# IN-ORBIT OPERATING MANAGEMENT FOR BEIJING-1 SMALL SATELLITE

Wang Zhiyong *1, Wu Shuang 1, Liu Chang *2, Sun Xinrong 2 and James Northam3
1Twenty First Century Aerospace Technology Co., Ltd. Beijing 100096
Tel: 0086-10-62929966; E-mail:wangzy@21stc.com.cn

2Beijing Landview Mapping Information Technology Co., Ltd. Beijing 100096
Tel: 0086-10-62929966; E-mail:liuchang@21stc.com.cn

3Surrey Satellite Technology Limited, Guildford, United Kingdom, GU2 7YE
Tel: +44 1483 803803; E-mail: J.Northam@sstl.co.uk

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**ABSTRACT**: High-performance Earth Observation small satellite "Beijing-1" (DMC+4) was launched by 3M rocket at Plesetsk Cosmodrome of Russia on 27th October, 2005. The small satellite had successfully operated for 5 years of its design lifetime and it is safely entering the extended operating period by now. This paper introduces the In-orbit operating management strategies which include telemetry analysis, battery maintenance, data selected download based on satellite cloud atlas, and balance of task and lifetime for Beijing-1 small satellite associated with its performances and characteristics. The application of those management strategies has promoted the output and achieved long term operation of the satellite.

## 1. INTRODUCTION

Beijing-1 satellite was manufactured by Surrey Satellite Technology Limited (SSTL) cooperated with BLMIT and successfully launched on 27th October 2005. BLMIT is responsible for operation and maintenance of the satellite, sales and delivery of the data products, research and development of small satellite technologies. So far, the Beijing-1 satellite has been in operation for nearly 6-year and its data has been used for many application fields such as governmental management, natural resources management, urban planning and environmental monitoring.

The Beijing-1 satellite (Fig.1) only weights about 166 kg and operates at the orbit altitude of 686 km. The satellite has two types of data recorders: one is Solid State Data Recorder (SSDR); the other is Hard Drive Data Recorder (HDDR). Impressively, compared with other applied satellites such as Landsat and SPOT-5, Beijing-1 initially uses HDDR as the Commercial-On-The-Shelf (COTS) for on-board data storage of the small satellite.

Fig.1 Front-view (left) and rear-view (right) of the Beijing-1 satellite (image credit © SSTL)

Further, The Beijing-1 imaging payload has two sensors, two groups of multispectral push-broom cameras (MSI0 and MSI1) and a panchromatic camera. The multispectral cameras can provide a swath of 600 km with the spatial of 32 m. It can capture 3 spectral bands which are green, red and infrared. The panchromatic imager can provide a swath of 24 km with the spatial resolution of 4 m. Also, the data downlink can use 8 Mbps via S-Band or 20/40 Mbps via X-Band, alternatively.

Moreover, there are several strategies include telemetry analysis, battery maintenance, data selected download based on satellite cloud atlas, balance of task and lifetime, which are used for Beijing-1 in-orbit operation management. Telemetry analysis is used for anomaly diagnosis of Beijing-1; battery maintenance is beneficial to achieve long-life operation; selective download has greatly improved efficiency of valid image obtained; balance of task and lifetime is also very useful for achieving long term of Beijing-1 in-orbit operation.

Based on above-mentioned strategies, Beijing-1 satellite had been successfully in operation for 5 years of its design lifetime and it has operated its extended period for nearly 1 year.

## 2. TELEMETRY ANALYSIS

### 2.1 Telemetry data process

Beijing-1 has 2 types of telemetry data, real-time telemetry (TLM) and whole orbit data (WOD). Both types can be processed into .wst file and are easily to output for inquiry (Fig.2).

