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THE ACTIVE MAGNETOSPHERIC PARTICLE TRACER EXPLORERS PROGRAM

The Active Magnetospheric Particle Tracer Explorers (AMPTE) mission will release and monitor tracer ions (lithium and barium) in the solar wind and within the distant magnetosphere in order to study access of solar wind ions to the magnetosphere and the processes that transport and accelerate magnetospheric particles. In addition, a single massive release of barium in the dawn magnetosheath will create a visible artificial comet in the flowing solar wind plasma within which studies of a number of different plasma effects will be made. The AMPTE will also obtain comprehensive measurements of the elemental composition and dynamics of the natural magnetospheric particle populations.

INTRODUCTION AND BACKGROUND

The magnetosphere is that large volume of space around the earth dominated by the earth's magnetic field. The hot solar wind plasma flowing outward from the sun is diverted around this obstacle at the magnetopause (the magnetohydrodynamic boundary between the earth's field and the solar wind), and distinctly separate plasma populations and processes characterize the space environment inward of that surface. Ever since the discovery of the intense Van Allen radiation belts around the earth, there has been great interest in the physics of magnetospheric plasma populations—including their sources, their interactions with the solar wind and the rotating earth, and the processes that accelerate particles to high energy. The solar wind was early thought to be a possible source,¹⁻³ and Nakada *et al.*⁴ proposed that the region of access was the magnetospheric boundary, with subsequent inward diffusion and energization. The limited data available in the mid-60's were thought to support this hypothesis, and the diffusion-convection model has so far provided the main theoretical framework for explaining particle energization in the near-earth magnetosphere.

Nevertheless, increasing appreciation of the complexity of the magnetospheric system has resulted in a continuing search for ways of identifying the sources of magnetospheric plasma and of testing particle acceleration and transport models. The discovery that a significant component of the near-earth hot magnetospheric plasma was of ionospheric origin⁵ further complicated the situation. Spacecraft measurements of geomagnetically trapped alpha particles and

medium nuclei (carbon, nitrogen, and oxygen ions)^{6,7} did not resolve the source question, because the observed proton-to-helium and helium-to-medium energetic particle ratios were dissimilar to ratios in either solar wind or ionospheric source plasmas. This fact, however, led to the recognition that source elemental abundances are subject to modification by transport and energization processes within the magnetosphere. Extensive plasma composition studies over the last decade have revealed that the relative contributions of the ionospheric and solar wind sources are extremely variable and that either can dominate at any given time.^{8,9} Because of the complexity of the natural system, injection of artificial "tracer" ions at a known location and time offers a promising tool for attacking the issues of plasma entry, acceleration, transport, and loss within the magnetosphere.

In June 1971, one of us (SMK) wrote to NASA Headquarters suggesting the idea of a tracer ion release in the solar wind, combined with an appropriately instrumented spacecraft inside the magnetosphere to detect the released ions as they were transported through the system. A feasibility study was undertaken by APL and the Max Planck Institute for Extraterrestrial Physics, with support from NASA and the Bundesministerium für Forschung und Technologie. The AMPTE project was selected for inclusion in the NASA Explorer program in 1977 and, after an extended mission definition study, the hardware phase began in 1981. The program has two primary spacecraft—the Ion Release Module (IRM) and the Charge Composition Explorer (CCE), which will be launched into elliptical orbits of apogee 18.7 and

9.0 earth radii, respectively. A supporting instrumented spacecraft, the United Kingdom Subsatellite (UKS), positioned a few hundred kilometers from the IRM, will provide two-point *in situ* plasma diagnostic measurements. All three spacecraft are currently scheduled for launch on a Delta 3924 vehicle from the Kennedy Space Center in early August 1984. AMPTE represents a unique international collaborative effort—it is the first program in which three nations have each provided a spacecraft to carry out a coordinated scientific mission.

AMPTE – Active Magnetospheric Particle Tracer Explorers
CCE – Charge Composition Explorer built by The Johns Hopkins University Applied Physics Laboratory
IRM – Ion Release Module built by the Max Planck Institute for Extraterrestrial Physics
UKS – United Kingdom Subsatellite built by the Rutherford Appleton Laboratory and Mullard Space Science Laboratory

SCIENTIFIC RATIONALE AND OBJECTIVES

The broad scientific objectives of the AMPTE program may be summarized as follows:

1. To investigate the transfer of mass from the solar wind to the magnetosphere and its further transport and acceleration within the magnetosphere;
2. To study the interaction between artificially injected and natural space plasmas;
3. To establish the elemental and charge composition and dynamics of the charged-particle population in the magnetosphere over a broad energy range (a few electron volts to a few megaelectronvolts);
4. To explore further the structure and dynamics of ambient plasmas in the magnetosphere, particularly in the boundary regions.

