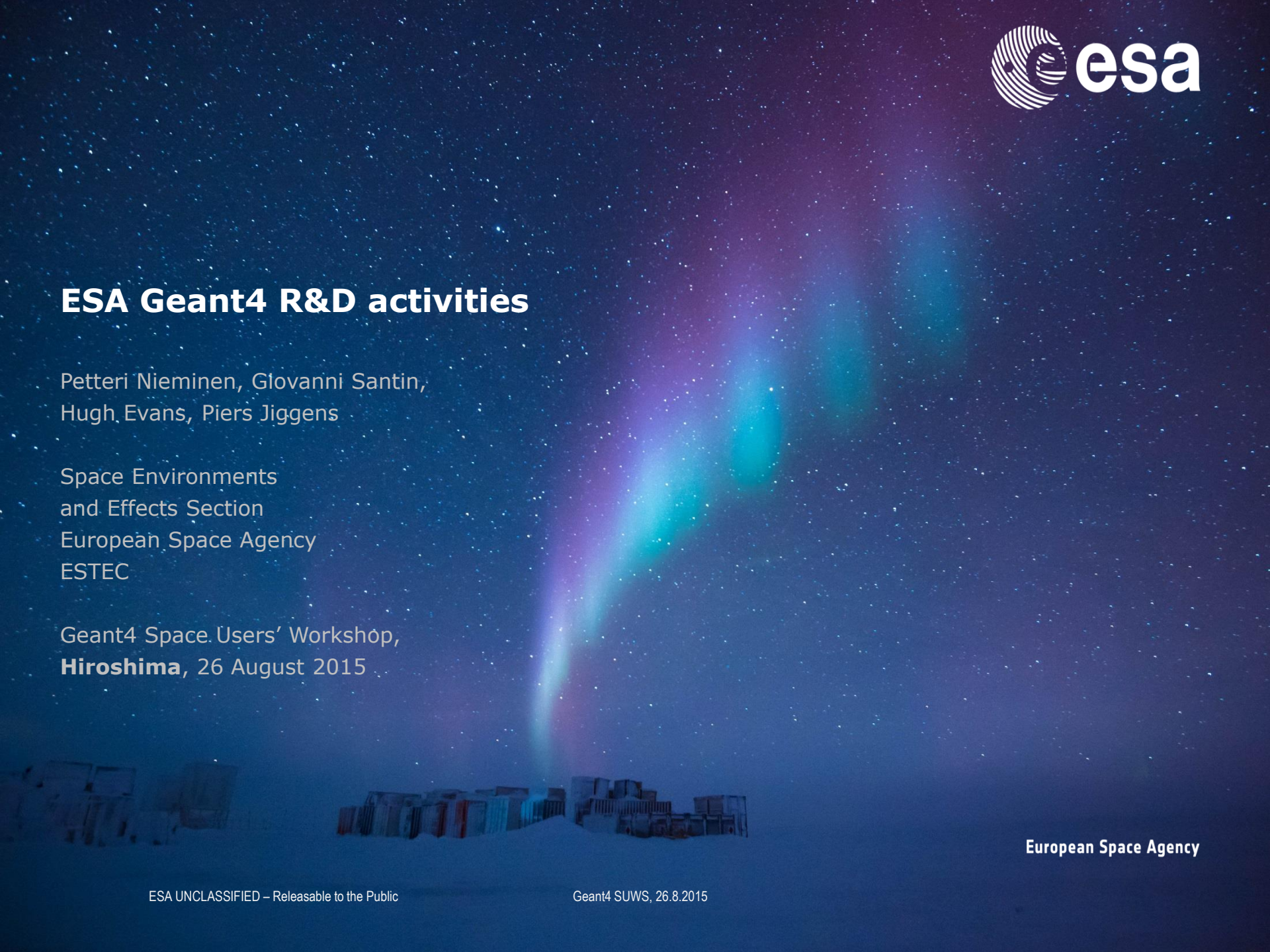


ESA Geant4 R&D activities

Petteri Nieminen, Giovanni Santin,
Hugh Evans, Piers Jiggens

Space Environments
and Effects Section
European Space Agency
ESTEC

Geant4 Space Users' Workshop,
Hiroshima, 26 August 2015

European Space Agency

Contents

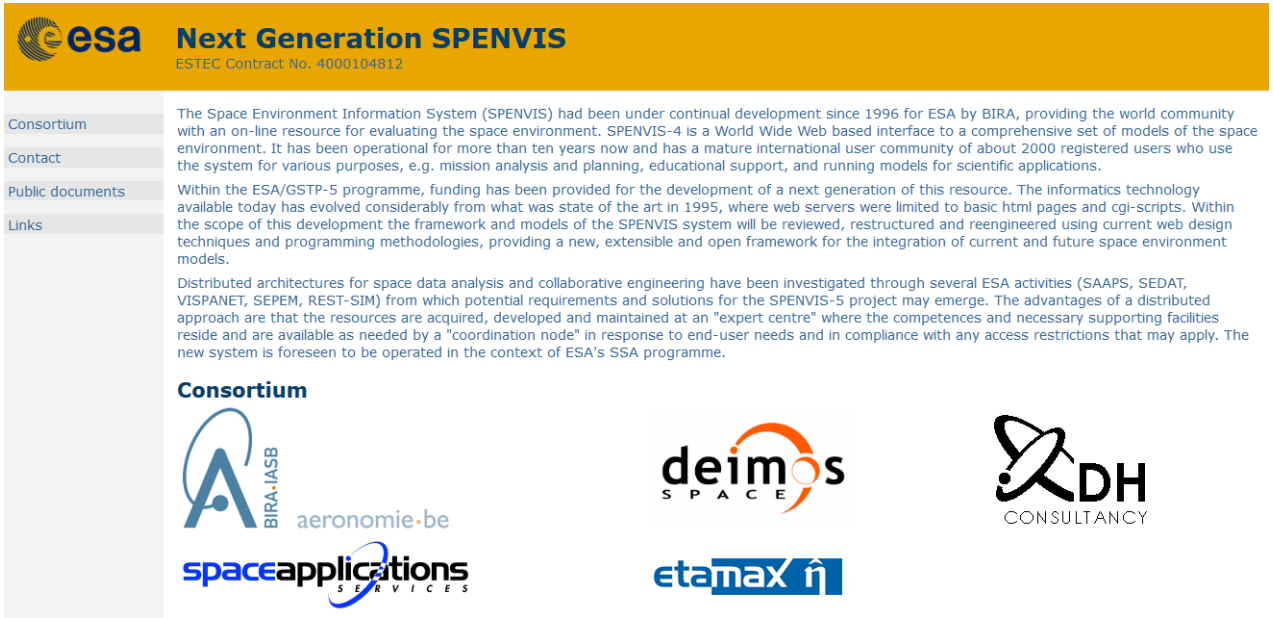
- ESA Programmes status and outlook 2015 on
- Main ESA missions where Geant4 is applied
- Geant4-based radiation engineering tools and models
- (Some) ongoing and planned R&D activities
- Outlook and Conclusions

ESA Programmes Outlook
(in context of energetic particle interactions)

- Demanding Science missions
  - ✓ Rosetta, GAIA ongoing
  - ✓ In preparation: JUICE, Athena , Solar Orbiter, ExoMars, Cheops
  - ✓ LISA Pathfinder to be launched by end of 2015; BepiColombo in 2017
- Human missions:
  - ✓ ESA will construct service module for Orion (needs high immunity from radiation effects): Airbus design selected in May 2014
  - ✓ Preparation for missions beyond LEO (shielding, biological effects), possibly Moon
- Earth observation missions with considerable on-board processing (susceptibilities, especially SEE)
- Telecom and Navigation (Galileo) in highly severe outer radiation belt environment
- Technology spacecraft ("Proba" series), next Proba-3

Radiation Engineering tools: SPENVIS https://www.spenvis.oma.be/

- 10,000 + registered users
- Models and tools for the space environments effects analysis
- Web Interface
- A range of Geant4-derived tools and models (MULASSIS, SSAT, GEMAT,…)
- Link to GRAS
- Jupiter-related models and tools to target the JUICE mission under “JOREM”: JOSE environment, shielding assessment. Now also Ganymede environment “GREET”
- New NIEL models (INFN Milan) implemented to SPENVIS in 2015

