CHINA'S "SHIJIAN(PRACTICE)-4" SATELLITE

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ABSTRACT

This paper describes China's small satellite "Shijian(Practice)-4", which was launched into space on a new launch vehicle "Long March-3A". In this paper the payloads and the platform of the satellite and its operation in orbit are given.

DESCRIPTION OF "SHIJIAN-4"

On February 8, 1994, China successfully launched a small scientific and technical experimental satellite "Shijian(Practice)-4" into space on a new launch vehicle "Long March-3A".

"Shijian-4" satellite was designed exclusively to explore and measure the energy spectrums and space distribution of the charged particles in near Earth space and to study their effects on electronics onboard spacecraft. The satellite was put into a geosynchronous transfer orbit of 203km perigee height and 36133km apogee height and with a 28.6 degree inclination. The orbital period was about 10.7 hours. An orbit of this kind is very suitable for research of space charged particles. The satellite could reach a varies of altitudes, it could pass through from the center to the outside of the Van Allen radiation belt and received the radiation of charged particles with various energy levels.

"Shijian-4" satellite weighed 400kg. It would have been much lighter than that designed, but it was required to be a heavier piggyback payload and a counterbalance weight for the maiden flight of the "Long March-3A" launch vehicle. The satellite was a cylindrical body of 1.6m in diameter and 0.96m in height, and its total height, including tracking and telemetry antennas, was 2.18m. Its designed lifetime was six months.

PAYLOADS

The payloads of the "Shijian-4" satellite included six instruments: a semiconductor high energy electrons detector, a semiconductor protons and heavy ions detector, a static electrical analyser, an electrical potentiometer, a static single event monitor and a dynamic single event monitor.

The semiconductor high energy electrons detector was used to detect and measure the energy spectrums of electrons only, removing the information
about protons and heavy ions.

The semiconductor protons and heavy ions detector was used to measure the energy of high energy protons and heavy ions.

The static electrical analyser was used to analyse the energy spectrums of electrons and protons and to detect the charged particles incoming from seven directions to obtain their angular distribution respectively.

The electrical potentiometer was used to measure the electrical potential at various positions in the satellite with the aid of three transducers fitted at top, waist and bottom of the cylindrical body respectively.

The static and the dynamic single event monitors were composed of random access memories (RAM) and used to detect and record the state changes in the memories of the RAMs caused by the incident charged particles.

PLATFORM

The platform of the “Shijian-4” satellite consisted of five support subsystems, which are structure, thermal control, attitude measurement, electrical power supply and tracking, telemetry and command (TT&C) subsystems.

The structure subsystem adopted frame structure form with a central cylindrical tube to bear the loads. All the instruments and equipment were fixed on the plates at the middle part of the satellite. The transducers of the instruments were distributed at the top, waist and bottom of the satellite. A conic adapter to mate with the launch vehicle was at the bottom of the satellite.

The thermal control was implemented mostly by means of passive thermal control mode with local active mode subsidiary. To make heat balance all over the satellite, a variety of coating materials of high ratio of solar absorbance to emittance and of low emissance were covered the outer surfaces of the satellite. Its inner surfaces were covered with multi-layer heat insulation blankets to reduce heat dissipation and temperature change inside the satellite. By using these measures the environmental temperatures inside the satellite were maintained in the range of -10~45°C.

On the basis of the mature and space-proved technologies, the “Shijian-4” adopted spin-stabilization for attitude control in orbit at a spin rate of 10~20 revolutions per minute. The attitude angles, solar angle and spin rate were measured by a group of solar sensors and dual-axis magnetometers.

The electrical power needed for the onboard instruments was supplied by about 11000 2×2cm silicon solar cells, which were fixed on the top, side and bottom of the outer surfaces of the cylindrical body and would output 65W at the end of life, and the Cd-Ni batteries, which was used to provide the electrical power instead of solar cell array during
satellite eclipse. Therefore, the solar cells should charge the Cd-Ni batteries as well during sun shine. When the satellite entered the shadow of the Earth, causing the solar cells to cease to be effective, the batteries would supply the power for the onboard instruments. The bus voltage of the electrical power subsystem was 27V. The voltages other than 27V were provided by the DC-DC converters.

