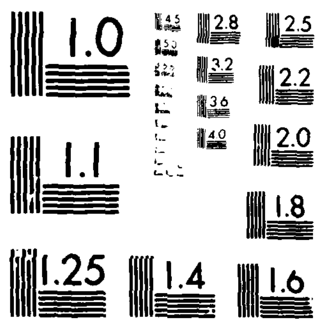
AD-A085 472 NAVAL RESEARCH LAB WASHINGTON DC F/G 4/1
PLUMEX I: COINCIDENT RADAR AND ROCKET OBSERVATIONS OF EQUATORIA--ETC(U)
MAR 80 E P SZUSZCZEWICZ, R T TSUNODA
UNCLASSIFIED NRL-MR-4201 SBIE-AD-E000 430 NL

1 OF 1
AD
A085472

END
DATE
FILMED
7-80
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NRL Memorandum Report 4201	2. GOVT ACCESSION NO. AD-A085 471	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) PLUMEX I: COINCIDENT RADAR AND ROCKET OBSERVATIONS OF EQUATORIAL SPREAD-F		5. TYPE OF REPORT & PERIOD COVERED Interim report on a continuing DNA problem.
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) E. P. Szuszczewicz, R. T. Tsunoda*, R. Narcisi†, and J. C. Holmes		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Research Laboratory Washington, DC 20375		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 61153N; RR033-02-44; 71-0949-0-0; DNA Subtask I25AAXHX640
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research Arlington, Virginia 22217		12. REPORT DATE March 17, 1980
		13. NUMBER OF PAGES 28
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

*Present address: SRI International, 333 Ravenwood Ave., Menlo Park, CA 94025.
†Present address: Air Force Geophysics Laboratory, Hanscom Air Force Base, Bedford, MA 01731.
This work was partially sponsored by the Defense Nuclear Agency under Subtask I25AAXHX640, Communications Effects Experiments, and under contract DNA 001-C-0153.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Ionosphere
Electron density
Spread-F
In situ measurements

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Coordinated measurements of equatorial spread-F conducted during July 1979 at the Kwajalein Atoll have yielded the first definitive space- and time coincident radar and rocket observations of small scale irregularities and large scale plasma depletions. The results have shown that:

(a) Within a large-scale topside F-layer depletion radar backscatter energy is at a level much lower than that observed on the depletion's topside. The same is true of "in situ" irregularity observations, and

(Continues)

20. Abstract (Continued)

(b) Ion composition within a topside depletion can provide signatures of its bottomside source domain and estimates of average maximum vertical drift velocity. For long-lived depletions, molecular-ion signatures (NO^+ and O_2^+) can be lost while bottomside levels of N^+ can be maintained when $[O^+] \approx N_e \gg [NO^+] + [O_2^+]$, and finally,

(c) Large scale fluctuations of O^+ accompanied by a near-constant level of NO^+ and O_2^+ on the bottomside F-layer gradient suggests that neutral atmospheric turbulence is not a major source for bottomside ionospheric plasma irregularities.

CONTENTS

I. INTRODUCTION

Accumulated information regarding equatorial spread-F phenomena has pointed toward a definite causal relationship between the large scale depletions (also referred to as holes, bite-outs, or bubbles) and range-time-intensity observations of large ionospheric domains with strong radar backscatter returns from the much smaller (meter size) irregularities (called plumes). Woodman and LaHoz (1976) and Kelly, et al. (1976), have suggested that a plume was due to a rising bubble leaving behind a wake of short wavelength irregularities. Another proposal (Szuszczewicz, 1978), arising from considerations of chemistry and transport, suggested that the radar returns originate across the density gradients at the boundaries of large scale depletions. This concept is supported by the work of Ossakow, et al. (1979) where it is inferred that a bubble rising through the F-layer will bifurcate on its topside and produce shorter and shorter wavelength irregularities, either by a cascade or two-step mechanism. Experimental evidence to verify this position has come from an Altair radar experiment (Tsunoda, 1980a) which showed that backscatter maxima tend to occur at altitudes corresponding either to the electron density minima or the upper wall of the plasma depletion. More recently, Tsunoda (1980b) concluded that during the decay phase of meter scale backscatter plumes, the radar returns were maximum on the upper walls of the plasma depletions.

Note: Manuscript submitted February 22, 1980.

Efforts to examine the exact relationship between radar plumes and ionospheric depletions by performing simultaneous "in situ" and ground-based radar observations (Kelly, et al. 1976; Morse, et al. 1977) have been limited to conditions of bottomside spread-F and required extrapolations in space and time to establish correlations. As expected for bottomside spread-F, the "in situ" probes only observed plasma fluctuations along the portion of the trajectory below the F-layer peak density while the ionosphere above the peak was quite smooth.

The ion composition within the depletions has also been the subject of a number of investigations. Typically, satellite mass spectrometric observations (Brinton et al. 1975; McClure et al, 1977; Szuszczewicz, 1978) have shown that the ion composition can be vastly different inside and outside the bite-outs. Fe^+ ions may be enhanced or depleted, with molecular ions usually more abundant inside the bite-out. Brinton et al. (1975) and McClure et al. (1977) have found O^+ depleted by as much as a factor of 10^3 to a concentration below that of NO^+. The molecular ion NO^+ was found to be dominant in the O^+ depleted region, with the bite-outs varying from a few kilometers to tens of kilometers in width. An analysis of the Atmospheric Explorer-C data (Szuszczewicz, 1978) suggested that a given chemical volume on the bottomside F-layer ($[NO^+]$, $[O_2^+] > [O^+]$) could move upward through a stationary neutral atmosphere and appear at higher altitudes as a bite-out in the local plasma density. As the bottomside F-region plasma cell moved upward, the relative magnitudes of its ionic components would depend on transit time and on altitude through the height distribution of the neutral gases. This model was consistent with the satellite observations as well as the computational work of Scannapieco and Ossakow (1976).

In a continuing effort to understand the detailed relationships involving large scale plasma depletions, meter-size irregularities and associated ion-chemical signatures, a rocket payload instrumented with a plasma diagnostics complement (plasma probes, electric field sensors, mass spectrometer and a two-frequency beacon experiment) was launched into the topside F-region ionosphere above Roi-Namur in the Kwajalein Atoll (4.3° N dip latitude). The investigation was part of a major effort which coordinated rocket and Altair radar observations with bottomside soundings and ground-based photometric measurements of F-region winds. We present here the initial coordinated observations of the radar plumes and the "in situ" measurements of the rocket-borne plasma probes and mass spectrometer.

II. EXPERIMENTAL RESULTS

A. Ionospheric Conditions and Radar Maps

By 2100 hr LT on the night of the rocket launch, ionograms showed that the nominal bottomside of the F-layer had risen to an altitude of 400 km. At that point, the F-layer began drifting downward with an almost immediate occurrence of spread-F. The downward drifting continued (as did the spread-F) at an approximate average velocity of 10m/sec with the bottomside F-layer having descended to an altitude near 270 km when the rocket was launched (12:31:30 UT on day 198; 00:31:30, 17 July 1979, LT).

Operating at 155.5 Mhz radar backscatter returns from 1 m ionospheric irregularities) the Altair radar executed consecutive east-west scans in a plane that included the penetration of the rocket's upleg trajectory. Figure 1 presents the contours of constant backscatter strength plotted in 10 dB increments. (For details of the Altair system see Tsunoda <u>et</u> <u>al</u>., 1979). The first panel in Figure 1 shows a backscatter plume just moving out of the radar's eastern-most field of view. That plume, with its highest and most intense backscatter region near 510 km, is connected to backscatter domains extending down to the bottomside of the F-layer. The second panel, with a center scan time 137 seconds later than the first, shows the intense backscatter region further to the east, having drifted there with an approximate west-east velocity of 160m/sec. In the third panel the plume has nearly moved completely out of the radar's field of view and the intense region near 510 km has decayed.

B. <u>Rocket Profile and Comparison with Radar</u>

The rocket payload that was launched into the spread-F conditions depicted in Figure 1 carried a quadrupole ion mass spectrometer (from the Air Force Geophysics Laboratory) a pair of pulsed plasma probes (from the Naval Research Laboratory), vector electric field sensors (from Utah State University) and a two-frequency beacon experiment (SRI International). The pair of pulsed probes simultaneously tracked ion and electron saturation currents while generating conventional Langmuir probe characteristics (see e.g., Szuszczewicz and Holmes, (1977). Figure 2 displays the upleg measurements of relative electron density as presented by correlated ion and electron saturation currents. The ordinate has a linear scale for time-after-launch with altitude superimposed at 50 second increments. (Because ion and electron saturation currents have significantly different sensitivities to velocity, sheath and magnetic field effects (e.g., Szuszczewicz and Takacs, 1979) data points not corroborated by both polarity currents were attributed to the various aspect sensitivities and therefore were not included in Figure 1. This approach facilitates quick look analysis and establishes credibility in the interpretation of the curves as relative electron density profiles.)

