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DAMPE Operations at Chinese Space Science Mission Center

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Dark Matter Particle Explorer (DAMPE) mission is one of the scientific space science missions within the framework of the Strategic Pioneer Program on Space Science of the Chinese Academy of Science (CAS).The main scientific objective of DAMPE is to detect electrons and photons in the range of 5 GeV–10 TeV with unprecedented energy resolution (1.5% at 100 GeV) in order to identify possible Dark Matter(DM) signatures. There are five payloads on-board the satellite: Si-Pin array, plastic scintillation hodoscope array, BGO calorimeter, neutron detector and payload data management system. DAMPE was launched in Dec.17, 2015. China Space Science Mission Center as one of the composition of DAMPE ground segments is responsible for the operation of the on-board payloads. The satellite ,the ground segment, the basic processes, the mission preparation and the satellite commissioning are described.

Nomenclature

DAMPE =Dark Matter Particle Explorer satellite
DM =Dark Matter
STK =the Silicon Tracker
BGO =the BGO calorimeter
PSD =the Plastic Scintillator Detector
NUD =the Neutron De-tector
PMS =the Payload Management System
SAA =South Atlantic Anomaly
MC =the Mission Center
SSDC =the Space Science Data Center
SC =the Science Center
CCC =Chinese Control Center
CAS= Chinese Academy of Science

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I. Introduction

Dark Matter Particle Explorer (DAMPE) mission is one of the scientific space science missions within the framework of the Strategic Pioneer Program on Space Science of the Chinese Academy of Science (CAS). DAMPE makes the observations of high-energy electrons and gamma rays， and explores the evidence of Dark Matter, researches the quality and spatial character of Dark Matter.[1,2]

DAMPE satellite was successfully launched at the Jiu Quan Satellite Launch Center at 8:12 on Dec. 17, 2015, and then was entering the commissioning phase . The payloads were powered on on Dec. 20, and the payloads in-orbit testing was began . Up to Mar.17, 2016, DAMPE completed all the test items, all the detectors and systems were running normally, and the satellite entered into the Operational phase.

II. Satellite

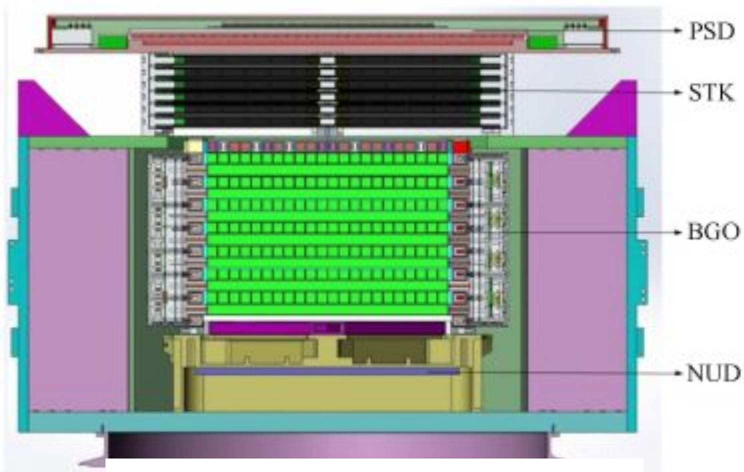

Figure 1. DAMPE cross section[3]

DAMPE is Sun-synchronous orbit satellite in 500km altitude. Payloads weigh about 1400kg, Power Consumption about 400 watts, about 12G bytes of science data per day.

The payload is composed of four sub-detectors the Plastic Scintillator Detector (PSD), the Silicon Tracker (STK),the BGO calorimeter (BGO) and the Neutron Detector (NUD).

PSD is used to identify electrons and gamma rays. Simultaneously, as the back-up of the STK, it is also used to discriminate heavy ion species by measuring the energy loss of incident particles in the PSD.

The main purpose of the STK is to measure the incident direction of particles, as well as the charge .

A BGO calorimeter for the space observation of high energy cosmic-rays has been designed . It is composed of 308 BGO crystal bars with a dimension of 2.5 cm × 2.5 cm × 60.0 cm. The BGO crystals form 14 layers with an area of about 60 cm × 60cm each. The energy response to electrons and gamma-rays varies from 5 GeV to 10 TeV.

