SPACEMON: Space Environment Monitoring Workshop 2017

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Book of Abstracts

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3D Silicon Sensors for radiation monitoring in space

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The recent revival of space exploration implies an increased interest in space travels that are associated with challenges and risks, mostly related to the ever-changing space weather. Radiation of any types can be detrimental to astronauts and the equipment on-board. Monitoring radiation levels reliably in space is therefore becoming a critical aspect for space missions. Many existing radiation monitoring systems are bulky and require high operating voltages and powers, for example, the Tissue Equivalent Proportional Counter (TEPC). Other systems are often fabricated using off-the-shelf components, including Si diodes for radiation detection, but lack the necessary radiation tolerance to ensure sensor survival throughout the mission. The 3D silicon sensor technology provides unique solutions to the limitations of the existing technologies for radiation monitoring in space. This new technology was introduced to mitigate the effects of radiation damage in High Energy Physics Experiments. Through state-of-the-art micro-machining, 3D technology decouples the inter-electrode spacing from the thickness of the sensor. Columnar electrodes are etched through the silicon bulk, allowing for inter-electrode spacing independent of the bulk thickness. The reduction in electrode spacing delivers low operating voltage (<10 V), fast sensor response (< 1ns), and increased radiation hardness. 3D silicon pixel sensors fabricated for the ATLAS experiment at CERN, demonstrated operation up to fluences in excess of $1\text{x}10^{16}$ n_{eq}/cm^2. Design, fabrication, and testing of a novel 3D silicon sensors tailored to space applications and manufactured at SINTEF MiNaLab are here reported. Electrical characteristics and sensor response to radioactive sources will be presented. Further tests plans will be discussed together with a development plan aiming at a portable, real-time on-line micro-dosimeter for space applications realised in collaboration with the Centre for Medical Radiation Physics at the University of Wollongong, Australia.

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(Proposed) Space Environments and Effects Monitoring with a Cubesat for JPL Earth and Planetary Science Missions

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Space is not empty. Although it is near vacuum, it actually contains copious amounts of different environmental species that may affect the design and operation of spacecraft. It is customary to describe the space environment in terms of 4 physical components: neutrals, plasma (low energy charged particles with <˜10 keV), high-energy radiation (e.g., charged particles with > ˜10 keV), and particulate environments (micrometeoroid and orbital debris or MMOD). The space environment is also dynamic and often unpredictable, and its interaction with spacecraft is complex. If not properly designed against the anticipated space environment condition, mission success could be compromised, sometimes in a grand scale (i.e., total mission failure). In fact, there are many anomalies and failures of space missions due to space environmental effects. Often, however, it has been very difficult (sometimes almost impossible) to find the root-cause of those anomalies and failures because of the lack of in-situ environmental data from the affected spacecraft – making it necessary to spend a lot of effort (in terms of time and resources) to analyze the failures. Here, we describe a space environmental monitoring program that is being proposed for future JPL's Earth and planetary science missions, which will be flexible in design and will utilize technologically ready sensors and supporting electronics in a cubesat form factor.

The data would provide invaluable information for potential anomaly/failure investigation and also used as the source for improving/updating the existing environment models.

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A millimetre wavelength in-situ radar for 100 to 10 mm-sized debris on a sun-synchronous LEO

