Giotto

Achievements: first cometary close flyby; first dual-comet mission; first European deep space mission; first European gravity-assist mission; first reactivation of an ESA spacecraft
Launch date: 2 July 1985
Mission end: 2 April 1986 (Halley flyby); 23 July 1992 Giotto Extended Mission
Launch vehicle/site: Ariane-1 from Kourou, French Guiana
Launch mass: 960 kg (574 kg at time of Halley flyby)
Orbit: injected into 199x36 000 km, 7° GTO; Mage boosted Giotto on 3 July 1985 into heliocentric orbit with 120 000 km Halley miss-distance
Principal contractors: British Aerospace (prime), Alcatel Thomson Espace (telecommunications), SEP (antenna despin, kick motor), FIAR (power), Fokker (thermal), TPD (starmapper), Dornier (structure)

Giotto's flyby of Comet Halley in March 1986 was the culmination of the international effort to investigate the most famous of all comets. Halley was selected because, of all the >1000 comets then known, it was unique in being young, active and with a well-defined path – essential for an intercept mission. ESA's probe was also unique: of all the worldwide scientific instrumentation focused on the comet, Giotto was the only platform that could take a payload close in to the nucleus. It was the first – and remains the only – spacecraft to do this.

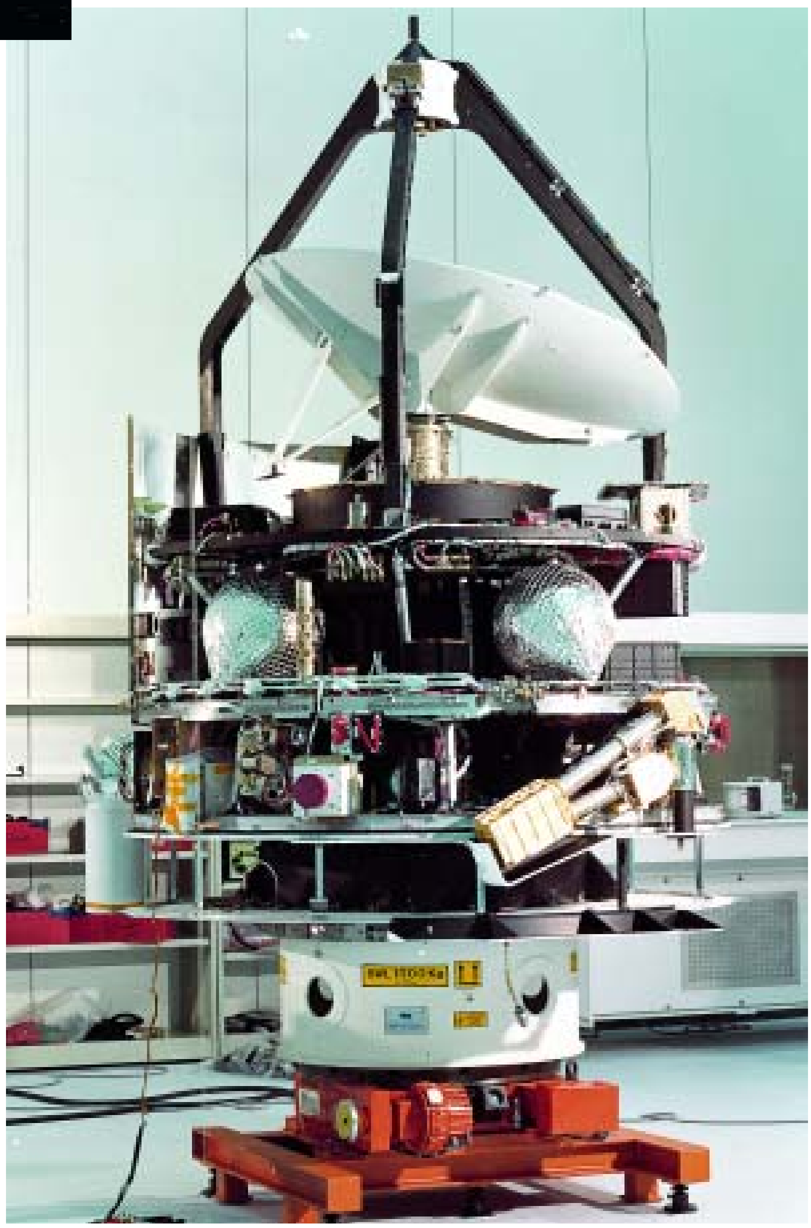
Observations from the two Soviet Vega probes were crucial for pin-pointing Halley's nucleus, reducing the Earth-based error from 1500 km to 75 km. At 21:00 UT on 12 March 1986, the JPA instrument signalled the beginning of the encounter, detecting the first Halley hydrogen ions 7.8 million km from the nucleus. At 19:40 UT on 13 March, and still 1 064 000 km out, Giotto crossed the bowshock in the solar wind. The formal 4 h encounter began 35 min later. The first of 12 000 dust impacts came 122 min before closest approach. At 23:58 UT, at a distance of 20 100 km, Giotto passed through the contact surface where the solar wind was turned away by cometary material. The closest approach of 596 km occurred at 00:03:02 UT on 14 March over the sunlit hemisphere.

