Highlights of the SPACESTORM project

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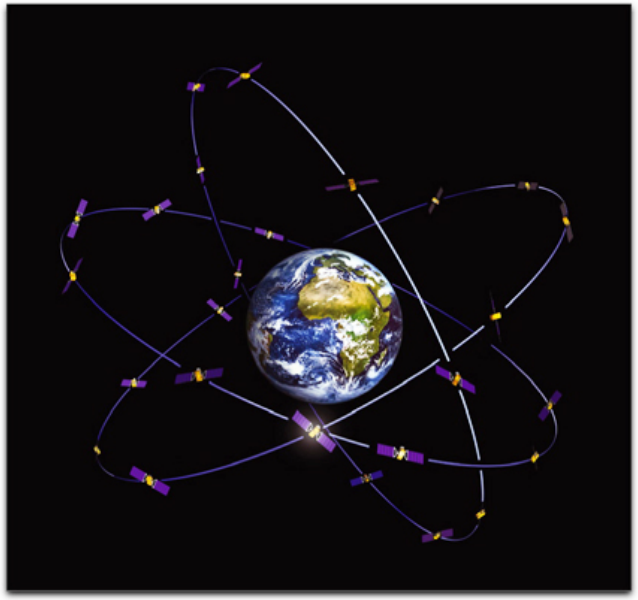
Close Out Meeting, Cambridge, UK, 23 March 2017



Background

- Space is strategically important
  - Business
  - Construction, launch, operation, Insurance
- Over 1400 operational satellites
- Satellite are vulnerable to high energy particles
- Vulnerability a concern
  - Growing reliance on satellites
  - Electric orbit raising
  - New technology
- Extreme Space Weather causes risk of damage
  - Impact?
  - National Risk Register



Galileo - Courtesy of ESA

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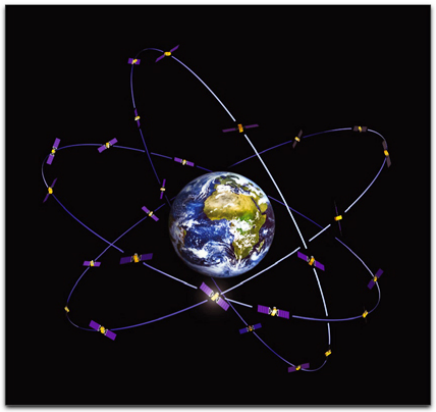
Satellite Anomalies – Related to Space Weather

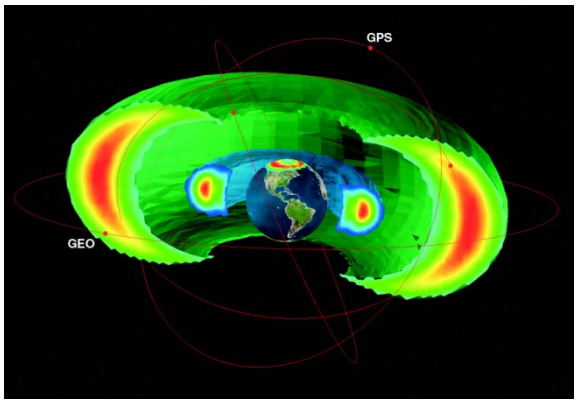
- 20th Jan 1994
  - Intelsat 4 and Anik E1 - recovered in a few hours
  - Anik E2 - Loss of service for 6 months
- 11th January 1997
  - Telstar 401 - Total loss – Insurance payout $132m
- 19th May 1998
  - Galaxy IV - Total loss – Insurance payout $165m
- 23rd Oct to 6th Nov 2003
  - 47 satellites reported malfunctions – 1 total loss
  - 10 satellites – loss of service for more than 1 day
- 3rd Aug 2004
  - Galaxy 10R – loss of propulsion – Insurance payout $75m
- 5th Apr 2010
  - Galaxy 15 - Loss of service for 8 months - risk of collision
- 7th March 2012,
  - Sky Terra 1 and Spaceway 3 - Safe mode, loss of service for hours – days
- April 2015 - loss 4 days before insurance policy ran out – insurance claim
- 16, Jan 2016
  - AMOS 5 declared dead – insurance claim

SPACESTORM - The Goal

Satellites



Radiation Belts



- Goal
  - To model severe and extreme space weather events and mitigate their effects on satellites
  - by developing better mitigation guidelines, forecasting
  - by experimental testing of new materials and methodologies to reduce vulnerability.

