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FINAL REPORT
to the
National Aeronautics and Space Administration
for
Detailed Analysis of Low Energy Plasma Data (NAGW-1209)
under the Voyager Uranus Data Analysis Program

October 1, 1987 - September 30, 1991

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Contracting Organization: Massachusetts Institute of Technology

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I. INTRODUCTION

This is the final report on the efforts made in the Uranus Data Analysis Program (UDAP) under grant NAGW-1209. The proposal was originally submitted on January 14, 1987 describing a three-year effort with a total estimated cost of $252,788. Funding for the program began on October 1, 1987. Near the nominal termination of the program, a no-cost extension (through September 30, 1991) was granted and a subcontract written for the continued participation of Dr. McNutt, who left M.I.T. for Visidyne, Inc. in early September, 1990. The P.I.-ship was transferred to Professor Belcher on September 11, 1990 and a subcontract was let to Visidyne, Inc. on November 9, 1990. The original proposal contains the rationale for this program as well as vitae, publication lists of the investigators, and the scientific background and rationale for the tasks described therein. Second-year and third-year renewal proposals report on progress made through March 1, 1989 (submission date of the third-year proposal).

This report follows the format of the original 3 year proposal. Completed reseach is reported immediately below and a summary of talks and papers published for the entire effort follows. Work by a graduate student M. Zhang on both Uranus and Neptune data was supported by this grant.

II. RESEARCH EFFORT TO DATE

A. The PLS Data Analysis Program

(i) Modifications to the data fitting procedure. and *(ii) Elimination of Possible Noise and Electron "Contamination"*. More tests were run on the analysis code corections which were implemented under this program. These have not been reapplied to the Uranus data as had been anticipated; however, they were used in checking these effects in the Neptune data gathered during the Voyager 2 encounter and for analyzing selected plasma spectra from the warm Io torus [*McNutt*, 1988*a*; *Bagenal et al.*, 1992].

The cross corrections between electron and ion spectra have been found probably to affect other Voyager data sets even more profoundly than that acquired at Uranus [*McNutt*, 1988*b*]. In particular the electron "biteout" region observed by Voyager 1 near Saturn's moon Titan [*Hartle et al.*, 1982] is probably to be understood as due to secondary electrons formed by ion impact rather than by a lack of hot electrons. A full study and reworking of the Saturn PLS data has not yet taken place due to funding constraints.

The same situation holds for the "voids" at Jupiter. The Uranus data was invaluable for sorting out some of the void effects. The original manuscript disscusing this aspect of the Voyager Uranus data in the Jovian context [*McNutt*, 1989] has yet to be published. Referees reports urged that the paper be downsized and preliminary discussions with a member of the LECP team (B. Mauk at APL) suggested that PLS/LECP comparisons needed to be modified prior to publication as a results of new insights about the response of the LECP instrument in the "void" environment. The paper was formally withdrawn from consideration for publication in its current form by mutual consent with then-editor C. K. Goertz. This effort has not (yet) been revived due to funding limitations.

B. Difficulties in Interpretation of the Data

Our assessment at the time of the third renewal proposal remains and was actually strengthened by work under this grant and by results obtained with the PLS experiment at Neptune. In the last renewal proposal we stated: "We believe that all the the complicating factors are understood in a semi-quantitative way. No other effects which could be responsible for difficulties have been identified, although this assessment must be regarded as provisional until a more quantitative treatment is available." Given the current state of knowledge, we no longer regard this assessment as provisional. A more quantitative model could be

developed and would probably add to the information extractable from the Jupiter data set. Such a model would have no major advanced impact on the Uranus data and, therefore, was not pursued.

C. Models of Plasma Sources and Flows

A major task accomplished was the summary of Uranus-related research in the U. S. National Report to the International Union of Geodesy and Geophysics for the 1987 through 1990 quadrennium. A limited amount of work was accomplished on assessing the Pedersen conductivity of the ionosphere and comparing it with inferred values from shielding by the Uranian ring current [*McNutt*, unpublished manuscript].

D. Bow Shock Crossings

Under this grant there has been a great deal of effort expended on identifying and classifying plasma waves and oscillations in the magnetosheath and solar wind downstream from Uranus. As reported in the last renewal proposal, large amplitude oscillations in plasma parameters are found in the magnetosheath, with density changes of up to a factor of ten occurring on times scales of minutes. A complete description of these oscillations was completed during the last year of work [*Richardson et al.*, 1990].

We previously reported on low-frequency waves in the solar wind observed downstream from Uranus. These are observed for more than 2 weeks after the encounter and are present whenever the IMF is oriented such that field lines connect back to the Uranian bow shock. The waves are right-hand polarized, propagate along the IMF away from Uranus, and decay in amplitude with distance from the planet. The waves are associated with the presence of energetic ions observed by the LECP experiment on Voyager. A complete description of the observations and possibly applicable theories has been published by *Zhang et al.* [1991].

New algorithms developed for analyzing the inbound bow shock crossing of Neptune [*Szabo et al.*, 1991] will probably be applied to a more detailed analysis of the Uranus shock in the near future.

UDAP Supported Publications and Talks
(October 1, 1987 – September 30, 1991)

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