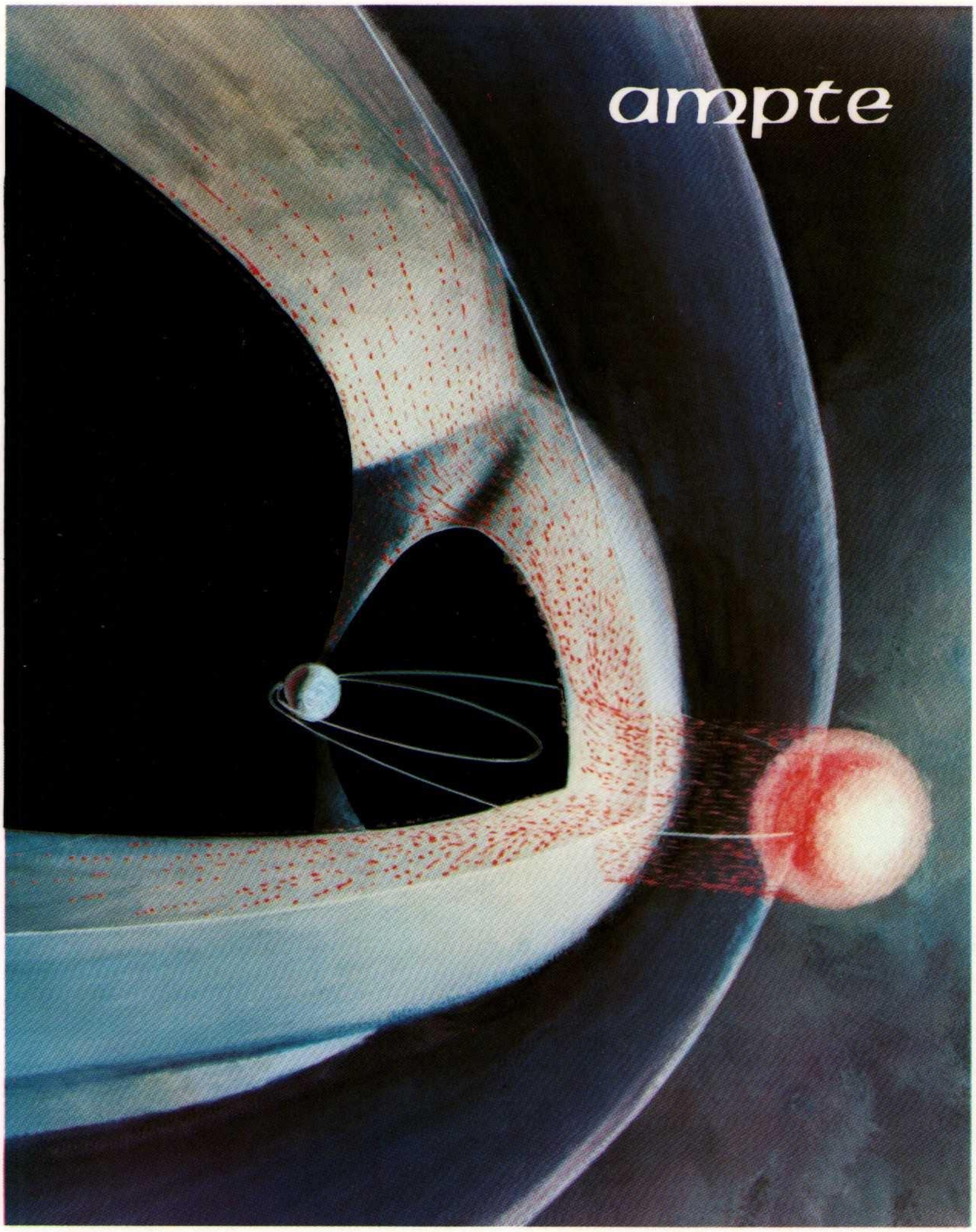
# ampte



# active magnetospheric particle tracer explorers

# ampte

AMPTE, **A**ctive **M**agnetospheric **P**article **T**racer **E**xplorers, is a three-satellite project of the United States, the Federal Republic of Germany and the United Kingdom. It uses artificial injection of rare ionic species for long-range tracing of mass transport into and through the magnetosphere system. The injection of lithium, barium and europium ions in the solar wind and magnetotail provides at the same time an excellent opportunity for studying fundamental interaction processes between two cosmical plasmas. Further aims of this mission are a systematic exploration of the highly variable mass and charge composition of the natural plasma population and a detailed investigation of the magnetospheric boundaries.

# AIMS

The AMPTE program will utilize injection of tracer ions at selected locations and times to address several issues of space plasma and magnetospheric physics. The conditions for injection will be chosen on the basis of real-time in situ measurements.

## INTERACTION

The density of the injected plasma will be high enough for short periods after the releases to initiate collective interactions with the ambient plasma. The formation and decay of a **magnetic cavity,** lasting from a few seconds (for lithium releases) to several minutes (for barium releases) will allow to simulate the plasma interactions of a comet and to study the processes by which the magnetic field diffuses into the injected plasma cloud. The development of macro- and micro-**instabilities** and the eventual **interchange of momentum** with the ambient plasma will be studied.

## ENTRY AND CIRCULATION

Although it is generally accepted that solar wind plasma enters the magnetosphere, circulates through the system, becomes energized by **magnetic pumping** and populates the radiation belts, many aspects of this process are still unknown. AMPTE will address the question of the percentage of solar wind **transmitted** through the magnetopause, and its **circulation** and **energization** inside the magnetosphere in a quantitative manner. In addition, it will provide insight into possible entry locations.

## COMPOSITION

Measurements of the naturally occurring ion population and elemental ratios in the magnetosphere will allow identification of **particle sources** and studies of the dependence of **acceleration** and **transport processes** on ion charge and mass. Detailed knowledge of elemental and charge composition in a wide energy range is fundamental for the understanding of the structure and dynamics of the ring current and the radiation belts.

## BOUNDARIES

The maintenance of boundaries between collisionfree plasmas of different temperature and density is of great interest. Particularly intriguing are the processes that give rise to the **transfer** of mass, momentum and energy, as well as to **changes of the magnetic topology.** Examples of such boundaries in the magnetosphere are the bow shock, the magnetopause and the plasma sheet boundaries.

# TOOLS

The AMPTE program consists of three spacecraft - the Ion Relase Module (IRM) provided by the Federal Republic of Germany, the United Kingdom Subsatellite (UKS), and the US/NASA Charge Composition Explorer (CCE). All three spacecraft will be launched by a Delta 3924 launch vehicle from the Kennedy Space Center in August 1984, into a $28^{\circ}$ inclined elliptical orbit with an apogee of 9.0 $R_E$ geocentric. The IRM and UKS stay together and on the second orbit are boosted to an 18.7 $R_E$ apogee by the IRM kick motor. The CCE also contains a sizable rocket motor, which is fired at apogee to reduce the CCE orbit inclination to near $0^{\circ}$ . Thus the initial operational orbits are $28^{\circ}$ elliptical with apogees in the solar wind for the IRM and UKS, and equatorial with a 9.0 $R_E$ apogee for the CCE.