The NUD endeavors to measure the later thermal neutron shower activity by detecting the boron capture of these thermal neutrons in a boron-doped plastic scintillator, located underneath the BGO calorimeter.

III. Ground Segment

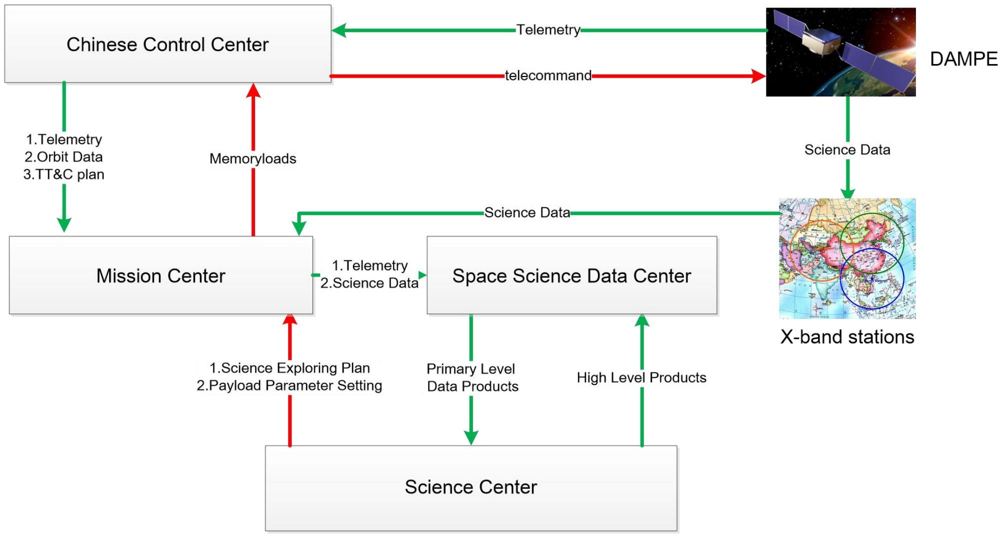

Figure 1. DAMPE Ground segment

The DAMPE ground segment is composed of five parts, include the Chinese Control Center, the Mission Center, the Space Science Data Center and three X-band stations.

The Chinese Control Center (CCC) which also be known as Xi'An Center, manages the satellite in each phase. CCC is in charge of the TT&C of the DAMPE, includes up-linking the tele-commands to the satellite ,downloading the S-band telemetry from the satellite, and determination the satellite orbit parameters. The downloaded S-band telemetry raw data transfers to the Mission Center in real-time for payload status monitoring. The tele-commands for the payload are generated by Mission Center.

The Mission Center (MC) is responsible for payload operations. The main functions are described below : 1) make mission planning and scheduling, 2)schedule X-band ground stations data reception, 3) payload tele-commands management, 4)generate commands for the detectors , PMS , and X-band subsystems, 5)verify command execution,6)send TC plan (tele-commands) to the CCC,6)Receive S-band telemetry data, satellite orbit parameters and attitude data from the CCC, 7)receive the science data from X-band stations, 8)monitor the payload health & status.

The Space Science Data Center (SSDC) is responsible for science data processing, managing, archiving, permanent preservation and distribution.

The X-band stations includes Miyun, Sanya and Kashi stations. They response for scientific satellite tracking, science data reception, raw data recording and formatted outputting, and transfering the data to Mission Center.

Science Center (SC) is also known as Science Application System. DAMPE Science Center proposes scientific exploration plan, generates high-level data products ,and organizes the research and application.

IV. Basic Processes

The basic processes of payload operation in the Mission Center are the payload control process and the data real-time processing and monitoring process.

