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Application system and data description of the China Seismo-Electromagnetic Satellite

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Abstract: The China Seismo-Electromagnetic Satellite, launched into orbit from Jiuquan Satellite Launch Centre on February 2nd, 2018 , is China's first space satellite dedicated to geophysical exporation. The satellite carries eight scientific payloads including high-precision magnetometers to detect electromagnetic changes in space, in particular changes associated with global earthquake disasters. In order to encourage and facilitate use by geophysical scientists of data from the satellite's payloads, this paper introduces the application systems developed for the China Seismo-Electromagnetic Satellite by the Institute of Crustal Dynamics, China Earthquake Administration; these include platform construction, data classification, data storage, data format, and data access and acquisition.

Keywords: China Seismo-Electromagnetic Satellite; application system; geophysical field; data classification

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1. Introduction

The China Seismo-Electromagnetic Satellite (CSES, also called ZH-1) is China's first satellite dedicated to geophysics; it is also the first component of the space-based Chinese earthquake stereoscopic monitoring system (Shen XH et al., 2018). Its scientific goal is to preliminarily explore the characteristics and mechanisms of changes in ionospheric response before and after earthquakes, based on real-time monitoring of changes in the state of the space electromagnetic environment. In addition, it helps to study the earth system, especially the interaction and effects of the ionosphere with other related Earth's spheres. There are 8 payloads on the satellite (Figure 1), which are divided into 3 categories, including electromagnetic type of high-precision magnetometers (Cheng BJ et al., 2018), search-coil magnetometers (Cao JB et al., 2018), and electric field detector (Huang JP et al., 2018), in-situ detection type as plasma analyzer and Langmuir probe (Liu C et al., 2018), and high energy particle detection package, structural type of GNSS occultation receivers (Cheng Y et al., 2018; Lin J et al., 2018) and tri-band beacon transmitters (Chen L et al., 2018). The satellite is also equipped with another high-energy particle detector (Ambrosi et al., 2018) from the Italian Space Agency. The satellite has a flying height of 507 km, inclination angle of 97.4°, a descending local time node of 14:00, and a revisiting period of 5 days.

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In accordance with the engineering requirements and construction design of the ZH-1 satellite, the project is divided into six parts: a satellite system, a launch vehicle system, a launch site system, a measurement and control system, a ground system, and an application system. The satellite system is responsible for the development of the satellite platform and payloads; the launch vehicle system is responsible for the development of the rocket; the launch site system is responsible for launching the satellite into the target orbit; the measurement and control system is responsible for monitoring and controlling satellite operations, receiving the telemetry data transmitted by the satellite and transmitting it to the ground system; the ground system is responsible for coding the satellite work instructions, with the ground station receiving scientific data and conducting primary processing; and the application system is responsible for satellite mission planning, data processing data service, and scientific applications. The satellite transmits the scientific data through the X-band at the downlink rate of 120 Mbps; the telemetry data is transmitted through the S-band (Yuan SG et al., 2018). Data links among the measurement and control systems and the ground system, and the ground system and application systems, are transmitted through the fiber-optic line.

The structure of this paper is as follows: Chapter 2 explains the overall construction of the application system. Chapters 3 and 4 respectively introduce data classification criteria and data processing procedures. Chapters 5 and 6 introduce data storage solutions and data service solutions. Chapter 7 suggests desirable future optimizations.

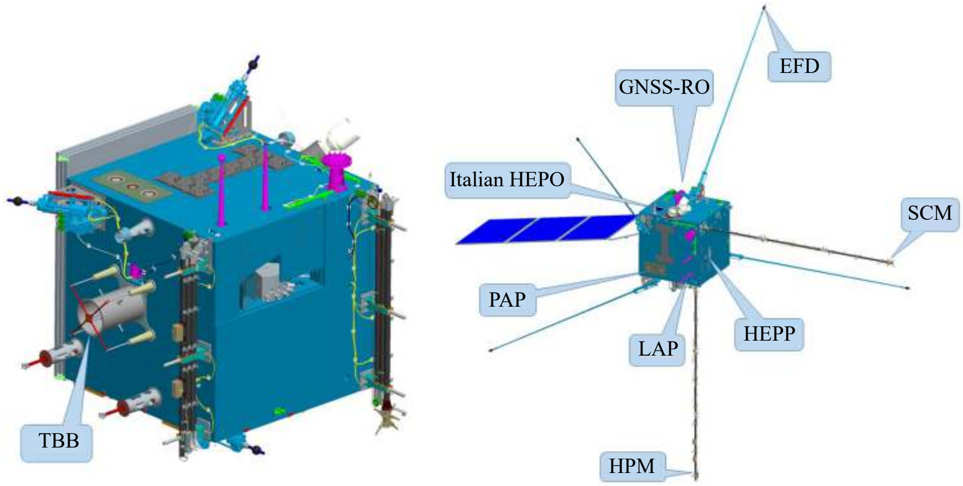

Figure 1. Configuration and on-board load installation structure of ZH-1.