**IRM** The main task of the Ion Release Module is to release substantial amounts of tracer elements in the solar wind, the magnetosheath and the magnetotail. The IRM is equipped with instruments well suited not only to study the interaction of the artificial ion clouds with the ambient medium, but also to investigate the magnetospheric boundary regions and the natural plasma composition.

**UKS** The United Kingdom Subsatellite is kept at close distance to the IRM. A complement of UKS charged particle and field instruments similar to that on the IRM will help the IRM to distinguish between spatial and temporal variations in the injected plasma clouds as well as in naturally occurring structures.

**CCE** The Charge Composition Explorer is optimally instrumented for the detection of minute (about $10^{-9}$ per cc) quantities of tracer ions in the presence of a large ambient proton population (about $10^{2}$ per cc) over a broad energy range (a few electron volts to several million electron volts). A magnetometer and plasma wave spectrometer complement the particle measurements.

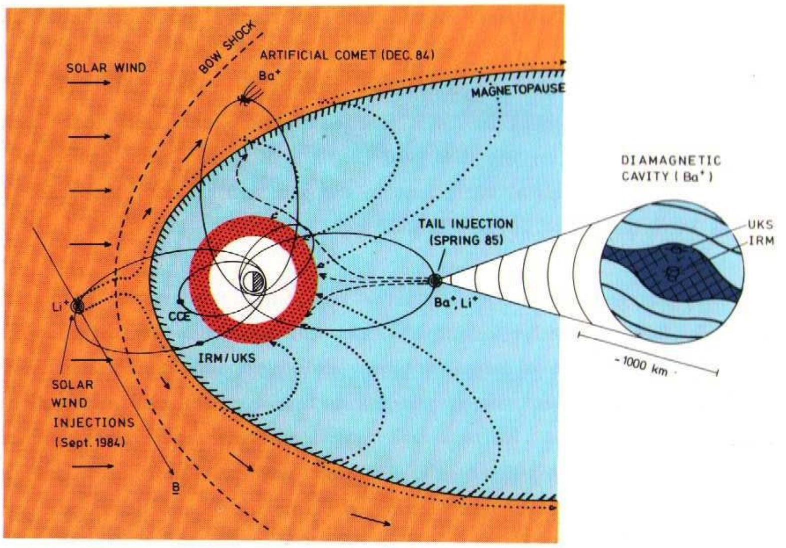
| S/C | Weight | Spin Rate | Spin Orientation | Data Coverage |
|---|---|---|---|---|
| IRM | 693 kg | 15 rpm<br>plane | perp. ecliptic | 35 - 100% |
| UKS | 74 kg | 12 rpm<br>plane | perp. ecliptic | 2x4 hours per orbit |
| CCE | 230 kg | 10 rpm<br>plane | in ecliptic | 100% |

# ORBITS AND EVENTS

## ORBITS

The orbits of the AMPTE spacecraft have been designed to meet the prime objective of tracer ion release and detection. The inital apogee is placed at 2:30 pm local time. After separation, IRM/UKS and CCE will be injected into their final orbits by firing their kick-motors. Upon achievement of the final orbit, IRM and UKS will separate from each other. The UKS carries sufficient propellant to remain within a few hundred km from the IRM.

| Final Orbits | CCE | IRM | UKS |
|---|---|---|---|
| Apogee (geocentric) | 9.0 $R_E$ | 18.7 $R_E$ | 18.7 $R_E$ |
| Perigee (height) | 550 km | 550 km | 550 km |
| Period | 16.0 hrs | 43.8 hrs | 43.8 hrs |
| Inclination | $5^{\circ}$ | $28.5^{\circ}$ | $28.5^{\circ}$ |



AMPTE sequence of events and sketch of ion transport

## TIMELINE OF RELEASES

After a period of spacecraft and instrument checkout, two lithium releases are performed around the time of equinox in the solar wind in front of the bow shock. Four months later the orbits will have precessed to local morning, at which time the artificial comet release will take place within the magnetosheath. Three to four months after the comet release, additional releases of lithium and barium are scheduled to be made in the magnetotail.

# EXPERIMENTS

## ACTIVE EXPERIMENTS

The opportunities for chemical releases are restricted by a number of constraints such as spacecraft location, "space weather" and ground visibility for the barium releases. These constraints are different for the three types of releases. The following release criteria have to be met:

### Solar Wind Release

- IRM located between 16.5-18.7 $R_E$ radial distance and 1230-1330 local time, and within 1 $R_E$ from the ecliptic.
- CCE located between 6 $R_E$ and apogee.
- Interplanetary magnetic field directed 60-80$^o$ to sun-earth line.

### "Artificial Comet" Release

- IRM located outside magnetopause and at 0530-0730 local time.
- IRM/UKS separation vector nearly aligned with magnetosheath flow, with IRM upstream.

### Magnetotail Release

- IRM located outside 10 $R_E$ at 2300 to 0100 local time, inside plasma sheet (real-time monitoring).
- CCE located between 6 $R_E$ and apogee.

Information of the "space weather" is obtained from the real time data.

## PASSIVE MEASUREMENTS

The large distance range and low inclination of the CCE orbit is ideally suited for the study of the natural ionic composition of magnetospheric particles and its response to solar wind conditions and geomagnetic activity. This study is complemented by the IRM which covers larger radial distance and higher magnetic latitudes.

Although optimized for the chemical releases, the IRM/UKS orbit is also well suited for the study of magnetospheric boundaries. For several months after injection, the satellites will cross the bow shock and magnetopause regions twice every orbit. Once the orbits have precessed to the nightside, crossings of the plasma sheet and its boundaries will follow.

# GEOSPACE

Until the satellite era, scientists assumed that the Earth's magnetic field could be reasonably approximated by a dipole model like that of a uniformly magnetized sphere. The idea that the Earth may be a great magnet dates back to William Gilbert, physician (later promoted to "electrician") to Queen Elizabeth, who published in 1600 his proclamation "Magnus magnes ipse est globus terrestrius" (the Earth itself is a great magnet). Predating the satellite era by only a few years, Biermann, from his studies of ionized comet tails, proposed in the early 1950's that the sun emits a steady "wind" of ionized gas (consisting of an equal number of electrons and positive ions - referred to today as a "plasma"). This "solar wind" is now known to play a very important role in Solar-Terrestrial processes and is also responsible for distorting the Earth's magnetic field into a comet-shaped configuration called the "magnetosphere".

