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Overview of the LASSII Experiment on the Combined Release and Radiation Effects Satellite

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Introduction

THE Combined Release and Radiation Effects Satellite (CRRES) was launched into Earth orbit on July 25, 1990. Onboard CRRES is the Low Altitude Satellite Study of Ionospheric Irregularities (LASSII) experiment. The objective of LASSII is to study plasma irregularities in the ionosphere caused by naturally occurring and artificially created plasma instabilities. Specific investigations include equatorial spread-F, chemical releases, ionospheric modification by intense radio waves, and solar flare disturbances of the ionosphere. These studies will extend our understanding of the effects of ionospheric irregularities on radio-wave propagation in ionospheric ducts, through scintillating regions, and from space-based radars. We present an overview of the LASSII instruments, their measurement characteristics, and the planned orbit operations.

The LASSII experiment was originally proposed to the Department of Defense space test program in 1977 as a Shuttle-launched free flyer experiment that would be placed in orbit for a 1-2 week period, then recaptured for return to Earth and refurbishment, and reflight on subsequent Shuttle missions. In that concept, LASSII was to provide up to 10 different diagnostic measurements of the ionospheric plasma environment at low- and medium-magnetic latitudes, with the goal of providing a detailed understanding of spread-F irregularities, ionospheric chemical reactions, and plasma turbulence associated with these processes.[1] In its original version, the LASSII experiment was similar to what is now referred to as a "lightsat" experiment.

Although LASSII had a high priorty ranking, there was difficulty in getting enough funding to support the experiment; it was therefore decided to modify the experiment and combine it with other DoD and NASA missions, which resulted in LASSII becoming part of CRRES in 1981. The CRRES mission represented the first joint DoD/NASA space experiment of its kind, and would use the Shuttle to place CRRES into a circular orbit of 350 km altitude and 27 deg inclination. LASSII became the prime experiment to provide in-situ diagnostics of the NASA chemical releases to be performed in low Earth orbit (LEO). This low earth orbit mission would last 90 days, during which a total of about 48 chemical release experiments would take place. After those initial 90 ays, CRRES would be boosted into a geosynchronous trans- r orbit (GTO), where the rest of the radiation effects part of ıe mission would continue for at least one year. In this plan, ASSII would have performed most of its original mission most unchanged.

Major changes to the CRRES mission were required after ıe Shuttle Challenger was lost. As a result of the restructured nd constrained Shuttle schedule, it was decided that CRRES ould be launched aboard an expendable launch vehicle[2] (the tlas-Centaur). This new launch mode required a substantial reduction in weight for CRRES, in which about half of the chemical canisters for the NASA experiment were off-loaded, to be launched into the ionosphere from sounding rockets. LASSII experiments were reduced in weight by removal of a swept frequency plasma wave analyzer. In addition, the telemetry resources of the spacecraft were reduced so that the high speed data rates (256 and 64 kbps) originally planned for LASSII were eliminated, leaving only the low rate of 16 kbps. The planned sequence of operations involving separate LEO and GTO operations were also combined so that formerly LEO operations now took place during the perigee portion of the GTO orbit. These various changes in overall operations resulted in general descoping of the LASSII experiment and of the original plans; however, the basic mission to study the low-latitude ionosphere and to diagnose low-altitude chemical releases remained intact. One phase of the LASSII experiment plans was actually enhanced by the restructured mission, and that was to perform in-situ measurements in coordination with powerful ground-based high-frequency radio wave transmitters. This enhancement came about because the orbit inclination had to be reduced to 18 deg, thereby allowing CRRES to fly over the ionospheric diagnostics facility at Arecibo, Puerto Rico. Current plans call for the use of the hf ionospheric heater at Arecibo to conduct experiments in artificial stimulation of plasma instabilities in the ionosphere.

Experiment Overview

LASSII is composed of three space plasma experiments:

1) A Langmuir probe experiment that operates as two pulsed plasma probes (P^3) and is used to measure ionospheric electron densities and temperatures.

