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# Flexible Data Handling in the Flight Control Decision Software for Space Science Satellites

Y.Z. Zhang,[1] and X.D. Peng[2]
*National Space Science Center, Chinese Academy of Sciences, Beijing, 100190, China*

and
C. Gao[3]
*University of Chinese Academy of Sciences, Beijing, 100049, China*

**In order to support the in-orbit operation of the satellites in the Strategic Priority Program on Space Science, the Flight Control Decision Support Software (FCDSS) is developed. It belongs to the mission operation subsystem of the ground support system of the Strategic Priority Program on Space Science. The FCDSS is responsible for the comprehensive analysis of the operating status of the onboard equipment, the use of the satellite resources, the scientific detection results, and full life cycle visualization of the scientific mission in real time and afterwards, and mission situation analysis. The software contains two parts--"Flight Control Decision Analysis and Comprehensive Situation Visualization Unit" and "Full-lifecycle Data Processing Unit". The latter is the main focus in this paper. It is responsible for acquiring required data (such as telemetry data) from the database and do calculations for coverage analysis, observation plan analysis and etc. Due to the various types and massive amount of data need to be processed, it posed high requirements to data processing. In brief, in this paper, we will first describe the software architecture in detail. Then, give detailed information on the design and implementation of the data processing layer. At last, mission applications of the software will be shown with conclusions on the performance and lessons we have learned as the four mission carries on.**

## I. Introduction

The main goal of the Strategic Priority Program on Space Science is dedicating to deepen our understanding of the universe and planet earth, seeking new discoveries and new breakthroughs in space science via the implementation of both independent and co-operational space science missions [1]. It implemented the following missions and studies: Hard X-ray Modulation Telescope (HXMT), Quantum Experiments at Space Scale (QUESS), Dark Matter Particle Explorer (DAMPE), and Shijian-10 (SJ10), see Fig. 1(figures shown from left to right are HXMT, QUESS, DAMPE and SJ10). These satellites carried out various experiments and explorations with advanced payloads.

**Fig. 1 Missions in Strategic Priority Program on Space Science**

In order to support the in-orbit operation of these satellites, the Flight Control Decision Support Software (FCDSS) is developed. It belongs to the mission operation subsystem of the ground support system of the Strategic Priority Program on Space Science. The ground system is responsible for the implementation of satellite payload in orbit operation and management, support the scientific application system to complete the experiments and explorations;

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[1] Assistant Professor, Laboratory of System Simulation and Concurrent Design Technology.
[2] Professor, Laboratory of System Simulation and Concurrent Design Technology.
[3] Doctorate Candidate, Laboratory of System Simulation and Concurrent Design Technology.

receive experimental data; experimental data preprocessing to generate primary data products, data products for standardized quality control, unified management and permanent filing, public release of mission information, carry out popular science propaganda, to provide technical support for the experiments.

In the following sections, the FCDSS software architecture is described in detail in Section II. Then, detailed information on the flexible data handling's concept is given in Section III. In Section IV, the design and implementation of the data processing layer is given. At last, mission applications of the software will be shown with conclusions on the performance and lessons we have learned as the four mission carries on.

## II. FCDSS Software Architecture

The Ground Support System of the Strategic Priority Program on Space Science has the following tasks:

1) manage on-orbit operation payloads
2) support scientific application systems to complete science experiments
3) receive experimental data
4) perform preliminary data processing for experimental data
5) provide technical support for experimental tasks
6) conduct standardized quality control of data products
7) unified management and permanent archiving
8) release mission information to the public and conducting popular science propaganda

The mission (DAMPE, SJ-10, QUESS and HXMT) subsystems of the ground support systems together form the mission subsystem of the Ground Support System of the Strategic Priority Program on Space Science (hereinafter referred to as mission operation subsystem).

The mission operation subsystem is an important part of the Strategic Priority Program on Space Science. It is the center for comprehensive operation and management of scientific missions of various space science satellites. The main task of the mission operation subsystem is to:

1) comprehensively plan and analyze space science satellite missions based on scientific detection requirements and the conditions of the resources. Then, feasible scientific operation plans and payload control instructions are generated based on this
2) transmission of downlink data
3) telemetry data collection and real time data processing
4) on-orbit payload status monitoring
5) providing services, including mission analysis, exploration planning, payload status monitoring, and analysis and evaluation, to scientific application systems and scientific users through remote network service

The FCDSS is part of the mission operation subsystem which is responsible for:

1) comprehensive analysis of the operational status of space-ground equipment, the use of satellite resources, and the scientific detection results, and visualizes the operational status and results of the scientific missions in real time and afterwards, and performs mission situation analysis;
2) advanced techniques in visualization that supports situational display and analysis which can be used for reporting, demonstration and decision-making.

