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 aurorae at the North pole simultaneously, while monitoring the in-situ plasma environment. Following the recommendation of the joint scientific evaluation panel to select the proposal SMILE, SMILE was selected by SPC in November 2015, with a target launch date by 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 payload funding 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 a international cooperation project of space science exploration jointly leaded by CAS and ESA, it is a new milestones 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 study 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 study 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 By affect storms. Figure1 is the SXI intensity simulation result.

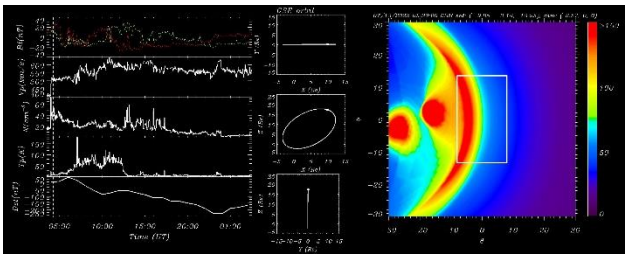

Fig 1 MHD Simulation of the X-ray Intensity during a magnetic storm event on 17th Mar, 2015. The left panel shows the time variation of solar wind parameters and the Dst index. From top to bottom, the parameters are: interplanetary magnetic field (yellow: By, red: Bz), plasma velocity, number density, 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 test 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. The performance of SXI is as follows:

1) Energy band: 0.2～5keV
2) Optic FOV: ≥ 27.3°×15.6°
3) PSF(central focus): 6′ FWHM
4) Detector energy resolution: ≤ 42eV @0.5keV
5) Time resolution: 60s

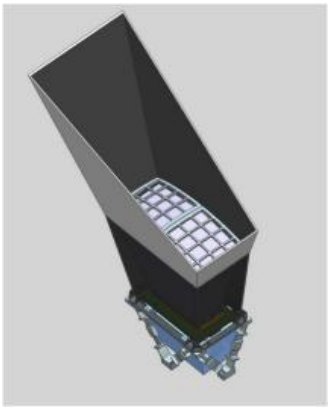

Fig 2 Illustration Diagram of SXI

UV mainly developed by University of Calgary and NSSC is charge of the development of UVI-E(Electronics box). 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: 60s
5) Sensitivity:20Rayleigh(60s exposure)

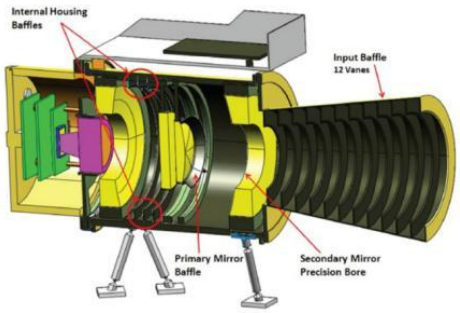

图 3 Structure Digaram of UVI

LIA is developed by NSSC. The technic will heritage from the payloads installed on Chang'E-1 and Chang'E-2 and Figure 4 is the photograph of LIA.

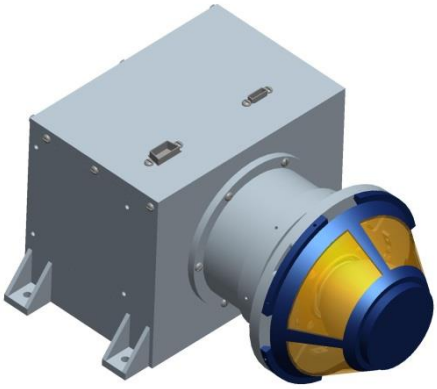

Fig 4 Photograph of LIA

The performance of LIA is as follows:

1) Energy range: 50eV/q~20keV/q
2) Energy resolution (△ E/E): ≤ 10%
3) View of azimuth angle: 360°
4) View of elevation angle: ≥ 44° (10~20 keV), 90° (≤10 keV)
5) Angle resolution: ≤7.5° in azimuth, ≤6° in elevation
6) Time resolution: 2s

MAG is developed by NSSC and its performance is as follows:

Fig 5 Photograph of MAG

1) Measurement range:
   Science mode: +/- 12800nT
   Ground testing mode: +/- 64000nT
2) Resolution: 24bit
3) Noise: <0.1nT (RMS)
4) Sampling rate: 40Hz

4. SMILE Mission

1) satellite system

Satellite Orbit is a big inclination and highly ellipse orbit with apogee altitude of about 19Re and perigee of ~5000km. The inclination is about 98.2° if launching with Soyuz or Arian 62, or some number between 63° and 100° if launching with Vega-C, and the perigee argument is 280°.

