PLANS FOR COMET HALLEY

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1. Introduction

When comet Halley is again near the Sun and Earth in 1985/86, we have the unique opportunity to measure cometary properties *in situ*, through special Halley missions flying through the comet at times of high activity. In the following sections, characteristics of three already approved missions will briefly be described. The main features of these missions are listed in Table 1 which is based on Friedman (1980) and Reinhard and Dale (1980).

Table 1

Characteristics for Comet Halley Missions

	ESA (Giotto)	Japan (Planet-A)	USSR (Venera)
Launch date	July 1985	August 1985	December 1984
Launch vehicle	Ariane	Impr. Mu-3S	Proton
Spacecraft mass	750 kg	120 kg	~ 1000 kg
Spacecraft type	Spin	Spin/despin	Three-axis
Communication rate	53 kbit/s	128 bit/s	10 kbit/s
Encounter date	13 March 1986	9 March 1986	8 March 1986
Encounter speed	68 km/s	70 km/s	70-80 km/s
Targetted miss distance	10^3 km	10^5 km	10^4 km
1σ aiming accuracy	90 km	10^5 km	10^4 km
Nucleus position knowledge	500 km	500 km	500 km
Payload mass	53 kg	10 kg	50 kg

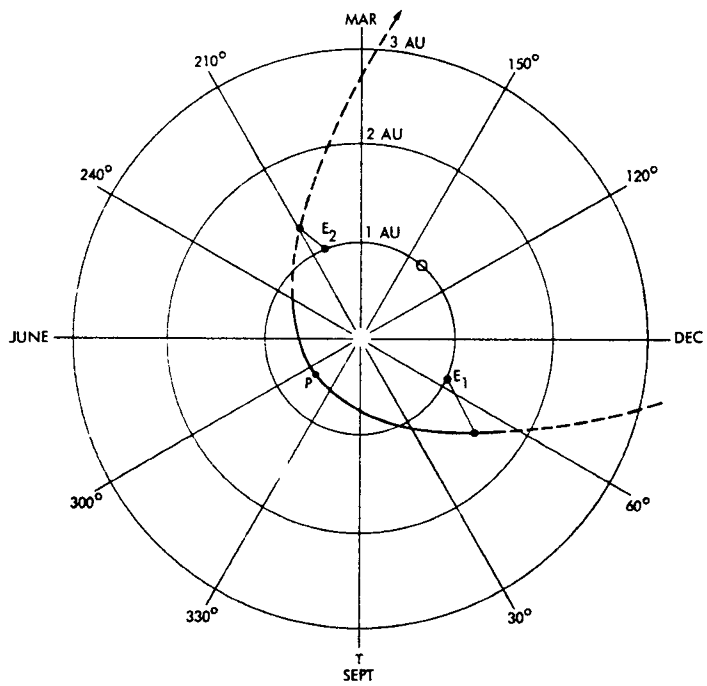
2. The Orbit of Comet Halley

The comet's orbit was calculated by D. K. Yeomans (1981). This prediction is based on 885 observations, obtained in 1759, 1835-36, and 1909-11. He gives the following set of osculating orbital elements:

Epoch	1986 Feb. 19.0 (E.T.)
T	1986 Feb. 9.6613 (E.T.)
q	0.587096 AU
e	0.967267
ω	111°.8534
Ω	58°.1531
i	162°.2378

Figure 1 shows the relative positions of comet Halley and the Earth in 1985-86. The comet will pass perihelion on February 9, 1986, at heliocentric and geocentric distances of r = 0.59 AU and d = 1.54 AU, respectively. The dates of the comet's closest approach to Earth before and after perihelion passage are November 27, 1985 (r = 1.5 AU, d = 0.62 AU) and April 11, 1986 (r = 1.3 AU, d = 0.42 AU), respectively. The comet will cross the ecliptic plane twice, first on November 9, 1985 (r = 1.8 AU, d = 0.9 AU), and again on March 11, 1986 (r = 0.85 AU, d = 1.0 AU).

