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Halley's Comet 1985-86: A Unique Opportunity for Space Exploration

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ABSTRACT

A coordinated program to explore Halley's comet in 1985-86 is proposed. The program employs a variety of observational systems for remote observations and utilizes spacecraft encounters with the comet to obtain in-situ measurements. Included in the observational network are ground-based observatories, the Space Telescope, a Spacelab cometary observatory, small astronomical satellites, and experiments carried on airborne observatories and sounding rockets. It is assumed that a ballistic flythrough technique will be used to carry out the spacecraft encounters. The proposed strategy calls for the simultaneous launch of two spacecraft towards an intercept with Halley in March 1986. Following the Halley encounter one spacecraft is retargeted to intercept comet Borrelly in January 1988, while the other spacecraft proceeds to an encounter with comet Tempel-2 in September 1988.

HALLEY'S COMET 1985-86: A UNIQUE OPPORTUNITY FOR SPACE EXPLORATION

"In the seventh year of Chin Shih-Huang-Ti a comet first appeared in the E., then in the N., during the fifth month it was seen in the W. for 16 days"

Record of Halley's comet
China, 240 B.C.

The return of Halley's comet in 1985-86 will attract worldwide attention from the general public as well as the scientific community. Of all the comets documented in history, Halley is by far the most interesting. It is the *only* short-period comet that exhibits the full range of cometary phenomena associated with "young" and active long-period comets. It is the *only* really bright comet with a long history of prior observations. It is also the *only* large comet whose return can be accurately predicted. The last point is particularly important for planning a mission to a comet. The upcoming apparition of Halley's comet will offer scientists a once-in-a-lifetime opportunity to obtain in-situ measurements of a big bright comet. The next return of Halley's comet will not occur until the year 2061.

Halley's comet is also noteworthy as a link with Man's past. Its close association with important historical events of Western Civilization has helped to bring about an unusual public awareness of the extraordinary nature of this comet. Ancient Chinese chronicles referring to Halley's comet have been used to identify returns as early as 240 B.C. In 66 A.D. it was seen over Jerusalem shortly before the start of the war which led to the destruction of the Holy City. In 451 it was observed in Europe about the time of the celebrated battle of Chalons, when Attila the Hun was defeated by the Roman general Aetius. Probably the most famous appearance of Halley's comet is that of 1066 because it coincided with the Norman conquest of England (see Figure 1). The apparition of 1456 caused Pope Calixtus III to order the ringing of churchbells at midday to remind all Christians "to aid by their prayers those engaged in battle with the Turk."

Figure 1 Halley's Comet in 1066 as Depicted on the Bayeux Tapestry

Halley's long history of spectacular appearances created considerable popular interest in its 1910 apparition. Unfortunately, newspaper articles containing glowing and sensational accounts of what the comet would do, and what it would look like (see Figure 2), raised expectations beyond all reason (not unlike the Kohoutek fiasco of 1973-74). Nevertheless, in spite of this handicap, the public seemed to be favorably impressed by the cometary display.

Public interest in Halley's 1985-86 apparition should be at least as great as that of 1910. It is hoped that this interest will generate the support that is needed to initiate a broad-based program to explore Halley's comet. Program planning should begin as soon as possible because the comet's arrival is now only six years away. A carefully coordinated program incorporating a wide variety of

Figure 2 A Fanciful View of Halley's Comet in 1910

observational and experimental systems will be needed to fully exploit the very-rare Halley opportunity. A proposed structure for this program is shown schematically in Figure 3.

The centerpiece of the Halley program would be spacecraft encounters with the comet to obtain in-situ data. It is assumed here that a ballistic flythrough technique will be used to execute these encounters. Flyby speeds for ballistic intercepts of Halley's comet will be about 58 km/sec. This fast encounter velocity will preclude high resolution imaging of the nuclear region and spatial resolution will be degraded somewhat for all experiments. However, it is expected that all major goals for an exploratory mission to Halley's comet can be satisfied with a ballistic intercept. Even at this high flyby speed, the spacecraft will be inside the visible coma region for over an hour and will remain within Halley's extended hydrogen atmosphere for about two days.

