TWO YEARS' OPERATION RESULTS IN ORBIT OF WHALE ECOLOGY OBSERVATION SATELLITE (WEOS)

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ABSTRACT

A Whale Ecology Observation satellite (WEOS) was launched on 14 December 2002 by H-IIA rocket as one of the piggyback satellites into a polar orbit (774x812 km) from Tanegashima Space Center. The WEOS is working well on the orbit more than two years as planned. This paper describes the WEOS system, and evaluation of its performance.

1. INTRODUCTION

The objective of the WEOS is to collect the data from probes, attached to whales for studying the ecology of whales globally, and evaluate the performance of our technology adopted for cost reducing trial (Reference 4).
Although the probe is not attached to a whale yet, we floated a buoy on the sea to study the global surface flow. All functions of the WEOS such as attitude control, thermal control, communications, power control, collecting data of a buoy such as position, temperature of the sea and GPS satellite's data receiving are working well satisfactorily.

2. SYSTEM OF THE WEOS

The size of the WEOS is a cube with the side length of 50 cm, and the weight is 47.7 kg. We applied gravity gradient attitude control technique to the attitude stabilization of the WEOS as the first trial in Japan for pointing the communications antennas toward the earth, and the GPS antenna toward the zenith. Figure-1 shows the block diagram of the WEOS.
The WEOS system consists of the following units: Whale Central Unit (WCU), an S-Band transmitter, a UHF receiver, a DSP unit, a GPS receiver, a magnetic torquer coil, a magnetic attitude sensor, a gravity gradient control mast/mass, Si (BSFR) solar cell panels, 4AH Ni-Cd batteries, and power control unit Reference (1, 2, 3, 4).
The heart of the WEOS is the WCU, whose functions are telemetry/command processing, attitude control, data storage, and processing of house keeping and attitude control data. Major functions of the WEOS are carried out by 16 bit CPU system.
The functions of the DSP unit are as follows: (1) detection of the probe signal under noisy condition by using FFT processing, (2) control of the loop band-width for receiving the probe data in good

S/N condition, (3) BPSK demodulation and Viterbi decoding to receive susceptible signal from the probes on the sea. The DSP unit has also a role for measuring Doppler frequency shift of the probe signal to determine the probe position, as the backup means for a GPS receiver in the probe.