The profile shows that the payload entered the very bottom of the F-layer at $t \simeq 103$ sec ($Z \simeq 240$ km). From that point, to an apogee near 590 km, the "in situ" measurements revealed a number of plasma depletions depicted in the figure as regions C, D-E, F-G, H-I, and J-K. The largest depletion was in region H-I where $\Delta N_e/N_e^o \simeq 0.85$ with a halfminimum vertical extent approximatley equal to 23 km.

In the regions of the large-scale depletions, the "in situ" measurements also revealed much smaller scale irregularities. The central plot of "irregularity intensity" in Figure 2 identifies the regions of smaller irregularities and attempts to establish a preliminary quantification for their intensity. ("Irregularity intensities" were scaled directly from probe current fluctuations about an estimated mean. As an illustration, the -4.5 to +4.5 irregularity intensity within region C represents a factor of 9 in the largest peak-to-peak fluctuation measured in that region. (If vehicle potential, plasma temperature and ion composition were constant during the irregularity measurements, then $I \propto N_e$.) More quantitative analyses along with power spectral densities will be determined for future publication.) The results show that the most intense irregularities occurred on the bottomside gradient (region C) with corresponding measurements at all other altitudes at a much lower level. We note that the fluctuations in the largest depletion (region H-I) are smaller than those at "C". The data also indicate that the more intense fluctuations occur on positive density gradients (C,D,E, and I).

The payload's upleg trajectory has been superimposed on the radar maps in Figure 1 with domains A through K (and their associated times of observation) identified on the panel best matched for time coincidence with the radar results. A step-wise comparison of "in situ" irregularity observations (Fig. 2) with the radar maps reveals some interesting correlations:

Point "A" corresponds to the lowest position of the bottomside F-layer, while "B" is midway up the steep bottomside and very near the point of maximum positive density gradient. Region "C" is at the boundary of the third highest backscatter level (30 dB), and appears to represent the mid-phase development of large scale Rayleigh-Taylor turbulence. Observations at "D", "E", "F" and "G" occur along the western "wall" of the plume, and encompass an altitude domain identified with the F-layer peak. Point "G" represents the payload's entry into the large scale depletion centered near 240 sec (490 km) on the upleg trajectory. The payload's transit from "G" to "I" is marked by a positive gradient in backscatter radar energy, with the maximum return occurring on the topside (region "I" and above) of the H-I depletion. Above the large scale depletion, observations "K" and "J" begin to track the western "wall" of the plume in the topside F-region.

C. Ion Composition

O^+ was observed to be the dominant ion component throughout the entire F-region. From points of view focussed on turbulence and transport the chemical constituency of two regions are worthy of note:

In the H-I depletion on the topside F-layer the major observed ion components were $[O^+] \simeq 0.998\ N_e$, $[N^+] \simeq 0.002\ N_e$ and $([NO^+] + [O_2^+]) < 10^{-4} N_e$. In the adjacent domains there was a different distribution of ions, i.e., outside the depletion we found $[O^+] \simeq 0.992\ N_e$, $[N^+] \simeq 0.007\ N_e$ and $([NO^+] + [O_2^+]) < 2\ (10^{-5})\ N_e$, a distribution typical of the zero-order ionosphere at those altitudes.

The ion composition within the H-I depletion suggests that it may have originated at or near the bottomside F-region where $[O^+] \simeq [O^+]_{H-I}$. Such a region exists at 112 sec ($Z \simeq 262$ km) on the upleg trajectory where it was observed that $[NO^+]$ and $[O_2^+]$ were 1-2% of N_e and the $[O^+]/[N^+]$ ratio was nearly identical to that observed in the H-I domain. This points to N^+ as a long-lived tracer ion for bottomside source regions of topside depletions. The fact that the source region levels of NO^+ and O_2^+ have not been preserved in the topside hole results from their losses by dissociative recombination and a simultaneous loss in production by ion-atom interchange and charge exchange reactions since $[N_2]$ and $[O_2]$ decrease markedly with altitude. The longer it takes a bottomside depletion to move upward into the topside F-layer, the more likely the elimination of molecular ion signatures when $[O^+] \approx N_e \gg ([NO^+] + [O_2^+])$. In the case of the H-I depletion, a vertical transport time greater than 360 seconds would account for the molecular ion deficiency. (To arrive at this estimate we assumed an instaneous displacement of the bottomside ion composition to the H-I altitude and calculated that in about 6 minutes the molecular ions would decrease to a concentration less than 5 cm^{-3}.) This time estimate suggests an upper limit of about 600 m/sec for the depletion's average vertical drift velocity, a value which is consistent with the wide range in predicted bubble rise velocities (Ossakow and Chaturvedi, 1978; Ossakow et al., 1979; Anderson and Haerendel, 1979). (While this conclusion is correct in its own right, we note that Altair data prior to that shown in Fig. 1 reveal that the backscatter plume was at the nominal altitude shown in Figure 1 for more than 30 minutes.)

The second region of special note is "C" where it was observed that O^+ followed the intense plasma density fluctuations while the molecular ions NO^+ and O_2^+ (representing @0.5-1.0% N_e) did not. Such a result has a possible explanation in an assumption that requires steady state chemical equilibrium in an O^+ dominant domain. (Molecular ions in region "C" can achieve equilibrium concentrations in less than 10 minutes.) Under this condition, molecular ion concentrations are independent of O^+ and vary only with the scale height of the neutral atmospheric constituents N_2 and O_2. The observations conform to this model with a standard zero-order atmospheric distribution, suggesting that neutral atmospheric turbulence is not a major source for the observed plasma fluctuations on the bottomside F-region.

D. North-South Extent of the Depletions

Figure 3 presents the up- and downleg profiles of relative electron density as measured by "in situ" probe electron-saturation currents. (The integrity of the downleg profile was established by the same procedure utilized in Figure 2.) A comparison of the profiles shows very good agreement in the two observations of plasma depletions. Attention is directed to the large scale depletion of the topside (region H-I):

The up- and downleg measurements of the large topside hole were separated in time by approximately 340 seconds and in range by 112 km. During this 340 second interval Altair radar measurements of plume movement showed an average easterly drift at a 160 m/sec rate resulting in a total eastward displacement of 54 km. Adding 14 km to account for depletion alignment along the magnetic meridian (9°E of true azimuth) yields a calculated total E-W displacement of 68 km between the times of the two rocket observations of the hole. During this time interval the payload had an eastward range velocity approximately equal to 215 m/sec, resulting in an east-west separation in the up- and downleg observations of region H-I equal to 73 km. From this we can conclude near-perfect up- and downleg targeting of the hole. The agreement in the two observations of the H-I domain therefore suggests that the depletion is aligned with the magnetic field for at least 112 km. (Parallel arguments dealing with the depletion at (t,Z) $\simeq$ (153s, 350 km) would suggest a field alignment at least as great as 163 km, while the radar observations of Tsunoda [1980b] showed plasma bubble alignment can extend to 1100 km.)

III. COMMENTS AND CONCLUSIONS

Space- and time coincident measurements of equatorial spread-F conducted during July 1979 at the Kwajalein Atoll have yielded the first definitive observations of small scale irregularities (@1 meter) and large scale plasma depletions as measured independently throughout the F-region by ground-based radar and "in situ" plasma instrumentation. Preliminary analysis of the results leads to the following comments and conclusions:

(a) Within a large-scale, decay-phase, topside F-layer depletion where "in situ" irregularities were reduced (compared with the depletion's topside wall), the radar's backscatter energy was also reduced (compared with the topside wall). This result suggests the co-location of maximum radar returns with the upper regions of a depletion (its topside wall and above) and not with the depletion minimum or bottomside wall.

(b) The "in situ" measurements established field alignment of large scale depletions to distances at least as great as 163 km. This result supports the topside sounder data of Dyson and Benson (1968), the airglow observations of Weber et al., (1978), the recent radar measurements of Tsunoda (1980 a,b) and the assumption of depleted flux tubes in the theoretical considerations of Anderson and Haerendel (1979).

