N88-10851 J22-18
102856
7P

THE COMBINED RELEASE AND RADIATION EFFECTS SATELLITE, A JOINT NASA/DOD PROGRAM

D. J. Berrier
The Aerospace Corporation

AG 163093

ABSTRACT

A permanent presence in space requires a clear understanding of the space environment and its effects (1). This environment consists of complicated and variable plasmas and fields that have significant effects on space systems and on man in space. The Combined Release and Radiation Effects Satellite (CRRES) has been developed to help clarify the space environment picture.

INTRODUCTION

CRRES is a two-phase joint USAF/NASA program consisting of a low earth orbit phase (LEO) and geosynchronous transfer orbit (GTO) phase (2). The program offices for the CRRES are at USAF/SD and NASA headquarters. At USAF/SD, The Aerospace Corporation provides technical review for the SD Program Office. NASA Marshall Space Flight Center (MSFC) has the responsibility to acquire the CRRES and has a contract with Ball Aerospace Systems Division (BASD) for design, development, integration, and test of the CRRES (see Figure 1). In addition, MSFC has management responsibility for the NASA experiment program in LEO and GTO.

The 360 km circular 28.5 degree inclined low earth orbit phase will last 45 to 90 days and will be managed by NASA (see Figures 2 and 3). During this phase, active experiments will consist of tracer chemicals that will be released over ground observation sites. Their interaction with the ionosphere, atmosphere, and earth's magnetic field, enhanced by orbital kinetic energy, will be monitored by passive CRRES-mounted instruments and ground-based instruments. The CRRES-mounted instruments, developed by the Naval Research Laboratory, will also monitor the near-earth environment under steadystate conditions, i.e., when no chemical releases occur. The intent of ionospheric monitoring of chemical releases and steady-state conditions is to improve knowledge of coupling of the upper atmosphere with the ionosphere, the structures irregularity, the chemistries and other conditions of the ionosphere that affect communications.

The geosynchronous transfer orbit phase will last three to five years and will be managed by the U.S. Air Force. The 400 x 36,800 km, 18 degree inclination orbit will be achieved using a modified Minuteman III third-stage solid rocket motor, which will be jettisoned after the burn is completed. This orbit will cause the CRRES to transition through the earth's inner and outer radiation belts approximately every ten hours and encounter variable plasmas and fields from near earth to geosynchronous altitudes in a nearly infinite number of orientations. During this orbital phase, the variable intensity and composition of the radiation belts plasma and fields will be accurately measured and mapped. Over 50 instruments will be used to perform this task, including instruments to measure magnetic and electric fields, particles, waves, total radiation dose, cosmic rays, heavy ions, low/medium/ high energy electrons and their pitch angles, and the effects of tracer chemicals. See Figure 4.

The CRRES geosynchronous transfer orbit instruments have been developed by several agencies. The Air Force Geophysics Laboratory in Bedford, Massachusetts, is responsible for the Space Radiation Experiment, which consists of five deployable booms and 28 electronics units including a set of state-of-the-art microelectronics to be exposed and correlated to space radiation. The Office of Naval Research, Washington, D.C., has sponsored the Energetic Particles and Ion Composition Experiment, developed by the Lockheed Palo Alto Research Laboratory, and the Isotopes in Solar Flares Experiment, developed by the University of Chicago.

In addition, an experimental set of new type gallium arsenide solar panels will be onboard CRRES, to determine their radiation hardness, thermal annealing, and high efficiency power generation characteristics in the space environment. This experiment will operate during both phases of the mission and has been developed by the Air Force Aero-Propulsion Laboratory, Air Force Wright Aeronautical Laboratories, WrightPatterson Air Force Base, Ohio.

CRRES launch will be on the Shuttle and is scheduled for mid-1989 from Kennedy Space Center. Data will be recovered and processed through 1994 and beyond. These data will give us a much clearer picture of the space environment and its effects, and help assure a permanent presence in space.

CRRES MISSION DATA

Engineering, modeling, and science data obtained by CRRES will improve understanding of the geospace environment and its effects.

Engineering data will chronicle environmental effects on advanced solid-state microelectronics and other materials, such as gallium arsenide solar cells and dielectrics.

Modeling and science data will be collected to significantly improve the existing radiation belt model by refining existing data and by filling gaps in existing models. Better equatorial data above 8000 km altitude, higher energies and more accurate angular distribution data will be obtained. Additional science data will improve understanding of geospace dynamics. This includes particle acceleration and transport, particle sources and losses, and magnetic storm effects (3).