The space exploration data acquired by the payloads and the engineering parameters about the status of the support subsystems were transmitted via VHF dual frequency tracking and telemetry subsystem to the ground stations. An onboard memory was used to store the obtained data and the measured parameters when the satellite was flying abroad, and then the stored information sent down in time-delay mode when flying over our country.

By fully utilizing the plentiful experience and mature techniques accumulated in the course of developing the previous satellites, especially the returnable satellites and the "Shijian (Practice)" satellite series, making full use of the available facilities and greatly reducing the development procedures, the time for developing the "Shijian" satellite from conceptual study to launch was decreased to only less than two years.

OPERATING IN ORBIT

Since "Shijian-4" was injected into preset orbit, it had operated normally for more than the designed six months. All instruments and equipment onboard of both the payloads and the subsystems have operated normally and acquired and sent to the ground stations a great deal of scientific and technical data.

The attitude of the satellite at injection was right and accurate, it was spun up normally and the initial spin rate was 21.6 rpm. The temperatures inside the satellite were within the designed range. The environmental temperatures around the most of the onboard instruments were within an ideal range of 10~25°C, which showed that the thermal control subsystem well implemented its functions.

The electrical power subsystem operated normally too. It produced the required electrical voltages and currents. The bus voltage was kept 27±1.5V, conforming to that required for onboard instruments.

The actual operating ranges of tracking, telemetry and command reached 40000, 35000 and 25000 kilometers respectively, farther than those designed.

The experimental H-Ni battery began to be space-tested fiftieth day after injection. The battery was charged by solar cell array. In the course of six-month lifetime its voltages, currents and temperatures were all in regularity during both its charging and discharging. The test results showed that the newly developed H-Ni battery was initially
space-qualified and it may be allowable to be put into use in spacecraft.

All of the instruments of the payloads functioned properly. The electron, proton and heavy ions detectors detected the energy spectrum of both high and low energy electrons and acquired the data about their distribution in space.

The electrical potentiometer detected a -2000V surface potential on satellite. The static single event monitor detected and measured the single event upsets (SEU) that happened 3.4 times per day in average. The dynamic single event monitor detected the single event upsets of even higher repetition.

The satellite passed through the central areas of the inner and outer Van Allen radiation belts four times a day, which provided good chances to detect the space charged particles, but created an inferior operation condition for satellite. The single event lock (SEL) happened three times in satellite. One of the SEL took place in a CMOS circuit in the dynamic single event monitor, causing an increased current up to 800mA, which led to overcurrent protection in a DC-DC converter and the electrical power subsystem stopped supplying electrical energy.

The experimental results obtained by the charged particles detectors and the single event monitors are of great significance for further understanding the near Earth space environment and providing a great deal of experience in effective application and protection of space-borne computers and large scale integrated circuits.

Now the “Shijian-4” satellite has successfully completed its experimental tasks expected in its six-month lifetime. It obtained not only a great deal of data on space charged particles and their effects on space-borne electronics but also some information on designing of long-lifetime and high-reliability spacecraft. In addition, the “Shijian-4” satellite laid a foundation of the development of small satellites and their piggyback launching approach to a certain degree.

CONCLUSION

“Shijian-4” is the fourth of the “Shijian” series of Chinese scientific and technical experimental satellite. The “Shijian-1” was launched into space on March 3, 1971 and had operated normally for eight years before it reentered the atmosphere. The “Shijian-2”, “-2A” and “-2 B” were three space physics exploration satellites and launched on one launch vehicle on September 20, 1981. As for the “Shijian-3” program, its preliminary design was completed but aborted partly because of its indistinctive mission and objective.

Under the support and with the aid of the National Defence Science Technology and Industry Commission, the “863” Specialists Commission on Space, the China AeroSpace Corporation and the