Objectives 1 and 2, the principal scientific objectives of the program, are to be carried out by actively releasing tracer elements (lithium and barium) into the solar wind, into the magnetosheath, and into the distant magnetotail, and by detecting and monitoring the resulting tracer ions at both the point of release and much closer to the earth within the magnetosphere. These measurements will provide information on the access of solar wind ions to the magnetosphere, the mechanisms and points of entry into the magnetosphere, the degree of energization and loss of solar wind particles, and convective motions within the magnetotail. Although the tracer ions will act as individual test particles, the density will be high enough for short periods after releases to initiate col-

lective interactions with the ambient plasma. Specifically, the barium release in the magnetosheath (and to a lesser extent, the releases in the magnetotail) will create an artificial comet. The formation and evolution of the diamagnetic “coma,” or head, of our artificial comet and the erosion of plasma to form a comet “tail” will be monitored at the point of release by the IRM and UKS instrumentation, and remotely by ground optical observations. An artist’s concept of the releases is shown in Fig. 1.

The measurement of the detailed elemental and charge composition of the naturally occurring energetic particles (~ 0.05 kiloelectronvolt (keV) per charge to ≥ 6 megaelectronvolts (MeV)) within the magnetosphere makes possible the study of the dependence of ion acceleration and transport processes on the ion nuclear mass and charge.¹⁰ An immediate and important by-product of such measurements will be the determination of the heretofore unmeasured¹¹ ion composition of the quiet and storm-time ring current distributions at energies greater than 30 keV. In addition, measurements of the naturally occurring tracer elements and element ratios in the magnetosphere ($^2\text{H}/^1\text{H}$, C/O, $^4\text{He}/^{20}\text{Ne}$, etc.) will allow sources of radiation-belt particles to be inferred.

Selection of an element as a plasma tracer involves a variety of both physical and practical considerations. For example, the seeded element should be rare in the natural environment in order to be distinguishable. It must have a sufficiently large charge-to-mass ratio to maximize the diffusion coefficient.¹² It must have a time scale for photoionization long enough to allow the neutral gas to expand over a substantial volume of space before ionization occurs, so that perturbation of the local medium via a diamagnetic cavity can be kept small, yet short enough for plasma to be injected at reasonable densities. The element must have a sufficiently low evaporation temperature for it to be readily vaporized by standard chemical methods. These considerations led to the selection of the element lithium, with a photoionization time constant of about 1 hour.

On the other hand, the criteria for interaction studies between an injected and a natural plasma differ in some important aspects from those established for tracer element releases. Where an artificial comet or an extensive diamagnetic cavity is the objective, it is necessary to have a short ionization time constant. The element most suitable for this aspect of the science objectives is barium, with a photoionization time constant of 28 seconds.

Thus, the elements selected for the AMPTE releases are lithium and barium, the former for use as a tracer in the solar wind and magnetotail releases and the latter for use both in the creation of the artificial comet and in magnetotail plasma interaction and tracer releases.

EXPERIMENT CONCEPT

The experiment concept of AMPTE is illustrated schematically in Fig. 1, to scale with the nominal

