Preliminary Results of CHARGE-2 Tethered Payload Experiment (U.S./Japan Cooperative Experiment)

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Abstract

The fourth Tethered Payload Experiment (CHARGE-2) was carried out by NASA sounding rocket, Black-Brant VB, at White Sands Missile Range in New Mexico in December 1985. It was intended to perform a new type of active experiment in space by injecting an electron beam by means of the tethered mother-daughter payload system. The electron beam up to 1 kV 80 mA was injected and a conductive wire was deployed to 426 m. The electron gun system and diagnostic instruments functioned correctly throughout the flight. The charging effect, wave generation and current induction on the wire by the beam emission were studied by these experiments. This paper presents the results of quick analysis using real time data obtained at the launch site.

1. Introduction

Electron beam experiment with a tethered mother-daughter payload system has been considered to be an ingenious way to study beam-plasma interaction in space. A large-scale modification of surrounding medium, associated wave generation, and vehicle charging induced by the beam emission from the mother payload can be measured by diagnostics onboard both mother and daughter payloads.

This program was initiated jointly by the Institute of Space and Astronautical science (ISAS) and Utah State University (USU) in 1980 using a Japanese sounding rocket. The experiment was repeated twice in 1981 and 1983 [Refs.1,2]. However, due to a power supply failure, the electron beam experiment was not successful after the mother-daughter separation in the three experiments.

After the third experiment (CHARGE-1), the mother payload which was recovered was refurbished and the daughter payload was re-built for the fouth experiment (CHARGE-2). The reflight was prepared under the collaboration of USU, ISAS, Stanford University and University of Michigan. USU provided an electron gun, two photometers, a data handling system and an experiment controller. ISAS prepared a tether wire deployment system, HF/VLF wave detectors, a plasma probe array and two cameras. Stanford Univ. and Univ. of Michigan provided charge probes and a particle energy analyzer, respectively. USU was responsible for the integration of scientific instruments, while NASA GSFC was responsible for the payload integration, system test and launch.

2. CHARGE-2 Experiment

Figure 1 shows the configuration of the payload instruments. The mother payload was composed of an electron gun, a floating/Langmuir probe array (PLP), a thermal electron energy detector (TED), photometers, cameras, an electrostatic electron energy analyzer, a charge probe and a tether voltage/current monitor. The daughter payload consisted of the tether deployment system, HF/VLF wave

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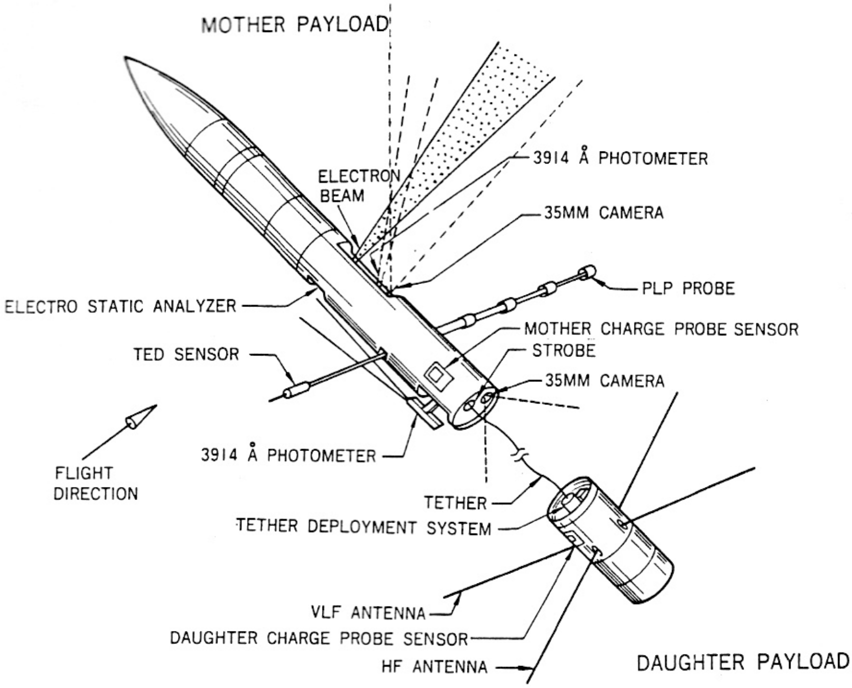
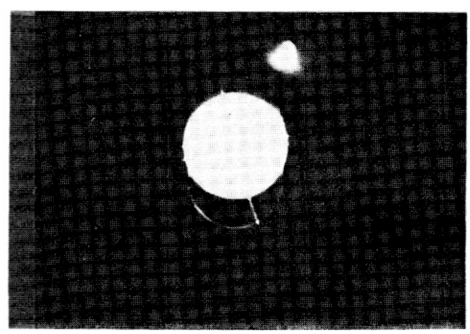


