Progress of Solar Wind Magnetosphere Ionosphere Link Explorer (SMILE) Mission

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1. Introduction

The SMILE (Solar wind Magnetosphere Ionosphere Link Explorer) mission was proposed as a candidate in response to the ESA & CAS (Chinese Academy of Sciences) joint call for a small class mission released in January 2015. SMILE aims at increasing our understanding of the connection between the interaction of the Solar wind with the Earth magnetosphere by looking at the nose and cusps of the magnetosphere, and the aurora at the North pole simultaneously, while monitoring the in-situ plasma environment. Following the recommendation of the joint scientific evaluation panel, SMILE was selected by SPC (Science Programme Committee) in November 2015, with a target launch date in early 2022. Final mission adoption by SPC (allowing the start of the implementation phase) is presently scheduled for November 2018. The SMILE mission is a joint ESA – CAS project, with the payloads funded by ESA Member States and CAS.

The Joint Scientific Evaluation Panel highly evaluated SMILE Mission: “SMILE Mission will use novel soft X-ray imaging technology to obtain for the first time the global image of solar wind - Magnetosphere Ionosphere interaction. This is critical to quantitative analysing and understanding of the global feature of the solar-terrestrial system"

SMILE mission is an international cooperation project of space science exploration jointly led by CAS and ESA, it is a new milestone of comprehensive and deep cooperation among scientists from both parties. CAS is responsible for the study and development of satellite Platform (PF), TC/TM (CLTC), Science Application System (SAS) as well as Ground Support System (GSS), also responsible for the development of Magnetometer(MAG) and Light Ion Analyzer (LIA). On the other hand, ESA is responsible for the study and development of Payload Module (PLM), Launch Vehicle, Launch Site and Science Operation Center(SOC), station support and service when it is necessary from Chinese part, also responsible for the development of Soft X-ray Imager(SXI) and Ultra-Violet Imager(UVI)

2. Scientific Objectives

Understanding and thus predicting the non-linear global system behaviour of the magnetosphere has remained both the central objective and grand challenge of solar-terrestrial physics in particular for more than 50 years. In situ data have dramatically improved our understanding of the localised physical processes involved. However, piecing the individual parts together to make a coherent overall picture, capable of explaining and predicting the dynamics of the magnetosphere at the system level has proved to be extremely difficult.

The Science object of SMILE mission are:

(1) Explore the fundamental modes of the dayside solar wind/magnetosphere interaction.

Determine when and where transient and steady magnetopause reconnection dominates. Determine how solar wind parameters, IMF clock angle and Mach numbers control magnetic reconnection. Quantitative estimates of the entry of energy and mass into the Earth's magnetosphere from solar wind.

(2) Understand the substorm cycle, Define the substorm cycle, including timing and flux transfer amplitudes. Determine how open flux control the sequence of

substorm process.

(3) Determine how CME-driven storms arise and development. Find if there is any relation between ring current/partial ring current and magnetopause location during geomagnetic storms. Define the development of CME-driven storms, including whether they are sequences of substorms. Determine if storms affect the threshold of substorms. Determine if solar wind density, pressure, or IMF B_y affect storms. Figure 1 is the SXI intensity simulation result.

