OHB System AG
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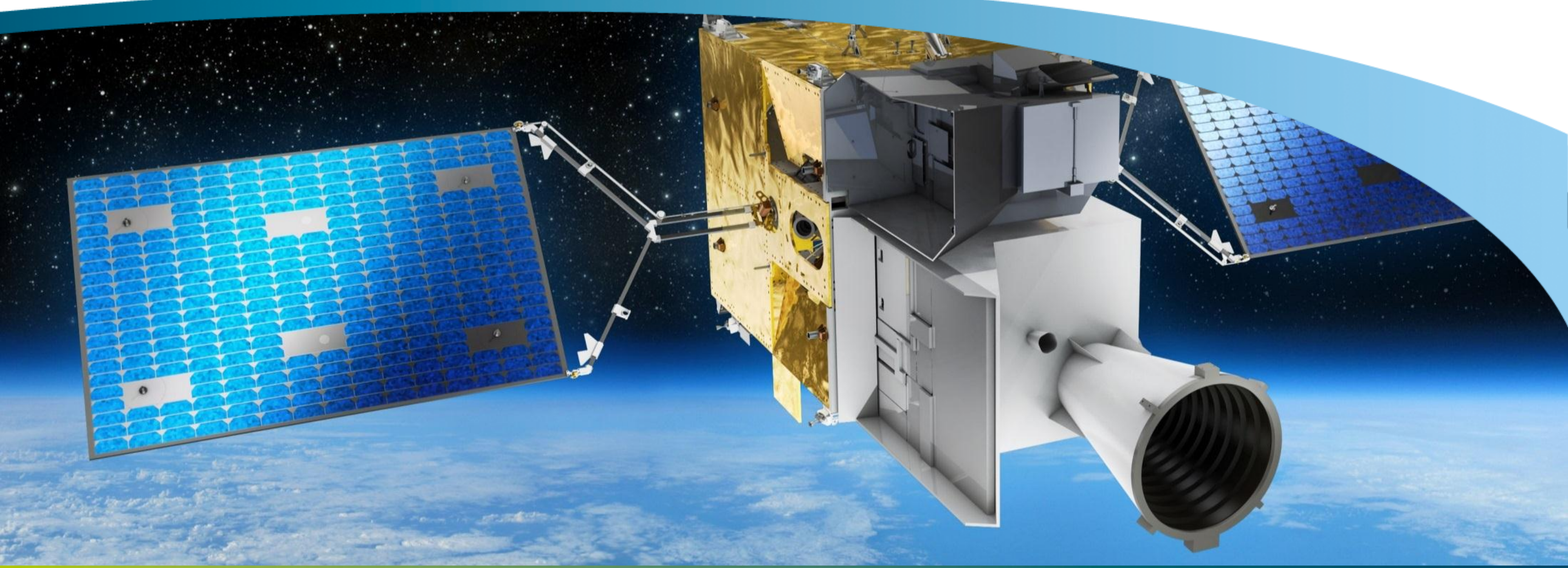
Space Environment Monitoring Workshop 2017
14 December 2017, ESTEC, Netherlands



SPACE SYSTEMS

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

We. Create. Space.

Satellite missions are facing new challenges:

- all future (telecom) satellites will use Electrical Propulsion Orbit Raising (EPOR)
  - Instead of chemical GTO of 14 days, expect electrical GTO of 142~387 days
  - Total dose example: 200 days EPOR GTO = 6.7 years GEO
    - Literature: [Horne and Pitchford, Space Weather Concerns for All-Electric (2015)]
  - 150% total dose during mission lifetime of a satellite:
    - up to 50 % during EPOR GTO
    - 100 % during 15 years in GEO
- Not enough data of EPOR GTO region in the models = high uncertainties
- Extreme SW events:
  - Carrington (1859), Quebec (1989), Halloween (2003), CME near miss to Earth (2012)
    - Literature: [Extreme space weather - impacts on engineered systems and infrastructure(2013)]
- High-Altitude-Nuclear- Explosion (HANE): EMP & Radiation belt pumping
    - Literature: [Collateral Damage to Satellites from an EMP Attack (2010)]

AGU PUBLICATIONS

Space Weather

FEATURE ARTICLE

10.1002/2015SW001198

Space Weather Concerns for All-Electric Propulsion Satellites

Richard B. Horne and David Pitchford

Citation:
Horne, R. B., and D. Pitchford (2015), Space Weather Concerns for All-Electric Propulsion Satellites, *Space Weather*, *13*, doi:10.1002/2015SW001198.