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Currently, debris models are the main relying method for mission planning, however it is still unclear how to provide with a continuous feed to further validate these models, especially for space debris, as micrometeoroids are probabilistically approached. Model validation is key to slow down the Kessler syndrome. One way to accomplish it, is by setting a local in-situ debris detector in the orbit of interest, providing with proper debris feed. Here, the focus of the research is centred on a hypothetical mission on a sun-synchronous LEO, which is set to encounter and detect small particle debris on the size range of 100mm to 10mm inside a 1km radius sphere. The analysed instrument is a mm-wavelength radar mounted on board of the spacecraft. In order to accomplish it, certain radar parameters are to be looked into: power, beam size ideal frequency, and waveform. These are to be derived from a bottom-top theoretical approach. Starting by a close look into the frequency-normalized radar cross-section relation, providing a confirmation of the ideal frequency, found to be 39GHz, and wavelength. Afterwards, the consequences of the frequency on other radar parameters are briefly sketched, leading to an analysis of the waveform and its implications, resulting in an easy-to-use Continuous Wave (CW)-waveform radar. Results concerning probability of detection and false detection will be presented for several trade-offs between mission accomplishments and physical constraints. Once all the radar involved parameters and options were decided upon, use was made of ESA's Program for Radar and Optical Observations Forecasting (PROOF) to compare the theoretical detection results to this ESA's model. Finally, results and evolution of capability and quality of mission accomplishment will be provided.

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AMBER : The French Plasma detector aboard JASON3 - First results

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Jason 3 was launched january the 16th, 2016 with CARMEN3 expériment onboard. Outside the spacecraft AMBER, a top-hat detector made with a cooperation between CNES/IRAP/EREMS/COMAT, register, in 500ms, the incoming plasma (0-30keV). Thanks to the positive head, the voltage response of the spacecraft is also given. Results are now open to the whole scientific community on CLWeb at IRAP: http://clweb.irap.omp.eu/. The objective of this presentation is to present AMBRE-CARMEN3 plasma detector and for the first time, the very first flight results ... is kilovolt charging in PEO in somme seconds, possible ?

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CNES sensors for understanding the space environment and the effects on materials

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The CNES works for several years on the use of detectors during operational spatial missions as well as on the dedicated missions. By detectors we understand specific sensors to measure one of the parameters of the environment and/or the spatial structures which in case of return to earth can become surfaces witnesses to measure the effects of the environment on materials. We will focus more on the first item in the rest of the presentation
The importance of this approach " in flight tests " is justified by several factors:

- Improve our knowledge of our close environment ·
- To better understand the phenomena of synergy between several parameters of the environment
- To supply entries for models of environment and design
- To compare the flight data with the ground test
- To optimize our tests and save cost

The opportunities of flight being rather rare, the resources limited, the design of these experiments was optimized in order to be used on several carriers while limiting the mass, the power and the exchange of data.
Three parameters/sensors are going to be presented:

- Micrometeoroids and orbital debris (M&D)

The instruments proposed for different mission have used an active detection system: SODAD and a passive detection system based on a new material: Silica Aerogel.

- ATOX (monoatomic oxygen)

The instruments use resistance measurement of reference material.

- Thermo-optical coating properties change

The instrument (THERME) proposed for different missions (LEO, GEO) is simple, adjustable and with a robust definition and has 20 years of flight heritage

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Experience of on-board radiation control on Medium-Earth Orbit

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Space radiation detector's features will be presented (the sensitive element of the detector is MNOS transistor). Some effects, which we observed during its expluatation, and flight results will be shown and discussed. Heavy ion detector's features will be presented (the ensitive element of thedetector is SRAM).

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FGDOS: Floating Gate DOSimeter for Space applications. Introduction. Tests and results. Moon Flyby

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FGDOS is a Floating Gate based dosimeter on-chip designed, developed and commercialized by iC-Malaga. Its high linearity and sensitivity response makes it a good candidate for space, medical and high-energy physics applications. A brief introduction on the FGDOS features and configurations will be done in order to better understand the suitability as a dosimeter for space applications. In this presentation the FGDOS radiation test results carried out in collaboration with CERN in several facilities will be presented. Mainly four different tests are exposed to foresee the FGDOS responseness under different sources and conditions (protons, neutrons, 60Co and mixed-field). Limitations and second-degree effects are discussed. In addition, an overview of the 4M Lunar flyby Mission organized by Luxpsace where two FGDOS were embedded is presented. The 4M Mission launched, as a payload attached to the final stage of a Chinese Long March 3C rocket, two FGDOS in October 23th 2014.

