

# **SPEAR-1 Charging Behavior**

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Presented at the  
ESA Space Environment Analysis Workshop

ESTEC  
9-12 October 1990  
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## **ABSTRACT**

Space Power Experiment Aboard Rocket (SPEAR) 1 was launched on 13 December 1987 from NASA Wallops Flight Facility. The purpose of the experiment was to determine the feasibility of exposing high voltage systems to the ionospheric plasma, without substantial arcing. The application of voltages up to 45 kV to deployed booms was successful in this regard. A result of this bias process was to force the rocket body potential to negative voltages of up to 10 kV. These voltages were substantially reduced when the attitude control system emitted cold nitrogen gas. This paper illustrates the charging response of SPEAR-1, as deduced from ion measurements with electrostatic analyzers.

## **INTRODUCTION**

Future space systems will require operations at high power levels, and hence high voltage levels. One of the main design problems with such systems is providing the necessary electrical isolation for the charged system, and to cope properly with the currents drawn from the ambient plasma. The current collection issue will be important for proposed systems, such as electrodynamic tethers (Banks, 1989). Previous experience with high voltage systems comes primarily from rocket-borne electron beam experiments, such as the ECHO series conducted by the University of Minnesota (Winckler et al, 1989), and the MAIMIK experiment (Maehlum et al, 1988), and the CHARGE-2 experiment (Neubert et al, 1990). These experiments were characterized by highly disturbed environments, however, since the electron beam modified the ambient plasma and neutral environment.

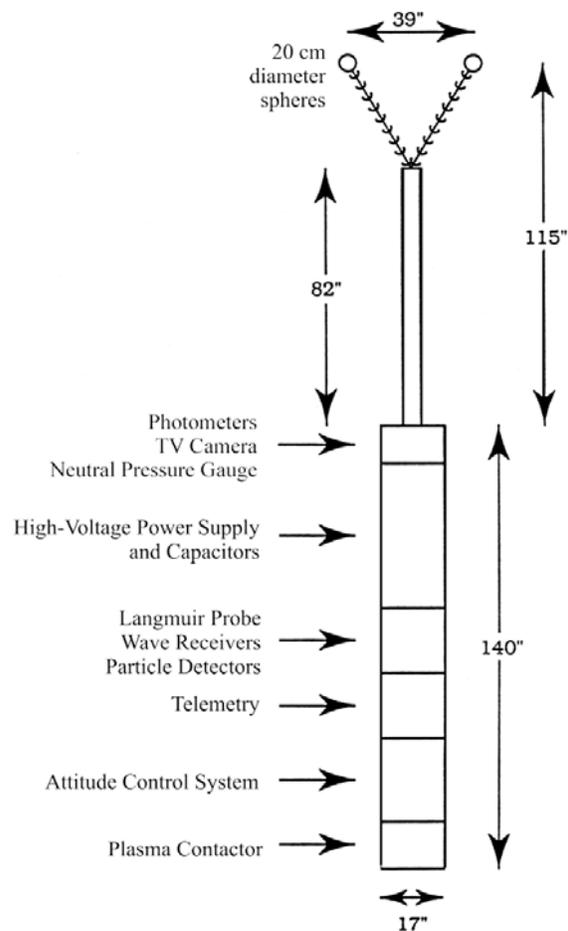
The Space Power Experiment Aboard Rocket (SPEAR) program was conceived in order to test the results of biasing electrical systems to voltages as high as 45 kV in the ionosphere. The experiment showed that with proper design, it was possible to operate with high bias voltages without electrical breakdown (Foley, 1987, Allred et al 1988). In addition, it is possible to leave carefully constructed systems exposed to the ambient environment, without insulating the biased surfaces.

The charging response for SPEAR-1 was successfully modelled by Katz et al (1989). The currents drawn to the deployed spheres varied approximately linearly with the sphere potentials, and indicated a typical impedance to the ionospheric plasma of about 1 meg-Ohm. During and after attitude maneuvers, however, there was evidence of enhanced currents due to ionization of the nearby gas (Raitt, 1988). This result is consistent with results found on CHARGE-2 during ACS maneuvers (Myers et al, 1990), and with the results from ground tests motivated by the SPEAR program (Alport et al, 1990).

The purpose of this paper is to show in detail the charging response of the SPEAR-1 payload, with the first analysis of the payload potential response to the attitude gas releases.