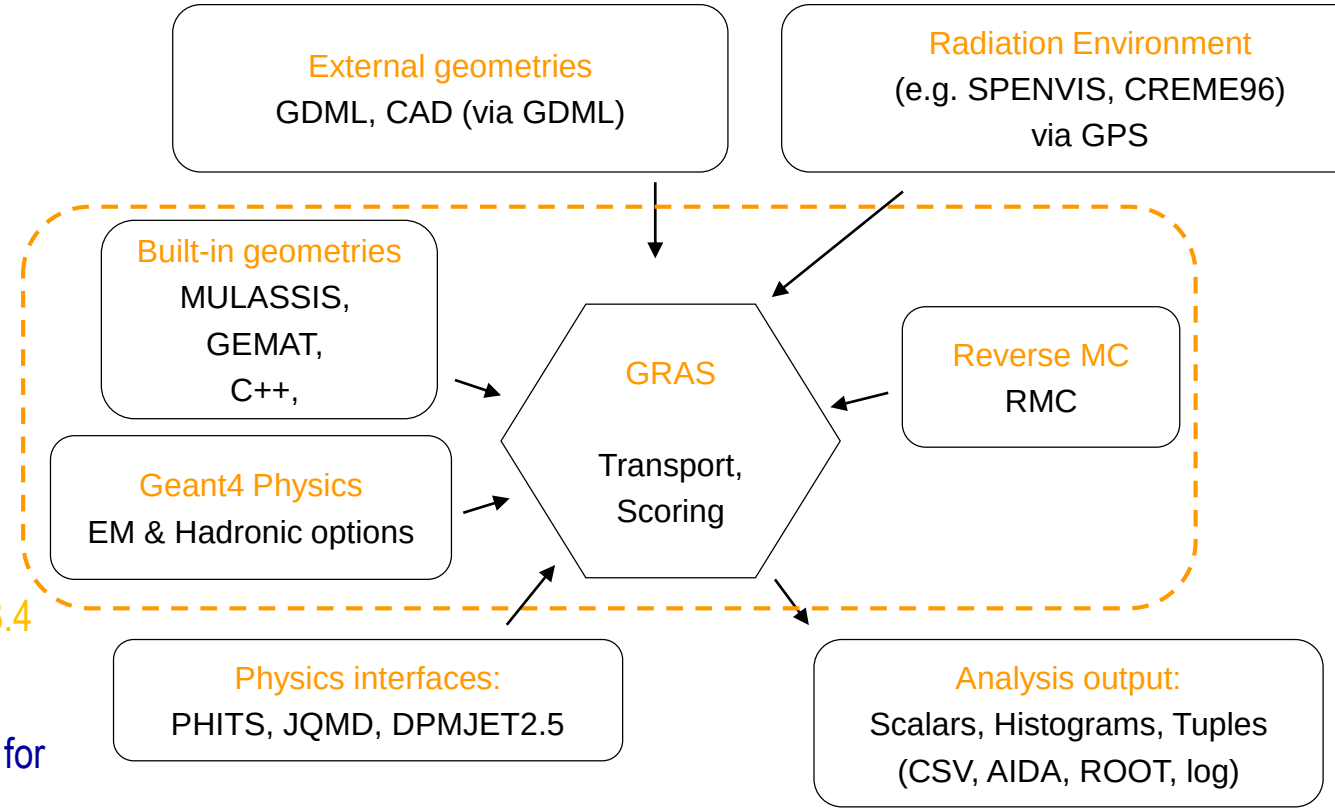


Under development: Next Generation of the system ‘(“SPENVIS-NG”), to be deployed in 2015

Geant4 tool integration: GRAS

(Geant4 Radiation Analysis for Space)

- Ready-To-Use tool
  - Multi-mission approach
- Quick assessments
  - Ray-tracing ↔ MC
  - 1D ↔ 3D
  - EM ↔ Hadronics
  - LET ↔ SV details
- Modular progress
  - Open to collaborations and contributions
- Currently GRAS v3.3, v.3.4 in preparation 2015-2016
- Increasingly the baseline for much of ESA analyses
- Reverse MC: Substantial effort by Laurent Desorgher in 2014-2015

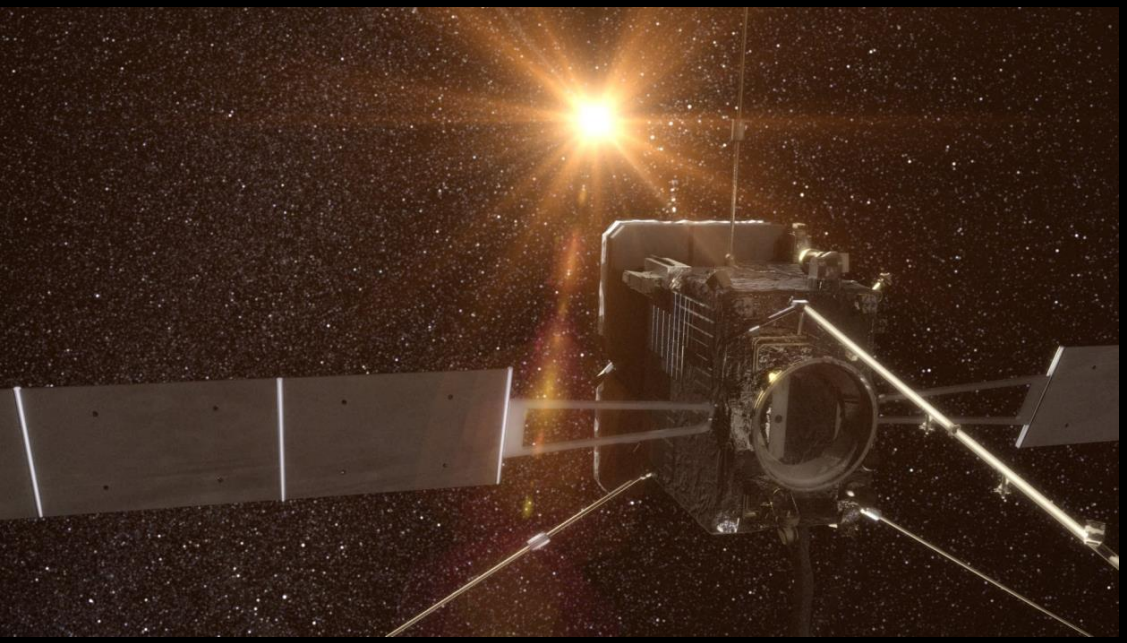


G Santin, V Ivantchenko et al, IEEE Trans. Nucl. Sci. 52, 2005

http://space-env.esa.int/index.php/geant4-radiation-analysis-for-space.html

https://www.spenvis.oma.be/help/models/gras.html

ESA Cosmic Vision M-class mission Solar Orbiter



- Examine how the Sun controls the heliosphere
- Launch planned for October 2018; mission of 7 years (+3 years extended)
- High-latitude (>25°) observations between 0.28 and 0.94 AU
- Combination of remote sensing and in situ observations, with 10 instruments
- Highly demanding mission environment
- Various Geant4 instrument analyses

Journal of Instrumentation > Volume 10 > February 2015
O. Grimm *et al* 2015 *JINST* **10** C02011 doi:10.1088/1748-0221/10/02/C02011

Performance and qualification of CdTe pixel detectors for the Spectrometer/Telescope for Imaging X-rays

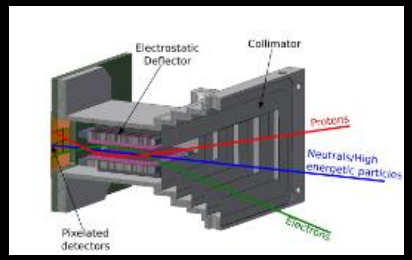
7TH INTERNATIONAL WORKSHOP ON SEMICONDUCTOR PIXEL DETECTORS FOR PARTICLES AND IMAGING

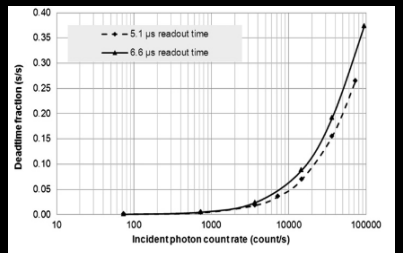
O. Grimm[a,d], M. Bednarzik[b], G. Birrer[b], N. Arnold[d], V. Commichau[a], G. Hurford[d], S. Krucker[d], O. Limousin[c] and A. Meuris[c]
Show affiliations

The SupraThermal Electrons, Ions and Neutrals (STEIN) detector for Solar Orbiter

Christoph Terasa[1] for the Solar Orbiter STEIN team[1], Robert P. Lin[2], Dong-Hun Lee[3], Ho Jin[3], Olivier Limousin[4]

[1] Christian-Albrechts-Universität, Kiel, Germany [2] Space Sciences Laboratory, University of California, Berkeley, CA, United States [3] Kyung-Hee University, Yongin, Gyeonggi, Republic of Korea, [4]CEA/Saclay, DSM/Irfu/Sap F-91191,Gif-Sur-Yvette, France





Dissertation (Metadaten)

Titel (original):	**Developments and Numerical Simulations for the Electron-Proton-Telescope Onboard Solar Orbiter**
(übersetzt):	Vorarbeiten und numerische Simulationen für das Electron-Proton-Teleskop an Bord von Solar Orbiter
Autor:	Rolf Paspirgilis
URN:NBN:	urn:nbn:de:gbv:8-diss-104689
Fakultät:	Mathematisch-Naturwissenschaftliche Fakultät
DDC Sachgebiet:	530 Physik

Caliste-SO X-ray micro-camera for the STIX instrument on-board Solar Orbiter space mission

A. Meuris[a], G. Hurford[b], M. Bednarzik[c], O. Limousin[a], O. Gevin[a], I. Le Mer[a], J. Martignac[a], B. Horeau[a], O. Grimm[d], R. Resanovic[c], S. Krucker[d], P. Orleański[e]
Show more

