FINAL REPORT ON CONTRACT NAS 5-9278: GSFC SUPPORT FOR E-24 DATA REDUCTION AND ANALYSIS

1. INTRODUCTION

Since March of 1968 the TRW investigators have been reducing and analyzing data from the E-24 Plasma Wave Detector under NASA Contract NAS5-9278, administered by the OGO Project at Goddard Space Flight Center. During the early years of this investigation Mr. G. M. Crook served as Principal Investigator, and in recent years Dr. F. L. Scarf assumed this responsibility. Dr. R. W. Fredricks and Dr. I. M. Green were the Co-Investigators. Others who worked actively on the data analysis and reduction phases are Dr. C. F. Kennel and Dr. F. V. Coroniti of UCLA, and the TRW employees A. Cowan and Mrs. S. Thomas, Mr. J. Burgess, Mr. A. Bellobradic, and Mr. J. H. McGehee.

This analysis and reduction project is not yet completed, but since OGO-5 is now retired and the Project Office at GSFC is being closed, future funding will come from NASA Headquarters. The present report is a final report for the work carried out under Contract NAS5-9278, but it is an interim progress report for the overall E-24 data reduction and analysis program.

2. MAIN RESULTS TO DATE

The OGO-5 spacecraft delivered large amounts of high quality digital and analog wave data, and the E-24 investigators were strongly and continuously supported in their analysis program by several of the investigator groups on the spacecraft (in particular, by groups from UCLA, JPL, the University of Iowa, and Lockheed). The highlights of our analysis program are summarized in the following pages.

RESULTS FROM
THE OGO-5 PLASMA WAVE INVESTIGATION:
PUBLICATIONS IN SCIENTIFIC BOOKS AND JOURNALS

A. Papers Already Published

1. Fredricks, R. W., C. F. Kennel, F. L. Scarf, G. M. Crook, and I. M. Green, Detection of Electric Field Turbulence in the Earth's Bow Shock, Phys. Rev. Lett., 21, 1761, 1968.

2. Scarf, F. L., G. M. Crook, R. W. Fredricks, I. M. Green, and C. F. Kennel, Observations of Plasma Waves in Space, Plasma Waves in Space and Laboratory, Ed. by J. O. Thomas and B. J. Landmark (Edinburgh University Press, Edinburgh), 379, 1969.

3. Fredricks, R. W., and P. J. Coleman, Jr., Observations of the Microstructure of the Earth's Bow Shock, Plasma Instabilities in Astrophysics, Ed. by D. G. Wentzel and D. A. Tidman (Gordon and Breach Science Publishers, New York), 199, 1969.

4. Fredricks, R. W., and F. L. Scarf, The Fine Structure of the Earth's Collisionless Shock Wave, Collision-Free Shocks in the Laboratory and Space, ESRO SP-51, 1969; AIAA Paper No. 69-676, 1969.

5. Crook, G. M., F. L. Scarf, R. W. Fredricks, I. M. Green, and P. Lukas, The OGO-V Plasma Wave Detector: Instrumentation and In-Flight Operation, IEEE Trans. on Geosci. Electronics, GE-7, 120, 1969.

6. Scarf, F. L., R. W. Fredricks, and C. F. Kennel, AC Electric and Magnetic Fields and Collisionless Shock Structures, Particles and Fields in the Magnetosphere, Ed. by B. M. McCormac (D. Reidel Pub. Co., Dordrecht, Holland), 102, 1970.

7. Kennel, C. F., R. W. Fredricks, and F. L. Scarf, High Frequency Electrostatic Waves in the Magnetosphere, Particles and Fields in the Magnetosphere, Ed. by B. M. McCormac (D. Reidel Pub. Co., Dordrecht, Holland), 257, 1970.

8. Scarf, F. L., C. F. Kennel, R. W. Fredricks, I. M. Green, and G. M. Crook, AC Fields and Wave Particle Interactions, Particles and Fields in the Magnetosphere, Ed. by B. M. McCormac (D. Reidel Pub. Co., Dordrecht, Holland), 275, 1970.

9. Scarf, F. L., P. J. Coleman, Jr., R. W. Fredricks, C. F. Kennel, and C. T. Russell, Magnetic and Electric Field Changes Across the Shock and in the Magnetosheath, Intercorrelated Satellite Observations Related to Solar Events, Ed. by Manno and Page (D. Reidel Pub. Co., Dordrecht, Holland), 181, 1970.