The software architecture of FCDSS is shown in Fig. 2.

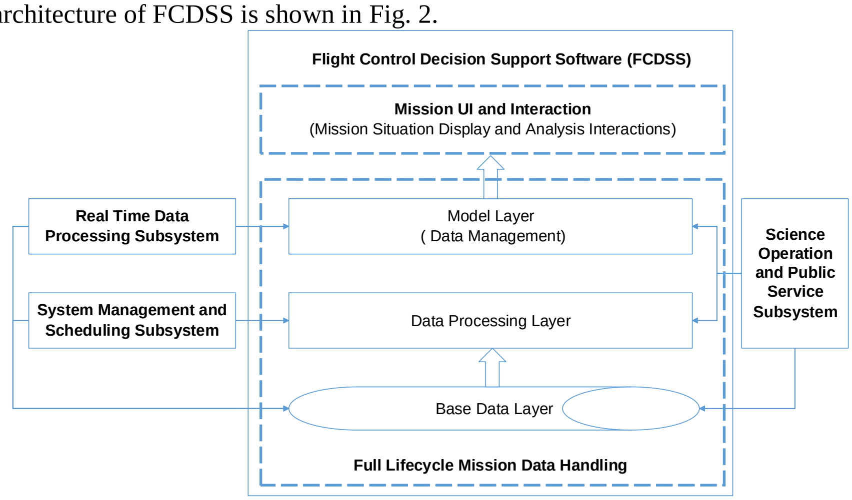


**Fig. 2 FCDSS Software Architecture**

### A. Base Data Layer

The base data layer refers to the scientific mission full life cycle related data, which is stored in the database or in the form of files in the mission control subsystem. Its main types include science mission configuration information data table, planning and execution process record data table, basic data files such as satellite uplink and downlink parameters and satellite orbital attitude, ground station configuration information, and ground station equipment operation parameter files, space environment event files, and etc.

### B. Data Processing Layer

The data processing layer is mainly responsible for standardizing, layering, and saving the data, from the Base Data Layer or the data obtained by actively invoking other software services, as files. The purpose of this design is to optimize the reading and querying time of massive data and minimize the data volume. Therefore, the core issue in this layer is the data layering method that will be used to optimize the reading and querying process, so that the subsequent calculation and visualization can achieve real time.

In addition, after the full-cycle data content and format are determined, how to maintain and update it in real time will be the main issue of the data processing layer. Therefore, data processing is divided into four main functionalities: data acquisition and maintenance, data processing, data storage management, real-time data synchronization. Data acquisition and maintenance mainly implements the reading and invoking of databases, files, and services, and design interfaces and updating methods for different data sources; Data processing realizes the standardization, reorganization, and interpolation operations, etc. Data storage management is responsible for saving the data as file groups according to the characteristics the data. Real time data synchronization is mainly used to ensure that the model and Mission UI and Interaction Layer can be updated to the latest real time data, without having to frequently access layered data files.

### C. Model Layer

The function of the model layer is relatively clear, that is, to meet the requirement of comprehensive mission situation visualization, which means the establishment of data organization and correlation model. Data organization and correlation is responsible for establishing interactive relationships between various life cycle data, making the various type of data form as organized scientific exploration mission data, which can reflect the intrinsic links between data when displaying information to the user and during analyzing.

### D. Mission UI and Interaction

The Mission UI and Interaction Unit is particularly important in FCDSS for it directly provides information services to users. It is mainly responsible for mission situation visualization.

## III. Flexible Data Handling Concept

The FCDSS is divided into: "Flight Control Decision Analysis and Comprehensive Situation Visualization Unit" and "Full-lifecycle Data Processing Unit". This section mainly focuses on the latter.