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Fraunhofer Onboard Radiation Sensors (FORS)

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Fraunhofer INT develops systems for onboard radiation sensing. Onboard in this context means on printed circuit boards (PCB) inside electronic boxes in close proximity to radiation sensitive electronic devices. The goals of these radiation sensor systems are: [U+F06E] - they should be simple, robust, cheap and easy to integrate, - it should be possible to measure total ionizing dose (TID) and/or to detect solar particle events (SPE) locally on the PCB, - they can support anomaly investigation.
This ability to measure dose and/or particle fluxes on the PCB is particularly of interest as this is where radiation hurts the most. Furthermore it can help to reduce radiation design margins for successive missions because you get a better knowledge of the received dose inside your electronic box in a given environment. In addition in the case of in orbit verification or validation (IOV) missions it is of major importance to verify the predicted reliability of your design against the actual dose received.
Our approach is to add as little as possible devices and make use of already installed hardware e.g. microprocessors to operate them. And the output of those sensor devices should already be digital. So we propose to integrate extra memory devices on the PCB such as non-volatile UV-EPROMs to measure dose or SRAMs to detect high energy (solar) particles.

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From radiation monitor data to energetic particle fluxes

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The derivation of reliable proton and electron fluxes using radiation monitor data is often a cumbersome task. In this paper, we present various techniques that have been developed and applied for the calculation and the cross-calibration of energetic particle fluxes. These techniques include using Singular Value Decomposition, Neural Network, Bow-Tie, Correlative analysis to calibrate the counts to fluxes, methods to determine channel effective energies and cross calibration methods that lead to the production of reliable level 2 datasets. Characteristic examples that emerged from the application of these techniques on various instruments, such as ESA/SREM, Galileo/EMU, Himawari/SEDA, ALPHASAT/MFS and NOAA/GOES/EPS are presented and discussed.

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HelMod Forecasting of the Intensities of Ion Cosmic Rays

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The HelMod (heliospheric modulation) model was developed to account for the transport of Galactic Cosmic Ray through the heliosphere. At present, the model is also used to forecast Ions Cosmic Rays Intensities in the current and coming solar cycles. The latter procedure include a fine tuning on the current solar cycle. HelMod is a 2-D Monte Carlo and includes a general description of symmetric and antisymmetric parts of diffusion tensor, thus properly treating particle drift effects as well as convection due to solar wind and adiabatic energy losses. Particular care was dedicated to describe polar regions of the heliosphere. The HelMod tool is available for public use as a set of Online Calculators at www.helmod.org. The Model accounts for 1) all the data observed by ulysses mission outside the ecliptic plane at several distances from the Earth (KET measurements) and 2) the spectra observed in deep space during high and low solar activity periods, including data from SREM detectors (onboard of ROSETTA, PLANCK, Integral, etc). We present the latest results of the model reproducing the measured cosmic rays spectra at Earth and in deep space.

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Highly miniaturised ASIC radiation detector

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A highly miniaturized radiation detector has been proposed to ESA and the proof of concept study was initiated some months ago. The goal is to end with a device whose size, power consumption and radiation data output will increase the level of crew autonomy as far as it concerns operational decisions related to radiation hazards. Future exploration missions beyond

ISS pose these requirements. Information on the type and fluence spectra of the particles acquired by a wearable device could help to reach the goal stated above. The device core is a plastic scintillator for neutron detection enclosed in a titanium box surrounded by silicon monolithic pixel sensors. The device concept and status, as well as simulations of its response to charged particles and neutrons highlighting its potential will be discussed.