2. The Overall Construction of the Application System

The main task of the application system is to develop a work plan for the satellite and payloads, and receive scientific data and telemetry data transmitted from the ground system. Based on the above work products, it then produces standardized advanced products and scientific application products in order to provide data in formats suited to the needs of users. Therefore, the construction design of the entire application system is divided into an operation management subsystem, a data management subsystem, a data processing subsystem, a product quality evaluation subsystem, and a data service subsystem. For ahe block diagram of the structure, see Figure 2.

The operation management subsystem is further divided into two principal subsystems, dedicated to (1) mission planning and (2) task operation and control. The mission planning subsystem is responsible for formulating and pushing the work plan of areas with the burst mode and satellite (and payloads) to the ground system (Figure 3). The satellite and load operations are monitored according to telemetry data pushed by the ground system. In addition, satellite orbit calculation, simulation, and prediction are carried out instantaneously through the orbit, pushed by the ground system. The task operation and control subsystem is responsible for sending tasks of data processing, archiving, and management of the entire system, and for monitoring the operating state between task flow, the subsystems, the application system, and the external interface.

The data management subsystem is further subdivided into a data access subsystem and a data archiving and query subsystem. The data access subsystem is responsible for receiving scientific data and telemetry data at 0-2 levels, pushed by the ground system, and auxiliary data (including earthquake catalogue, space weather index, etc.) required by scientific applications. The data archiving and query subsystem is responsible for archiving received data and products at all levels in the form of a file directory, and querying, displaying and downloading data in various forms according to daily needs.

The data processing and analysis subsystem is divided into eight payload processing subsystems and one integrated processing subsystem in order to realize single processing and comprehensive product display of each level for all data from each payload. At present, the format and procedure for the Italian high-energy particle payload have not been fully confirmed; these specifications will be provided to China for integration into the overall plan.

Through a web interface, the data service subsystem provides users, based on user levels and rights, with these functions: data registration, browsing, query and download.

3. Data Description

3.1 The Classification of Scientific Data

ZH-1 satellite data are divided into scientific data, telemetry data, and auxiliary data. Principal telemetry data include satellite position and speed, payload telemetry parameters, and other information. Examples of auxiliary data are calibration parameters for data processing, seismic catalogs, and space weather indices.

The scientific data and products are divided into the following categories and levels according to their content and processing actions.

Raw data: Raw data are data received by the ground receiving station, including the data from the satellite, and data from each station received by the tri-band beacon-receiving station of a particular application system.

Level 0 data product: Level 0 data include time-aligned scientific data and engineering parameters from each payload after frame synchronization, descrambling, error correction, and de-duplication, and observation data received by the tri-band beacon ground station.

Level 1 product: Time-aligned physical quantity data obtained after format conversion and calibration processing of Level 0 data are termed Level 1.

Level 2 product: Physical quantity data with information of geographic and geomagnetic coordinate system, time, position and attitude, generated after coordinate transformation and inversion of Level 1 data, are termed Level 2.