10. Scarf, F. L., Interplanetary Waves and their Effects on the Magnetosphere, Progress in Radio Science 1966-1969, Vol. 1, Ionosphere, Magnetosphere, Radio Noise, Ed. by G. M. Crown, N. D. Clarence, and M. J. Rycroft (URSI, Brussels), 233, 1970.

11. Fredricks, R. W., F. V. Coroniti, C. F. Kennel, and F. L. Scarf, Fast Time-Resolved Spectra of Electrostatic Turbulence in the Earth's Bow Shock, Phys. Rev. Lett., 24, 994, 1970.

12. Scarf, F. L., R. W. Fredricks, I. M. Green, and M. Neugebauer, OGO-5 Observations of Quasi-Trapped Electromagnetic Waves in the Solar Wind, J. Geophys. Res., 75, 3735, 1970.

13. Fredricks, R. W., G. M. Crook, C. F. Kennel, I. M. Green, F. L. Scarf, P. J. Coleman, Jr., and C. T. Russell, OGO-5 Observations of Electrostatic Turbulence in Bow Shock Magnetic Structures, J. Geophys. Res., 75, 3751, 1970.

14. Kennel, C. F., F. L. Scarf, R. W. Fredricks, J. H. McGehee, and F. V. Coroniti, VLF Electric Field Observations in the Magnetosphere, J. Geophys. Res., 75, 6136, 1970.

15. Scarf, F. L., R. W. Fredricks, L. A. Frank, C. T. Russell, P. J. Coleman, Jr., and M. Neugebauer, Direct Correlations of Large Amplitude Waves with Suprathermal Protons in the Magnetosheath and Solar Wind, J. Geophys. Res., 75, 7316, 1970.

16. Scarf, F. L., Microscopic Structure of the Solar Wind, Space Sci. Rev., 11, 234, 1970.

17. Kennel, C. F., F. L. Scarf, F. V. Coroniti, R. W. Fredricks, and J. H. McGehee, Jr., Complex Electric Field Emissions Observed by OGO 5 on August 15, 1968, ESRO Geostationary Magnetospheric Satellite, ESRO SP-60, Proceedings of an ESRO Colloquium Held in Lyngby, Denmark, 91, 1971.

18. Coroniti, F. V., R. W. Fredricks, C. F. Kennel, and F. L. Scarf, Fast Time Resolved Spectral Analysis of VLF Banded Emissions, J. Geophys. Res., 76, 2366, 1971.

19. Scarf, F. L., R. W. Fredricks, L. A. Frank, and M. Neugebauer, Non-Thermal Electrons and High Frequency Waves in the Upstream Solar Wind: Part 1, Observations, J. Geophys. Res., 76, 5162, 1971.

20. Fredricks, R. W., F. L. Scarf, and L. A. Frank, Non-Thermal Electrons and High Frequency Waves in the Upstream Solar Wind: Part 2, Analysis and Interpretation, J. Geophys. Res., 76, 6691, 1971.

21. Russell, C. T., C. R. Chappell, M. D. Montgomery, M. Neugebauer, and F. L. Scarf, OGO-5 Observations of the Polar Cusp on November 1, 1968, J. Geophys. Res., 76, 6743, 1971.

22. Fredricks, R. W., Plasma Instability at $(N + 1/2)f_c$ and its Relationship to Some Satellite Observations, J. Geophys. Res., 76, 5344, 1971.

23. Fredricks, R. W., F. L. Scarf, and I. M. Green, Distributions of Electron Plasma Oscillations Upstream from Earth's Bow Shock, J. Geophys. Res., 77, 1300, 1972.

24. Scarf, F. L., R. W. Fredricks, E. J. Smith, A. M. A. Frandsen, and G. P. Serbu, OGO-5 Observations of Discrete Whistlers and Emissions during a large Magnetic Storm, J. Geophys. Res., 77, 1776, 1972.

25. Scarf, F. L., R. W. Fredricks, I. M. Green, and C. T. Russell, Plasma Waves in the Dayside Polar Cusp, Part 1: Magnetospheric Observations, J. Geophys. Res., 77, 2274, 1972.

26. Fredricks, R. W., F. L. Scarf, and I. M. Green, Electron Plasma Oscillations in the Near-Earth Solar Wind: Preliminary Observations and Interpretations, Solar Wind, NASA SP-308, 353, 1972.

27. Scarf, F. L., R. W. Fredricks, and I. M. Green, Comparison of Deep Space and Near-Earth Observations of Plasma Turbulence at Solar Wind Discontinuities, Solar Wind, NASA SP-308, 421, 1972.