EP 4.42: Poster

Dienstag, 26. Februar 2013, 11:15–12:45, Poster OG

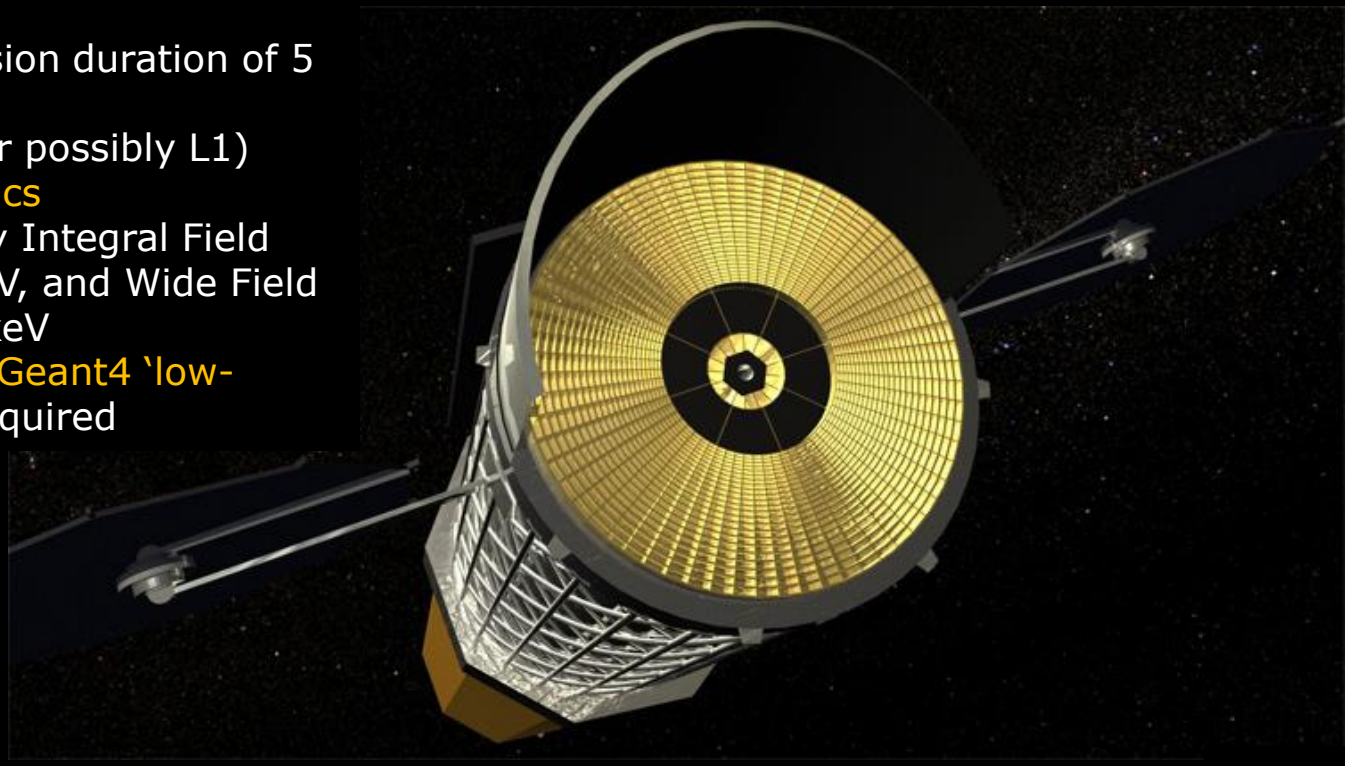
Auswahlstatus für diesen Beitrag: gemäß den Sitzungseinstellungen

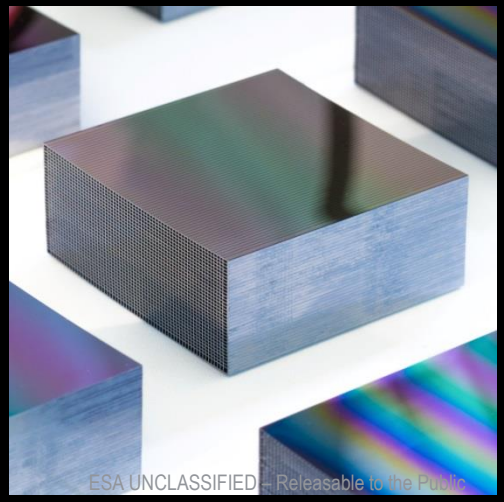
Scintillation quenching in BGO crystal of the Solar Orbiter HET – J. Grunau, S.R. Kulkarni, C. Martin, S. Boettcher, L. Seimetz, B. Schuster, A. Kulemzin, and R.F. Wimmer-Schweingruber – IEAP, Christian-Albrechts-Universität zu Kiel, Germany

The High-Energy Telescope (HET) on ESA's Solar Orbiter mission will measure electrons from 300 keV up to about 30 MeV, protons from 10 to 100 MeV and heavy ions from approximately 20 to 200 MeV/nuc. These measurement capabilities are reached by a combination of solid-state tracking detectors and a scintillator calorimeter. This setup can perform particle identification via the dE/dx vs total E technique. The scintillator approach provides a good resolution over the complete energy range but the total energy deposition has to be corrected for the scintillation quenching. The quenching lowers light output depending on the type and energy of the incident particle. We measured the crystal response for different heavy ions and energies and compared them to simulated values. Simulations were carried out using the GEANT4 toolkit provided by CERN. From comparison of simulated and measured data we were able to calculate quenching factors for the BGO crystals for ions up to iron. The results are of great interest for later data analysis with the HET telescope.

ESA Cosmic Vision L-class mission Athena

- Primary goals: Mapping hot gas structures and determining their properties; searching for supermassive black holes
- Launch 2028, with mission duration of 5 years
- Halo orbit around L2 (or possibly L1)
- Utilises silicon pore optics
- Two instruments: X-Ray Integral Field Unit (X-IFU), 0.3-10 keV, and Wide Field Imager (WFI), 0.1-12 keV
- Radiation background: Geant4 'low-energy' e.m. physics required

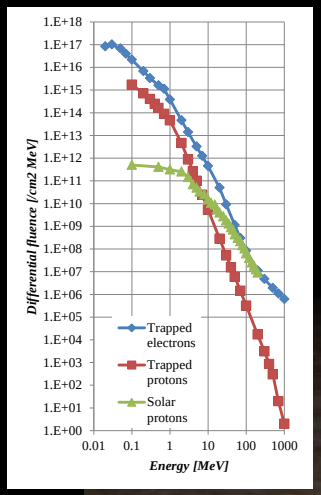


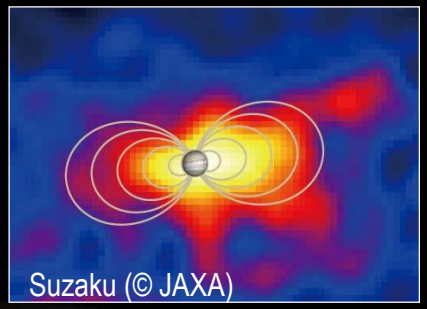


- Athena Radiation Environment Models and Effects Simulators (AREMBES): ITT closing on 25.9.2015
- Other R&D with Geant4 context in planning

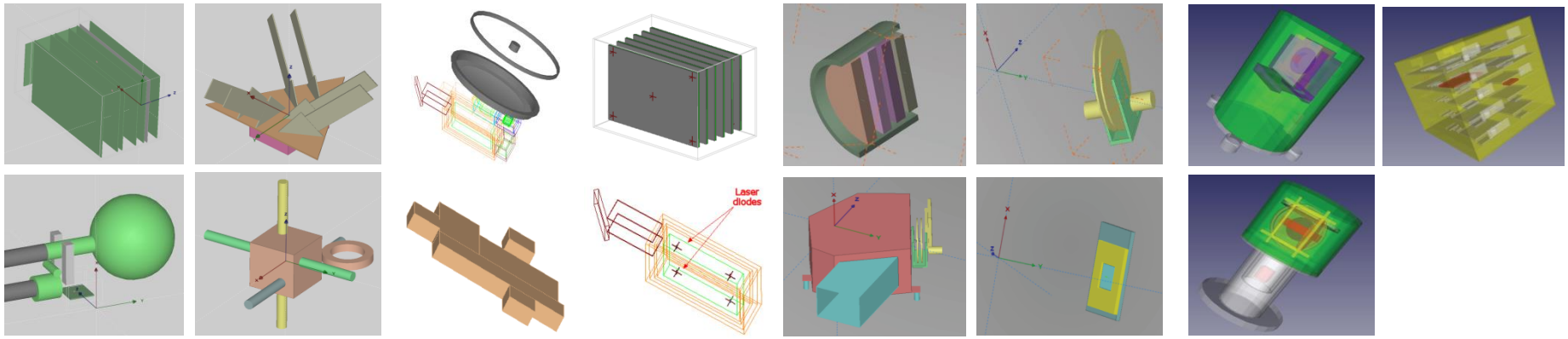
ESA Cosmic Vision L-Class mission JUICE (Jupiter ICy moons Explorer)

