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NRL Memorandum Report 4149

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# NRL-701/LASSII

## A Sortie-Mode Satellite Designed to Exploit the Shuttle in Studies of Natural and Artificial Ionospheric Irregularities and Their Associated Effects on Military Systems

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Based on a presentation to the Navy Space Test Program Review Committee (25 September 1979)

E. P. SZUSZCZEWICZ  
Space Science Division

February 22, 1980

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20 ABSTRACT (Continue on reverse side if necessary and identify by block number)  The LASSII spacecraft is a sortie-mode satellite designed to be launched and recovered by Shuttle, and instrumented with a complement of plasma diagnostic tools which have been specifically designed to spatially and temporally resolve all the active elements within an ionospheric irregularity. The satellite, configured for maximum flexibility as an investigative platform, will co-orbit in tandem or in overflight with a Shuttle-borne plasma diagnostics complement, making possible separation of space and time dependencies and allowing important determinations of		

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20. ABSTRACT (Continued)

- growth and transport mechanisms in turbulent ionospheric plasmas and their associated effects on military systems. The satellite will be able to execute Hohmann and Crocco maneuvers with complete flexibility for selection of time spacing between Shuttle-borne and LASSII free-flyer measurements of a given ionospheric volume.

The uniqueness of the LASSII Mission makes it compatible with all Shuttle orbits from 200 to 1000 km and for all inclinations. The nature of the program, with emphasis on naturally-occurring as well as artificially-produced ionospheric irregularities, is accommodated by Shuttle regardless of season or solar conditions. Program planning will focus on short-duration (7-30 days) experiments which will take advantage of built-in flexibility in the LASSII payload complement. The experiment duration will help develop efficiency through a concentrated approach designed to provide near-term solutions to research and development problems.

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## **PREFACE**

This document has been prepared in an effort to provide an overview of the LASSII Program from perspectives which consider early-phase mission objectives and philosophy, military relevance, scientific considerations, spacecraft design rationale, instrumentation and Shuttle-unique capabilities. Since LASSII is intended as a facility-class capability for DoD-wide research and the test development of military systems impacted by the near-Earth ionospheric and magnetospheric environments, it is hoped that this document will provide potential users with sufficient information to select those aspects of the LASSII program which can support or expand their own investigations. Where necessary, additional instrumentation can become part of the spacecraft complement, the additions being made possible by a 30% subsystem (power, TM, etc.) growth capability.

**Edward P. Szuszczewicz**  
**LASSII Program Manager**

NRL-701/LASSII

**A SORTIE-MODE SATELLITE DESIGNED TO  
EXPLOIT THE SHUTTLE IN STUDIES OF NATURAL AND  
ARTIFICIAL IONOSPHERIC IRREGULARITIES AND THEIR  
ASSOCIATED EFFECTS ON MILITARY SYSTEMS**

**I. INTRODUCTION**

The Department of Defense has a continuing need for improved understanding of plasma processes in the near-earth charged particle environment and their relationships to military personnel and systems. In the case of transionospheric radiowave propagation, it is important to know ionospheric plasma production-loss mechanisms and the multitude of processes which control distribution and kinetics. In this regard solar and magnetospheric coupling as well as *our planetary fields and wind systems all play important roles.*

Over the years ground-based radar and ionosonde measurements as well as "in situ" rocket and satellite data have coupled with developing theoretical and computational models to provide basic descriptions of ionospheric conditions which affect many systems. Among the many problem areas are long range HF propagation, accuracy of direction finding, and naturally occurring scintillation phenomena.

Recent advances in technology and improved scientific understanding have been able to probe beyond these basic descriptions of the zero order quiescent ionosphere. Efforts are now focusing on details of the fundamental cause-effect relationships responsible for ionospheric irregularities and associated plasma instability mechanisms. These efforts represent important

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E. P. SZUSZCZEWICZ

challenges in an ever-maturing science which looks to the quiet and turbulent ionosphere as a charged-particle environment that can be controlled and utilized for plasma and systems experiments untenable in confining laboratory chambers. To meet this challenge, the Naval Research Laboratory in collaboration with a large number of government agencies, universities, and private institutions has developed the LASSII (Low Altitude Satellite Studies of ionospheric Irrregularities) program in a way intended to synthesize military needs with the latest thinking in theoretical and experimental plasma physics, ionospheric research, spacecraft technology and communication engineering.

## II. PROGRAM OVERVIEW

LASSII is a coordinated investigation into the cause-effect relationships between plasma irregularities and C<sup>3</sup>/I (Command, Control, Communications and Intelligence) failure modes within a naturally and artificially disturbed ionosphere. It is directed at the exploitation of ionospheric phenomena and shuttle unique capabilities to develop techniques for mitigation of C<sup>3</sup>/I failure modes through ionospheric control and adaptive system design.

LASSII utilizes a sortie-mode satellite designed to be launched and recovered by Shuttle. Formation flights of the satellite with Shuttle-borne sensor packages will provide the first capability for the separation of space and time variations in the ionosphere and their effects on command, control and communications systems.

There are three coupled objectives in the LASSII program. First is the development of a truly predictive capability for the onset of natural and artificial ionospheric irregularities and their associated effects on C<sup>3</sup>/I systems. Second is the development of techniques for mitigation of perturbing plasma effects in the near-earth environment through ionospheric control and properly conceived adaptive system design. The ionospheric plasma effects include natural

NRL-701 SHUTTLED LASSII

A COORDINATED INVESTIGATION INTO THE CAUSE EFFECT RELATIONSHIPS BETWEEN PLASMA IRREGULARITIES AND  $C^3I$  FAILURE MODES WITHIN THE NATURAL AND ARTIFICIALLY DISTURBED IONOSPHERE

EXPLOITATION OF IONOSPHERIC PHENOMENA AND SHUTTLE-UNIQUE CAPABILITIES TO DEVELOP TECHNIQUES FOR MITIGATION OF  $C^3I$  FAILURE MODES THROUGH IONOSPHERIC CONTROL AND/OR ADAPTIVE SYSTEM DESIGN

Figure 1 - General Programmatic Considerations

causes (e.g., equatorial spread F, energetic particle precipitation) or man-made effects (chemical releases, atmospheric detonations, artificial injection of energetic beams, and nuclear warfare). The third objective is the development of a facility-class capability for general application to DoD-wide ionospheric research as well as the test and development of military systems affected by geophysical plasma phenomena.