### SPEAR

The SPEAR-1 vehicle and payload are illustrated in Figure 1. The pertinent features are the overall geometry, the locations of the 20 cm diameter spheres, and the location of the particle detectors. Note that the particle detectors are on the rocket body, and are a substantial distance away from the spheres. The attitude control system (ACS) is located at the bottom of the rocket, and is well removed from the sphere locations. The "plasma contactor" was a hollow cathode plasma source, designed to control the rocket body potential. It did not do so, because the sealed cover did not come off at launch. (Allred et al, 1988)



The instrumentation used here are the 'tophat' electrostatic analyzers. These analyzers provide differential energy (and angle) analysis for ions and electrons from 10 eV to 30 keV. Data from 5 look directions are available, through a plane which includes the rocket body axis. Look directions are from 56° to 115° (small angles are towards the spheres). (VanHorn, 1990)

### Charging Results

There were 24 charging sequences run, where the two spheres were biased at voltages up to +45 kV with respect to the rocket body. Data will be shown from two sequences. During the first illustration, one sphere was biased to +45 kV, the other was near zero volt bias. This first example comes at 398 s, mission elapsed time (MET), at 361 km altitude. There is little or no ACS activity during the first illustrated event. During the second, both spheres are biased, with sphere 1 at +7 kV, and sphere 2 at +21 kV. This sequence is run at 416 s (MET), at 352 km altitude.

Figure 2 shows a spectrogram representation of the electrostatic analyzer data from the '4C' detector, viewing at 95° from the rocket body axis. Six seconds of data are displayed in this energy vs time format. The vertical axis is roughly logarithmic, running from 10 eV to 30 keV, with 30 energy steps. The accumulation interval is 1 ms, and one energy sweep requires 32 ms. High flux is coded as black, low fluxes are coded as white. There is a clear charging peak associated with the negative rocket body potential, which decays monotonically with the sphere bias. There is some aliasing in the peak, due to gaps in the energy coverage (the channels do not overlap, energy bandwidth is 11%). The existence of substantial ion flux below the nominal rocket body potential is presumably due to sputtering on the rocket body by the atomic oxygen ions which form the charging peak, and due to ions created in the near rocket region by ionization of neutral gas.

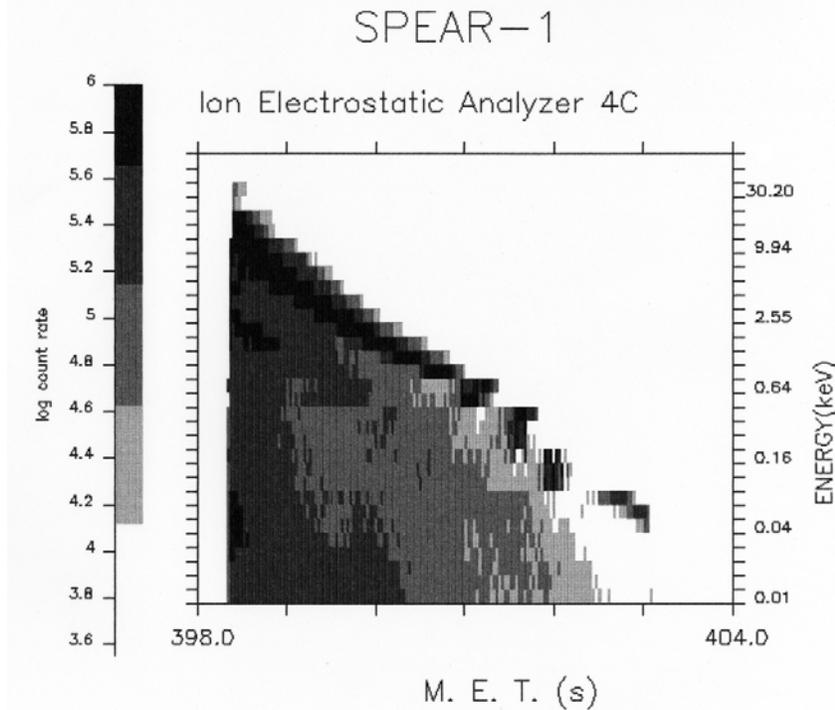
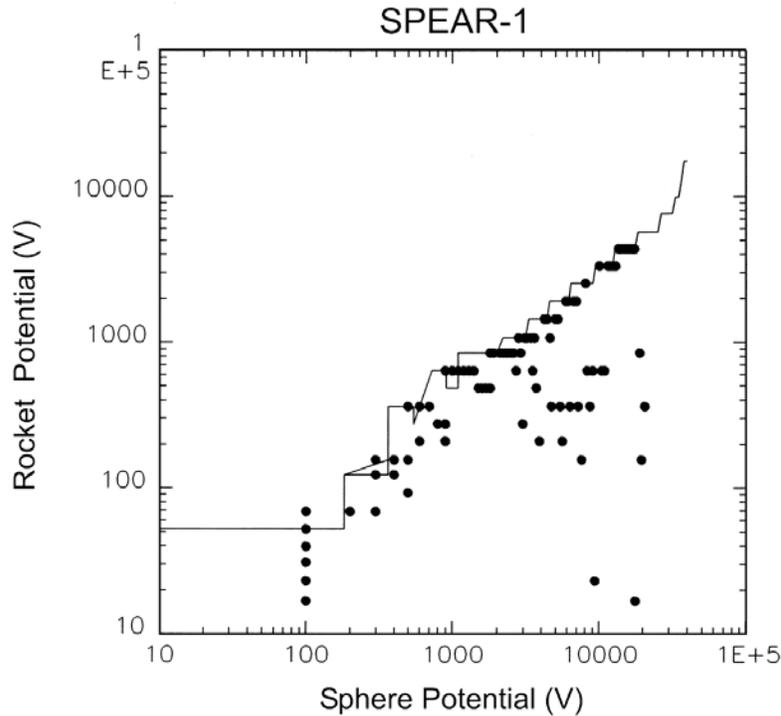


