Overview of Activities Europe-wide

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Overview of Spacecraft Charging activities Europe-wide

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***Abstract*— A number of advances in spacecraft charging have been made within Europe including many under ESA sponsorship. These are directed at improving knowledge and practices within European industry generally and supporting ESA missions in particular. Area of progress include improvements to charging simulation capabilities, development of instrumentation, characterisation of the environment and updating standards. In this presentation, an overview of recent and ongoing developments will be shown. Outside of ESA programmes, national agencies have their own activities and the focus of recent and ongoing French studies will be also made in this presentation.**

***Index Terms*—Satellites, space technology**

I. Space Technology research programmes

Within Europe, the largest dedicated funding of space technology research, including spacecraft charging, comes from the different ESA programmes(e.g. General studies programme, Technology research programme, General support technology programme). In addition European Union funding under Horizon 2020 and the upcoming Horizon Europe programmes are becoming increasingly significant. Many national agencies, such as CNES in France, have their own research programme. In addition, universities and research institutes may carry out research under their own budgets and industry may sponsor work to address specific goals.

II. ESA projects presently driving activities

Activities that are sponsored by ESA are frequently initiated in response to the needs of ESA missions and programmes. Often ESA science missions have the most demanding requirements. The following missions, listed with their operational location and expected launch date, are under development:

- JUICE (Jupiter, 2022) , Athena (L2, 2028), LISA (Heliocentric 1AU, 2034) – L-class
- Solar Orbiter (Heliocentric >0.28AU, 2019), Euclid (L2, 2021), Plato (L2, 2024), ARIEL (L2, 2028) – M-class
- CHEOPS (SSO, 2018), SMILE (Molniya, 2021) – S-class

There are three M-class candidate missions for a launch around 2032:

- Theseus (LEO), Spica (L2) and EnVision (Venus)

Outside of the science programme there are several other significant projects that influence spacecraft-plasma interaction developments:

- Electra (electric orbit raising – EOR)
- Space Situational Awareness (on-ground services and L5, SSO missions)
- Galileo 1st and 2nd Generation (EOR)
- Proba-3
- Cubesats e.g. Picasso

III. ECSS activities

The European Cooperation on Space Standardisation framework is the system of standards that are widely used by ESA and European industry. There have been recent developments in the field of spacecraft-plasma interactions.

Under a CNES initiative, and supported by ESA, a new handbook ECSS-E-HB-20-06A on 'Assessment of worst case charging' has been drafted. A working group comprising of ESA, CNES, ONERA, OHB, Airbus D&S and SES created this handbook to complement the spacecraft charging standard and to give practical information on how surface and internal charging assessments should be performed. This draft handbook is currently open to public review.

The ECSS-E-ST-20-06C Spacecraft Charging standard is now around 10 years old. To bring it up to date and to take account of a number of submitted change requests from industry, an update was requested by the ECSS secretariat. Because this fell within the same subject area as the already convened working group of ECSS-E-HB-20-06A, this working group's remit was expanded to include proposing the required changes. Responses to the change requests have been agreed within the working group a the new draft of the standard written. The new version of this standard is also open to public review.

The ECSS-E-ST-10-04C Space Environment standard is also around 10 years old and there have been a number of change requests. A working group from industry, ESA and

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CNES is currently actively working on an update. This standard includes charging environments. A number of changes to the charging aspects of this standard have been proposed resulting from the handbook and Spacecraft Charging changes. It is the intention that for spacecraft charging, the three standards shall be consistent with one another. The work on this standard is expected to be submitted to public review later in 2018.

IV. SPINE

Within Europe the Spacecraft Plasma Interactions Network in Europe (SPINE) is a forum for discussing developments in this field. At least one workshop is held per year and these generally attract around 40 attendees from universities, research organisations, industry and agencies. SPINE is regularly consulted on the needs for SPIS developments and SPINE members provide feed-back on issues they identify during their SPIS simulations.

V. ESA R&D ACTIVITIES

A. SPIS Developments

1) Improved Modelling of Electrical Thruster Induced Plasma Plume Interactions -SPIS-EP

This activity aims to improve the SPIS electrical plume model by modelling the cooling of electrons within the plume. It improves the spacecraft circuit including the thruster and cathodes, and updates surface erosion and contamination models. See the papers from Sarrailh et al. and Thiebault et al. at this conference.