(c) Ion composition measurements within a topside depletion showed little evidence of bottomside molecular tracer ions (i.e., NO^+ and O_2^+). This result points to the requirement for rapid bubble rise velocities and/or low plasma densities ($N_e << 10^4$ cm^{-3}) within the hole if the bottomside molecular ion composition is to be maintained as bubbles drift upward through the F-region (Szuszczewicz, 1978). However, the measurements did reveal N^+ as a longer lived tracer ion. This helped identify the lower altitude source region to be on the bottomside F-layer gradient.

(d) Strong irregularities on the bottomside F-region gradient showed O^+ following large scale density fluctuations while the molecular ions NO^+ and O_2^+ were relatively constant. Preliminary analysis of this result suggests chemical equilibrium and eliminates neutral atmospheric turbulence as a major source of the bottomside plasma irregularities.

(e) An estimate of bubble rise velocity was arrived at by preliminary ion chemical analysis of composition within the hole. The analysis suggests an upper limit of 600 m/sec for the average vertical velocity of an 85% depleted domain (85% on the topside, 100% at the F-peak) as it drifted upward from its bottomside source region near 260 km to the topside F-layer at 490 km. This upper limit is consistent with the wide range in predicted values (Ossakow and Chaturvedi, 1978; Ossakow et al., 1979; Anderson and Haerendel, 1979).

ACKNOWLEDGMENTS

Support for the plasma probe analysis was provided by the Defense Nuclear Agency (DNA) under Subtask Code I25AAXHX640, Communications Effects Experiments. The Altair radar analysis was also supported by DNA under contract DNA 001-C-0153. Support for the ion composition measurements was supplied mostly by the Air Force Office of Scientific Research under Task 2310-G3 and partially by DNA under Subtask I25AAXHX640, Work Unit 06. We also wish to acknowledge the dedicated technical support of E. Trzcinski, G. Federico, L. Wlodyka, L. Kegley and D. Walker, who independently and as a team contributed significantly to the successful execution of the rocket-borne plasma probe and mass spectrometer experiments. Development of the plasma probe technique was provided by the Office of Naval Research under Work Unit A02-11.11 (71-0949-0-0), Ionospheric and Stratospheric Interactions, Task Area RR 043-02-44.

REFERENCES

Anderson, D.N., and G. Haerendel, "The motion of depleted plasma regions in the equatorial ionosphere," J. Geophys. Res., 84, 4251, 1979.

Brinton, H.C., H. G. Mayr, and G. P. Newton, "Ion composition in the nighttime equatorial F-region: Implications for chemistry and dynamics" (abstract), Eos Trans. AGU, 56, 1038, 1975.

Dyson, P.L., and R.F. Benson, "Topside sounder observations of equatorial bubbles," Geophys. Res. Lett. 5, 795, 1978.

Kelly, M.C., G. Haerendel, H. Kappler, A. Valenzuela, B.B. Balsley, D.A. Carter, W.L. Ecklund, C.W. Carson, B. Hausler, and R. Torbert, "Evidence for a Rayleigh-Taylor type instability and upwelling of depleted density regions during equatorial spread F," Geophys. Res. Lett., 3, 448, 1976.

McClure, J.P., W.B. Hanson, and J.H. Hoffman, "Plasma bubbles and irregularities in the equatorial ionosphere," J. Geophys. Res., 82, 2650, 1977.

Morse, F. A., B.C. Edgar, H.C. Koons, C.J. Rice, W.J. Heikkila, J.H. Hoffman, B.A. Tinsley, J.D. Winningham, A.B. Christensen, R.F. Woodman, J. Pomalaza, and N.R. Teizeira, "Equion, and equatorial ionospheric irregularity experiment," J. Geophys. Res., 82, 578, 1977.

Ossakow, S. L., and P.K. Chaturvedi, "Morphological studies of rising equatorial spread-F bubbles," J. Geophys. Res., 83, 2084, 1978.

Ossakow, S.L., S.T. Zalesak, B.E. McDonald, and P.K. Chaturvedi, "Nonlinear equatorial spread F: Dependence on altitude of the F peak and bottomside background electron density scale length," J.Geophys. Res. 84, 17, 1979.

Scannapieco, A.J., and S.L. Ossakow, "Nonlinear equatorial spread F," Geophys. Res. Lett., 3, 451, 1976.

Szuszczewicz, E.P. and J.C. Holmes, "Observations of electron temperature gradients in mid-latitude E_s layers," J. Geophys. Res., 82, 5073, 1977.

Szuszczewicz, E.P., "Ionospheric holes and equatorial spread-F: Chemistry and transport," J. Geophys. Res. 83, 2665, 1978.

Szuszczewicz, E.P., and P.Z. Takacs, "Magnetosheath effects on cylindrical Langmuir probes," Phys. Fluids 22, 2424, 1979.

Tsunoda, R.T., M.J. Baron, J. Owen and D.M. Towle, "Altair: An Incoherent scatter radar for equatorial spread-F studies," Radio Sci., 14, in press, 1979.

Tsunoda, R.T., "On the spatial relationship of 1-m equatorial spread-F irregularities and plasma bubbles," J. Geophys. Res. 85, (in press, 1980a).

Tsunoda, R.T., "Magnetic-field-aligned characteristics of plasma bubbles in the nighttime equatorial ionosphere," J. Atmos. Terr. Phys. (submitted, January 1980).

Weber, E.J., J. Buchau, R.H. Eather, and S.B. Mende, "North-south aligned equatorial airglow depletions," J. Geophys. Res., 83, 712, 1978.

Woodman, R.F., and C. LaHoz, "Radar observations of F region equatorial irregularities," J. Geophys. Res., 81, 5447, 1976.

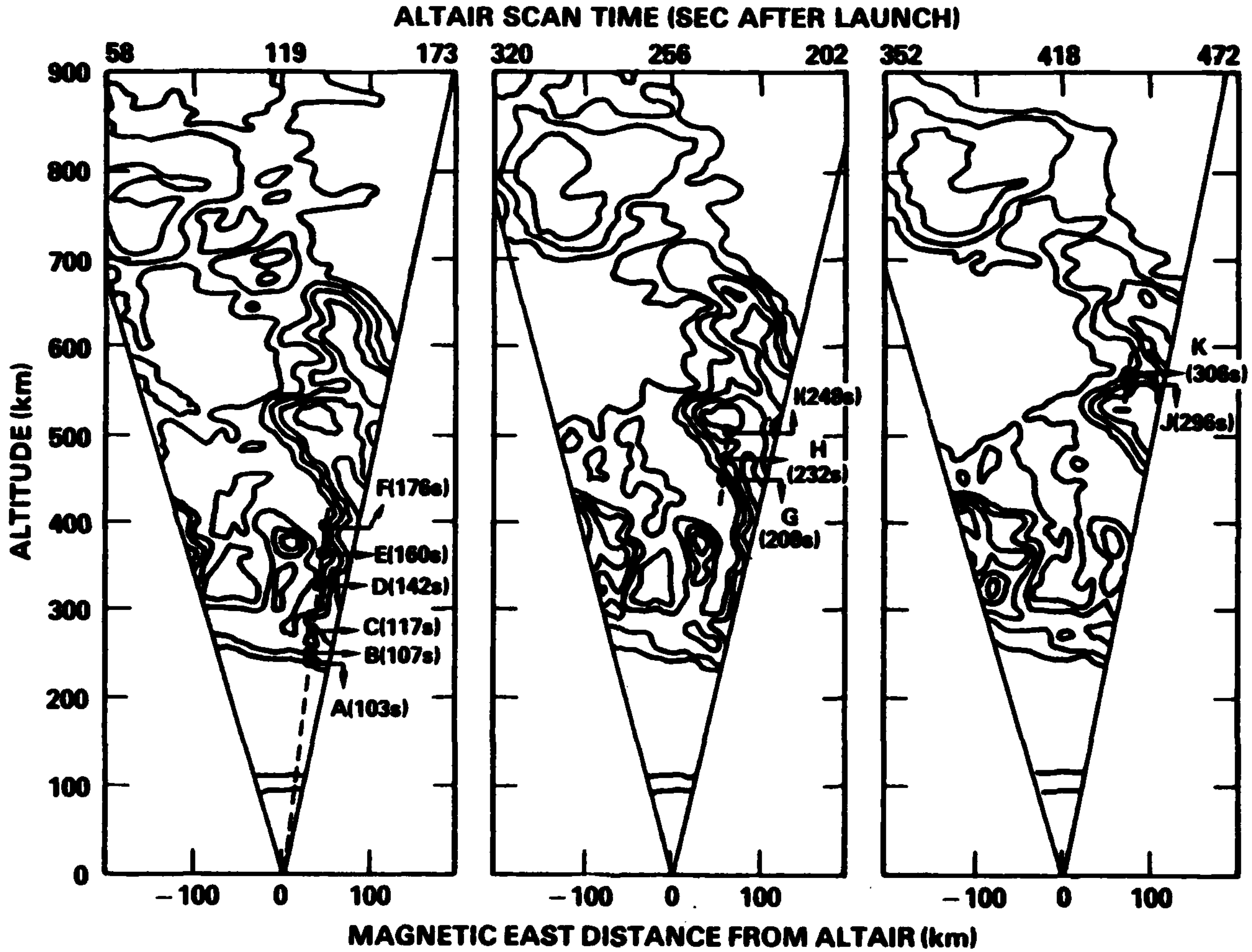


Fig. 1 — Backscatter intensity contour maps (contours are in 10 dB increments) with superposition of the rocket trajectory. The times identified with observations "A" through "K" are included for a more complete representation of temporal correlation with the successive radar scans.