2) A quadrupole ion mass spectrometer (QIMS) that is used to measure the densities of positive ions in both the natural ionosphere and in the chemical release experiments.

3) An extremely low frequency wave analyzer (ELFWA) that is used to measure the spectrum of both electric and magnetic field fluctuations.

Summarized diagnostic capabilities of each of these experiments are given in Tables 1 and 2. The LASSII instrument locations on the top deck of the CRRES satellite are depicted in Fig. 1, which also shows the sensor booms for the P^3 and

Table 1 LASSII summary

Principal investigator:
Paul Rodriguez, Naval Research Laboratory
Co-investigators:
Mark M. Baumback (pulsed plasma probe), Naval Research Lab.
Harry C. Koons (extremely low-frequency wave analyzer), Aerospace Corp.
Donald E. Hunton (quadrupole ion mass spectrometer), Phillips Lab.

Instrument summary:

	Boxes	Booms	Weight, kg	Power, W	Bit rate, bps	Commands
P^3	3	2	4.8	5.2	6274	2[a]
ELFWA	4	3	7.7	5.0	4030	14
QIMS	2	—	12.9	11.0	2024	12
Total	9	5	25.4	21.2	12,328	28

[a]Plus one serial digital command

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Table 2 LASSII instrument characteristics

Instrument	Measurement	Range	
P^3 (pulsed plasma probe)	Plasma density	$N_e = 10^2 - 5 \times 10^7$ cm^{-3}	
	Electron temperature	$Te = 200$–$20{,}000$ K	
	Density fluctuations	$\Delta N_e/N_e = 2\%$	
	Space-time resolution	$\Delta x = 40$ m	
		$\Delta t = 5$ ms	
	Fluctuation spectrum	$f_{nyq} = 100$ Hz	
	Spacecraft potential	$V_{sc}: \pm 14$ V	
		Electric field single axis, 4 m tip-to-tip	Magnetic field single loop, 0.5 m diam
ELFWA (ELF wave analyzer)	Sensitivity	$\Delta E = 1\ \mu$V m^{-1}	$\Delta B = 30$ nT
	Frequency range	$f = 0$–250 Hz	$f = 10$–125 Hz
	Dynamic range	100 dB	100 dB
QIMS (quadrupole ion mass spectrometer	Positive ion composition	N_i (M_{i+}): 1–150 amu	
	Ion mass resolution	(1–70 amu): adjacent masses	
		>70 amu: adjacent masses with few amu spread	
	Space-time resolution	Δx/mass peak = 120 m	
		Δt/mass peak = 16 ms	
	Sensitivity range	$N_i = 10$–10^6 cm^{-3}	

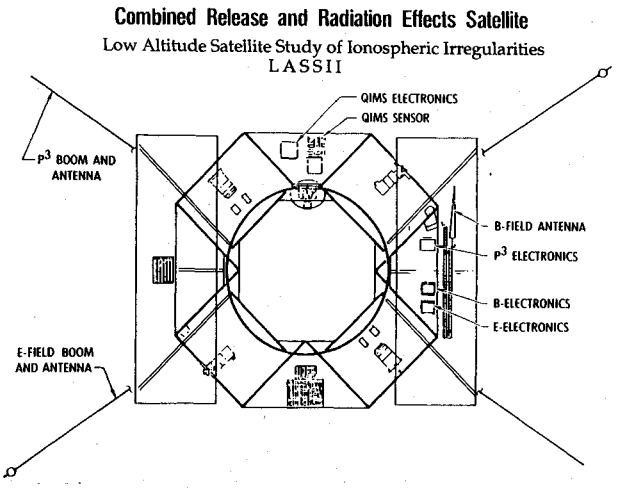

Fig. 1 Location of LASSII instruments on the top deck of CRRES.

