SECTION VIII. THEORETICAL AND EXPERIMENTAL STUDY OF BEAM PLASMA PHYSICS (TEBPP)
THEORETICAL AND EXPERIMENTAL STUDY OF BEAM-PLASMA-PHYSICS

INVESTIGATORS

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SCIENTIFIC OBJECTIVE -- TO UNDERSTAND QUANTITATIVELY THE INTERACTION OF AN ELECTRON BEAM (0-10 keV, 0-1.5 Amp) WITH THE PLASMA AND NEUTRAL ATMOSPHERE AT 200-400 KM ALTITUDE.

APPLICATIONS TO NEAR-EARTH AND COSMICAL PLASMAS.

THE INTERACTION OCCURS IN FOUR SPACE-TIME REGIONS:

I. NEAR ELECTRON GUN; BEAM COMING INTO EQUILIBRIUM WITH MEDIUM
II. EQUILIBRIUM PROPAGATION IN IONOSPHERE
III. AHEAD OF BEAM PULSE; TEMPORAL AND SPATIAL PRECURSORS
IV. BEHIND A BEAM PULSE

WHILE REGION II IS OF THE GREATEST INTEREST, IT IS ESSENTIAL TO STUDY REGION I BECAUSE IT DETERMINES THE CHARACTERISTICS OF THE BEAM AS IT ENTERS II-IV.
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SPECIFICALLY IN THE REGIONS

Region I - What are mechanisms for charge and current neutralization
- of injected beam?
- of accelerator and spacecraft?
- Is beam plasma discharge (BPD) an important mechanism?
What are dimensions of the region?
How is beam heated by BPD and altered by charging?

Region II - Quantitatively what is
Velocity redistribution of beam particles? Plateau?
Alteration of ambient plasma density and temperature?
Production of e-s and e-m waves?
Production of light?

Regions III and IV—What are characteristic times for the above effects?
Are the regions a good ordering of the phenomena?
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IMPLEMENTATION

THEORETICAL STUDIES

Analytical and numerical simulation of phenomena should provide models that predict quantitatively design parameters for experiments.

INTERPRETATION OF DATA

EXPERIMENTS -- MEASUREMENTS

ROCKET-BORNE

SCEX -- carrying on electron gun; Kellogg is P.I. 1980-1981
Passive auroral plasma; Anderson is P.I. 1980-1982
E & B, NRC; Bernstein and Whalen 1978; 1979

LABORATORY

Large vacuum facility at JSC--Bernstein and entire group.

These are ongoing experiments.
IMPLEMENTATION -- CONTINUED

Experiments using Spacelab

MISSION MUST CARRY

Electron accelerator SEPAC
Neutral gas source
Imager LLLTV

WE BUILD THESE DIAGNOSTICS

Pulsed plasma probe -- Szuszczejewicz

$3 \times 10^2 < N_e < 10^8 \text{ cm}^{-3}$

$0.025 < T_e < 3 \text{ eV}$

Plasma potential, -50 to +150 volts

Plasma wave receiver ($E$ and $B$) -- Kellogg

$10 \text{ Hz} < f < 20 \text{ MHz}$

Charged particle spectrometer -- Anderson

$10 \text{ ev} < E < 20 \text{ keV}$

$\Delta E/E \sim 5\%$

Flux $10^6$ to $10^{13}$

Photometer if not otherwise available.

These are to be mounted on the RMS or a free-flyer to scan along and radially from the beam.

We will also consider optical and E-M wave measurements from selected ground sites.
Scan in Region I -- \( z < 100 \text{ m} \)
Scan end of I -- \( z = 100 \text{ m} \)
Scan Region II -- \( z 1-10 \text{ km} \)

K waves

HV characteristic radiation

Possible ground station
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CLOSELY RELATED EXPERIMENTS AND FACILITIES

SEPAC
LLLTV
ALL FREE FLYERS
MMP
PDP
STSS
WISP
The electron detector is fixed in the center of the target.

The beam is moved, changing $r$, by driving the cart on the floor.

The angles $\alpha$, $\alpha_{\text{inj}}$, can be independently varied.

Other probes and antennas are located between gun and target at various values of $r$. 
The electron detector is fixed in the center of the target.

The beam is moved, changing $r$, by driving the cart on the floor.

The angles $\alpha$, $\alpha_{INJ}$, can be independently varied.

Other probes and antennas are located between gun and target at various values of $r$. 
P = 7 \times 10^{-6} \text{ TORR}
B = 1.2 \text{ G}
V_G = 2000 \text{ VOLTS}
I = 25 \text{ MA}

OBLIQUE INJECTION, \alpha_{INJ} = 130^\circ
TEBPP

\[ P = 7 \times 10^{-6} \text{ TORR} \]
\[ B = 1.2 \text{ G} \]
\[ V_G = 2000 \text{ VOLTS} \]
\[ I = 8 \text{ MA} \]

**Parallel Injection,** \( \alpha_{\text{INJ}} = 180^\circ \)
TEBPP

\[ P = 7 \times 10^{-6} \text{ T}
\]

\[ B = 1.2 \text{ G} \]

\[ V_g = 2000 \text{ Volts} \]

\[ I = 40 \text{ MA} \]

PARALLEL INJECTION, \( \alpha_{\text{INJ}} = 180^\circ \)
P = 7 x 10^{-6} \text{ TORR}
B = 1.2 \text{ G}
V_G = 2000 \text{ VOLTS}
I = 70 \text{ MA}
PARALLEL INJECTION, \alpha_{INJ} = 180^\circ
FULL BPD
Tebpp

$P = 3 \times 10^{-6}$ Torr

$B = 1.2$ G

$V_G = 1850$ Volts

$I$ as given, BPD at 80 mA

$\alpha = 125^\circ$ (maximum flux)

$\alpha_{inj} = 180^\circ$

$R = 2.0$ m
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\[ p = 7 \times 10^{-6} \text{ torr} \]
\[ B = 1.2 \text{ G} \]
\[ V_G = 2100 \text{ volts} \]

As given, BPD at higher I.
\[ \alpha = 180^\circ \]
\[ \alpha_{\text{INJ}} = 180^\circ \]
\[ R = 0.9 \text{ m} \]
COMMENTS ON PARTICLE MEASUREMENTS

Depending on energy, flux = $E^{-R/R_0}$ with $R_0 \sim 0.4$ m.

We presently have no data at energies between ~10 eV (ionization potential) and ~200 eV.

Energies between 200 eV and $V_{\text{gun}}$ are relatively more populated in BPD for large $R$ and $\alpha < 180^\circ$.

A particle detector mounted alongside the gun looking at $\alpha = 0^\circ$ saw only a featureless energy spectrum. Clear evidence of BPD is not seen in these spectra.

Preliminary measurements indicate that the BPD may require several msec to develop, depending on the ratio $I/I_C$ and $N_e$. 
<table>
<thead>
<tr>
<th>Parameter</th>
<th>E-Folding Distance ( \perp ) to Beam</th>
<th>E-Folding Distance ( \parallel ) to Beam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma density</td>
<td>2.0 m</td>
<td></td>
</tr>
<tr>
<td>Plasma temp.</td>
<td>2.5 m</td>
<td></td>
</tr>
<tr>
<td>Energetic particle flux</td>
<td>.43 to .14 m</td>
<td></td>
</tr>
<tr>
<td>Electric field strength</td>
<td></td>
<td></td>
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</tbody>
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Figure 1. BPD ignition occurs ~ 5 ms after initiation of pulse.
Pulse width = 30 ms.
Interpulse period = 400 ms
Figure 2: BPD ignition occurs.