Due to the requirements for processing of various types of data, massive amount of engineering data, real time data updating, and adaptive for multiple missions and so on, a flexible data handling processor is needed. Therefore, based on the simulation engine we are using at NSSC, data processors are designed as simulation models. Our micro-core simulation kernel is updated and modified over the years of application in different scenarios.

1) The 1st version is used in the Chang'E-3 Rover Simulation Software [2][3]. The software provided auxiliary decision-making and analysis methods, and completes the simulation analysis of the complex robotic arm movement.
2) The 2nd version is used during concurrent design and simulation of several space science missions, during which complex system modeling and simulation techniques have been further applied to support the configuration and assembly of multi-resolution simulation models.

In FCDSS, the simulation kernel is modified as a multi-type data processing engine to meet the requirements mentioned above. The simulation model is replaced by various types of data processing "models" to implement the query and analysis of the system's integrated state parameters. The design of this flexible data handling concept is shown in Fig. 3.

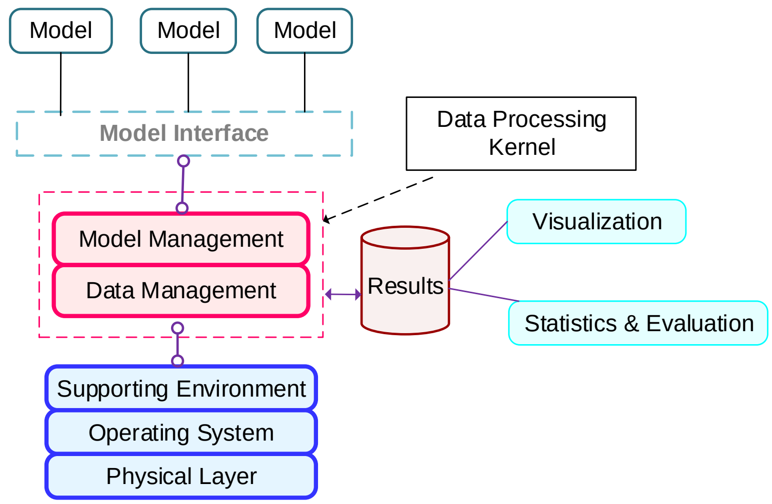


**Fig. 3  Data Processing Layer Design**

## IV.   Flexible Data Processing Design and Implementation

The data processing layer includes server's user interface, processor management, data processing, and database agent. The key is the data processing, which is designed for real time data processing, engineering data maintenance, general data processing, and offline engineering data generation. The various kinds and huge amount of data, with different analysis requirements for the four missions post lots of difficulties for the data processing layer of the FCDSS. There are two main difficulties. One is the flexibility of the server which means it could do the job for all four mission with little change of the code, so that it increases software development efficiency. Another one is that it must have good performance under the huge workload of data handling. To deal with the two issues, we proposed configurable data handling strategy and adopted parallel computation. The former makes two functions configurable—the kind of data to query and the process of data query itself. The latter makes the data query, calculations, and I/O work parallel and also the data handling process for each kind of data.

### A.  Data Type

There are two main types of data: sample and record. The description information of the sample data model is described according to Fig. 4 and the description information of the record data model is described according to Fig. 5. The model configuration files are written in XML format.