RELATIVE POSITIONS OF COMET HALLEY AND EARTH 1985-86



P = PERIHELION OF COMET HALLEY
E_1 = POSITION OF EARTH AT PRE-PERIHELION CLOSE APPROACH OF COMET (NOV. 27, 1985)
E_2 = POSITION OF EARTH AT POST-PERIHELION CLOSE APPROACH OF COMET (APR. 11, 1986)
O = POSITION OF EARTH AT PERIHELION OF COMET HALLEY (FEB. 9, 1986)

Figure 1. Schematic drawing of Earth and comet Halley's orbit in 1985-86.

Several space agencies have studied flyby or flythrough missions to Comet Halley in 1985/86. A variety of different trajectories and plans is possible and has been discussed in the literature (e.g., Farquhar and Wooden, 1977; Friedman, 1980). Launch energies for pre- and post-perihelion encounters are low (c_3 = 5 to 20 km^2 s^{-2}), and the flyby speeds are approximately 70 km s^{-1}. The requirement of minimum launch energy demands an encounter of the probe with the comet in the ecliptic plane, to which Halley's orbit has an inclination of 162°. The launch energy necessary for a pre-perihelion encounter (about November 9, 1985) is considerably higher than the one for a post-perihelion encounter (about March 11, 1986). Since in addition, the comet's activity is expected to be higher after perihelion than before, most attention is being given to a post-perihelion encounter.

3. ESA's Giotto Mission

The European Space Agency (ESA) will fly a post-perihelion flythrough mission using a spinning Earth-Orbiting Satellite (Fig 2.; this Figure as well as Figs. 3 and 4 are taken from ESA Bulletin 24, 1980). It is called the "Giotto" mission. The science instruments have already been selected (see Table 2). The nominal launch date is July 10, 1985, encounter date is March 13,

Table 2

Giotto Payload with Mass Allocation
(as of March 1981)

Experiment	Mass (kg)	Power (w)	Telemetry Bps
Halley Multicolor camera	10.2	10.5	20,000
Mass and Energy Spectrometer System for Analysis of the Gaseous Environment	10.0	9	4,184
Ion Mass Spectrometer	8.2	9	3,200
Particulate Impact Analyzer	10.0	11.4	6,000
Dust Impact Detection System	2.5	2.8	2,000
Plasma Analyzer	3.6		
Positive Ion Cluster Composition Analyzer	0.5	5.5	2,200
Implanted Ion Analyzer	2.1		
Halley Optical Probe Experiment	1.0	1.0	368/1,368

