NASA

National Aeronautics and
Space Administration

Washington, D.C.
20546

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TO: Distribution

FROM: S/Associate Administrator for Space Science and Applications

SUBJECT: CRRES Prelaunch Mission Operation Report

The enclosed Mission Operation Report (MOR) covers the Combined Release and Radiation Effects Satellite (CRRES) mission. The CRRES spacecraft is currently scheduled for launch by an Atlas/Centaur launch vehicle on July 9, 1990.

Although the CRRES program consists of chemical releases from both satellites and sounding rockets, this MOR deals mainly with the chemical release experiments associated with the CRRES/Geosynchronous Transfer Orbit (GTO) mission to be carried out by the CRRES spacecraft.

This report describes the objectives of the CRRES/GTO mission and mission sequence, a brief description of the CRRES spacecraft, the Atlas/Centaur launch vehicle, and the mission operations and management.

L. A. Fisk

Enclosure

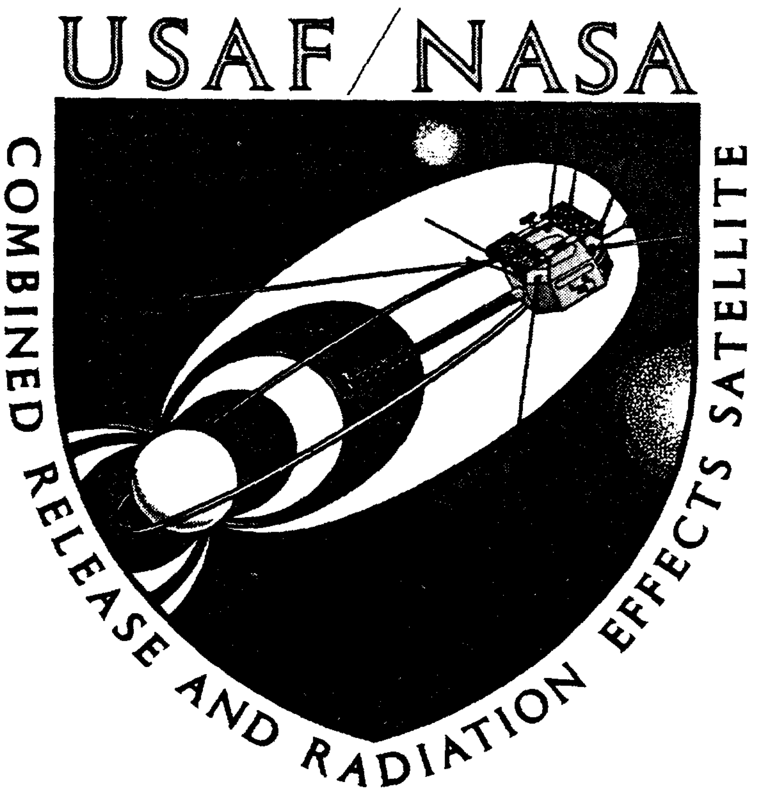
NASA

National Aeronautics and
Space Administration

Mission Operation Report

Office of Space Science and Applications

Report No. S-145-90-02



CRRES/GTO

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GENERAL

The overall NASA Combined Release and Radiation Effects Satellite (CRRES) program consists of a series of chemical releases from the PEGSAT spacecraft, the CRRES spacecraft and sounding rockets. The first chemical releases were made from the PEGSAT spacecraft in April, 1990 over northern Canada. In addition to the releases planned from the CRRES spacecraft there are releases from sounding rockets planned from the Kwajalein rocket range in July and August, 1990 and from Puerto Rico in June and July, 1991. Table 1 shows the major milestones in the overall CRRES program.

This Mission Operations Report only describes the NASA mission objectives of the CRRES/Geosynchronous Transfer Orbit (GTO) mission.

The CRRES/GTO program is a joint National Aeronautics and Space Administration (NASA) and Department of Defense (DoD) effort. The NASA portion of the program is managed by the Space Physics Division at NASA Headquarters and the Marshall Space Flight Center (MSFC), and the DoD portion is managed by the Air Force Space Systems Division's Space Test and Transportation (ST&T) Office. NASA provides spacecraft development and integration, launch on the Atlas I, spacecraft initialization/ checkout, and chemical experiment management. The DoD provides the DoD experiments, spacecraft funding, on-orbit mission operations, and prime mission data analysis. One of the instruments on the CRRES spacecraft is the Cosmic Ray Isotope Experiment (CRIE). This experiment is managed by the Space Physics Division and the Astrophysics Division at NASA Headquarters and the Goddard Space Flight Center under the Explorer Program. The Atlas I is being procured from General Dynamics Corporation by the NASA/Lewis Research Center. The spacecraft and the payload adapter were designed, built, and tested by Ball Space Systems Division under NASA/MSFC contract.

