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STUDY PLASMA INTERACTIONS IN THE AURORAL IONOSPHERE

Final Report on Grant NAG6-5

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September 1983

Prepared for

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16. Abstract

Analyzed data from an earlier rocket flight, 29.007UE. (Support for analysis was also provided by NSF.) Principal completed results are: a) In a discrete electron arc the measured upward moving electrons are well accounted for by secondaries produced in collisional scattering of the measured downcoming electrons. No collective mechanisms need be invoked. b) The low energy downcoming electrons are accounted for by thermal plasma accelerated through a potential drop of a few kV that specularly reflects upward-moving lower energy electrons. No low altitude collective effects need be invoked in the arc. c) Simultaneous measurements of electric field by double probes on 29.007 and the Chatanika Radar allow one to infer that: there are upward drifting ions above the discrete electron arc; and there is a westward neutral wind in the discrete arc. Built two rocket payloads to investigate plasma effects in the pulsating aurora. These were designated 33.023/024 and launched 11/82 and 1/83 with support from a follow-on contract to SAI, #NAS5-26944. Refurbished a frequency spectrum analyzer, recovered from rocket 29.013 (reflight of 29.007; on 29.013 a 2nd-stage engine failed) for use on the U.of MN SCEX rocket, 27.045UE launched in 1/83.

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STUDY OF PLASMA INTERACTIONS IN THE AURORAL IONOSPHERE

The history of events and accomplishments supported by Grant NAG6-5 is as follows:

1) The proposal from which the grant resulted was submitted to NASA in September 1979, by Rice University. The Principal Investigator was Dr. Hugh R. Anderson, Professor of Space Physics at Rice. The proposal asked two years' support for three tasks:

a) Analysis of ion and electric field data from rocket 29.007.

b) Construction and launch of two payloads to study thin layers in the pulsating aurora.

c) Construction of an electric field frequency spectrum analyzer for operation on rocket 27.045, commonly called SCEX, for which Dr. Paul Kellogg at the University of Minnesota is the PI (SCEX carries an electron accelerator and a suite of diagnostic instruments to observe effects of the electron beam.)

elec

Coinvestigators were Dr. T.J. Hallinan and H.C. Stenbaek-Nielsen of the University of Alaska and Dr. E.A. Bering of the University of Houston.

3) In August 1980 Grant NAG6-5 was awarded for one year (1 July 1980 - 30 June 1981)

Work began in summer of 1980 on all phases of the payload except the photometers, which were built in their entirety by our Coinvestigator Dr. Hallinan at the University of Alaska.

The Project Initiation Conference was held at WFC on 14 October 1980.

The Design Review was held 13 April 1981.

A paper was published based on data from rocket 29.007.

4) In June 1981, a renewal proposal for the period 1 July 1981 to 30 June 1982 was submitted to:

Continue Task A
Complete Task B
Initiate and complete Task C

The Principal Investigator for this second year was Dr. R.A. Wolf, Professor of Space Physics at Rice. This change was agreed to by Anderson and Wolf because Anderson resigned from the Rice University faculty effective 15 August 1981 and joined the staff of Science Applications, Inc. (SAI) in their Seattle area office.

In this second year we continued analysis of data from 29.007 and a second paper was published on it.

Work continued on all aspects of the new rocket payloads. Circuit boards for the $\Delta N/N$ experiment were delivered by Rice to the University of Houston where Dr. E.A. Bering, our Coinvestigator who designed that detector, completed it. The photometer design was completed by T.J. Hallinan in Alaska, and the detailed solid state detector design were completed by Anderson in Seattle with support from the grant as noted above, and with additional support from SAI. The electron optics design of the electrostatic analyzers was also completed by Anderson. Other portions of the work were carried out by John McGarity, the project engineer at Rice, with support by Del Oehme, also at Rice. These men were in regular contact with Anderson, who continued to take responsibility for the scientific program.

Launch had been planned for March 1982, but in December 1981 it became obvious that the payloads would not be complete in time, and a status report from John McGarity in January 1982 made this quite clear. This situation and future plans were reported to NASA by SAI and Rice in Status Report #1 dated 12 February 1982 (included in Appendix).