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LEO electron and proton data obtained with ICARE instruments on the SAC-C, SAC-D, JASON-2 and JASON-3 missions

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Miniaturised Readout Solutions for Spaceborne Ionising Radiation Detectors

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Space radiation monitoring has been carried out for decades. Traditionally, space radiation monitoring relies on large and costly science-grade instruments embarked on a few spacecrafts. Recently, technological advancement and pressure on both project cost and time changed the paradigms. For example, constellations demand low-cost and compact instruments deployable aboard SmallSat or CubeSat platforms. These constellations will form the backbone for future space environmental monitoring. In this approach the data quality for each satellite may be reduced. However, now- and forecasting capabilities are strongly enhanced by the availability of large data sets in near-real time.
In this presentation we will outline two readout solutions developed by IDEAS that can contribute to future instrument developments. These integrated circuits (IC) are already used aboard ESA space missions e.g. JUICE, BepiColombo and EDRS-C. For the detection of ionising radiation ICs with a large degree of integration have been designed that can now be reused for constellation-type instruments, namely:

- The IDE3466 for particle telescopes using silicon diodes such as JUICE's RADEM or the proposed Belgian-Norwegian mEPT instrument;
- The IDE3380 for multi-channel SiPM readout. The IDE3380 is used in combination with a scintillator for the GMOD gamma ray detector to fly aboard the Irish CubeSat EIRSAT-1.

Furthermore, the Norwegian Radiation Monitor (NORM) is under development at the University of Oslo and IDEAS serving as proof of concept for the creation of a constellation-type CubeSat instrument for energetic particle detection. This will serve as a stepping stone towards instruments such as the mEPT. In addition, IDEAS is investigating the release of a rad-hard latch-up protection circuit that will be beneficial for any hybrid instrument using COTS parts.

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Observations of galactic cosmic-ray flux short-term depressions aboard LISA Pathfinder: characteristics and energy-dependence

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Energetic particles in the interplanetary medium penetrate spacecraft and limit the efficiency of instruments placed aboard. LISA Pathfinder, the mission of the European Space Agency for the testing of the technology that will be placed aboard the first interferometer for gravitational wave detection in space, LISA, carried a particle detector for proton and helium nuclei monitoring above 70 MeV/n and four magnetometers. Cosmic-ray data were analysed between February 18th 2016 and July 3rd 2017. The characteristics and energy dependence of forty-five short-term depressions of the galactic cosmic-ray flux were estimated. A detailed study of a Forbush decrease dated August 2nd, 2016, associated with the transit of an interplanetary coronal mass ejection, was also carried out. The outcomes of the present work can be used in Monte Carlo simulations for space instrument performance estimates.

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OHB's proposal of an in-orbit cross calibration of space environment sensors

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Space radiation sensors are normally only calibrated on ground. Cross calibration is only applied afterwards when data sets of different sensors are compiled into one radiation model. Both methods have their disadvantages. Ground calibration can't reproduce space radiation spectrum and provides only a partial calibration. Post-calibration of data sets is difficult when sensors flew on different satellites at different locations under different conditions. In-orbit cross calibration of two (or more) space radiation sensors, on the same satellite, would provide a full comparison, at the same location & time, and under the same conditions. The in-flight cross calibration would enhance the scientific value of the data sets of all involved sensors. ESA's new NGRM radiation monitor will fly on the EDRS-C and MTG satellites, built by OHB. OHB proposes to fly further radiation (and space environment) sensors for the purpose of in-orbit cross calibration. OHB is encouraging ESA and other satellite manufactures and operators to make a joint effort to implement cross calibration in space for the benefit of the whole community.

5

Radiation dosimetry in space by means of compact passive luminescent detectors

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Radiation dose rates in space are two orders of magnitude higher than on earth. This impacts human health and instrumentation performance. Also biological experiments are affected. Therefore, dose assessment in space is of primordial importance. The radiation field in space is also more complex than on earth. Therefore, precise dose assessment can only be performed by combining computer simulations and measurements.