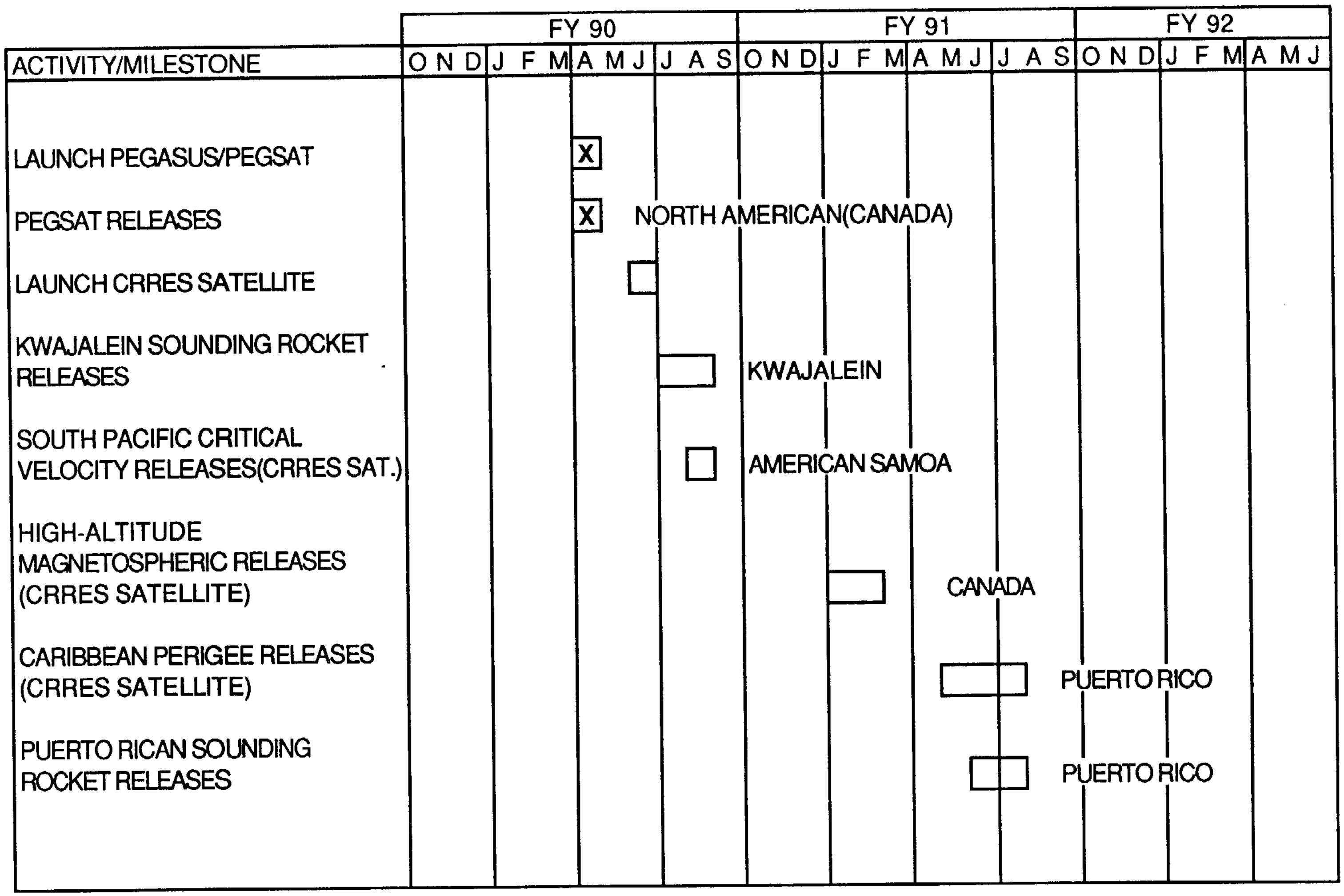
The CRRES mission operations shall be conducted jointly by NASA and DoD with each having distinct roles. The NASA activity includes the operations functions carried out by MSFC. MSFC shall be responsible for directing the operations associated with spacecraft integrity, launch, on-orbit initialization/checkout of the spacecraft, and the chemical release campaigns.

The DoD activity includes the operations functions carried out by the Air Force. The Air Force shall be responsible for directing and controlling the operations associated with spacecraft integrity, tracking and control, data handling, and DoD experimentation following the spacecraft initialization and checkout.

The NASA/DoD CRRES operations have an on-orbit lifetime goal of 3 years. The CRRES/GTO joint mission is nominally scheduled for 1 year after spacecraft launch. The DoD will conduct an additional 2 year science mission following the joint NASA/DoD CRRES/ GTO mission. Following the third year of the CRRES/GTO mission, the CRRES spacecraft becomes part of the NASA Global Geospace Science (GGS) mission. In this extended mission phase, the CRRES spacecraft will still be operated by the DoD but science measurements will be coordinated with GGS.

The NASA CRRES science experiments will permit the release of tracer chemicals that will interact with the ionosphere and magnetospheric plasma and the earth's magnetic field.