The best of Giotto's 2112 images, from 18 270 km, showed a lumpy nucleus 15 km long and 7-10 km wide, the full width being obscured by two large jets of dust and gas on the active sunward side. The dark

Giotto during the solar simulation test at Intespace in Toulouse, France. Visible are the Halley Multicolour Camera (white baffle, two horns for balancing during camera rotation) and the starmapper (red cover).

Giotto depicted a few days before closest approach to Halley's Comet. The diameter of Halley's visible dust coma at the time of encounter was about 100 000 km.

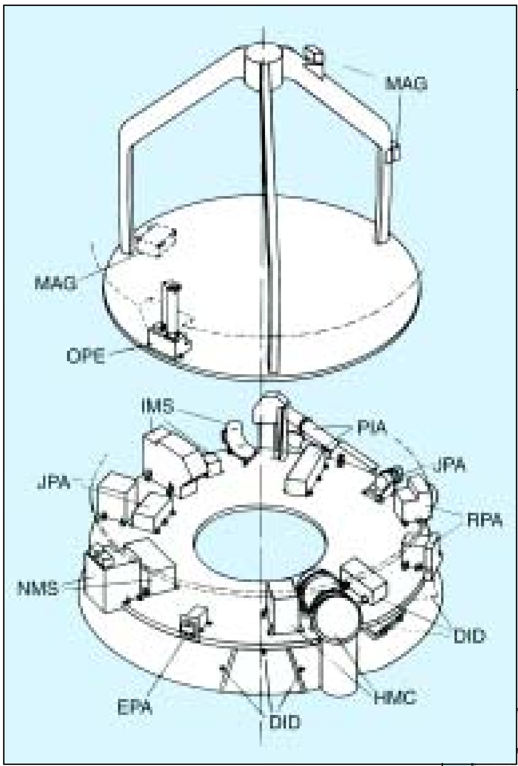
Giotto with the cylindrical solar cell array removed. Shown on the payload platform are (from left to right) the Halley Multicolour Camera (HMC), the electronics box of the Dust Impact Detection System (DIDS), the Rème Plasma Analyser (RPA) with its red cover on, and the dust mass spectrometer (PIA). Seen on the upper platform are two of the four hydrazine fuel tanks for attitude and orbit control.