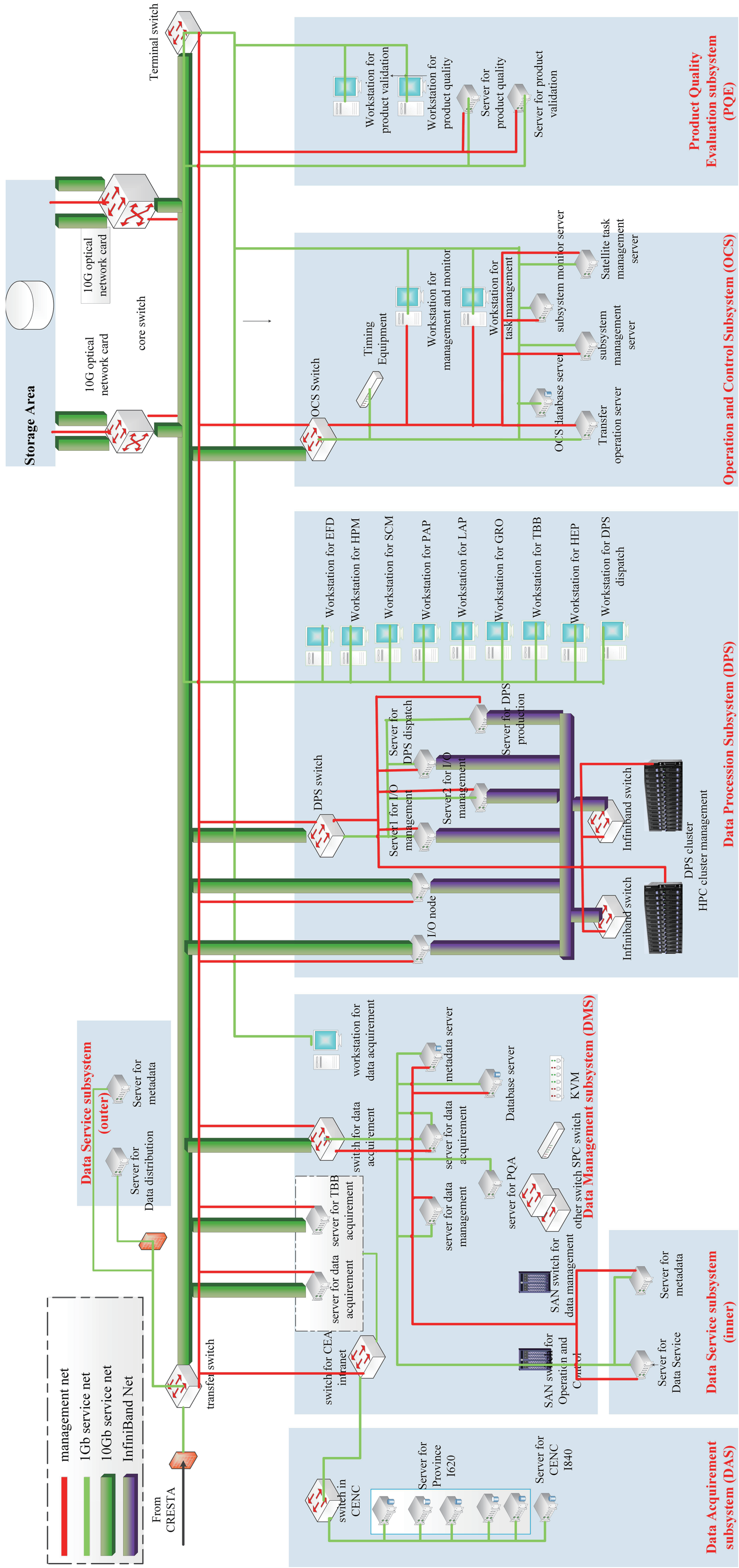

Figure 2. Construction of the application system.

