This/PLACES Barium Event Jan: Quick-Look Field Report of "In Situ" Probe Measurements

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On 12 December 1980, a 48 kg barium payload was launched from the A-15 site of the Eglin/Santa Rosa Island Test Range. The barium was released in the F region of the ionosphere at an altitude of 182.7 km. Approximately 32 minutes later a second rocket was launched, carrying a plasma diagnostics complement which included a pair of pulsed-plasma-probes and an ion mass spectrometer for direct measurements of electron density $N_e$, temperature $T_e$, density fluctuations $\delta N_e$, associated density fluctuation power spectra $P_{\delta N_e}(k)$, and ion composition $M_i$. The barium release and all associated measurements have been designated by code name JAN. (Continues)
This report presents quick-look field analyses of the pulsed-plasma-probe data. A brief description is given on the probe instrumentation, vehicle/payload performance, and "in situ" observations of barium cloud plasma densities and structure.
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DNA/PLACES BARIUM EVENT JAN: QUICK-LOOK FIELD REPORT OF "IN SITU" PROBE MEASUREMENTS

I. INTRODUCTION

At 2311:00 (GMT) on 12 December 1980, a 48 kg barium payload was launched from the A-15 site of Eglin/Santa Rosa Island Test Range. The barium was released in the $F_1$ region of the ionosphere at 2313:42.1 and at an altitude of 182.7 km.

At 2342:50.8 a second rocket was launched, carrying a plasma diagnostic complement which included a pair of pulsed-plasma-probes and an ion mass spectrometer for direct measurements of electron density $N_e$, temperature $T_e$, density fluctuation $\delta N_e$, associated density fluctuation power spectra $P_n(k)$, and ion composition $M_i$. The probe payload penetrated the highest density region (i.e., the highest density observed along the payload's trajectory) of the barium ion cloud at 2344:40.8, a time defined as R+31 MIN. The barium release and all associated measurements have been designated by code name JAN.

This report presents quick-look field analyses of the pulsed-plasma-probe data. A brief description will be given on the probe instrumentation, vehicle/payload performance, and "in situ" observations of plasma densities and structure in the ambient ionosphere and throughout the intense barium ion cloud structure.

II. PROBE INSTRUMENTATION, PAYLOAD CONFIGURATION AND OVERALL SYSTEM PERFORMANCE

A pair of pulsed-plasma-probes were diametrically deployed from the forward-most lateral surface of the payload.

The payload's ACS was designed to maintain the vehicle axis parallel to the geomagnetic field throughout flight... a condition which optimized data integrity from points of view focused on magnetic-field and vehicle aspect perturbations. Initial results indicate that the ACS functioned according to design. Table 1 lists timer functions and altitudes related to the plasma instrumentation on the probe payload while Figure 1 presents the payload trajectory (alt vs time) as determined by a single station radar solution. The Figure was constructed from the trajectory data listed in Table 2.

The pulsed-plasma-probe\(^1-4\) is a specially designed Langmuir technique which eliminates distortions of the measurement procedure known to degrade the conventional approach to Langmuir probe measurements. In addition, the pulsed probe technique makes possible the determination of absolute electron density under fluctuating plasma conditions and simultaneously determines the electron density \(N_e\), temperature \(T_e\), density fluctuations \(\delta N_e\), associated power spectra \(P_n(k)\) and mean ion mass \(<M_i>\). The probe's highest resolution capability in event JAN involved \(\delta N_e\), with resolution down to scale sizes equal to 0.5 meters at a 1km/sec payload velocity.

III. ELECTRON DENSITY PROFILES

The relative electron density profile observed "in situ" by the pulsed probe measurement of baseline electron current \(I^e_B\) (See e.g., Ref. 1 or 2) is presented in Figure 2.
The abscissa is expressed as seconds-after-launch, extending over the domain \( t_0 + 75 \leq t \leq t_0 + 373 \); while the ordinate is \( \log (I_B^e) \). The barium ion cloud was encountered on the upleg portion of the trajectory at \( t \approx 99.5 \text{ sec} \) (ALT \( \approx 145 \text{ Km} \)). Peak densities within the cloud were observed at \( t \approx 110 \text{ sec} \) (ALT \( \approx 155 \text{ Km} \)). For \( t > 135 \text{ sec} \) the probe continued relative density measurements within the undisturbed background ionosphere to an apogee of 241 Km \( (t = 245 \text{ sec}) \). (That \( I_B^e \) is a reasonable representation of relative electron density without major distortions from aspect sensitivities and/or vehicle potential effects has been verified by a simultaneous measurement of baseline ion saturation currents \( I_B^i \) shown in Figure 3. For discussions relative to this point see References 4 and 5.)

To establish initial estimates of absolute electron densities, I-V characteristics generated by the pulsed sweep currents (See e.g., Ref. 3) were hand analyzed at three positions within the cloud. The results indicated a simple \( I_B^e \) to \( N_e \) conversion according to

\[
N_e (\text{cm}^{-3}) = 5.62 \times 10^{10} I_B^e \text{ (amps)}
\]

with an estimated accuracy of \( \pm 32\% \). More exact analyses will result in absolute density determinations with a better than 10% accuracy. This conversion has been applied to Figure 2, resulting in initial estimates of peak barium ion densities \( (t \approx 110 \text{ sec}, \text{ALT} = 155 \text{ Km}) \) of \( 7.3 \times 10^6 \text{ cm}^{-3} \). This value represents an enhancement of 300 over ambient
ionospheric conditions at that altitude. An expanded view of the ion cloud domain \((95 < t \text{ (sec)} < 135)\) is shown in Figure 4 while Table 3 lists densities, altitudes and coordinates of specific observations relevant to a first-order view of the ion cloud and the background ionosphere.
Table 1 — Timer Events Related to the Plasma Instrumentation on the Probe Payload