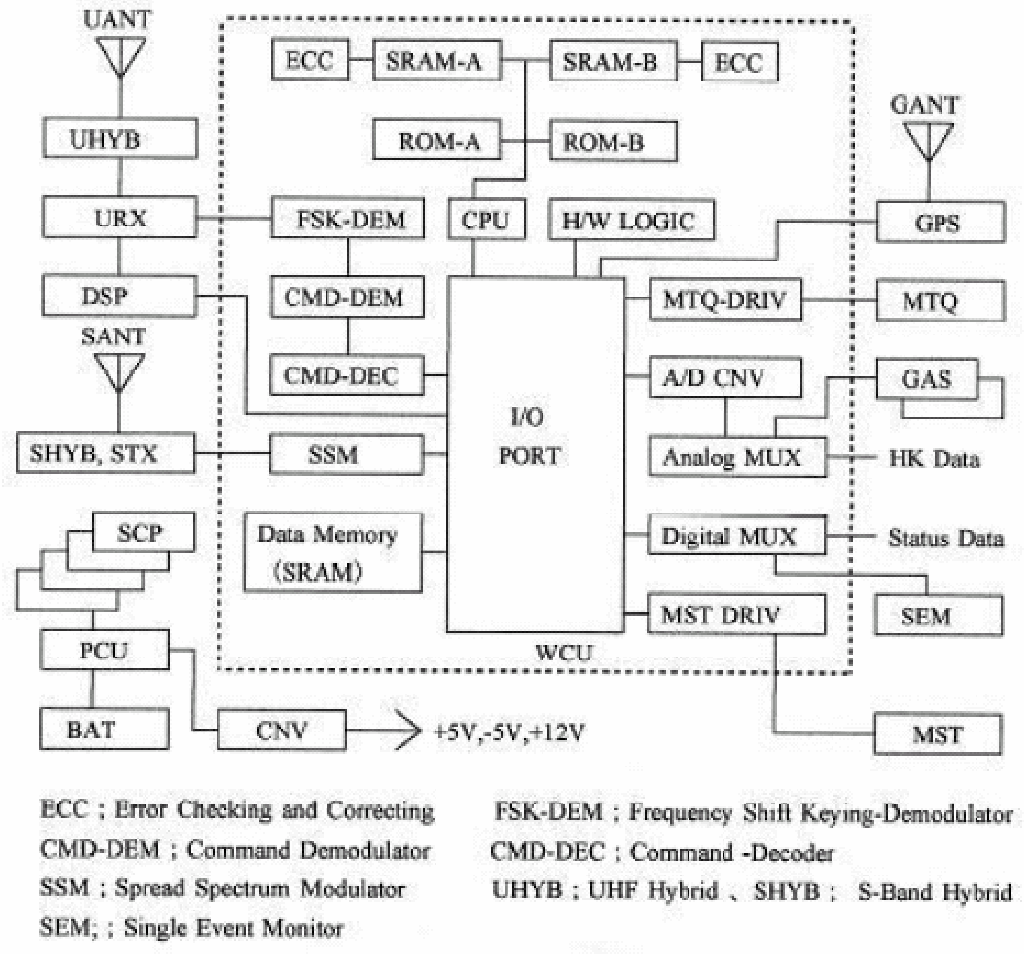

Figure-1 System diagram for WEOS

3. FUNCTION EVALUATION

3.1. Attitude control

The WEOS rotated about 0.37 rpm just after the separation from H-IIA rocket due to the imbalance force of separation springs. We then sent out command signal and loaded parameters for reducing spin rate to onboard software. The spin rate thus reduced to 0.05 rpm by controlling the electric current in a magnetic coil using the data of a geomagnetic attitude sensor. We surveyed the timing for mast extension for one month after the launch by using the information of the polarization and signal strength of S-Band telemetry and command RF link, geomagnetic attitude sensor data, and top surface temperature. After the extension of the mast, we confirmed the establishment of the gravity gradient attitude stabilization in one week. After that, the spin rate around the Z-axis went down gradually to 0.034 rpm by October 2004. Judging from the communication link and attitude sensor data, we consider that the pointing accuracy and the stabilization of the WEOS is satisfactory.

3.2. Temperature control

Passive thermal control technique is adopted using thermal blanket, thermal insulator and paint. All equipments are instrumented on a central structure, which serves as conductive heat path and contributes to equalization of the spacecraft temperature. Average temperature of the central structure per month and temperature of a solar panel is shown in Figure-2.

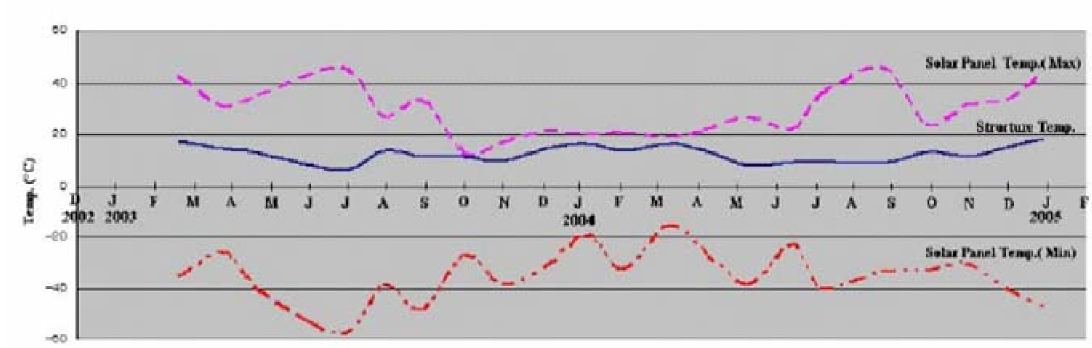

Figure-2 Average temperature of the central structure and solar panel

3.3. Power generation and battery

The WEOS used Chinese space-use solar cell (mono Crystal Si, BSFR type) manufactured and assembled by the Chinese Academy of Space Technology (CAST). The thickness of cover glass is 0.1 mm, and conversion efficiency is 14.2%.