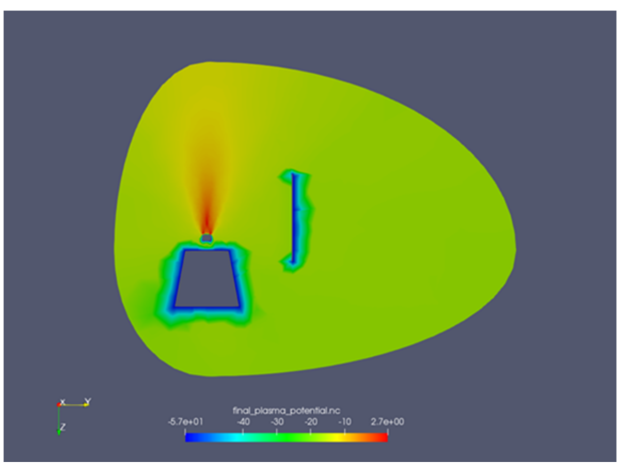

Fig. 1. SPIS simulation of potential for a spacecraft with electric propulsion [1].

2) Dust electrostatic charging, transport and contamination model for Lunar Lander and human exploration missions -SPIS-DUST

A recent study has continued the development of SPIS-DUST by providing new capabilities for modelling of the lunar surface, a new landing feature, the merging of lander/lunar surfaces, shadowing visualisation and validation cases

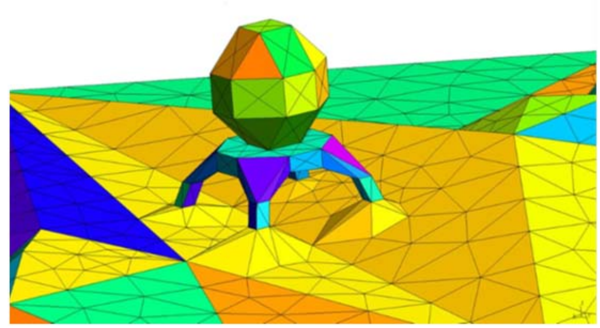

Fig. 2. An example of a SPIS geometry showing the merging of the lander and the lunar surfaces [2].

3) Electrostatic Cleanliness of Ion Emitting Spacecraft

This currently active study is improving the modelling of Cluster-like spacecraft accounting for plasma potential perturbations in the volume due to the presence of ion beams (e.g. for spacecraft potential control) and calculating the effects, primarily on electric field instruments.

4) Development and validation of a contamination package in SPIS for liquid based electric propulsion subsystems for LISA

This activity will create a SPIS simulation module for the quantification of contamination on LISA spacecraft surfaces, due to the creation of droplets by thrusters.

B. Other Developments

1) 3D energetic Electron Spectrometer

In this activity a novel high grade instrument is being developed to characterise energy and angular distributions in the radiation belts. Although the instrument is capable of measuring ions and electrons, the target population are the electrons in the outer radiation belt that cause internal charging and dose effects. The instrument adopts techniques developed for the EPT instrument. It has good angular resolution over a number of viewing directions, as well as good energy resolution and separation of ions and electrons.

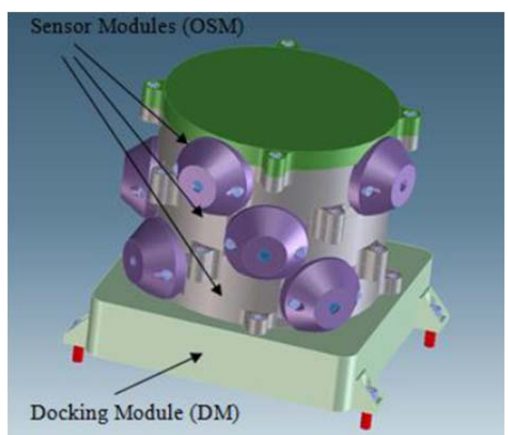

Fig. 3. A possible configuration of a 3DEES module with 6 view directions [3].

2) JUICE Charging Analysis Tools

This was a study that aimed to improve several aspects of the JUICE charging assessment. It created statistical models of the plasma and electron radiation belt populations to be used for JUICE worst case analyses. It also development a 1-d internal charging tool (MCICT) using Geant4-based Monte Carlo radiation transport that can be used for assessments of internal charging at Jupiter and in the Earth's radiation belts.