<table>
<thead>
<tr>
<th>TIME</th>
<th>EVENT</th>
<th>ALTITUDE (Nom.)</th>
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<tbody>
<tr>
<td>$t_o$</td>
<td>Launch</td>
<td>0</td>
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<tr>
<td>$t_o + 66$</td>
<td>a) Nose Cone Separation</td>
<td>90 Km</td>
</tr>
<tr>
<td></td>
<td>b) Probe Door Deploy</td>
<td></td>
</tr>
<tr>
<td>$t_o + 76$</td>
<td>a) Payload Separation</td>
<td>105 Km</td>
</tr>
<tr>
<td></td>
<td>b) ACS ON</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c) Mass Spec RF ON</td>
<td></td>
</tr>
<tr>
<td>$t_o + 78$</td>
<td>Yo-Yo Despin</td>
<td>110 Km</td>
</tr>
<tr>
<td>$t_o + 80$</td>
<td>Probe Deploy</td>
<td>112 Km</td>
</tr>
<tr>
<td>$t_o + 93$</td>
<td>Mass Spec HV ON</td>
<td>120 Km</td>
</tr>
<tr>
<td>$t_o + 108$</td>
<td>ACS de-activate</td>
<td>152 Km</td>
</tr>
<tr>
<td>$t_o + 166$</td>
<td>ACS Re-activate</td>
<td>213 Km</td>
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Fig. 1 - Probe payload trajectory from single radar station solution (See Table 2)
Table 2 — Event JAN Probe Payload Trajectory Information Excerpted from a Single Station Radar Solution Prior to Smoothing

<table>
<thead>
<tr>
<th>TIME AFTER LIFT-OFF (SEC)</th>
<th>GMT</th>
<th>ALTITUDE</th>
<th>RANGE</th>
<th>LAT</th>
<th>LONG</th>
<th>VEL</th>
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<tr>
<td>50</td>
<td>2343:40.8</td>
<td>225,862</td>
<td>251,479</td>
<td>68.83</td>
<td>167.31</td>
<td>6721</td>
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<tr>
<td>100</td>
<td>2344:30.8</td>
<td>479,240</td>
<td>549,004</td>
<td>146.05</td>
<td>29.6615</td>
<td>2.05</td>
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<tr>
<td>150</td>
<td>2345:20.8</td>
<td>658,330</td>
<td>783,270</td>
<td>200.63</td>
<td>29.2428</td>
<td>1.65</td>
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<tr>
<td>200</td>
<td>2346:10.8</td>
<td>761,631</td>
<td>956,354</td>
<td>232.11</td>
<td>28.8321</td>
<td>1.29</td>
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<tr>
<td>245.3</td>
<td>2346:56.1</td>
<td>791,530</td>
<td>1,067,348</td>
<td>241.22</td>
<td>325.28</td>
<td>1.04</td>
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<td>250</td>
<td>2347:0.8</td>
<td>791,208</td>
<td>1,076,545</td>
<td>241.13</td>
<td>328.09</td>
<td>0.94</td>
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<td>300</td>
<td>2347:50.8</td>
<td>747,856</td>
<td>1,115,627</td>
<td>1,076,545</td>
<td>352.19</td>
<td>0.94</td>
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<td>350</td>
<td>2348:40.8</td>
<td>650,406</td>
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<td>400</td>
<td>2349:30.8</td>
<td>437,197</td>
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<td>448</td>
<td>2350:18.7</td>
<td>178,136</td>
<td>1,336,673</td>
<td>1,260,127</td>
<td>407.36</td>
<td>2.31</td>
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Fig 2 - Relative electron density profile as measured by baseline electron current $I_B^e$ as a function of seconds after launch. Absolute electron densities can be estimated from the conversion $N_e [\text{cm}^{-3}] = 5.62 \times 10^{10} I_B^e [\text{amps}]$. See text for statement of accuracy.
Fig. 3 - Relative electron density profile as measured by baseline ion current $I_B$ as a function of seconds after launch. Note that ion current increases downward. Agreement between Figures 2 and 3 establishes credibility in the $I_B$ measurements as a reasonable representation of relative density (See text).
Fig 4 - An expanded view of the barium ion cloud density profile as measured by baseline electron currents. Absolute electron densities can be estimated within an accuracy of $\pm 32\%$ (detailed analyses will yield $\pm 10\%$ or better) by the conversion $N_e [\text{cm}^{-3}] = 5.62 \times 10^{10} I_B [$amps$]$. 

DNR PLACES-NRL E PROBE LIFT UP TIME 347 17 42 50
Table 3 — Summary of Relevant Plasma Densities and Coordinates

<table>
<thead>
<tr>
<th>POINT OF INTEREST</th>
<th>SEC AFTER LAUNCH</th>
<th>ELECTRON DENSITY</th>
<th>ALT</th>
<th>LAT</th>
<th>LONG</th>
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<tr>
<td>Cloud Entry</td>
<td>99.5</td>
<td>$1.7 \times 10^4$</td>
<td>145</td>
<td>29.67°</td>
<td>86.87°</td>
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<td>Cloud Peak</td>
<td>110</td>
<td>$2.4 \times 10^4$</td>
<td>155</td>
<td>29.58°</td>
<td>86.88°</td>
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<td>Cloud Exit</td>
<td>135</td>
<td>$5.6 \times 10^4$</td>
<td>185</td>
<td>29.41°</td>
<td>86.9°</td>
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<td>Apogee</td>
<td>245</td>
<td>$5.6 \times 10^5$</td>
<td>241</td>
<td>28.468</td>
<td>87.022</td>
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