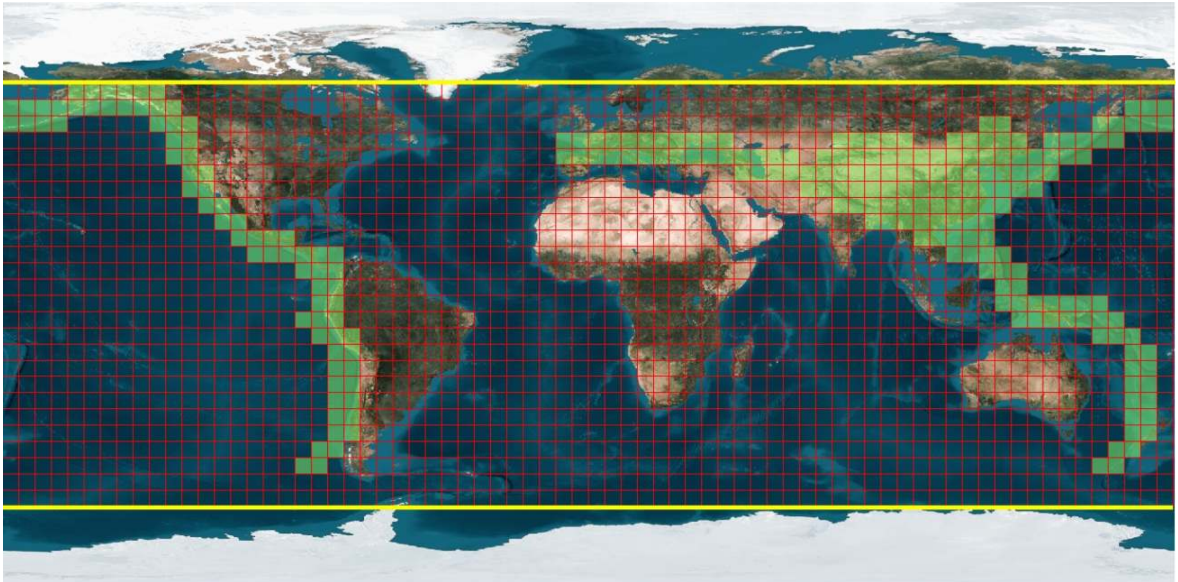

Figure 3. The schematic diagram of satellite working area. Yellow line refers to 65° north latitude and 65° south latitude; the green square refers to the working area in burst mode; within the yellow line and outside the green square is the working area in survey mode.

Level 2A product: Level 2A data include (1) electric field observation data generated after removing the influence of the $V_s \times B$ electric field based on the electric field waveform data of the Level 2 payload coordinate system; (2) GNSS Radio occultation observation data obtained after precise orbit determination and inversion of Level 1 data.

Level 3 product: Time series data of the revisited orbits generated by resampling based on Level 2 and 2A data, or the ionospheric and atmospheric 2D structure data generated by inversion based on 2 and 2A level data, are termed Level 3.

Level 4 product: Spatial evolution data associated with a particular region generated after spatial interpolation processing, based on Level 2 and 2A data.

3.2 Data Storage Solution

The designed work scope of ZH-1 is the area between 65° north latitude and 65° south latitude, and the designed working modes of the payloads are burst and survey. According to the timeliness of data downlink, the data are divided into real-time data and revisit data. Therefore, in order to facilitate data storage, reading, and effective identification, ZH-1 data files are stored according to the orbit number, payload, and sub-probe. The stored content include the data file and relevant image product, the processing report, and the configuration file.

3.2.1 File naming

The data file naming rules are as follows in Figure 4.

Among them:

(1) Satellite name (4 characters): represented by CSES.

(2) Satellite number (2 digits): starting from 01 and increasing in order; 01 for ZH-1.

(3) Payload code (3 characters): HPM, SCM, EFD, LAP, PAP, GRO, TBB, HEP, respectively, represent the eight payloads of High-Precision Magnetometer, Search Coil Magnetometer, Electric Field Detector, Langmuir Probe, Plasma Analyzer Package, GNSS Radio Occultation, Tri-Band Beacon, and High-Energy Particle package.

(4) Payload serial number (1 digit): used to distinguish multiple similar detector data generated by one payload, starting from 1 and increasing in sequence. If there is no necessity to distinguish the probe, it is represented by 0. If necessary, the digital correspondence is shown in the table.

(5) Data hierarchical coding (1-bit symbol, 2 digits): from left to right, the first digit is “L”, and the right two digits represent the data level. 0–4 levels are represented by 00, 01, 02/2A, 03 and 04, respectively.

(6) Observation object code (2 digits): the observing object code, set according to the "Seismo-Electromagnetic Satellite Survey

CSES_01_XXX_X_XXX_XX_XXXXXX_YYYYMMDD_hhmmss_YYYYMMDD_hhmmss_XXX.dat (a)
(1) (2) (3) (4) (5) (6) (7) (8) (9) (10) (11) (12)

CSES_01_XXX_X_XXX_XX_XXXXXX_YYYYMMDD_hhmmss_YYYYMMDD_hhmmss_XXX.h5 (b)
(1) (2) (3) (4) (5) (6) (7) (8) (9) (10) (11) (12)

Figure 4. The data file naming rules for Level 0 (a) and Level 1–4 (b).

Classification and Code" (draft for review). For Level 0 data, the observation object is coded as 00; for Level 1-4 of data, A1 represents satellite electric field observation, A2 represents satellite magnetic field observation, A3 represents satellite plasma in situ observation, A4 represents satellite high-energy particle observation, and A5 represents satellite ionospheric observation. The details are shown in Appendix Table 1A .

(7) Orbit number (5 digits): used to organize data files by track, starting from 00001, accumulating in turn. The data products that cannot be marked with a track number are represented by "00000".

(8) Descending/Ascending mark (1 digit): the descending is 1 (satellite flying from north to south) and the ascending is 0 (south to north).