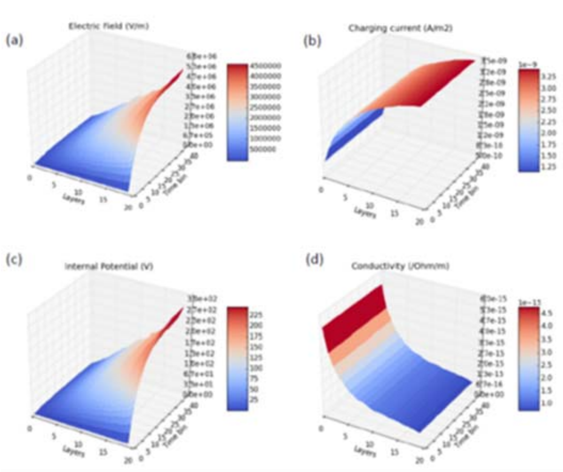

Fig. 4. Graphic output from MCICT showing potentials, electric fields, charging currents and conductivity across the 1-d insulating material [4].

3) *Galileo EMU Radiation Data Exploitation*

This ongoing activity is using data from the Environment Monitoring Units on the Galileo navigation satellites. Part of this study involves comparisons of data with environment models for internal charging and dose assessment. Finally it is expected that the MOBE-DIC model of internal charging fluxes will be updates.

4) *Multi-Needle Langmuir probe*

This development is mainly directed at space weather observations of plasma in low Earth orbit. It involves the development of a high time resolution (~5kHz) Langmuir probe for plasma density measurements in LEO [6]. This allows spatial resolution of a little over 1m, which allows observations of plasma density irregularities associated with disruption of communications and GNSS signals. The latest work has concentrated on redesigning the boom deployment system, improving EMC performance and testing of the EQM.

5) *Experimental Validation of ESA Internal Charging Tools Using REEF*

This is a small ongoing activity which is being performed to complement a parallel activity by CNES with ONERA. It aims to validate internal charging simulation codes using experimentally produced results from REEF and to compare the experimental data that can be obtained from the U.Surrey facility with that from ONERA. See the presentation by Alex Hands in this conference and the complementary presentation by Remi Pacaud.

6) *SPENVIS Next Generation*

This long-running activity [7] includes environment models and simple tools for surface and internal charging analysis. It involves a complete redesign of the SPENVIS framework with a new, modular, distributed philosophy. An alpha release has been made but the system is not yet mature enough to replace SPENVIS-4.

VI. SUMMARY

Developments in the field of spacecraft-plasma interactions are continuing in Europe.

ECSS standards are being updated and a handbook has been prepared.

For surface charging analysis

- SPIS is still developing
- The needs of electric propulsion are being met with new developments

For internal charging

- Instrument developments are being supported
- A new 1-d internal charging tool is available
- Validation is being performed against laboratory irradiations
- Environment models are being validated against Galileo/EMU data and will be updated

REFERENCES

[1] Sébastien HESS and Pierre SARRAILH, Improved Modelling of Electrical Thruster Induced Plasma plume Interaction (SPIS-EP) https://indico.esa.int/indico/event/235/session/8/contribution/17

[2] Jean-Charles Matéo Vélez, Pierre Sarrailh, Sébastien Hess, Benjamin Jeanty-Ruard, Nicolas Chabalier, Julien Forest, Dust electrostatic charging, transport and contamination model for Lunar Lander and human exploration missions https://indico.esa.int/indico/event/188/session/0/contribution/20

[3] M.Cyamukungu et al. 3DEES - FINAL REPORT, 3DEES-TN-045-CS, 30.09.2014

[4] I.Sandberg, Data exploitation of new Galileo environmental monitoring units https://indico.esa.int/indico/event/235/session/8/contribution/1/material/slides/4.pdf

[5] P.Truscott, F.Lei, E.Roussos, M.Franz, H.Krupp, D.Heynderickx, J-W.Wahlund, K.Agren, P.Kollmann, A.Hands and K.Ryden, JUICE Charging Analysis Tools, Final report ESA contract 400010999/13/NL/AK, December 2017

[6] Tore André Bekkeng, Multi-Needle Langmuir Probe (M-NLP) development, https://indico.esa.int/indico/event/235/session/7/contribution/0

[7] Neophytos Mesios, SPENVIS Next Generation, https://indico.esa.int/indico/event/235/session/6/contribution/3