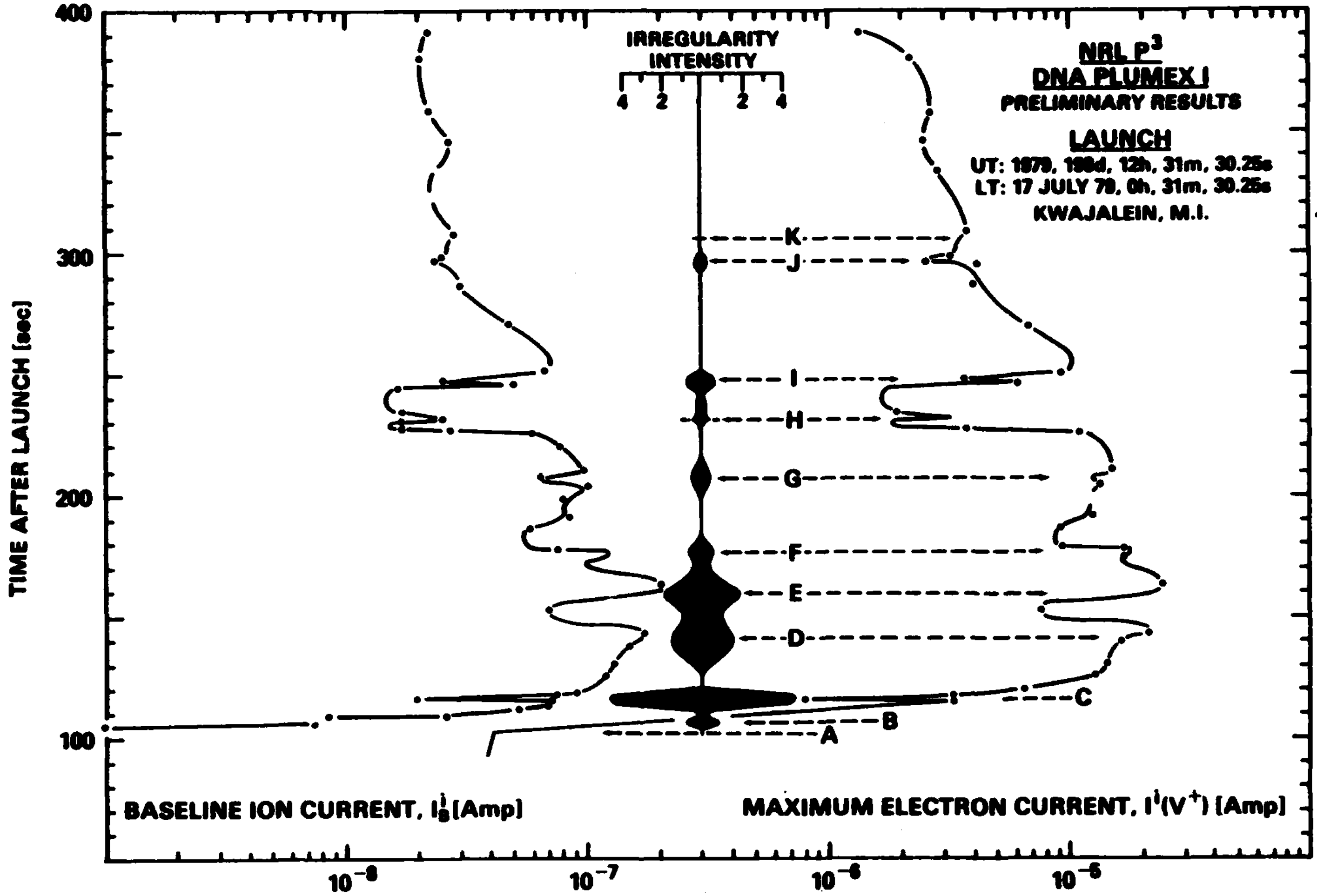


Fig. 2— Relative electron density profile as measured simultaneously by ion and electron saturation probe currents collected on the upleg trajectory. The "irregularity intensity" provides an approximate measure of smaller scale structure as scaled from analog strip chart records of probe current fluctuations.

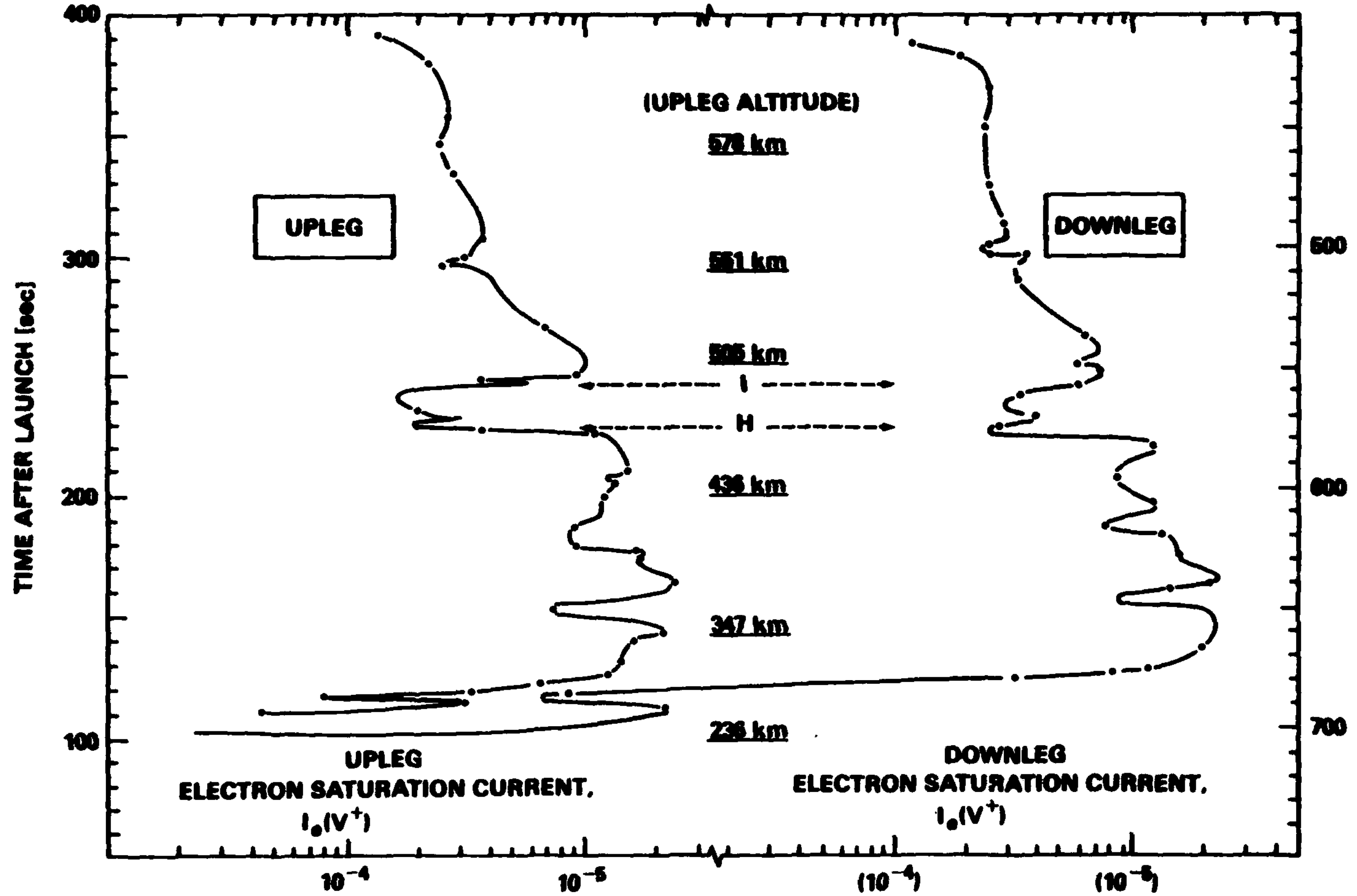


Fig. 3— Comparison of up- and downleg plasma profiles

DISTRIBUTION LIST

DEPARTMENT OF DEFENSE

ASSISTANT SECRETARY OF DEFENSE
COMM, CMD, CONT & INTELL
WASHINGTON, D.C. 20301
01CY ATTN J. BABCOCK
01CY ATTN M. EPSTEIN

ASSISTANT TO THE SECRETARY OF DEFENSE
ATOMIC ENERGY
WASHINGTON, D.C. 20301
01CY ATTN EXECUTIVE ASSISTANT

DIRECTOR
COMMAND CONTROL TECHNICAL CENTER
PENTAGON RM BE 685
WASHINGTON, D.C. 20301
01CY ATTN C-650
01CY ATTN C-312 R. MASON