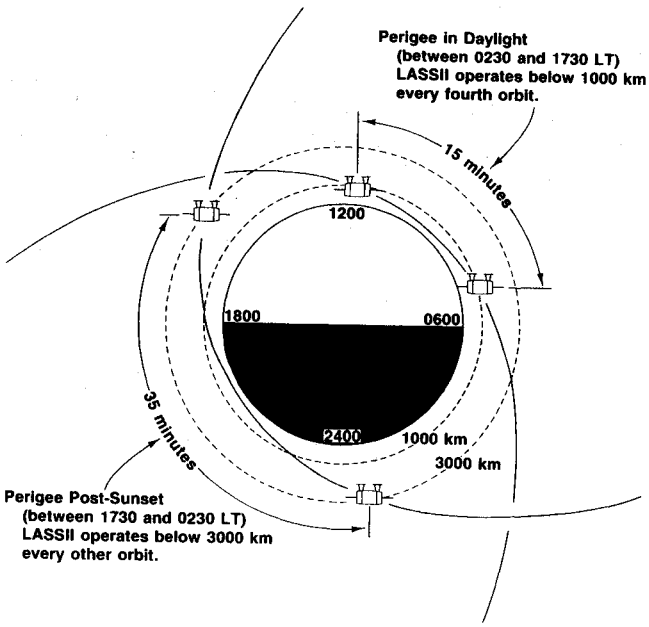

Fig. 2 LASSII operations in the CRRES orbit.

ELFWA experiments. In the following papers on the individual LASSII instruments, further details of the experiment operations and measurements are provided.

Orbit Operations

The LASSII experiment is scheduled to operate over the low-altitude portion of the CRRES orbit, which is essentially a geosychronous transfer orbit (apogee at about $6.5R_e$, perigee at 385 km, inclination 18 deg). The orbital period is about 9.8 h. The duty cycling for LASSII orbit operations is illustrated in Fig. 2. Prime scientific interest is in the nighttime sector of the orbit and in the dawn and dust transitions, for altitudes below about 3000 km. Since the CRRES orbit precesses, orbit perigee swings around the Earth with an apparent drift period of 1.5 years. When perigee is in the nighttime sector, LASSII acquires in-situ measurements every other orbit below 3000 km altitude. This duty cycling was derived as a compromise with the space radiation effects experiments, which required data acquisition during an entire orbit. Because the telemetry system design on CRRES could not be modified after the change to an expendable vehicle launch, it was not possible to operate both LASSII and the space radiation experiments simultaneously. Even so, a key subset of space radiation experiments were accommodated into the normal LASSII telemetry format so that continuous data could be acquired even when LASSII was operating. When perigee precesses into the daytime ionosphere, the orbit operations call for LASSII data to be acquired every fourth orbit below 3000 km. A significant modification to these operations is related to the NASA chemical release experiments which are to take place at low altitude. For these two campaigns (one in the South Pacific in September 1990, and one in the Caribbean in July and August 1991), the LASSII experiment will be operational on every orbit below 3000 km beginning several orbits before the first chemical release and ending several orbits after the last chemical release. This plan allows orbit-by-orbit measurement of the background ionosphere and perturbations to the ionosphere by the chemical releases. Fortunately, in the Caribbean campaign the orbit is to be adjusted into a three-day cycle that will bring the perigee of CRRES over the Arecibo ionospheric diagnostic facility in Puerto Rico at about the same time every seven orbits. This three-day cycle offers the best opportunity for LASSII to perform in-situ measurements when the ionosphere is modified by the high-power radio wave heater at Arecibo.

References

[1]Szuszczewicz, E. P., and Palma, R. E., "The LASSII Program: Objectives, Spacecraft Design, and Mission Scenarios for Full-Scale, Shuttle-Launched, Free-Flyer Operations," Naval Research Lab., NRL Rept. 8420, Washington, DC, June, 1982.

[2]*CRRES System Description Handbook,* Ball Aerospace, Space Systems Division, Boulder, CO, 1989.