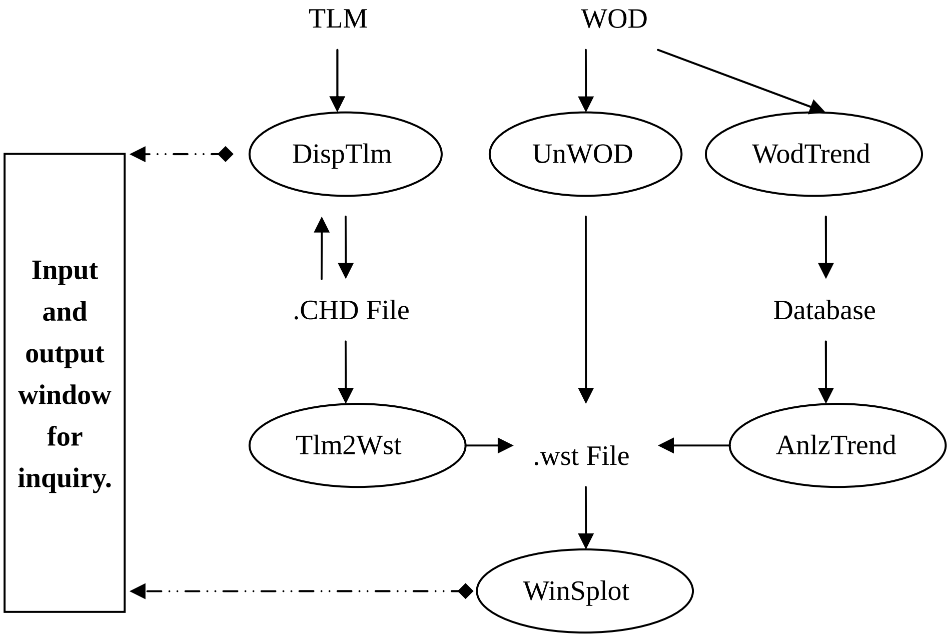


Fig.2 Telemetry process procedure

### 2.2 Telemetry analysis

Correspondingly, telemetry analysis of Beijing-1 will base on these two types which are called as TLM and WOD. TLM means real-time telemetry which is obtained during the duration that satellite contacts with ground-station. TLM will be displayed on the screen of telemetry monitor directly. The satellite's state and alarm analysis is achieved by a system of data management. The management system will process the received data and then compare these data with the alarm threshold set in the database; alarm call will be triggered if the data is out of normal range. The operator will be reminded to take measures to handle this to avoid further deterioration.

In general, the whole orbit data (WOD) collects 6 or 24 hours classified telemetry data. Compared with TLM, WOD has better continuity whereas it has less data collection points. WOD is able to provide full state data of the satellite even it is not in view of the ground-station.

WOD-Trend collected all the WOD files and put these into a database for trend analysis. Each telemetry channel in the database will be collected one single point every 3 hour. These trend data can be used to analyze a long-term of the satellite's status changes and corresponding trend. It is very useful for the operators to fully understand the satellite's performance and to achieve task allocation reasonably. Finally, this will ensure the satellite's in-orbit long life operation. The figure below shows Battery0's temperature trend for previous 6 months.