The SPACESTORM Team

BAS

U. of Surrey

DH Consultancy

FMI

ONERA

And many other international collaborations common for research projects

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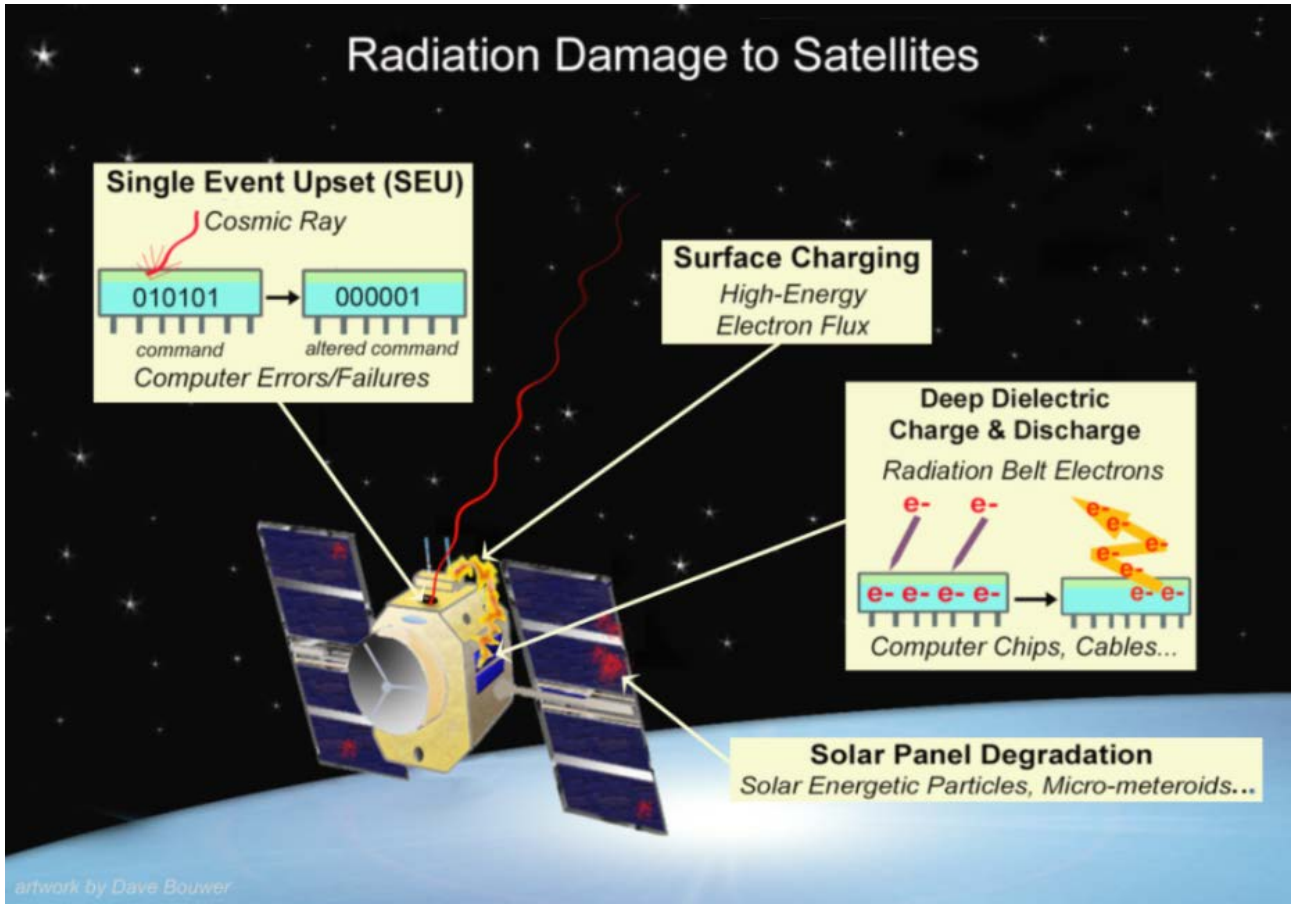
Stakeholder Advisory Team

- David Pitchford — SES, Luxembourg
- Justin Likar — UTC Aerospace Systems, USA
- David Wade — Atrium Space Insurance Consortium, London
- Janet Green — Space Hazards Applications, USA
- Richard Thorne — University of California, Los Angeles
- Carlos Amiens — EC Joint Research Centre, Italy