Fig.1 CHARGE-2 payload configuration

receivers, and a charge probe.

The payload was launched at 00:16 on 14th December 1985 at White Sands Missile Range, New Mexico, using Black Brant and Terrier motors (NASA 36.009UE). It reached an apogee of 262 km. At 68 sec, the rocket was despun and then oriented in a magnetic east-west direction at 109 sec. At 115.8 sec (161 km), the sequence of beam firing started. 9 sequences of beam firings were performed during the flight. The mother and daughter sections were separated by a multiple spring system at 141.9 sec (193 km) with initial velocity of 1.05 m/sec. The Reaction Control System (RCS) onboard the daughter payload was operated for 3 sec every 36.5 sec to keep the separation velocity against the frictional force in the tether deployment system. The wire snapped at 442.0 sec (118 km). During the deployment, the mother payload was rolled by ACS so as that the beam was injected with different pitch angles with respect to the geomagnetic field every 45 degrees. A high voltage up to 500 V was occasionally



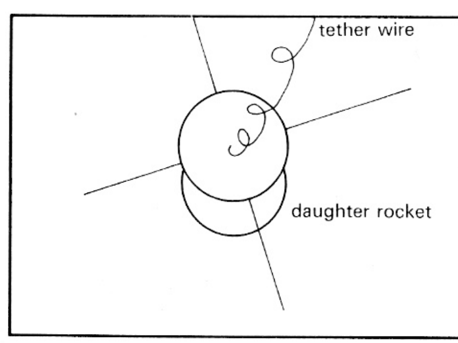


Fig.2 Daughter payload observed from the mother payload

applied between the two payloads through the conductive wire with and without the beam firings. The two payloads were recovered after the experiment in good physical condition. Ground observation of VLF waves and light emission by the beam was also performed.

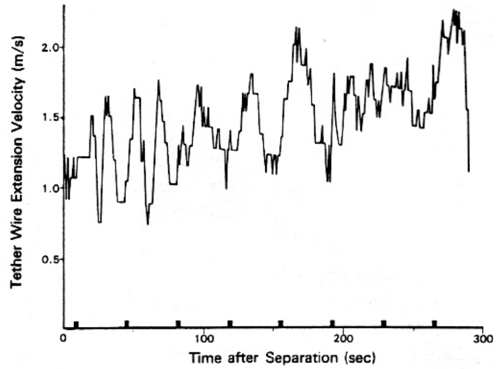


Fig.3 Deployment speed of tether wire

3. Experimental Results

3-1. Tether Wire Deployment

The speed of mother/daughter separation is estimated as 1.05 m/s(average velocity for the first 1.5 sec). Figure 2 shows the daughter payload observed by the still camera onboard the mother payload after separation. The pictures show that the attitude of the two payloads was stable after the separation. The wire near the payload was continually observed during the deployment, and was found to be twisting all the time before the wire cut. The wire was tangled after the wire-cut. Figure 3 depicts the deployment speed of the tether wire plotted against the time after separation. At the bottom, the thrustering of RCS is designated. The speed gradually increased on average and reached about 2 m/sec at the last stage. The average speed during deployment is 1.47 m/sec. There is a clear relation between the RCS firings (3 sec every 36.5 sec) and the increase of the velocity. Figure 4 shows the wire length against the time after separation. The wire length reached 426 m during 289 sec.