ENGINEERING DATA

The CRRES microelectronics experiment will provide data to improve satellite survivability and reliability in the space radiation environment. It will measure effects of long-term total radiation dose degradation and short-term radiation soft error, or single event upset (bit-flip) rates, on over 300 representative advanced microelectronics parts and compare these effects to radiation content and orbit position. Total radiation dose effects on microelectronics devices limit satellite operational lifetime and therefore increase costs, and soft error (bitflip) rates limit on-orbit system reliability. Also, performance of these 60 types of microelectronics test devices will be correlated with the radiation environment data from onboard instruments so that the adequacy of existing microelectronics ground test radiation simulation programs can be determined.

A functional duplicate of the spaceborne microelectronics package will be used for ground test so that deficiencies in ground test simulation programs can be identified and existing ground test simulations can be improved, during and after the CRRES mission. The microelectronics experiment is part of the Air Force Geophysics Laboratory group of Spacerad instruments (4).

Another engineering data experiment is the Air Force Aero-Propulsion Laboratory's High Efficiency Solar Panel experiment. Gallium arsenide cells have been shown in the laboratory to have beginning of life electrical power generation efficiencies as high as 18 percent, as compared to 14.6 percent for silicon cells. To date, silicon has been the commonly used material for spacecraft solar cells. It has also been shown in the laboratory that gallium arsenide is nearly three times as efficient as silicon at high temperatures, and is also more efficient at end of life, after exposure to high electron radiation flux.

The laboratory environment cannot simulate all space radiation events simultaneously, and thus there is a question about the accuracy of the laboratory data on gallium arsenide solar cell radiation damage. Measurements of different types of gallium arsenide solar cells, along with the measurements of the radiation in space, will provide highly accurate engineering data for the design of space solar cell panels. The effect of annealing the space radiation damage in gallium arsenide solar cells will also be studied. This will be accomplished by running the cells at an elevated temperature and evaluating their degradation. Different types of panel fabrication technology will be used to remove this source of data bias from the experiment. Welded and soldered solar cell strings of the same type will be used, for example, to remove the possibility of getting erroneous data caused by the use of improper interconnects (5).

A third engineering data experiment is the Air Force Geophysics Laboratory's Internal Discharge Monitor, which will detect, analyze and record internal electrical discharges on 16 typical spacecraft materials in the measured space environment (4). These electrical discharges are due to charge buildup in dielectrics, which is caused by penetrating radiation.

RADIATION BELT MODELING AND SCIENCE DATA

The increasing demands for space systems electronics capability, reliability and lifetime, and for operability in a hostile environment require more accurate modeling of the geospace environment. The biological effects on man of long-duration exposure to the space environment will become even more important with the advent of the space station.

The CRRES will use the most complete set to date of accurate cross-calibrated extended-range instruments, to provide improved particle type modeling and wave modeling over the 3- to 5-year term. In addition, CRRES will give a better understanding of geospace dynamics such that process ordering algorithms can be derived to improve our ability to predict geospace dynamics. (4)

CRRES experiments will provide much of the data missing in existing radiation belt data models including energetic heavy ion measurements at low altitudes; very high energy electrons greater than 5 MeV throughout the orbit and very high energy protons from 50 to greater than 300 MeV below 10,000 km. Dosimeters will measure true dose under controlled shielding conditions (3).

The CRRES particle detectors are all cross-calibrated and cover with high accuracy the full range of geospace energies for electrons, protons, and ions. The total energy spectrum covers from 10 ev to above 9 Gev (4).

Field and wave experiments include accurate 3-axis fluxgate and search coil magnetometers mounted on a 6-meter boom, which cover the frequency range from dc to 10 kHz, a passive plasma sounder with 100 M tip-to-tip wire booms, which covers the E-field from 5.6 Hz to 400 kHz; and a microprocessor-controlled thermal plasma probe with 100 M tip-to-tip booms and spherical probes, that covers the thermal plasma range to 10 EV and the E-field from dc to 1 kHz (4).

In the low earth orbit phase of the CRRES mission, the Naval Research Laboratory's Low Altitude Satellite Study of Ionospheric Irregularities will be operated in three primary modes: a low data rate (16 kbps) mode to provide survey measurements of the nightside ionosphere, an intermediate/high rate (64/256 kbps) mode in the region of high probability for the occurrence of spread-F irregularities, and a high rate (256 kbps) mode centered about the chemical releases. This set of Naval Research Laboratory instruments includes pulsed plasma probes for measuring electron density fluctuations, temperature, mean-ion-mass fluctuations, and spacecraft potential. Also included is a quadrupole ion mass spectrometer to measure positive and negative ion composition and density fluctuations; and a VLF wave analyzer to measure the E-field spectrum from dc to 100 kHz and B-field spectrum from 1 Hz to 100 kHz (5). These instruments will collect data at low altitude (360 km) and complement the previously discussed wave and particle experiments, which will be used in the geosynchronous transfer orbit.