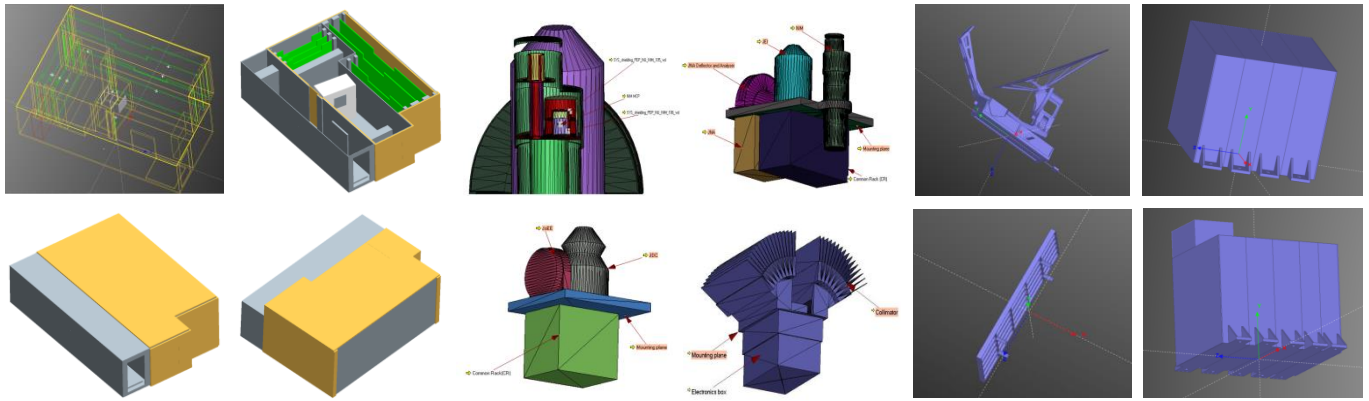
- Launch planned for 2022, arrival 2030
- Prime (Airbus) selected 17 July 2015
- 11 science instruments to be flown: http://sci.esa.int/juice/50073-science-payload/
- Japanese and US collaborations
- Giant Jovian magnetosphere and e- radiation belts up to several tens of MeV; protons
- Substantial shielding and background issues
- Broad range of radiation analysis activities (TID, charging, DD, noise, SEE) for platform and instruments, including Geant4 and GRAS





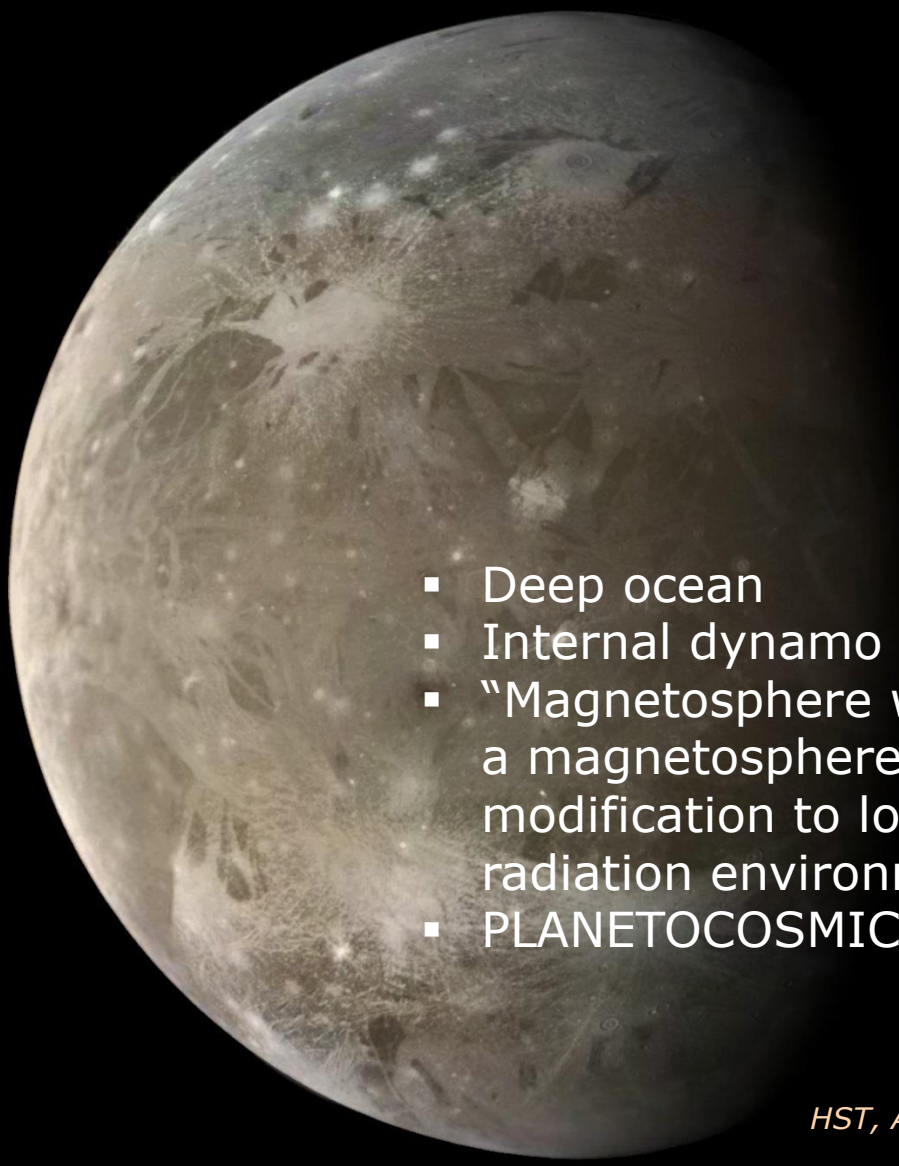
JUICE Instrument radiation models (GDML)



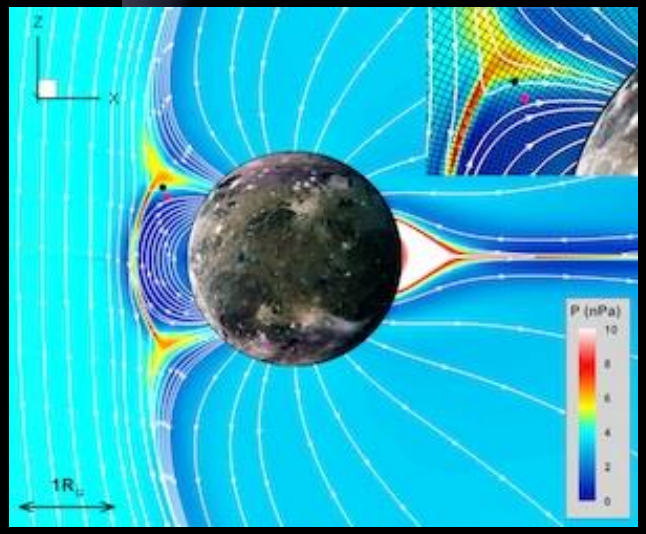


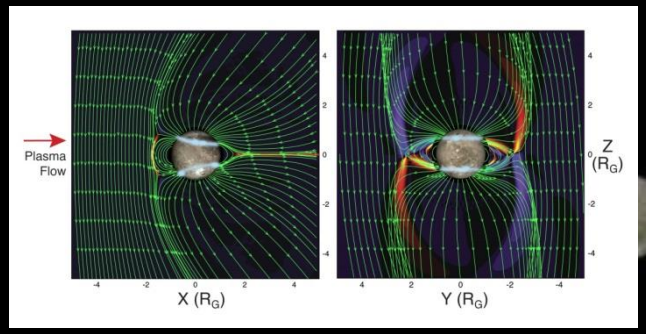
- Variety of radiation tools by instrument teams & industry
- GDML chosen as interface format
- Models used for accommodation studies and optimisation

Ganymede



- Deep ocean
- Internal dynamo
- "Magnetosphere within a magnetosphere" → modification to local radiation environment
- PLANETOCOSMICS-J