The magnetosphere separates near-earth space from interplanetary space, and contains a variety of features, such as the aurorae, the Van Allen radiation belts and the ionosphere, that are controlled by the interaction of charged particles with the Earth's magnetic field. One of the most outstanding problems in magnetospheric physics is the transmission of energy and mass from the solar wind into the magnetosphere. This is a particularly difficult question, because the magnetosphere is surrounded by a "shock front" in a manner similar to that around a solid sphere immersed in a fluid moving at supersonic speed. How do the various ionic species cross this shock and how do they find their way into the magnetosphere? How are the energies of these particles increased by factors of a thousand or even a million as they make their journey? Are these solar wind particles really the source of the Van Allen radiation belts (which, if not replenished on a continuous basis, would cease to exist)? These are the questions that AMPTE will seek to answer by injecting a "dye" marker into the invisible plasma environment of the Earth.

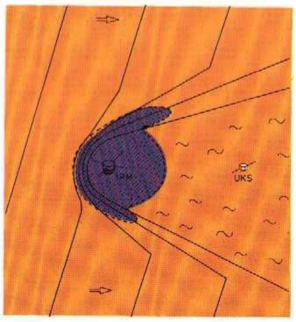
In addition to learning more about the terrestrial environment, another compelling reason to study the magnetosphere is that it is the most easily accessible cosmic plasma. AMPTE will not only study it passively as almost all previous satellites did, but will use it also as a cosmic laboratory. Thus AMPTE is a space mission dedicated to a deeper understanding of fundamental physical processes which are ubiquitous in the universe.

# INVESTIGATIONS

## INTERACTION OF TWO PLASMAS

The interaction of the injected lithium and barium ions with the plasma environment proceeds in two phases, the **diamagnetic** and **momentum coupling** phases. Because of the high dynamic pressure of the expanding ion cloud, the magnetic field becomes strongly inflated initially. A **magnetic cavity** is formed. About 90% of the quickly photo-ionized barium is contained in this cavity. For lithium with its long ionization time (~1 hour) the effect is of little importance. The lifetime of the magnetic cavity is limited to a few minutes by the joint action of several macro- and micro-instabilities. With the return of the magnetic field momentum can be transferred from the ambient to the injected plasma. **Acceleration** to the ambient flow speed, however, takes several hours for barium. Lithium ions, on the other hand, behave like single test particles picked up by the ambient flow after the short diamagnetic phase.

Typical Li and Ba injections involve $5 \cdot 10^{25}$ and $10^{25}$ atoms, respectively. The velocities of expansion are 1.0 and 4.5 km/sec (≈ 1 eV). The size of the **magnetic cavity** is determined by the pressure equilibrium with the plasma environment and this depends on the magnitude of magnetic field and ambient flow speed. Typical values are 100 km for Ba and 20 km for Li injections. These scales are of the same magnitude as the gyroradius of the injected ions. The plasma density during the diamagnetic phase ranges between $\sim 10^3$ and $10^4$ $\text{cm}^{-3}$



The **artificial comet** release which occurs outside the magnetopause on the morning flank leads to the asymmetric situation shown in the Figure. The interplanetary field becomes partially captured and substantially compressed in the "head" of the barium cloud. Inside the magnetosphere the situation is more symmetric (cf page 4).

The **momentum coupling** from the ambient flow progresses from the outskirts to the core of the cloud because of the varying mass loading of the magnetic field, i.e. the barium cloud becomes slowly **eroded.**

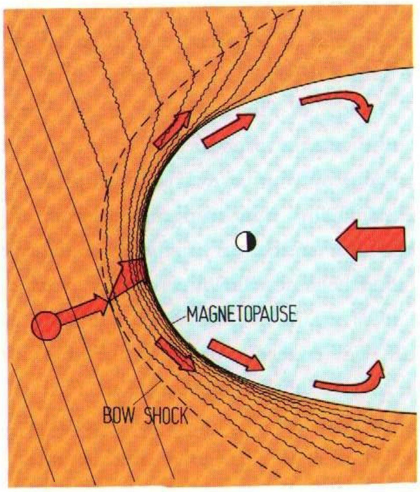
All phases of this interaction will be covered by in-situ diagnostic measurements on IRM and UKS and remote optical observations from the ground and airplanes. Of particular interest are plasma wave excitations, particle heating, the formation of small-scale irregularities (striations, rays) and the dynamical time-scales.

# INVESTIGATIONS

## ION TRACING

The prime objective of the AMPTE mission is to undertake a unique series of active ion tracer experiments in the Earth's magnetosphere and in the solar wind with the intention of subsequently detecting them with the CCE deeper inside the magnetosphere in the ring current region and radiation belts. How charged particles enter the magnetosphere, find their way through the Earth's magnetic field while being energized, and constitute the Van Allen belts is largely unknown. Furthermore, in situ observations of particles within the magnetosphere in the past have clearly indicated that considerable particle acceleration occurs in the magnetotail and the outer magnetosphere.

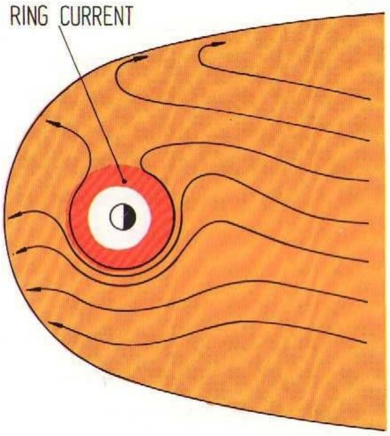
The solar wind releases will consist of lithium clouds. The Li-ions are created with essentially zero energy and will be picked up by the moving interplanetary magnetic field. They reach the bow shock in about one gyration with a speed depending on the distance of the point of ionization from the shock. The interaction of the lithium ions with the bow shock leads to a refraction, i.e. a change of the angle of the ion velocity with the shock normal, and possibly to a reflection and energization. Once in the magnetosheath, the ions are subject to turbulent electric and magnetic field fluctuations. They may spend many gyroperiods in the magnetosheath and the ion motion can become more or less coupled to the plasma flow. The coupling depends strongly on the fluctuation level and the nature of the turbulence. Once the lithium ions hit the magnetopause they can enter the magnetosphere depending on the prevailing magnetopause structure. Inside the magnetosphere, radial diffusion will bring the particles into the radiation belts where they can become energized and trapped.



Schematic of the lithium transport through the bow shock and into the magnetospere

# INVESTIGATIONS

The magnetotail releases will consist of two barium and one or two lithium clouds. The two different rare species will enable to assess the dependence of the transport efficiency and associated acceleration on mass and charge. Upon ionization the lithium ions will pick up a speed perpendicular to the field lines of the order of the ambient flow speed. In the dawn to dusk electric field the ions then drift toward the weaker field regions at the center of the plasma sheet. Rapid field-aligned acceleration can occur when the particles cross the neutral sheet so that they emerge as a field aligned beam with several hundred eV energy. On their way from the tail into the inner magnetosphere the ions are further accelerated so that the energy in the vicinity of the CCE's apogee has typical values of a few keV. Some of these ions are likely to become trapped in the radiation belts and gain energies of several hundred keV by inward radial diffusion.



Flow lines of internal magnetospheric convection. Ions seeded in the tail will follow these paths.