DIRECTOR
DEFENSE ADVANCED RSCH PROJ AGENCY
ARCHITECT BUILDING
1400 WILSON BLVD.
ARLINGTON, VA. 22209
01CY ATTN NUCLEAR MONITORING RESEARCH
01CY ATTN STRATEGIC TECH OFFICE

DEFENSE COMMUNICATION ENGINEER CENTER
1860 WIEHLE AVENUE
RESTON, VA. 22090
01CY ATTN CODE R820
01CY ATTN CODE R410 JAMES W. MCLEAN
01CY ATTN CODE R720 J. WORTHINGTON

DIRECTOR
DEFENSE COMMUNICATIONS AGENCY
WASHINGTON, D.C. 20305
(ADR CNWDI: ATTN CODE 240 FOR)

01CY ATTN CODE 101B

DEFENSE DOCUMENTATION CENTER
CAMERON STATION
ALEXANDRIA, VA. 22314
(12 COPIES IF OPEN PUBLICATION, OTHERWISE 2 COPIES)
12CY ATTN TC

DIRECTOR
DEFENSE INTELLIGENCE AGENCY
WASHINGTON, D.C. 20301
01CY ATTN DT-1B
01CY ATTN DB-4C E. O'FARRELL
01CY ATTN DIAAP A. WISE
01CY ATTN DIAST-5
01CY ATTN DT-1BZ R. MORTON
01CY ATTN HQ-TR J. STEWART
01CY ATTN W. WITTIG DC-7D

DIRECTOR
DEFENSE NUCLEAR AGENCY
WASHINGTON, D.C. 20305
01CY ATTN STVL
04CY ATTN TITL
01CY ATTN DDST
03CY ATTN RAAE

COMMANDER
FIELD COMMAND
DEFENSE NUCLEAR AGENCY
KIRTLAND AFB, NM 87115
01CY ATTN FCPR

DIRECTOR
INTERSERVICE NUCLEAR WEAPONS SCHOOL
KIRTLAND AFB, NM 87115
01CY ATTN DOCUMENT CONTROL

JOINT CHIEFS OF STAFF
WASHINGTON, D.C. 20301
01CY ATTN J-3 WWMCCS EVALUATION OFFICE

DIRECTOR
JOINT STRAT TGT PLANNING STAFF
OFFUTT AFB
OMAHA, NB 68113
01CY ATTN JLTW-2
01CY ATTN JPST G. GOETZ

CHIEF
LIVERMORE DIVISION FLD COMMAND DNA
DEPARTMENT OF DEFENSE
LAWRENCE LIVERMORE LABORATORY
P. O. BOX 808
LIVERMORE, CA 94550
01CY ATTN FCPRL

DIRECTOR
NATIONAL SECURITY AGENCY
DEPARTMENT OF DEFENSE
FT. GEORGE G. MEADE, MD 20755
01CY ATTN JOHN SKILLMAN R52
01CY ATTN FRANK LEONARD
01CY ATTN W14 PAT CLARK
01CY ATTN OLIVER H. BARTLETT W32
01CY ATTN R5

COMMANDANT
NATO SCHOOL (SHAPE)
APO NEW YORK 09172
01CY ATTN U.S. DOCUMENTS OFFICER

UNDER SECY OF DEF FOR RSCH & ENGRG
DEPARTMENT OF DEFENSE
WASHINGTON, D.C. 20301
01CY ATTN STRATEGIC & SPACE SYSTEMS (OS)

WWMCCS SYSTEM ENGINEERING ORG
WASHINGTON, D.C. 20305
01CY ATTN R. CRAWFORD

COMMANDER/DIRECTOR
ATMOSPHERIC SCIENCES LABORATORY
U.S. ARMY ELECTRONICS COMMAND
WHITE SANDS MISSILE RANGE, NM 88002
01CY ATTN DELAS-EO F. NILES

DIRECTOR
BMD ADVANCED TECH CTR
HUNTSVILLE OFFICE
P. O. BOX 1500
HUNTSVILLE, AL 35807
01CY ATTN ATC-T MELVIN T. CAPPS
01CY ATTN ATC-O W. DAVIES
01CY ATTN ATC-R DON RUSS

PROGRAM MANAGER
BMD PROGRAM OFFICE
5001 EISENHOWER AVENUE
ALEXANDRIA, VA 22333
01CY ATTN DACS-BMT J. SHEA

CHIEF C-E SERVICES DIVISION
U.S. ARMY COMMUNICATIONS CMD
PENTAGON RM 1B269
WASHINGTON, D.C. 20310
01CY ATTN C-E-SERVICES DIVISION

COMMANDER
FRADCOM TECHNICAL SUPPORT ACTIVITY
DEPARTMENT OF THE ARMY
FORT MONMOUTH, N.J. 07703
01CY ATTN DRSEL-NL-RD H. BENNET
01CY ATTN DRSEL-PL-ENV H. BOMKE
01CY ATTN J. E. QUIGLEY

COMMANDER
HARRY DIAMOND LABORATORIES
DEPARTMENT OF THE ARMY
2800 POWDER MILL ROAD
ADELPHI, MD 20783
(CNWDI-INNER ENVELOPE: ATTN: DELHD-RBH)
01CY ATTN DELHD-TI M. WEINER
01CY ATTN DELHD-RB R. WILLIAMS
01CY ATTN DELHD-NP F. WIMENITZ
01CY ATTN DELHD-NP C. MOAZED

COMMANDER
U.S. ARMY COMM-ELEC ENGRG INSTAL AGY
FT. HUACHUCA, AZ 85613

01CY ATTN CCC-EMEO GEORGE LANE

COMMANDER
U.S. ARMY FOREIGN SCIENCE & TECH CTR
220 7TH STREET, NE
CHARLOTTESVILLE, VA 22901
01CY ATTN DRXST-SD
01CY ATTN R. JONES

COMMANDER
U.S. ARMY MATERIEL DEV & READINESS CMD
5001 EISENHOWER AVENUE
ALEXANDRIA, VA 22333
01CY ATTN DRCLDC J. A. BENDER

COMMANDER
U.S. ARMY NUCLEAR AND CHEMICAL AGENCY
7500 BACKLICK ROAD
BLDG 2073
SPRINGFIELD, VA 22150
01CY ATTN LIBRARY

DIRECTOR
U.S. ARMY BALLISTIC RESEARCH LABS
ABERDEEN PROVING GROUND, MD 21005
01CY ATTN TECH LIB EDWARD BAICY

COMMANDER
U.S. ARMY SATCOM AGENCY
FT. MONMOUTH, NJ 07703
01CY ATTN DOCUMENT CONTROL

COMMANDER
U.S. ARMY MISSILE INTELLIGENCE AGENCY
REDSTONE ARSENAL, AL 35809
01CY ATTN JIM GAMBLE

DIRECTOR
U.S. ARMY TRADOC SYSTEMS ANALYSIS ACTIVITY
WHITE SANDS MISSILE RANGE, NM 88002
01CY ATTN ATAA-SA
01CY ATTN TCC/F. PAYAN JR.
01CY ATTN ATAA-TAC LTC J. HESSE

COMMANDER
NAVAL ELECTRONIC SYSTEMS COMMAND
WASHINGTON, D.C. 20360
01CY ATTN NAVALEX 034 T. HUGHES
01CY ATTN PME 117
01CY ATTN PME 117-T
01CY ATTN CODE 5011

