Compatibility of CALorimetric Electron Telescope (CALET) for JEM Exposed Facility on International Space Station

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Abstract

We have been proposing the CALorimetric Electron Telescope (CALET) as a suitable mission on the Exposed Facility (EF) of the Japanese Experiment Module (JEM) which is one of the most characteristic external accommodations on the International Space Station (ISS). Since 1998, we have made a conceptual design of the instrument and have proved CALET to be a promising candidate of future program on JEM-EF. Because CALET is a calorimetric detector for high-energy cosmic rays with a large surface density, large mass is an essential requirement for its instrumentation. JEM-EF has 10 attach points and 2 among them are capable for heavy payloads up to 2.5 tons. CALET is now being developed as a heavy payload.

In this paper, we will outline system design of CALET and discuss its compatibily as a payload on JEM-EF.

1. Introduction

Japan is participating in ISS Program and the development of JEM is one of the Japanese major contributions on the program. As shown in Fig. 1, JEM consists of 4 elements including the exposed facility (JEM-EF) for experiments directly exposed to outer space. The construction of ISS has begun in 1998 and these Japanese elements will be launched around 2007.

JEM-EF is a platform-type accommodation of which size is about 4m x 6m. The standard envelope of payloads for JEM-EF is 1.85m x 0.8m x 1.0m and the maximum allowed mass is 500 kg for each. However, 2 out of 10 payload mounting interfaces of JEM-EF are capable for a large payload which weighs up to 2.5 tons. Because ISS is a multi-purpose orbital accommodation, especially for micro-gravity experiments conducted mainly in pressurized sections, the fine attitude control will be not made to avoid the violation of micro-gravity conditions. The instability of its orbit and attitude must, therefore, be considered in JEM-EF utilization. For example, ISS is not suitable for an optical telescope which needs fine pointing and stable platform.

pp. 2181–2184

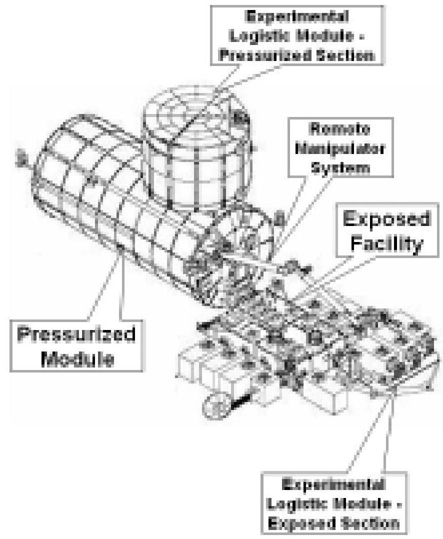

Fig. 1. The Japanese Experiment Module (JEM) on the International Space Station

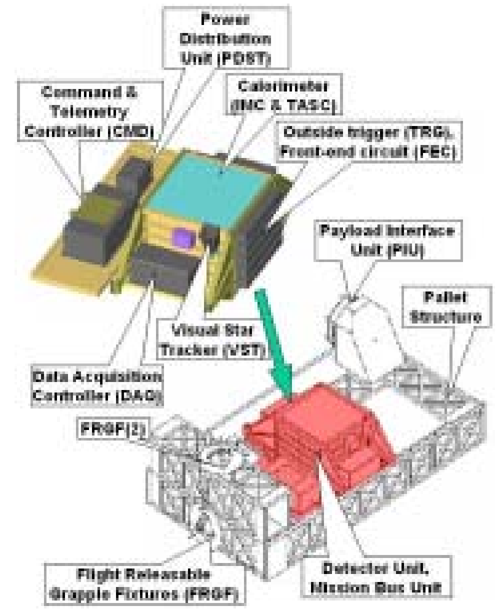

Fig. 2. CALET System

CALET includes detectors made of scintillating fibers with lead absorber layers and BGO logs. The total mass of the detectors is much larger than 500kg because CALET observes high-energy cosmic rays up to the orders of TeV. Sensors of such a large mass cannot be accommodated on a small free-flying-type satellite. The requirement for pointing accuracy is around the orders of 0.1 degree for cosmic-ray observation. On these points of view, CALET can be considered as one of the most suitable space observation missions aboard ISS to be adjusted to limitations and capabilities of ISS.

2. CALET System Concept

According to scientific requirements of CALET [1,2] as a space-borne observatory of high-energy cosmic rays and to interface requirements from ISS and JEM-EF, we have made a conceptual design of CALET instrument. CALET consists mainly of 3 units, the detector unit, the mission-bus unit and the pallet structure. Figure 2 shows the conceptual drawing of the instrument. The mass allocation is listed in Table 1. Functions and structures of each part are summarized as following.

Detector Unit: The main component of the detector unit is the calorimeter consists of the imaging calorimeter (IMC) and the total absorption calorimeter (TASC). IMC is assembled by scintillating fiber belts and TASC is made of BGO log layers. The unit also includes electrical circuits such as the outside trigger (TRG), the front-end circuit (FEC) and the data acquisition controller (DAQ).

