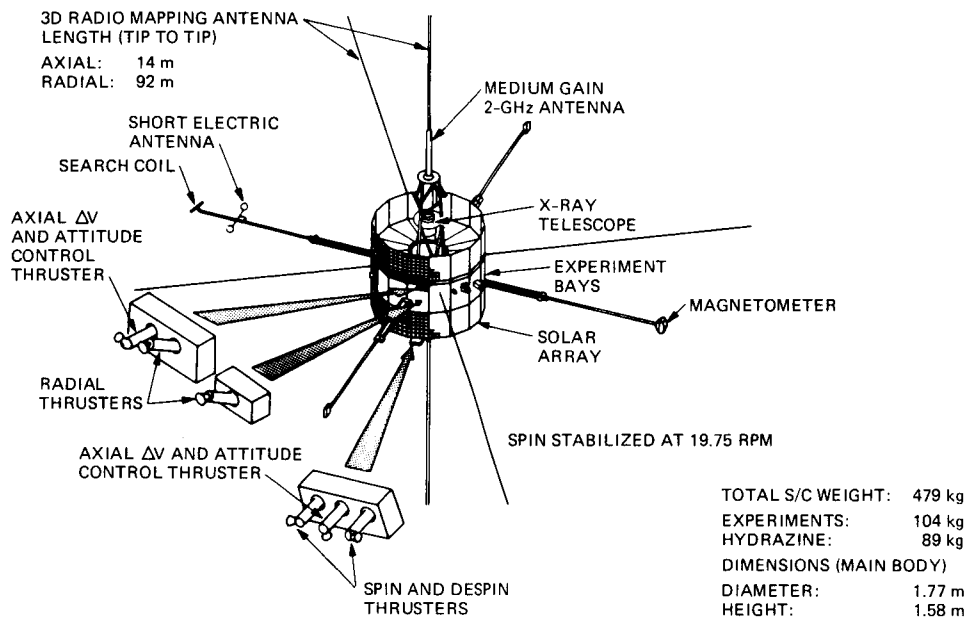


Fig. 2. The ICE spacecraft

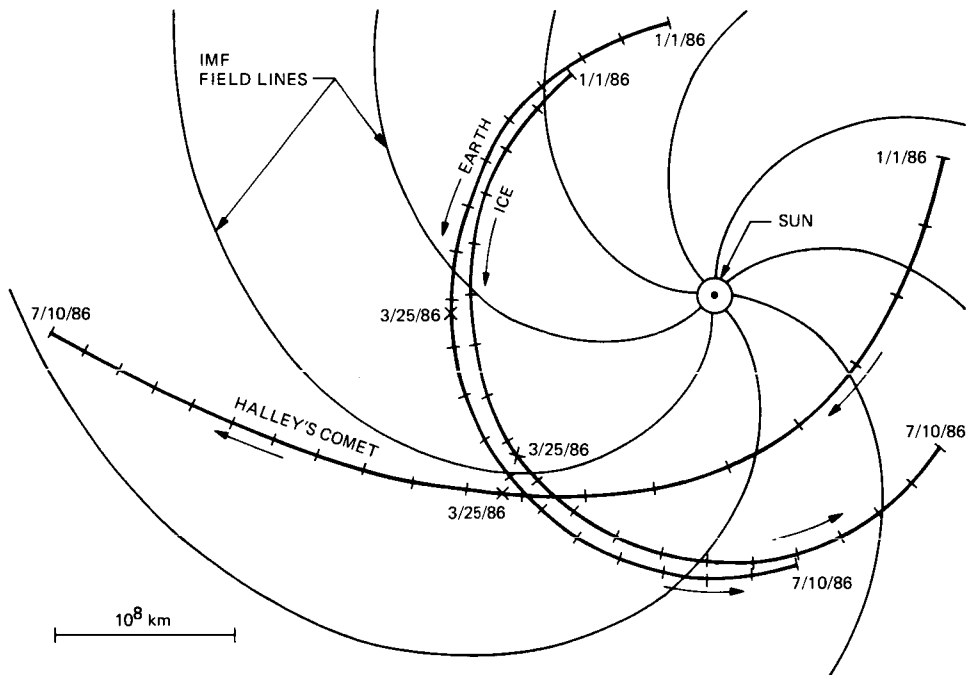


Fig. 3. Heliocentric orbits of ICE, Halley's Comet and Earth projected onto the ecliptic plane, 1 Jan. 1986 to 10 July 1986. Time tics are at 10-day intervals. IMF field lines illustrated schematically.