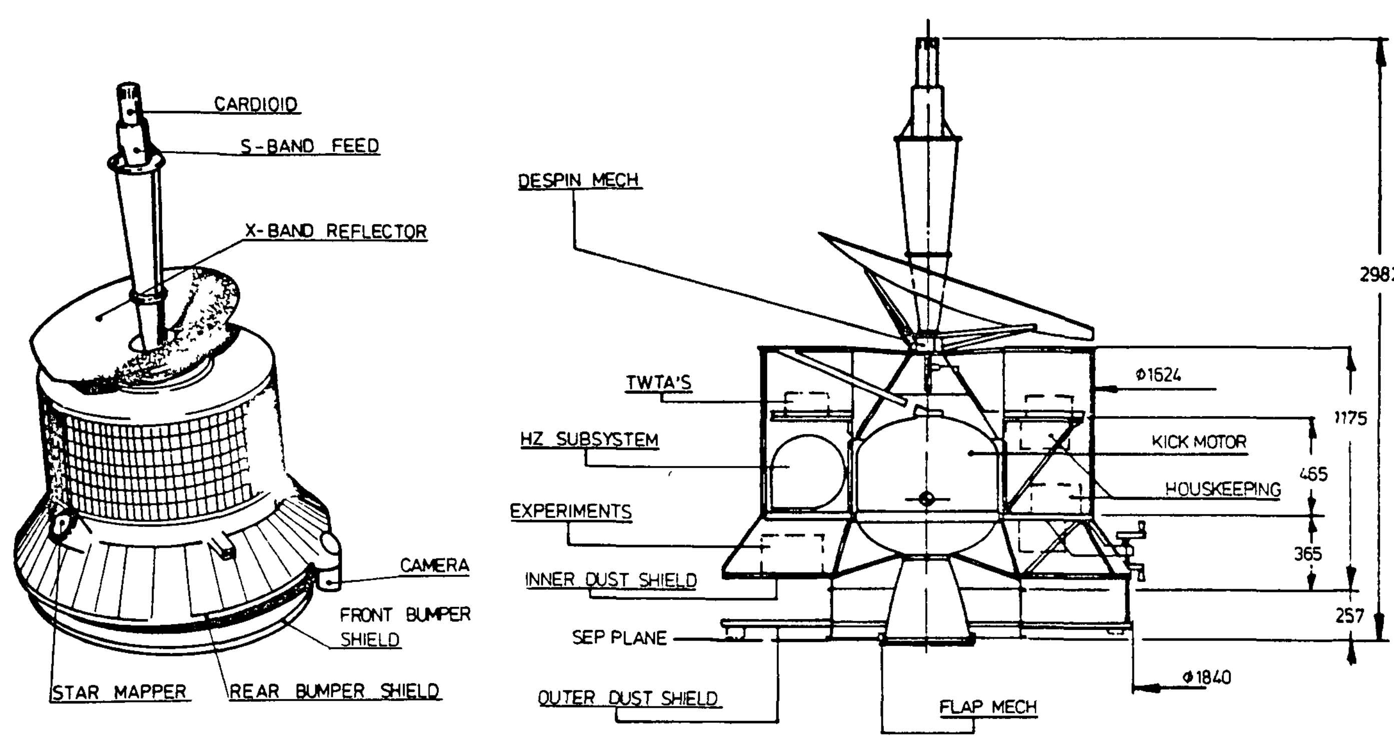


Figure 2. The Giotto spacecraft.