A. Payload control process

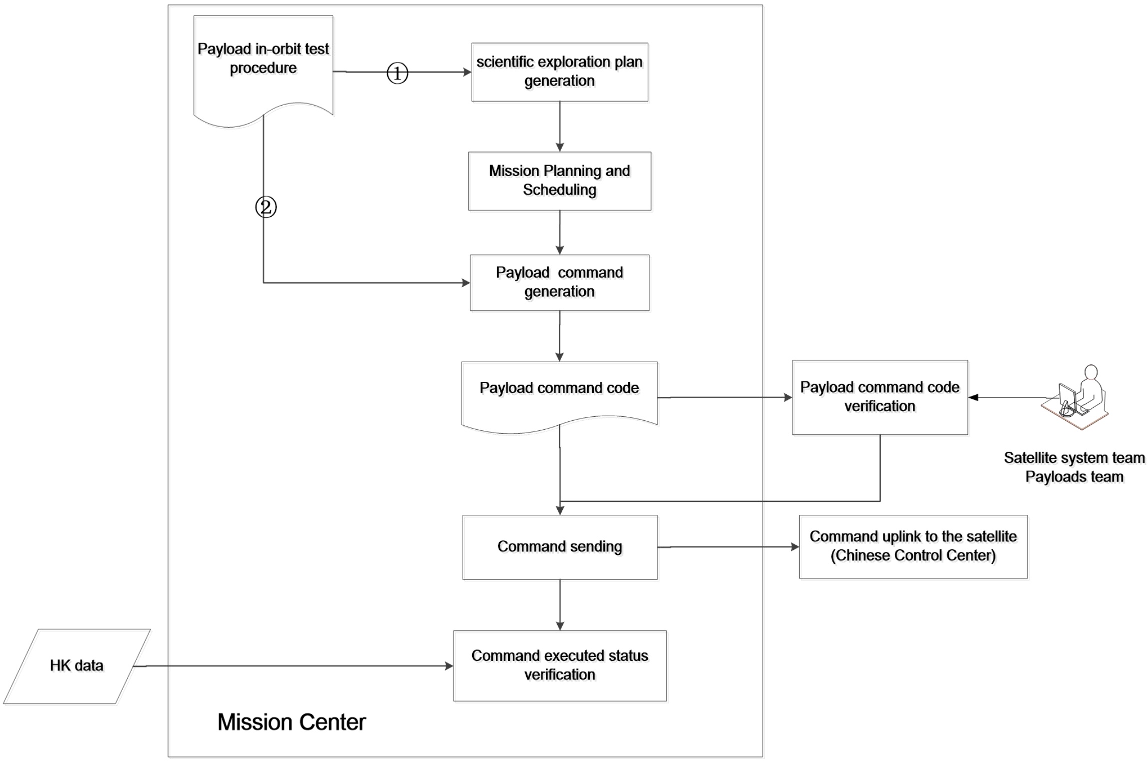

Figure 3. Payload control process

The basic payload control process shown as figure 3, gives the main processes for the data reception scheduling and the payload working planing.

In commissioning phase, the input of the process is "the payload in-orbit test procedure". There are two ways can be selected to generate the tele-command for the payload. The first way is creating a scientific exploration plan by the assistant tool, and then making the payload working plan, and from the working plan turn into the payload tele-command automatically. This way si shown as ① in the figure. The second way is create the payload tele-command using the software manually. This way si shown as ② in the figure.

So from the basic payload control process we can get all three processes, the first one , the second one and both the first and second.