Table 1. Overall CRRES Program Schedule



NASA MISSION OBJECTIVES

The primary objectives of the CRRES/GTO mission are to launch the spacecraft into a highly elliptical geosynchronous transfer orbit (GTO) with an initial perigee of 350 kilometers altitude and an apogee at geosynchronous altitude of 35,786 kilometers and inclined at near 18 degrees to the equator. The GTO orbit will enable NASA performance of active chemical release experiments in the ionosphere and magnetosphere.

The chemical releases will permit (1) the study of low latitude electric fields and the transport of ions along magnetic field lines to the conjugate ionosphere; (2) artificial creation of ionospheric perturbations and production of ionospheric irregularities, study of momentum coupling, and testing of the critical ionization hypothesis; and (3) effects of artificial plasma seeding of the magnetosphere.

The primary objective of CRIE is to investigate particle acceleration processes in the Sun through the measurement of the isotopic and elemental composition of high energy particles in the magnetosphere.

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MISSION DESCRIPTION

Following launch on an Atlas I vehicle, the CRRES spacecraft will operate in a highly elliptical geosynchronous transfer orbit (GTO) with an initial perigee of 350 kilometers altitude and an apogee at geosynchronous altitude of 35,786 kilometers and inclined at near 18 degrees to the equator. Operations in this orbit support both NASA and DoD scientific experimental objectives. There are three major objectives: (1) NASA performance of active chemical release experiments in the ionosphere and magnetosphere, (2) DoD studies of the natural radiation environment and studies of the effects of this radiation environment upon microelectronic components as CRRES travels through the inner and outer radiation belts of the earth, and (3) DoD low altitude studies of ionospheric irregularities which are performed in the ionosphere near the orbit perigee.

CRRES will carry a complement of chemical release canisters which will be released at certain times over ground observation sites and diagnostic facilities. These releases form large clouds that will interact with the ionospheric and magnetospheric plasma and the earth's magnetic field. These interactions will be studied with optical, radar, and plasma wave and particle instruments from the ground, aircraft, and the CRRES spacecraft.

Those controlled experiments which are performed near perigee will further the understanding of the interaction of plasmas with magnetic fields, the coupling of the upper atmosphere with the ionosphere, the structure and chemistry of the ionosphere, and the structure of low-altitude electric fields. Those which are performed near apogee in the earth's magnetosphere will study the formation of diamagnetic cavities, coupling between the magnetosphere and ionosphere, and the effects of artificial plasma injections upon the stability of the trapped particles in the radiation belts. The chemical release experiments and associated ground and airborne diagnostics were selected by the NASA Announcement of Opportunity process. A CRRES Investigators Working Group has been formed, and the investigators divided into teams based on mutual scientific interests and the ability to make coordinated multipoint observations. Table 2 lists the principal investigators and the experiments planned for the CRRES/GTO mission. Also listed in Table 2 is information about the chemicals, times and locations and observational support for each experiment. The chemical release teams for the CRRES/GTO Mission are:

Team 1 - Electric Fields and Ion Transport The study of low-latitude electric fields and the transport of ions along magnetic field lines to the conjugate ionosphere.

Team 2 - Ionospheric Modifications/Plasma Processes Artificial creation of ionospheric perturbations and production of ionospheric irregularities. Study of momentum coupling from injected plasmas and the background ionosphere. Testing of the critical ionization hypothesis by injection of neutral atoms at orbital velocities. Comparison of observed behavior of injected plasma with computer models.

Team 3 - High Altitude Releases Effects of artificial plasma seeding of the magnetosphere. This team will work in conjunction with the DoD particle and wave investigators. Ground based optical and radar diagnostics will observe large scale phenomena, while in situ CRRES measurements will examine localized microscale effects. The CRRES instruments will also determine the state of the magnetosphere, providing valuable data to allow the determination of optimal conditions for releases.

The mission orbit is nominally 350 x 35,786 km and near 18 degrees inclination. The orbit has a period of about 10 1/2 hours. The mission duration is nominally scheduled for 1 year with an on-orbit lifetime goal of 3 years and the hope of an extended mission to six years to support the NASA GGS program starting in 1992/93.