Radiation measurements in space typically rely on bulky, complex and expensive active monitors providing real time information on the intensity and composition of the radiation field. However, also compact and cheap passive detectors are useful as they don't require power and are easily made in sub-cm dimensions. This is convenient for detailed mapping, dose assessment for biological experiments and organ dose assessments using anthropomorphic phantoms.
SCK•CEN has strong expertise in passive optically and thermally stimulated luminescent detectors (Luxel, LiF:Mg,Ti, LiF:Mg,Cu,P). Reading is performed in specialized labs with the commercial Harshaw 5500 for thermoluminescent detectors and a homemade laser system for optically stimulated luminescent detectors. The reading and analysis protocols are optimized based on detector characterization by radiation transport simulations and irradiations in our calibration lab and at ion beam facilities.
In the framework of the international DOSIS and DOSIS 3D projects we have been sending our detectors to the ISS typically every 6 months since 2009 for mapping of the dose rates in the Columbus module. Further, we have regularly been sending our detectors together with biological experiments on the inside and outside of the ISS and inside other spacecraft such as FOTON-M4 and BION. These measurements have shown dose rates expressed in terms of absorbed dose in water between 100 and 1000 μGy/day and a strong dependence on altitude and inclination of the orbit, solar cycle and shielding.

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Radiation Monitoring at SSTL

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SSTL presents our radiation monitoring capabilities both current and upcoming with specifications and models of our current radiation monitor, a presentation of data collected on orbit, including from our technical demonstrator spacecraft TDS-1, and technical information on our latest monitor SPHERE.
RadMon is SSTL's low mass, low power and highly adaptable radiation monitor. It is suited to a wide range of missions in LEO and provides operators with critical engineering data in near real time to identify and mitigate against the effects of the space radiation environment and provide mission operations support. RadMon has sensors to measure ionising dose in up to four locations, dose rate, protons and heavy ions.
Building on the success of RadMon, SPHERE is SSTL's next generation radiation monitor, designed to extend the range of SSTL's radiation monitor offering to new mission profiles in high LEO, GNSS and geostationary orbits. SPHERE is a low mass and low power monitor, measuring radiation effects in energy ranges proven to cause loss of function or performance in spacecraft systems. SPHERE has 2 proton telescopes, a heavy ion telescope and a deep dielectric charge monitor as well as up to 5 ionising dose monitors which can be placed remotely to monitor dose in specific systems or locations on the host spacecraft. SPHERE is offered in two variants – a COTS system for short duration missions or lower orbits and a radiation hardened version for longer durations or harsh orbits. It can also be specified with a range of common communication interfaces.
SSTL's suite of supporting software allows us to offer a range of data products, from raw data for the scientific community, to fully processed information and reports which would be of use to a satellite operator.

3

RadMag combined cosmic ray and magnetic field measuring space weather instrument development for CubeSat/SmallSat

applications

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To study space weather and to protect our technology, as a first step, it is necessary to develop and establish an advanced, real-time monitoring system to provide scientific data on space radiation (electron and proton spectra, flux of heavier ions) and the status of the magnetosphere in order to gain the possibility for a reliable forecast capability. The expansion of the CubeSat/SmallSat industry will make it possible in the near future to launch orbital constellations with relevant, miniaturised instrumentation providing in-situ measurements of the space weather environment in near real-time. Thus the development of a new, combined, space weather monitoring instrument package (called RadMag) has been initiated at the Centre for Energy Research, Hungarian Academy of Sciences in the frame of ESA GSTP programme in collaboration with Imperial College London and Astronika. The instrument consists of silicon detector based, complex radiation telescopes that cover a wide range of cosmic ray particles, and an inboard and an outboard magnetometer to measure the magnetic field strength in three directions. A small deployment system will be designed with 80 cm-long deployed length as a part of the instrument to host the outboard magnetometer. By realizing a compact design, fitting into ˜1.2U following CubeSat standards, global monitoring of the particle radiation environment and the magnetic field environment will be possible with sufficient statistics in the Near-Earth region on board a fleet of CubeSats/SmallSats. Additionally, the RadMag instrument may provide a low-cost alternative for commercially supporting radiation damage estimates on future satellite missions. The first in-orbit demonstration of the instrument will be performed within a 3U CubeSat mission, called RADCUBE, lead by C3S LLC in Hungary as an ESA GSTP IOD project, which is expected to be launched in early 2019.