B. Data real-time Processing and Monitoring Process

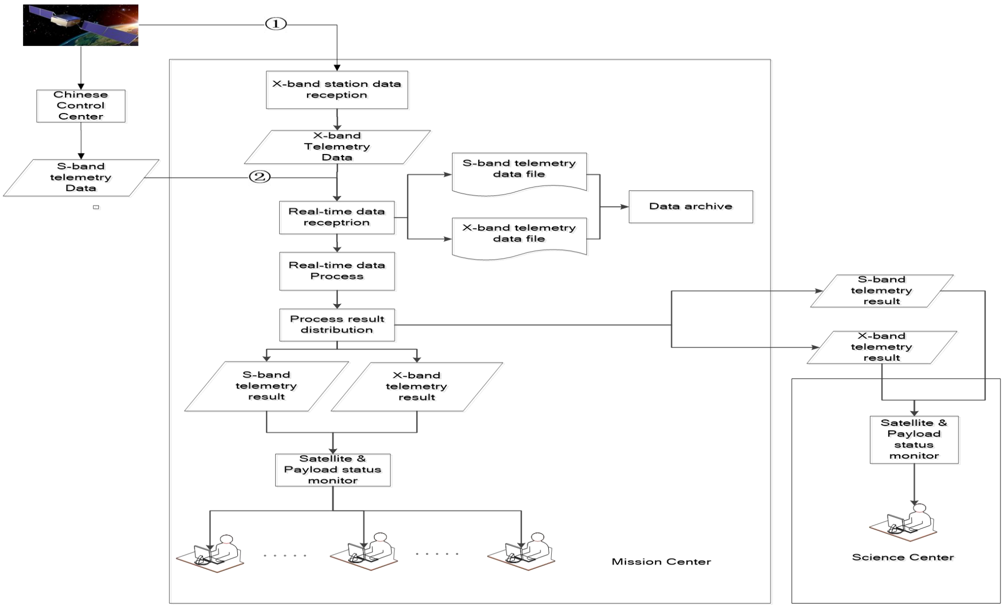

Figure 4. Data real-time processing and monitoring process

The Basic download data real-time processing and monitoring process can be separated by the the different input. One is the X-band telemetry data process, the other is the S-band telemetry data process. For the two inputs the process is almost the same.

The real-time data reception software receives the data, and sends the data to the real-time data process software, and saves the data into a local file for archive. The real-time data process software receives the data, and decodes the frame, decodes the package, and processes the raw data into the parameter values, distributes the result values to the clients for monitoring the status of payloads by the operational teams in Mission Center.

The processed result values are sent to the Science Center in same time. The Scientists in the Science Center can monitor the X-band data result and S-band data result in real-time also.

V. Preparation for the Mission Operations in MC

A. Operational Group

One month before the satellite launch, The DAMPE Payload Commissioning Working Group was built up. As figure 5. Shown, the working group composed of operational decision workgroup , operational perform workgroup, HuaiRou Subgroup, Data Receiving Subgroup,and In Xi'an Center Subgroup.

Operational decision workgroup is the technical core of the commissioning working group, and makes the technology decision.

Operational perform workgroup cooperates with the operational decision workgroup, organizes the staff training before the satellite launch, organizes the verify of the payload in-orbit test procedure ,writes the summary reports in the commissioning phase.

Huai Rou Subgroup is composed of operational team, data process team, satellite system team, space environment team and system guarantee team. The operational team is in MC and responsible for the payload operation. The data process team is in SSDC and responsible for data production generation and management. The satellite system team attends the payload operation process and obtains the data production service.

Data Receiving Subgroup is composed of three stations and the station operation team.

In Xi'an Center Subgroup is on behalf of the commissioning working group working in CCC.

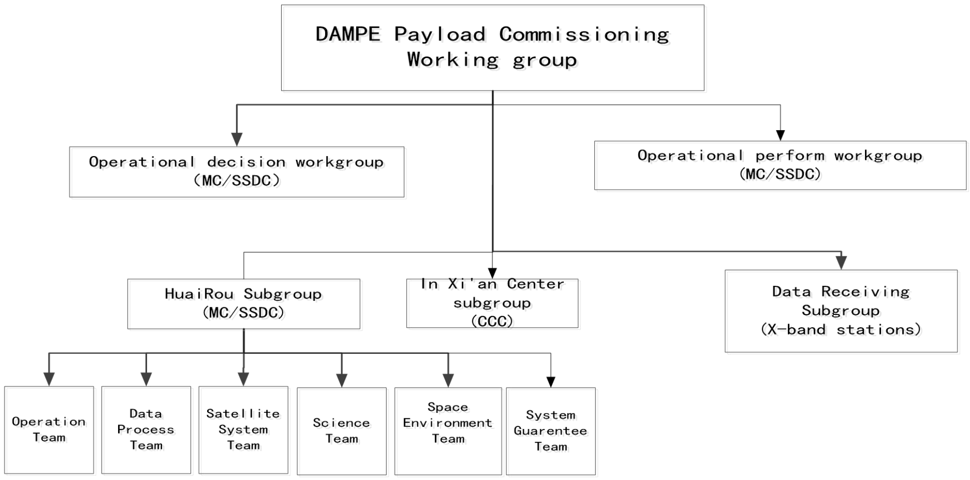

Figure 5. DAMPE payloads commissioning working group

Mission operational group sets four posts, the planning and scheduling, the payload control, the system scheduling and the satellite status monitoring.