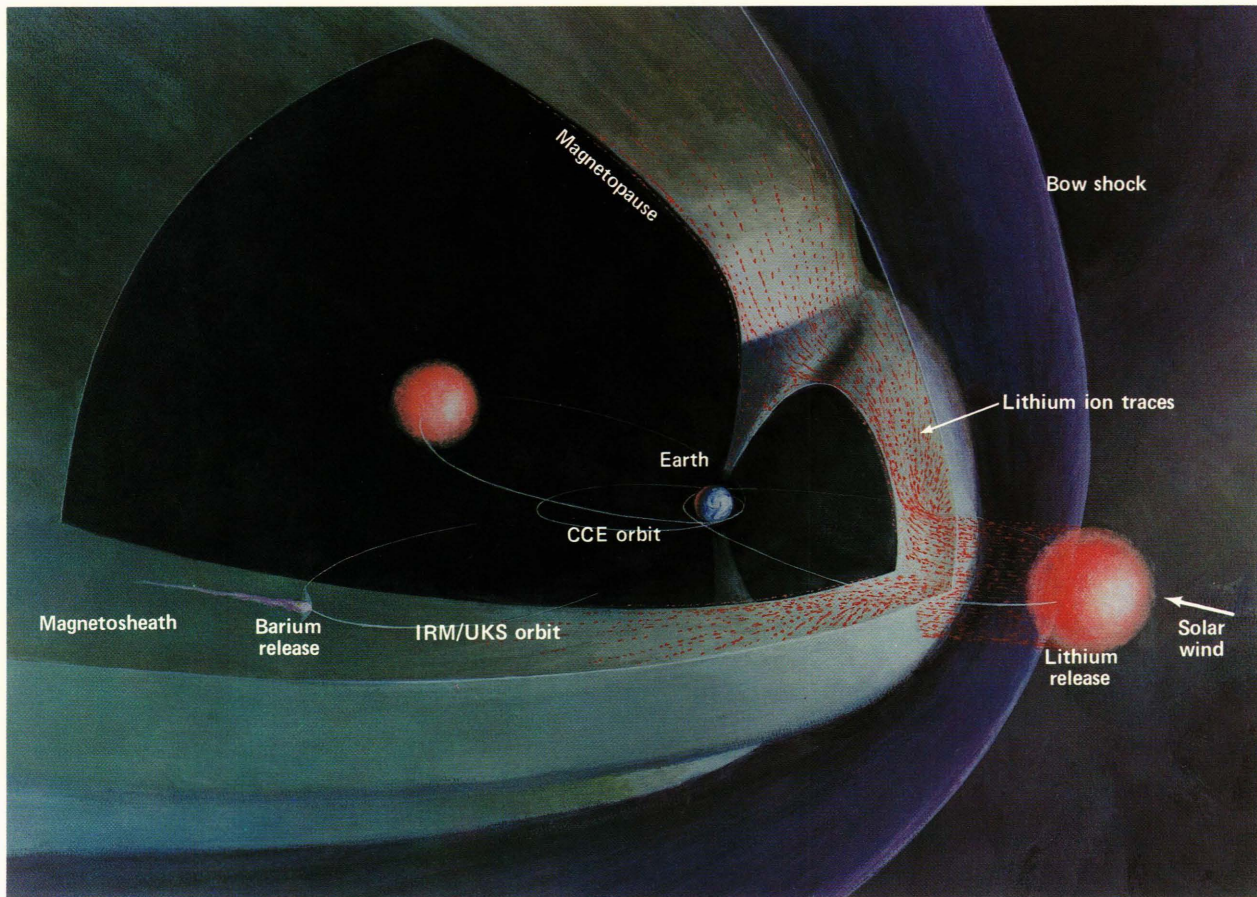


Figure 1 — The AMPTE program consists of three spacecraft that will be launched in 1984 to inject tracer ions (lithium and barium) inside and outside the earth's magnetosphere, and to detect and monitor those ions as they convect and diffuse through the inner magnetosphere. This artist's conception shows a lithium release in the solar wind on the sunward side of the earth, a barium release generating an artificial comet in the dawn magnetosheath, and a lithium tracer release in the deep magnetospheric tail. The lithium ions are shown being swept out of the neutral release cloud into the front of the earth's bow shock and magnetopause.

magnetosphere. After about 1 hour, the diameter of neutral lithium clouds is approximately 5 earth radii in either the solar wind or the magnetotail; the coma of the "comet" barium release at the dawn magnetosheath will be about 150 kilometers in diameter. The figure also depicts the orbits of the IRM and UKS spacecraft for each release and of the CCE spacecraft at the time of the magnetotail releases.

The physical concepts involved in the tracer element release are illustrated in Fig. 2. The initial expansion velocity of the neutral lithium cloud is about 4.5 kilometers per second. Following photoionization, ions are injected at very low thermal velocity into the flow of the collision-free solar wind plasma; they react immediately to the electric field experienced in the rest frame of reference, acquiring, within a gyroperiod, the drift velocity

$$\vec{v}_d = c \frac{\vec{E} \times \vec{B}}{B^2}, \quad (1)$$

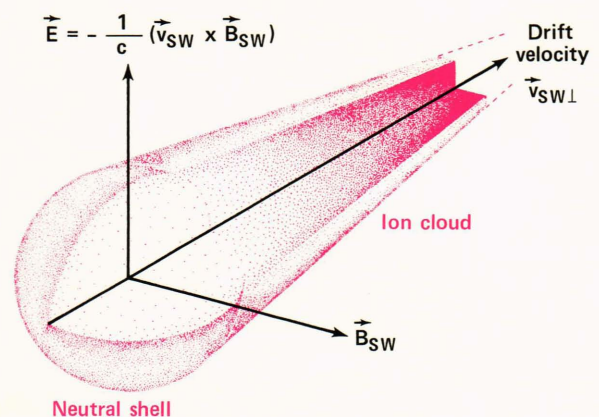


Figure 2 — Conceptual view of a lithium release in the solar wind (SW). Neutral lithium atoms expand in a hollow spherical shell and are photoionized with a time constant of ≤ 1 hour. As each lithium ion is created, it experiences the $\vec{v}_{\text{SW}} \times \vec{B}_{\text{SW}}$ convection electric field and drifts away from $\vec{v}_{\text{SW}} \times \vec{B}_{\text{SW}}$ the injection sphere.

which constitutes the transverse part of the flow velocity of the solar wind. As the figure shows, each ion will be swept away at a speed of nearly 400 kilometers per second (approximately 6 keV total energy in the spacecraft frame) by the solar wind convection field, forming a solid cylinder of lithium ions with radius and density that vary as a function of time, as shown in Fig. 3. In an hour, the ion densities are on the order of 10^{-5} per cubic centimeter, with approximately 60% of the neutral lithium having been photoionized.

The lithium ion injection lasts essentially for 6000 seconds (80% ionization), and we estimate that 10^{24} lithium ions (from 3×10^{25} lithium atoms in the release) and 6×10^{29} protons will have been transferred through the magnetopause in that time interval. The resulting ratio of lithium to proton fluxes in the plasma entering the magnetosphere should be on the order of 10^{-6} . A variety of considerations leads to the estimate that the intensity of lithium inside the orbit of the CCE spacecraft in the inner magnetosphere will be about 30 per square centimeter · second · steradian.