The program addresses important operational needs threatened by ionospheric effects. For example,  $C^3I$  capabilities are impaired by solar ionospheric disturbances. The entire electromagnetic spectrum from ELF to EHF hinges critically on the propagation medium and presently there are no inherent capabilities to monitor, analyze and forecast solar/ionospheric disturbances or assess impact on  $C^3I$  system performance. Specific illustration includes the well

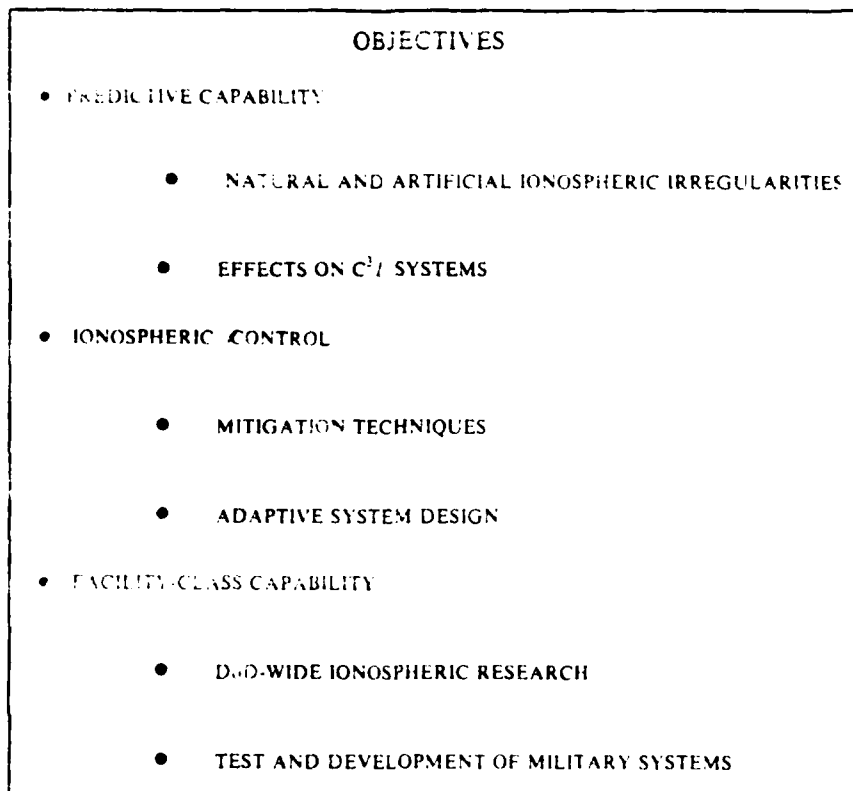


Figure 2 — LASSII Program Objectives

known scintillation problems which seriously limit the reliability of operational satellites, particularly those operating in the UHF domain (e.g., GAPFILLER and FLEETSATCOM). Studies showed that scintillations near 250 megahertz can be very intense, exceeding 25 db peak-to-peak, fading quite regularly into the system noise. Existing data exhibit UHF satellite systems with 50% outages between 1800 and 2400 hours local time in equatorial regions.

OPERATIONAL NEEDS

ELECTROMAGNETIC PREDICTION AND ASSESSMENT SYSTEM

(EPAS)

OR-0903-CC

*THREAT*

- EM AND M WEAPONS AND SENSOR SYSTEMS THREATENED BY IONOSPHERIC EFFECTS ON PROPAGATION MEDIUM
- EFFECTIVE USE OF DOD RESOURCES REQUIRE TIMELY AND ACCURATE ASSESSMENT OF NEAR-EARTH SPACE ENVIRONMENT

*OPERATIONAL PROBLEM*

- $C^3I$  CAPABILITIES IMPAIRED BY SOLAR/IONOSPHERIC DISTURBANCES
- ELF — EHF PERFORMANCES HINGE CRITICALLY ON THE PROPAGATION MEDIUM
- PRESENTLY NO INHERENT CAPABILITY TO MONITOR, ANALYZE OR FORECAST SOLAR/IONOSPHERIC DISTURBANCES OR ASSESS IMPACT ON  $C^3I$  SYSTEM PERFORMANCE.

Figure 3 — Some of the operational needs addressed by the program

AN EXAMPLE OF A  
DOD OPERATIONAL DEFICIENCY

1. SCINTILLATIONS SERIOUSLY LIMIT THE RELIABILITY OF OPERATIONAL SATELLITES PARTICULARLY THOSE OPERATING IN THE UHF (e.g. *GAP-FILLER ELTSATCOM*)

"THE UHF SCINTILLATION NEAR 250 MHz WAS VERY INTENSE, EXCEEDING 25 dB PEAK-TO-PEAK, AND FADED QUITE REGULARLY INTO THE SYSTEM NOISE"

2. PRESENTLY NO UNDERSTANDING OF CAUSE-EFFECT RELATIONSHIPS BETWEEN PLASMA INSTABILITIES, IONOSPHERIC IRREGULARITIES AND SCINTILLATION PHENOMENA THEREFORE WE HAVE NO TRULY PREDICTIVE CAPABILITY

"UHF SATELLITE SYSTEMS HAVE 50% OUTAGES BETWEEN 1800 AND 2400 HR LT IN EQUATORIAL REGIONS"

Figure 4 — An example of a long standing DoD deficiency.

Various experimental observations indicate that ionospheric irregularities (i.e. spatial and temporal variations in the ambient plasma electron density) are the cause of many of these signal channel effects. These irregularities can occur at all ionospheric altitudes and are known to result from natural as well as artificial causes. The current technology base has been largely determined by naturally occurring irregularities (e.g., equatorial spread F, auroral phenomena, solar flare effects, etc.) which have reasonably well defined morphologies. The morphological models, however, provide no intrinsic understanding of the cause-effect relationships and consequently provide no predictive capabilities necessary for a fail-safe C<sup>3</sup>I posture. While the LASSII program unfolds the fundamental cause-effect relationships active in the naturally irregular ionosphere it will apply the developing understanding to effective applications in ionospheric control. Just how this is done is easily illustrated by selecting only one of the important areas in which the LASSII efforts will be directed. The area selected is that of equatorial F region irregularities, more specifically, equatorial spread F.

### III. THE SYNERGISM OF NATURAL AND ARTIFICIAL IONOSPHERIC CONTROLS

While equatorial spread F is essentially a nighttime phenomenon, it has significant latitudinal, diurnal, seasonal and solar cycle variations, with day-to-day perturbations superimposed. For almost thirty years it has been known that during the occurrence of equatorial spread F there were simultaneous occurrences of broadband scintillation phenomena.