(9) Data starting time, expressed by 14 digits: year (4 digits), month (2 digits), day (2 digits), hour (2 digits), minute (2 digits), and second (2 digits). For the TBB receiving station, this is the starting time received by each station. For the station chain data, it is the starting time of the chain combined by several stations along the same orbit.

(10) The data ending time: format is the same as (9). For the TBB receiving station, it is the ending time received by each station; for the station chain data, it is the ending time of the chain.

(11) Receiving station code (3 digits): refers to the information of earth station or GNSS satellite or TBB receiving station. The high 0 represents the data from the earth receiving station, and the code is recursed from 001. When the high bit stays at least 1, it indicates that the data is received from the TBB station. The highest bit refers to the link number, starting from 1, and the lower two bits refer to the station number, starting from 01. For example, the station code in chain 1 is 101-199 and the station code in chain 2 is 201-299. When the lower two bits are 00, it represents all the station data of a certain link. For example, 100 represents all the station data of the first link. For the GNSS occultation receiver, it represents the satellite signal of the received signal source, with the first digit representing GPS or BeiDou (G or B); the last two digits represent the satellite number.

(12) File extension name: if dat, it represents a data file stored in binary format. If the file name extension is h5, it means that the data is stored in hdf format.

The naming of scientific data product images and processing report files is similar, formed by modifying some of the files and adding the relevant suffix of "_XX.png" based on the naming of scientific data. Figure 5 is an example.

Table 1. Correspondence between load number and load data

Load name	Load number	Data content
High precision magnetometer	1	Vector magnetic field data of fluxgate probe 1
	2	Vector magnetic field data of fluxgate probe 2
	3	Scalar magnetic field data
Electric field instrument	1	ULF electric field waveform/power spectrum
	2	ELF electric field waveform/power spectrum
	3	VLF electric field waveform/power spectrum
	4	HF electric field waveform/power spectrum
Search coil magnetometer	1	ULF induced magnetic field waveform/power spectrum
	2	ELF induced magnetic field waveform/power spectrum
	3	VLF induced magnetic field waveform/power spectrum
GNSS Radio Occultation	1	Positioning data
	2	Ionospheric occultation event
	3	Atmospheric occultation event
High-energy particle package	1	Low-energy segment particle flux spectrum
	2	High-energy segment particle flux spectrum
	3	Italian load particle flux spectrum
	4	X-ray flux spectrum
Langmuir probe	1	Electronic temperature and density detected by 50 mm balls
	2	Electronic temperature and density detected by 10 mm balls

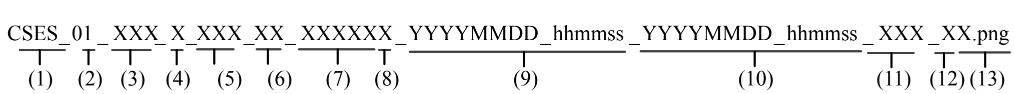

Figure 5. File extension naming rules.

(13) The expansion code of the observation object consists of two characters. The first digit is used to distinguish different regions: 1 for China, 2 for the global area, and 0 for no distinction of area; the second digit is used to distinguish among multiple images of the same payload, starting from 1 and increasing sequentially.

Because the Level 4 image is a spatial image, independent of the orbit, (7) (in Figure 5) is set at zero. (9) represents the year, month and day of the first day of the last 5 days; the hour, minute, and second are set at 0. (11) represents the year, month and day of the fifth day, that is, the current day; the hour, minute, and second are set at 0.

3.2.2 File content

Standard scientific products are in hdf format, and the contents include interpretation of file attribute and data. Taking the ULF frequency band of the electric field as an example, the content of the second-level product is listed in Table 2 and Table 3.

The number of A111 in Table 3 is the data item code, which is

Table 2. Description of the data file attribute of ULF Level-2 data of the electric field detector

Number	Attribute name	Attribute content	Remarks
1	PAYLOADID	Instrument code	
2	ORBITNUM	Track number	
3	ORBITTYPE	Symbols of ascending and descending orbits,	Ascending orbits, descending orbits
4	SAMPLERATE	Sampling rate	ULF: 125 Hz
5	SOFTVERSION	Program version number	
6	FREQRANGE	Frequency band range	ULF: DC–16 Hz

Table 3. Description of ULF Level-2 data of the electric field detector in tableau format