The anticipated results from the different types of releases are summarized in Table 1, which also includes the expected count rates in various energy intervals, taking into account the geometric factors of the instruments on board the CCE spacecraft. Expected fluxes from the solar wind release are rather low, placing stringent requirements on the instrumentation in terms of species resolution and rejection of background. Despite the difficulties of making such measurements in an ambient particle population many orders of magnitude higher, the CCE instruments are designed to provide the required sensitivity and resolution.

MISSION AND SPACECRAFT DESCRIPTION

As discussed in the Introduction, the program consists of three spacecraft: the Ion Release Module, which will release the clouds of tracer ions from a high apogee (18.7 earth radii) orbit; the Charge Composition Explorer, with an apogee of 9.0 earth radii; and the UKS spacecraft, which will keep station with the IRM at controllable distances of a few hundred kilometers to provide two-point measurements (a) within the released ion clouds and (b) of natural magnetospheric boundary phenomena. The scientific objectives of the program essentially fix the orbital parameters for the CCE and IRM spacecraft. We want the inclination of the CCE's orbit to be small, since the naturally occurring magnetospheric trapped ion distributions of elements heavier than hydrogen are very strongly peaked at the equator.¹³⁻¹⁷ We expect the trapped flux of the injected tracer ions to be similarly concentrated at the magnetic equator. The final inclination of the CCE ($\sim 0 \pm 5^\circ$) is achieved after an initial 28° inclination orbit by firing a solid-fuel rocket motor at apogee. The CCE apogee is high

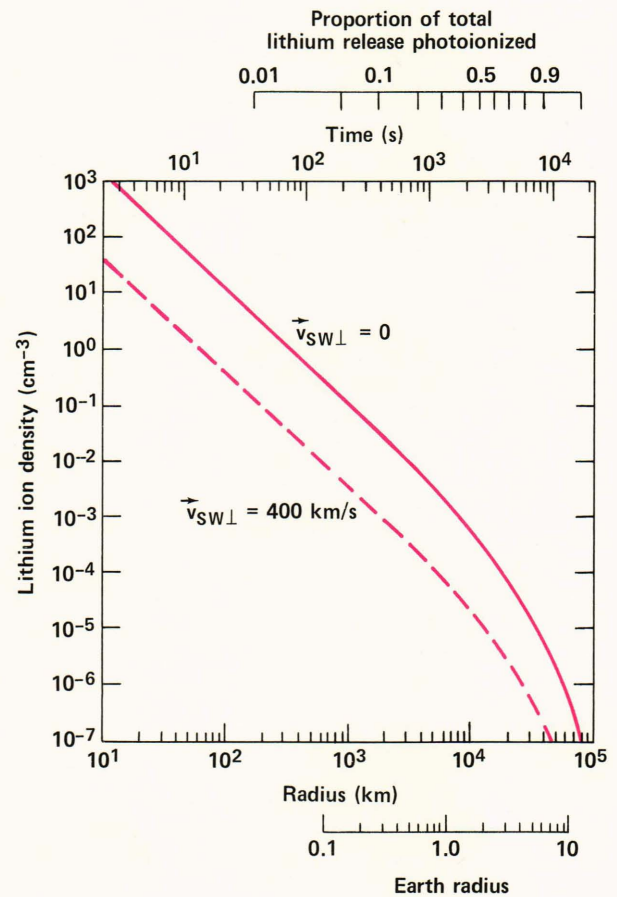


Figure 3 — The ion densities created by a lithium tracer release in the solar wind as a function of time after the release, for cases in which the component of the solar wind velocity perpendicular to the solar wind magnetic field \vec{B}_{SW} is 0 and 400 kilometers/second.

enough to allow observation of the inward diffusion of the tracer ions while still providing complete coverage of the inner magnetosphere within a reasonably short orbital period (16 hours).

The IRM remains at the 28° inclination of the injection orbit and increases its apogee from 9.0 to 18.7 earth radii by firing a solid rocket at perigee. This final apogee is a trade-off between two important considerations:

1. The ion release in the solar wind must be distant enough that no appreciable percentage of neutral lithium can penetrate into the inner magnetosphere before ionization.
2. The release in the magnetotail must be close enough to the earth for the local magnetic field geometry to favor the convection of the released ions toward, rather than away from, the earth.

An equatorial projection of the orbits of the three spacecraft in the earth-sun frame is shown in Fig. 4. The initial orbit is placed at about 2:30 PM local time to allow ample time for checking out the spacecraft

Table 1—Estimated tracer ion flux at the CCE.

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

* Artificial comet (Ba^+):	Angular width of cloud (17.7 earth radii)	$\sim 0.1^\circ$
	Initial brightness	$\leq 700 \text{ kR}$
	Visual magnitude of ionized cloud	+ 2.4
	Time scale for plasma detachment	100 s
	Duration (100 R threshold)	$\sim 10 \text{ min}$
	Apparent length of tail (at threshold)	$\sim 10^\circ$

and experiments prior to the first of two lithium releases in the solar wind that are to be performed around the time of equinox between mid-September and early October. 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. The UKS has sufficient thruster gas reserves to maintain an orbit essentially identical to that of the IRM for at least a year.