Table 2. CRRES Satellite Chemical Release Experiments

EXPERIMENT	Release Number	CANISTER TYPE and CHEMICAL	CHEM.* Wt. (kg)	RELEASE LOCATION	RELEASE ALTITUDE	RELEASE SEQUENCE	RELEASE PERIOD	RELEASE CONDITIONS	OBSERVATIONAL SUPPORT
Critical Velocity									
Critical Velocity Ionization	G-13	Large/Sr Large/Ba	10 12.1	South Pacific (American Samoa)	450-600 km	First 2.5 sec. later	Aug. 1990	moon down, dusk 1900 LT	Two aircraft required Ground sites in Samoa and Fiji
	G-14	Large/Ca Large/Ba	9.5 12.1	South Pacific (American Samoa)	450-600 km	First 2.5 sec. later	Aug. 1990	moon down, dusk 1900 LT	
High-Altitude Magnetospheric									
Diamagnetic Cavity, Plasma Coupling	G-1 G-2 G-3 G-4	Small Ba,2% Sr Small Ba,2% Sr Small Ba,2% Sr Small Ba,2% Sr	3.4 3.4 3.4 3.4	North America North America North America North America	1.3 Re 1.8 Re 3.5 Re 5.5 Re	n/a n/a n/a n/a	N. Hemisphere Winter 1991	moon down	Northern Canada-NASA DC-8 and AFGL KC-135 Northern Pacific- Learjet South America-Argentine 707 Ground sites in both northern and southern hemispheres
Stimulated Electron Precipitation/ Aurora Prod.	G-5	2 Large Li,3% Eu	18.5	North America	>6.0 Re	both same time	N. Hemisphere Winter, 91	moon down 0000-0200 LT	Same as G-1,-2,-3,-4 with addition of Millstone Hill radar(foot of field)
Stimulated Ion-Cyclotron Waves and Ion Precipitation	G-6	2 Large Li,3% Eu	18.5	North America	>6.0 Re	both same time	N. Hemisphere Winter, 91	moon down 2200-2400 LT	Same as G-1,-2,-3,-4 with addition of Millstone Hill radar(foot of field)
Ion Tracing and Acceleration	G-7	2 Large Li,3% Eu	18.5	North America	>6.0 Re	both same time	N. Hemisphere Winter, 91	moon down 2000-2400LT	Same as G-1,-2,-3,-4 with addition of Millstone Hill radar(foot of field)
Stimulating a Magneto-spheric Substorm	G-10	2 Large Ba,4% Li	24.8	North America	>6.0 Re	both same time	N. Hemisphere Winter, 91	moon down 0000-0200LT	Ground sites in both northern and southern hemispheres
Caribbean Perigee									
Gravitational Instability, Field Equipotentiality	G-8	2 Large Ba,2% Sr	24.4	field line pass thru Jicamarca,Peru (Grand Cayman Is.)	450-800 km	both same time	N. Hemisphere Summer,91	moon down, dawn 0500 LT	NASA DC-8 and Argentine 707 ground sites in Ecuador, Dom. Rep. Jicamarca radar
Field Line Tracing and Equipotentiality	G-9 G-11A G-11B G-12A G-12B	2 Large Ba,2% Sr Small Ba,2% Sr Small Ba,2% Sr Small Ba,2% Sr Small Ba,2% Sr	24.8 3.4 3.4 3.4 3.4	Caribbean latitudes Caribbean latitudes Caribbean latitudes Caribbean latitudes Caribbean latitudes	450-800 km 450-800 km 450-800 km 450-800 km 450-800 km	both same time n/a n/a n/a n/a	N. Hemisphere Summer, 91	two successive moon down periods, dawn 0500 LT	NASA DC-8 and AFGL KC-135 in Caribbean, Argentine 707 and Learjet in South America Arecibo radar and Jicamarca radar

RELEASE #	PRINCIPAL INVESTIGATOR
G-1,G-2,G-3	HOFFMAN
G-4,G-6	MENDE
G-5	BERNHARDT+ HAERENDEL
G-7	PETERSON
G-8	HAERENDEL
G-9	PONGRATZ + WESCOTT
G-10	SIMONS
G-11,G-12	WESCOTT
G-13,G-14	WESCOTT

