LIMADOU-CSES

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CSES (China Seismo-Electromagnetic Satellite) is a scientific space mission dedicated to monitoring electromagnetic field and waves, plasma and particle perturbations of the atmosphere, ionosphere and magnetosphere induced by natural sources and anthropocentric emitters and to study their correlations with the occurrence of seismic events. More in general, CSES mission will investigate the structure and the dynamics of the topside ionosphere, the coupling mechanisms with the lower and higher plasma layers and the temporal variations of the geomagnetic field, in quiet and disturbed conditions. Data collected by the mission will also allow studying solar-terrestrial interactions and phenomena of solar physics, namely Coronal Mass Ejections (CMEs), solar flares and cosmic ray solar modulation. The satellite mission is part of a collaboration program between the China National Space Administration (CNSA) and the Italian Space Agency (ASI), and developed by China Earthquake Administration (CEA) and INFN, together with several Chinese and Italian Universities and research Institutes. Italy participates to the CSES mission with the LIMADOU project funded by ASI in collaboration with the Universities of Roma Tor Vergata, Uninettuno, Trento, Bologna and Perugia, as well as the INFN-LNF, INGV (Italian National Institute of Geophysics and Volcanology) and INAF-IAPS (Italian National Institute of Astrophysics and Planetology). This program has been selected in Italy to be funded by the Ministry of Education, University and Research (MIUR) in the context of the programs "Premiali". The launch of CSES, the first of a series of several planned satellite missions, took place successfully on February 2nd, 2018 from the Jiuquan, Gansu Cosmodrome (Inner Mongolia). The CSES satellite (fig.1) based on the Chinese 3-axis stabilized CAST2000 platform, moves along a sun-synchronous orbit at 507 km of altitude and with a 97 degree inclination, with a periodic 5-day ground track.The expected lifetime of the mission is five years.

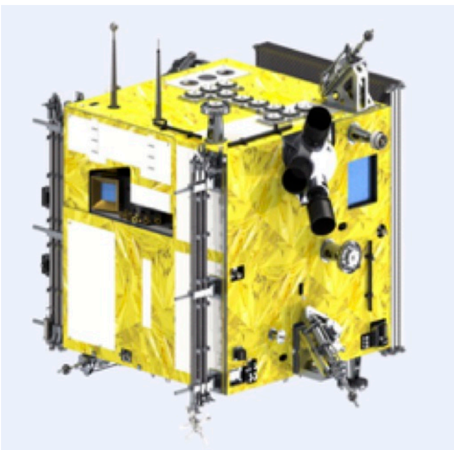

Figure 1: *Layout of the CSES satellite.*

The configuration of the CSES detectors provides measurements of energetic particle fluxes, ionospheric plasma parameters and electromagnetic fields, in a wide range of energies and frequencies. The main sensors onboard the satellite are the HEPD (High Energy Particle Detector) developed by the Italian participants, and the following Chinese sensors: LEPD (Low Energy Particle Detector), LP (Langmuir Probes), IDM (Ion Drift Meter), ICM (Ion Capture Meter), RPA (Retarding Potential Analyzer), EFD (Electric Field Detector) developed in collaboration with the Italian team, HPM (High Precision Magnetometer) and SCM (Search-Coil Magnetometer). The objectives of the Project LIMADOU/CSES cover several aspects: scientific, engineering and application ones. The scientific objectives of the project are related to the to study the ionospheric perturbations possibly associated with earthquakes and to explore new approaches for short-term and imminent prediction. The objectives in the engineering aspect of the project are to check the reliability and effectiveness of the proposed electromagnetic satellite monitoring system by utilizing a set of new techniques and equipment, in order to obtain world-wide data of space environment of the electromagnetic field, plasma and energetic particles. The objectives for the aspect of application of the project are to extract the electromagnetic information possibly associated with the earthquakes of $M \geq 6$ within Chinese territory and its neighboring area (1000 km) and those of $M \geq 7$ in the global scale; to analyze the features of seismo-ionospheric perturbations, in order to test the possibility for short-term earthquake forecasting experimentally in terms of satellite observation; to provide the data sharing service for international cooperation and scientific community. The INFN Section of Roma Tor Vergata and LNF are fully in charge of the HEPD and collaborate to the EFD realization (design, test, qualification, analysis). The HEPD, schematically shown in fig.2, has been designed to provide good energy resolution and high angular resolution for electrons $(3 - 100MeV)$ and protons $(30 - 200MeV)$.