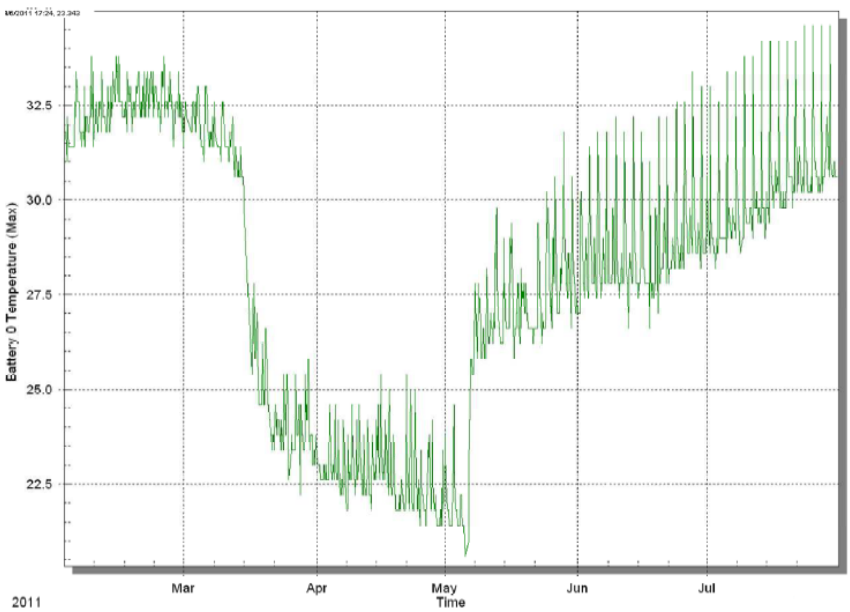


Fig.3 Battery 0 maximum temperature trend for previous six months

## 3. BATTERY MAINTENANCE

There are 2 packs of 4Ah Ni-cad Battery on Beijing-1 to provide power supply for eclipse pass. Each pack consists of 22 cells and its output voltage is 28v. The main effects that drive the battery life are the thermal environment and the usage of the battery pack, the higher the pack temperature or the more energy removed from the pack the quicker the pack will degrade and the shorter the lifetime will be. Therefore to maintain the same operational level a low battery temperature will increase the operational lifetime of the battery, the optimal average temperature for the battery would be between +15ºC to +25ºC. Memory effect is an undesirable feature of Ni-Cad cells. Memory effect occurs when cells are not close to full charge or full discharge over a number of cycles, meaning that the Veoc and Veod achieved are not at the cell's operating limits. Repeating this process over a number of cycles means that the cell begins to remember where these limits are, and when it achieves these limits again in future cycles, stops accepting charge (or giving out charge) when demanded. The end result of this is a drop in the capacity of the cell and also a differing Veoc and Veod to the other cells in the pack.

Based on the above analysis of Ni-cad battery, it's necessary to apply the strategy to reduce memory effect and to reduce its temperature as for the satellite's long-term in-orbit operation. Battery pack conditioning can be carried out to help correct cell divergence and to reduce any memory effect that exists in the cells. However, in case of this method of conditioning is applied, the battery will be driven into, and out of, conditioning mode via relays. It is possible that the relays could fail to energies their coils and so the pack could be held in conditioning mode indefinitely. This would jeopardize the mission as it would effectively be running with only one battery pack to supply the power. Consider all possible factors, accurate charge control regimes is applied. Also we pay close attention to the cell temperatures and divergence. That is to say, a battery task software is used to control the charge current and implement a hard charge cycle every two days (or 28 orbits). This will ensure that memory effect does not limit the capacity of the cells, or change the Veoc of cells drastically, by forcing the cells up to their maximum operating limit. This hard charge cycle will also help to prevent dendrites appearing in the cells in future.

On the other hand, yaw strategy is applied to reduce battery's temperature further. This strategy is based on the time of eclipse exit; yaw will be set to +30° at T0 while T0 is defined as eclipse exit. Then yaw will be set to -30° half hour later equally at T+30minutes. 30minutes later (T+60minutes), yaw will be set to 0°. The temperature of battery reduced 10 degree with this strategy applied as shown in the below figure.