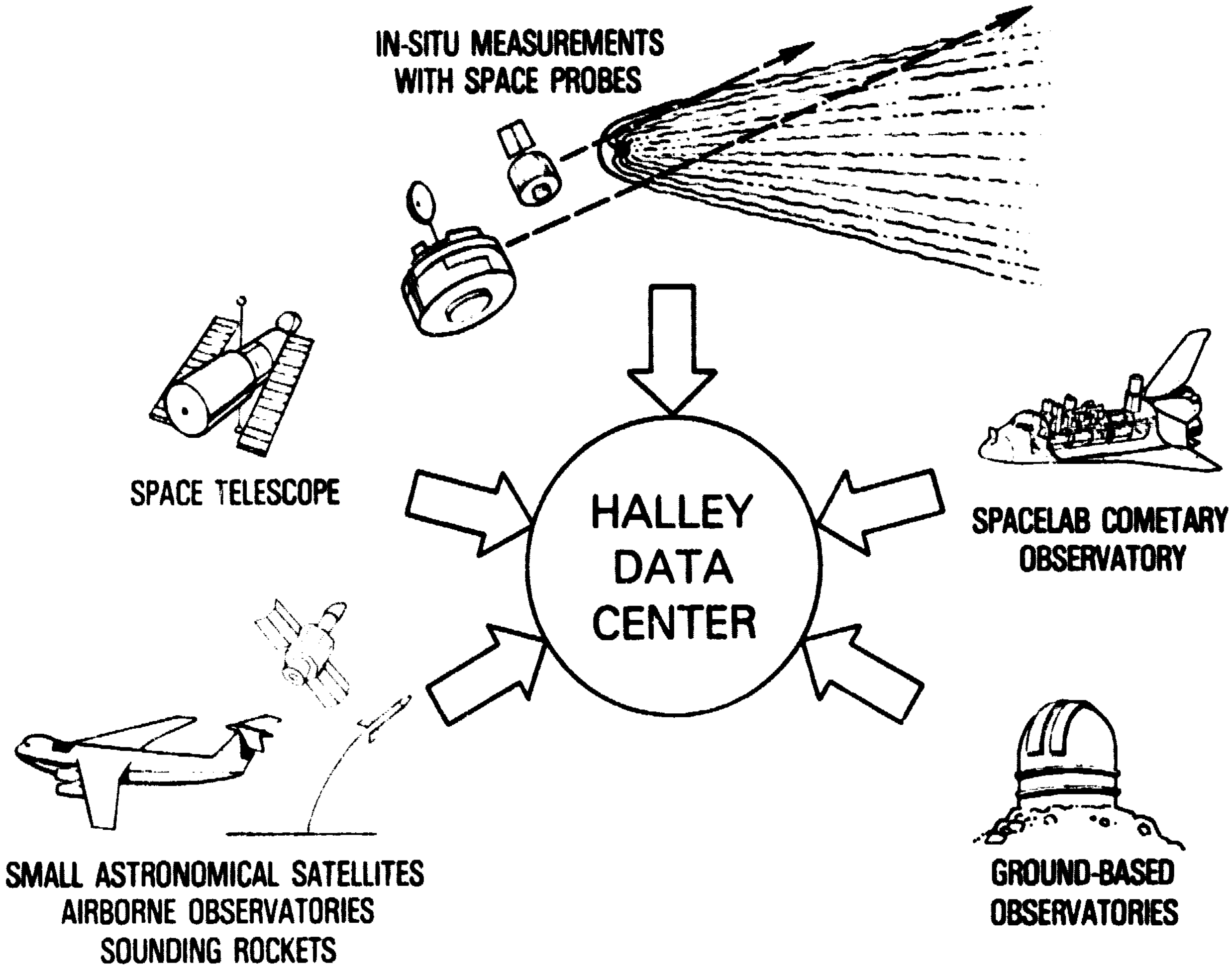

Figure 3 Key Elements of Halley Exploration Program

The main scientific objectives for a fast-flyby mission to Halley's comet are

- Imaging of the nuclear region at moderate resolution, determining the nature of the multiple nuclear condensations that have been observed in Halley's comet, attempting to confirm the postulated existence of a halo of icy grains surrounding the nuclear region, and measuring the sizes and shapes of the nuclear condensations.

- Determining the abundance and spatial distribution of the neutral molecules and radicals in the coma.