The release strategy shown in Fig. 4 is that tentatively adopted by the AMPTE Joint Science Working Group. The exact release locations are the subject of continued studies; timing will be dictated by the available diagnostic information on the interplanetary magnetic field and solar wind provided by *in situ* IRM measurements.

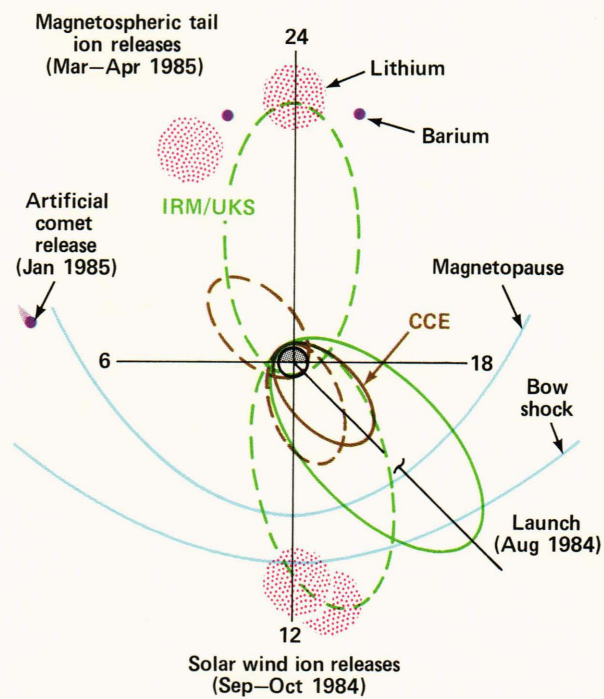
The three AMPTE spacecraft will be launched in a single stack. A schematic representation of the three spacecraft and associated experiments is shown in Figs. 5 and 6. Both the CCE and IRM contain solid fuel kick stages, which are used to change the inclination of CCE to approximately 0° , as noted above, and to reach an apogee of 18.7 earth radii for the IRM and UKS. The weights of CCE, IRM, and UKS are 220, 690, and 70 kilograms, respectively.

Each spacecraft contains a full complement of science instruments designed to address the AMPTE objectives; these payloads are described in Tables 2 through 4. Over 52 scientists from four countries are participating in the science investigations on the AMPTE program. The lead investigator for each instrument team, together with the two principal inves-

tigators (S. M. Krimigis for the CCE, G. Haerendel for the IRM), and the lead investigator and project scientist for the UKS (D. A. Bryant) constitute the Joint Science Working Group, which serves as the decision-making body for the implementation of the science objectives of this mission. R. W. McEntire is the project scientist at APL, where the CCE spacecraft is being built; G. Paschmann is the project scientist at the Max Planck Institute for Extraterrestrial Physics, where the IRM is being built; and M. Acuna is the AMPTE project scientist at Goddard Space Flight Center, which has management oversight of the program for NASA. The UKS is being constructed at the Rutherford Appleton Laboratory and the Mullard Space Science Laboratory. The two principal investigators are cochairmen of the Joint Science Working Group, and the overall program is coordinated through the AMPTE Joint Working Group, cochaired by the NASA and the Bundesministerium für Forschung und Technologie project managers (G. W. Ousley and D. U. Joneleit, respectively).

DATA ACQUISITION, REDUCTION, AND ANALYSIS PLAN

The instrument complement on all three AMPTE spacecraft is dedicated to making unified measurements, which are necessary for meeting the scientific objectives. For this reason, a concerted effort has been made to facilitate unified analysis by establishing a single science database for each spacecraft. The data reside in, and are distributed from, Science Data Centers in the United States, the Federal Republic of Germany, and the United Kingdom.



	CCE	IRM	UKS
Apogee (R_E)	9.0	18.7	18.7
Period (h)	16.0	43.8	43.8
Inclination	$< 5^\circ$	28.5°	28.5°
Mass (kg)	220	690	70
Releases		7	
Precession ($^\circ$ /mo)	22.6	29.9	29.9

Figure 4 — Orbit configuration of the CCE and IRM/UKS at launch (solid lines) and at times of solar wind and magnetotail releases (dashed lines). The orbits will precess in the earth-sun frame after launch, as shown, allowing, first, two separate lithium releases upstream from the bow shock, then the “artificial comet” barium release in the dawn magnetosheath, and later two lithium and two barium releases as the IRM apogee precesses through the magnetotail.

As an example of this data flow, the arrangement for the U.S. site is shown in Fig. 7. Data from the CCE spacecraft are routed through the NASA Deep Space Network to the Jet Propulsion Laboratory, where preliminary trajectory information is introduced. From there, the data can either be sent over a high-speed line via the Goddard Space Flight Center to the U.S. AMPTE Science Data Center at APL or, in cases where it is unnecessary to send data in real time, magnetic tapes may be mailed to the same data center. All processing and analysis of the CCE data are carried out on the U.S. Science Data Center central computer, with remote terminals at each institution involved. The U.S. Science Data Center supplies system programming, maintenance, and operations, while the lead investigators provide all data reduction and analysis software for their specific instruments.