Accepted article online 14 JUL 2015

Abstract The introduction of all-electric propulsion satellites is a game changer in the quest for low-cost access to space. It also raises new questions for satellite manufacturers, operators, and the insurance industry regarding the general risks and specifically the threat of adverse space weather. The issues surrounding this new concept were discussed by research scientists and up to 30 representatives from the space industry at a special meeting at the European Space Weather Week held in November 2014. Here we report on the discussions at that meeting. We show that for a satellite undergoing electric orbit raising for 200 days the radiation dose due to electrons is equivalent to approximately 6.7 year operation at geostationary orbit or approximately half the typical design life. We also show that electrons can be injected into the slot region (8000 km) where they pose a risk of satellite internal charging. The results highlight the importance of additional radiation protection. We also discuss the benefits, the operational considerations, the other risks from the Van Allen radiation belts, the new business opportunities for space insurance, and the need for space situation awareness in medium Earth orbit where electric orbit raising takes place.

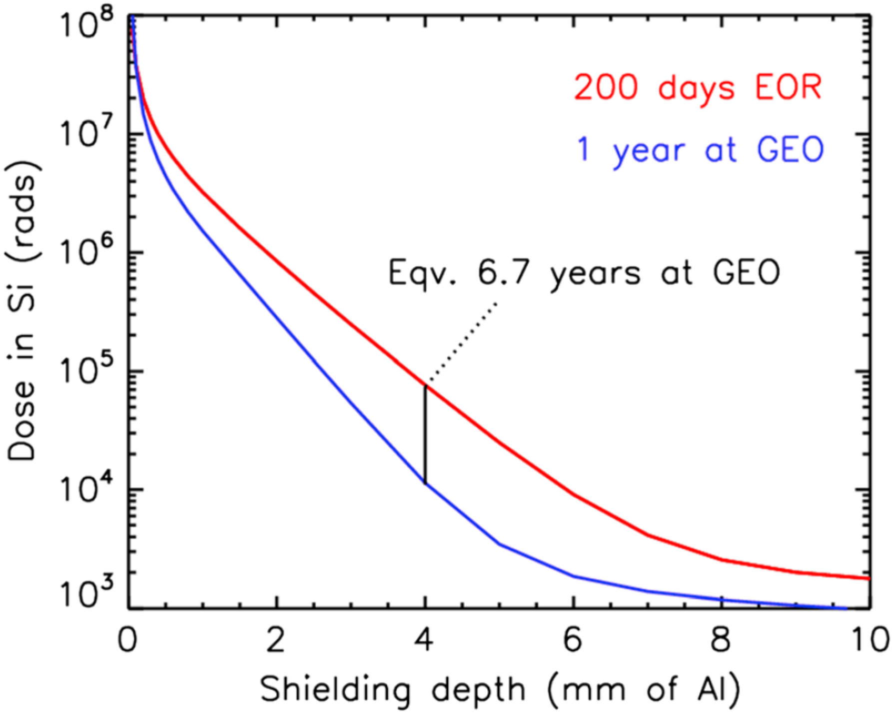


Figure 1. Comparison between (in red) the radiation dose accumulated over 200 days by a satellite undergoing electric orbit raising compared to (in blue) that accumulated over 1 year at Geostationary orbit at 115° W. Assuming a shielding of 4 mm of Al the dose for 200 days of electric orbit raising is equivalent to 6.7 years of operation at geostationary orbit. The dose is dominated by radiation belt electrons and the flattening of the curves beyond 6 mm of Al is due to Bremsstrahlung radiation. The calculations assume that the satellite was launched on 12 March 2015 during solar maximum using the electron and proton spectra from the AE8 and AP8 radiation models at the 97.73% confidence level. The initial perigee and apogee were 400 and 3600 km altitude, respectively, with an inclination of 25°. The perigee and inclination were changed in 10 equal steps to reach a final geostationary orbit at 115° W with zero inclination. The dose was calculated using the SHIELDOSE-2 model assuming a semi-infinite slab of Al shielding. The models were accessed via the space environment information system SPENVIS.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DTRA-IR-10-22

TECHNICAL REPORT

Collateral Damage to Satellites from an EMP Attack

Approved for public release; distribution is unlimited.