* CHEMICAL WEIGHT INCLUDES THERMITE CHEMICALS

MISSION SEQUENCE

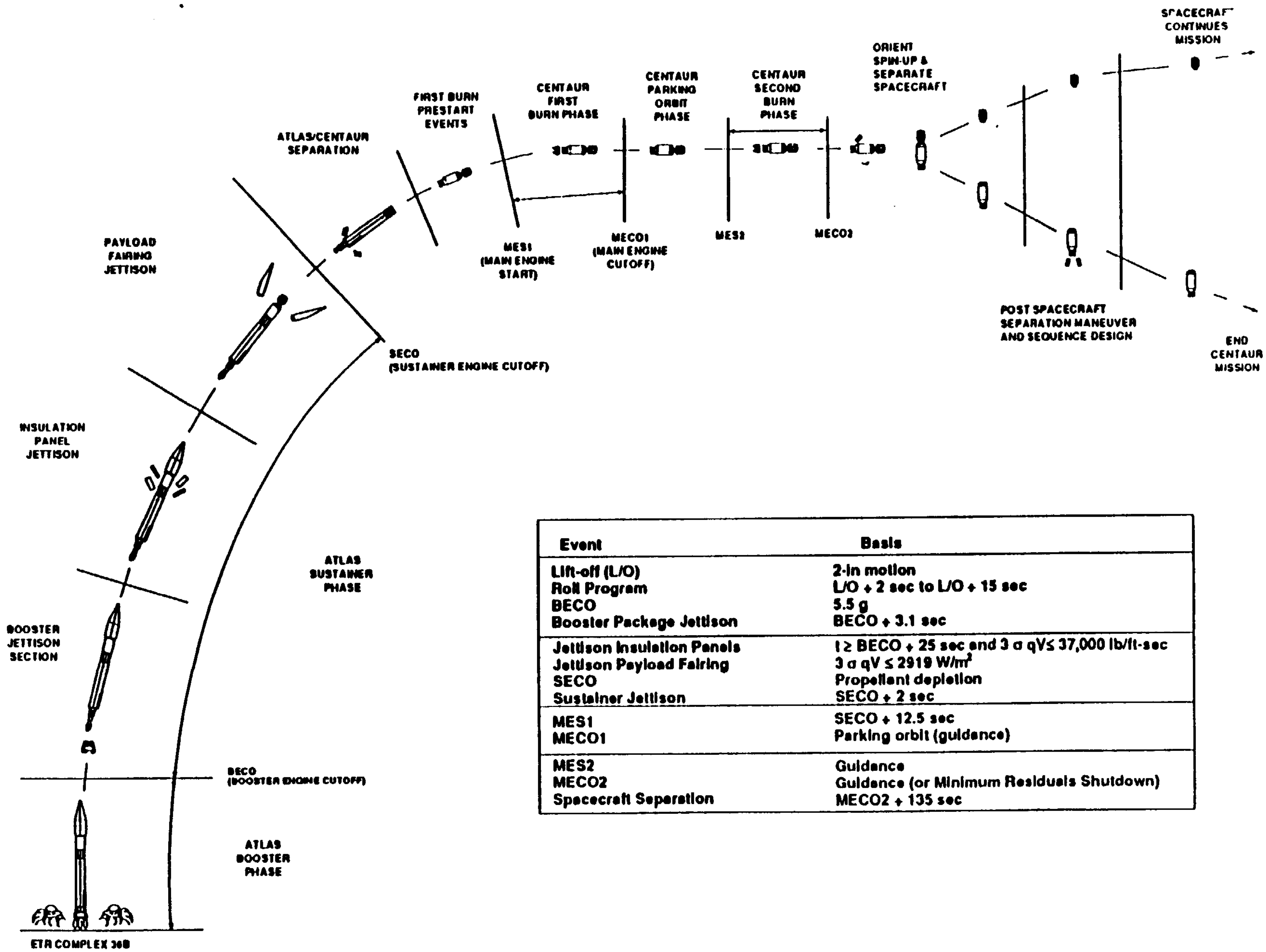
The CRRES spacecraft will be launched from the Cape Canaveral Air Force Station (Space Launch Complex 36B) by an Atlas I launch vehicle no earlier than June 23, 1990. The Atlas I flight profile is shown in Figure 1. The spacecraft will be inserted into a nominal orbit of 350 x 35,786 km and near 18 degrees inclination. Following orbit insertion, the Centaur will maneuver to the CRRES' required separation attitude, such that the spacecraft (+) Z-axis is parallel to the ecliptic plane and points 12 degrees ahead of the Sun's apparent motion. The Centaur will then initiate the required spin-up (2.2 + 0.2 rpm) and issue the separation command. After providing sufficient clearance from the separated spacecraft, the Centaur will perform the post-separation maneuvers for collision and contamination avoidance.

The spacecraft initialization phase is an approximately 30-day period after separation from the Centaur, during which the spacecraft subsystems and experiment payloads are configured and checked out in preparation for normal on-orbit operations. Vehicle checkout and initialization shall be accomplished within the first 72 hours of the mission. Some critical DoD science instruments shall be initialized as soon as possible, following separation (with a goal of within the first 24 hours). Initialization of the remaining instruments and instrument boom deployment shall not begin until all subsystems have been initialized and checked out. After final initialization and check-out of the CRRES spacecraft and its instruments is complete, normal on-orbit operations will begin.

Chemical releases are permitted at any time after completing spacecraft subsystem initialization and will normally occur after completing instrument initialization. The CRRES/GTO NASA science experiments consist of three chemical release campaigns.

The first chemical release campaign will be the South Pacific Critical Velocity Releases which will be done during the moon-down period approximately two months after launch when perigee is over the South Pacific at dusk local time. The CRRES/GTO High Altitude Releases will be conducted most probably in two successive moon-down periods in December 1990 and January 1991 when apogee is in the geotail for the first time. The final campaign will be the CRRES/GTO Caribbean Releases to be conducted in the Summer 1991 when perigee is over the Caribbean at dawn local times.