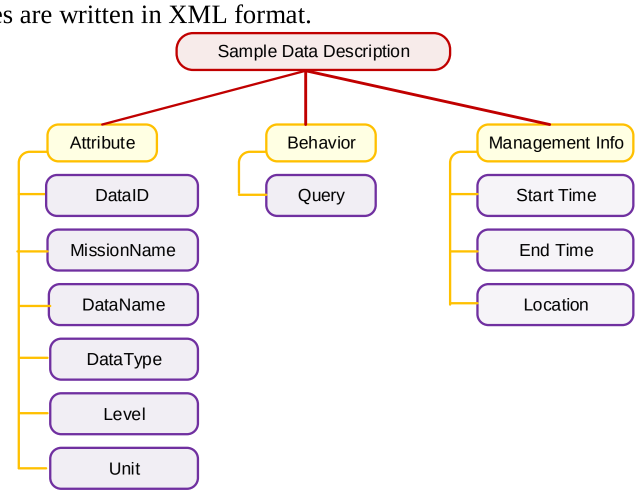


**Fig. 4  Sample Data Description Information**

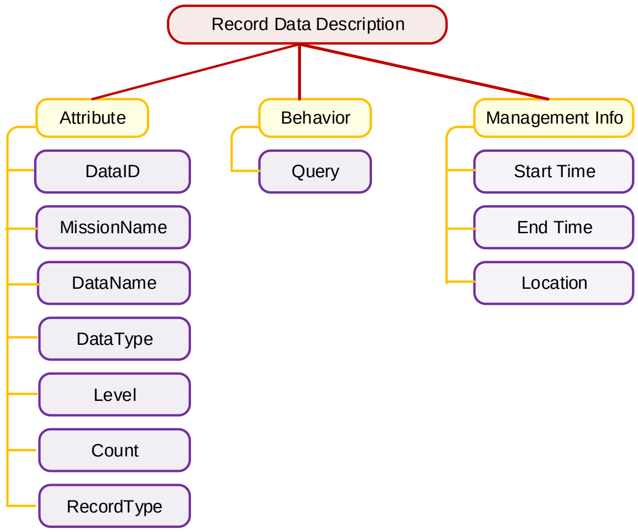


**Fig. 5  Record Data Description Information**

An example of the XML is shown in Fig. 6. With the definition of the two types of data above, the steps for the implementation of specific data processor is as follows:

1) inherit the sample or record data definition;
2) write the processor with predefined interface “Query”, and the structure of the data is defined according to specific kind of data that the processor is going to handle.


```xml
<?xml version="1.0" encoding="UTF-8"?>
  <mDataID>Log</mDataID>
  <mMissionName>HXMT</mMissionName>
  <mDataName>HXMT-111</mDataName>
  <mDataStoragePath>Log</mDataStoragePath>
  <mDataType>Record</mDataType>
  <mStartTime>0001-01-01T00:00:00</mStartTime>
  <mEndTime>0001-01-01T00:00:00</mEndTime>
  <mRecordDescription>
    <mRecordType>EVENT</mRecordType>
  </mRecordDescription>
  <MaxSampleCountForFile>31536000</MaxSampleCountForFile>
```


**Fig. 6  An Example of Record Data Configuration**

## B. Process View

The Full-lifecycle Data Processing Unit contains four processes which is shown in Table 1.

**Table 1   Process and threads in the data processing module**

| Process Name | Description |
|---|---|
| Data processing primary process | Responsible for drawing the interface for the “Full-lifecycle Data Processing Unit”, parsing the mission configuration information, and starting other threads. |
| Project execution thread | Responsible for establishing mission data object, updating the configuration according to the message returned from the database, starting all the mission data processing thread, and retrieving data update information. |
| Data processing thread | Responsible for reading, processing, and storing of specific data types in blocks, and returning updated information |
| Interaction thread | Interact with the "Flight Control Decision Analysis and Comprehensive Situation Visualization Unit" |

## C. Component View

The Full-lifecycle Data Processing Unit contains 5 components (shown in Fig. 7), including ProcessorConfig.xml, ServiceInterface.xml, ProjectConfig.xml, Database and FCDSS.exe,

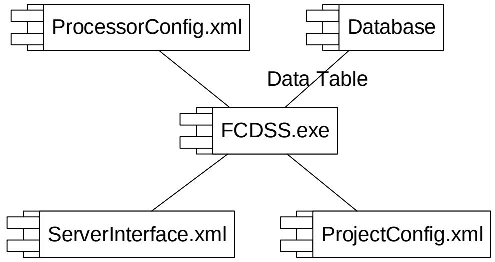


**Fig. 7 Component View of FCDSS**

## V. Applications

At present, the FCDSS is giving support to DAMPE, SJ-10, QUESS and HXMT. The number of data processed is over 5000 per mission and the software is running continuously over 2 years. Its performance is good, which could be upgraded in later versions. The data processing engine will be integrated into the next version of the software for new missions. An example of the application is shown in Fig. 8. In Fig. 8, it shows the plan execution status according to the data processed.

**Fig. 8 Mission Application**

## VI. Conclusion

At present, the FCDSS is giving support to DAMPE, SJ-10, QUESS and HXMT. As the missions carries on, the software showed good performance and proved that the concept of designing the data processors as models according to data types is a good design. In future missions, we will focus more on making online data processor modification possible so that when engineering data structure changes, the software can be updated without stop.

## References

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