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

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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.
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. 

THSE ARE ONGOING EXPERIMENTS.
IMPLEMENTATION -- continued

Experiments using Spacelab

Mission must carry

- Electron accelerator
- SEPAC
- Neutral gas source
- LLL TV
- Imager

We build these diagnostics

Pulsed plasma probe -- Szuszczeniaicz

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

$0.025 < T_e < 3 \ eV$

Plasma potential, -50 to +150 volts

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

$10 \ Hz < f < 20 \ MHz$

Charged particle spectrometer -- Anderson

$10 \ eV < E < 20 \ keV$

$\Delta E/E \sim 5%$

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.
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Scan in Region I -- \( \xi < 100 \) m
Scan end of I -- \( \xi = 100 \) m
Scan Region II -- \( \xi 1-10 \) 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 $\alpha$, $\alpha_{\text{INJ}}$, can be independently varied.

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

OBLIQUE INJECTION, $\alpha_{INJ} = 130^\circ$
$p = 7 \times 10^{-6} \text{ Torr}$

$B = 1.2 \text{ G}$

$V_G = 2000 \text{ Volts}$

$I = 8 \text{ MA}$

Parallel injection, $\alpha_{\text{INJ}} = 180^\circ$
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$P = 7 \times 10^{-6}\ \text{Torr}$

$B = 1.2\ \text{G}$

$V_G = 2000\ \text{Volts}$

$I = 40\ \text{MA}$

PARALLEL INJECTION, $\alpha_{INJ} = 180^\circ$
$P = 7 \times 10^{-6}$ TORR
$B = 1.2$ G
$V_G = 2000$ VOLTS
$I = 70$ MA
PARALLEL INJECTION, $\alpha_{INJ} = 180^\circ$
FULL BPD
- TEBPP

\[ p = 3 \times 10^{-6} \text{ Torr} \]
\[ B = 1.2 \text{ G} \]
\[ V_G = 1850 \text{ Volts} \]
- I as given, BPD at 80 ma
- \( \alpha = 125^\circ \) (maximum flux)
- \( a_{\text{inj}} = 180^\circ \)
- \( R = 2.0 \text{ m} \)
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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 \( \sim 10 \) eV (ionization potential) and \( \sim 200 \) 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 \( N_e \).
## TEBPP

**Gradients Observed in Various Parameters**

<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>
</table>
Figure 1. BPD ignition occurs ~5 ms after initiation of pulse.

Pulse width = 30 ms.

Interpulse period = 400 ms.
Figure 2. BPD ignition occurs.