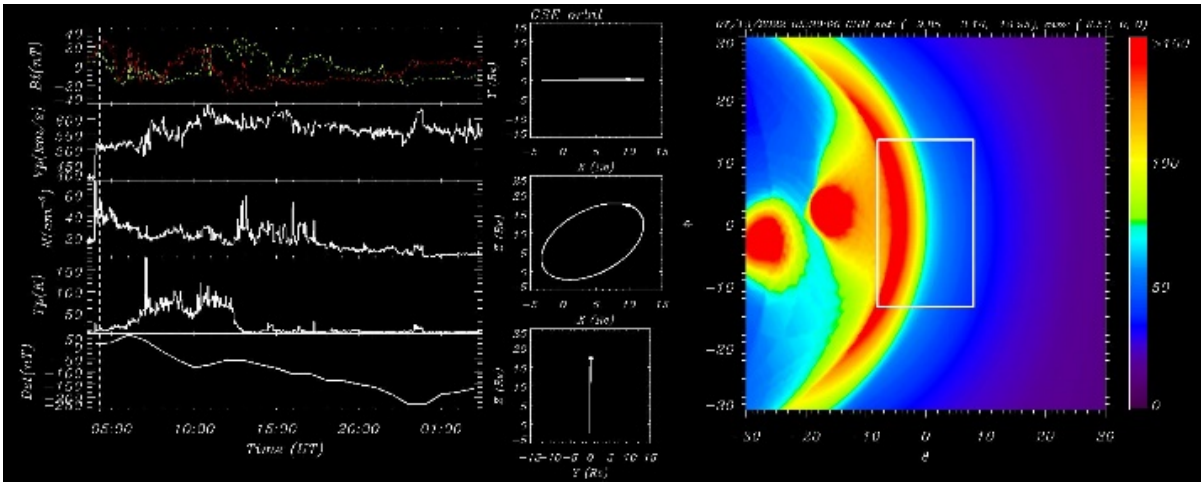

Fig. 1 MHD Simulation of the X-ray Intensity during a magnetic storm event on 17th Mar, 2015. The left panel shows the time variation of solar wind parameters and the *Dst* index. From top to bottom, the parameters are: interplanetary magnetic field (yellow: B_y, red: B_z), plasma velocity, number density, temperature and Dst. The orbit of SMILE is plotted in the middle panel. The right panel presents the simulated X-ray image, with the white box showing the field of view of SXI

3. Scientific Payloads

In order to achieve the scientific objectives, four payloads will be installed on the SMILE satellite, SXI, UVI, MAG and LIA. SXI will provide the X-image of day side magnetopause. UVI will provide the global distribution map of polar aurora. SXI and UVI will coordinate to provide the global image of solar wind - Magnetosphere Ionosphere interaction. MAG and LIA will measure magnetic field and plasma in the upstream solar wind and magnethosheath in situ in real time to determine the original driver.

SXI is mainly developed by University of Leicester, and NSSC take part in the development (see Figure 2). The performance of SXI is as follows.

(1) Energy band: 0.2–5 keV.

(2) Optic FOV: ≥ 27.3°×15.6°.

(3) PSF(central focus): 6′ FWHM.

(4) Detector energy resolution: ≤42eV @0.5 keV.

(5) Time resolution: 60 s.

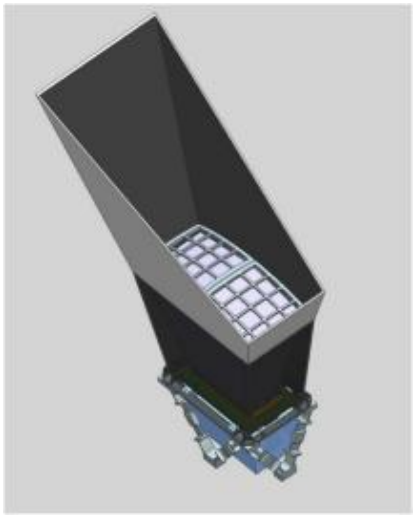

Fig. 2 Illustration diagram of SXI

UV is mainly developed by University of Calgary and NSSC is charge of the development of UVI-E (Electronics box) (see Figure 3). The main performance of UVI is as follows.

(1) Wavelength band: 140nm–180nm.

(2) FOV: 10°×10°.

(3) Spatial resolution: 0.04°/pixel.

(4) Time resolution: 60 s.

(5) Sensitivity: 20Rayleigh (60s exposure).

LIA is developed by NSSC, with a heritage from the

payloads installed on Chang'E-1 and Chang'E-2. Figure 4 is the photograph of LIA.

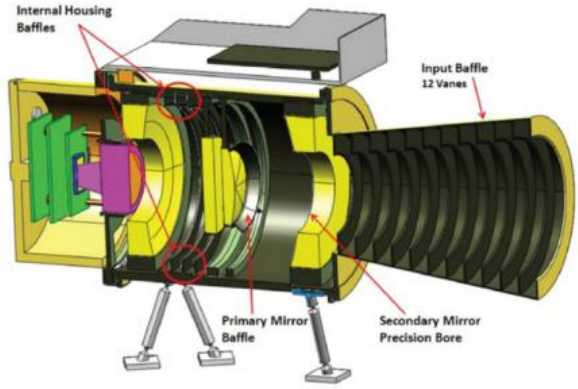

Fig. 3 Structure diagram of UVI

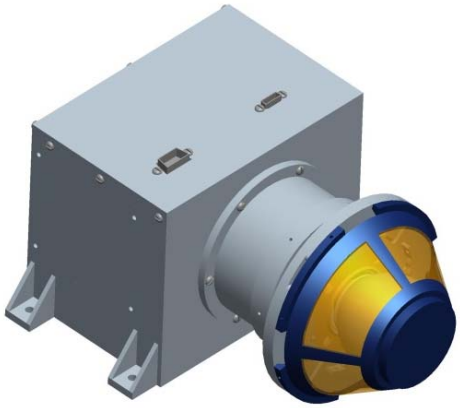

Fig. 4 Picture of LIA

The performance of LIA is as follows.