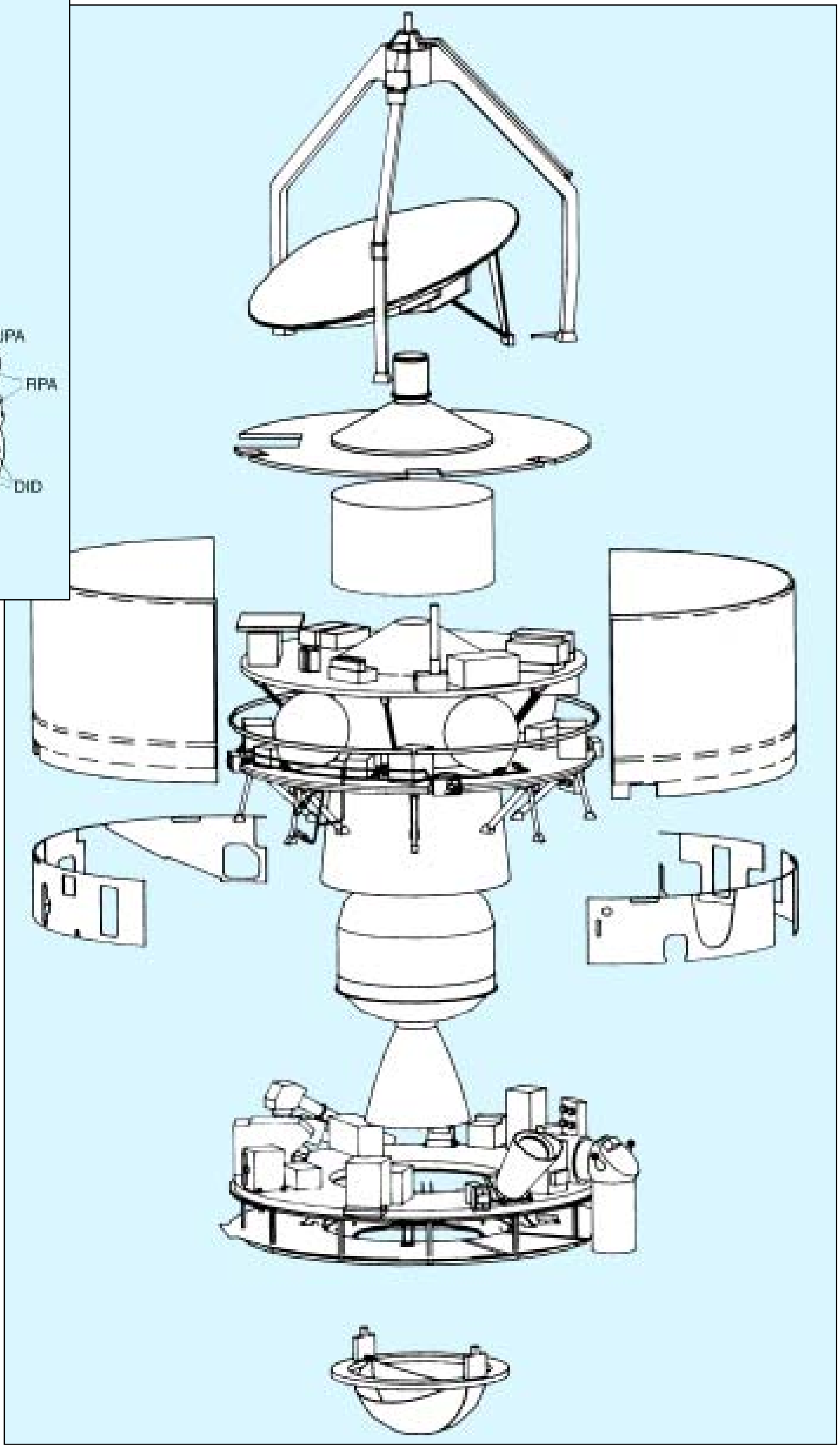
side, with an unexpectedly low albedo of 2-4%, was quiescent but image enhancement revealed circular structures, valleys and hills over the entire surface. The jets broke through the dark crust that insulated the underlying ice from solar radiation.

Images continued to within 1372 km, 18 s before closest approach. The rate of dust impacts rose sharply in the final few minutes, and in the last seconds there were 230 strikes as Giotto apparently penetrated one of the jets. Only 7.6 s before closest approach, it was hit by a particle large enough to break Earth lock, although data for the following 30 min were later recovered from the degraded signal.

Giotto confirmed that Halley had formed 4500 million years ago from ices condensing onto grains of interstellar dust, and had then remained almost unaltered in the cold, outer regions of the Solar System. Analysis of the dust particles provided some surprises. Comets are not dirty snowballs, as previously believed, but largely dust with embedded ice. Tiny grains the size of smoke particles were much more abundant than expected, and – unlike most space dust – they were



Locations of Giotto's scientific instruments. The abbreviations are explained in the table.



