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SMART-1 SPEDE: Results and Legacy after 10 Years

Walter Schmidt (1) and Anssi Mälkki (2)

(1) Finnish Meteorological Institute, Earth Observation, Helsinki, Finland (walter.schmidt@fmi.fi, +358 29539 3146), (2) Research and Innovation Council of Finland, Helsinki, Finland

The Spacecraft Potential, Electron and Dust Experiment (SPEDE) [1], one of the instruments on the SMART-1 spacecraft, the European Space Agency's first Lunar mission, was part of the monitoring instruments supervising the propulsion system and supporting corrective actions to its operation when needed. During mission phases with inactive propulsion system the plasma instrument measured electron and ion densities and temperatures of the natural plasma in the vicinity of the spacecraft. While the spacecraft was slowly spiraling out of an Earth orbit towards a Moon trajectory it spent many months inside the Earth radiation belt. During this time SPEDE recorded the plasma parameters as a function of altitude and solar conditions and monitored also the effects of the major solar CME of October 28, the so-called "Halloween Storm" [2], [3].
After reaching the Moon on November 15, 2004, it continued to monitor the plasma and dust impacts onto the spacecraft until the end of the mission on September 3, 2006. Most of the Moon orbits lasted about 5 hours with an initial perilune distance of 2208 and an apolune distance of 4618 km, changing to 300 km and 3000km, respectively towards the end of the mission with a controlled impact onto the Lunar surface. A total of over 200 orbits were covered [4]. Covered by the SPEDE instrument are three areas of scientific interest:
- A detailed altitude profile of the plasma parameters inside the radiation belt under different environmental condition – SPEDE was one of the few instruments active inside the radiation belt while normally all instruments on space missions are kept off to prevent damage,
- a plasma parameter map in Lunar orbit with the Moon inside and outside the Earth magnetosphere,
- plasma wave measurements around the moon with signatures of dust impacts onto the spacecraft monitoring the dust lifting processes on the Moon surface to escape velocities under certain solar wind conditions.

Technical legacy: The Langmuir Probe sensor area treatment was optimized for SPEDE and used in all subsequent Langmuir probe designs of IRF/Uppsala. The algorithm implemented inside the SPEDE on-board software to analyze the plasma wave measurements was optimized during the SMART-1 mission and later uplinked to the ESA Rosetta spacecraft lander Philae, where it is now used to analyze and compress the data of the permittivity probe, also used as a plasma wave monitor with W.Schmidt as PI. The experience gained from the FPGA-implementation of a self-developed processor was later used in preparation of ESA's ExoMars 2016 pressure sensor controller and the Swedish plasma instrument LINA for a Russian Lunar mission as well as for the ESA JUICE mission to the Jupiter system.

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