Following this realization, work proceeded on the payloads through the balance of the grant period. On 14 April 1982, SAI submitted a proposal to NASA to complete and launch the payloads in a third year, 1 July 1982 to 30 June 1983. In support of this, R.A. Wolf and J.O. McGarity of Rice proposed to SAI to complete their portion of the program under subcontract to SAI. The proposal from SAI was accepted by NASA and Contract NAS5-26944 between NASA and SAI resulted. Under this contract SAI and Rice completed the payloads and launched them (rockets 33.023 and 33.024) from Poker Flat Research Range, Alaska, in the winter of 1982-83.

The work on Task C, the electric field frequency spectrum analyzer, was brought to a successful conclusion under Grant NAG6-5. The analyzer that had been recovered in 1979 from 29.013 was refurbished, delivered to the University of Minnesota, and launched on 27.045UE from Churchill Research Range in January 1982. A retarding potential analyzer (RPA) was

also built at Rice and successfully launched on 27.045. Prior to launch the 27.045 mother payload, carrying the electron accelerator and RPA, were operated in the Space Simulation Chamber A at NASA-JSC. Interesting data resulted (see appendices on this related work). The RPA was built with support from a subcontract to Rice from the University of Minnesota and from the NASA SR&T grant to Rice, NGL44-006-012.

APPENDIX 1

STATUS REPORT #1

12 February 1982

SAI/NW-HRA-482-02
February 12, 1982

STATUS REPORT #1

on Grant NAG6-5

From NASA-Wallops Flight Center to Rice University

STUDY PLASMA INTERACTIONS IN THE AURORAL IONOSPHERE

Prepared for

Rice University
Department of Space Physics
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By

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Hugh R. Anderson
Co-Investigator

I. BACKGROUND

This program was initially proposed by H.R. Anderson at Rice University in September 1979, and funding approval was given in August 1980 for work beginning July 1980 under Grant NAG6-5 to Rice University. The work as proposed was planned for a period of two years. A renewal proposal for the second year was submitted by Rice in June 1981, with R.A. Wolf as the Principal Investigator. This change in PI was made because Anderson resigned from Rice effective 15 August 1981, and has become a full-time employee of Science Applications, Inc. He remains Adjunct Professor at Rice. His work at SAI on Grant NAG6-5 is supported by PO 22183 from Rice University.

II. WORK ACCOMPLISHED THROUGH 30 JANUARY 1982

Three tasks were proposed in June 1981. Their status follows.

Task A. Further analysis of data from rocket 29.007 is proceeding slowly. Work is being done by Anderson at SAI, by E.A. Bering at the University of Houston, by R.M. Robinson at Stanford Research International, and by M.H. Rees at the University of Alaska (the latter three are not supported by NAG6-5). Publication of the following paper was supported by NAG6-5; preparation was supported in part by NSF:

> Robinson, R.M., E.A. Bering, R.R. Vondrak, H.R. Anderson, and P.A. Cloutier, "Simultaneous rocket and radar measurements of currents in an auroral arc", J. Geophys. Res. 86, 7703-7717 (1981).

A reprint is appended.

Task C. The refurbished electric field frequency analyzer was delivered to the University of Minnesota for use on rocket 27.045UE (called SCEX, with Paul Kellogg the PI). A retarding potential analyzer was delivered earlier; its construction was supported in part by a PO from the University of Minnesota to Rice.

H.R. Anderson participated in the launch from Churchill during the period 16-30 January; travel was funded by the University of Minnesota. The rocket was successfully launched over an aurora, and both of the above instruments worked and detected effects of the electron accelerator carried by the rocket. Data will be reduced at SAI in the coming months.

Task B. This task includes construction and launch of payloads on rockets 33.023 and 33.024, and eventually reduction and analysis of data. Design and construction of the payloads is being accomplished at Rice University under the direction of J.O. McGarity with the following exceptions:

1) The $\Delta N/N$ experiment is being tested by E.A. Bering at the University of Houston. The instrument was designed by Bering and built at Rice. It is complete and functioning.

2) The photometers were designed, built and tested under the direction of T.J. Hallinan at the University of Alaska. The photometers are complete but tests show inadequate sensitivity so that some rework may be necessary.

3) Analysis of electron trajectories and geometric design of the electrostatic analyzers was done by H.R. Anderson at SAI and forwarded to Rice in August 1981.