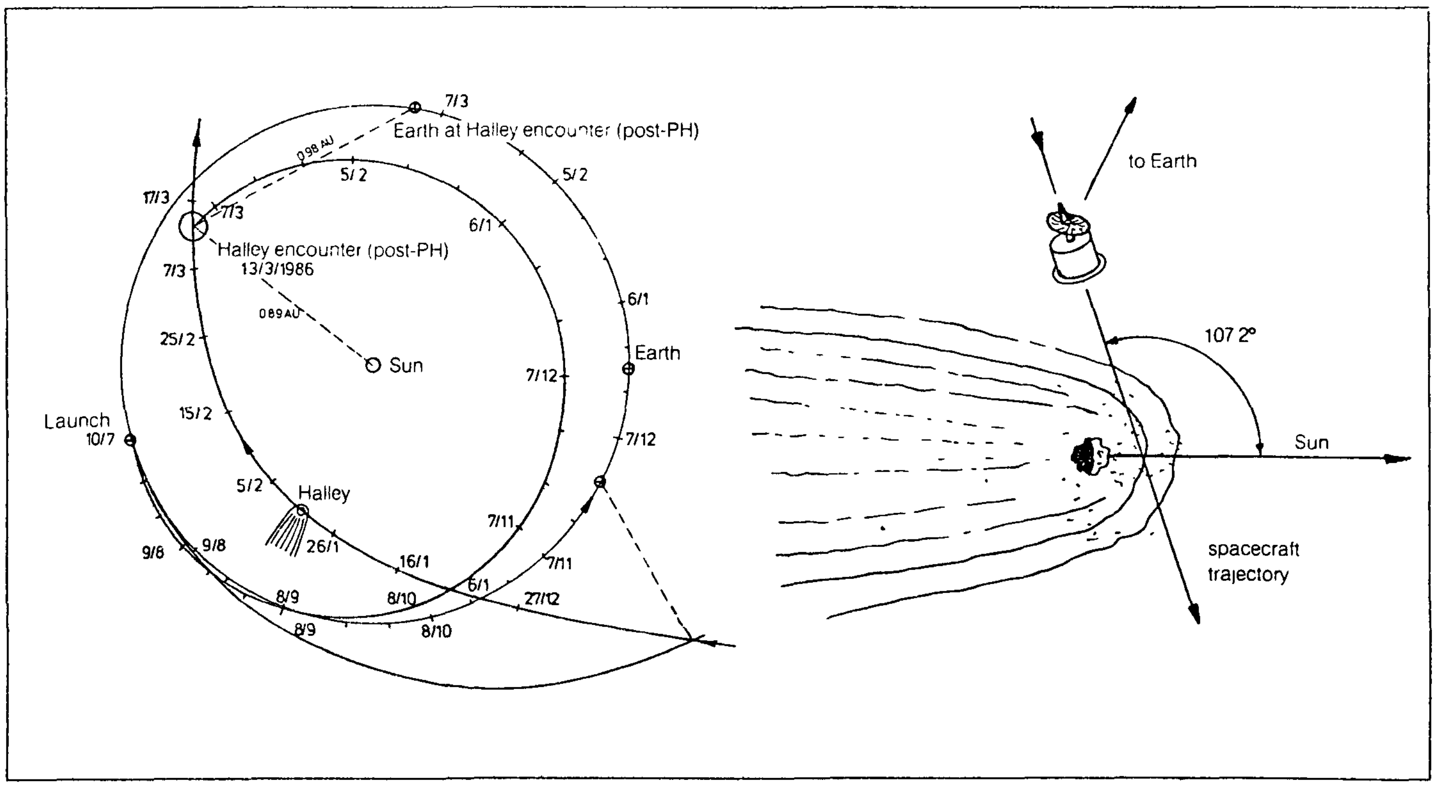


Figure 3. Left: Trajectory for Giotto for launch on July 10, 1985, and post-perihelion encounter on March 13, 1986. Right: Geometry of encounter. The spacecraft trajectory is only schematically illustrated.

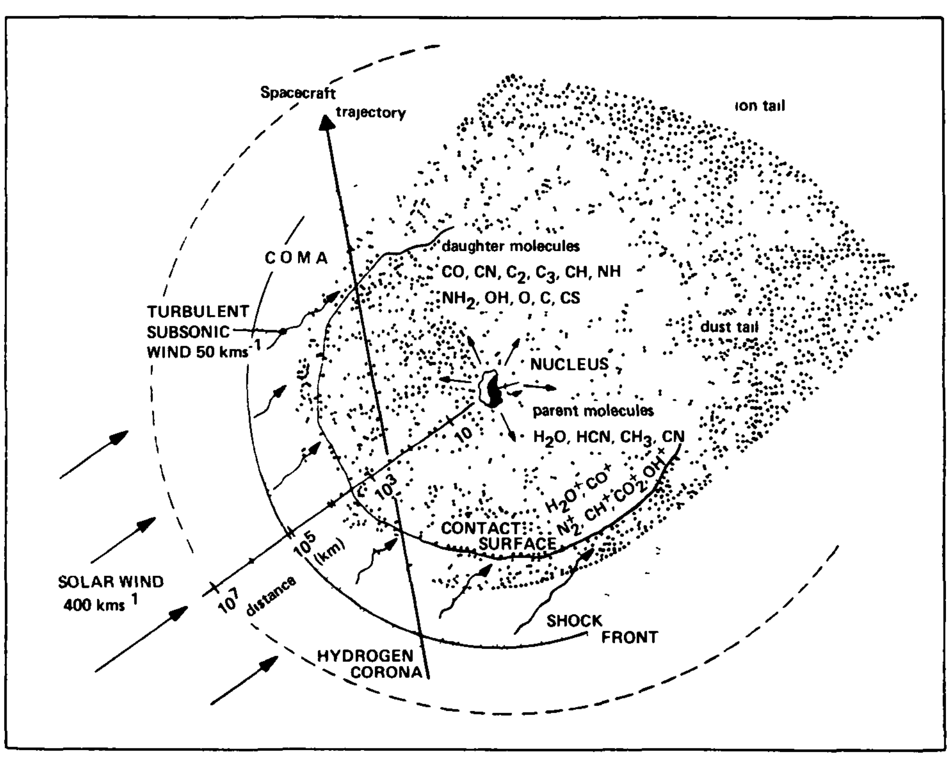


Figure 4. Model of cometary coma and spacecraft trajectory (schematic).