- Measuring the density, spatial distribution, and energy distribution of the charged particles in the coma and tail regions.

- Investigating the properties of the cometary plasma and magnetic field.

- Determining the nature of the solar-wind/comet interaction and finding the locations of the bow shock and the contact surface (if they exist).

- Surveying the characteristics of the dust grains, especially size distribution, spatial distribution, and composition.

- Investigating the time variation of the coma's structure, including its hydrogen halo by making spectrophotometric measurements during the cometary approach and departure phases.

A representative payload for the Halley flyby is given in Table 1. Although this list is intended to be a minimum payload, these experiments would fulfill all of the scientific objectives. With the exception of the neutral mass spectrometer, flight-proven instrumentation or slightly modified versions of current designs will be able to satisfy the mission requirements.

Table 1

Experiment Complement for Halley Flyby Mission

Instrument	Comments
Imaging system Lyman-alpha photometer	Performance optimized for moderate resolution.
Neutral-mass spectrometer Ion-mass spectrometer	Instrumentation is expected to give good performance at high flyby speeds.
Magnetometer Plasma-wave detector Electron analyzer Plasma composition	Performance of these instruments will be relatively insensitive to flyby speed.
Dust composition	Flyby speed should be greater than 10 km/sec.

The other program elements depicted in Figure 3 are concerned with remote observations. Because of the dynamic character of Halley's comet, a comprehensive program of remote observations will be needed to guarantee sufficient coverage before and after perihelion passage. It will also be necessary to obtain a large number of astrometric measurements of the comet to reduce ephemeris errors. Accurate cometary ephemerides are required for spacecraft navigation.*

*The combination of ground-based observations and onboard optical data will yield a spacecraft targeting error of less than 2000 km at the Halley encounter.

Another important task for the observational network will be to monitor physical characteristics of the comet at the same time that in-situ measurements are recorded. Photographs of the coma and tail regions should be taken at frequent intervals to track the motions of nuclear fragments and tail condensations. Spectral coverage of cometary activity in the ultraviolet and infrared can be obtained by Earth-orbiting telescopes. The remote observations will provide complementary and correlative data that will be needed for interpretation of the in-situ measurements.

Several types of instruments and observing techniques will be used in the Halley observational program. The different roles of the components of this program are briefly summarized here.

- *Ground-Based Observatories* – This will be the primary source of observations over extended periods of time. Coordination of observing schedules at a large number of observatories throughout the world will be necessary to obtain adequate coverage of the different cometary features. Ground-based observatories will also be responsible for astrometric measurements. A number of redundant sites should be available for this critical supporting function to prevent the occurrence of lengthy data gaps.

- *Spacelab* – The Spacelab system will provide an instrument platform that can take advantage of the extended wavelength coverage, superior image quality, and darkness of the night sky above the Earth's atmosphere. A possible instrument complement for cometary observations is illustrated in Figure 4. One of the principal instruments shown here is the one-meter UV-optical telescope which will provide high angular-resolution ($\sim$0.3 arc seconds) imagery over a 0.5° field of view. Large cometary features can be monitored by the Schmidt cameras which have a field of view of $\sim$11° with a 20 arc-second resolution. Although the Spacelab system is an extremely powerful tool for cometary observations, its period of operation will be limited to about two weeks per Shuttle flight.

- *Space Telescope* – The Space Telescope is able to produce images with a resolution of $\sim$0.1 arc seconds ($\sim$75 km at 1 AU), but its field of view is only 3 arc minutes ($\sim$130,000 km at 1 AU). This instrument will be very useful for observing time variations in the inner coma region, especially when coverage from the Spacelab one-meter telescope is not available. However, the total viewing time allotted for cometary observations may be rather small due to other observing priorities.

- *Small Astronomical Satellites, Airborne Observatories, and Sounding Rockets* – These systems might be able to fill in some gaps in the coverage provided by the instruments mentioned above. Again however, the total time available for cometary observations will probably not be very great.