August 2010

20101029076

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More space environment sensors on satellites are needed:

- House keeping:
  - actually measuring (total dose, charging, …), instead of guessing (based on models)
- Anomaly Investigation:
  - Satellite operators want more sensor data to analyse in-orbit behaviour
- Mission operations planning:
  - Mission life extension: actually dose versus design dose
- Future Designs:
  - Adding more in-orbit measurements to the models
  - Validation of the models
  - if necessary updating satellite design for future missions
- Insurance:
  - more sensor data helps to build a good track record = lower premiums

calibration of space environment sensors

- 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 (mix of particles and 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
- more in-orbit cross calibration and qualification is needed

in-orbit cross calibration

- In-orbit cross calibration of two (or more) space environment sensors:
    - on the same satellite
    - at the same location & time
    - under the same conditions
    - would provide a full comparison
- The in-flight cross calibration would enhance the scientific value of the data sets of all involved sensors
- Cross calibration and qualification could happen at the same time:
    - old and new sensors flying next to each other on the same satellite

Parallel measurements of two (or more) sensors

- Overlapping measurements can serve many purposes:
  - Calibration
  - Qualification
  - Correlation
- Many possibilities of combing two (or more) sensors:
  - total dose + total dose
  - total dose + charging + plasma
  - old sensor (heritage) + new sensor (no heritage)
  - old data sets + new data sets
  - sensitive sensor (many channels) + non-sensitive sensor (few channels)
  - external + external
  - external + internal

possible candidates for cross calibration

- ESA‘s Standard Radiation Monitor (SREM), flying 7 satellites, 2 spare units left over
- ESA‘s Next Generation Radiation Monitor (NGRM), 14 to 17 units planned
- ESA's new NGRM radiation monitor will fly on satellites build by OHB:
  - EDRS-C
  - MTG satellites
  - possible on a EPOR telecom satellite (TBC)
- OHB proposes to fly further radiation (and space environment) sensors next to the NGRM for the purpose of in-orbit cross calibration (and qualification of new sensors):
  - e.g. NGRM + SREM spare unit
  - e.g. NGRM + two new radiation and charging sensors
  - preferable on an Electrical Propulsion Orbit Raising (EPOR) mission
  - OHB could fly sensors on their satellites
  - other manufactures could fly sensors on their satellites

Galileo – perfect candidate for overlapping measurements

- Galileo First Orbiting Constellation (FOC)
    - 34 satellites build by OHB
    - but only 2 radiation sensors (EMU)
    - direct insertion into MEO, no GTO phase
- Galileo work-order 4 (WO4) and Galileo 2nd generation (G2G) would be nice candidates:
    - each Galileo Satellite could carry a different sensor
    - high number of satellites = many sensors in the same orbit
    - many satellites flying in the same orbit = inter-calibration of sensors
    - G2G will use EPOR = higher radiation exposure then Galileo FOC
- the Space community should lobby the European Commission:
    - to initiate a hosted payload programme for all kind of space environment sensors
    - to fly as many sensors as possible on Galileo WO4 and G2G

roadmap for OHB cross calibration intiative

- kick-off at SpaceMon 2017 workshop
  - overview of all current space environment sensors available and in planning
  - collecting specification of space environment sensors
- raising awareness and collecting feedback from the space community
- preferable getting feedback and endorsement from ESA and CNES and space industry
- motivating other satellite manufactures to join the initiative:
  - Thales Alenia Space (TAS) is building the NGRM sensors
  - TAS is as well a satellite manufacturer
  - cooperation with TAS would be a win-win-situation
- meeting of the main stake holders
  - selecting the best sensor candidates for overlapping measurements
- initiate an internal feasibility study at OHB

roadmap for OHB cross calibration intiative

- OHB internal feasibility study:
  - looking at the integration of several candidate sensors on different upcoming OHB sat.
  - calculating the integration costs
- other manufactors should as well calculate their integraton costs of sensor candidates
- round table with all stake holders:
  - review of the integration costs
  - review of possible sources to fund the sensors and the integration costs
- contractual agreement
- integrate the sensors
- fly the sensors
- share the sensor data with the community
- update the space environment models and improve the satellite designs

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

Questions ?

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