ATLAS/CENTAUR FLIGHT PROFILE



Event	Basis
Lift-off (L/O)	2-in motion
Roll Program	L/O + 2 sec to L/O + 15 sec
BECO	5.5 g
Booster Package Jettison	BECO + 3.1 sec
Jettison Insulation Panels	t ≥ BECO + 25 sec and 3 σ qV ≤ 37,000 lb/ft-sec
Jettison Payload Fairing	3 σ qV ≤ 2919 W/m²
SECO	Propellant depletion
Sustainer Jettison	SECO + 2 sec
MES1	SECO + 12.5 sec
MECO1	Parking orbit (guidance)
MES2	Guidance
MECO2	Guidance (or Minimum Residuals Shutdown)
Spacecraft Separation	MECO2 + 135 sec

Figure 1.

SPACECRAFT DESCRIPTION

The 3,842 pound CRRES spacecraft (Figure 2) is configured to contain eight compartments for holding science electronics, chemical canisters (Ba, Li, Ca, and Sr), an electrical power subsystem (EPS), a hydrazine reaction control subsystem (RCS), an attitude determination and control subsystem (ADCS), a telemetry, tracking, and control subsystem (TT&C), a magnetometer boom assembly, and a hoop antenna boom assembly. Also, TT&C subsystem antennas, science (wire and boom) antennas, science experiments and electronics, a nutation damper subsystem, and two solar arrays (SA) panels are located on the lower and upper decks of the spacecraft. To meet weight requirements necessitated by the change from a Space Transportation System (STS) launch to an ELV launch, two compartments that previously held two chemical modules containing 24 chemical canisters have been removed.

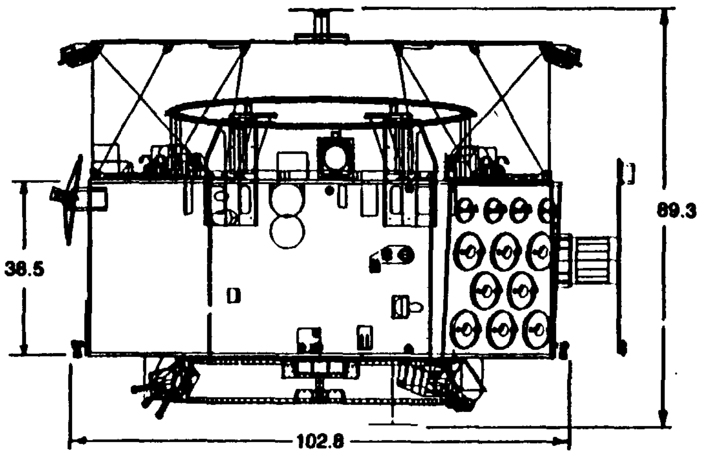
The EPS provides uninterrupted +28 dc power to the spacecraft power distribution system (PDS). The two SA panels mounted on the top deck provide relatively constant power to the spacecraft, and keep the two redundant nickel- cadmium batteries charged so they can provide spacecraft power during Sun eclipse periods. The EPS is a highly redundant system with the solar arrays, batteries, and the power control unit being fully redundant.

The command system provides up to 448 discrete commands, 32 serial digital commands, and 256 stored commands with about one second resolution and approximately 12 hours maximum delay. Data can be stored on redundant tape recorders at 16 kbps with a playback data rate of 256 kbps.

The ADCS subsystem, in conjunction with the RCS, provides for change in velocity and precession maneuvers and spacecraft spin-rate control. Precession maneuvers use the Sun and horizon sensors as a reference. Spin rate maneuvers use the Sun sensors as a reference. The horizon and Sun sensors also provide data for Sun acquisition. The attitude control electronics provides conditioned Sun sensor, horizon sensor, and magnetometer data to the telemetry data stream.

The on-board scientific experiments consist of 46 electronic boxes, 10 booms, and 24 chemical canisters. There are 16 PIs responsible for the 16 separate chemical releases (24 chemical canisters) planned for release at various times during the CRRES mission.