Observing prospects for Halley can be evaluated by inspecting the orbital geometry shown in Figure 5. Although the comet will be lost in the Sun's brightness near perihelion, it will be favorably

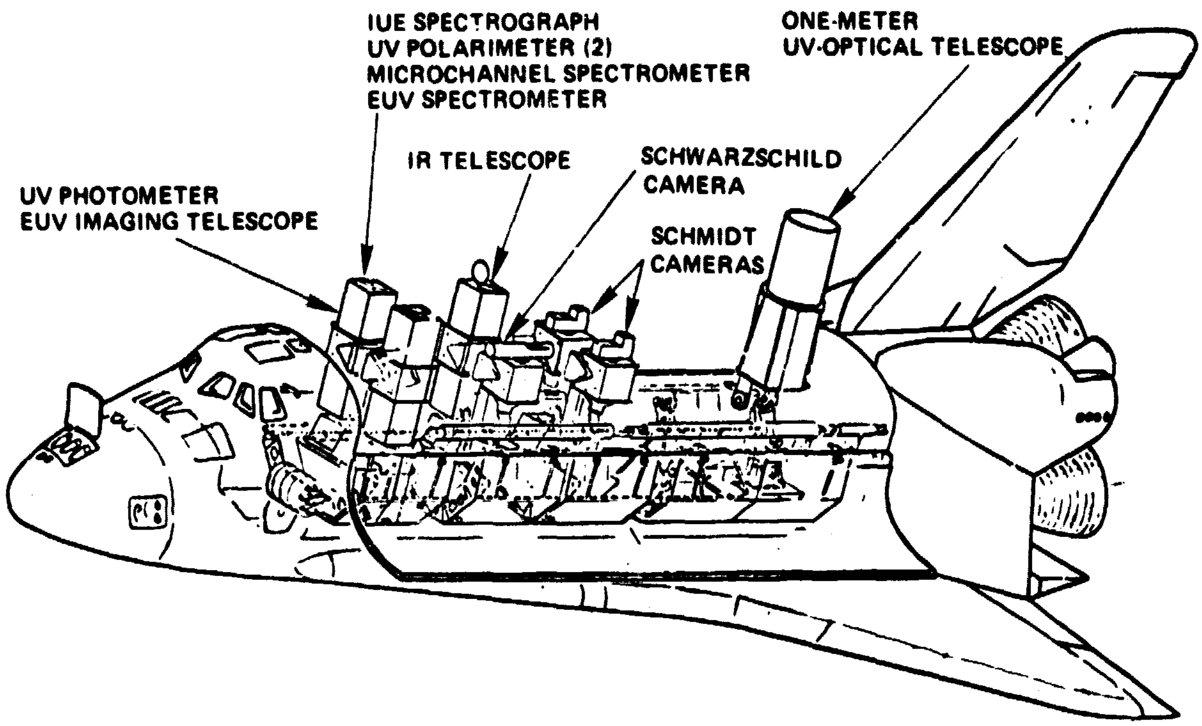

Figure 4 Spacelab Cometary Observatory

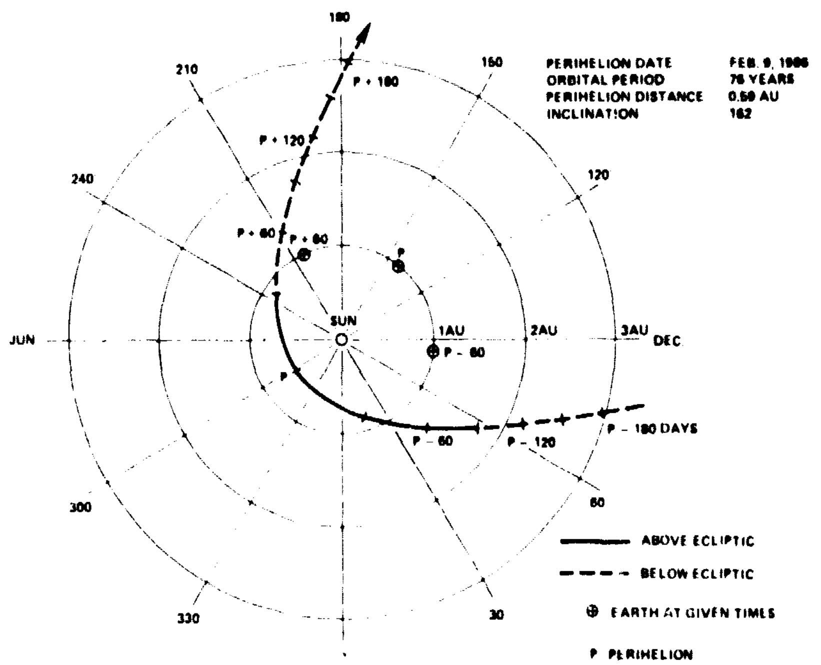

Figure 5 Orbital Geometry for Halley's Comet in 1985-86

situated for long intervals before and after perihelion. The best period for naked-eye observations should occur in the post-perihelion phase around the end of March and beginning of April in 1986. It also happens that this is a particularly good time to carry out the spacecraft encounters.

As shown in Figure 6, it is possible to place a spacecraft into a trajectory that first intercepts Halley and then returns to the Earth's vicinity one year after launch. This "boomerang" trajectory concept makes it possible to retarget the spacecraft to another comet after the Halley flyby. By using a series of Earth-swingby maneuvers, the original spacecraft trajectory can be reshaped to accomplish the second cometary encounter. Alternative maneuver sequences involving a variety of additional cometary targets have been documented in Reference 1.