Perhaps the largest data base for the time and space development of equatorial spread F has come from the Jicamarca Observatory operating at 50 megahertz and sensitive to 3-meter size irregularities. The grey scale in Fig. 5 shows the intensity of radar energy reflected from three-meter irregularities. The darker the image, the greater the reflected energy. The dotted

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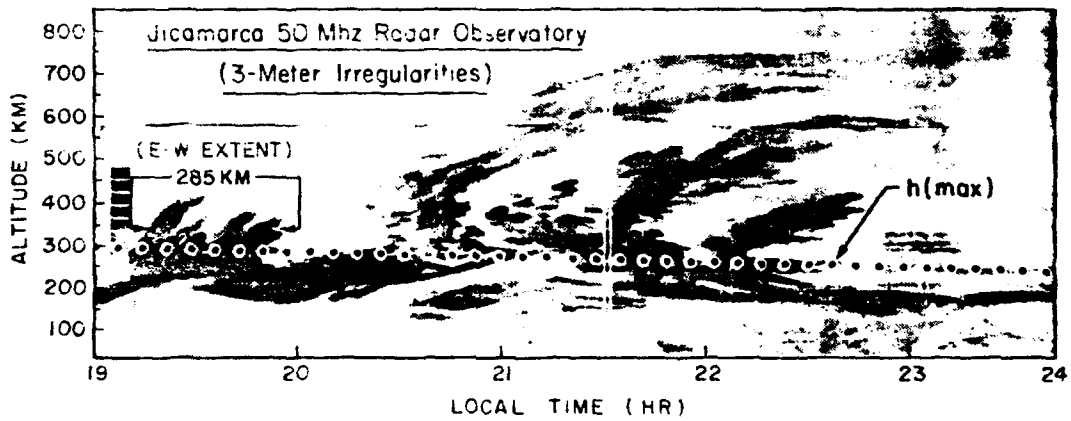


Figure 5 - Range-time-intensity (RTI) plot of backscatter energy at Jicamarca Observatory. Superimposed is the nominal location of the F-layer peak (from "PLASMA INSTABILITIES IN THE EQUATORIAL F-REGION: NATURAL AND ARTIFICIAL MECHANISMS" by E. P. Szuszczewicz, S. L. Ossakow, G. W. Sjolander, J. C. Holmes, and D. N. Walker in NRL Memorandum Report 3940 (April 17, 1979)).

line on the RTi plot locates the nominal altitude of the F layer peak. Salient features in this figure are as follows:

The three-meter size irregularities are fundamentally a bottom-side spread F condition in the early evening hours. Irregularities tend to rise up and break away from their lower altitude source region. This observation has spawned the use of the term "bubbles", "plumes", and "fingers" to describe the motion of the irregularity domains. The irregularities that break away generally move upward with their intensity decreasing as time moves into the early morning hours. Bottom-side irregularities generally persist throughout the entire period of spread F conditions. This is not the case for the topside irregularities.

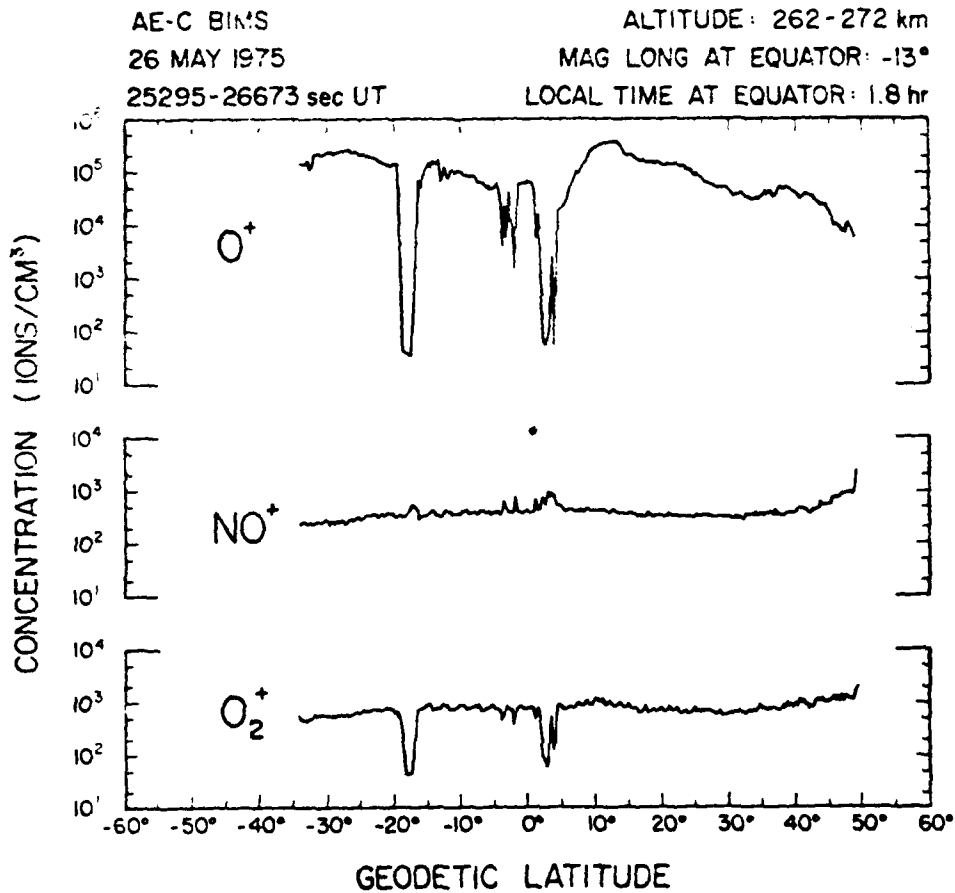


Figure 6 — AE-C Bennett ion mass spectrometer (BIMS) measurement of  $O^+$ ,  $O_2^+$ , and  $NO^+$  in a single equatorial crossing near 265 km (from Szuszczewicz, "Ionospheric holes and equatorial spread F: Chemistry and transport," J. Geophys. Res. 83, 2365, 1978).

For years it appeared that the majority of irregularities fell into the noise-like structure with an altitude increasing approximately as the irregularity scale size. Some satellite studies showed an apparent continuous distribution of irregularities from 70 meters to 7 kilometers. More recently, however, there has been a great deal of satellite work that indicates that equatorial bite-outs (or holes as they are often referred to) occur more frequently than was originally thought, and in fact, are considered just as characteristic of spread F as the less intense irregularities. Figure 6 shows data from a satellite pass at F region altitudes near the equatorial domain. Normally, the F region ionosphere is dominated by the  $O^+$  species. As the satellite passed through the equator in the nighttime hemisphere the data revealed two, three, and four decade drops in the ionospheric plasma density with  $O^+$  falling to levels lower than  $NO^+$  (normally a minor constituent at the altitudes in question). Parallel theoretical and experimental studies began to identify the occurrence of these large scale ionospheric depletions with the much smaller scale size irregularity structures studied for many years by range-time-intensity plots. Ion chemistry and transport considerations were found to support the concept that equatorial holes and equatorial spread F could be one and the same phenomenon with the smaller scale irregularities imbedded within the much larger scale ionospheric depletions. The chemistry and transport model which emerged from the analysis considered a given chemical volume on the bottom-side of the F layer moving upward through a stationary neutral ionosphere, and appearing at higher altitudes as a bite-out in the local plasma density. As this plasma cell moved upward the relative magnitudes of ionospheric components depended on the height distribution of the neutral gases. The concept of the upward moving ionospheric plasma cell was found to be in agreement with drift velocity measurements on the same satellite as well as being consistent with computational work which showed that bottom-side F region irregularities at low plasma densities could move upward and appear at higher altitudes as ionospheric holes.