Number	Table name	Table content	Table type	Table size	Table attribute	Remarks
1	VERSE_TIME	Relative time	64-bit integer long	N×1		
2	UTC_TIME	Correction time	64-bit integer long	N×1		
3	WORKMODE	Operating mode	32-bit integer int	N×1	1: Burst 2: Survey -1: Invalid	
4	A111_W	X	64-bit floating-point double	N×256	Unit: mV/m	Electric field X component
5	A112_W	Y	64-bit floating-point double	N×256	Unit: mV/m	Electric field Y component
6	A113_W	Z	64-bit floating-point double	N×256	Unit: mV/m	Electric field Z component
7	A111_P	CH1	64-bit floating-point double	N×128	Unit: mV/m	Electric field power spectrum of probe a-b combination
8	A112_P	CH2	64-bit floating-point double	N×128	Unit: mV/m	Electric field power spectrum of probe a-b combination
9	A113_P	CH3	64-bit floating-point double	N×128	Unit: mV/m	Electric field power spectrum of probe a-b combination
10	MAG_LON	Geomagnetic longitude	32-bit floating-point float	N×1	The range of geomagnetic longitude	
11	MAG_LAT	Geomagnetic latitude	32-bit floating-point float	N×1	The range of geomagnetic latitude	
12	GEO_LAT	Geomagnetic latitude	32-bit floating-point float	N×1	The range of geomagnetic latitude	
13	GEO_LON	Geomagnetic longitude	64-bit floating-point double	N×1	The range of geomagnetic longitude	
14	FLAG		32-bit integer int	N×1		Data quality label
15	FREQ	Power spectrum frequency value	32-bit floating-point float	N×1		

based on the “Classification and Code of Seismic Satellite Electromagnetic Observation Items” issued by the China Earthquake Administration in 2017 (DB/T 67-2017). The corresponding meanings are shown in the Appendix Table A1.

4. Data Service

According to the requirements of the “China National Space Administration and China Earthquake Administration's Notice on Strengthening Electromagnetic Monitoring and Test Satellite Data Management” issued by China National Space Administration and the China Earthquake Administration in 2018, the application system will be responsible for the updating, service, release and maintenance of ZH-1 satellite data. At present, the primary data service webpage has been built (www.leos.ac.cn) to provide related functions such as user registration and data download.

4.1 User Registration

On the website of the Center for Satellite Application in Earthquake Science of the China Earthquake Administration, there are the column of “Data Service” and the function of user login/user registration. New users must click the user registration and fill in relevant information online. After the platform confirming relevant information, users can click the data download in the data service section to select the required data based on the data selection method provided on the page.

4.2 Sharing Products

Data products of the ZH-1 Satellite will be shared for scientific application objectives; data products to be shared are shown in Table 4.

4.3 Share Permissions

After registering, users will gain corresponding levels of ZH-1 satellite data according to the rights agreement. The corresponding relationship is as presented in Table 5.

According to the “China National Space Administration and China Earthquake Administration's Notice on Strengthening Electromagnetic Monitoring and Test Satellite Data Management”, payload R&D users refer to companies or individuals involved in specific research and development of satellite engineering, especially in payload research and development. The project cooperation users refer to users who signed the agreement on the ZH-1 satellite data with data management administrations of the ZH-1 satellite, such as China National Space Administration, China Earthquake Administration, and Institute of Crustal Dynamics, China Earthquake Administration; such users can obtain relevant data according to the agreement. General professional users refer to scientific and technological personnel with professional tech-

Table 4. Catalogue of ZH-1 shared products

Load name	Physical quantity		Sampling rate		Region*
HPM	B, B_x, B_y, B_z		1 Hz		All
SCM	B_x, B_y, B_z	Waveform	50 kHz		Burst
		Spectrum	50 kHz		Survey
EFD	E_x, E_y, E_z	Waveform	ULF	255 Hz	Burst
			ELF	5 kHz	
			VLF	50 kHz	
			HF	10 MHz	
		Spectrum	ULF	255 Hz	Survey
			ELF	5 kHz	
			VLF	50 kHz	
			HF	10 MHz	
LAP	N_e, T_e		3 s		All
PAP	ΔN_i		3 s		All
HEP (Chinese)	Flux, counts, Pitch Angle	Electron	100 keV–50 MeV		All
		Proton	2 Mev–200 MeV		
HEPD (Italy)	Flux, counts, Pitch Angle	Electron	3 MeV–50 MeV		All
		Proton	20 MeV–200 MeV		
GRO	N_e, TEC	Ionosphere	20 Hz		All
	Ta, Pa	Atmosphere	100 Hz		
TBB	N_e, TEC		50 Hz		China

*Note: Burst : area covers the all of China and the two global seismic belts. Survey: area within the geo-latitude of 65° except for the burst region. All: area within the geo-latitude of 65°.