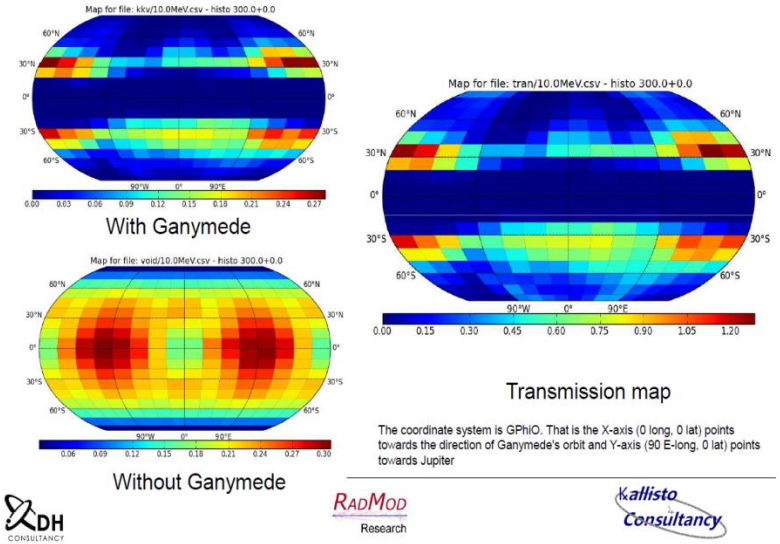


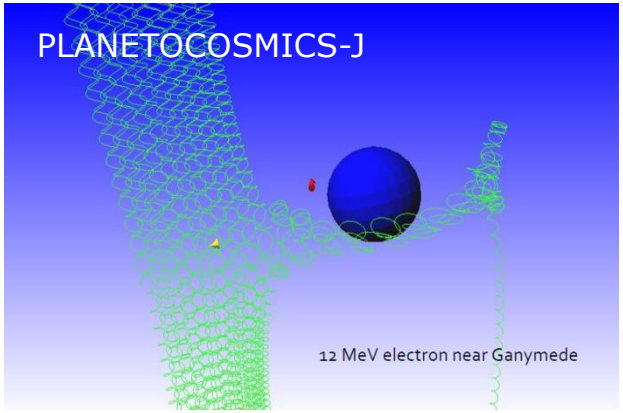
HST, April 9 2007

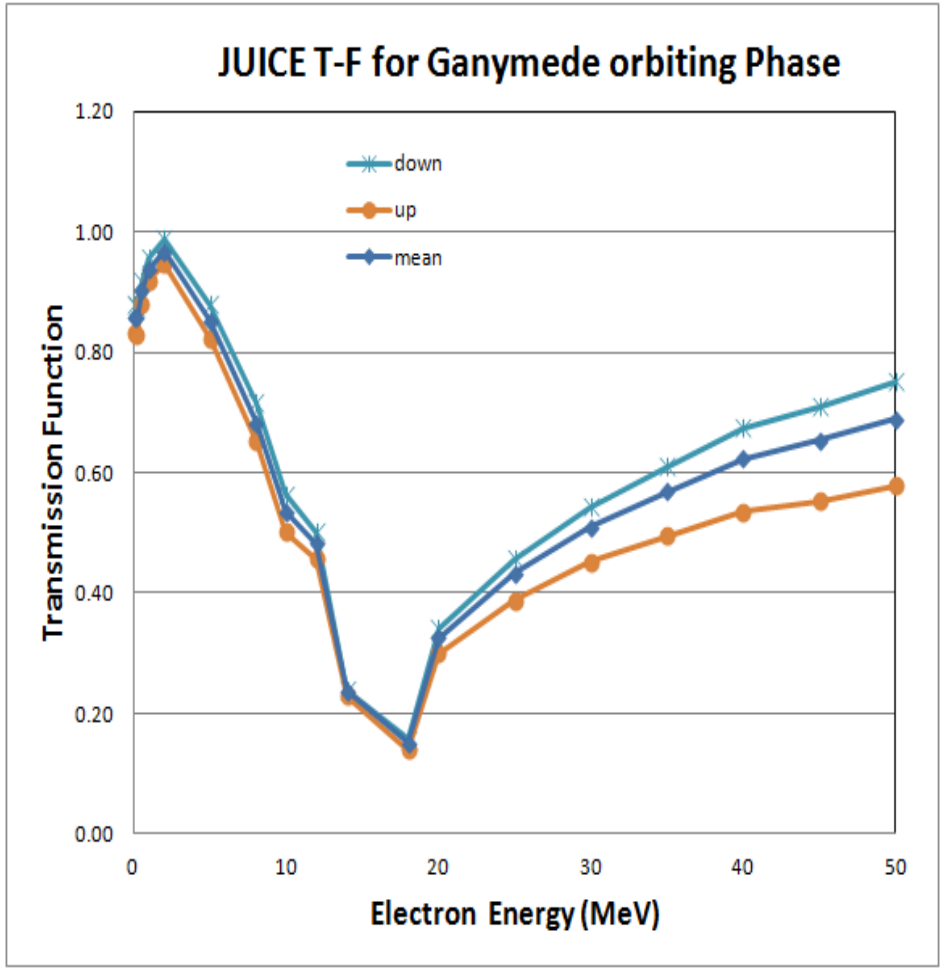
European Space Agency

Ganymede Radiation Environment Engineering Tool (GREET)

Transmission map calculation example



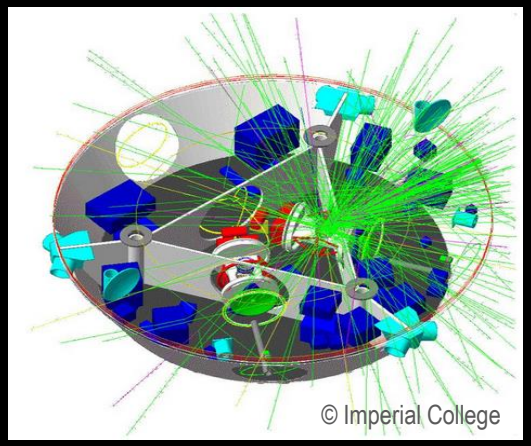


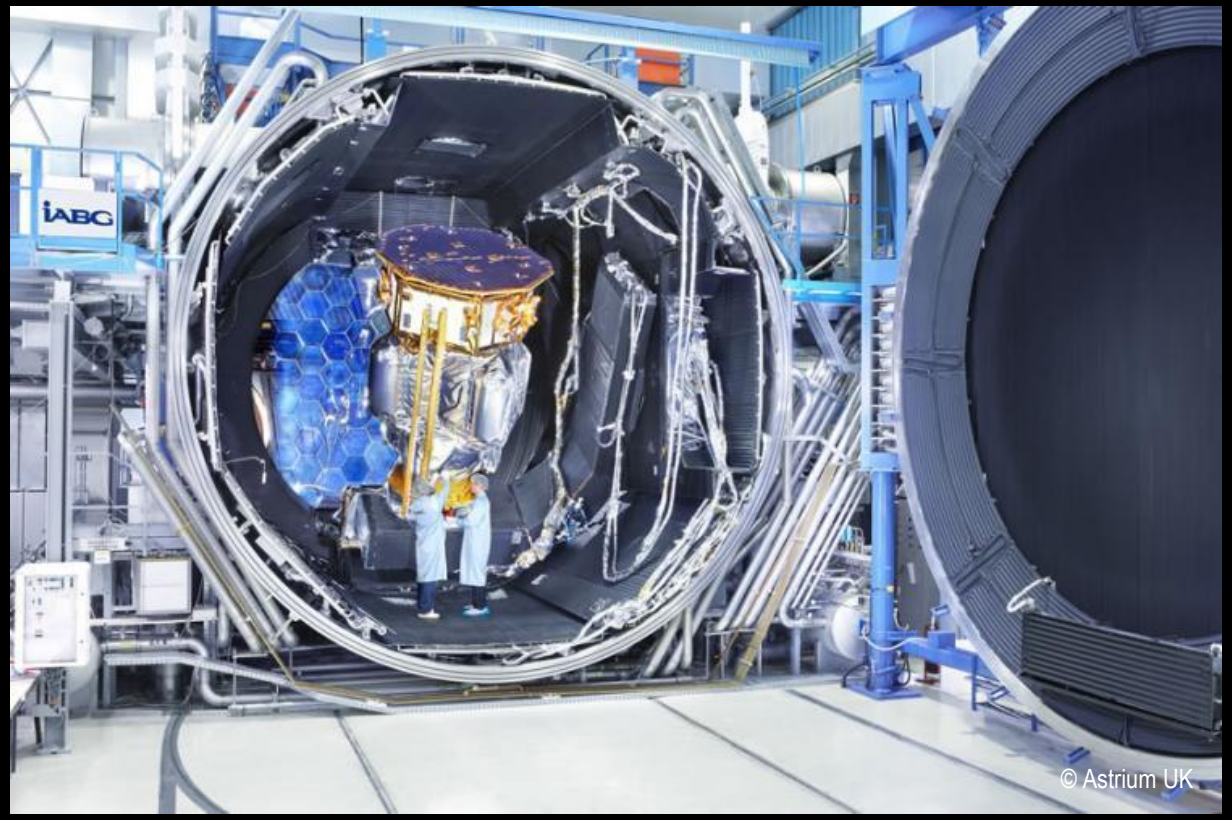


P. Truscott, D. Heyndericks, R. Nartallo, Fan Lei, A. Sicard-Piet, S. Bourdarie, J. Sorensen, L.Desorgher, "Application of PLANETOCOSMICS to Simulate the Radiation Environment at the Galilean Moons", Vol. 5, EPSC2010-808, 2010

LISA Pathfinder

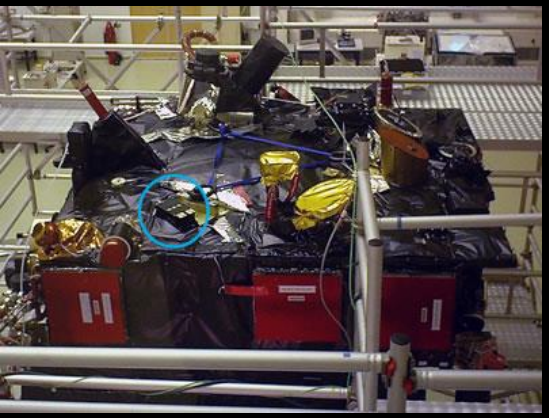
- Launch scheduled for autumn 2015
- Precursor to the potential ESA L3 mission ("eLISA") for gravitational waves
- Highly sensitive gravitational proof mass technology
- Detailed charging / radiation monitor simulations by MC, including Geant4