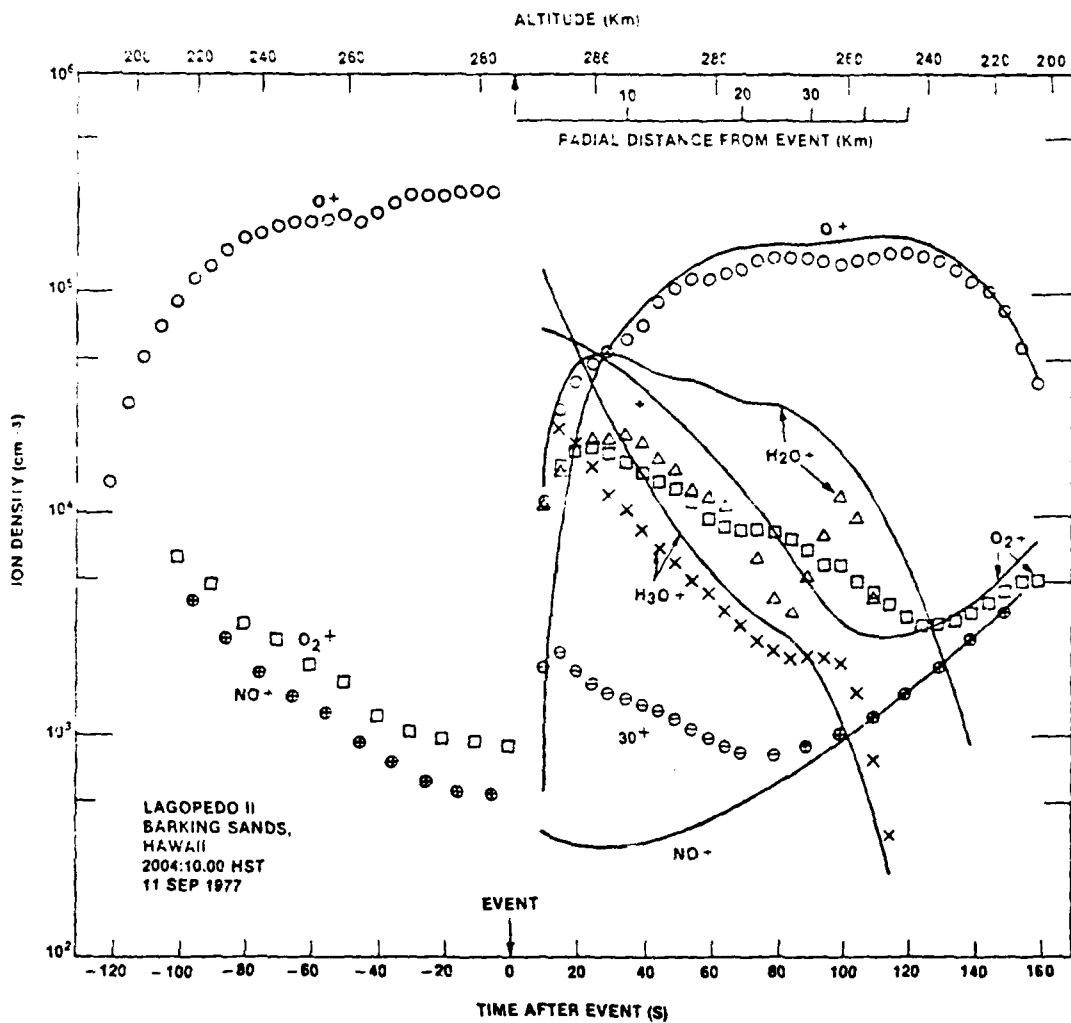


Figure 7 — Lagonedo II rocket-borne mass spectrometer results (symbols) and computer simulation (solid lines). The data is presented as a function of time and radial distance (see inset at top of figure) relative to the event (i.e.  $r \equiv 0$  for explosive detonation). Rocket altitude is presented on the top abscissa (from Sjolander and Szuszczewicz, "Chemically depleted  $F_2$  ion composition: Measurements and theory," *J. Geophys. Res.* **84**, 4393, 1979.)

With an improved understanding of naturally occurring equatorial spread F came a parallel interest in the creation of artificial ionospheric holes by chemical injection. The principle of ionospheric control by chemical injection involves the release of a chemically reactive gas, (for example,  $\text{H}_2$  or  $\text{H}_2\text{O}$ ) into the  $\text{O}^+$  dominant F region. This enhances the normally slow depletion-limiting reactions by introducing a more rapid process of charge exchange. The subsequent dissociative recombination of the artificially produced molecular ions results in a charge depletion process which exceeds that naturally occurring in the  $\text{O}^+$  dominant ionospheric F region.

This concept was tested in a recent experiment referred to as Project Lagopedo. This experiment employed an 88 kilogram release of nitro-methane ammonium nitrate explosive which yielded an approximately equal distribution of  $\text{H}_2\text{O}$ ,  $\text{CO}_2$ , and  $\text{N}_2$ . The results, shown in Fig. 7 include: First, the unequivocal determination of an artificial hole with an approximate radius of 40 kilometers and local depletions ranging from three orders of magnitude in the near-event space-time domain to approximately a factor of 50% near the edges of the injected cloud of gases. The second result was the presence of ion components normally not found in the natural ionosphere, for example  $\text{H}_3\text{O}^+$ ,  $\text{H}_2\text{O}^+$ ,  $\text{HCO}^+$ ,  $\text{HCO}_2^+$  and aluminum from the disintegration of the explosive canister. These products of the injection process could prove themselves as easily identified tracers in an application to artificial spread F, particularly if the holes were created on the bottom-side and rose to higher altitudes.

The coupling is almost complete. On the one hand we have the natural occurrence of equatorial spread F, the appearance of small scale irregularities, and the apparent coexistence of large ionospheric depletions referred to as ionospheric holes. On the other hand we now have the demonstrated capability for creating our own ionospheric hole. The question arises as to whether or not we can in fact artificially generate equatorial spread F by the release of chemically reactive gases on the bottom-side of the F layer.