Giotto's principal elements. Most of the experiments were housed on the bottom section, behind the dual bumper shield. At the very bottom is the closure mechanism that sealed the shield after the firing of the solid-propellant motor.

not stony but organic. Giotto discovered particles rich in carbon, hydrogen, oxygen and nitrogen – elements essential for life. Dust from comets could have fertilised Earth, supplying the raw materials for nucleic acids and proteins to form.

Giotto's encounter with Halley proved to be a magnificent success, providing unprecedented information on the solar system's most active but least known class of object. Although its primary mission was successfully completed, Giotto was placed in

Installation of Giotto on its Ariane launcher at Kourou. The dome cover of the third stage liquid hydrogen tank can be seen protruding through the centre of the Vehicle Equipment Bay. (CSG/CNES/Arianespace)

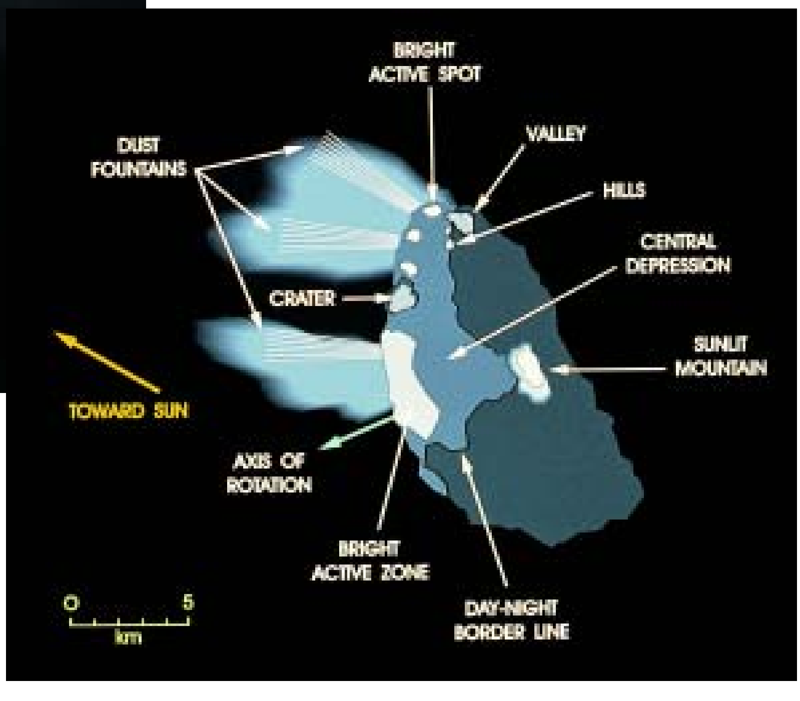
The Giotto mission begins. (CSG/CNES/Arianespace)

hibernation on 2 April 1986 in the hope that another mission could be attempted.

ESOC reactivated Giotto in 1990 after 1419 days in hibernation to assess its condition for the Giotto Extended Mission (GEM). This time, a flyby of Comet Grigg-Skjellerup complemented the Halley observations by studying a far less active comet. The camera proved to be unusable because it was blocked by its Halley-damaged baffle, but

Giotto returned more than 2000 images during its close flyby of Comet Halley. The six shown here range from #3416 375 s before closest approach to #3496 only 55 s before closest approach. (MPAE, courtesy Dr. H.U. Keller)

This composite of seven Halley images highlights details on the nucleus and the dust jets emanating from the sunlit side. (MPAE, courtesy Dr. H.U. Keller)



Principal features identified on Giotto's images of Comet Halley.

eight scientific instruments were still active. JPA detected the first cometary ions 440 000 km from the nucleus, and MAG found exciting wave phenomena not previously seen in a natural plasma. EPA saw surprising differences in the structures compared with Halley. OPE provided the first indication of entering the dust coma at 17 000 km; combined with MAG data, it showed that Giotto passed by on the dark tail side. Closest approach was about 100 km at 15:30:43 UT on 10 July 1992.

