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CALET on-orbit operations and data analysis system at the Waseda CALET Operations Center (WCOC)

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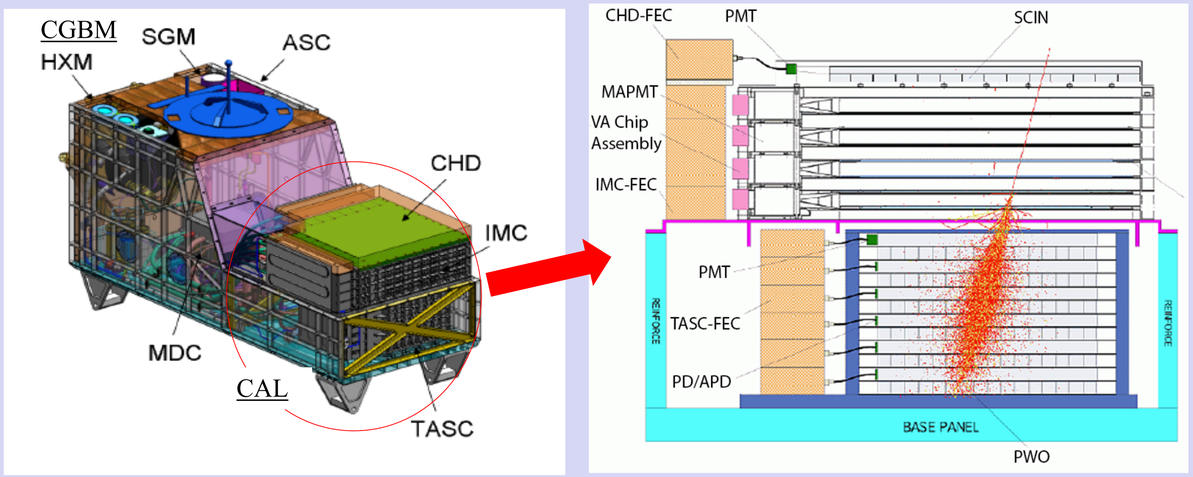
CALET is the long-term high energy cosmic ray observation mission on JEM-EF of the International Space Station. In order to extend measurements of electrons and gamma rays to the 10-20 TeV region and protons and nuclei to several hundred TeV, the CALET calorimeter (CAL) has a thickness of 30 radiation lengths. The data taken by CALET are passed to the ISS and sent to the ground immediately via NASA and JAXA data relay links. At JAXA's Tsukuba Space Center, a ground operation system (JAXA-GSE) then transmits the data to the Waseda CALET Operations Center (WCOC) at Waseda University. Monitoring of the instrument's observation status has been performed since October 2015 at JAXA.

Simultaneously, the CALET science team monitors the scientific mission and the data transmission on a 24-hour 7-day basis in WCOC. Monitoring at the WCOC is performed by Quick Look software developed at Waseda. When the Quick Look GUI detects observed values exceeding predetermined thresholds, an alarm is issued. In order to provide flexibility for the scientific operation, the CALET' observing schedule is updated daily. In addition, the observation data file is processed for transmission to the science team. Raw (Level-0) data processed at JAXA-GSE are converted to engineering (Level-1) data for distribution to the international CALET collaboration. Finally, individual detector temperature dependences, time variations, etc. are included in the final (Level-2) data which are used for detailed science analysis.