The NASA Marshall Space Flight Center will be conducting chemical release experiments in low earth orbit and out to geosynchronous altitude. These experiments will also help clarify the geospace environment picture. Their objectives include tracing low-latitude electric fields and studying ion transport along magnetic flux lines. Artificial ionospheric instabilities will also be induced chemically and ground-to-satellite communications effects will be studied. Attempts will be made to induce holes in the ionosphere and to use those holes to focus HF radio waves. The effects of heating ion clouds using ground-based HF transmitters will also be studied. Operation of the Naval Research Lab's low altitude instruments onboard CRRES will be coordinated with all low earth orbit chemical release experiments.

Additional NASA chemical release experiments will include performing Alfen wave dynamics critical velocity experiments on ions at orbital velocity and studying ion cloud dynamics under divergent magnetic field strengths in both CRRES orbits. Also, artificially perturbing high energy trapped particle populations by injecting Li seeding plasma in the geosynchronous transfer orbit will add to our understanding of the effects of extreme radiation at synchronous altitudes (7).

SUMMARY AND CONCLUSION

The CRRES mission has been carefully planned to help clarify the geospace environment picture and its effects on space hardware, communications and on man. CRRES instruments have been selected for synergism, accuracy, and applicability, and will be cross-calibrated for consistency. They will provide data to fill the gaps in geospace modeling data already obtained, and will update and correct existing models. The chemical release experiments and low altitude instruments will clarify the character of the ionosphere in low earth orbit and the high altitude chemical release experiments will improve knowledge of how trapped particle populations behave out as far as synchronous altitudes. The ionospheric studies will lead to significantly improved earth-space intercommunications.

REFERENCES

1. H. Garrett and S. Worden, Capt USAF Space Division, "The Space Environment, Friend or Foe?" (1984).

2. CRRES System Description Handbook, Rev. A, Ball Aerospace Systems Division, NASA/MSFC, (2 April 1985).

3. F. Djuth, "CRRES Mission Data and Inclination Change," The Aerospace Corporation (2 February 1984).

4. E. G. Mullen, "Spacerad Overview," Air Force Geophysics Laboratory (7 April 1986).

5. T. M. Trumble, "Space Applications of GaAs Solar Cells," Air Force Wright Aeronautical Laboratory (27 November 1982).

6. E. Szuszczewicz, "LASSII/CRRES Experiment Requirements Document," Naval Research Laboratory (11 February 1983).

7. D. Reasoner, "CRRES Chemical Release Mission Scientific Objectives," NASA Marshall Space Flight Center (1 November 1984).