Table 5. User catalogue and their rights to ZH-1 products

User level data permission	Payload development user (payload R&D)	Project cooperation user	General professional user
0-level	√		
1-level	√	√	
2-level	√	√	√

nical backgrounds, such as seismic science and space physics science investigators, who plan to conduct public welfare scientific research based on ZH-1 satellite data.

5. Conclusion

The ZH-1 Satellite has been operating for more than 8 months to complete **commissioning** tests. The sub-systems of the application system are in regular operation, and preliminary scientific data products are ready to be officially released. The current working status shows that the operational control, data processing, data management, and data service of the application system of ZH-1 satellite have achieved designed functions and performance metrics. Since the satellite was launched into orbit, the **commissioning** tests have shown that the payload records contain not only information in the field of the space geophysics but also other information, including from the satellite platform itself. Future tasks include additional optimization of data processing algorithms. Dynamic and timely updating of the data content and data processing plan are needed for the application system to ensure the data quality of the ZH-1 satellite, improve the application efficiency of the data, and to exert greater scientific and social value.

Acknowledgments

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Table A1. Classification and code for electromagnetic observation of earthquake satellites

Code	Name	Description
A	Satellite electromagnetic observation	
A1	Satellite electromagnetic observation	
A11	Frequency band 1 of satellite electromagnetic observation	3 Hz–30 Hz frequency band (DC–16 Hz)
A111	Frequency band 1 of satellite electromagnetic observation *X*-component	The northward component of the geographic coordinate system
A112	Frequency band 1 of satellite electromagnetic observation *Y*-component	The eastward component of the geographic coordinate system
A113	Frequency band 1 of satellite electromagnetic observation *Z*-component	The vertical component of the geographic coordinate system
A12	Frequency band 2 of satellite electromagnetic observation	300 Hz–3 kHz frequency band (6 Hz–2.2 kHz)
A121	Frequency band 2 of satellite electromagnetic observation *X*-component	The northward component of the geographic coordinate system
A122	Frequency band 2 of satellite electromagnetic observation *Y*-component	The eastward component of the geographic coordinate system
A123	Frequency band 2 of satellite electromagnetic observation *Z*-component	The vertical component of the geographic coordinate system
A13	Frequency band 3 of satellite electromagnetic observation	3 kHz–30 kHz frequency band (1.8 kHz–20 kHz)
A131	Frequency band 3 of satellite electromagnetic observation *X*-component	The northward component of the geographic coordinate system
A132	Frequency band 3 of satellite electromagnetic observation *Y*-component	The eastward component of the geographic coordinate system
A133	Frequency band 3 of satellite electromagnetic observation *Z*-component	The vertical component of the geographic coordinate system
A14	Frequency band 4 of satellite electromagnetic observation	3 MHz–30 MHz frequency band (18 kHz–3.5 MHz)
A141	Frequency band 4 of satellite electromagnetic observation *X*-component	The northward component of the geographic coordinate system