CALET Onboard ISS

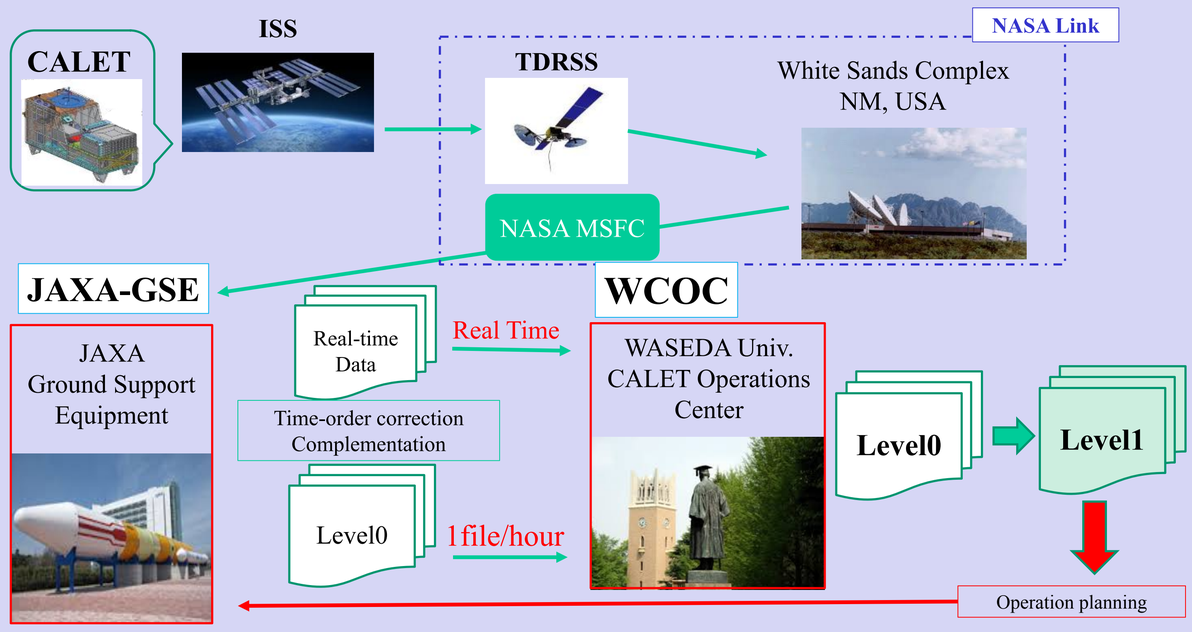
The calorimeter of 30 radiation-length thickness completely absorbs electron shower energy in the TeV energy range and separates electrons from the overwhelming number of protons using the difference in shower development in the fully-active and thick calorimeter.



The CALET calorimeter (CAL) is composed of a lead tungstate (PWO) Total AbSorption Calorimeter (TASC), a tungsten-scintillating fiber IMaging Calorimeter (IMC), and a plastic scintillator CHarge Detector (CHD). Shower image shows a 1TeV electron created by Monte-Carlo simulation.

Data flow between ISS and WCOC

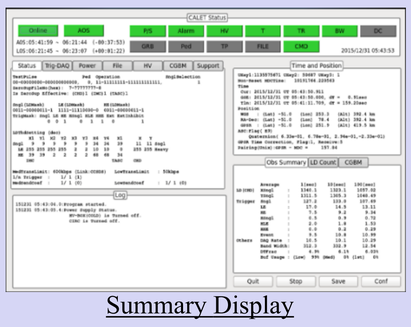
The observation data obtained with CALET onboard ISS is transferred to JAXA. To operate and to monitor CALET, the JAXA Ground Support Equipment (JAXA-GSE) at JAXA Tsukuba Space Center (TKSC) and Waseda CALET Operations Center (WCOC) in Waseda Univ. have been established. The real-time data received by JAXA-GSE are immediately transferred to WCOC.