28. Scarf, F. L., and R. W. Fredricks, Electrostatic Waves in the Magnetosphere, Earth's Magnetospheric Processes, Ed. by B. M. McCormac (D. Reidel Publishing Company, Dordrecht,Holland), 319, 1972.

29. Fredricks, R. W., F. L. Scarf, C. T. Russell, and M. Neugebauer, Detection of Solar Wind Electron Plasma Frequency Fluctuations in an Oblique Nonlinear MHD Wave, J. Geophys. Res., 77, 3598, 1972.

30. Wu, C. S., and R. W. Fredricks, Cyclotron Drift Instability in the Bow Shock, J. Geophys. Res., 77, 5585, 1972.

B. Papers Accepted and in Press

31. Scarf, F. L., and R. W. Fredricks, Transmission Losses Associated with Plasma Perturbations, Proceedings of the Naval Research Laboratory Conference on Antennas and Transionospheric Propagation as Related to ELF/VLF Downlink Satellite Communications, in press.

32. Scarf, F. L., R. W. Fredricks, C. F. Kennel, and F. V. Coroniti, Satellite Studies of Magnetospheric Substorms on August 15, 1968: OGO-5 Plasma Wave Observations, J. Geophys. Res., in press.

33. Fredricks, R. W., and F. L. Scarf, Recent Studies of Magnetospheric Electric Field Emissions above the Electron Gyrofrequency, J. Geophys. Res., in press.

34. Scarf, F. L., and C. R. Chappell, An Association of Magnetospheric Whistler Dispersion Characteristics with Changes in Local Plasma Density, in press.

C. Papers Completed and Submitted for Publication

35. Fredricks, R. W., F. L. Scarf, and C. T. Russell, Field-Aligned Currents, Plasma Waves, and Anomalous Resistivity in the Disturbed Polar Cusp, submitted to J. Geophys. Res.

36. Scarf, F. L., R. W. Fredricks, C. T. Russell, M. Kivelson, M. Neugebauer, and C. R. Chappell, Observations of a Current-Driven Plasma Instability at the Outer Zone-Plasma Sheet Boundary, submitted to J. Geophys. Res.

37. Fredricks, R. W., and C. T. Russell, Ion Cyclotron Waves Observed in the Polar Cusp, submitted to J. Geophys. Res.

38. Kivelson, M. G., C. T. Russell, M. Neugebauer, F. L. Scarf, and R. W. Fredricks, The Dependence of the Polar Cusp on the North-South Component of the Interplanetary Magnetic Field, submitted to J. Geophys. Res.

D. Other Publications in which E-24 Data are Displayed and Analyzed

1. Scarf, F. L., I. M. Green, G. L. Siscoe, D. S. Intriligator, D. D. McKibbin, and J. H. Wolfe, Pioneer 8 Electric Field Measurements in the Distant Geomagnetic Tail, J. Geophys. Res., 75, 3167, 1970.

2. Scarf, F. L., I. M. Green, and G. M. Crook, The Pioneer 9 Electric Field Experiment: Part 1, Near Earth Observations, Cosmic Electrodynamics, 1, 496, 1971.

3. Neugebauer, M., Initial Deceleration of Solar Wind Positive Ions in the Earth's Bow Shock, J. Geophys. Res., 75, 717, 1970.

4. Parks, G. K., G. Laval, and R. Pellat, Behavior of Outer Radiation Zone and a New Model of Magnetospheric Substorm, Proceedings of the XV IUGG General Assembly Session on Magnetospheric Substorms, to be published.

5. Ossakow, S. L., G. W. Sharp, and K. K. Harris, Spectrometer Observations in the Region near the Bow Shock on March 12, 1968, J. Geophys. Res., 75, 6024, 1970.

6. Cornwall, J., VLF Emissions and Electron Instabilities, Progress in Radio Science 1966-1969, Vol. 1, Ed. by G. M. Brown, N. D. Clarence, and M. J. Rycroft (URSI, Brussels), 171, 1970.

7. Russell, C. T., R. L. McPherron, and P. J. Coleman, Jr., Fluctuating Magnetic Fields in the Magnetosphere. 1. ELF and VLF Fluctuations, Space Sci. Rev., 12, 810, 1972.

8. Shawhan, S. D., The Use of Multiple Receivers to Measure the Wave Characteristics of Very-Low-Frequency Noise in Space, Space Sci. Rev., 10, 689, 1970.

9. The E-24 observations in the magnetosphere form the basis for the MIT Ph.D. Thesis by T. S. T. Young. An account of this work was presented in the Trans. Amer. Geophys. Union, 52, 329, 1971, and a paper is in press in J. Geophys. Res., "High Frequency Electrostatic Waves in the Magnetosphere," by Young, Callen, and McCune.