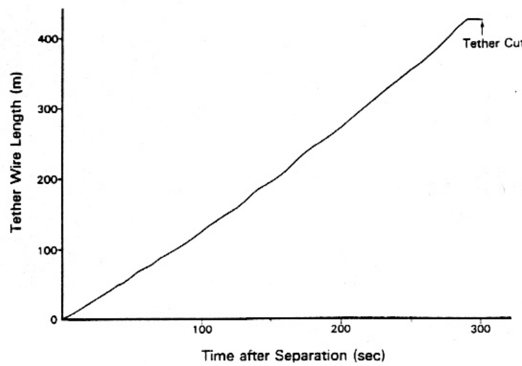


Fig.4 Deployment length of tether wire

3-2. Charging by Electron Beam Emission

PLP FP (-1100V) and MCP high gain data (-9V) have been used to analyze the rocket potential during the beam emission. The measurements of PLP top probe located at 1 m from the rocket skin and the potential between the two payloads measured by MCP agreed quite well at least when the potential was less than 9 V.

As is shown in Fig.5, the charging was relatively lower at the higher altitude when the beam current was less than 80 mA. No such trend has been detected for the beam of 80 mA. The measurement of the PLP top probe during 80 mA emission always exceeded 100 V. No clear dependence on the pitch angle has been detected. For the beam emission less than 80 mA, the charging decreases with the

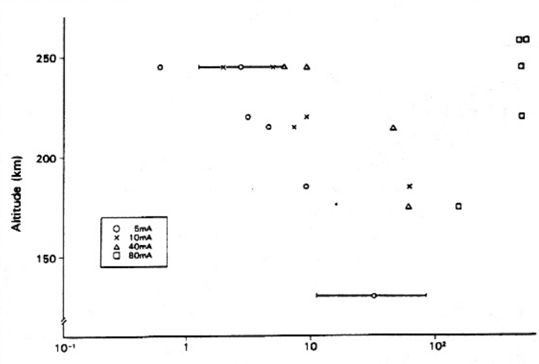


Fig.5 Charging by electron beam emission

background plasma density. This suggests that the outgassing effect which must be decreased with time or the background gas effect which decreases with height was not the major factor to determine the rocket potential for this case.

No remarkable difference of the charging was detected when the daughter and mother payloads were electrically connected or disconnected, or biased up to 500 V during the beam emission (80 mA). This means that the electron current collected by the daughter payload was negligibly smaller as compared to 80 mA of the beam current.

3-3. Tether Current

1. Tether Current without Beam Emission

No current has been detected on the QL chart even when 500 V was applied between the mother and daughter payloads. The current must have been too small to be detected by the present system.

2. Current during Beam Emission

Tether current was detected during the beam emission. The current was increased by about 50 % when +500 V was applied to the daughter payload. The tether current was larger in the higher altitudes, which can be explained by the larger density of surrounding plasma.

3-4 Beam Trajectory

The beam trajectory was observed by the still camera only when 80 mA, 6.2 sec was injected (exposure 7.87 sec). The typical example is shown in Fig.6. The image was obtained on 400 ASA film, pushed to four times during processing. Airglow, star field and city lights on ground are also observed. The blue emission from the beam may be excited by the sorrounding nitrogen molecules (3914 Å).

3-5. VLF Wave Enhancement with Tether Deployment

The VLF AGC level (integrated wave intensity up to 30 kHz) measured from the daughter payload has been investigated. The background level increased with the length of the tether wire on average after the separation (Fig.7). It decreased abruptly when the tether wire was cut at the daughter payload. These suggest that the tether wire acted as a VLF antenna, of which impedance decreased with tether length. The same effect has been observed in