Figure 3 shows how the rocket body potential varies with the bias voltage on sphere 1. The solid curve is the plot for the period illustrated in Figure 2, the solid dots apply to the next example. For

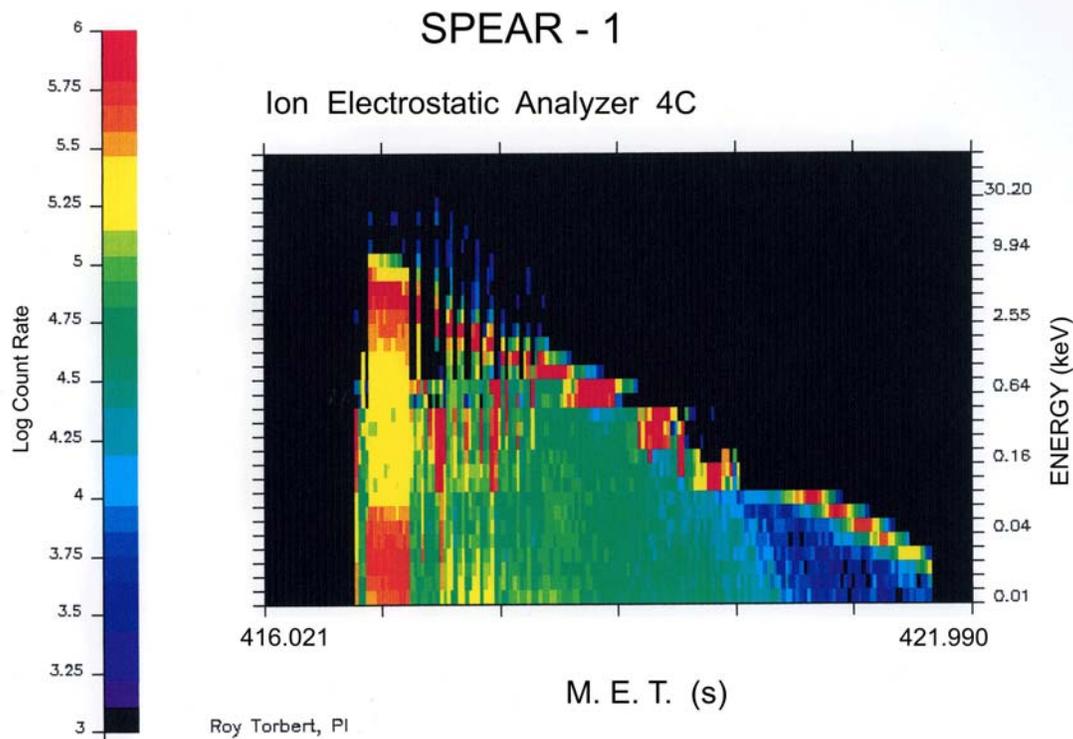
all but the highest sphere voltages, the solid curve is essentially a straight line. This same curve is found for the first 12 bias sequences, all carried out with the plane of the spheres perpendicular to the local Magnetic field. During the later sequences, in other orientations, slightly lower rocket body potentials were found. This may also have been an altitude effect, however, as these later sequences tended to occur at lower altitudes.



There is an interesting increase in rocket body potential, consistently seen at the highest voltages (above 40 kV sphere bias). A similar increase is seen in the current collected by the sphere at these levels, indicating that some new process is operative at these voltage levels.

These results are similar to those presented previously (Figure 9, Allred et al, 1988; Figure 4, Katz et al, 1989). This work was extended to include analysis of the data from the '4B', '4C', and '5A' detectors for all of the discharge sequences. The most interesting additional finding was that the rocket body potential was reduced during ACS firings.

Figure 4 shows a spectrogram for 6 seconds of data taken during a bias sequence following the first major ACS maneuver. ACS telemetry indicates that cold nitrogen gas was still being emitted during the bias sequence. There are substantial, obvious decreases in the potential from 417-418 S MET. The potential drops to a few hundred volts.