10. Smith, D. F., Plasma Radiation from Collisionless MHD Shock Waves and the High-Frequency Waves in the Upstream Solar Wind, J. Geophys. Res., in press.

11. Oya, H., Turbulence of Electrostatic Electron Cyclotron Harmonic Observed by OGO-5, J. Geophys. Res., 77, 3483, 1972.

12. Nambu, Mitsuhiro, Nonlinear Theory of Plasma Instability at $(n + 1/2)\ \Omega_e$, J. Geophys. Res., in press.

E. Published Abstracts

1. Scarf, F. L., G. M. Crook, R. W. Fredricks, I. M. Green, and C. F. Kennel, OGO-5 Observations of Plasma Waves in the Magnetosphere, Book of Summaries and Abstracts, International Symposium on the Physics of the Magnetosphere, 8-5, 1968.

2. Fredricks, R. W., F. L. Scarf, G. M. Crook, I. M. Green, and C. F. Kennel, OGO-5 Observations of Plasma Waves near the Bow Shock, and Preliminary Analysis of Shock Structure, Book of Summaries and Abstracts, International Symposium on the Physics of the Magnetosphere, 1-4, 1968.

3. Green, I. M., E. W. Greenstadt, and F. L. Scarf, OGO-5 Plasma Wave Observations of Magnetic Storms in the Solar Wind and Magnetosphere, Trans. AGU, 49, 734, 1968.

4. Fredricks, R. W., F. L. Scarf, G. M. Crook, I. M. Green, and C. F. Kennel, OGO-5 Observations of Electrostatic Plasma Oscillations in the Magnetopause Layer, Trans. AGU, 50, 278, 1969.

5. Fredricks, R. W., F. L. Scarf, G. M. Crook, I. M. Green, and C. F. Kennel, OGO-5 Observations of Anomalous Resistivity in the Bow Shock, Trans. AGU, 50, 278, 1969.

6. Kennel, C. F., R. W. Fredricks, and F. L. Scarf, OGO-5 Observations of Auroral Electric Field Noise Above the Equatorial Electron Cyclotron Frequency, Trans. AGU, 50, 291, 1969.

7. Brody, K. I., R. E. Holzer, E. J. Smith, C. F. Kennel, R. W. Fredricks, and F. L. Scarf, Night Side Auroral Electric and Magnetic Noise in the Equatorial Plane, Trans. AGU, 50, 291, 1969.

8. Scarf, F. L., I. M. Green, R. W. Fredricks, and M. Neugebauer, Detection of Interplanetary 70 kHz Noise Bursts Near the Local Critical Frequency, Trans. AGU, 50, 303, 1969.

9. Fredricks, R. W., Plasma Oscillations and Dissipation Mechanisms in the Bow Shock, Trans. AGU, 50, 461, 1969.

10. Fredricks, R. W., and F. L. Scarf, The Fine Structure of the Earth's Collisionless Shock Wave, AIAA Bulletin, 6, 293, 1969.

11. Scarf, F. L., Interplanetary Waves and their Effects on the Magnetosphere, URSI XVIth General Assembly Book of Abstracts IV-5, 59, 1969.

12. Scarf, F. L., OGO-5 Plasma Wave Measurements and Related Magnetospheric Instability Phenomena, Program and Abstracts for the General Scientific Assembly, IAGA Bulletin No. 26, 222, 1969.

13. Kennel, C. F., F. L. Scarf, F. V. Coroniti, R. W. Fredricks, and J. H. McGehee, Complex Electric Field Emissions Observed on OGO-5, Proc. USNC/URSI-IEEE Spring Meeting, 41, 1970.

14. Coroniti, F. V., R. W. Fredricks, C. F. Kennel, and F. L. Scarf, Fast Time Resolved Spectra of VLF Banded Chorus, Trans. AGU, 51, 400, 1970.

15. Fredricks, R. W., F. V. Coroniti, C. F. Kennel, and F. L. Scarf, Fast Time Resolved Spectra of Electrostatic Turbulence in the Bow Shock, Trans. AGU, 51, 408, 1970.

16. Fredricks, R. W., Microinstabilities Observed in the Earth's Bow Shock, Trans. of the American Physics Society Div. of Plasma Phys. Bulletin, 11, 15, 1471, 1970.