The slow expansion and rapid ionization of barium atoms result in the formation of compact and dense ion clouds, which will take the form of field-aligned filaments. These filaments accelerate slowly over many hours to the ambient flow speed. A small fraction of the ions may acquire initial energies up to ~ 1 keV. Thus the clouds may act as a source of keV barium ions for many hours, producing long-lived energy-dispersed streams of energetic ions near the CCE orbit.

| Type of Release | Ion Species | Expected Range of Energies | Expected Range of Fluxes, $cm^{-2}s^{-1}sr^{-1}$ | Count Rates, $s^{-1}$ | Number of Counts in 2000 s |
|---|---|---|---|---|---|
| Solar Wind | $Li^+$ | 5–100 keV | 1–200 | 0.001–0.2 | 2–400 |
| | | >100 keV | 0.1–20 | 0.001–0.2 | 2–400 |
| Tail | $Li^+$ | 4 eV–10 keV | 10–500 | 0.5–25 | $10^3$–$5 \times 10^4$ |
| Tail | $Ba^+$ | 5 eV–50 keV | 150–5000 | 10–250 | $2 \times 10^4$–$5 \times 10^5$ |

Estimated tracer ion flux at CCE.

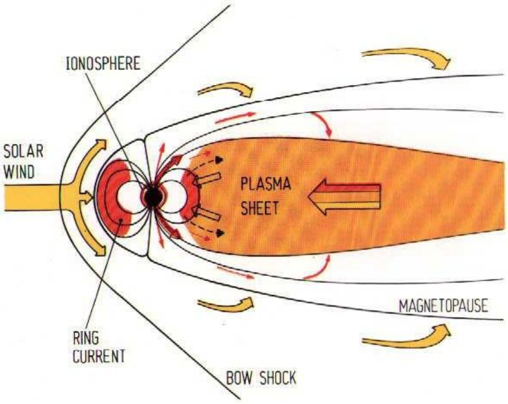
# INVESTIGATIONS

## NATURAL IONIC POPULATIONS

The study of the mass and charge composition of ionic populations and their dynamics is of great value in understanding the origin, transport, energization and loss processes associated with the hot magnetospheric plasmas.

Ionic composition provides a natural indicator of the plasma origin due to unique ionic constituents in the two major sources, the solar wind and the ionosphere. The solar wind consists primarily of $H^+$ with a few percent of $He^{2+}$ and only a minor fraction of higher mass ions, while the ionosphere mainly contains $He^+$, $O^+$, and $H^+$. Energization during the transport of the plasma to the equatorial plasma sheet and ring current strongly depends on the magnetic field as well as the ionic mass and charge. Thus the knowledge of spectral, spatial and temporal variations in the ionic populations as a function of mass and charge provides direct information on the fundamental processes involved. Deep within the magnetosphere the ionic populations are strongly influenced by loss processes. These include charge exchange with the ambient neutral exospheric hydrogen and wave particle interactions which scatter the ions into the atmosphere. Both processes are mass and charge dependent and result in dramatically different signatures in the particle populations.

The AMPTE instrumentation will for the first time provide ionic composition measurements over the entire energy range from a few eV to several MeV, including the critical energy gap in prior measurements ($\sim$30-200 keV) where the bulk of the storm time ring current particles reside. The CCE orbit will perform complete radial scans of the equatorial ring current region. Simultaneously, the IRM will provide solar wind or plasma sheet composition data depending on the actual apogee orientation of the IRM orbit.



Sources and storage regions of magnetospheric plasma.

# INVESTIGATIONS

## MAGNETOSPHERIC BOUNDARIES

Boundaries between plasmas of different temperature, density and velocity are of great interest since they are the site of intriguing plasma-physical processes allowing the transfer of mass, momentum and energy. Natural plasma boundaries occuring in and around the magnetosphere are the bow shock, the magnetopause and the poleward surfaces of the plasma sheet in the magnetotail.

At the bow shock, it is the process of dissipation of ordered, streaming energy into unordered, thermal motion which is of fundamental interest because the collisionless nature of the dilute solar wind plasma only permits dissipation from collective plasma behavior. The bow shock is also the site of particle reflection and acceleration and can serve as a prototype for shock acceleration processes invoked in the generation of high-energy particles in our universe.

The magnetopause represents the boundary between the cold, streaming solar wind, carrying along the interplanetary magnetic field, and the very dilute, hot and nearly stagnant plasma in the strong magnetic field of the earth's magnetosphere. This boundary, however, is not impermeable. Through a process by which interplanetary and terrestrial magnetic field lines open and reconnect across the magnetopause solar wind plasma as well as momentum and energy can flow into the magnetosphere. This reconnection process is thought to operate at similar plasma bounderies which are common in numerous astrophysical situations. Only the magnetosphere, however, provides the opportunity for in-situ studies of this process.

The polar boundary of the plasma sheet in the geomagnetic tail is the site of strong plasma flows and electric currents passing along magnetic field lines into the polar ionosphere, setting up the conditions for the occurrence of the spectacular displays of the aurora.

Magnetospheric boundaries are not static, so it is often difficult to tell by measurements from a single spacecraft whether repeated crossings are due to a to-and-fro movement of a boundary or whether they are the result of motion through a static boundary of complex structure. The IRM and UKS, following essentially the same orbit approximately three minutes apart, will be able to distinguish between the temporal and spatial interpretation of the observations, much the same way the ISEE-1 and -2 spacecraft have been able to do. With its improved instrumentation and analysis capabilities, the AMPTE spacecraft will be able to significantly advance our knowledge of the processes governing the magnetospheric boundaries.

# THE SPACECRAFT

## IRM

The Ion Release Module has the following objectives:

- To release lithium and barium in solar wind, magnetosheath and geomagnetic tail.
- To make in-situ measurements of the released ions and to study their interaction with the ambient, natural plasma.
- To provide high-resolution measurements of particles and fields throughout the magnetosphere and its boundaries.