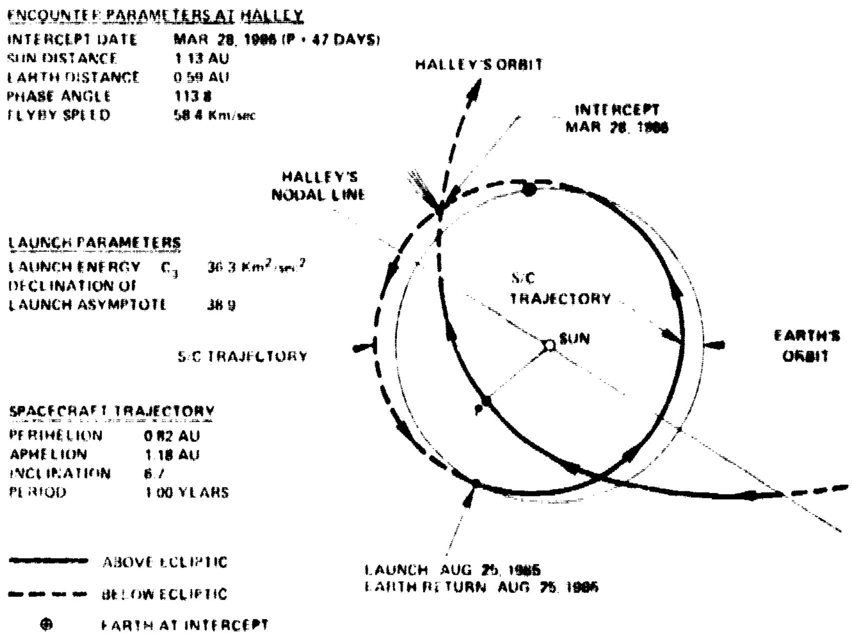

Figure 6 Halley Intercept Using Earth-Return Trajectory

A particularly attractive scenario is summarized in Table 2. This plan calls for a "piggyback" launch of two spacecraft towards a post-perihelion encounter with Halley in March 1986. One spacecraft is targeted for a close flyby of the nucleus while the other traverses the tail region (see Figure 7). Simultaneous measurements in the coma and tail regions will provide valuable data on

Table 2

Dual-Spacecraft Multi-Comet Mission Summary

- Launch Date: August 25, 1985
- Launch Vehicle: Shuttle with Interim Upper Stage
- Simultaneous Launch of Two Spacecraft
  - Spacecraft #1: Targeted for Encounters with Comets Halley and Borrelly
  - Spacecraft #2: Targeted for Encounters with Comets Halley and Tempel-2

Encounter Data	Sun Distance (AU)	Earth Distance (AU)	Flyby Speed (km/sec)
Comet Halley March 28, 1986	1.13	0.59	58.4
Comet Borrelly January 16, 1988	1.40	0.70	17.7
Comet Tempel-2 September 22, 1988	1.39	0.99	13.2