$N_0 \times 10^{-5} \text{ CM}^{-3}$

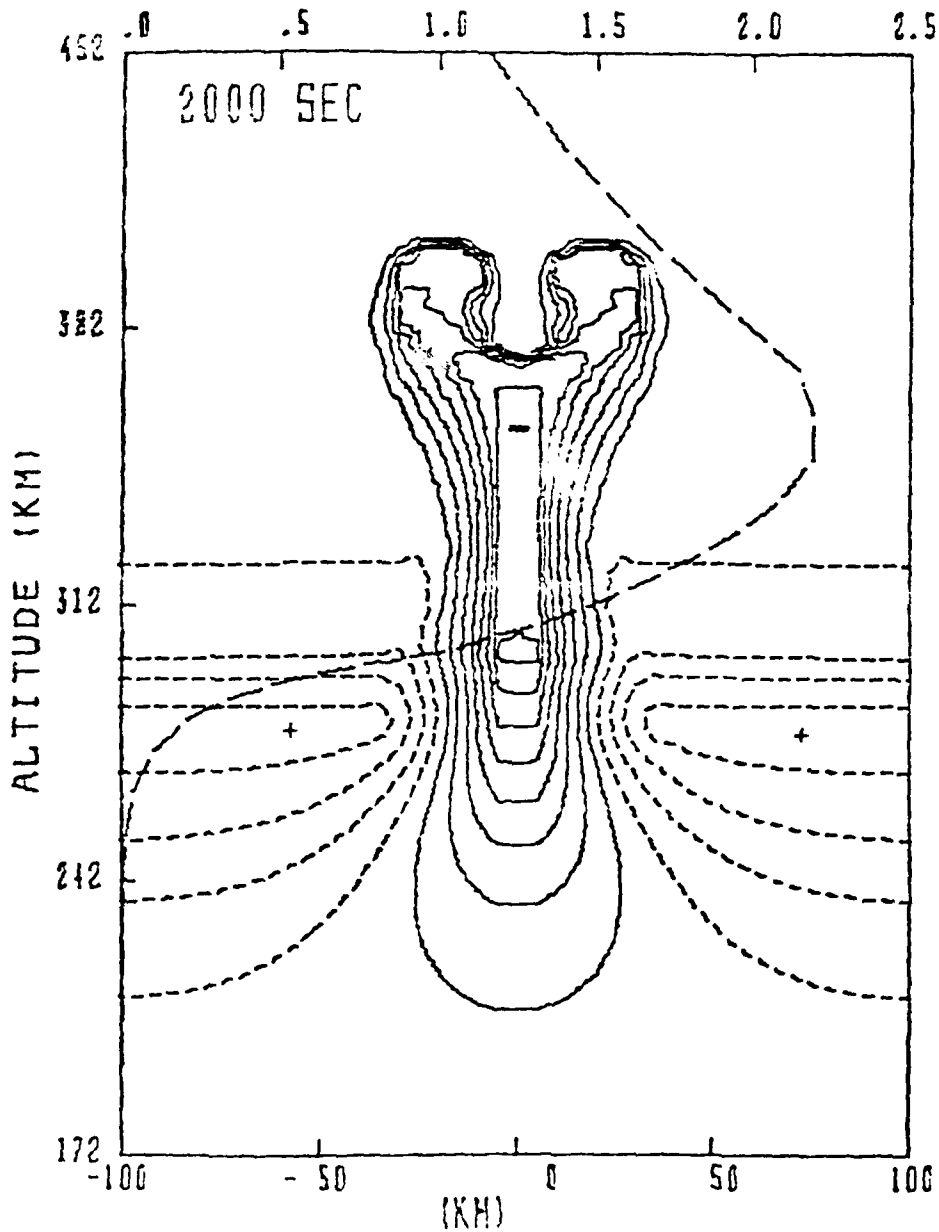


Figure 8 - Contour plots of constant  $n_1/n_0$  for  $t = 2000$  sec. The large dashed curve represents a plot of the ambient electron number density (values on upper horizontal axis)  $n_0$ , as a function of altitude. The vertical ( $z$ ) axis represents altitude, the lower horizontal ( $x$ ) axis eastwest range, and the ambient magnetic field is out of the figure ( $z$ ). At  $t = 0$  sec the computer code assumes a reactive chemical release on the bottomside  $F$  region at a 300 km altitude. The "a priori" description of the hole defines the innermost depletion at the 96° level. At  $t = 2000$  sec the code predicts that the depletion would have risen through the  $F$  peak and bifurcated on its topside gradient. The contours present equidensity domains with (+) representing local plasma enhancements and (-) representing depletions (from Ossakow et al., Ionospheric modification. An initial report on artificially created equatorial spread  $F$ , Geophys. Res. L. 5, 691, 1978).

In order to explore the possibility of artificial spread F, a computational model was developed which merged the principles of Lagopedo with previous nonlinear numerical codes. The model did not follow the chemical kinetics of the actual time- and space-dependent depletion process, but followed the evolution of the hole after it was produced (assuming time-dependent chemistry was no longer in effect). One of the simulations assumed the F-layer at 350 km with a peak background plasma density  $n_e = 2.2 (10^5) \text{ cm}^{-3}$ . Initial conditions on the hole assumed a constant 97% depletion over a central 30 km domain decreasing to the ambient density over a 20 km extent on each side (total extent of the assumed hole was 70 km). The hole was located on the bottom-side gradient at a release altitude of 300 km. A "snapshot" in the evolutionary process of the bubble is shown in Fig. 8 where at  $t = 2000$  sec the top of the hole has penetrated the F-peak. If our understanding is correct, small scale irregularities and scintillation effects will be coexistent in space and time. These results and others in the same work point to the realistic application of chemical modification to artificial equatorial spread F.

While much progress has already been made in understanding equatorial spread F phenomena, more detailed work needs to be done on the fundamental plasma processes in order to definitively unfold the active first principles. For example, we have yet to define the electron density fluctuation power spectrum over the broad domain encompassed by equatorial spread F. The preceding discussions clearly point to the importance of these measurements as a first approach in understanding the multi-step plasma processes in which large scale irregularities cascade to much smaller dimensions. We need to determine specific effects of the zero-order ionospheric conditions like the location and the intensity of the F layer peak, the effect of the scale size of the bottom-side gradient, and the importance of ion inertia. We need to study equatorial spread F bubble decay processes relative to diffusion parallel and perpendicular to the magnetic field. We need to test the concept of plasma cells transporting bottom-side zero-order ion composition to higher altitudes. We need to explore and understand detailed irregularity

spectral characteristics as a function of space, time and F layer parameters. We need to study the spectral indices in, across, and outside the ionospheric holes, and of course, we need to study the degradation of satellite-to-satellite and satellite-to-ground communication channels as a function of these spectral indices and possible controls by artificial means.