Several types of science files (ranging from approximately 6.4-minute averages to the highest time resolution) are maintained in the central database and are accessible to all team members for unified anal-

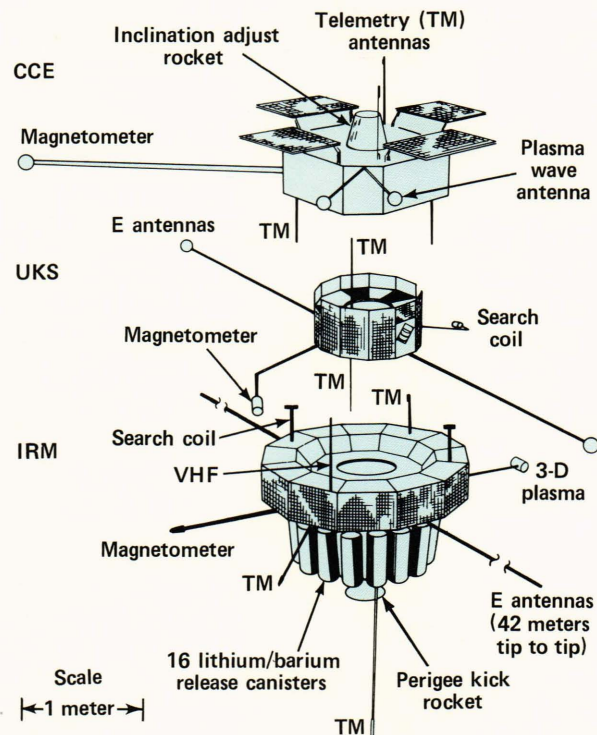


Figure 5 — The three AMPTE spacecraft—the CCE, the IRM, and the UKS—are shown here in an exploded view of the flight configuration with solar arrays, booms, and antennas deployed. All are spin stabilized—the IRM and UKS with spin axes perpendicular to the ecliptic plane and the CCE with spin axis in the equatorial plane $\sim 20^\circ$ from the sun line.

ysis for the life of the mission. Simple and interactive communication of data displays between team members via the central computer will greatly enhance joint analysis. As shown on Fig. 7, the U.S. Science Data Center will be connected to its German equivalent, which in turn is connected with the United Kingdom data center. Data will be transferred between the U.S. and German centers either via dial-up data lines or by magnetic tape, as appropriate. The German and United Kingdom AMPTE Science Data Centers are organized similarly to the one in the United States.

An essential function of the AMPTE Science Data Centers is to provide real-time displays of relevant data near and during times of tracer releases. The current plan calls for receiving data in real time or within a few seconds of real time for a few days before and after a tracer release. The data must be received, reduced, and analyzed very quickly (in less than 1 hour) so that the Joint Science Working Group will be able to make rapid decisions on the timing of subsequent releases.

It is evident from the strategy for releases illustrated in Fig. 4 that all analysis software must be working and in place prior to launch. The U.S. Science Data Center hardware, including the central computer and associated terminals, has already been received and systems programming is under way.

Table 2—AMPTE CCE instrumentation.

<i>Instrument</i>	<i>Coverage</i>	<i>Measurement Technique</i>	<i>Investigator Team</i>	
Plasma composition measurement spectrometer	Ion composition, 0 eV/ q to 17 keV/ q	Retarding potential electrostatic analyzer; $E \times B$ analyzer	E. Shelley (L.I.) R. Sharp, R. Johnson, W. Peterson	LPARL
	Electrons, 50 eV to 25 keV	Magnetic analyzers	J. Geiss, P. Eberhardt, H. Balsiger, A. Ghielmetti D. Young G. Haerendel H. Rosenbauer	U. Bern LANL MPE MPAE
Charge energy mass spectrometer	Ion composition, ~ 1 keV/ q to 300 keV/ q	Electrostatic analyzer; time-of-flight and total E	G. Gloeckler (L.I.), F. Ipavich B. Wilken, W. Stüdemann D. Hovestadt	U. Md. MPAE MPE
Medium energy particle analyzer	Ion composition, 0.01 to ≥ 1.0 MeV/nucleon	Time-of-flight and total E	R. McEntire (L.I.), S. Krimigis, A.T.Y. Lui	APL
Magnetometer	DC to 50 Hz	Vector fluxgate	T. Potemra (L.I.) M. Acuna	APL GSFC
Plasma wave spectrometer	AC E fields, 5 Hz to 178 kHz	Electric dipole	F. Scarf (L.I.)	TRW, Inc.

L. I., Lead investigator
 LPARL, Lockheed Palo Alto Research Laboratory
 U. Bern, University of Bern, Switzerland
 LANL, Los Alamos National Laboratory

MPE, Max Planck Institute for Extraterrestrial Physics
 MPAE, Max Planck Institute for Aeronomy
 U. Md., University of Maryland
 GSFC, NASA/Goddard Space Flight Center

Table 3—AMPTE IRM instrumentation.