COMMANDING OFFICER
NAVAL INTELLIGENCE SUPPORT CTR
4301 SUITLAND ROAD, BLDG. 5
WASHINGTON, D.C. 20390
01CY ATTN MR. DUBBIN STIC 12
01CY ATTN NISC-50
01CY ATTN CODE 5404 J. GALET

COMMANDER
NAVAL SURFACE WEAPONS CENTER
DAHLGREN LABORATORY
DAHLGREN, VA 22448
01CY ATTN CODE DF-14 R. BUTLER

COMMANDING OFFICER
NAVY SPACE SYSTEMS ACTIVITY
P.O. BOX 92960
WORLDWAY POSTAL CENTER
LOS ANGELES, CA. 90009
01CY ATTN CODE 52

OFFICE OF NAVAL RESEARCH
ARLINGTON, VA 22217
01CY ATTN CODE 465
01CY ATTN CODE 461
01CY ATTN CODE 402
01CY ATTN CODE 420
01CY ATTN CODE 421

COMMANDER
AEROSPACE DEFENSE COMMAND/DC
DEPARTMENT OF THE AIR FORCE
ENT AFB, CO 80912
01CY ATTN DC MR. LONG

COMMANDER
AEROSPACE DEFENSE COMMAND/XPD
DEPARTMENT OF THE AIR FORCE
ENT AFB, CO 80912
01CY ATTN XPDQQ
01CY ATTN XP

AIR FORCE GEOPHYSICS LABORATORY
HANSCOM AFB, MA 01731
01CY ATTN OPR HAROLD GARDNER
01CY ATTN OPR-1 JAMES C. ULWICK
01CY ATTN LKB KENNETH S. W. CHAMPION
01CY ATTN OPR ALVA T. STAIR
01CY ATTN PHP JULES AARONS
01CY ATTN PHD JURGEN BUCHAU
01CY ATTN PHD JOHN P. MULLEN

AF WEAPONS LABORATORY
KIRTLAND AFB, NM 87117
01CY ATTN SUL
01CY ATTN CA ARTHUR H. GUENTHER
01CY ATTN DYC CAPT J. BARRY
01CY ATTN DYC JOHN M. KAMM
01CY ATTN DYT CAPT MARK A. FRY
01CY ATTN DES MAJ GARY GANONG
01CY ATTN DYC J. JANNI

AFTAC
PATRICK AFB, FL 32925
01CY ATTN TF/MAJ WILEY
01CY ATTN TN

AIR FORCE AVIONICS LABORATORY
WRIGHT-PATTERSON AFB, OH 45433
01CY ATTN AAD WADE HUNT
01CY ATTN AAD ALLEN JOHNSON

DEPUTY CHIEF OF STAFF
RESEARCH, DEVELOPMENT, & ACQ
DEPARTMENT OF THE AIR FORCE
WASHINGTON, D.C. 20330
01CY ATTN AFRDQ

HEADQUARTERS
ELECTRONIC SYSTEMS DIVISION/XR
DEPARTMENT OF THE AIR FORCE
HANSCOM AFB, MA 01731
01CY ATTN XR J. DEAS

HEADQUARTERS
ELECTRONIC SYSTEMS DIVISION/YSEA
DEPARTMENT OF THE AIR FORCE
HANSCOM AFB, MA 01731
01CY ATTN YSEA

COMMANDER
NAVAL OCEAN SYSTEMS CENTER
SAN DIEGO, CA 92152
03CY ATTN CODE 532 W. MOLER
01CY ATTN CODE 0230 C. BAGGETT
01CY ATTN CODE 81 R. EASTMAN

DIRECTOR
NAVAL RESEARCH LABORATORY
WASHINGTON, D.C. 20375
01CY ATTN CODE 6700 TIMOTHY P. COFFEY
(25 CYS IF UNCLASS, 1 CY IF CLASS)
01CY ATTN CODE 6701 JACK D. BROWN
01CY ATTN CODE 6780 BRANCH HEAD (150 CYS
IF UNCLASS, 1 CY IF CLASS)
01CY ATTN CODE 7500 HQ COMM DIR BRUCE WALD
01CY ATTN CODE 7550 J. DAVIS
01CY ATTN CODE 7580
01CY ATTN CODE 7551
01CY ATTN CODE 7555
01CY ATTN CODE 6730 E. MCLEAN
01CY ATTN CODE 7127 C. JOHNSON

COMMANDER
NAVAL SEA SYSTEMS COMMAND
WASHINGTON, D.C. 20362
01CY ATTN CAPT R. PITKIN

COMMANDER
NAVAL SPACE SURVEILLANCE SYSTEM
DAHLGREN, VA 22448
01CY ATTN CAPT J. H. BURTON

OFFICER-IN-CHARGE
NAVAL SURFACE WEAPONS CENTER
WHITE OAK, SILVER SPRING, MD 20910
01CY ATTN CODE F31

DIRECTOR
STRATEGIC SYSTEMS PROJECT OFFICE
DEPARTMENT OF THE NAVY
WASHINGTON, D.C. 20376
01CY ATTN NSP-2141
01CY ATTN NSSP-2722 FRED WIMBERLY

NAVAL SPACE SYSTEM ACTIVITY
P. O. BOX 92960
WORLDWAY POSTAL CENTER
LOS ANGELES, CALIF. 90009
01CY ATTN A. B. HAZZARD

HEADQUARTERS
ELECTRONIC SYSTEMS DIVISION/DC
DEPARTMENT OF THE AIR FORCE
HANSCOM AFB, MA 01731
01CY ATTN DCKC MAJ J. C. CLARK

COMMANDER
FOREIGN TECHNOLOGY DIVISION, AFSC
WRIGHT-PATTERSON AFB, OH 45433
01CY ATTN NICD LIBRARY
01CY ATTN ETDP B. BALLARD

COMMANDER
ROME AIR DEVELOPMENT CENTER, AFSC
GRIFFISS AFB, NY 13441
01CY ATTN DOC LIBRARY/TSLD
01CY ATTN OCSE V. COYNE

SAMSO/SZ
POST OFFICE BOX 92960
WORLDWAY POSTAL CENTER
LOS ANGELES, CA 90009
(SPACE DEFENSE SYSTEMS)
01CY ATTN SZJ

STRATEGIC AIR COMMAND/XPFS
OFFUTT AFB, NB 68113
01CY ATTN XPFS MAJ B. STEPHAN
01CY ATTN ADWATE MAJ BRUCE BAUER
01CY ATTN NRT
01CY ATTN DOK CHIEF SCIENTIST

SAMSO/YA
P. O. BOX 92960
WORLDWAY POSTAL CENTER
LOS ANGELES, CA 90009
01CY ATTN YAT CAPT L. BLACKWELDER

SAMSO/SK
P. O. BOX 92960
WORLDWAY POSTAL CENTER
LOS ANGELES, CA 90009
01CY ATTN SKA (SPACE COMM SYSTEMS) M. CLAVIN

SAMSO/MN
NORTON AFB, CA 92409
(MINUTEMAN)
01CY ATTN MNNL LTC KENNEDY

COMMANDER
ROME AIR DEVELOPMENT CENTER, AFSC
HANSCOM AFB, MA 01731
01CY ATTN EEP A. LORENTZEN

DEPARTMENT OF ENERGY

DEPARTMENT OF ENERGY
ALBUQUERQUE OPERATIONS OFFICE
P. O. BOX 5400
ALBUQUERQUE, NM 87115
01CY ATTN DOC CON FOR D. SHERWOOD

DEPARTMENT OF ENERGY
LIBRARY ROOM G-042
WASHINGTON, D.C. 20545
01CY ATTN DOC CON FOR A. LABOWITZ

EG&G, INC.
LOS ALAMOS DIVISION
P. O. BOX 809
LOS ALAMOS, NM 85544
01CY ATTN DOC CON FOR J. BREEDLOVE

UNIVERSITY OF CALIFORNIA
LAWRENCE LIVERMORE LABORATORY
P. O. BOX 808
LIVERMORE, CA 94550
01CY ATTN DOC CON FOR TECH INFO DEPT
01CY ATTN DOC CON FOR L-389 R. OTT
01CY ATTN DOC CON FOR L-31 R. HAGER
01CY ATTN DOC CON FOR L-46 F. SEWARD