B. Staff Training and Mission Practice

As DAMPE is the first mission for the Mission Center, before the satellite launch, we organized serials training activities.

Before the training, we prepared several documents , includes "The Collaborative Work flow For DAMPE Mission Operations", "Operations Work flow and Post Operation Procedure in MC", and "Training Plan for DAMPE Payload commissioning working group".

"The Collaborative Work flow For DAMPE Mission Operations", gives a definite specification for the contents，the ways and the procedure of information transfer between other centers （CCC，SSDC，SC and X-band stations）with MC, in commissioning phase.

"Operations Work flow and Post Operation Procedure in MC", describes the duty and detail operational procedure of all posts in operation process.

"Training Plan for DAMPE Payload commissioning working group",gives the mission practice plan before the satellite launch, includes the schedule, the input data, the software, and so on.

From Dec.1 to 15, 2015, DAMPE payload commissioning working group performed up to 100 times mission practices. The mission practices covered all the operational process, all the posts and all the staffs in MC.

C. Critical Event Discussion

Before the satellite launch, the operational decision workgroup organized serials meetings for the critical events of the mission. The minutes of the meetings are the important guidance for the satellite operation and commissioning.

1) Payload working mode in SAA

The South Atlantic Anomaly (SAA) is an area where the Earth's inner Van Allen radiation belt comes closest to the Earth's surface.This leads to an increased flux of energetic particles in this region and exposes orbiting satellites to higher-than-usual levels of radiation. [4] The detector PSD，BGO and NUD in DAMPE must work in high volt. For the detector safety, the operational decision workgroup organized a discussion about the requirements for decreasing the working-volt for the detectors before the satellite go into the SAA, and increasing the working-volt after the satellite go out of the SAA. According to the analysis and the discussion, the group gave a decision that the detectors kept the normal working mode in the SAA, and when they out of the SAA, the detectors made a calibration. That means the detectors do not decrease the high volt in SAA. The payload in-orbit test results proved this decision is correct, and the detectors in SAA is safety.

2)Payload fault countermeasure discussion

All the payload teams have prepared the fault countermeasure for operational using. The operational decision workgroup discuss how to perform the countermeasure, include the telemetry to detect the fault, the countermeasure perform process, the command for the countermeasure, and the result evaluation. Also the fault countermeasure process has been performed in the mission practices.

VI. Operations in Commissioning Phase

A. Payload in-orbit test contents

Since Dec. 17, 2015 the successful launch of DAMPE, the in-orbit test contents for payload include:

1) From Dec. 17, 2015 to 20, the payload kept in powered off, satellite maintained the temperature of the detectors.
2) From Dec. 20, 2015 to 24, the payload powered on, and kept in low volt working mode, the detectors began to collect baseline, and performed baseline calibration.
3) On Dec. 24, 2015, from orbit 106 to 108, the payload increased the volt to the normal working mode, and the detectors began to collect the science data.
4) From Dec.25, 2015 to Mar. 17 2016, the detectors collected baseline in different frequency, collected the MIPs signal, set different trigger-lock delay time, collected cosmic-rays, adjusted the current threshold for protection, updated RMS threshold, and so on.
5) The normal working mode was driven by the events table, which was up-linked irregularly in commissioning phase.

B. Commissioning Perform

1) Planning and command

In the commissioning phase, the operational team scheduled the payloads working plan and generated the tele-commands according to the payload in-orbit test procedure. The tele-commands were sent to CCC to up-link to the satellite.

Up to Mar. 17, 2016, near 1000 frames of payload tele-commands were up-linked to the satellite. The payload FEE setting command was more than 600 frames.The events table command was about 200 frames. The payload threshold setting command and data receiving command were about 200 frames.

All the tele-commands up-linked to the satellite executed correctly .

2) X-band data reception

According to data reception schedule , the X-band stations tracked the satellite 500 orbits , worked 3718 minutes cumulatively, and received 2.4TB Raw data.