SPACECRAFT ARRANGEMENT



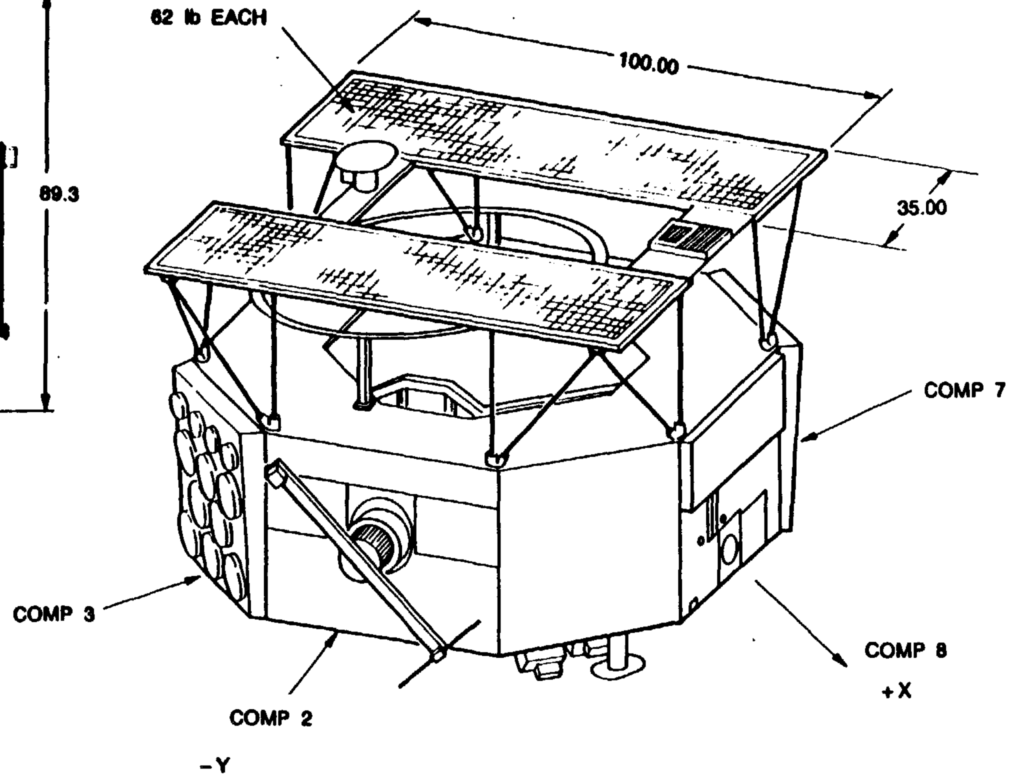


Figure 2.

LAUNCH-VEHICLE DESCRIPTION

The CRRES spacecraft will be launched from the Cape Canaveral Air Force Station (Space Launch Complex 36B) by an Atlas I launch vehicle. The length of the overall launch vehicle, including payload fairing, is 155.8 ft. The maximum diameter of the Atlas I is 10 ft while the diameter of the payload fairing is 13.75 ft.

The Atlas I launch vehicle system consists of the Atlas booster, the Centaur upper stage vehicle, and the payload fairing. The Atlas booster is 10 ft in diameter and 72.7 ft long and is powered by liquid oxygen and RP-1 fuel.

Atlas booster propulsion is provided by the Rocketdyne MA-5 engine system, which includes the sustainer, two vernier, and two booster engines. All engines are ignited prior to liftoff and develop a total sea level rated thrust of 439,338 pounds.

The Atlas I Centaur upper stage is 10 ft in diameter and 30 ft long and is integrated with the Atlas booster by the interstage adapter. The Centaur employs liquid hydrogen and liquid oxygen propellants. The propulsion system uses two RL10A-3-3A Pratt & Whitney engines. Each engine has a rated thrust of 16,500 pounds.

The payload compartment consists of the payload adapter and payload fairing. Figure 3 shows the CRRES in the launch configuration within the payload compartment. The CRRES is mounted to the launch vehicle using a payload adapter. This structure provides the mounting interface between the spacecraft and the Centaur equipment module.

The payload fairing which is a two-half-shell structure protects the CRRES from time of encapsulation through atmospheric ascent. The total length of the fairing is 40.1 ft. The cylindrical section provides 14 ft of length for the spacecraft and is 13.75 ft in diameter.