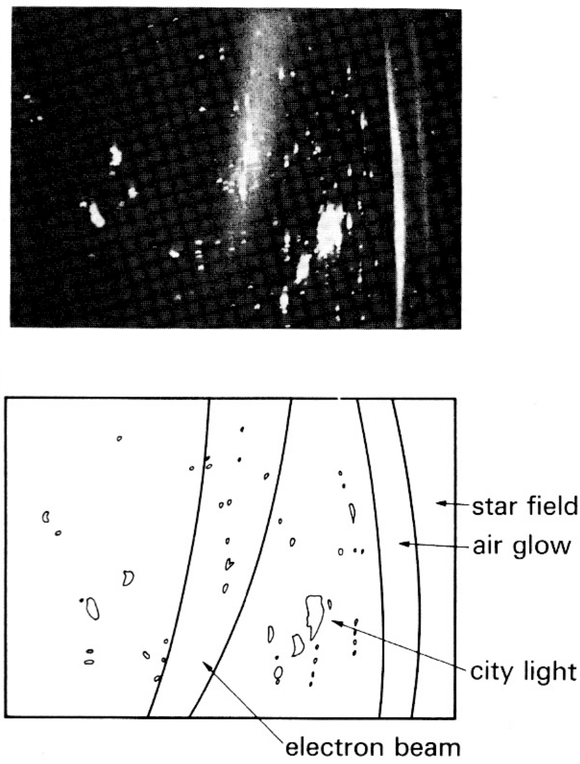


Fig.6 Beam trajectory observed by still camera

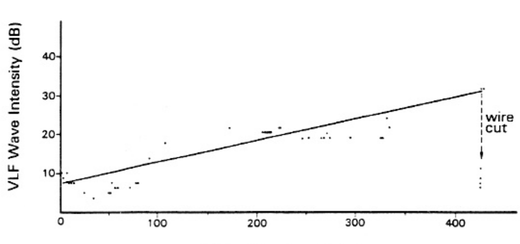


Fig.7 VLF wave intensity during wire deployment

the last experiment (CHARGE-1).

3-6. Wave Generation by Beam Emission

The AGC level was always saturated during 80 mA emission. The wave intensity increased with the beam current. For the beam emission less than 80 mA, the wave intensity was relatively smaller in the higher altitudes (Fig.8), which corresponds to the lower charging or to the larger plasma density, as shown in Fig.5. No definite dependence on the pitch angle has been seen. No definite reduction of the wave intensity with the distance between the two payloads has been detected.

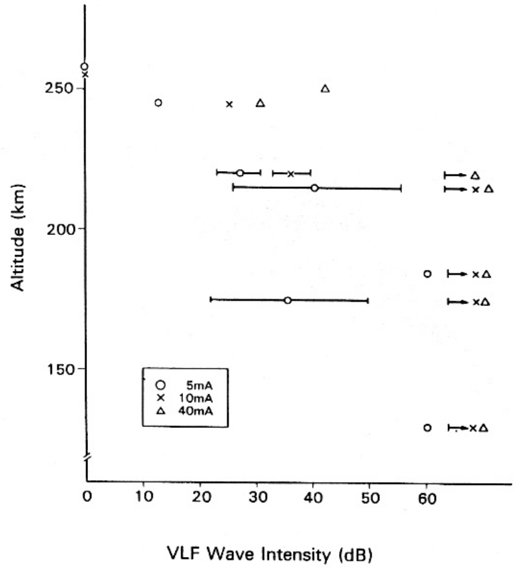


Fig.8 VLF wave excitation by beam injection

4. Summary

Followings have been found in the quick look analysis of CHARGE-2 experiment.

1. The tether wire was extended to 426 m during 289 sec.
2. The experiment was carried out below F-layer (the plasma density increased with height during the experiment)
3. The charging of the mother payload due to the beam emission was measured by floating probe and from the daughter payload, independently. Both measurements agreed quite well so long as the charging was less than 9 V.
4. The charging was generally lower at the higher altitude, where the plasma density was relatively higher.
5. No significant effect on the charging has been detected when a positive bias up to 500 V was applied to the daughter payload during the beam emission.
6. The background VLF wave intensity increased with the length of the tether wire. The same effect was observed in the last experiment (CHARGE-1).
7. The VLF emission during the beam emission did not decrease with the distance between the mother and daughter payloads.
8. The VLF emission during the beam emission was larger when the charging effect was relatively higher (or, when the background plasma density was relatively lower).
9. Tether current was not clearly detected when bias voltage up to 500 V was applied to the daughter payload without the beam emission.
10. Small tether current was detected when the bias voltage was applied to the daughter payload during the beam emission near the apogee.
11. Beam trajectory was detected by the camera when 80 mA 6.2 sec beam was injected.
12. The daughter payload and the wire were observed only when the strobe light was irradiated. The motion of the daughter payload was stable after the separation. Tether wire near the mother was twisted.

References

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