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CHAWS INSTRUMENT DEVELOPMENT AND MEASUREMENTS ANALYSIS

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Final Report

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" This technical report has been reviewed and is approved for publication."

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14. ABSTRACT
We propose to study the appropriate wake environment and support the development of detectors for the Charge Hazards and Wake Studies (CHAWS) Missions. Both computer simulations of the detector and laboratory calibrations will be performed. The propose detector will consist of a high energy resolution Retarding Potential Energy Analyzer and a high spatial resolution drift chamber with MicroChannel Plates. The electric field inside the detector is designed such that the one-to-one correspondence between the incident ion and the collected signal is guaranteed. A fluid dynamic model will be set up to study the effect of the secondary electron, the backscattering, and the negative ion trapping on the potential profile and ion trajectories in the wake. The results of the fluid dynamic model will be compared to hat from the other models. The CHAWS results will be analyzed based on the simulation, including the secondary effects and the time evolution of the plasma parameters. The position of the probes and the operational time sequence of these probes will be modified for best performance.

15. SUBJECT TERMS
Charge Hazards and Wake Studies (CHAWS), Retarding Potential Energy Analyzer, MicroChannel Plates, plasma detectors

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Final Review
Contract F19628-94-C-0087

This review is provided in lieu of a contract final report due to the dissolution of the performing research group in the final months of the contract. Throughout the performance period, the work was of a high quality and we, AFRL, were pleased with the results of the effort. The basis of this review is the author's general familiarity with the work, and the collected quarterly reports.

The original period of performance for this contract was 29 September 1994 - 29 September 1997. The performance period was extended to a completion date of 30 Sept 1999. Contractor's Release was signed on 14 February 2000, effectively ending the contract.

This contract supported AFRL research in two broad and related areas. One was the Charge Hazards and Wake Studies experiment (CHAWS) that was flown twice on the Space Shuttle as a secondary experiment on the Wake Shield Facility (WSF). The other area was the design of Digital Ion Drift Meter (DIDM) that was first flown in support of CHAWS, and later on the STEP-4, and CHAMP satellite missions.

Between the first CHAWS flight on STS60 in Feb. 1994, and the second flight on STS69 in Aug. 1995, the Northeastern University (NU), group performed laboratory analysis on the CHAWS high voltage probe cover. The STS60 flight has indicated that the ion generated secondary electron emission level from the probe was extremely sensitive to the on-orbit contamination caused by the space vacuum epitaxy experiments on the WSF. The NU group provided a thorough experimental investigation of the ion generated secondary yield that was critical to interpreting the results of CHAWS experiment. This work is discussed in December 1994 quarterly report.

With the next report, the NU group moves into electrostatic simulations to support the design of the Digital Ion Drift Meter instrument. They used the program SIMION to model the original detector flown on CHAWS, now known as DIDM-0. This analysis demonstrated that the ion optics of that device were not suitable for use as a precision drift meter, and they explored a number of design variations that each produced some improvement in the optics.

The previous period's work also identified some short comings in the SIMION program, which lead AFRL to purchase an alternative program, ELECTRO, that used a different method to solve for the electric field inside of DIDM; the Boundary Element Method rather that SIMION's Finite Difference method. Although ELECTRO's field solution was superior, the NU group quickly demonstrated that the software's ion trajectory tracker had some serious flaws. A series of tests were devised, and the NU group worked with the ELECTRO authors to develop a new adaptive step tracking algorithm that passed all the tests and allowed the simulation work to continue. This work was documented in the June 1995 quarterly report.

In the October 1995 report, the NU group returns to SIMION simulation to investigate alternative designs for the DIDM back-plane which is shown to exert significant affect on the ion trajectories. This is the design that is subsequently adopted for all the later DIDM instruments.

In the March 1996 report, The NU group has used the newly revised ELECTRO to confirm the SIMION findings. This work results in basic confirmation of the earlier work, but also further refinement since ELECTRO can model arbitrary shapes while SIMION is limited to stepped shapes on its rectangular grid.

Over the next year, the NU group concentrated on moving from 2D to 3D modeling. This was accomplished with the new SIMION-3D, and an equally new COULOMB program from Integrated Software, the producers of ELECTRO. The reports document slow going due to the slower execution times of each program and the increased difficulty of verifying the results. This work does however produce some very useful insight into the limitations of aperture size due to 3D effects, and into the effects of the screens that are used in DIDM to control and shape the potential.

In the March 1997 report, the NU group has continued its support of the DIDM effort by using SIMION and ELECTRO to model the calibration tests that AFRL has been conducting using the DIDM-1 prototype, constructed by AFRL and another support contractor, Amptek. These tests show that DIDM-1 is experiencing a slight energy dependence in the ion optics. Since the calibration beam at AFRL cannot function below about 15 Volts of ion energy, and the intended measurement will be at 5 Volts and less in space, the NU work is critical in establishing that the higher energy calibrations will be useable in understand the flight results. In this report, they also begin work on a neural-network approach to interpreting the instrument data.

In the September 1997 report, the NU group has continued its investigation into whether a neural-network approach can be useful in deconvolving the combined effects of finite aperture and thermal distribution of the measured ions.

January 1998 is the date of the last R&D status report. It effectively summarizes the work done to date and described above, but in much greater detail. After this date, the departure of some of the key personnel results in a cessation in the reporting. There was however some very good work performed after this point in developing a Monte Carlo FORTRAN simulation program for the DIDM-2 instrument called SimDIDM. A version of this program is still being used in the analysis of data from the DIDM-2 instrument on the CHAMP satellite.

In the final months of the contract, no one was left at NU to continue the work and AFRL moved to de-scope and discontinue the effort.