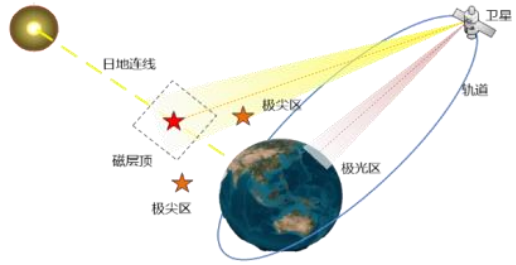

Fig 6 SMILE Satellite HEO Orbit

SMILE system 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.

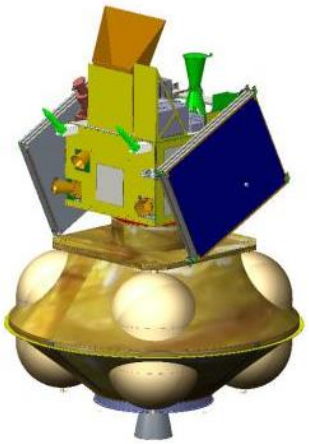

Fig 7 Diagram of Satellite Structure

2) Launch Vehicle

Launch Vehicle is ESA's responsibility. The options include dual launching with Soyuz or Ariane62, or single launching with Vega-C into the initial orbit at Kourou.

3) Launch Site.

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

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 responsible for the TC/TM before the satellite separation with Launch Vehicle. Besides, ESA will also provide the support of ground station during the emergency.

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 satellite during 13th Five Year Plan. Mainly responsible for the operation and management of payloads, scientific data receiving, L0 data processing, data archiving of different level, and distribution service of

scientific data to the science community.

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). The both parties will cooperate coordinately to make science strategic plan and exploration plan, monitor the execution of the plan, analysis the performance of the payloads in orbit, implement the calibration of the payloads, produce quick look scientific data and produce L1 above scientific data products.

5. Ground Segment-Data Processing

Ground Segment(GS) of SMILE mission including 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.

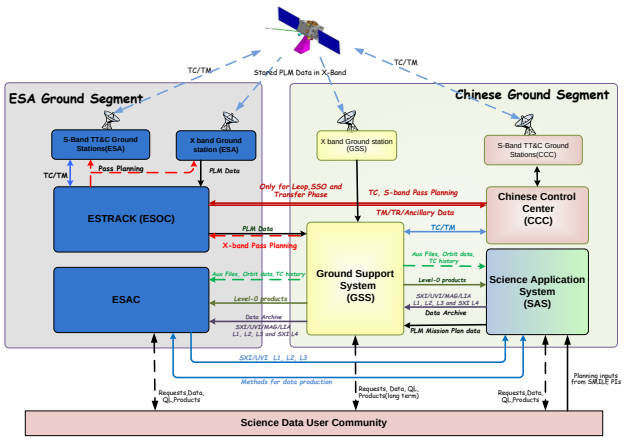

Fig 8 Ground Segment Block Diagram of SMILE Mission

CLTC(CCC) will be responsible to compile the command of the satellite and upload TC through S-band ground station belong to CLTC, it also will 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 above data of SXI and UVI and transfer to SAS. SAS is responsible to produce L1 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 already adopted by Bureau of Major Research and Development(BMRD) in November 2016 and goes into Phase A study. After SMILE was selected by SPC in November 2015, SMILE mission of ESA part also goes 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, PF and PLM SRR and GS SRR, and Joint Mission SRR will be conducted in June 2018, after that SMILE Mission of CAS will goes into Phase B. ESA will make mission adoption in November 2018 and then goes to Phase B study.

7. Acknowledgment

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