Spacecraft configuration: 1.867 m diameter, 2.848 m high, cylindrical bus (derived from Geos design). Central aluminium thrust tube supported three aluminium sandwich platforms: the top one carried the despun antenna and telecommunications equipment; the central one housed the four propellant tanks; the bottom one carried most of the experiments behind the bumper shield. Because of the 68 km/s Halley encounter speed, Giotto ventured into the coma protected by dual bumper shield capable of stopping of a 1 g particle: a 1 mm-thick aluminium alloy outer shield 23 cm in front of a 13.5 mm-thick Kevlar sandwich.

Attitude/orbit control: spin-stabilised at 15 rpm about main axis. Redundant sets of four 2 N thrusters (69 kg hydrazine loaded) provided spin control and orbit adjust. Mage 1SB solid-propellant motor provided 1.4 km/s boost from GTO into Halley intercept orbit. Mage was housed in the thrust tube, firing through a central hole in the bumper shield, which was then closed by two quadrispherical aluminium shells. Attitude reference by Earth and Sun sensors for near-Earth, then Sun and star mapper.

Power system: 5032 Si cells on the cylindrical body were sized to provide 190 W at Halley encounter, supported by four 16 Ah silver cadmium batteries for peak demands.

Communications: the 1.47 m-diameter 20 W S/X-band antenna was canted 44.3° to the spin axis to point at Earth during the Halley flyby. The 8.4 GHz X-band provided 40 kbit/s realtime data to ESOC – there was no onboard storage as Giotto might not have survived encounter. Two low-gain antennas were used for near-Earth operations.

Giotto Science Instruments

Halley Multicolour Camera (HMC)

CCD camera with f/7.68 Ritchey-Chretien telescope, 22 m resolution from 1000 km.13.5 kg, 11.5 W.
PI: H.U. Keller, MPI für Aeronomie (D)

Neutral Mass Spectrometer (NMS)

Energy/mass of neutral atomic particles: 1-36 amu, 20-2110 eV. 12.7 kg, 11.3 W.
PI: D. Krankowsky, MPI für Kernphysik (D)

Ion Mass Spectrometer (IMS)

Energy/mass of ions. 9.0 kg, 6.3 W.
PI: H. Balsiger, Univ. of Bern (CH)

Dust Mass Spectrometer (PIA)

Mass ($3x10^{-16}$-$5x10^{-10}$ g) and composition (1-110 amu) of dust particles. 9.9 kg, 9.1 W.
PI: J. Kissel, MPI für Kernphysik (D)

Dust Impact Detector (DID)

Mass spectrum of dust particles: 10^{-17}-10^{-3} g. 2.3 kg, 1.9 W.
PI: J.A.M. McDonnell, Univ of Kent (UK)

Johnstone Plasma Analyser (JPA)

Solar wind and cometary ions 10 eV-20 keV, cometary ions 100 eV-70 keV/1-40 amu. 4.7 kg, 4.4 W. PI: A. Johnstone, Mullard Space Science Laboratory (UK)

Rème Plasma Analyser (RPA)

Solar wind and cometary ions 10 eV-30 keV, cometary ions 1-200 amu. 3.2 kg, 3.4 W.
PI: H. Rème, Centre d'Etude Spatiale des Rayonnements (F)

Energetic Particles Analyser (EPA)

3-D measurements of protons (15 keV-20 MeV), electrons (15-140 keV), α-particles (140 keV-12.5 MeV). 1.0 kg, 0.7 W. PI: S. McKenna-Lawlor, St Patrick's College (IRL)

Magnetometer (MAG)

0.004-65 536 nT. 1.4 kg, 0.8 W.
PI: F.M. Neubauer, Institut für Geophysik und Meteorolgie (D)

Optical Probe Experiment (OPE)

Coma brightness in dust and gas bands.
PI: A.C. Levasseur-Regourd, Service d'Aeronomie du CNRS (F)

Radio Science (GRE)

Cometary electron content and mass fluence.
PI: P. Edenhofer, Institut für Hoch- und Höchstfrequenztechnik (D)