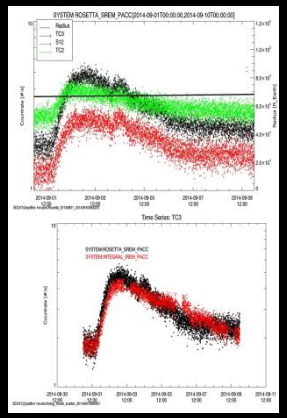


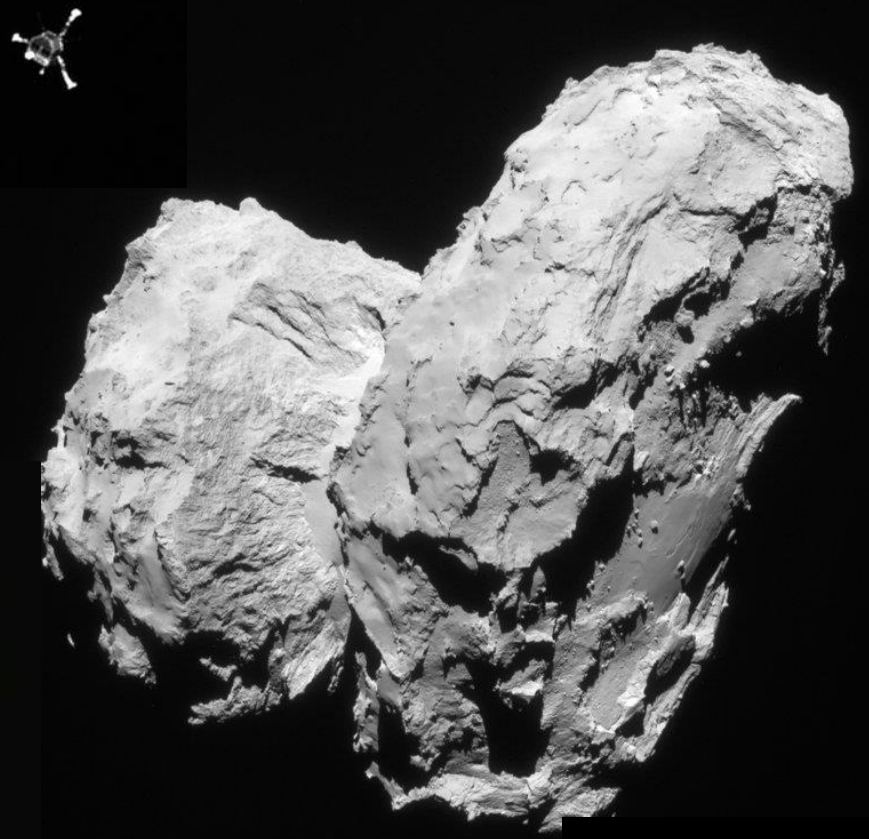


Rosetta

- Perihelion of Comet 67P/Churyumov–Gerasimenko on 13 August 2015
- Some (minor) SPEs observed by the onboard SREM instrument
- SREM response functions obtained by Geant4

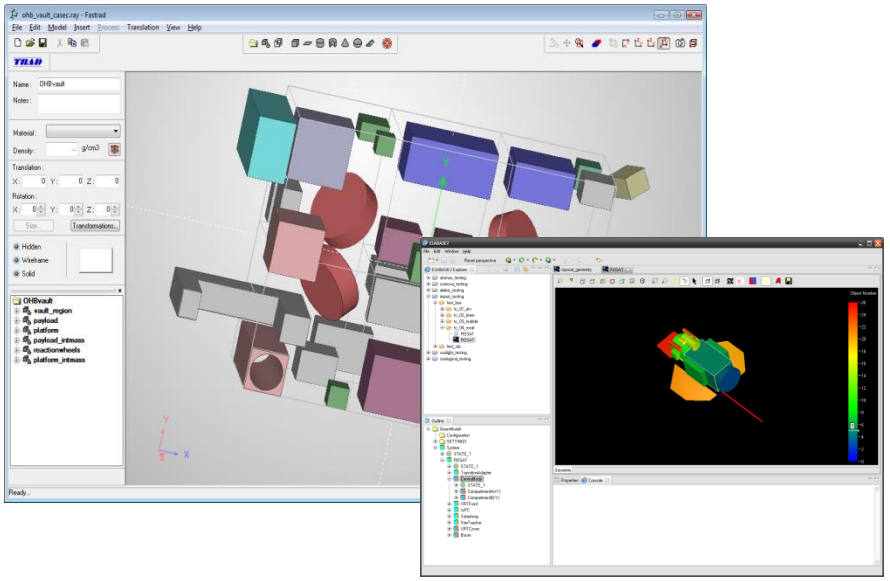


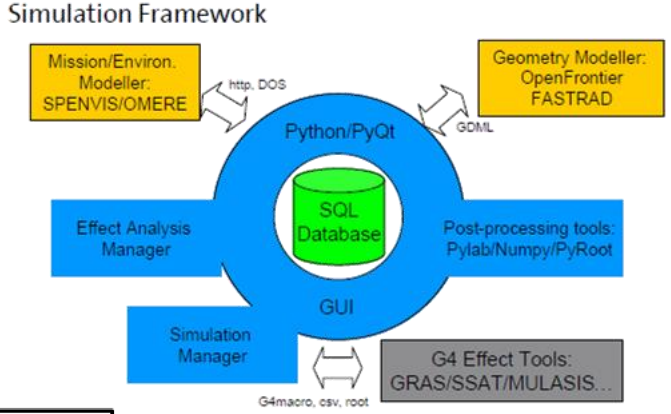




CIRSOS
Collaborative Iterative Radiation Shielding Optimisation System

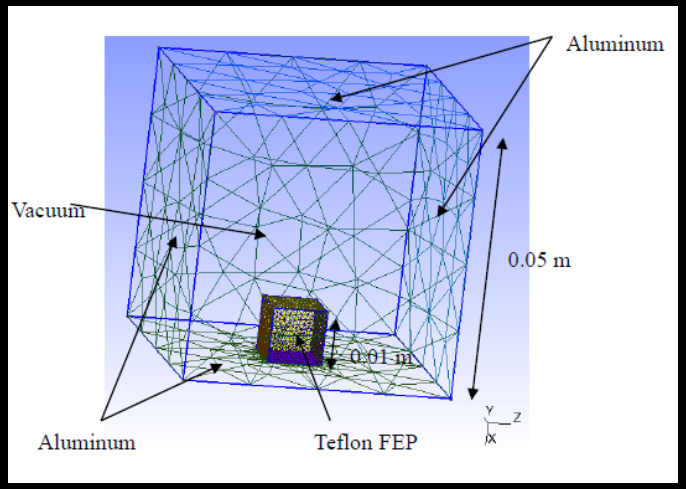
- Better interoperability of shielding analyses in multi-partner projects (e.g. JUICE)
- Mission specification and environment modeller based on REST-SIM reported in previous G4 SUWSs
- Integrated Modelling Environment
- Effects analysis tools
  - Internal charging (link also to ELSHIELD outcome)
  - Geant4-based applications (GRAS, FMC and RMC, SSAT, MULASSIS)
- Post-processing manager
  - Visualisation, plots
  - Response matrices / formulae / algorithms
- See the dedicated presentation