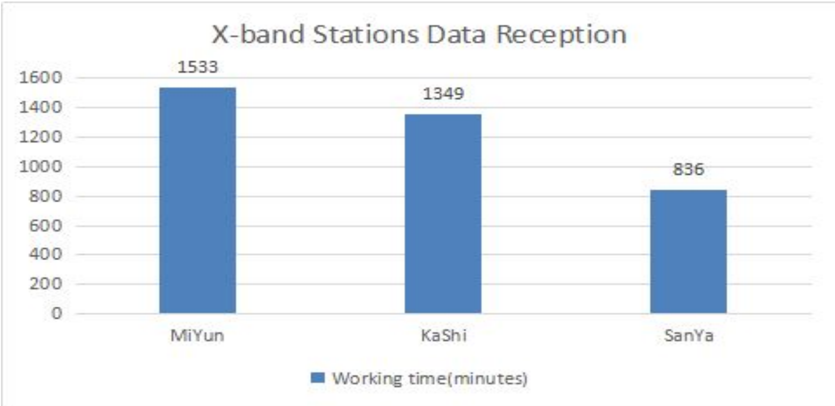

Figure 6. Data reception

3)Payload status monitor

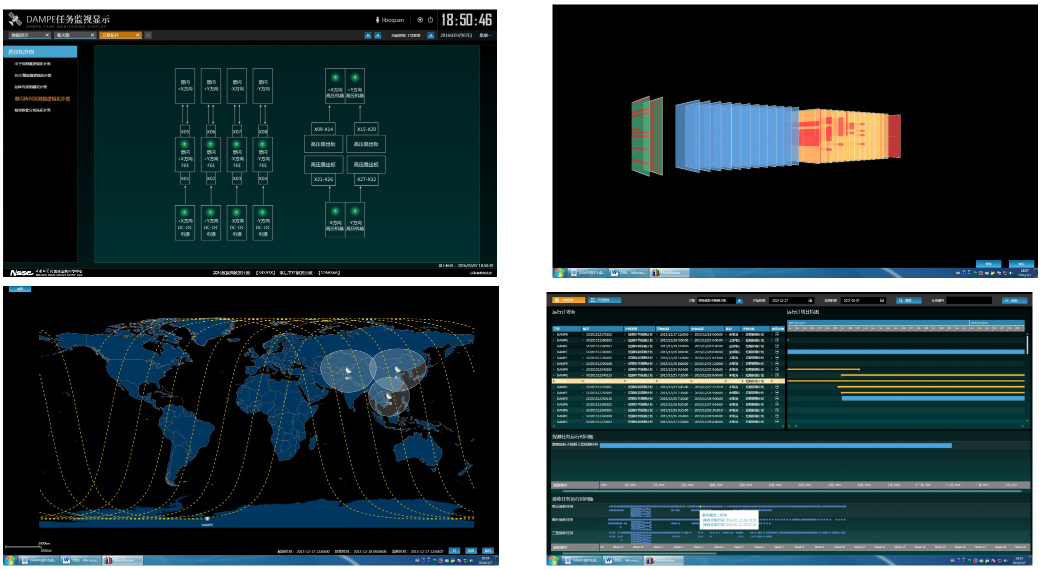

Figure 7. Data monitoring

The operational team gave the completely monitoring for the payload, include the s-band telemetry parameters, X-band housekeeping parameters, X-band science data, the satellite orbit, the working plan status, and so on.

C. Commissioning Result

After 3 months in-orbit testing, DAMPE finished the commissioning successfully. All the payload in-orbit test contents are performed. The satellite and all the detectors are perfectly in good status.

During the commissioning , all the tele-commands up-linked to the satellite are executed correctly, the link between satellite and ground is smooth, all the technical indicators meet or exceed expectations.

VII. Operational preparation

In operational phase , DAMPE will spend two years taking general sky surveys and the third year scanning key spots.

We set up a working group for the operational phase, and defined the collaborative workflow among SC, SSDC, CCC, and MC.

VIII. Conclusion

DAMPE commissioning is successful, we get many experience from the mission. And for the other more scientific space science missions, the experience is significant. Adequate preparation before the satellite launch is the most import.

The preparation include the system, the organization, the training, the mission practice, the critical events discussion and decision, and so on.

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