- Plus a wider Stakeholder community – ESWW 11, 12, 13

Radiation Damage to Satellites



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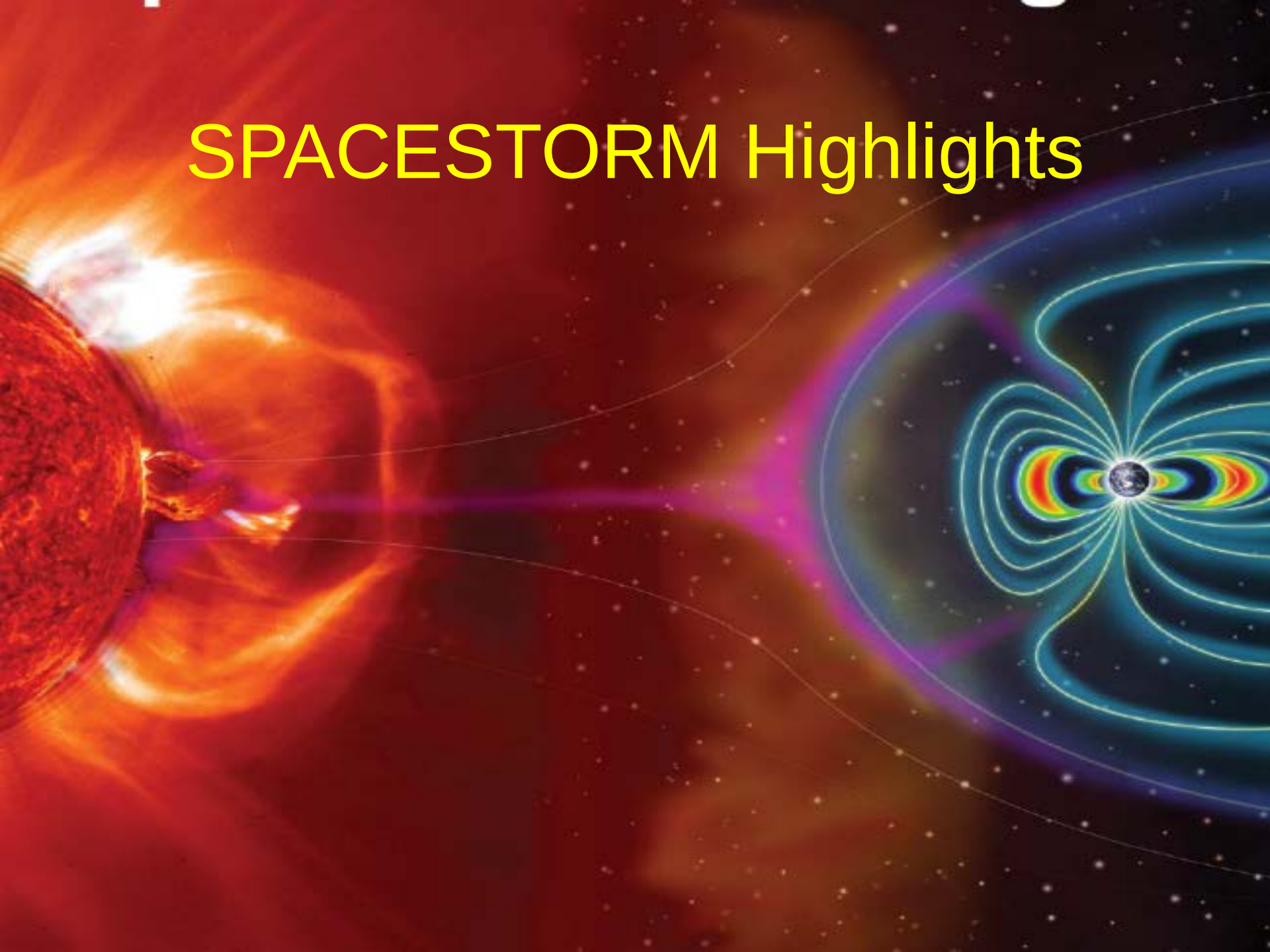
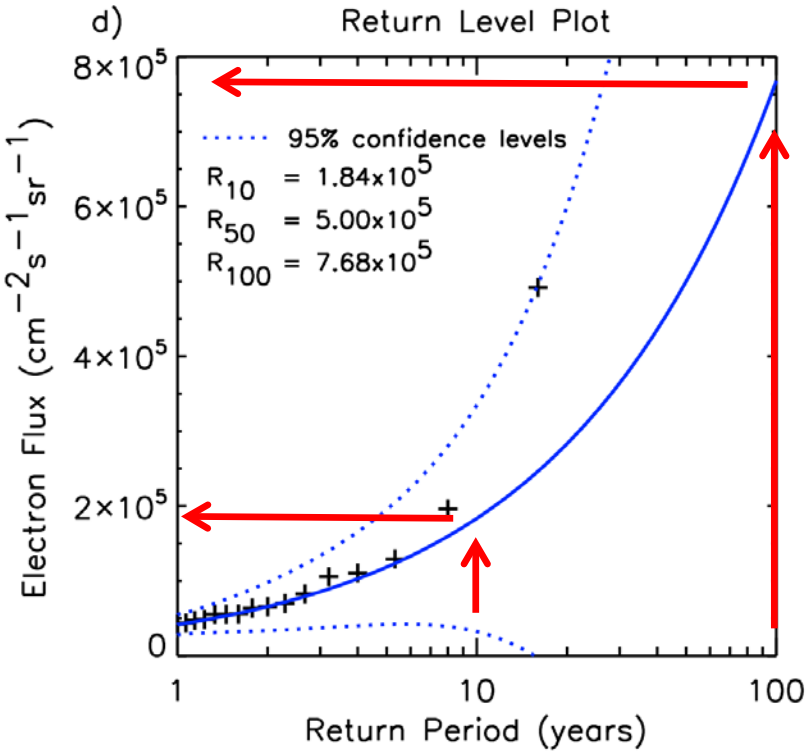
SPACESTORM Highlights