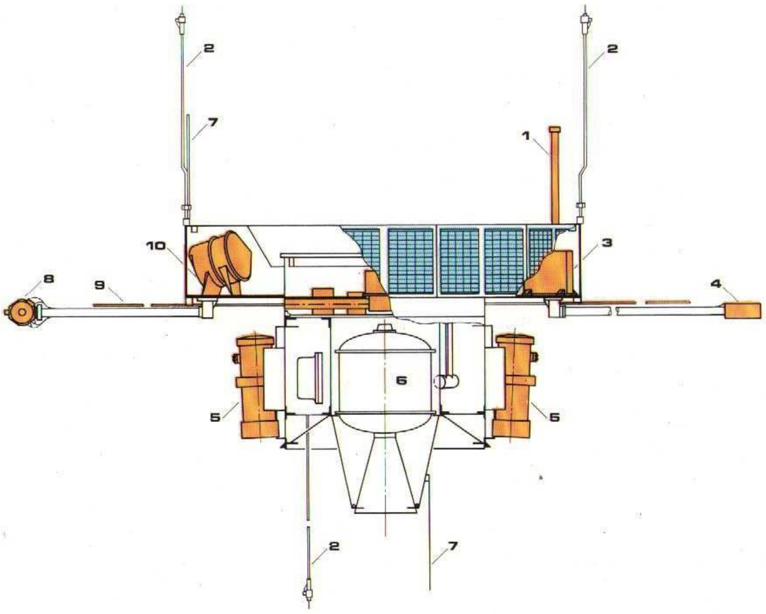
To meet the first objective, the IRM carries 16 release canisters. Of these, 8 are filled with ~ 5.8 kg each of a Li-CuO mixture, the other 8 with ~ 13.5 kg each of a Ba-CuO mixture. The canisters will be ejected pairwise from the IRM and the mixture ignited after 10 minutes. In addition, the IRM includes a full complement of scientific instruments. The 3D plasma analyzer measures ions and electrons up to 30 keV/charge with high time resolution over 4 π solid angle. The Mass Separating Ion Sensor (MSIS) measures ions up to 24 keV/charge and utilizes magnetic deflection for mass separation. The Suprathermal Energy Ionic Charge Analyzer (SULEICA) combines electrostatic deflection, time-of-flight analysis and total energy measurement to determine mass and charge of ions between 10 and ~ 300 keV. SULEICA also monitors energetic electrons. A magnetometer is mounted on a 2 m long radial boom. It measures direction and magnitude of the DC magnetic field with a sensitivity of 0.1 nT. The intensities of the electric fields associated with plasma waves in the frequency range up to ~ 5 MHz are measured with two long (42 m tip-to-tip) antennas, which are extended after launch. Two search coils supported by 1 m long axial booms measure the intensity of the magnetic wave fields in a similar frequency range.

The IRM weighs 693 kg. A solid-fuel kickstage ist fired after separation from the CCE and puts the IRM/UKS stack into their proper orbit. In orbit the IRM is spin-stabilized at 15 rpm. The spacecraft attitude is controlled by magnetic torquing in regions of strong geomagnetic field. Solar cells mounted around the body together with rechargeable batteries will provide the electrical power needed to operate the spacecraft. Commands from and data to the ground are transmitted via short S-band antennas.

The IRM spacecraft is being built and integrated at MPE. G. Haerendel is the German principal investigator for AMPTE and has overall responsibility for the IRM/UKS activities.

# ION RELEASE MODULE

1 Search Coil Magnetometer
2 Telemetry Antenna
3 Supra Thermal Particle Detector
4 DC Magnetometer
5 Ba and Li Canisters
6 Kick Motor
7 Ranging Antenna
8 3D Plasma Analyzer
9 E-Field Antenna
10 Mass Spectrometer



## AMPTE IRM INSTRUMENTATION

(SPACECRAFT BIT RATE IS 2, 4 OR 8 kbps)

| INSTRUMENT | COVERAGE | MEASUREMENT TECHNIQUE | INVESTIGATOR TEAM | |
|---|---|---|---|---|
| 3-D PLASMA ANALYZER (IONS AND ELECTRONS) | ~ 0 eV – 25 eV<br>15 eV – 30 keV | RETARDING POTENTIAL ANALYZER; SYMMETRICAL QUADRISPHERES (2) | G. PASCHMANN (L.I.)<br>N. SCHOPKE<br>W. BAUMJOHANN<br>C. CARLSON | MPE<br>MPE<br>MPE<br>UCB |
| MASS SEPARATING ION SENSOR | 0.01 – 12 keV/q | QUADRISPHERICAL E/q ANALYSIS, MAGNETIC ANALYSIS | H. ROSENBAUER (L.I.)<br>H. GRÜNWALDT<br>H. GOLDSTEIN<br>M. WITTE | MPAE<br>MPAE<br>MPAE<br>MPAE |
| SUPRATHERMAL ENERGY IONIC CHARGE ANALYZER (SULEICA) | 10 – 300 keV/q | ELECTROSTATIC ANALYZER, TIME-OF-FLIGHT AND TOTAL E | D. HOVESTADT (L.I.)<br>E. MÖBIUS<br>M. SCHOLER<br>B. KLECKER<br>F. IPAVICH<br>G. GLOECKLER | MPE<br>MPE<br>MPE<br>MPE<br>U.MD.<br>U.MD. |
| MAGNETOMETER | DC – 50 Hz | VECTOR FLUXGATE | H. LÜHR (L.I.)<br>N. KLÖCKER<br>B. HÄUSLER<br>M. ACUNA | TUB<br>TUB<br>MPE<br>GSFC |
| PLASMA WAVE SPECTROMETER | E: DC – 5 MHz<br>B: 30 Hz – 1 MHz | 42 m. (T to T) ANTENNA<br>BOOM-MOUNTED SEARCH COILS (2) | B. HÄUSLER (L.I.)<br>R. TREUMANN<br>D. GURNETT<br>R. ANDERSON<br>R. HOLZWORTH<br>H. KOONS | MPE<br>MPE<br>U. OF I.<br>U. OF I.<br>U. WASH.<br>AEROSP |
| Li/Ba – RELEASE EXPERIMENTS | 8 Li RELEASE CANISTERS (52 kg)<br>8 Ba RELEASE CANISTERS (108 kg) | CuO THERMITE REACTION | A. VALENZUELA (L.I.)<br>H. FÖPPL<br>E. RIEGER<br>G. HAERENDEL<br>O. BAUER | MPE<br>MPE<br>MPE<br>MPE<br>MPE |

## UKS

The UKS is injected as a subsatellite into the same final orbit as the IRM. Its purpose is:

- To contribute to the knowledge of the original plasma conditions into which ion releases are made.
- To examine plasma phenomena initiated by the releases at a point away from the centre of release.
- To help distinguishing between spatial structures encountered along the common trajectory and temporal changes engulfing both spacecraft simultaneously.