Table 1. Mass Allocation

ITEM	Mass (kg)
Detector Unit	
Calorimeter	1,760
Imaging Calorimeter (IMC)	
Total Absorption Calorimeter (TASC)	
Electronics of Detector Unit	150
Outside Trigger (TRG)	
Front-end Circuit (FEC)	
Visual Star Tracker (VST)	
Data Acquisition Controller (DAQ)	
Mission Bus Unit	53
Power Distribution Unit (PDST)	
Command & Telemetry Controller (CMD)	
Pallet Structure	
Main Structure	168
Payload Interface Unit (PIU)	36
Flight Releasable Grapple Fixture (FRGF)	26
Outer Equipment	
Cargo Attach Mechanism	50
Multilayered Insulator (MLI)	10
Electrical Harness	115
Contingency	132
Total	2,500

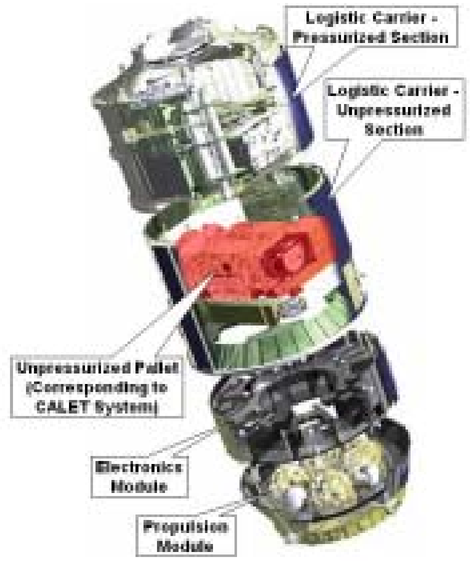

Fig. 3. H-II Transfer Vehicle (HTV)

The visual star tracker (VST) is attached directly on the side of the calorimeter. Detected photons in IMC and TASC are converted to electrical signals by FEC. After the A/D conversion, these signals will be sent to DAQ. DAQ will make the signal processing such as data discrimination and compression. The mass of the calorimeter with its support structures is estimated to be 1,760kg and other electrical components weigh 150kg. The detector unit occupies about 76% of CALET instrument mass.

Mission bus unit : The mission-bus unit has a function of direct electrical interfaces with JEM-EF and consists of two components, the command and telemetry controller (CMD) and the power distribution unit (PDST). CMD receives CALET control commands from JEM-EF and decodes them to control the detector unit. Observational data from the detector unit will be sent to JEM-EF with the system health and status telemetry after editing and format conversion by CMD. The electrical power from JEM-EF, 120VDC, will be converted to appropriate voltages to supply to each unit by PDST.

Pallet structure : CALET has a pallet-shaped main structure of which size is about 2m(W) x 3.7m(L) x 0.5m(T) as shown in Fig. 2. Considering the launch vehicle and the reduction of development cost, we adopt the same design to the pallet which will be installed in the unpressurized logistic carrier of the H-II transfer vehicle (HTV). HTV is Japanese own unmanned carrier system for ISS logistics launched by the H-II rocket. The pallet of HTV is capable for 3 payloads of the standard envelop (1.85m x 0.8m x 1.0m, 500kg) on it. However, as shown in Fig.3, the structural concept of CALET is that the instrument includes the pallet interface within itself and has a direct interface to the unpressurized logistic carrier of HTV. CALET will attach to JEM-EF by the payload interface unit (PIU) through which the system resource services from the JEM system, such as electric power, communication and the thermal control fluid are supplied. Two flight-releasable grapple fixtures (FRGF) are needed on CALET because the operational scenario for installation of CALET on ISS includes hand-off between two manipulators, from the ISS manipulator to that of JEM.

3. Structural and Thermal Analysis

We have confirmed by structural analysis the compatibility of CALET for the basic structural requirements, the stiffness and generated loads on JEM-EF in orbit. The stiffness requirement for large-size payloads on JEM-EF is that the 1st mode structural eigen value must be above 2Hz. The stiffness of CALET instrument is controlled by the position of the detector unit on the main structure because almost all mass is concentrated to it. We have confirmed CALET to fulfill the stiffness requirement if the position of the detector unit is nearer to PIU side than the center of the pallet. We have also made a load analysis and confirmed CALET cannot generate loads to be harmful to JEM-EF on orbit.

Thermal analysis was also made for each component from the launching phase to orbital visiting phase in hot and cold cases. Estimated temperature ranges were not critical in every component. They are still preliminary values using of preliminary estimation of power consumptions for some electrical components. We will make better estimates of power consumptions and more accurate thermal analysis. JEM-EF has an active thermal control service up to 3kW by fluid circulations. After more detailed thermal analysis, we will decide the thermal control method by the fluid interface or by a traditional passive way.

4. Summary

We have made a conceptual system design of CALET. In this design, we have defined CALET system structure, estimated weights and power consumptions of components, made the structural and the thermal analyses and decided the basic structural concept adopting a pallet structure. The compatibility of CALET was confirmed as a heavy payload on the JEM Exposed Facility.

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References

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2. Torii S., *et. al.* 2003, in this volume