4) Detailed mechanical and electrical design of the solid state detectors and breadboarding of circuits was completed by H.R. Anderson in December 1981, and designs were sent to Rice. Some circuit changes were suggested by McGarity. Parts were machined in the Rice shop and recently returned to SAI for assembly and test.

The status of the payloads is summarized in the attached memo from McGarity to Wolf and Anderson. Obviously, construction is substantially behind schedule, and we have to postpone the rocket launches from the 1981-82 season to the following winter. Launch was initially scheduled for January 1982, and a slip to March 1982 was requested in the fall of 1981. We now project that launch from Poker Flat can be accomplished in the dark-moon period 10-28 November 1982. We request support in this period.

There are no special technical problems that have caused the delay. Each of the detector types has been used before on rockets or in laboratory measurements, but Anderson and McGarity underestimated the difficulty of adapting these for a rocket. Other factors have been:

a) Anderson's move to SAI took some time in the summer of 1981. In addition, the lack of daily communication between Anderson and McGarity may have caused some inefficiency.

b) In early 1981 Anderson and McGarity spent a lot of time on beam-plasma experiments in the large vacuum chamber at Johnson Space Center.

c) Anderson spent most of the period May-September 1981 writing reports and proposals for the Spacelab beam-plasma physics program (TEBPP) supported by NASA-MSFC. Definition phase is completed and we are in Preliminary Design so the work load is less.

d) Construction of the instruments for the Kellogg rocket took substantial time. That work has come to a successful conclusion (Task C).

e) Most importantly, less manpower has been available than was used for previous projects. From the beginning there has been no postdoctoral fellow and no graduate student involved with this project. For 29.007 and 29.013 there were two students, two faculty, a full-time postdoc and, during some periods, a very able undergraduate technician.

There will be no change in the manpower during payload construction. Anderson plans to have a graduate student from the University of Washington work on data analysis beginning in the fall of 1982.

III. WORK TO BE ACCOMPLISHED 1 FEBRUARY-30 JUNE 1982

Detailed success criteria and the launch window will be defined promptly.

Analysis of data from 29.007 and 27.045 will proceed.

The GSE and payloads for 33.023 and 33.024 will be completed and tested. It is possible that testing and integration at WFC can also be accomplished during this period. Anderson will be at Rice for 1-2 weeks in March and during this time a new schedule and budget will be prepared for the balance of the period.

In order to launch the payloads and analyze the results, we need an additional year's time (1 July 1982 - 30 June 1983) and some additional financial support. We understand that a formal proposal for this work must be submitted. Anderson will submit this from Science Applications, Inc., requesting a contract to complete the work, unless NASA-WFC strongly prefers to continue with a grant to Rice. SAI, as prime contractor, will then subcontract with Rice for engineering services during the launch. Such an arrangement will correspond to the fact that:

a) Most of the third year's work will be data analysis at SAI;

b) Responsibility should reside with H.R. Anderson.

Attach.: Robinson, et al. (1981).
Memo: McGarity/Wolf&Anderson
Letter: Hallinan/Anderson

APPENDIX 2

REPORT TO NASA HEADQUARTERS ON GRANT NAG6-5 AND RELATED WORK ON SR&T GRANTS (INCLUDES BIBLIOGRAPHY)

TO: E.R. Schmerling, NASA Headquarters
August 1981

Supporting Research at Rice University and SAI/Northwest

A. SR&T Grant NGL 44-006-012

1. Built a high resolution electrostatic analyzer for electronics in laboratory beam-plasma experiments.

2. Built a retarding potential analyzer to cover the electron energy range 5-400 eV, measuring currents from 10^{-11} to 10^{-7} A in four auto-ranging decades for lab and SCEX rocket.

3. Conducted laborat investigation with William Bernstein and R. Jerry Jost at the JSC Chamber A:

   a. Measured the scaling laws for BPD ignition;

   b. Measured the time delay in evolution of BPD ignition as a function of beam current;

   c. Measured the power spectral density spectrum of electric field oscillations as a function of position in the BPD interaction region -- strong radial dependence is observed;

   d. Measured energy spectrum of electrons resulting from beam-plasma interactions, including BPD -- both beam heating and ambient heating are seen.