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The meteoroid environment model IMEM-2 for the inner solar system

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The interplanetary dust complex is currently understood to be largely the result of dust production from Jupiter-family comets, with contributions also from longer period comets (Halley and Oort type) and collisionally-produced asteroidal dust. Here we develop a model of the interplanetary dust cloud from these source populations, in order to develop a risk hazard assessment tool for interplanetary meteoroids in the inner solar system. Long-duration integrations of dust grains from Jupiter family and Halley type comets, and main belt asteroids, are compared to COBE infrared data, meteor data and the diameter distribution of lunar microcraters. This allows the constraint of various model parameters. We present here the first attempt at generating a model that can simultaneously describe these sets of observations.

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The miniaturised Energetic Particle Telescope (mEPT): A Compact Space Weather Monitor for Application within the Distributed Space Weather Sensor System (D3S)

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Science-class space radiation spectrometers / monitors are useful tools embarked on spacecraft to collect data for various applications including spacecraft anomaly diagnosis, space weather services and validation / improvement / development of radiation environment models.
The operational principle of the Energetic Particle Telescope (EPT), predominantly a range telescope, has led to a{flushright}n instrument with excellent in-flight particle discrimination capability and immunity to contamination by off-field-of-view particles.
The objective of the mEPT development is to produce a compact radiation monitor / spectrometer that can be packaged as a hybrid chip of size <200 cm^3, but whose performance is comparable to that of the EPT. This implies reliable particle discrimination capability within their respective energy range (electrons: 0.1–7 MeV, protons: 3–400 MeV, heavier ions: >10 MeV) and the possibility to reconstruct the incident particle spectra with no condition on the predefined spectral shape. The instrument is designed to cope with fluxes of up to 10^8#/cm^2/s, thus capable of energetic charged particle sensing in GEO, GTO, MEO orbits and during Electric Propulsion orbit raising. The required telemetry data with the host satellite is reduced to minimum (<2.5 kbit per integration time for particle spectra of at least eight energy bins, dose information, housekeeping data…) and the targeted power consumption of the device should be <1 W. The necessary performance is achieved by use of integrated circuit (IC) technology repurposed from the ESA JUICE mission. A successor IC is proposed to power future mEPT devices.
The resulting data products and instrument compactness make the mEPT stand out as a suitable instrument that can be placed within a constellation for multi-point particle flux measurements as foreseen within ESA's D3S.
More details of this instrument and its possible applications will be presented.

6

Using platform magnetometers to observe and detect Space Weather events

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Magnetic field measurements are an essential tool for space weather and space physics. Many satellite missions that are not dedicated to these fields still carry fluxgate magnetometers, as part of their attitude control subsystem. These measurements are used directly on-board the satellite as input to an attitude determination and control loop, and are only send down in a housekeeping data stream, stored for possible engineering diagnostic purposes.
In this study, we have investigated the feasibility of using data from such non-dedicated magnetometers for space weather use. We have analysed the housekeeping telemetry data from ESA's GOCE and Swarm missions, in order to investigate the feasibility of using their platform data for mapping and monitoring high-latitude field-aligned currents. We have compared the results

with those derived from the science instruments on CHAMP and Swarm, as well as AMIE output during the geomagnetic storms of April 5, 2010 (GOCE) and March 17, 2015 (Swarm).
In addition, we have analysed the magnetometer data delivered by the diagnostics subsystem on ESA's LISA Pathfinder, and compared it to the commonly used IMF data from the space weather observatories WIND, ACE and DSCOVR, also orbiting the Sun-Earth L1 point. Due to the very stable and clean spacecraft design, the LISA Pathfinder IMF data compares very well with the IMF data from the dedicated missions, when a minimum time resolution of a few minutes is considered. The simultaneous availability of IMF data from three or four positions close to the Sun-Earth L1 point during parts of 2016 and 2017, opens up possibilities for an accurate assessment of the data quality, as well as enhanced studies of the propagation of the solar wind near the Earth.