Highlight – 1 in 100 Year Event

- Geostationary Orbit
- 1 in 100 year electron flux 7 times higher than earlier calculations
- Impact
- Used to update UK National Risk Register
- Used to evaluate satellite tenders by 1 Satellite Operator



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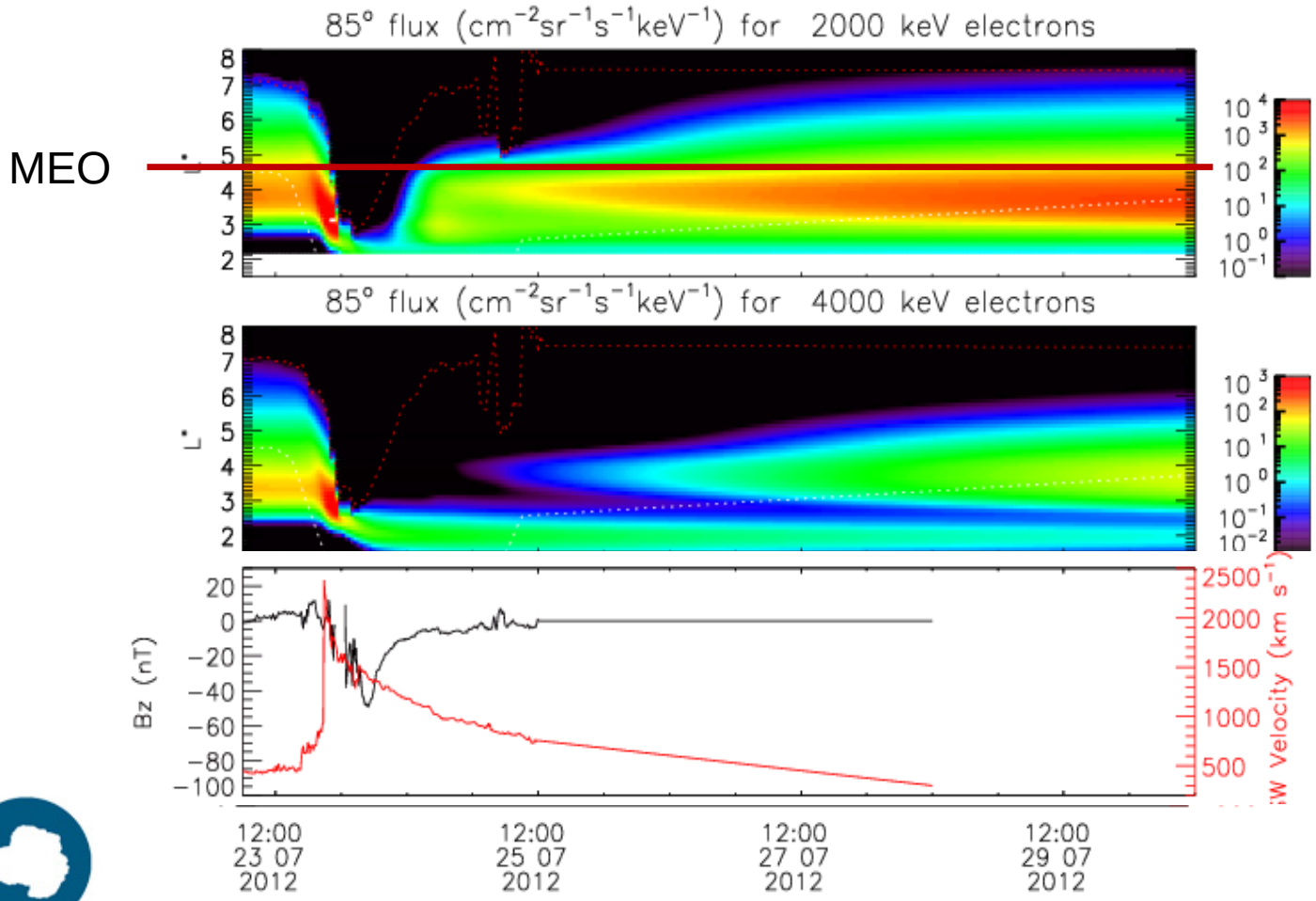
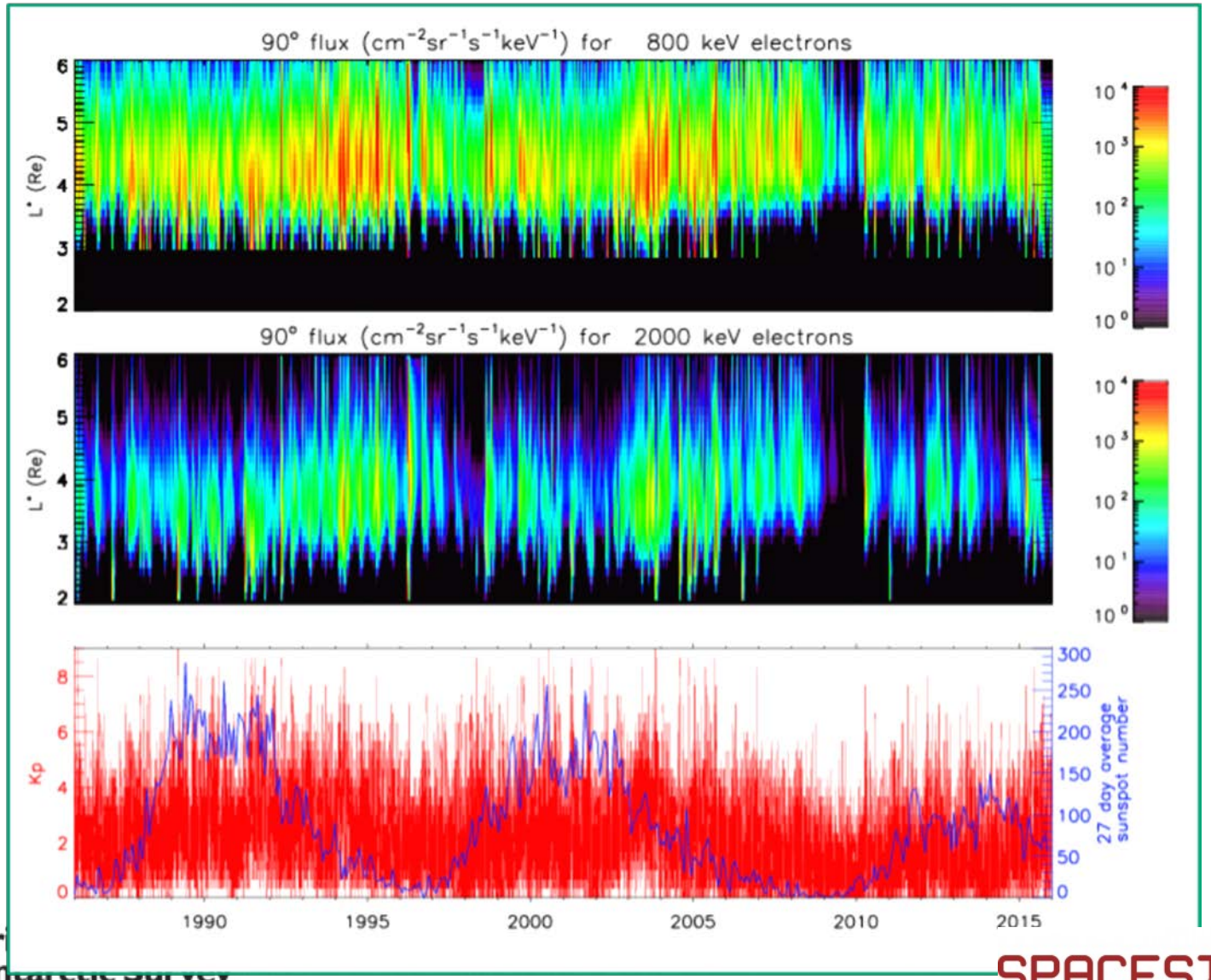
Highlight - Simulation of an Extreme SW Event