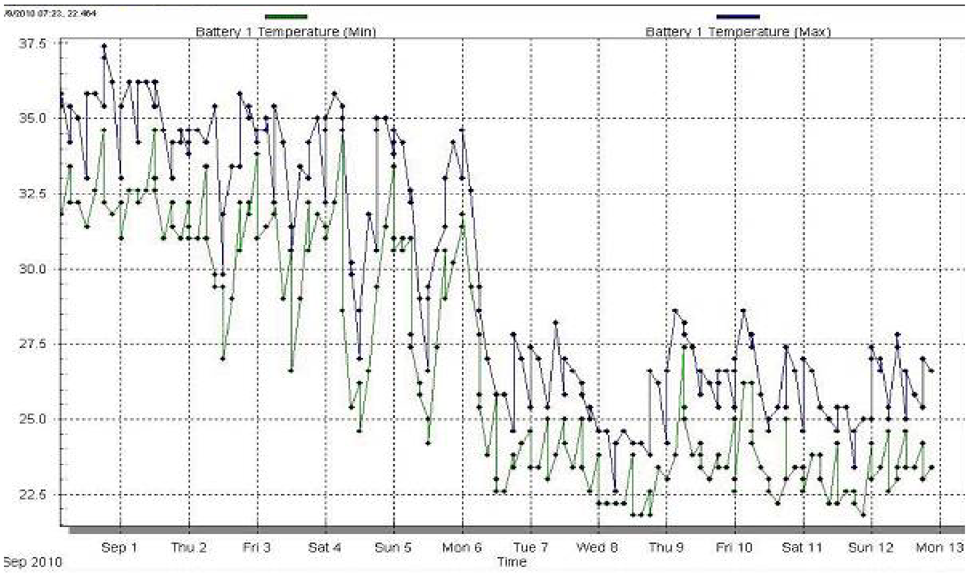


Fig.4 Battery 1 temperature trend with yaw strategy applied

## 4. SELECTIVE DOWNLOAD

As the main storage, HDDR's capacity has been greatly developed during in-orbit operation, and it is available to acquire multi-area, wide-swath, long-strip image. Its high-capacity meets the requirement of large-area image acquiring which will be applied for Land Resources Management, Agricultural Monitoring, Environmental Monitoring, and Disaster Relief. During the eclipse pass the system can not support long-strip imagery download due to its limited power support. Selective download provides a solution to the issues that there is multi-area of wide-swath and long-strip image need to be downloaded with limited data downlink rate. This method ensures the effective data can be downloaded in time and achieves balance of storage data and downlink rate.

When the observation mode is used for getting image with wide-swath, long-strip and large-area, area with cloud coverage will be 70% of image acquired as observation area is vast and climate diverse. To reduce small satellite data transmission pressure, avoid the cloud data download, and enhance the effective rate of data acquisition, the strategy of data area pointer in file storage has been studied. Based on this strategy, the mapping relationship of data piece of Pointers and ground coordinates is established, and image without cloud or less cloud has been got in terms of special satellites' cloud picture. This method makes up for the weaknesses of low transmission rate of small satellite data, limited energy compared with large satellite, breaks the bottleneck of small satellite data transmission channel mismatch with its observation ability, and achieves in-orbit effective data acquisition improvement. The following figure (Fig 5) will provide a description of the process of Selective download.

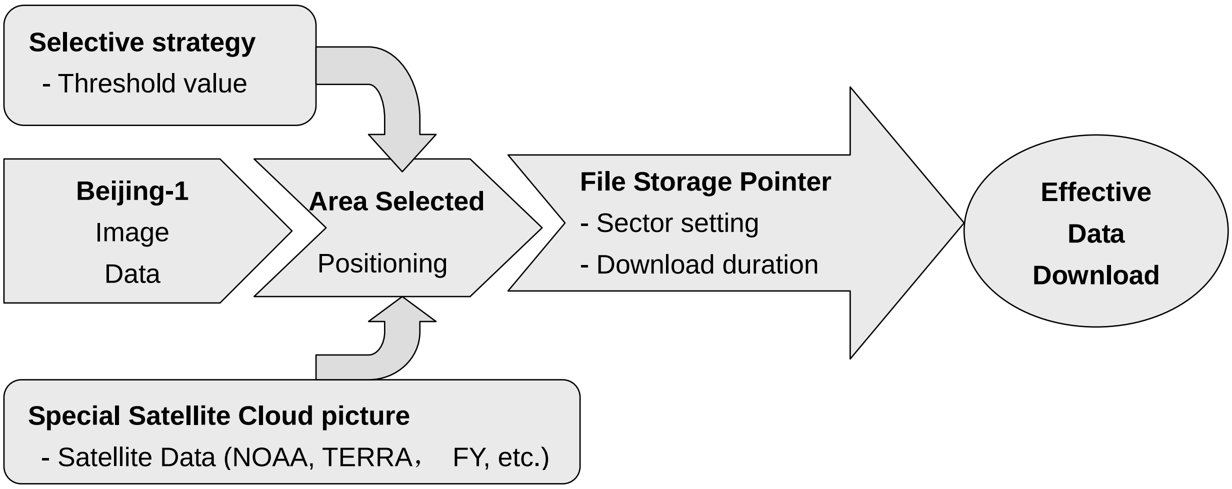


Fig.5 Process of data selective download

Special Satellite Cloud picture includes data of NOAA、TERRA and FY Series. Based on the threshold value of selective strategy, acquired image data of Beijing-1 shall be matched and positioned with cloud picture of special satellite. Then the area which has been predicated as free of cloud or less cloud will be downloaded. Threshold value can be set flexibly according to actual application requirement.