SPECIFIC ISSUES

- 1) IRREGULARITY SPECTRAL CHARACTERISTICS OVER "ENTIRE" SPECTRUM
  - FUNCTION OF SPACE, TIME, AND F-LAYER PARAMETERS
  - SPECTRAL INDICES IN-, ACROSS-, AND OUTSIDE HOLES
  - EFFECTS ON DIFFUSION
- 2) BALANCE BETWEEN CHEMISTRY AND DYNAMICS
  - ZERO-ORDER ION COMPOSITION
  - ROLE OF ION COMPOSITION IN BUBBLE FORMATION AND DECAY PROCESSES
  - ROLE OF ELECTRON TEMPERATURE (CHEMISTRY, DIFFUSION, GROWTH RATES AND CUT-OFFS)
- 3) MITIGATION AND CONTROL
  - ACTIVE EXPERIMENTATION IN SPACE
  - TESTS LEVEL OF UNDERSTANDING
  - IMPROVE MILITARY SYSTEM PERFORMANCE

Figure 9 - Some specific scientific issues directly related to ionospheric modification and control and their associated effects on military systems.

**IV. GENERAL AREAS OF INVESTIGATION**

Equatorial irregularities represent only one subset of the many areas that the LASSII program will begin to exploit. Other experiments in the category of chemical releases include the generation of artificial gravity waves by inert gases and striations by barium clouds. The pro-

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gram will also study electromagnetic wave propagation over the spectrum from the VLF to EHF. Attention will also be given to wave-particle interactions, ionospheric heating, pulse propagation and HF ducting. In addition, the details of beam plasma interactions will be investigated from a point of view that includes conductivity modifications, spacecraft charging, and the generation of artificial aurora. The opportunities for active experimentation and space system testing are limitless. Space laser applications, for example, is another area to exploit in the LASSII program.

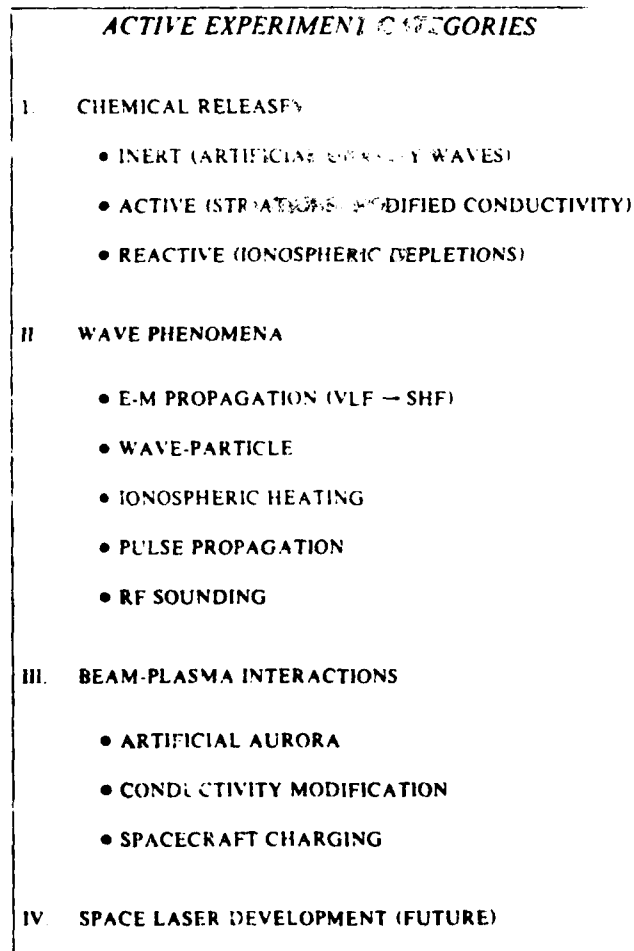


Figure 10 - Controlled active experimentation in space is a major element in the LASSII program

## V. INSTRUMENTATION AND SPACECRAFT DESIGN

The LASSII team has diligently pursued the active first principles in ionospheric plasma physics, it has synthesized current understanding, and is actively exploring it for applications to mitigation techniques. The team has generated a list of unknowns and associated observables that will help contribute to a complete understanding of the entire process of ionospheric plasma turbulence. The synthesis of existing experimental information and theoretical and computational work pointed to a comprehensive list of measurements involving four-frequency-band signal channel detection, electron density, temperature, density fluctuation power spectra, ion and neutral composition, temperature, drift velocities, electric and magnetic fields, energetic particle spectra, photometric and spectrometric diagnostics, and spacecraft potential.

### LASSII SCIENTIFIC INSTRUMENTS

FAR ULTRAVIOLET SPECTROGRAPH (FUVS)	RETARDING POTENTIAL ANALYZER (RPA)
VACUUM ULTRAVIOLET PHOTOMETER (VUVP)	COLD CATHODE ION GAUGE (CCIG)
FOUR FREQUENCY-DOMAIN RADIO PROPAGATION (FFRP)	MAGNETIC ELECTRON SPECTROMETER (MES)
PULSED PLASMA PROBE (P <sup>3</sup> )	RING CURRENT PARTICLE SYSTEM (RCPS)
ELECTRIC FIELD (E-FIELD)	PHOTOELECTRON SPECTROMETER (PES)
NEUTRAL ATMOSPHERE MASS SPECTROMETER (NAMS)	ELECTRON GUN (E-GUN)
QUADRUPOLE ION MASS SPECTROMETER (QIMS)	MAGNETOMETER (B-FIELD)
ION DRIFT METER (IDM)	

Figure 11 — Basic instrumentation on the spacecraft. A 30% subsystem growth capability (power telemetry, volume, etc.) allows for expansion of the instrument set and the test and development of new systems and concepts.

In generating a spacecraft design, the team focused on two important driving functions: (A) The scientific and systems' requirements of each of the instruments, and (B) The need to develop a general purpose spacecraft that could carry out the broadest spectrum of experiments envisioned within the DoD community for the next five to ten years. These considerations pointed to a double-spinning spacecraft design in which one section (the stator) maintains one face parallel to the velocity vector. The other portion of the spacecraft (the rotor) can spin at a selected rate between 0 and 20 times per minute. The arrangement of sensors in the spacecraft design took on the configuration shown in Fig. 12. The stator's ramming surface accommodates the high space-time resolution measurements by an ion drift meter, retarding potential analyzer, ion mass spectrometer, cold cathode ionization gauge, and plasma probe; while the spinning section accommodates the electric field sensor, photoelectron spectrometer, ring current particle detector, neutral atmospheric mass spectrometer, vacuum ultraviolet photometer, and an electron gun.

## VI. IN-ORBIT MANEUVERS

The spacecraft has been designed to be transported to orbital altitudes by the Shuttle, launched from the Shuttle, and operated in tandem or in over-flight with Shuttle-borne sensor packages (designated in Fig. 13 as LASSII (II)). Full advantage will be taken of ground-based diagnostic systems as well as existing transit and geostationary satellites in order to fully determine the effects of the turbulent ionosphere on the various signal channels. Reflights will test new and developing techniques for communications and tracking as well as their survivability in naturally and artificially perturbed ionospheric environments.