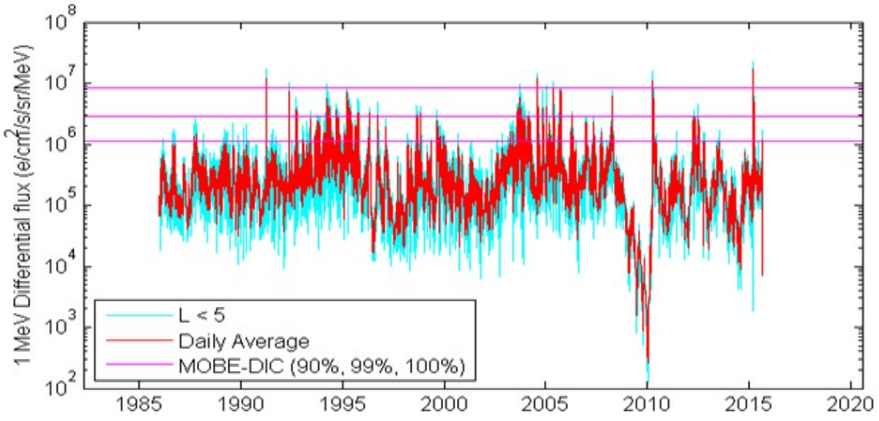
- What would happen if the July 2012 CME struck the Earth?
- Use satellite data from Baker et al., [2013]
- Satellites in Medium Earth Orbit more at risk – for days – also LEO?

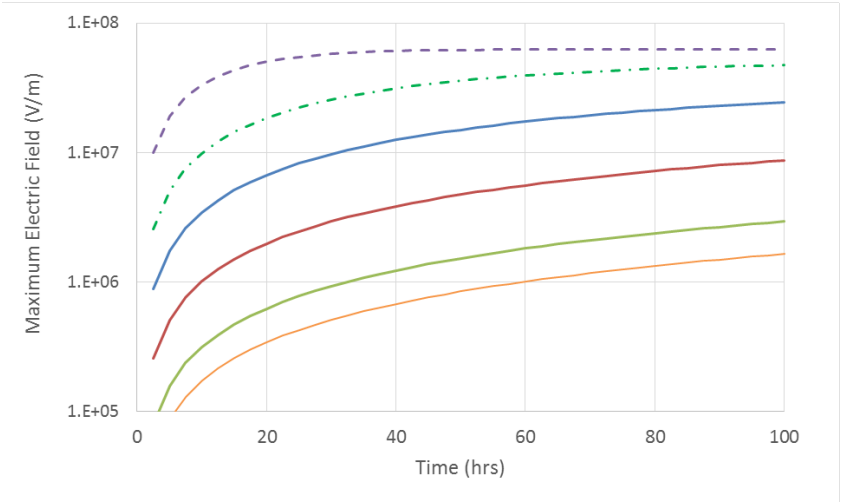


Highlight - 30 Year Simulation of the Radiation Belts



Highlight – Radiation Effects at Medium Earth Orbit





- Use the 30 year model reconstruction
- Galileo type orbit – MEO, inclined
- Select the “worst day”
- An ESD – anomaly - can occur within 2-3 hours
- Material = PEEK

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Highlight – Long Duration Low Intensity Experiments

- Satellites are designed for ~ 15 years
- But what are the effects of low intensity continuous radiation?
- Lab experiments at Surrey Space Centre for ~ 2 years

Realistic Electron Environment Facility (REEF)
(Sr-90 source)