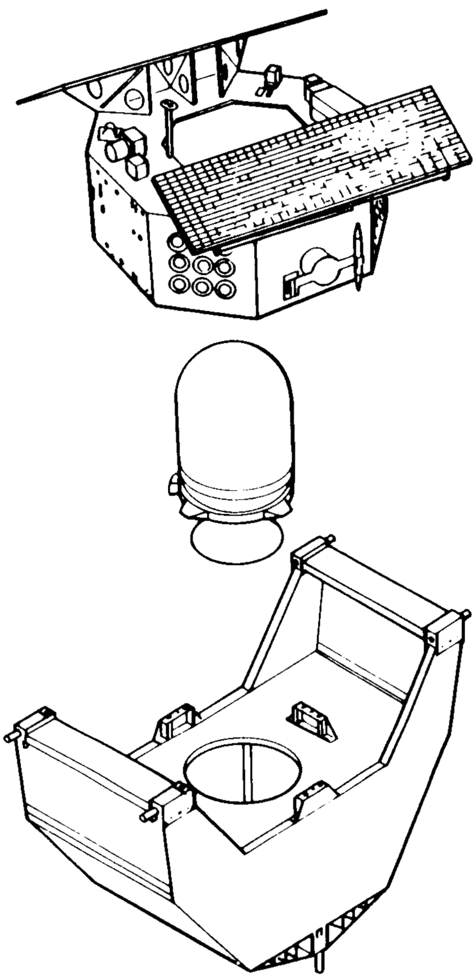

Figure 1. CRRES system

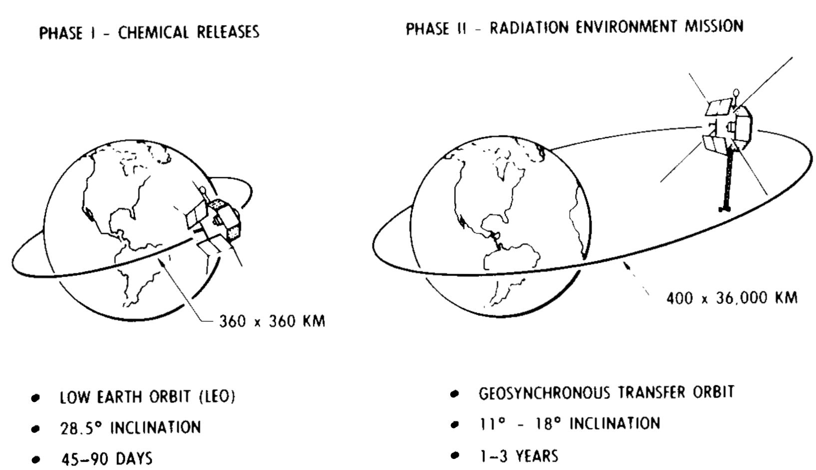

Figure 2. Combined release & radiation effects satellite (CRRES) two-phase mission

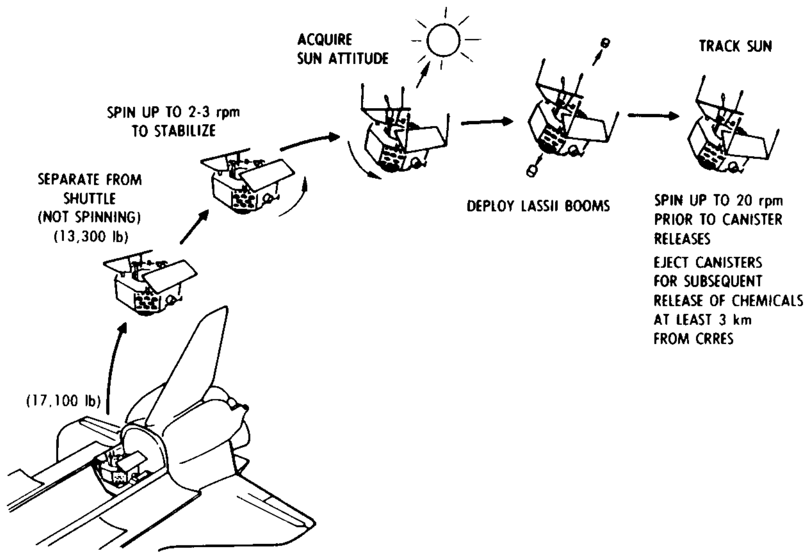

Figure 3. CRRES deployment and low earth orbit operations

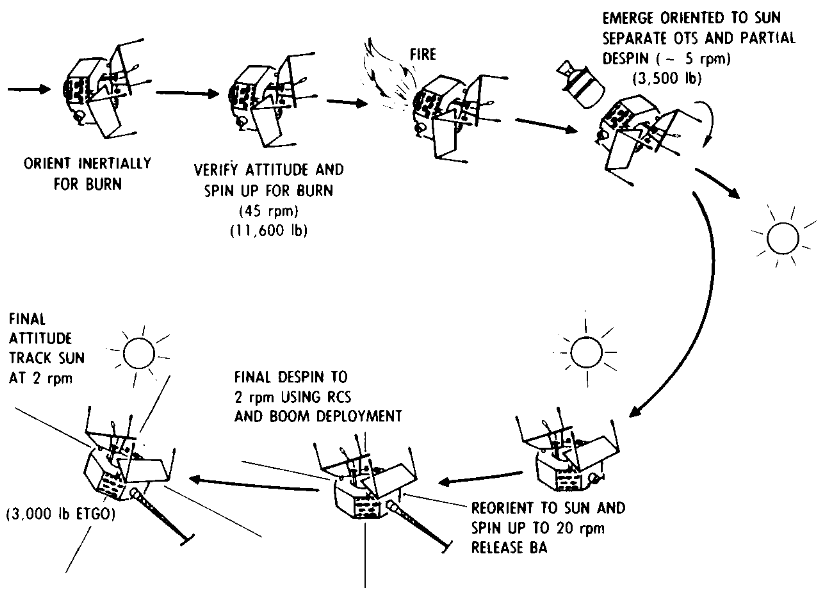

Figure 4. CRRES geosynchronous transfer orbit insertion and operations