(1) Energy range: 50eV/q–20keV/q.

(2) Energy resolution ($\Delta E/E$): ≤10%.

(3) View of azimuth angle: 360°.

(4) View of elevation angle: ≥44° (10–20 keV), 90° (≤10 keV).

(5) Angular resolution: ≤7.5° in azimuth, ≤6° in elevation.

(6) Time resolution: 2 s.

MAG (see Figure 5) is being developed by NSSC and its performance is as follows.

(1) Measurement range:

Science mode: +/– 12800nT,

Ground testing mode: +/– 64000nT.

(2) Resolution: 24 bit.

(3) Noise: <0.1nT (RMS).

(4) Sampling rate: 40 Hz.

Fig. 5 Photograph of MAG

4. SMILE Mission

4.1 Satellite System

Satellite Orbit is a big inclination and highly elliptic orbit with apogee about 19R_e and perigee altitude of ~5000 km (see Figure 6). The inclination is about 98.2° if launched by Soyuz or Arian 62, or between 63° and 100° if launched by Vega-C, and the perigee argument is 280°.

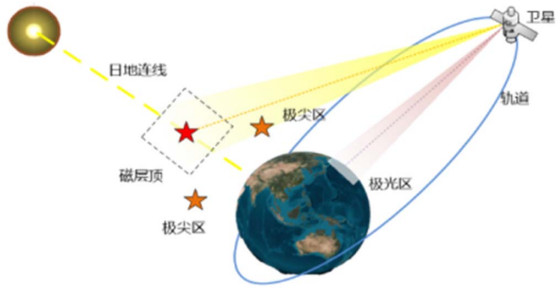

Fig. 6 SMILE Satellite HEO Orbit

SMILE is constituted by PlatForm(PF) and PayLoad Module(PLM) and is a three-axis stabilized satellite. CAS is in charge of the development of PF and ESA is in charge of the development of PLM. The mass of the satellite is less than 2000kg and the envelope is less than ϕ2200mm×3632mm. X-band transmission will meet CCSDS standard, data rate is 65Mbps, data volume is 38.5Gbits per orbit. Telemetry and telecommand will be Unified S-band TT&C system. The lifetime will be more than 3 years after delivered to user (see Figure 7).

4.2 Launch Vehicle

Launch Vehicle is under ESA's responsibility. The options include dual launch by Soyuz or Ariane62, or single

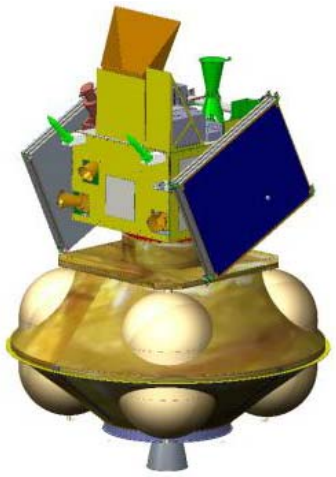

Fig. 7 Diagram of satellite structure

launch by Vega-C into the initial orbit from Kourou.

4.3 Launch Site

ESA is responsible for Launch Site and Launch service and will provide the ground segment support and logistics.

4.4 TC/TM

China Satellite Launch and Tracking Control General (CLTC) will be responsible for TC/TM of SMILE satellite. European Space Operation Center(ESOC) will be responsible for the TC/TM before the satellite separation with Launch Vehicle. Besides, ESA will also provide ground station support in case of emergency.

4.5 Ground Support System(GSS)

GSS has been constructed during 12th Five Year Plan and it will make some modifications according to the new requirements of the space science satellites during 13th Five Year Plan. It is mainly responsible for the operation and management of payloads, scientific data receiving, L0 data processing, data archiving of different levels, and distribution service of scientific data to the science community.