LOS ALAMOS SCIENTIFIC LABORATORY
P. O. BOX 1663
LOS ALAMOS, NM 87545
01CY ATTN DOC CON FOR J. WOLCOTT
01CY ATTN DOC CON FOR R. F. TASCHEK
01CY ATTN DOC CON FOR E. JONES
01CY ATTN DOC CON FOR J. MALIK
01CY ATTN DOC CON FOR R. JEFFRIES
01CY ATTN DOC CON FOR J. ZINN
01CY ATTN DOC CON FOR P. KEATON
01CY ATTN DOC CON FOR D. WESTERVELT

SANDIA LABORATORIES
P. O. BOX 5800
ALBUQUERQUE, NM 87115
01CY ATTN DOC CON FOR J. MARTIN
01CY ATTN DOC CON FOR W. BROWN
01CY ATTN DOC CON FOR A. THORNBROUGH
01CY ATTN DOC CON FOR T. WRIGHT
01CY ATTN DOC CON FOR D. DAHLGREN
01CY ATTN DOC CON FOR 3141
01CY ATTN DOC CON FOR SPACE PROJECT DIV

SANDIA LABORATORIES
LIVERMORE LABORATORY
P. O. BOX 969
LIVERMORE, CA 94550
01CY ATTN DOC CON FOR B. MURPHEY
01CY ATTN DOC CON FOR T. COOK

OFFICE OF MILITARY APPLICATION
DEPARTMENT OF ENERGY
WASHINGTON, D.C. 20545
01CY ATTN DOC CON FOR D. GALE

OTHER GOVERNMENT

CENTRAL INTELLIGENCE AGENCY
ATTN RD/SI, RM 5G48, HQ BLDG
WASHINGTON, D.C. 20505
01CY ATTN OSI/PSID RM 5F 19

DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON, D.C. 20234
(ALL CORRES: ATTN SEC OFFICER FOR)
01CY ATTN R. MOORE

DEPARTMENT OF TRANSPORTATION
OFFICE OF THE SECRETARY
TAD-44.1, ROOM 10402-B
400 7TH STREET, S.W.
WASHINGTON, D.C. 20590
01CY ATTN R. LEWIS
01CY ATTN R. DOHERTY

INSTITUTE FOR TELECOM SCIENCES
NATIONAL TELECOMMUNICATIONS & INFO ADMIN
BOULDER, CO 80303
01CY ATTN A. JEAN (UNCLASS ONLY)
01CY ATTN W. UTLAUT
01CY ATTN D. CROMBIE
01CY ATTN L. BERRY

NATIONAL OCEANIC & ATMOSPHERIC ADMIN
ENVIRONMENTAL RESEARCH LABORATORIES
DEPARTMENT OF COMMERCE
BOULDER, CO 80302
01CY ATTN R. GRUBB
01CY ATTN AERONOMY LAB G. REID

DEPARTMENT OF DEFENSE CONTRACTORS

AEROSPACE CORPORATION
P. O. BOX 92957
LOS ANGELES, CA 90009
01CY ATTN I. GARFUNKEL
01CY ATTN T. SALMI
01CY ATTN V. JOSEPHSON
01CY ATTN S. BOWER
01CY ATTN N. STOCKWELL
01CY ATTN D. OLSEN
01CY ATTN J. CARTER
01CY ATTN F. MORSE
01CY ATTN SMFA FOR PWW

ANALYTICAL SYSTEMS ENGINEERING CORP
5 OLD CONCORD ROAD
BURLINGTON, MA 01803
01CY ATTN RADIO SCIENCES

BERKELEY RESEARCH ASSOCIATES, INC.
P. O. BOX 983
BERKELEY, CA 94701
01CY ATTN J. WORKMAN

BOEING COMPANY, THE
P. O. BOX 3707
SEATTLE, WA 98124
01CY ATTN G. KEISTER
01CY ATTN D. MURRAY
01CY ATTN G. HALL
01CY ATTN J. KENNEY

CALIFORNIA AT SAN DIEGO, UNIV OF
IPAPS, B-019
LA JOLLA, CA 92093
01CY ATTN HENRY G. BOOKER

BROWN ENGINEERING COMPANY, INC.
CUMMINGS RESEARCH PARK
HUNTSVILLE, AL 35807
01CY ATTN ROMEO A. DELIBERIS

CHARLES STARK DRAPER LABORATORY, INC.
555 TECHNOLOGY SQUARE
CAMBRIDGE, MA 02139
01CY ATTN D. B. COX
01CY ATTN J. P. GILMORE

COMPUTER SCIENCES CORPORATION
6565 ARLINGTON BLVD
FALLS CHURCH, VA 22046
01CY ATTN H. BLANK
01CY ATTN JOHN SPOOR
01CY ATTN C. NAIL

COMSAT LABORATORIES
LINTHICUM ROAD
CLARKSBURG, MD 20734
01CY ATTN G. HYDE

CORNELL UNIVERSITY
DEPARTMENT OF ELECTRICAL ENGINEERING
ITHACA, NY 14850
01CY ATTN D. T. FARLEY JR

ELECTROSPACE SYSTEMS, INC.
BOX 1359
RICHARDSON, TX 75080
01CY ATTN H. LOGSTON
01CY ATTN SECURITY (PAUL PHILLIPS)

ESL INC.
495 JAVA DRIVE
SUNNYVALE, CA 94086
01CY ATTN J. ROBERTS
01CY ATTN JAMES MARSHALL
01CY ATTN C. W. PRETTIE

FORD AEROSPACE & COMMUNICATIONS CORP
3939 FABIAN WAY
PALO ALTO, CA 94303
01CY ATTN J. T. MATTINGLEY

GENERAL ELECTRIC COMPANY
SPACE DIVISION
VALLEY FORGE SPACE CENTER
GODDARD BLVD KING OF PRUSSIA
P. O. BOX 8555
PHILADELPHIA, PA 19101
01CY ATTN M. H. BORTNER SPACE SCI LAB

GENERAL ELECTRIC COMPANY
P. O. BOX 1122
SYRACUSE, NY 13201
01CY ATTN F. REIBERT

GENERAL ELECTRIC COMPANY
TEMPO-CENTER FOR ADVANCED STUDIES
816 STATE STREET (P.O. DRAWER QQ)
SANTA BARBARA, CA 93102
01CY ATTN DASIAC
01CY ATTN DON CHANDLER
01CY ATTN TOM BARRETT
01CY ATTN TIM STEPHANS
01CY ATTN WARREN S. KNAPP
01CY ATTN WILLIAM MCNAMARA
01CY ATTN B. GAMBILL
01CY ATTN MACK STANTON

GENERAL ELECTRIC TECH SERVICES CO., INC.
HMES
COURT STREET
SYRACUSE, NY 13201
01CY ATTN G. MILLMAN

GENERAL RESEARCH CORPORATION
SANTA BARBARA DIVISION
P. O. BOX 6770
SANTA BARBARA, CA 93111
01CY ATTN JOHN ISE JR
01CY ATTN JOEL GARBARINO

GEOPHYSICAL INSTITUTE
UNIVERSITY OF ALASKA
FAIRBANKS, AK 99701
(ALL CLASS ATTN: SECURITY OFFICER)
01CY ATTN T. N. DAVIS (UNCL ONLY)
01CY ATTN NEAL BROWN (UNCL ONLY)
01CY ATTN TECHNICAL LIBRARY

GTE SYLVANIA, INC.
ELECTRONICS SYSTEMS GRP-EASTERN DIV
77 A STREET
NEEDHAM, MA 02194
01CY ATTN MARSHAL CROSS

ILLINOIS, UNIVERSITY OF
DEPARTMENT OF ELECTRICAL ENGINEERING
URBANA, IL 61803
01CY ATTN K. YEH

ILLINOIS, UNIVERSITY OF
107 COBLE HALL
801 S. WRIGHT STREET
URBANA, IL 60630
(ALL CORRES ATTN SECURITY SUPERVISOR FOR)
01CY ATTN K. YEH

INSTITUTE FOR DEFENSE ANALYSES
400 ARMY-NAVY DRIVE
ARLINGTON, VA 22202
01CY ATTN J. M. AEIN
01CY ATTN ERNEST BAUER
01CY ATTN HANS WOLFHARD
01CY ATTN JOEL BENGSTON

HSS, INC.
2 ALFRED CIRCLE
BEDFORD, MA 01730
01CY ATTN DONALD HANSEN

INTL TEL & TELEGRAPH CORPORATION
500 WASHINGTON AVENUE
NUTLEY, NJ 07110
01CY ATTN TECHNICAL LIBRARY

JAYCOR
1401 CAMINO DEL MAR
DEL MAR, CA 92014
01CY ATTN S. R. GOLDMAN

JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY
JOHNS HOPKINS ROAD
LAUREL, MD 20810
01CY ATTN DOCUMENT LIBRARIAN
01CY ATTN THOMAS POTEMRA
01CY ATTN JOHN DASSOULAS