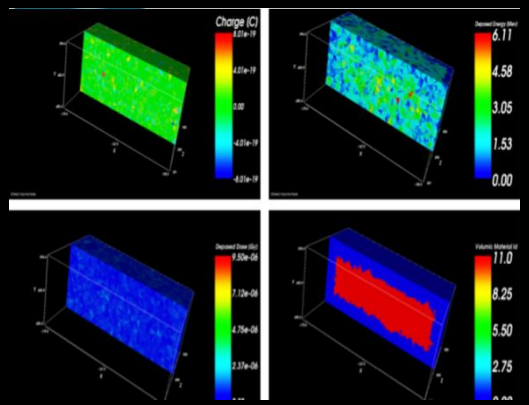


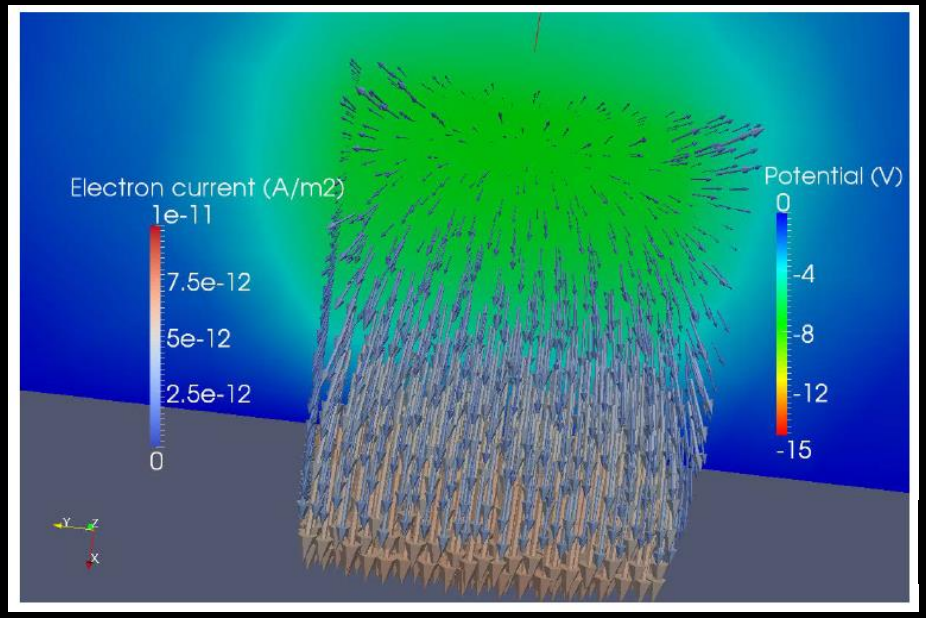


ELSHIELD 3D internal charging tool

- New 3D deep charging analysis capability, based on novel interfaces between CAD, SPENVIS, FASTRAD, Geant4 / GRAS particle transport, SPIS and circuit solvers
- Used as input to the 3D-MIX project (ONERA), to be completed in 2015

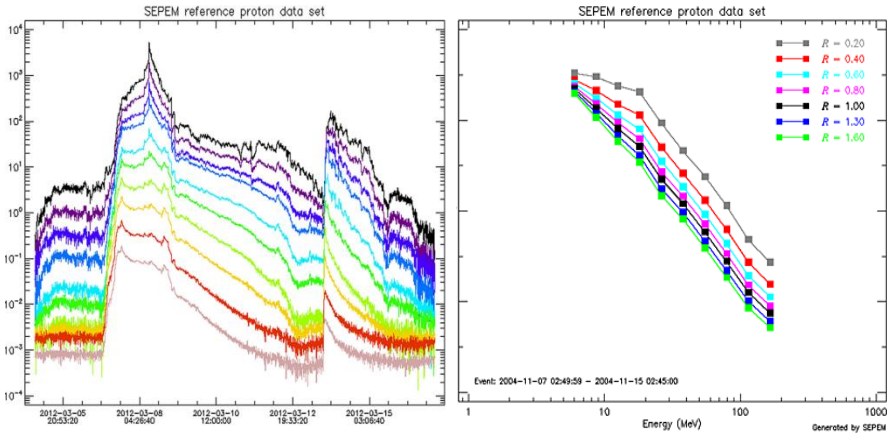


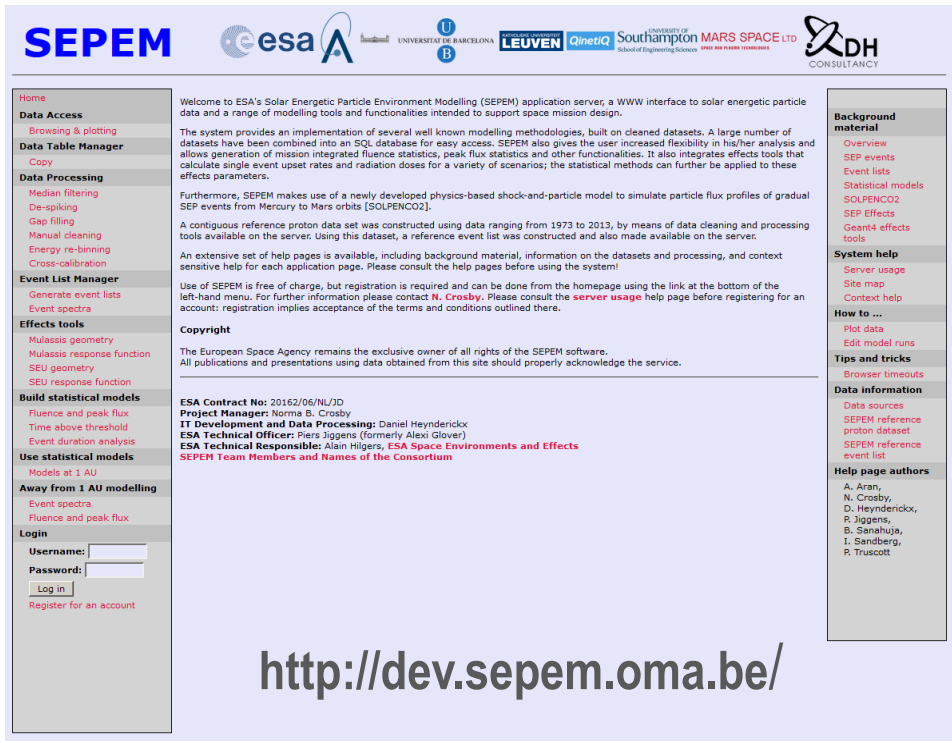




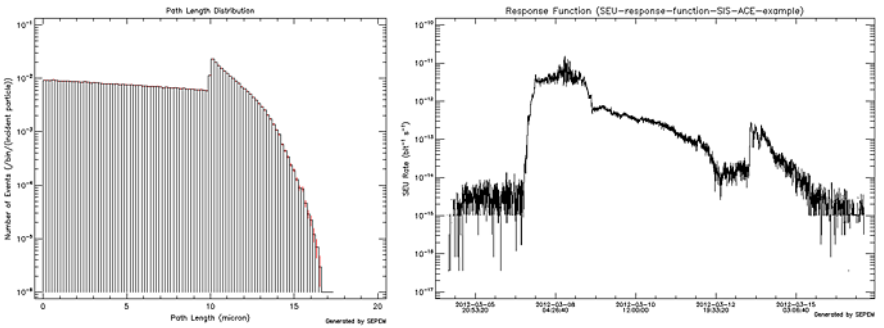
SEPEM
Solar Energetic Particle Environment Modelling

- Cross-calibrated SEP data from 1973 to 2013
- New modelling tools, statistical and physical modelling techniques
- 1 AU + inner heliosphere from 0.2 to 1.6 AU
- Peak flux and integrated fluence statistics, but also durations of high SEP flux periods
- Geant4-based effects analysis tools:
  - MULASSIS for dose and shielded particle fluxes
  - GEMAT for SEU analysis

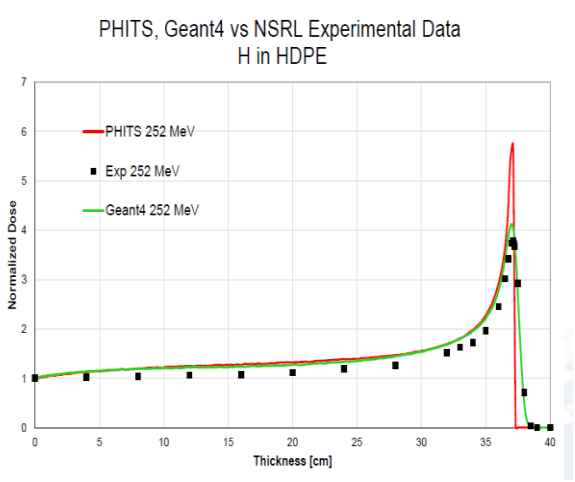


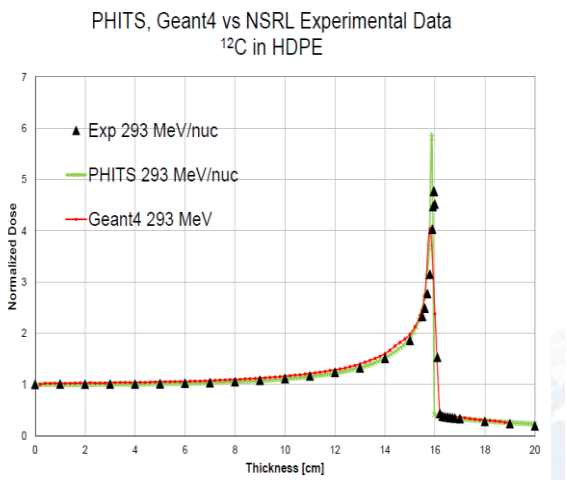


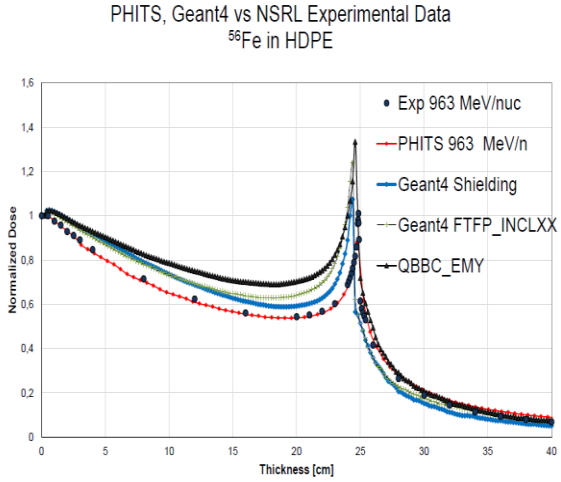
http://dev.sepem.oma.be/

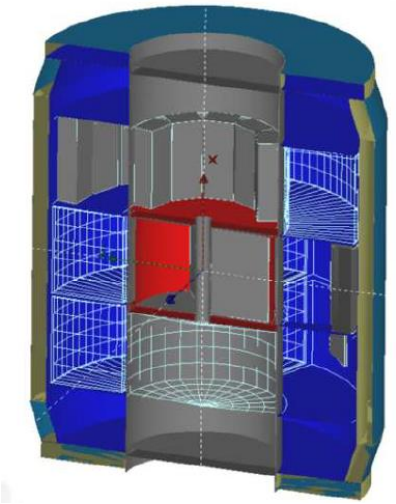


Radiation Shielding by ISRU and Innovative Materials for EVA, Vehicles and Habitats (ROSSINI2)