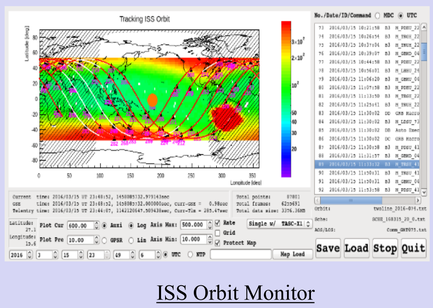


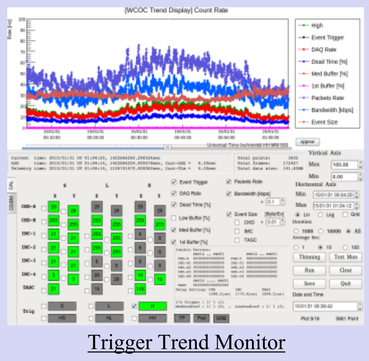
Observation Monitoring (QL system)

To monitor the observation status of CALET in real-time, a quick look (QL) system which consolidates and visualizes cosmic-ray event data and housekeeping data was developed. Since a large amount of data must be monitored in real-time in a comprehensive manner, it is necessary to summarize the data and to detect malfunctions automatically. An operator is always present at WCOC, and the science observation status of the system is summarized for 24 hours by watching the real time data forwarded from JAXA-GSE. Quick Look (QL) uses a monitor in each PC in WCOC to visualize it immediately.

Quick Look User Interfaces





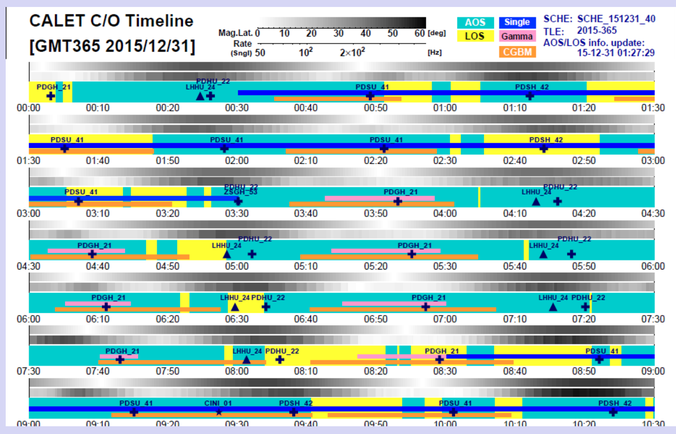


Observation Planning

Observation planning the trigger conditions for various parts of the orbit takes account of geomagnetic latitude with the goal of efficient observation of low-energy particles and calibration data while achieving the highest possible statistics for TeV electrons. It requires taking account of the dead time of ~5 ms /event.

Observation mode in a Schedule file

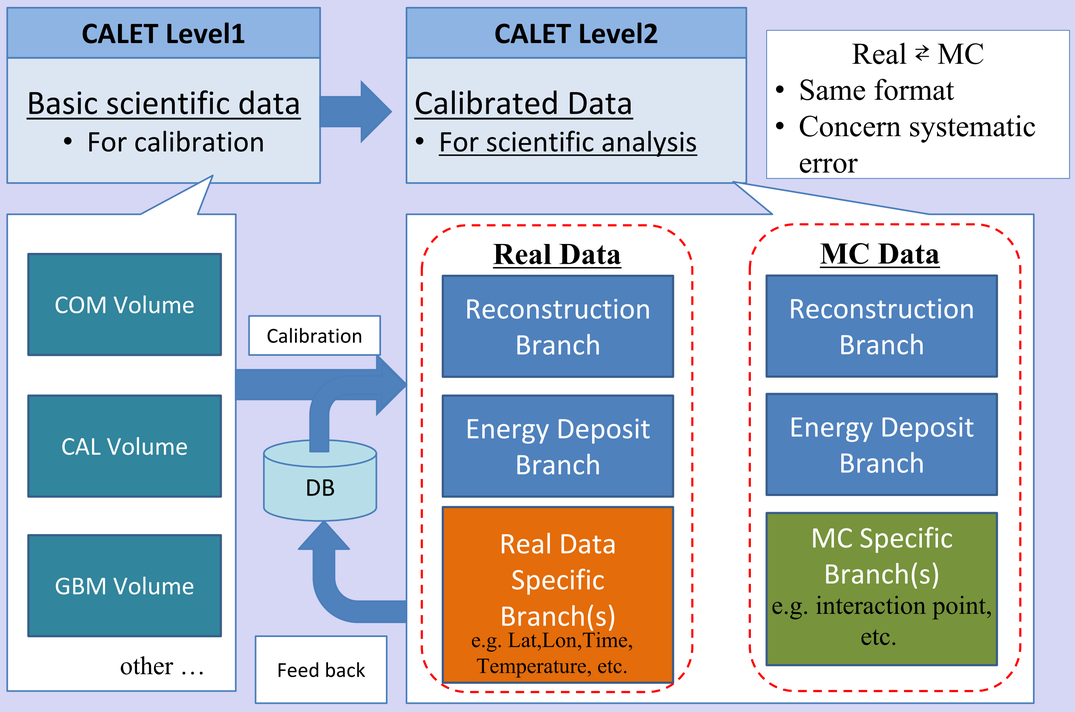
- **High Energy Shower observation**
  E>10GeV (Always activated)
- **Low Energy electron observation** ▲
  1GeV region electron(at High Geomagnetic latitude)
- **Low energy γ-ray observation**
  1GeV region electron (at Low Geomagnetic latitude)
- **Single run**
  Gain and stability check
- **Ultra Heavy nuclei observation**
  Z≧12 (Always activated)
- **Pedestal run**
  Stability monitoring(100events every 23minits)
- **CGBM observation**
  HV control for protection at high radiation rate area