LOCKHEED MISSILES & SPACE CO INC
P. O. BOX 504
SUNNYVALE, CA 94088
01CY ATTN DEPT 60-12
01CY ATTN D. R. CHURCHILL

LOCKHEED MISSILES AND SPACE CO INC
3251 HANOVER STREET
PALO ALTO, CA 94304
01CY ATTN MARTIN WALT DEPT 52-10
01CY ATTN RICHARD G. JOHNSON DEPT 52-12
01CY ATTN W. L. IMHOF DEPT 52-12

KAMAN SCIENCES CORP
P. O. BOX 7463
COLORADO SPRINGS, CO 80933
01CY ATTN T. MEAGHER

LINKABIT CORP
10453 ROSELLE
SAN DIEGO, CA 92121
01CY ATTN IRWIN JACOBS

LOWELL RSCH FOUNDATION, UNIVERSITY OF
450 AIKEN STREET
LOWELL, MA 01854
01CY ATTN K. BIBL

M.I.T. LINCOLN LABORATORY
P. O. BOX 73
LEXINGTON, MA 02173
01CY ATTN DAVID M. TOWLE
01CY ATTN P. WALDRON
01CY ATTN L. LOUGHLIN
01CY ATTN D. CLARK

MARTIN MARIETTA CORP
ORLANDO DIVISION
P. O. BOX 5837
ORLANDO, FL 32805
01CY ATTN R. HEFFNER

MCDONNELL DOUGLAS CORPORATION
5301 BOLSA AVENUE
HUNTINGTON BEACH, CA 92647
01CY ATTN N. HARRIS
01CY ATTN J. MOULE
01CY ATTN GEORGE MROZ
01CY ATTN W. OLSON
01CY ATTN R. W. HALPRIN
01CY ATTN TECHNICAL LIBRARY SERVICES

MISSION RESEARCH CORPORATION
735 STATE STREET
SANTA BARBARA, CA 93101
01CY ATTN P. FISCHER
01CY ATTN W. F. CREVIER
01CY ATTN STEVEN L. GUTSCHE
01CY ATTN D. SAPPENFIELD
01CY ATTN R. BOGUSCH
01CY ATTN R. HENDRICK
01CY ATTN RALPH KILB
01CY ATTN DAVE SOWLE
01CY ATTN F. FAJEN
01CY ATTN M. SCHEIBE
01CY ATTN CONRAD L. LONGMIRE
01CY ATTN WARREN A. SCHLUETER

MITRE CORPORATION, THE
P. O. BOX 208
BEDFORD, MA 01730
01CY ATTN JOHN MORGANSTERN
01CY ATTN G. HARDING
01CY ATTN C. E. CALLAHAN

MITRE CORP
WESTGATE RESEARCH PARK
1820 DOLLY MADISON BLVD
MCLEAN, VA 22101
01CY ATTN W. HALL
01CY ATTN W. FOSTER

PACIFIC-SIERRA RESEARCH CORP
1456 CLOVERFIELD BLVD.
SANTA MONICA, CA 90404
01CY ATTN E. C. FIELD JR

PENNSYLVANIA STATE UNIVERSITY
IONOSPHERE RESEARCH LAB
318 ELECTRICAL ENGINEERING EAST
UNIVERSITY PARK, PA 16802
(NO CLASSIFIED TO THIS ADDRESS)
01CY ATTN IONOSPHERIC RESEARCH LAB

IONOSPHERIC MODELING DISTRIBUTION LIST
UNCLASSIFIED ONLY

PLEASE DISTRIBUTE ONE COPY TO EACH OF THE FOLLOWING PEOPLE:

ADVANCED RESEARCH PROJECTS AGENCY (ARPA)
STRATEGIC TECHNOLOGY OFFICE
ARLINGTON, VIRGINIA

CAPT. DONALD M. LEVINE

NAVAL RESEARCH LABORATORY
WASHINGTON, D.C. 20375

DR. P. MANGE
DR. R. MEIER
DR. E. SZUSZCZEWICZ - CODE 4127
DR. TIMOTHY COFFEY - CODE 4700
DR. S. OSSAKOW - CODE 4780
DR. J. GOODMAN - CODE 7560

SCIENCE APPLICATIONS, INC.
1250 PROSPECT PLAZA
LA JOLLA, CALIFORNIA 92037

DR. D. A. HAMLIN
DR. L. LINSON
DR. D. SACHS

DIRECTOR OF SPACE AND ENVIRONMENTAL LABORATORY
NOAA
BOULDER, COLORADO 80302

DR. A. GLENN JEAN
DR. G. W. ADAMS
DR. D. N. ANDERSON
DR. K. DAVIES
DR. R. F. DONNELLY

A. F. GEOPHYSICS LABORATORY
L. G. HANSCOM FIELD
BEDFORD, MASS. 01730

DR. T. ELKINS
DR. W. SWIDER
MRS. R. SAGALYN
DR. J. M. FORBES
DR. T. J. KENESHEA
DR. J. AARONS

OFFICE OF NAVAL RESEARCH
800 NORTH QUINCY STREET
ARLINGTON, VIRGINIA 22217

DR. H. MULLANEY

COMMANDER
NAVAL ELECTRONICS LABORATORY CENTER
SAN DIEGO, CALIFORNIA 92152

DR. M. BLEIWEISS
DR. I. ROTHMULLER
DR. V. HILDEBRAND
MR. R. ROSE

U. S. ARMY ABERDEEN RESEARCH AND DEVELOPMENT CENTER
BALLISTIC RESEARCH LABORATORY
ABERDEEN, MARYLAND

DR. J. HEIMERL

COMMANDER
NAVAL AIR SYSTEMS COMMAND
DEPARTMENT OF THE NAVY
WASHINGTON, D.C. 20360

DR. T. CZUBA

HARVARD UNIVERSITY
HARVARD SQUARE
CAMBRIDGE, MASS. 02138

DR. M. B. MCELROY
DR. R. LINDZEN

PENNSYLVANIA STATE UNIVERSITY
UNIVERSITY PARK, PENNSYLVANIA 16802

DR. J. S. NISBET
DR. P. R. ROHRBAUGH
DR. D. E. BARAN
DR. L. A. CARPENTER
DR. M. LEE
DR. R. DIVANY
DR. P. BENNETT
DR. E. KLEVANS

UNIVERSITY OF CALIFORNIA, LOS ANGELES
405 HILLGARD AVENUE
LOS ANGELES, CALIFORNIA 90024

DR. F. V. CORONITI
DR. C. KENNEL

UNIVERSITY OF CALIFORNIA, BERKELEY
BERKELEY, CALIFORNIA 94720

DR. M. HUDSON

UTAH STATE UNIVERSITY
4TH N. AND 8TH STREETS
LOGAN, UTAH 84322

DR. P. M. BANKS
DR. R. HARRIS
DR. V. PETERSON
DR. R. MEGILL
DR. K. BAKER

CORNELL UNIVERSITY
ITHACA, NEW YORK 14850

DR. W. E. SWARTZ
DR. R. SUDAN
DR. D. FARLEY
DR. M. KELLEY

NASA
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND 20771

DR. S. CHANDRA
DR. K. MAEDO

PRINCETON UNIVERSITY
PLASMA PHYSICS LABORATORY
PRINCETON, NEW JERSEY 08540

DR. F. PERKINS
DR. E. FRIEMAN

INSTITUTE FOR DEFENSE ANALYSIS
400 ARMY/NAVY DRIVE
ARLINGTON, VIRGINIA 22202

DR. E. BAUER

UNIVERSITY OF MARYLAND
COLLEGE PARK, MD 20742
DR. K. PAPADOPOULOS
DR. E. OTT

UNIVERSITY OF PITTSBURGH
PITTSBURGH, PA. 15213

DR. N. ZABUSKY
DR. M. BIONDI

DEFENSE DOCUMENTATION CENTER
CAMERON STATION
ALEXANDRIA, VA. 22314

(12 COPIES IF OPEN PUBLICATION
OTHERWISE 2 COPIES) 12CY ATTN TC

UNIVERSITY OF CALIFORNIA
LOS ALAMOS SCIENTIFIC LABORATORY
J-10, MS-664
LOS ALAMOS, NEW MEXICO 87545

M. PONGRATZ
D. SIMONS
G. BARASCH
L. DUNCAN