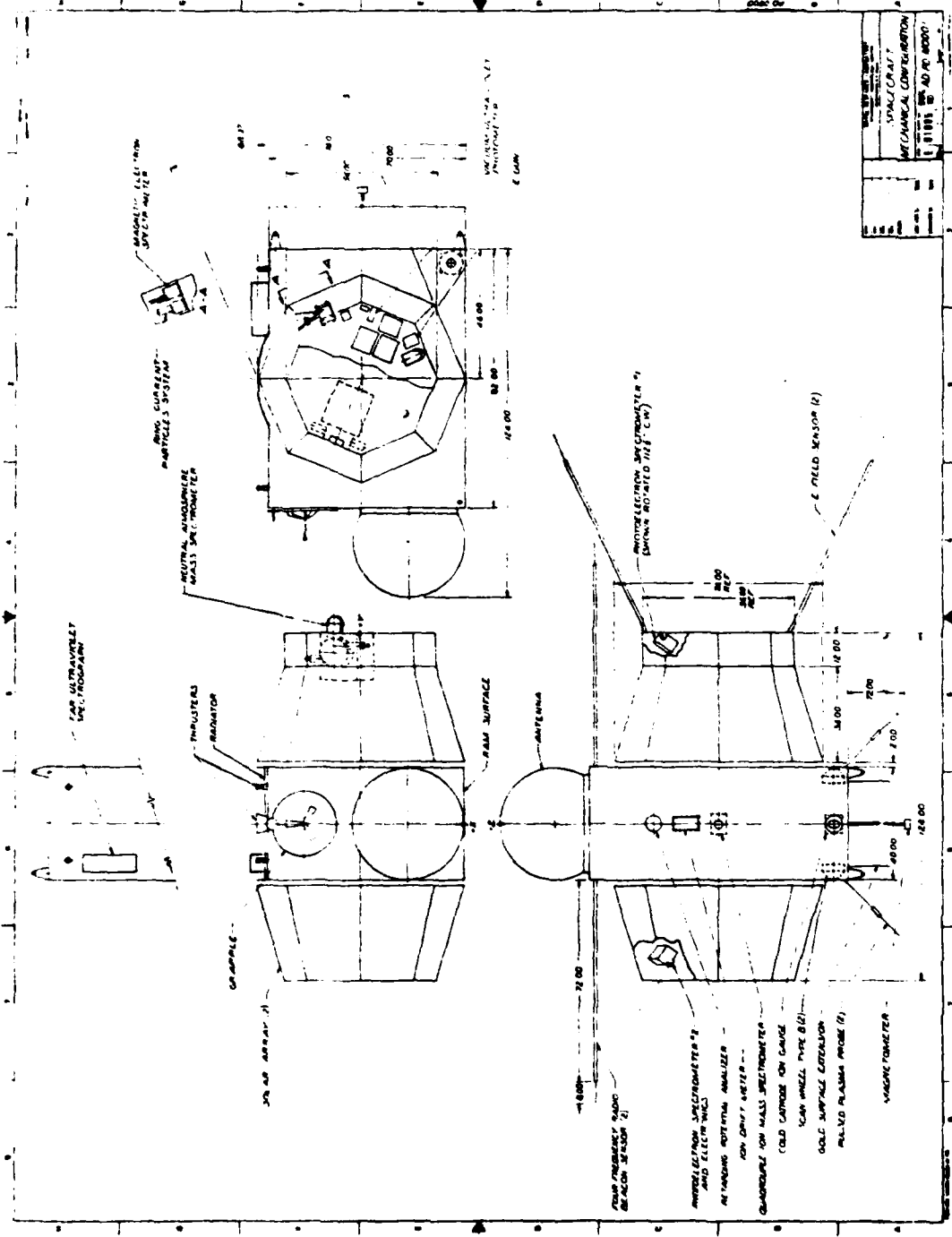


Figure 12 - Interim spacecraft design

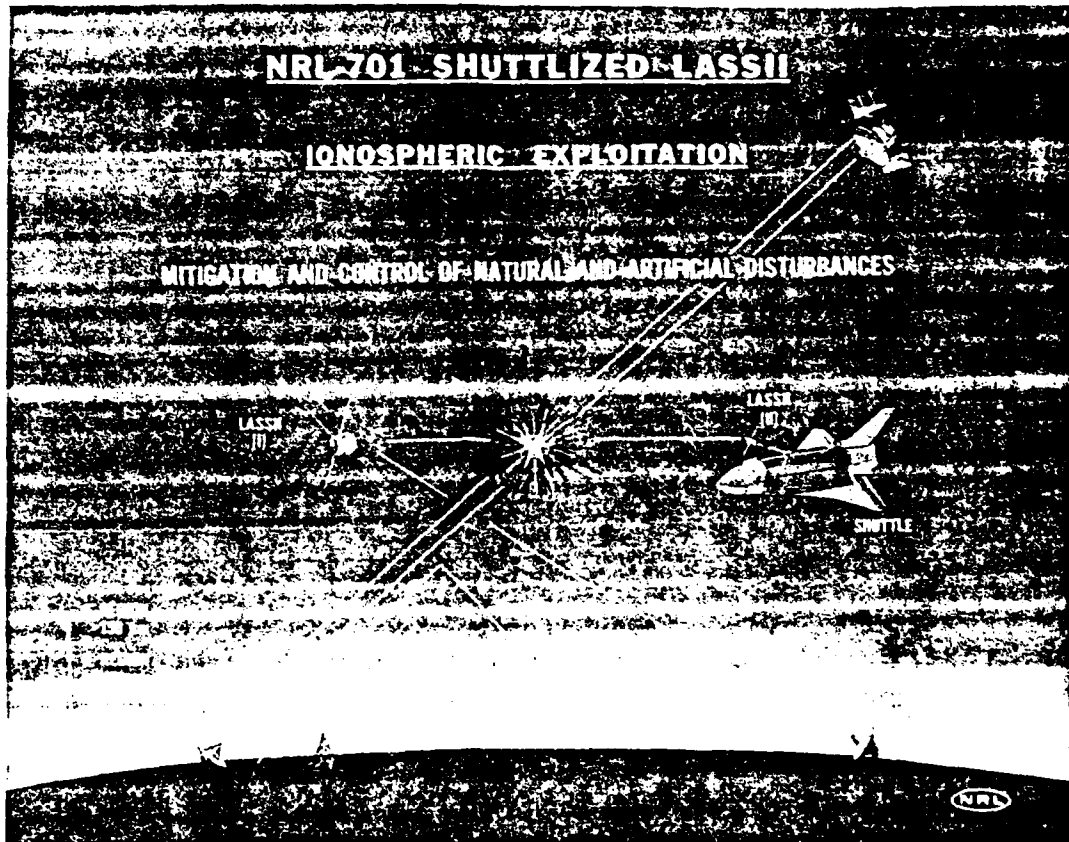


Figure 13 — Every advantage will be taken of existing transit and geostationary satellites as well as ground based diagnostics facilities in order to unfold space/time dependence of natural and artificial turbulence (represented by the explosion) and their effects on various military channels