Risk of ESD even at lowest current (0.01 pA/cm^2) for some materials

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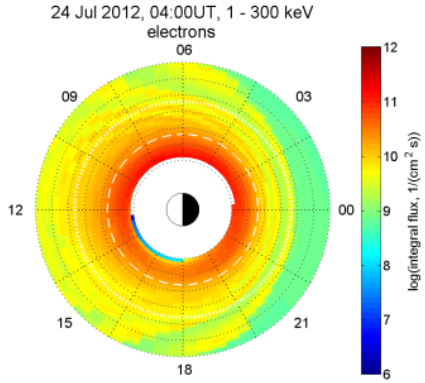
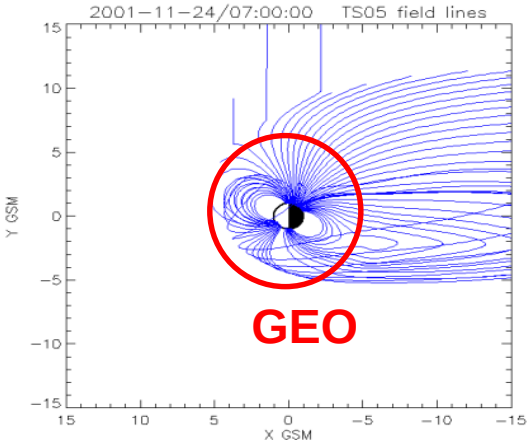
Extreme space storms

Low flux at GEO and MEO



Highly distrubed magnetic field lines



IMPTAM e- flux

- Surface charging is caused by injections of low energy electrons ~ keV
- Extreme surface charging can occur outside an extreme storm
- Modelling the time dependence is still a serious challenge

Highlights – Satellite Surface Charging

Using

- Model results (IMPTAM)
- 15 years of data from Los Alamos Satellites
- Our analysis of the flux for a 1 in 100 year event from POES

- Performed new simulations of satellite surface charging (using SPIS)

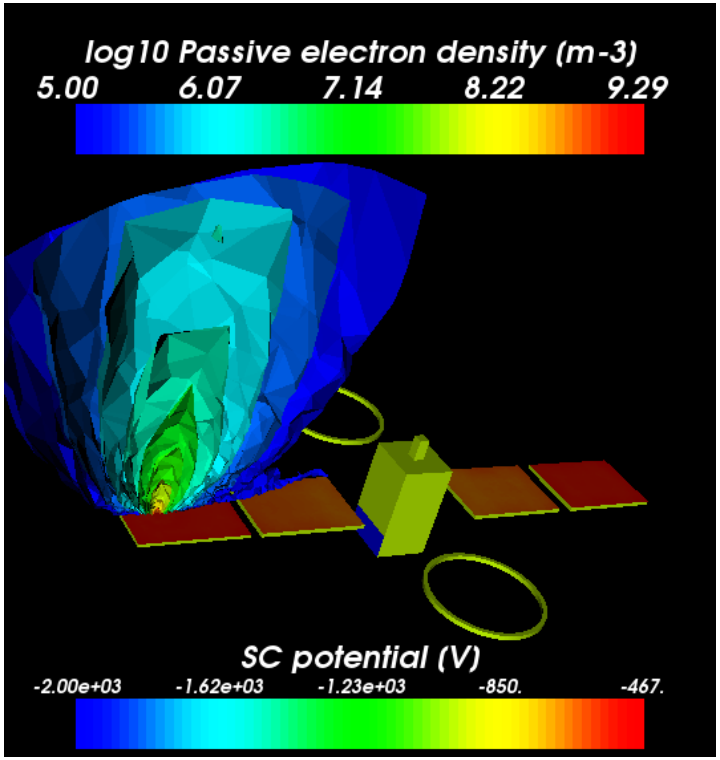
Key result

- Extreme SW events (e.g., CME of July 23, 2012) would increase the ESD risk by a factor of 5 wrt the European Standard (ECSS) worst-case
  - Both at GEO and at MEO

Impact

- New recommendations on what to use for the worst case
- Input to revise the European Standard (ECSS)

Highlight – Mitigating Surface Charging



- Passive electron emitter - reduce surface charge
- Important for solar arrays
- Tested several designs in the lab
- Used worst case environment for a telecom satellite at GEO
- Found that the charging potential can be reduced from 6 kV to 1 kV

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Highlight – Experimental Analysis of Satellite Charging

GEODUR facility

- New materials – what are the effects of radiation?
- Lab experiments are time limited, so
  - Use intense radiation to speed up the process
  - Is it valid?
- Tested Teflon, Kapton, PEEK, and ETFE cables
- Materials like ETFE cables
  - No radiation induced conductivity
  - Intense radiation method is valid
- Materials like PEEK and Kapton wires
  - Radiation increases conductivity
  - Method possible - after careful analysis