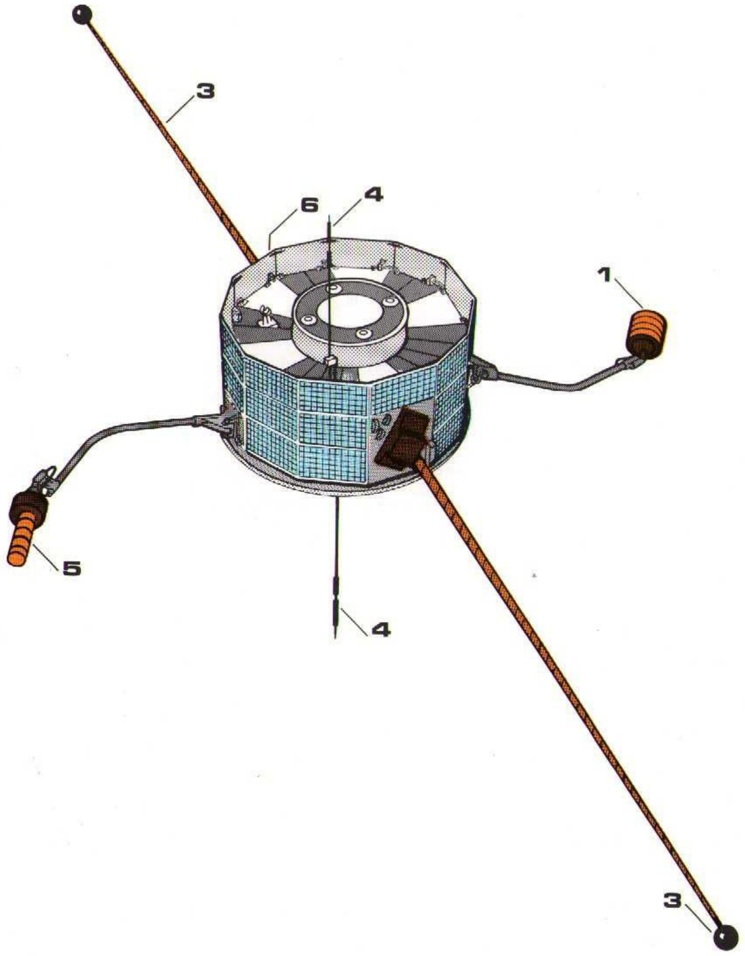
The UKS carries a comprehensive set of plasma measuring instruments. Electron and ion sensors employing hemispherical electrostatic analyzers and channel plate detectors measure three-dimensional distributions with high time and angular resolution. A modulation analyzer computes autocorrelation functions and fast Fourier transforms of the electron and ion modulations resulting from wave-particle interactions. The magnetometer is deployed on a rigid 1 m long boom. The wave experiment utilizes a pair of deployable booms to give 7 m tip-to-tip separation for the electric field sensors and a second 1 m rigid boom for the cored coil of the magnetic sensor.

The UKS weighs 74 kg. A cold gas (nitrogen) propulsion system provides attitude and spin control capability and the ability to adjust the separation distance between the UKS and IRM. This will be maintainted at ~100 km early in the mission but may be increased to ~ 6000 km after the plasma sheet releases. IRM-UKS separation will be gauged using an on-board radar transceiver and active transponder on the IRM. Electrical power is generated by a fixed array of solar cells providing 36 Watts at beginning of life. A battery stores sufficient electrical energy to permit 4-hour periods of operation with all experiments running. The command system provides for real-time and deferred commands. Data handling is performed by fixed and variable-format encoders working into an S-band telemetry transmitter.

The UKS is being produced as a collaborative effort between the Rutherford Appleton Laboratory of the UK Science and Engineering Research Council and the Mullard Space Science Laboratory of the University College London.

## UNITED KINGDOM SUBSATELLITE

| | |
|---|---|
| 1 | DC Magnetometer |
| 2 | 3D Electron Analyzer |
| 3 | E-Field Sensor |
| 4 | Telemetry Antenna |
| 5 | Search Coil Magnetometer |
| 6 | 3D Ion Analyzer |



### IRM UK SUBSATELLITE INSTRUMENTATION

(SUBSATELLITE BIT RATE IS 8–32 kbps)

| INSTRUMENT | COVERAGE | MEASUREMENT TECHNIQUE | INVESTIGATOR TEAM* | |
|---|---|---|---|---|
| 3-D ION ANALYZER | 10 eV/q – 20 keV/q | ELECTROSTATIC ANALYZER | A. JOHNSTONE | MSSL |
| 3-D ELECTRON ANALYZER | 25 eV – 25 keV | ELECTROSTATIC ANALYZER | D. HALL<br>C. CHALONER | RAL<br>RAL |
| PARTICLE MODULATION ANALYZER | ~1 Hz – ~1 MHz | ELECTRON & ION SIGNAL PROCESSING | M. GOUGH | U. SUSSEX |
| MAGNETOMETER | DC – 10 Hz | VECTOR FLUXGATE | D. SOUTHWOOD<br>S. COWLEY<br>C. RUSSELL | ICST<br>ICST<br>UCLA |
| PLASMA WAVES SPECTROMETER | E: 30 Hz – 132 kHz<br>4 SPOT FREQ. TO 2 MHz | 7 m TIP-TO-TIP PROBE | L. WOOLLISCROFT<br>P. CHRISTIANSEN<br>M. GOUGH | SHEFFIELD<br>U. SUSSEX<br>U. SUSSEX |
| | B: 30 Hz – 50 kHz | BOOM-MOUNTED SEARCH COIL | D. JONES | BAS |

*D.A. BRYANT IS LEAD INVESTIGATOR FOR THE UKS SCIENCE PAYLOAD

## CCE

The Charge Composition Explorer has two primary experimental objectives:

- To monitor the access, energization and transport of the artificially injected tracer ions from the AMPTE solar wind and magnetotail releases.
- To measure the detailed composition of the natural magnetospheric particle populations, and to study the spectral, spatial and temporal variations of these populations as a function of species and magnetospheric activity.

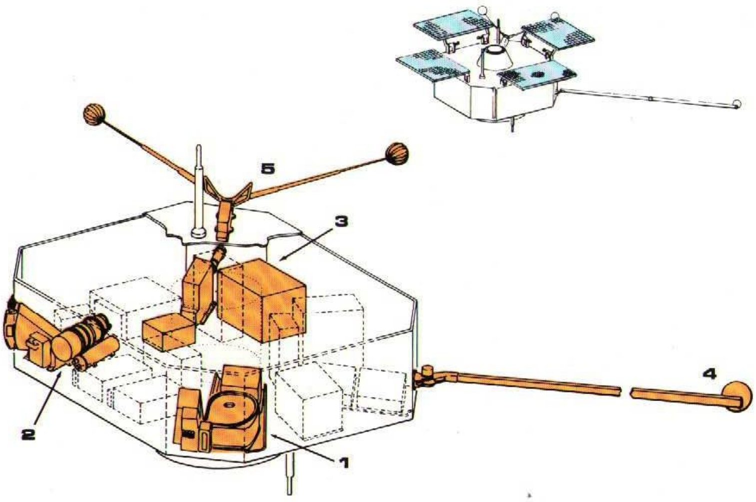
To meet these objectives Ion composition and pitch-angle distributions for both common and rare species will be measured from thermal energies up to many MeV by the Hot Plasma Composition Spectrometer (HPC), the Charge Energy Mass Spectrometer (CHEM) and the Medium-Energy Particle Analyzer (MEPA). The HPC measures ion energy/charge and mass/charge from a few eV up to 17 keV/charge. In the CHEM, after traversing an electrostatic analyzer, ions are accelerated through a 30 kV potential drop into a time-of-flight and total energy particle telescope covering the crucial ring current energy range from 1 to 300 keV/charge with both mass and charge state resolution. MEPA contains a time-of-flight and total energy telescope that covers energies from ~ 10 keV/nucleon up to many MeV, with multiple measurements of each particle's time-of-flight to reject accidental events. The magnetometer, on a 2.4 m boom, provides the ambient steady magnetic field and wave measurements for correlations with the observed particle dynamics.