The power generation depends on the WEOS attitude, and the maximum power generation was estimated 30.7W at the beginning of life. Sixteen (16) months after the launch, we have found from telemetry data that there is no evidence of degradation on the solar cell performance. A 4AH Ni-Cd battery cell unit is used for about 30 minutes eclipse operation. Judging from discharge characteristics of the battery unit, we have not observed the sign of degradation.

3.4. Radiation susceptibility

In order to reduce the satellite cost, major parts of the WEOS are implemented with commercial parts. As total dose tests were performed using radiation test model of each unit in advance for rejecting suspicious parts. On the other hand, we omitted SEU and SEL evaluation test and employed ECC circuit and circuit breaker.

SEL never happened for two years but a small number of SEU happened in the DSP unit. When abnormal operation was observed we restored the DSP unit by using DSP reset command. We consider that SEU should also have happened in 1 Mbit SRAM of the WCU's program RAM, but ECC circuit is working perfectly, and no problem has happened for CPU system of the WCU.

3.5. GPS data

The GSP receiver applied is a unit for car navigation use made of commercial parts. We asked software modification to the manufacturer for expanding of search frequency range, and elimination of a function for compensating ionosphere influence.
The GPS receiver is working well, captured eight GPS satellites and provides latitude, longitude, height and UTC data. Using the GPS data, we calculate the orbit of WEOS on the ground. The accuracy of the position determination of the WEOS on the orbit is considered to be +/- 50 m in the best condition (Reference 5).

3.6. Tracking of a buoy on the sea

As one of the applications of the WEOS system, study of global surface flow of the sea started by a team at the Chiba Institute of Technology. A GPS receiver, a temperature sensor, data processing unit and a UHF transmitter, similarly constructed as the probe for whales, are installed in the buoy powered with Lithium Batteries. The size of the buoy is around 35 cm in diameter, and we released it near Ogasawara Island on December 8 2004. Figure-3 shows the scenes of release and floating.
Since then the course of the buoy is kept tracking through the WEOS. Figure-4 shows tracking data of the buoy. Since global data on the surface flow of the sea is not ample at present, if we scatter many similar buoys on purpose, our system would become a useful tool for predicting the course of drifting objects and would contribute to the safety of navigation.

Figure-3 Release and Floating Scene of the Buoy

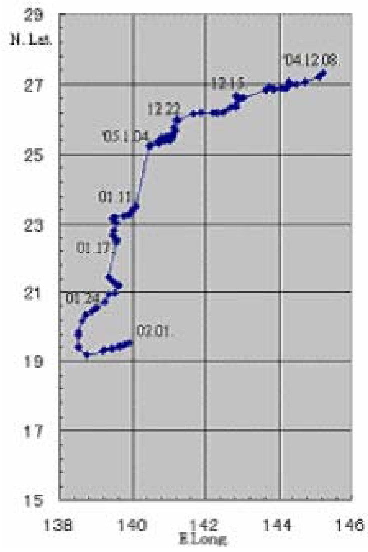

Figure-4 Course of the Buoy

4. CONCLUSION

The WEOS experienced more than 10,000 revolution of the earth, and operated more than two years. No operational degradation is observed and is working well, in spite of the low cost satellite about US$755,000 . Various experiments are possible using the WEOS functions, we would like to use the WEOS in various purpose internationally to activate micro satellite field.

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