A time line for CALET observation for operators in WCOC

WCOC Data analysis system

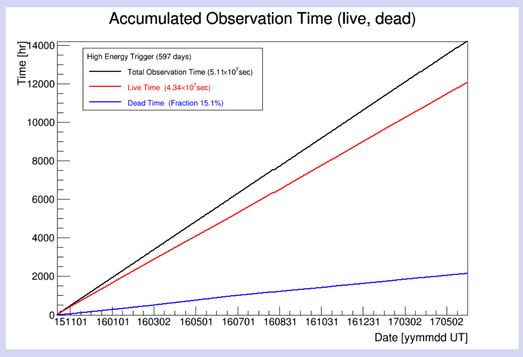
Scientific raw data are also transferred to WCOC on an hourly basis after time-order correcting and complementing replay data at JAXA-GSE. For the CALET project which aims at unique scientific goals by challenging the boundary of statistics and accuracy, it is very important to maintain detector performance and to carry out observation with high efficiency during the long term operations.

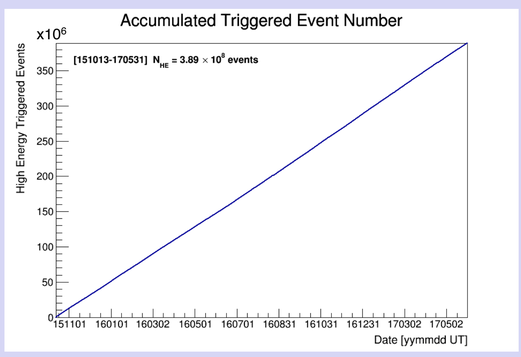


Summary

CALET is a long-term high energy cosmic ray observation mission and aims to make unique observations by extending the previous limits of direct measurements. It is important to continue stable operation, and stable operations have continued since they began in October 2015.

Since October 2015, observation time has increased smoothly without trouble. The transmission of data from JAXA-GSE to WCOC and processing the data for scientific analysis at WCOC has also proceeded smoothly. For ensuring continued stable operation, we are improving the monitoring system with the goal of alerting us immediately to any sudden change.





Left figure is an accumulation of observation time (black line). The red and blue line are live time and dead time. Total live time reaches 4.43×10^7 s. Right figure is an accumulation of HE triggered events. Total number of HE events through the end of May 2017 is 3.89×10^8.

Acknowledgement
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