<i>Instrument</i>	<i>Coverage</i>	<i>Measurement Technique</i>	<i>Investigator Team</i>	
3-D plasma analyzer (ions and electrons)	~ 0 to 25 eV 10 eV to 30 keV	Retarding potential analyzer; 2 symmetrical quadrispheres	G. Paschmann (L.I.), N. Schopke C. Carlson	MPE UCB
Mass separating ion sensor	0.01 to 12 keV/ q	Quadr spherical E/q analysis; magnetic analysis	H. Rosenbauer (L.I.), H. Grünwalt, M. Witte, H. Goldstein	MPAE
Suprathermal energy ionic charge analyzer	10 to 300 keV/ q	Electrostatic analyzer; time-of-flight and total E	D. Hovestadt (L.I.), E. Möbius, M. Scholer, B. Klecker F. Ipavich, G. Gloeckler	MPE U. Md.
Magnetometer	DC to 50 Hz	Vector fluxgate	H. Lühr (L.I.), N. Klöcker B. Häusler M. Acuna	TUB MPE GSFC
Plasma wave spectrometer	E: DC to 5 MHz B: 30 Hz to 1 MHz	42 m (tip-to-tip) antenna; 2 boom-mounted search coils	B. Hausler (L.I.), R. Treumann D. Gurnett, R. Anderson R. Holzworth H. Koons	MPE U. Iowa U. Wash. AEROSP
Li/Ba release experiments	8 Li release canisters (52 kg); 8 Ba release canisters (108 kg)	CuO thermite reaction	A. Valenzuela (L.I.), H. Föppl, E. Rieger, G. Haerendel, O. Bauer	MPE

UCB, Univ. of California at Berkeley
 TUB, Technical University of Braunschweig
 AEROSP, Aerospace Corp.

Table 4—IRM UK subsatellite instrumentation.

Instrument	Coverage	Measurement Technique	Investigator Team*	
3-D ion analyzer	0.01 to 20 keV/ <i>q</i>	Electrostatic analyzer	A. Johnstone	MSSL
3-D electron analyzer	25 eV to 25 keV	Electrostatic analyzer	D. Hall, C. Chaloner	RAL
Particle modulation analyzer	~ 1 Hz to ~ 1 MHz	Electron and ion signal processing	M. Gough	U. Sussex
Magnetometer	DC to 10 Hz	Vector fluxgate	D. Southwood, S. Cowley C. Russell	ICST UCLA
Plasma wave spectrometer	<i>E</i> : 0 to 128 kHz	7 m tip-to-tip probe	L. Woolliscroft P. Christiansen	U. Sheffield U. Sussex
	<i>B</i> : 30 Hz to 20 kHz spot frequency to 2 MHz	Boom-mounted search coil	M. Gough D. Jones	U. Sussex BAS

MSSL, Mullard Space Science Laboratory
 RAL, Rutherford Appleton Laboratory
 ICST, Imperial College of Science and Technology
 UCLA, Univ. of California at Los Angeles
 BAS, British Antarctic Survey

*D. A. Bryant is lead investigator for the UKS science payload.