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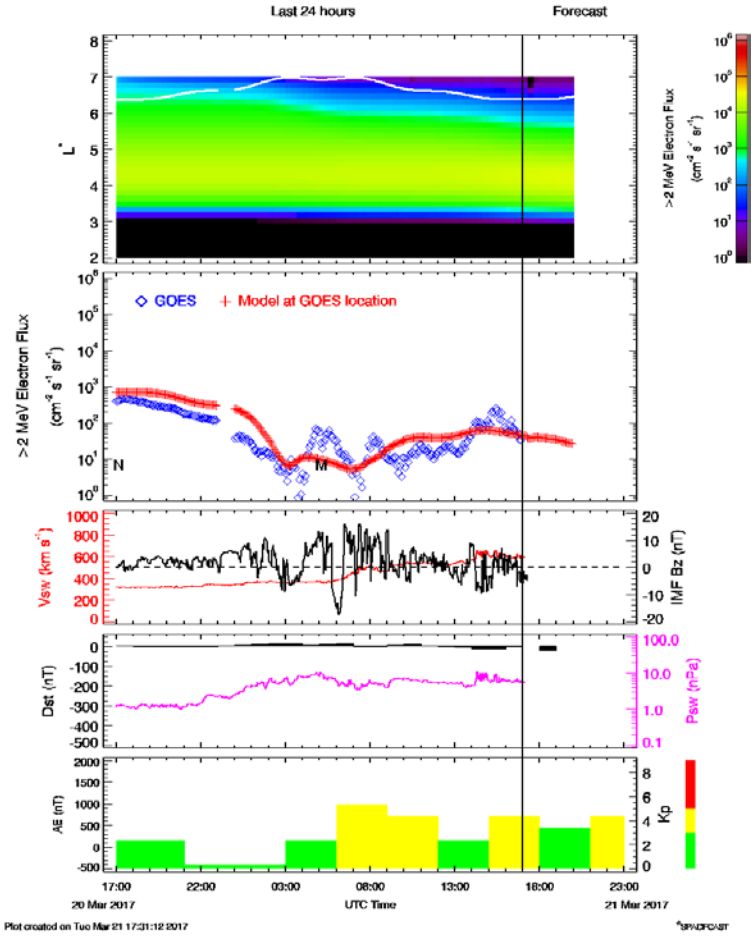
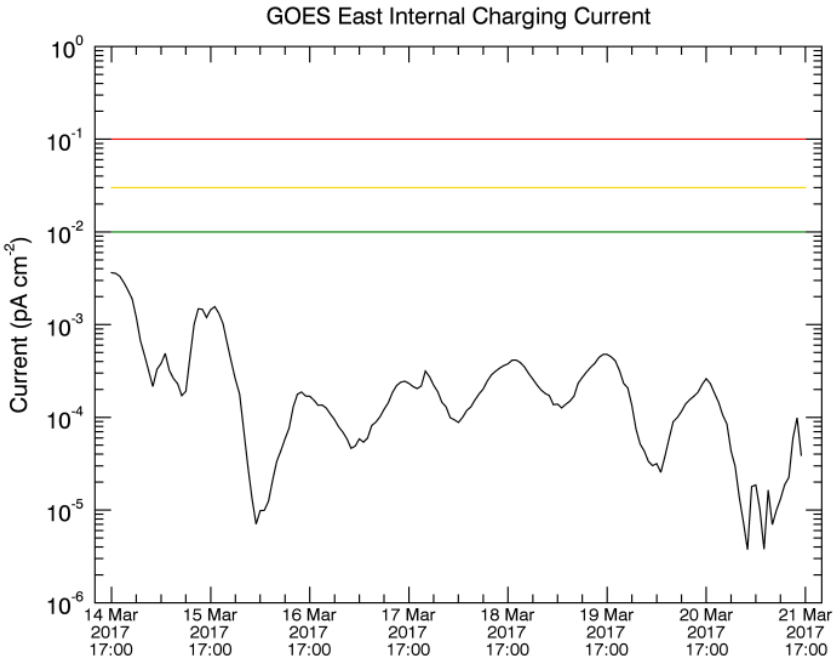
Integrate Radiation Environment with Effects on Materials



- Concept - Risk Indicator
- Charging current behind 2 mm of shielding
- Compare against NASA design standard
  - And our 1 in 100 year event level



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Achievements - Summary

- Brought together Science, Engineering and Businesses across Europe
- Published important new scientific and engineering results
  - Extreme Space Weather events
- Provided advice
  - To Government – UK Risk Register
  - To European Co-operation for Space Standardisation (ECSS) - charging
  - To European Space Agency – passive spacecraft charging aleviation
- Results have been used by European companies for satellite procurement
- Integrated the Space Environment with Radiation Effects on Satellites
- Significantly improved real-time Space Weather forecasts
- Significantly improved European test/research capabilities - REEF

Thank You

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