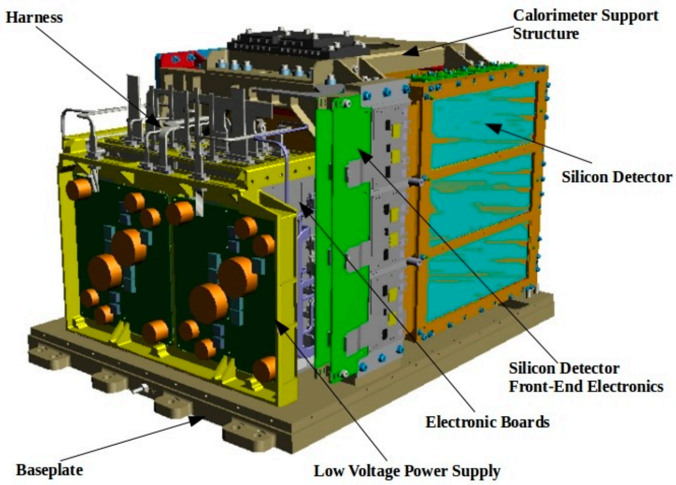

Figure 2: *Schematic view of the HEPD.*

The detector consists of two layers of segmented plastic scintillators and a calorimeter, constituted by a tower of scintillator counters. The direction of the incident particle is provided by two planes of double-side silicon micro-strip detectors placed in front of the trigger scintillator planes to limit the effect of Coulomb multiple scattering on the direction measurement. The EFD consists of four probes designed to be installed on four booms deployed from the three-axes stabilized satellite. The EFD can measure the electric field in a wide band of frequencies extending from quasi-DC up to about 5 MHz.

The main event in 2018, as already reported above, has been the launch in orbit of the satellite on February 2nd. On February 6th, the HEPD instrument was switched on for the first time. The apparatus underwent the commissioning phase (February-July 2018) during which several onboard configurations were changed for testing purposes. All parameters were found nominal, both for the satellite and instruments, and the commissioning phase finished without remarks. As to HEPD, these months were used to find stable conditions under which to operate the instrument in flight, optimizing some working parameters. Since August 2018, the science run of HEPD has started. Preliminary indications on the first inflight collection of proton- and electron data show that the particle rates are consistent with radiation models, as well as their distribution along the orbit. Thanks to HEPD acceptance energy window, its orientation with respect to the Earths magnetic-field lines, and satellite orbit, the instrument is capable of detecting different particle populations in space: solar particles, galactic particles, particles trapped in the inner and outer radiation belts including the SAA (South Atlantic anomaly), and albedo particles. The first scientific runs of the instrument attest its good functioning all along the orbit, and confirm that the HEPD is an optimal Space-Weather monitoring instrument.
Meanwhile, further agreements between the Agencies towards a second space mission, CSES-2, are in progress to develop a new payload and satellite, equipped with a similar suite of detectors, including a new version of the HEPD and EFD, foreseen to be launched in 2021-2022.

References

1. D. Badoni *et al.*, "A high-performance electric field detector for space missions"; Planetary and Space Science **153**, 107 (2018).

2. G. Ambrosi *et al.*, "The HEPD particle detector of the CSES satellite mission for investigating seismo-associated perturbations of the Van Allen belts"; Science China Technological Sciences **61**, 643 (2018).

3. XuHui Shen *et al.*, "The state-of-the-art of the China Seismo-Electromagnetic Satellite mission"; Science China Technological Sciences **61**, 634 (2018).

4. CSES-LIMADOU Collaboration, "CSES Preliminary Results on Ionospheric Variability and Its Connection with Seismic Activity and Solar Forcing"; Special Session S1 at 42nd COSPAR Assembly Conference, Pasadena, CA (USA), 14-22 July 2018.