The analysis results are shown in Figure 3 as the solid dots, with rocket potential plotted vs the bias on sphere 2. (The sphere 1 bias is one-third of the sphere 2 bias voltage during this sequence.) We see that the overall trend is the same, since an insignificant fraction of the charge on the bias capacitors is discharged during the ACS release.

The reduction in the (negative) potential of the rocket body implies a rise in the potential of the spheres relative to the ambient plasma. This seems reasonable, since the (measured) current to the spheres increases by a factor of 2 or 3.

## CONCLUSIONS

The SPEAR-1 results show a nearly linear relationship between rocket body potential and sphere bias voltage. This seems to be analogous to the nearly linear relationship between potential and current collected observed during this experiment. Emission of cold gas served to reduce the magnitude of the floating potential of the rocket body. This is in agreement with reports from the CHARGE-2 experiment. Our next step is to model the discharge period, and determine if the NASCAP/LEO code is as successful in modeling these events, as it was the non-ACS periods [Katz et al, 1989].

## ACKNOWLEDGEMENTS

We wish to acknowledge contract DNA-87-C-0015 to Utah State University for funding the development of the SPEAR-1 payload. DNA also funded research at NPS on SPEAR-1.

## REFERENCES

- Allred, D. B., J. D. Benson, H. A. Cohen, W. J. Raitt, D. A. Burt, I. Katz, G. A. Jongeward, J. Antoniadis, M. Alport, D. Boyd, W. C. Nunnally, W. Dillon, J. Pickett, and R. B. Torbert, The SPEAR-1 experiment: High voltage effects on space charging in the ionosphere, *IEEE Transactions on Nuclear Science*, 35, pages 1386-1393, 1988.
- Alport, M. J. m J. A. Antoniadis, D. A. Boyd, R. G. Greaves, and R. F. Ellis, Electrical breakdown at low pressure in the presence of a weak magnetic field, *Journal of Geophysical Research*, 95, pages 6145-6153, 1990.
- Banks, P. M., Review of electrodynamic tethers for space plasma science, *Journal of Spacecraft and Rockets*, 26, pages 234-239, 1989.
- Foley, T. M., SDI Suborbital launch yields data for high power platform design, *Aviation Week and Space Technology*, 127, No. 25, pages 26-27, December 21, 1987.
- Katz, I., G. A. Jongeward, V. A. Davis, M. J. Mandell, R. A. Kuharski, J. R. Lilley, W. J. Raitt, D. L. Cooke, R. B. Torbert, G. Larson, and D. Rau, Structure of the bipolar plasma sheath generated by SPEAR 1, *Journal of Geophysical Research*, 94, pages 1450-1458, 1989.
- Maehlum, B. N., J. Troim, N. C. Maynard, W. F. Denig, M. Friedrich, and K. M. Torkar, Studies of the electrical charging of the tethered electron accelerator mother-daughter rocket MAIMIK. *Geophysical Research Letters*, 15, pages 725-728, 1988
- Myers, N. B., W. J. Raitt, B. E. Gilchrist, P. M. Banks, T. Neubert, P. R. Williamson, S. Sasaki, A comparison of current-voltage relationships of collectors in the Earth's ionosphere with and without electron beam emission, *Geophysical Research Letters*, 16, pages 365-368, 1989.
- Myers, N. B., W. J. Raitt, A. B. White, P. M. Banks, B. E. Gilchrist, and S. Sasaki, Vehicle charging effects during electron beam emission from the CHARGE-2 experiment, *Journal of Spacecraft and Rockets*, 27, pages 25-37, 1990.
- Neubert, T., M. J. Mandell, S. Sasaki, B. E. Gilchrist, P. M. Banks, P. R. Williamson, W. J. Raitt, N. B. Myers, K. I. Oyama, and I. Katz, The sheath structure around a negatively charged rocket payload, *Journal of Geophysical Research*, 95, pages 6155-6165, 1990.
- Raitt, W. J., Space Power Experiments Aboard Rockets, SPEAR-1, Final Report to Defense Nuclear Agency, Utah State University, October, 1988.
- VanHorn, T., Determination of SPEAR-1 rocket body potential during high-voltage experiments, M.S. Thesis, Naval Postgraduate School, June, 1990.
- Winckler, J. R., P. R. Malcolm, R. L. Arnoldy, W. J. Burke, K. N. Erickson, J. Ernstmeyer, R. C. Franz, T. J. Hallinan, P. J. Kellogg, S. J. Monson, K. A. Lynch, G. Murphy, and R. J. Nemzek, ECHO 7: An electron beam experiment in the magnetosphere, *EOS (Transactions, American Geophysical Union)*, 70, No. 25, pages 657, 666-668, June 20, 1989.

# SPEAR - 1

Ion Electrostatic Analyzer 5A