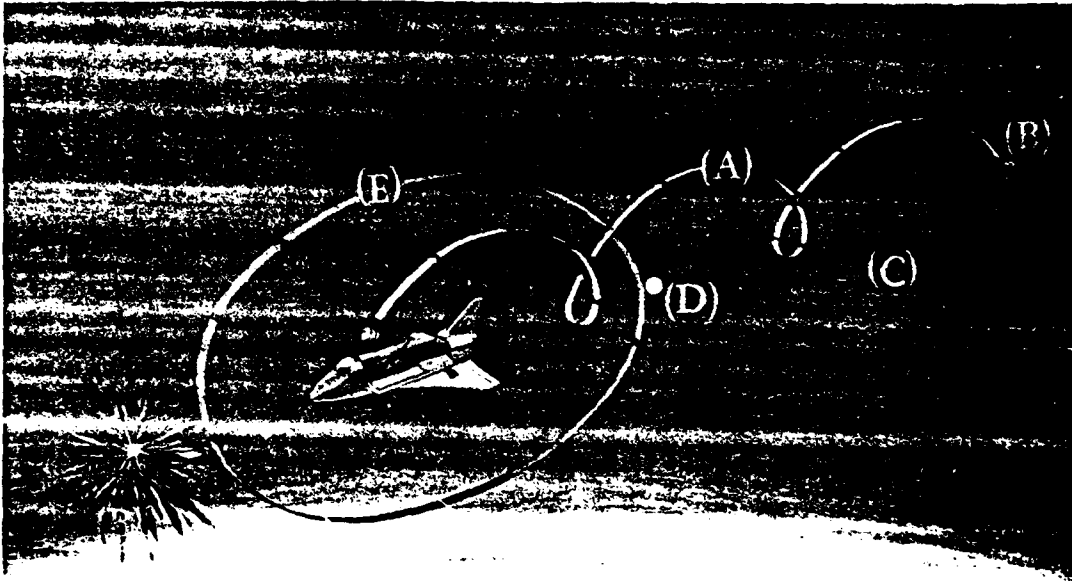


Figure 14 — Spacecraft maneuverability (Hohmann and Crocco transfers) are extremely important elements in the LASSII design. Half-orbit separation in tandem operations and  $\pm 90$  km over-and-under flights are capabilities in the spacecraft design. The explosion represents a controlled active experiment.

One of the problem areas proposed for solution involved the triggering of equatorial spread F by the artificial injection of chemicals in the bottom-side layer. It was proposed that artificial species like  $\text{H}_3\text{O}^+$ ,  $\text{HCO}_2^+$ ,  $\text{HCO}^+$  might act as tracers of the bottom side hole as it worked its way up through the F layer peak and appeared as a larger bite-out on the topside F region. To accomplish all the facets of space and time dependence in the development of plasma instability mechanisms it was necessary to build into the LASSII spacecraft rather extensive maneuvering capabilities encompassing both Homann and Crocco type transfers. The Homann maneuver is illustrated in Fig. 14 by the movement of the payload from "A" to parking position "B." In this tandem flight arrangement, the sensor package on the Shuttle and those on the LASSII spacecraft could pass through the same volume of plasma space at different times, unfolding the temporal development and the instability growth rate. In the Crocco maneuver, an over-and-under flight configuration illustrated by "E," the combination of Shuttle packages and LASSII free-flyer measurements will be able to unfold simultaneous space and time determinations of vertical plasma distributions and their related effects on turbulent plasma processes and  $C^3I$  systems.

#### VII. GENERAL COMMENT

The complementarity of instrumentation as well as the LASSII spacecraft design and maneuvering capabilities have all been designed to encompass areas of basic and applied plasma research and the associated development and tests on DoD space networks. The payload subsystems (power, telemetry, etc.) include a thirty percent growth capability for expansion into developing areas and the test of new concepts within the LASSII mission profile. Planning strategies, scientific inputs from the theoretical and experimental points of view, as well as communication engineering and spacecraft technology have all come into the LASSII program plan from a rather extensive team that crosses Division and Directorate boundaries at NRL and involves many contributions from other government laboratories, as well as the industrial and university communities (see Figure 15).

*THE LASSII CONSORTIUM*

AEROSPACE CORPORATION	AC
AIR FORCE GEOPHYSICS LABORATORY	AFGL
DEFENSE NUCLEAR AGENCY	DNA
JOHNS HOPKINS UNIVERSITY/APPLIED PHYSICS LAB	JHU/APL
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	NASA
NATIONAL OCEANOGRAPHIC AND ATMOSPHERIC ASSOCIATION	NOAA
NAVAL OCEAN SYSTEMS CENTER	NOSC
NAVAL RESEARCH LABORATORY	NRL
STANFORD UNIVERSITY/RADIO SCIENCE LABORATORY	SU
UNIVERSITY OF TEXAS AT DALLAS	UTD

Figure 15 — Contributions to mission planning, spacecraft design and instrument complement, have come from a LASSII consortium which couples government and civilian sector of science, engineering and technology.

The success of LASSII will contribute significantly to understanding, mitigating, and controlling natural and artificial ionospheric disturbances. The program's comprehensive nature is unique within the Department of Defense, making possible a much improved understanding of the near-earth environment and the exploitation of that understanding for the best interests of our defense posture.

**SUMMARY**

- MULTI-AGENCY, MULTI-PURPOSE MISSION
- R<sup>3</sup> (RECOVER, RECHARGE, REFLY) COMPATIBLE
- 30% SUBSYSTEM GROWTH CAPABILITY TO ACCOMMODATE OTHER EXPERIMENTS
- IMPOSES MINIMUM DEMANDS ON ORBITER SYSTEMS AND OPERATIONS
- EXTREMELY FLEXIBLE ORBITAL COMPATIBILITY
- HIGHLY FLEXIBLE MISSION CONCEPT
- DESIGNED FOR IONOSPHERIC EXPLOITATION (E.G., MITIGATION AND CONTROL OF IONOSPHERIC DISTURBANCES)

Figure 16 — Summary of some important features in the LASSII program. Recovery of the sortie-mode free-flyer is particularly important since mission-unique modifications can be made. Launches every six months are part of the current planning schedule

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