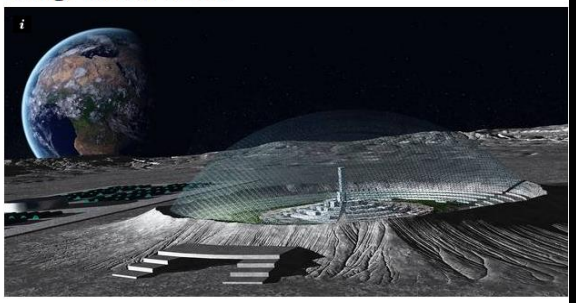
- TAS (Torino), GSI and INFN
- Goal: Design, develop, build and test innovative passive shielding solutions to be adopted in future human exploration missions
- High-Z, high-energy particles: GSI closure impacts the project; other facilities are sought (GSI discussions e.g. with NASA NSRL)
- Simulation framework developed based on Geant4 and PHITS – some discrepancies between the codes investigated
- Evaluation of radiation doses absorbed in human tissue, given the particle species and energy spectra observed behind the shields considered
- Design of eventual shielded refuges on lunar/planetary surfaces, habitats and deep space missions, starting in 2016

Long-term (2024 →) future: “Moon village” ?

THE INDEPENDENT Tuesday 14 July 2015

News > World > Europe Frontpage >

The new director of the ESA wants to build a village on the Moon

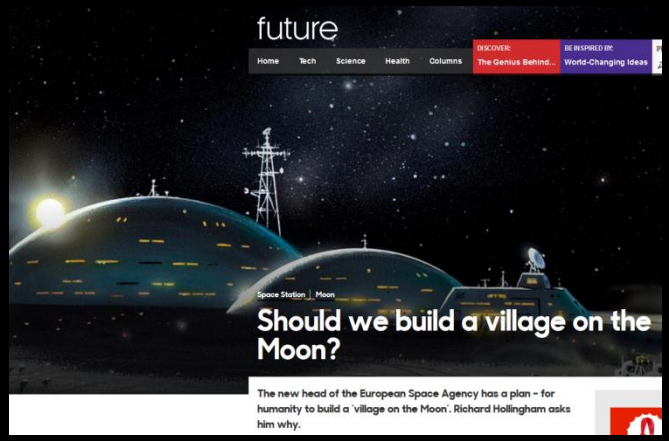


'I propose a Moon village on the far side of the Moon'

BBC

future

Home Tech Science Health Columns DISCOVER: The Genius Behind... BE INSPIRED BY: World-Changing Ideas



Space Station | Moon

Should we build a village on the Moon?

The new head of the European Space Agency has a plan – for humanity to build a 'village on the Moon'. Richard Hollingham asks him why.

Jan Wörner, ESA Director General.

nature International weekly journal of science

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News & Comment > News > Q&A > 2015 > August > Article

NATURE | NEWS: Q&A

Moon village would host first class research

Europe's new space chief Johann-Dietrich Wörner explains his lunar ambitions.

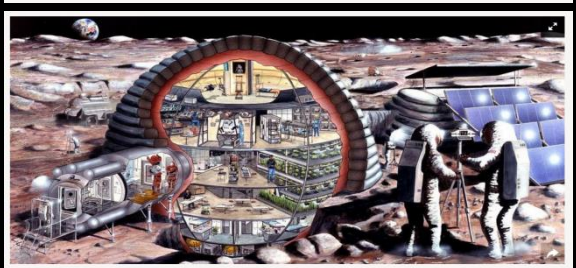
Elizabeth Gibney

Popular Mechanics

JUL 13, 2015 @ 2:03 PM

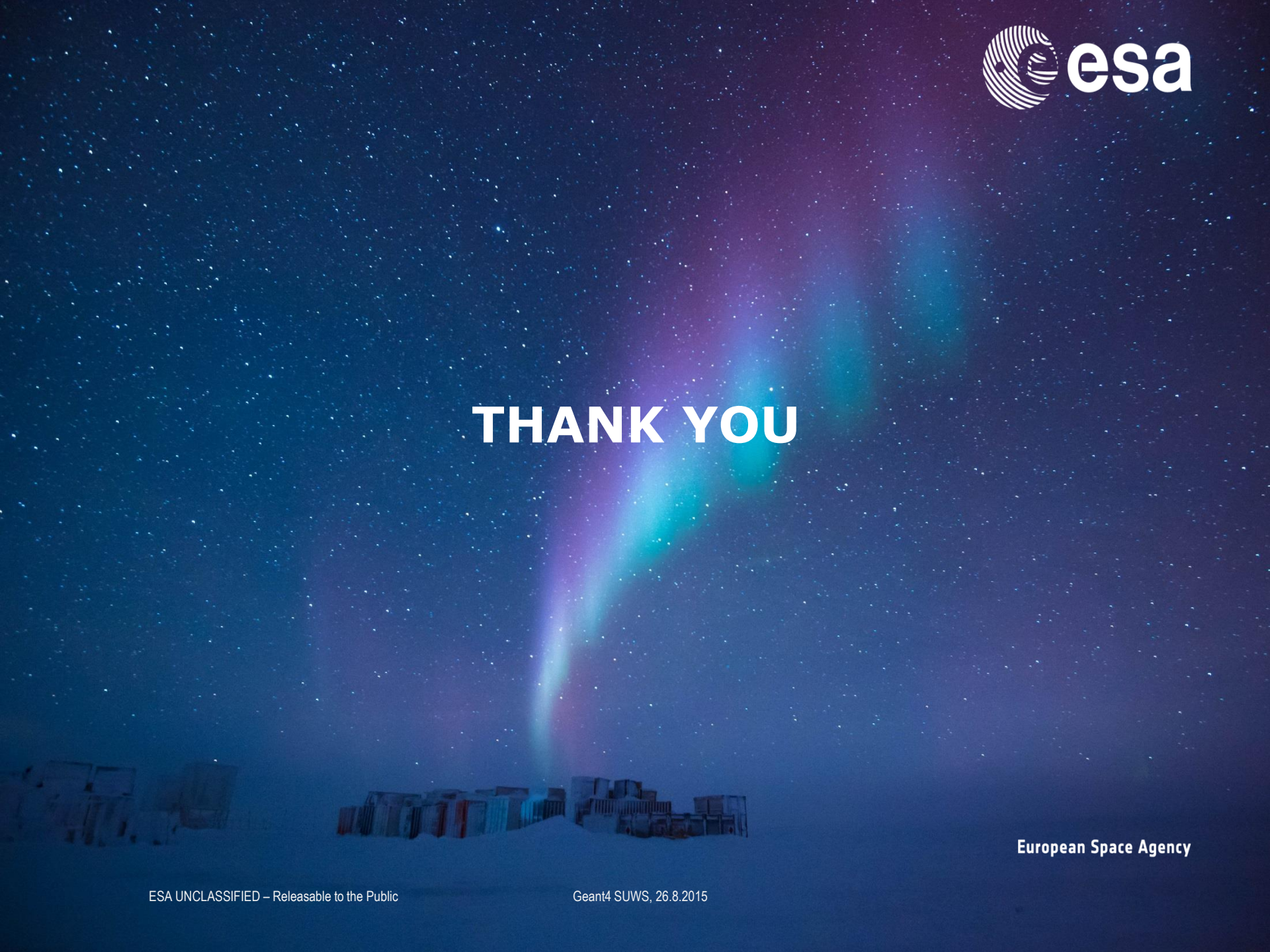
Europe's Space Chief: Let's Build a Moon Village

Humanity can, should, must, and will settle on the far side of the moon.



Outlook and conclusions

- ESA Large-class Science missions JUICE and ATHENA are major Geant4 tool, model and application customers at ESA. For ATHENA simulator, dedicated WP for low-E e.m. physics updates
- Planned call for L3 mission ("Gravitational Universe") concepts in 2016
- Other Science missions (e.g. Solar Orbiter) also face radiation issues
- Human spaceflight beyond the ISS? Shielding of the lunar radiation environment, Geant4-DNA
- Continued importance of easy-to-use and rapid tools (e.g. reverse MC, GRAS, SPENVIS(-NG), SEPEM Web-based applications, SEE models and tools) for spacecraft and instrument development
- Radiation instruments and Geant4: See separate presentation
- Some personnel changes and challenges created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THANK YOU
European Space Agency