CRRES IN LAUNCH CONFIGURATION

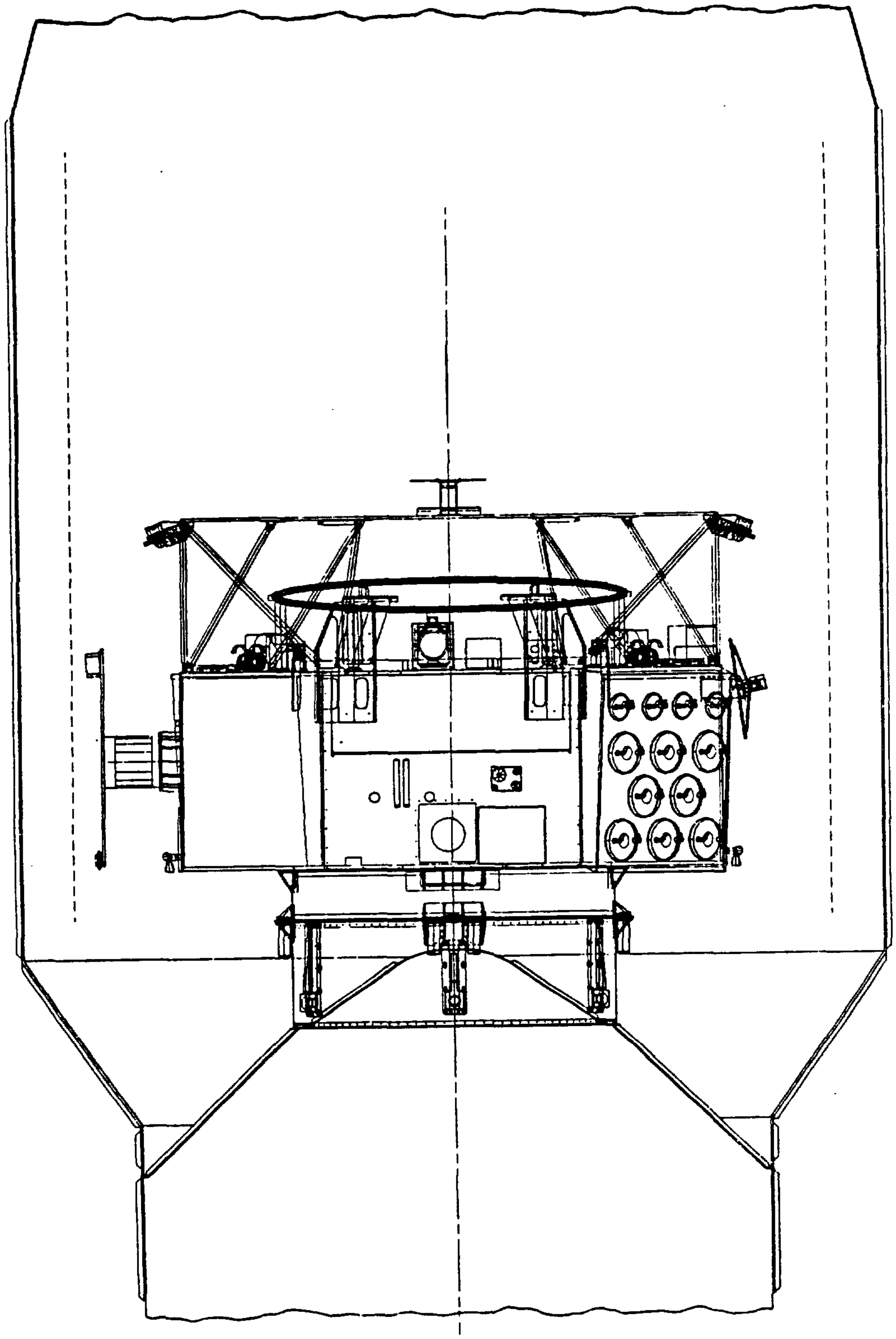


Figure 3.

MISSION SUPPORT

Support of the CRRES/GTO mission is a joint NASA/MSFC and Air Force/SSD effort. The Air Force's Consolidated Space Test Center (CSTC) will utilize the Air Force Satellite Control Network to receive and transmit all data to and from the CRRES spacecraft via the Space-Ground Link Subsystem (SGLS). The data link will be routed through the remote tracking stations to the CSTC located in Sunnyvale, California. The CSTC will perform the following tasks:

- Spacecraft health and status monitoring and control;
- Tracking station scheduling;
- Ephemeris generation to allow prediction of station contact and loss times, experiment operational opportunities, and for chemical releases;
- Spacecraft consumables and dynamic configuration status;
- Command generation and transmission to CRRES;
- CRRES maneuvers targeting computations;
- Coordination with NORAD relative to the proximity of the CRRES chemical releases to existing spacecraft in the affected orbits;
- CRRES/GTO mission data and communications support.

NASA/MSFC will support the NASA chemical releases segment of the mission by performing the following tasks:

- Chemical release planning and replanning utilizing data inputs provided by the CSTC;
- Chemical release times and location coordination with the NASA PI's;
- Observation aircraft, ground facilities, diplomatic liaisons, and communications coordination and support;
- Coordination of chemical release activities with the Air Force.

NASA/MSFC and Air Force/SSD will jointly support the operations associated with CRRES spacecraft operational integrity following spacecraft initialization/checkout. These operations include the CRRES system performance, long-term trend analysis, and anomalies.

MISSION MANAGEMENT RESPONSIBILITY

Overall management of the CRRES/GTO mission is a joint NASA and Air Force responsibility. The Office of Space Science and Applications (OSSA), NASA Headquarters, is responsible for the overall direction and evaluation of the NASA CRRES/GTO Program. The Associate Administrator for OSSA has assigned Headquarters responsibility for the CRRES/GTO Program to the Director of the Space Physics Division, who is responsible for program management of the CRRES Program.

The Marshall Space Flight Center (MSFC) has been assigned project management responsibility. Responsibility for management of the project at MSFC has been assigned to the CRRES Project Office of the Space Systems Projects Office.

NASA HEADQUARTERS

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NASA PROJECT COSTS

Estimated Costs of the NASA CRRES Chemical Release Program through FY 92*

PEGSAT	$2.3M
CRRES CHEMICAL CANISTERS, SCIENCE OPERATIONS AND DATA ANALYSIS	$22.5M
CRIE INSTRUMENT	$0.5M

*The estimated DoD cost for the CRRES spacecraft and the DoD experiments and investigations is approximately $150M.