17. Fredricks, R. W., Microscale Space and Time Phenomena in the Magnetosheath, Trans. AGU, 51, 832, 1970.

18. Fredricks, R. W., I. M. Green, and F. L. Scarf, OGO-5 Observations of Suprathermal Electron Plasma Oscillations Beyond the Bow Shock, Trans. AGU, 52, 336, 1971.

19. Scarf, F. L., R. W. Fredricks, and C. T. Russell, OGO-5 Wave Observations in the Dayside Polar Cusp Region, Trans. 1971 USNC/URSI-IEEE, 80, 1971.

20. Fredricks, R. W., F. L. Scarf, E. J. Smith, A. M. A. Frandsen, and G. P. Serbu, Trans. AGU 52, 903, 1971.

21. Scarf, F. L., C. F. Kennel, R. W. Fredricks, and F. V. Coroniti, VLF Wave Observations with Electric Field Sensors, XV General Assembly of IUGG, Program and Abstracts of the IAGA Symposium on Instabilities in the Magnetosphere, 377, 1971.

22. Russell, C. T., M. G. Kivelson, M. Neugebauer, and F. L. Scarf, The Dependence of the Polar Cusp on the North-South Component of the Interplanetary Field, Trans. AGU, 53, 494, 1972.

23. Fredricks, R. W., F. L. Scarf, C. T. Russell, and M. Neugebauer, Correlation between Local Solar Wind Plasma Density Fluctuations and Oblique, Nonlinear MHD Waves, Trans. AGU, 53, 509, 1972.

24. Fredricks, R. W., F. L. Scarf, and C. T. Russell, Field-Aligned Currents, Plasma Waves, and Anomalous Resistivity in the Disturbed Polar Cusp, to appear in Trans. AGU.

3. NEW TECHNOLOGY

During the hardware phase of Contract NAS5-9278, several new technology items were developed and these have already been reported (see Appendix I). No New Technology was developed during the reduction and analysis phase.

APPENDIX I. NEW TECHNOLOGY

to

FINAL REPORT ON CONTRACT NAS 5-9278
GSFC SUPPORT FOR E-24 DATA REDUCTION AND ANLYSIS

November 1972

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TRW

July 1, 1971

Mr. Donald S. Friedman
Technology Utilization Officer
National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

Subject: Amended Final New Technology Report
Annual Report on NAS 5-9278

Dear Mr. Friedman:

Your records will show that a final new technology report containing seven items was submitted on this contract on September 23, 1970. At that time, we were under the impression that the work to be performed had been completed and the "close-out" process was initiated. Since that time, the contract has been extended and is now scheduled to be completed on March 31, 1972.

In the interim, since that report, our search and review with project personnel have failed to uncover any new innovation, discovery, improvement, or invention. In fact, the additional work being performed involves only analysis of fresh data collected by the experiments on board the OGO 5. It is anticipated that these analyses will continue for the duration of the contract and that the opportunity to be innovative is virtually nil.

As before, no R & D subcontracts were awarded in support of the work performed nor is there any expectations that any will be awarded in the future.

As a consequence of the modification to this contract, I presume your office will automatically consider the "final" report of September 23, 1970, as an "annual" and that it and this report meet your requirements for compliance with the Clause.

Yours very truly, 10

Herbert H. Rosen
Director of Technology Utilization

HHR:amc

bc: Anthoni, M. H. SN 5402
Mosher, F. S.
Salzer, E. R.
Scarf, F. L.
Wilkinson, H. D.
Contract File

OSKOL

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND 20771

REPLY TO
ATTN OF:

October 21, 1970

TRW
One Space Park
Redondo Beach, California 90278

Subject: Reportable Item entitled, Time Display Printout"

Contract NAS 5-9278 NASA Case No. GSC 11,319-1

Gentlemen:

This will acknowledge receipt of the subject reportable item furnished in accordance with the requirements of the New Technology clause of the subject contract.

You are advised that this item may be disclosed or published at any time by NASA and is now being reviewed for possible publication under the NASA Technology Utilization Program. In case your report is not sufficiently complete, you may be asked to provide additional details concerning the nature, operation or characteristics of the reportable item. In addition, where necessary, the reportable item is being reviewed for the presence of invention and patent considerations under the Rights Section of the New Technology clause. In the event a waiver of title has not been previously considered, your attention is directed to the provisions of this Section relating to the opportunity to petition for waiver of title to inventions.

Please advise this office promptly if you desire that NASA delay or withhold release of information concerning the reportable item. Please advise, also, if you have any objection to the use of a credit to the individual(s) who made the reportable item.

Sincerely,

Donald S. Friedman
Technology Utilization Officer

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