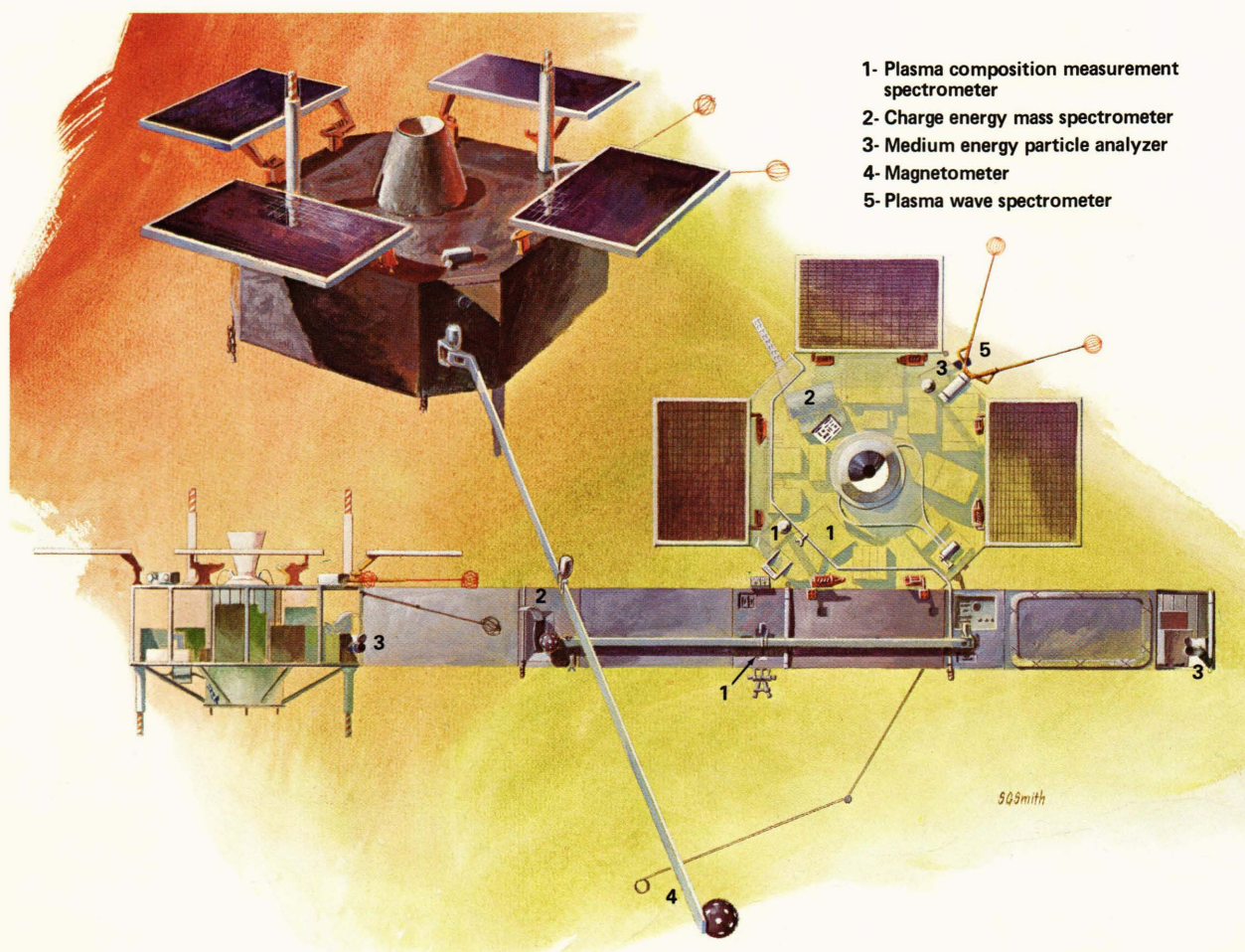


Figure 6 — An expanded artist's conception of the CCE, showing the spacecraft in flight configuration in the upper left, and with the thermal blankets removed and the skin unfolded to show internal package details below.

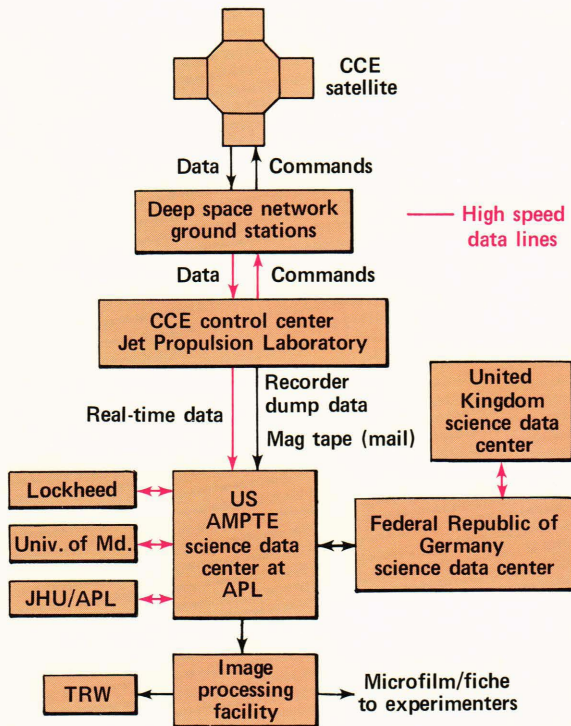


Figure 7 — Block diagram of the data flow from the CCE spacecraft through the NASA tracking networks into the U.S. AMPTE Science Data Center, of the interactive data analysis on the U.S. Science Data Center computer by the CCE science team, and of data interchange with the European AMPTE Science Data Centers.

CONCLUSION

The AMPTE program represents the first of a new type of high-altitude tracer and environmental perturbation experiment. As such, it offers the potential for some important advances in our understanding of the near-earth plasma environment and the processes controlling it. The project is oriented to a specific set of problems, and the spacecraft and instrument complements are specifically optimized to address those science objectives. The objectives also dictate the unified analysis of the data from the three spacecraft; steps have been taken to design a system that will facilitate such an approach.

Although we have discussed the tracer aspect of the program in some detail, the local plasma interactions—especially during the barium releases and the artificial comet creation—are at least as interesting and even more challenging. Questions of coupling between the injected and the ambient plasma, including thermalization, critical-velocity ionization, wave generation, instabilities, local acceleration of electrons, etc., will provide important tests for many analytical and simulation studies of such phenomena. All scientists involved are looking forward with great anticipation to this exciting new program. For those at APL, the mission is especially stimulating for several reasons: the concept originated

here; the CCE spacecraft and most of its systems are being designed and built at APL, as are the medium energy particle analyzer and magnetometer instruments; and we are extensively involved in the scientific return of the mission (the AMPTE U.S. principal investigator, most of the science team members for the two APL-built instruments, and the U.S. Science Data Center are located at the Applied Physics Laboratory).

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