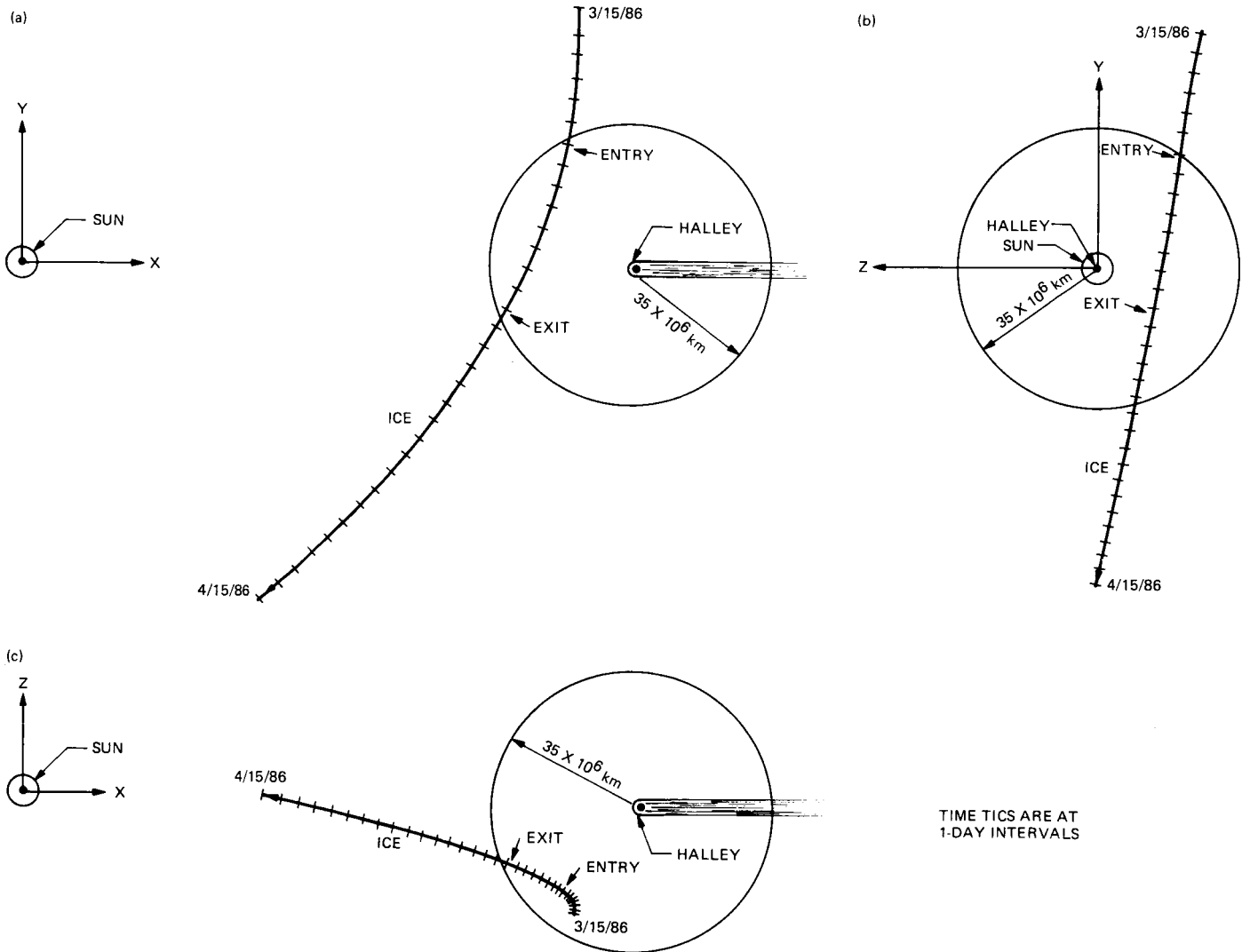


Fig. 4. Halley-centered orbit of ICE (15 March 1986 to 15 April 1986) and the projection of a 35×10^6 km radius sphere about the nucleus, as viewed by an observer (a) above the comet orbit plane, (b) looking toward the Sun along the Halley-Sun line from within the comet tail, and (c) in the comet orbit plane looking normal to the Sun-Halley line