4.6 Science Application System(SAS)

CAS will construct SAS located in NSSC and ESA will construct Science Operation Center (SOC) located in European Space Astronomy Center (ESAC). Both parties will cooperate coordinately to make science strategic plan and exploration plan, monitor the execution of the plan, analyze the performance of the payloads in orbit, implement the calibration of the payloads, produce quick look science data and produce L1 and above science data products.

5. Ground Segment-Data Processing

Ground Segment (GS) of SMILE mission consists of SAS, GSS and CLTC that belong to Chinese GS, also SOC and ESOC that belong to ESA's GS. The GS block diagram of SMILE mission is illustrated in Figure 8.

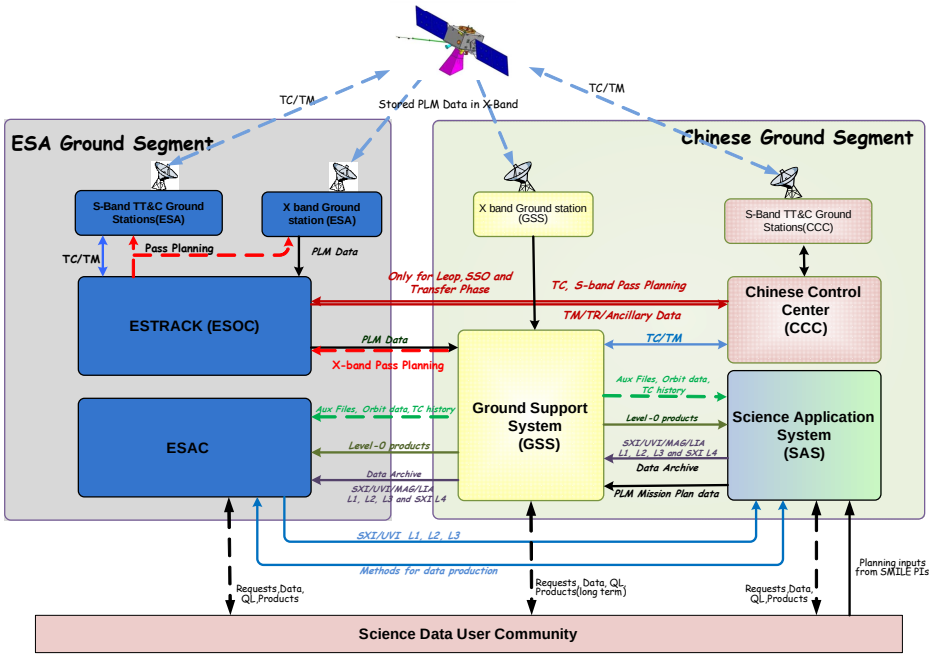

Fig. 8 Ground Segment Block Diagram of SMILE Mission

CLTC(CCC) will be responsible to compile commands of the satellite and upload TC through S-band ground station belong to CLTC, it will also use ESA's ground station during the LEOP and emergency condition. The S-band ground station will receive TM and transfer to GSS via CLTC, then GSS will perform the distribution.

ESA Troll X-band station as main and SanYa X-band station as redundancy will receive scientific data and transfer to GSS, GSS will make the sanity check, remove the duplicates and produce L0 data, then distribute L0 data to SAS and ESAC. ESAC is responsible to produce L1 and above data of SXI and UVI and transfer to SAS. SAS is responsible to produce L1 and above data of MAG and LIA and transfer four payloads products to GSS for archiving. GSS transfer all of the data products to ESAC for archiving. Another function of GSS is to provide the support and service of scientific data distribution to science community.

6. Development Plan and Current Status

SMILE mission of CAS part was adopted by Bureau of Major Research and Development(BMRD) in November 2016, and went into Phase A study. After SMILE was selected by SPC in November 2015, SMILE mission of ESA part also went into Phase A study. Currently SMILE mission has already finished Instrument consolidation review, PF and PLM consolidation review as well as Joint Mission consolidation review. Next steps are ISRR (Instrument System Requirement Review), PF and PLM SRR and GS SRR, and Joint Mission SRR will be conducted in June 2018, after that SMILE Mission of CAS will go into Phase B. ESA will make mission adoption in November 2018 and then will go into Phase B.

7. Acknowledgment

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