The CCE weighs 230 kg, including a 46 kg kick rocket. In orbit it is spin-stabilized at 10 rpm, with the spin vector maintained in the equatorial plane and a $22^{\circ}$ offset from the Earth-Sun line by both magnetic torquing and a cold gas thruster system. The spacecraft has a tape recorder to provide 100% data coverage at an average real-time data rate of 3.3 kbps. Solar cells mounted on four panels in the spin plane of the spacecraft provide the electrical system with the necessary power.

The CCE is being built and integrated by the Applied Physics Laboratory of The Johns Hopkins University (APL/JHU), and is managed by NASA/GSFC. S.M. Krimigis (APL/JHU), the US principal investigator for AMPTE, has overall responsibility for the CCE activities.

# CHARGE COMPOSITION EXPLORER

1 Hot Plasma Composition Spectrometer
2 Charge Energy Mass Spectrometer
3 Medium Energy Particle Analyzer
4 Magnetometer
5 Plasma Wave Spectrometer



## AMPTE CCE INSTRUMENTATION

(SPACECRAFT BIT RATE IS 3.3 kbps)

| INSTRUMENT | COVERAGE | MEASUREMENT TECHNIQUE | INVESTIGATOR TEAM | |
|---|---|---|---|---|
| HOT PLASMA COMPOSITION SPECTROMETER | ION COMPOSITION<br>0 eV/q–17 keV/q | RETARDING POTENTIAL, ELECTROSTATIC ANALYZER, ExB ANALYZER | E. SHELLEY (L.I.)<br>R. SHARP, R. JOHNSON, W. PETERSON | LPARL<br>LPARL |
| | ELECTRONS<br>50 eV – 25 keV | MAGNETIC ANALYZERS | J. GEISS, P. EBERHARDT, H. BALSIGER, A. GHIELMETTI | U. BERN |
| | | | D. YOUNG | LASL |
| | | | G. HAERENDEL | MPE |
| | | | H. ROSENBAUER | MPAE |
| CHARGE ENERGY MASS SPECTROMETER | ION COMPOSITION<br>~ 1 keV/q–300 keV/q | ELECTROSTATIC ANALYZER, TIME-OF-FLIGHT AND TOTAL E | G. GLOECKLER (L.I.),<br>F. IPAVICH, D. HAMILTON | U.MD.<br>U.MD. |
| | | | B. WILKEN, W. STÜDEMANN, G. KREMSER | MPAE |
| | | | D. HOVESTADT | MPE |
| MEDIUM ENERGY PARTICLE ANALYZER | ION COMPOSITION<br>10 keV/nucleon – ≳1.0 MeV/nucleon | TIME-OF-FLIGHT AND TOTAL E | R. McENTIRE (L.I.)<br>S. KRIMIGIS, A.T.Y. LUI | APL/JHU<br>APL/JHU |
| MAGNETOMETER | DC – 50 Hz | VECTOR FLUXGATE | T. POTEMRA (L.I.)<br>M. ACUNA | APL/JHU<br>GSFC |
| PLASMA WAVE SPECTROMETER | AC E FIELDS<br>5 Hz - 178 kHz | ELECTRIC DIPOLE | F. SCARF (L.I.) | TRW |

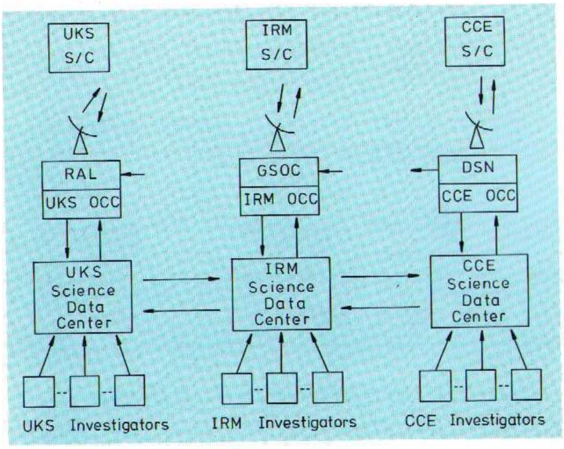
# DATA SYSTEM

## CONTROL AND DATA SYSTEMS

The complement of scientific instruments in the three AMPTE spacecraft is dedicated towards making **unified** rather than independent measurements. This is necessary to achieve as complete as possible an understanding of the scientific problems to be studied, from the local phenomena associated with the ion injection to the large-scale processes of transport and energization of the particles. In order to realize these objectives a coordinated and interactive data processing approach has been implemented for AMPTE.

The data from the three spacecraft will be received by ground stations of the Deep Space Network, the German Space Operations Center and the Rutherford Appleton Laboratories. From these stations the data are transmitted to the respective Operations Control Centers and Science Data Centers for each spacecraft, either in real time or via magnetic tape. The Operation Control Centers (OCC's) monitor the health of each spacecraft and send the commands to assure their proper operational status and to carry out the releases.

The Science Data Centers process the raw information from the instruments, spacecraft and that provided by the OCC's, into physical parameters suitable for scientific studies. A large amount of data storage capacity is available at these facilities. In addition, the Science Data Centers provide dedicated, interactive computational and data analysis capabilities which are available to investigators in each country via remote computer terminals and high-speed data lines. Investigators and Science Data Centers, in turn, can compare selected data sets and results with their counterparts at the other locations.



# OPTICAL PHENOMENA

**Artificial Comet** (Dec/Jan 1984/85)

| | |
|---|---|
| Total mass of Ba vapour | 2 kg = $10^{25}$ atoms |
| Initial max. diameter | 160 km = 5 arc min |
| Time of initial expansion | 80 sec |
| Max. visual magnitudes: | |
| Ba I (5535 A) | + 3.0 |
| Ba II(4934, 4554 A) | + 2.5 |
| Max. surface brightness of Ba II | 25 kR |
| Duration of visual phenomenon | 10 min |
| Observability by low-light-level TV | 40 - 60 min |
| Motion of Ba plasma cloud | 400 000 km or<br>$90^{\circ}$ during 1 hour |
| Maximum apparent length of tail | $5^{\circ}$ |

**Li Clouds in the Magnetotail** (March/April 1985)

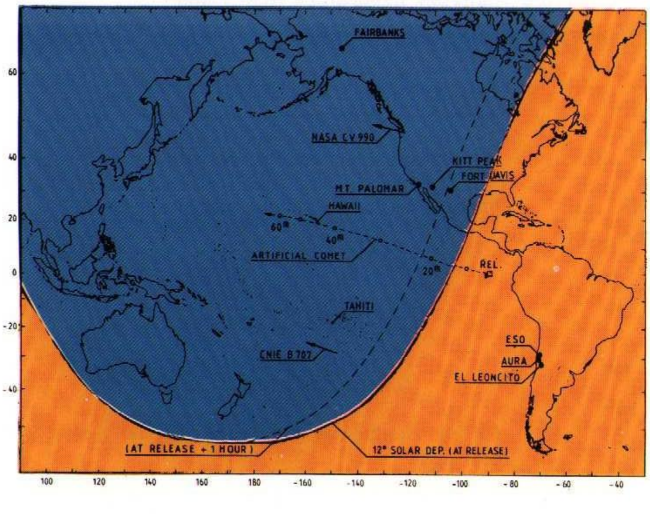
| | |
|---|---|
| Total mass of Li vapour | 0.5 kg = $5 \cdot 10^{25}$ atoms |
| Velocity of expansion | 4.5 km/sec = 8'/min |
| Visual magnitude: | |
| Li I (6708 A) | + 2.0 |
| Li II | not visible |