On one hand, the strategy of selective download to get image data stored in HDDR has been applied to ease the data download pressure of small satellite, and also enhance the storage system cycling. On the other hand, this technology innovation is beneficial to reduce the cloud data download and save satellite resources. It contributes to realize Beijing-1 long term and high stability in-orbit operation. According to the statistics of five years operation, the proportion of data with cloud free is 65% and efficiency of image with cloud free has been doubled. Overall，the effective data acquisition ability has been greatly improved.

## 5. BALANCE OF TASK AND LIFETIME

There are several main goals of satellite's operation and management which include balance of operation cost and performance, reduction of operation cost to maintain long-term and stable operation, collaborative work and independent viability. For the satellite's benefit maximization, it's necessary to balance its task and operation life to avoid the overweight task has negative impact on the satellite's life. Therefore, the satellite's task's impact on the platform's power has been taken into account when we make the image and download schedule. The schedule will be made to meet the requirement of power balance, moreover, the satellite's task will be adjusted accordingly based on the power supply season variation， and then， the satellite's long-term operational life and task will be effectively balanced.

The implementation of the scheduling for the observation mission plan of small satellite constellation should consider the power supply, quarterly changed output of solar panel and the options of observation mode synthetically and through the study on analysis model of telemetry parameter and the optical plan of observation mission, the best balance between power and observation plan could be achieved to ensure the long-term in-orbit operation of the satellite.

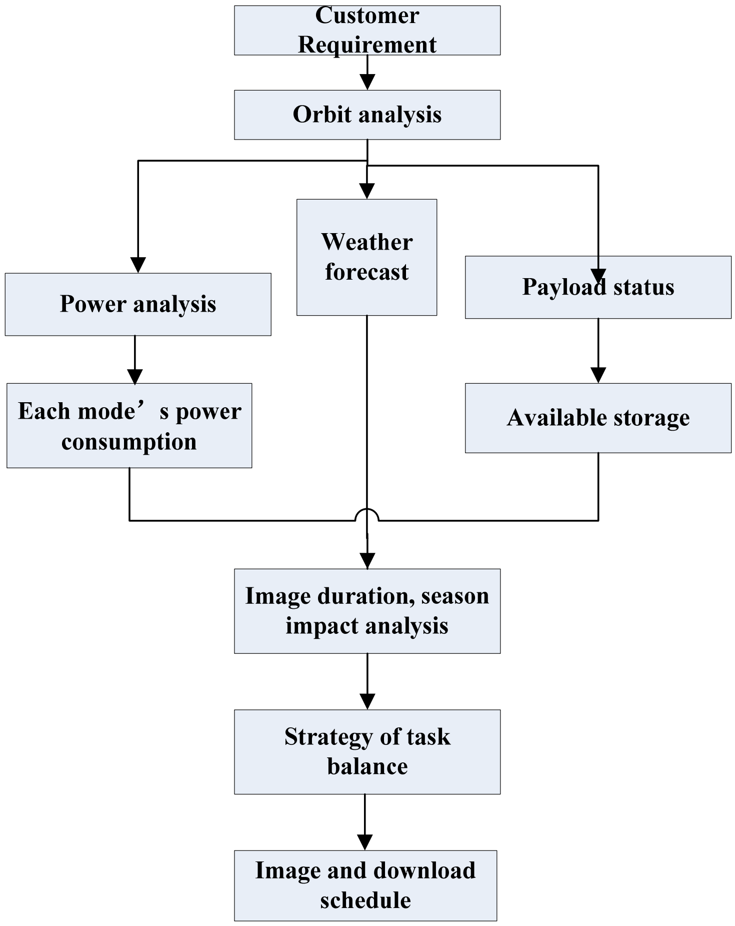


Fig. 6 Balance of long-term operation and task

The key point of research on long-term operation and mission balance technology is to analysis the major influential factors such as power system and attitude control system and rationally schedule the mission planning, which could support the high-efficiency and long-term operation of the small satellite constellation effectively.

## 6. CONCLUSION

As mentioned above, Beijing-1 satellite, since its successful launch in October 27, 2005, has been in orbit for more than 5 years. BLMIT, the company responsible for maintenance and operation of the satellite, has become the first company in China to construct an integrated system of data source, data delivery, value-added services, research and development of the applied satellite. Based on above operation strategies, BLMIT has successfully used Beijing-1 satellite data for a range of application fields and it is expected to extend its in-orbit life for 2 more years.

## 7. REFERENCES


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