1986; encounter speed is 68 km s^{-1}. To protect the spacecraft against the dust particles emitted by the comet and striking the spacecraft with a relative velocity of 68 km s^{-1}, a special bumper shield will be installed, consisting of a thin (1 mm) front and a somewhat thicker rear sheet that are about 25 cm apart. Since the survival of the spacecraft cannot be guaranteed, all scientific data will be transmitted in real time. The encounter geometry is illustrated in Figure 3. Giotto will be launched by an Ariane-2 in tandem configuration during a 15-day nominal launch in July 1985. It is estimated that an encounter distance of less than 500 km from the comet's nucleus can be achieved with a 50 percent probability.

The major spacecraft features are (Reinhard and Dale, 1980): a 1.5 m dish antenna, inclined and despun; a dual-sheet bumper shield; a solid-propellant injection motor; an active attitude and orbit control system using hydrazine; and a power budget and thermal concept that guarantees 4 h of active scientific data taking. The design of Giotto is similar to that of existing GEOS spacecraft. It is spin-stabilized (15 rpm) and will have a total mass of 750 kg at launch and of 430 kg at the time of encounter. The scientific payload will have a total mass of 53 kg.

The spacecraft will enter the H-corona, cross the shock front and contact surface, image the nucleus, and measure the dust, neutral and ionized particles (Fig. 4). The scientific instruments will run on power from solar-charged batteries, with a maximum operating period of about 4 hours.

4. Planet-A Mission

After more than 10 years of studies of the Earth's upper atmosphere from sounding rockets, the first Japanese scientific satellite "Ohsumi" was successfully launched in 1970. "Planet-A" will be the first spacecraft to study solar system objects besides the Earth. It is planned that the spacecraft will make measurements of the solar plasma and Venus during its cruise in interplanetary space and then approach comet Halley on March 9, 1986. The launch is scheduled for August 1985. The main instruments are listed in Table 3. They are a magnetometer, plasma analyzer, plasma wave instrument, ultraviolet spectrometer, and ultraviolet imaging instrument. The encounter speed will be about 70 km/sec, the spacecraft will pass the comet in a distance of about 100,000 km.

Table 3

Scientific Instruments of Planet-A

1. Magnetometer
2. Plasma Analyzer
3. Plasma Wave Instrument
4. Vacuum Ultraviolet Imaging Instrument
5. Vacuum Ultraviolet Spectrometer
6. Wave Propagation Experiment

5. Venera-Halley Mission

The Soviet mission will use two identical three-axis stabilized spacecraft that are similar to the Venera 11 and 12 missions. They will be launched in December 1984 and arrive at Venus in June 1985. The encounter distance with Venus is 30,000 km. Each spacecraft will release one probe to Venus and will then continue to fly to Halley where they will arrive on March 8, 1986. The first spacecraft will have an encounter distance with Halley of 10,000 km; the second spacecraft might go as close as 4,000 km, if the first one survives the dust hazard. The spacecraft will have a fixed antenna pointing to the earth, so that it cannot efficiently be protected against impacting dust particles. Already approved experiments are listed in the upper part of the table. Each spacecraft will carry a payload of about 50 kg.

Table 4.

Venera-Halley Mission Experiments

1. Approved experiments

   a. Camera, narrow field and wide field } On Platform

   b. UV and visible spectrophotometer } On Platform

   c. IR spectrometer

   d. Dust mass spectrometer

   e. Dust counter

   f. Plasma ion analyzer

   g. Plasma waves analyzer (0.1 - 200 hz)

   h. Plasma waves analyzer (100 - 30,000 hz)

   i. Magnetometer

2. Complementary list (to be decided in June 1981)

   a. H/D ratio by hydrogen cell

   b. Neutral mass spectrometer

   c. Cometary ions analyzer

   d. Solar oscillations

   e. Photopolarimeter

   f. VLBI transmitter

6. Conclusions

The characteristics of the different missions discussed will undoubtedly be modified, and the list of the science instrumentation listed in Tables 2, 3 and 4 might also be changed. But all missions will certainly provide the most important science return during the coming apparition.

Acknowledgements

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