**Eu-Tracer of the Tail Li-Clouds:**

| | |
|---|---|
| Total mass of Eu vapour | 100 g = $4 \cdot 10^{23}$ atoms |
| Effective width of Eu$^{+}$ cloud ( B) | 30 km = 1' |
| Initial brightness (after 1 min): | |
| Eu I (4662, 4627, 4594 A) | 60 kR |
| Eu II (4436, 4205, 4129 A) | 1 kR |

**Ba-Clouds in Magnetotail** (March/April 1985)

Similar to artificial comet



Main observing stations, ground track of Artificial Comet and illumination.

# PROJECT DEVELOPMENT

## HISTORY OF AMPTE

| | |
|---|---|
| 1961 | Biermann et al. propose "Artificial Comet" |
| 1964 | First barium cloud over Sahara produced by MPE |
| 1969 | Barium release from HEOS I in outer magnetosphere |
| 1972 | Krimigis and Haerendel propose AMPTE to NASA |
| 1974 | Proposal to BMFT |
| 1975 | Mission definition study (Scout class) |
| 1977 | Selected for new start in Explorer Program (two Scout launches) |
| 1980 | Beginning of S/C development based on Thor Delta launch. Addition of UKS. |
| 1982 | Critical design reviews |
| 1984 | August 9: Opening of launch window |

## SPONSORING COUNTRIES and AGENCIES

CCE: USA, NASA-OSSR
IRM: Federal Republic of Germany, BMFT
UKS: United Kingdom, SERC

## SPACECRAFT CONTRACTORS

CCE: Applied Physics Laboratory, The Johns Hopkins Univ. (APL)
IRM: Max-Planck-Institut für extraterrestrische Physik (MPE)
UKS: Rutherford Appleton Laboratory (RAL) and
Mullard Space Science Laboratory (MSSL)

# PERSONNEL

## KEY PERSONNEL

### U.S. AMPTE PROGRAM

| | |
|---|---|
| Program Scientist | J. T. Lynch, NASA-HQ |
| Program Manager | M. B. Weinreb, NASA-HQ |
| Project Scientist | M. H. Acuna, GSFC |
| Project Manager | G. W. Ousley, GSFC |
| Principal Investigator | S. M. Krimigis, JHU/APL |
| Project Scientist | R. W. McEntire, JHU/APL |
| Spacecraft Manager | J. Dassoulas, JHU/APL |

### GERMAN AMPTE PROGRAM

| | |
|---|---|
| Program Manager | M. Otterbein, BMFT |
| Project Coordinator | D. U. Joneleit, DFVLR |
| Principal Investigator | G. Haerendel, MPE |
| Project Scientist | G. Paschmann, MPE |
| Spacecraft Manager | B. Häusler, MPE |

### UK AMPTE PROGRAM

| | |
|---|---|
| Program Manager | A. H. Gabriel, RAL |
| Project Director | J. T. Houghton, RAL |
| Project Manager | A. K. Ward, RAL |
| Project Scientist | D. A. Bryant, RAL |
| Spacecraft Manager | T. Patrick, MSSL |

## USEFUL ADDRESSES

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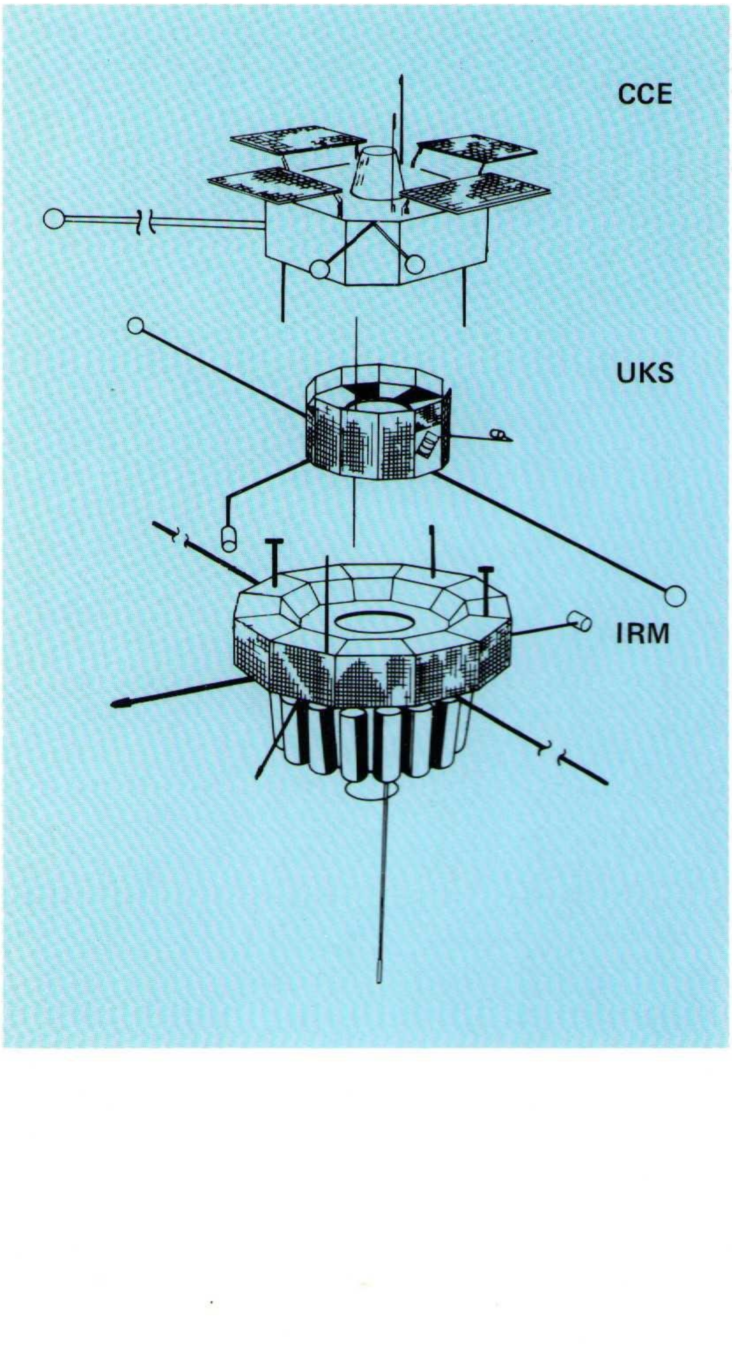
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UKS
IRM