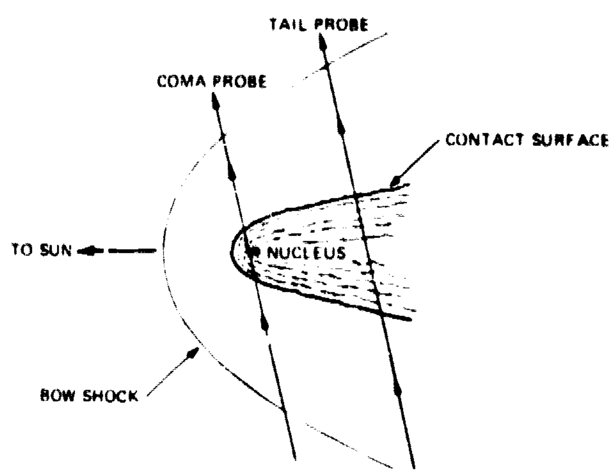

Figure 7 Dual-Probe Encounter Geometry

the large-scale features of Halley's comet. Following the Halley encounter, it is planned to use Earth-swingby maneuvers to retarget one spacecraft to comet Borrelly in January 1988, and the other to comet Tempel-2 in September 1988. The efficiency of the multi-comet profile is truly amazing. *In only three years, four separate encounters involving three different comets can be attained.**

The scientific value of investigating several comets in a single mission is especially noteworthy. Physical characteristics can vary substantially between different comets, and it will be necessary to obtain in-situ measurements from a variety of comets to fully understand cometary behavior. Because of Halley's unique status among short-period comets, a multi-comet mission that includes a Halley encounter will provide definitive scientific data for comparative studies of comets.

In addition to the desirable features discussed earlier, there are several other reasons to begin a Halley exploration program. Some of the reasons that could be cited are the following:

- *Popular Appeal* – The arrival of Halley's comet will be a major media event. Because the uniqueness of the Halley opportunity is easily understood, public support for a Halley exploration program should be enthusiastic.

- *Public Participation* – In previous space missions such as Viking, Voyager, almost everyone had to be content with being a spectator while an elite group of scientists announced their discoveries. Now, for the first time, amateur astronomers throughout the world will be able to play an active and important role in a prestigious space endeavor.

- *Potential for Cooperative Flight Projects* – The suggested Spacelab flight could accommodate a number of experiments from other nations. The possibility of some other country providing one of the spacecraft for the dual-spacecraft mission scenario should also be considered. [The European Space Agency (ESA) is currently engaged in definition studies for a cooperative Halley flyby mission (Reference 3)].

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*It is also possible to send one of the two spacecraft to Encke's comet instead of Borrelly or Tempel-2. The Encke intercept would take place in August 1987 and the flyby speed would be ~31 km/sec. Because Encke's comet is a prime candidate for a rendezvous mission in 1990 or 1994 (Reference 2), data obtained during the 1987 flyby encounter would be extremely useful in the selection and design of the science payload for a subsequent rendezvous mission.

- *Rendezvous Precursor* -- The ballistic fast-flyby mission mode is ideally suited for the initial reconnaissance of a comet. It is the simplest and least expensive way to begin a sequence of cometary missions. Without some preliminary data on the nature of a comet's nuclear region, it will be extremely difficult to design an effective science payload for a cometary rendezvous mission.

Serious efforts to implement a Halley program must begin in the near future or an exceptional opportunity for space exploration will be lost. This unfortunate consequence could have far-reaching effects as indicated by the following statement that appeared in the current NASA 5-Year Plan:

> "It would be regrettable if the agency chartered to explore the solar system had to ignore the best known and most spectacular periodic phenomenon in the solar system because of financial constraints. Our failure to undertake a comet mission that includes Halley's comet could be interpreted as a sign that the Agency, and perhaps the Nation, is backing off from the imaginative, pioneering tradition of previous generations that contributed to our Nation's progress by eagerly exploring the unknown."

REFERENCES

1. Farquhar, R. W., and Wooden, W. H., "Opportunities for Ballistic Missions to Halley's Comet," *NASA TN D-8453*, June 1977.

2. Farquhar, R. W., and Wooden, W. H., "Cometary Exploration in the Shuttle Era," *NASA TM 78033*, January 1978.

3. Delahais, M., and Dale, D., "Planning for the Next Scientific Projects," *ESA Bulletin, No. 18*, May 1979.