Continued from Table A1

Code	Name	Description
A142	Frequency band 4 of satellite electromagnetic observation *Y*-component	The eastward component of the geographic coordinate system
A143	Frequency band 4 of satellite electromagnetic observation *Z*-component	The vertical component of the geographic coordinate system
A2	Satellite magnetic observation	
A21	Total intensity of satellite magnetic field observations	
A211	Total intensity of satellite magnetic field observations	DC–0.3 Hz
A22	Satellite magnetic vector observation	DC–15 Hz
A221	Satellite magnetic vector observation *X*-component	The northward component of the geographic coordinate system
A222	Satellite magnetic vector observation *Y*-component	The eastward component of the geographic coordinate system
A223	Satellite magnetic vector observation *Z*-component	The vertical component of the geographic coordinate system
A23	Frequency band 1 of satellite magnetic disturbance observation	10 Hz–200 Hz
A231	Frequency band 1 of satellite magnetic disturbance observation *X* component	The northward component of the geographic coordinate system
A232	Frequency band 1 of satellite magnetic disturbance observation *Y*-component	The eastward component of the geographic coordinate system
A233	Frequency band 1 of satellite magnetic disturbance observation *Z*-component	The vertical component of the geographic coordinate system
A24	Frequency band 2 of satellite magnetic disturbance observation	200 Hz–2.2 kHz
A241	Frequency band 2 of satellite magnetic disturbance observation *X*-component	The northward component of the geographic coordinate system
A242	Frequency band 2 of satellite magnetic disturbance observation *Y*-component	The eastward component of the geographic coordinate system
A243	Frequency band 2 of satellite magnetic disturbance observation *Z*-component	The vertical component of the geographic coordinate system
A25	Frequency band 3 of satellite magnetic disturbance observation	1.8 kHz–20 kHz
A251	Frequency band 3 of satellite magnetic disturbance observation *X*-component	The northward component of the geographic coordinate system
A252	Frequency band 3 of satellite magnetic disturbance observation *Y*-component	The eastward component of the geographic coordinate system
A253	Frequency band 3 of satellite magnetic disturbance observation *Z*-component	The vertical component of the geographic coordinate system
A3	Satellite plasma in situ observation	
A31	Plasma density	Total number of major components in a unit volume
A311	Electron density	Total number of free electrons per unit volume
A312	Ion density	Total number of all kinds of ions per unit volume
A313	Hydrogen ion density	Total number of hydrogen ions per unit volume
A314	Helium ion density	Total number of helium ions per unit volume
A315	Oxygen ion density	Total number of oxygen ions per unit volume
A316	Nitric oxide ion density	Total number of nitric oxide ions per unit volume
A317	The ion density fluctuates	Small changes in ion density near its statistical average
A32	plasma temperature	Average kinetic energy of a plasma at thermodynamic equilibrium
A321	Electronic temperature	Average kinetic energy of electrons in a plasma
A322	Ion temperature	Average kinetic energy of ions in a plasma

Continued from Table A1

Code	Name	Description
A33	Ion drift velocity	Average moving speed of ions in a plasma under the action of an electric field
A331	*X*-component of Ion drift velocity	The northward component of the geographic coordinate system
A332	*Y*-component of Ion drift velocity	The eastward component of the geographic coordinate system
A333	*Z*-component of Ion drift velocity	The vertical component of the geographic coordinate system
A4	Observations of satellite high energy particle	
A41	Energy spectrum of high energy particle	Total number of high-energy particles in the solid angle per unit area and per unit time within a certain energy range
A411	Electron spectroscopy	Total number of electrons in the solid angle per unit area and per unit time within a certain energy range
A412	Proton spectroscopy	Total number of protons in the solid angle per unit area and per unit time within a certain energy range
A413	X-ray energy spectrum	Tal number of X-ray photons in the solid angle per unit area and per unit time within a certain energy range
A42	Direction spectrum of high energy particle	High-energy particle fluxes in the energy range of each direction within a certain direction
A421	Direction spectrum of electros	Electron flux of the energy region in the respective direction range within a certain direction
A422	Direction spectrum of protons	Proton flux in the energy range of each direction within a certain direction
A43	High energy particle flux	Total number of high energy particles per unit area and per unit time per solid Angle
A431	Electron flux	Total number of electrons per unit area, per unit time and per solid Angle
A432	Proton flux	Total number of protons in the solid Angle per unit area and per unit time
A433	X-ray flux	Total number of x-rays per unit area, per unit time and per solid Angle
A5	Satellite ionospheric observation	
A51	Ionospheric observation	Multi-dimensional observation of the distribution of ionospheric electron density in time and space
A511	Electron density profile	Electron density changes with height
A512	Three-dimensional structure of electron density	Structural changes in electron density with height, latitude, and height
A513	Four-dimensional structure of electron density	Structural changes in electron density with height, latitude, height, and local time
A514	Ionospheric scintillation index S4	Ionospheric scintillation refers to the rapid and random fluctuation of signal intensity and phase caused by the irregular structure of the ionosphere when radio waves cross the ionosphere. The S4 index is a standard deviation of mean normalization that represents the intensity of the ionospheric scintillation information and indicates signal strength.
A52	Total electron concentration (TEC)	The integral of the electron density per unit area along the transmit-receive path
A521	Absolute TEC	Total concentration of ionospheric electron concentration (TEC), also known as the ionospheric electron concentration column content, integral content, etc.. It is the integral of the electron concentration per unit area with the height.
A522	Relative TEC	Relative change in the total content of integrated electrons
A53	Neutral atmospheric observation	
A531	Atmospheric density profile	
A532	Atmospheric aerosol density profile	
A533	Atmospheric temperature profile	

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