B. Research Grant NAG6-5 for auroral plasma

1. Analyzed data from an earlier rocket flight, 29.007UE. (Support for analysis was also provided by NSF.) Principal completed results are:

   a. In a discrete electron arc the measured upward moving electrons are well accounted for by secondaries produced in collisional scattering of the measured downcoming electrons. No collective mechanisms need be invoked.

   b. The low energy downcoming electrons are accounted for by thermal plasma accelerated through a potential drop of a few kV that specularly reflects upward-moving lower energy electrons. No low altitude collective effects need be invoked in the arc.

   c. Simultaneous measurements of electric field by double probes on 29.007 and the Chatanika Radar allow one to infer that:

      - There are upward drifting ions above the discrete electron arc;

      - There is a westward neutral wind in the discrete arc.

2. We are building two rocket payloads to investigate plasma effects in the pulsating aurora, with launches planned for January 1982.

3. We will refurbish a frequency spectrum analyzer, recovered from rocket 29.013 (a reflight of 29.007; on 29.013 the second-stage engine failed) for use on the University of Minnesota SCEX rocket.

C. Future work: The scientific objective continues to be understanding of plasma (collective) processes in the ionosphere with emphasis on beam-plasma interactions. Analysis of existing data and new experiments with SCEX and pulsating aurora rocket payloads will continue during the next year. An immediate technological objective is to complete a microprocessor-controlled particle detector.

Hugh R. Anderson

SR&T NGL 44-006-012

Papers Presented

NATO Advanced Research Institute on
"Artificial Particle Beams Utilized in Space Plasma Physics"
Geilo, Norway, April 21-26, 1981

Anderson, H.R., R.J. Jost and J. Gordeuk, "Measured electron energy distribution in beam-plasma interactions: (1) laboratory experiments and (2) auroral observations."

Bernstein, W., P.J. Kellogg, S.J. Monson, R.H. Holzworth and B.A. Whalen, "Recent observations of injected beam-plasma interactions in the ionosphere and a comparison with laboratory studies of the beam-plasma discharge" (invited).

Hallinan, T.J., H. Leinbach and W. Bernstein, "Visible signatures of the multistep transition to a beam plasma discharge."

Jost, R.J., "The NASA space environment simulation laboratory."

Jost, R.J., "Temporal characteristics of BPD ignition."

Jost, R.J., H.R. Anderson and W. Bernstein, "Radial dependence of the HF wave field strength in the BPD column."

SR&T

Publications

Bernstein, W., F.H. Leinbach, P.J. Kellogg, S.J. Monson, T.J. Hallinan, O.K. Garriott, J. McCoy, A. Konradi, P. Daly, and H.R. Anderson, "The beam plasma discharge at low pressures and low magnetic field strengths," Geophys. Res. Letters 5:2, 1978.

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Bernstein, W. and P.J. Kellogg, "Laboratory simulation of the injection of energetic electron beams into the ionosphere - ignition of the beam plasma discharge," in Advances in Space Research, Vol. 1, pp. 347-360, COSPAR 1981.

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Grant NAG6-5

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Robinson, R.M., E.A. Bering, R.R. Vondrak, H.R. Anderson and P.A. Cloutier, "Simultaneous rocket and radar measurements of currents in an auroral arc," in press.

Presentations

Anderson, H.R., R.M. Robinson and E.A. Bering, "Birkeland current and electric field in auroral arcs," invited review at AGU Chapman Conference on Auroral Arcs, University of Alaska, July 1980.

Bering, E.A., H.R. Anderson et al., "Simultaneous rocket and radar observations of fields and plasma in a quiet auroral arc," Fourth General Assembly of IAGA, 1979.

Bering, E.A., H.R. Anderson and D.M. Pulliam, "Acceleration of auroral particles inferred from observed electron spectra and electric fields," IAGA Edinburgh Assembly, 1981.

Robinson, R.M., H.R. Anderson, E.A. Bering and R.R. Vondrak, "Rocket and radar electric field measurements in an auroral arc," AGU Chapman Conference on Auroral Arcs, University of Alaska, July 1980.

APPENDIX 3

PAPERS PUBLISHED WITH SUPPORT FROM NAG6-5