Open and new requirements - Space science and engineering

Procedure for recording & follow up of requirements from space domain yet to be started
Items not properly tracked
Last Space Users' Workshop in Greece, 2019

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ESA ESTEC

26/09/2022

27th Geant4 Collaboration Meeting
Rennes

Physics: Protons and Heavy ions (1)

Open (?) 2015: Cross Sections for High Z - High Energy (HZE) particles

Context: biological dose in long duration exploration missions to Moon and Mars – dominated by GCRs

ROSSINI 3 project (GCR innovative shielding materials - TAS-I, GSI, UniTo, ESA R&D)

Geant4 physics lists use dramatically different CSs: Fe 1GeV/n Bragg peak curve in Paraffin (reported in 2015 & 2020): **only CS in *INCLXX** reproduce data

Source: L.Bocchini, M.Giraudo @Thales Alenia Space Italia

Astronaut radioprotection: **Improve cross sections for hadronic processes (especially fragmentation)**

Source: S. Guatelli @UoWollongong

- Req: Review CSs models. Add relevant exp dataset to Geant4 validation suite

Additional information:

New review and useful dataset from ESA **ROSSINI 3 project: Cross Section database (ESA – GSI – NASA)**

- F Luoni et al 2021 New J. Phys. 23 101201 https://iopscience.iop.org/article/10.1088/1367-2630/ac27e1
- Made available at https://www.gsi.de/work/forschung/biophysik/fragmentation

Cross Section database (ESA – GSI – NASA)

- ESA **ROSSINI 3 project**
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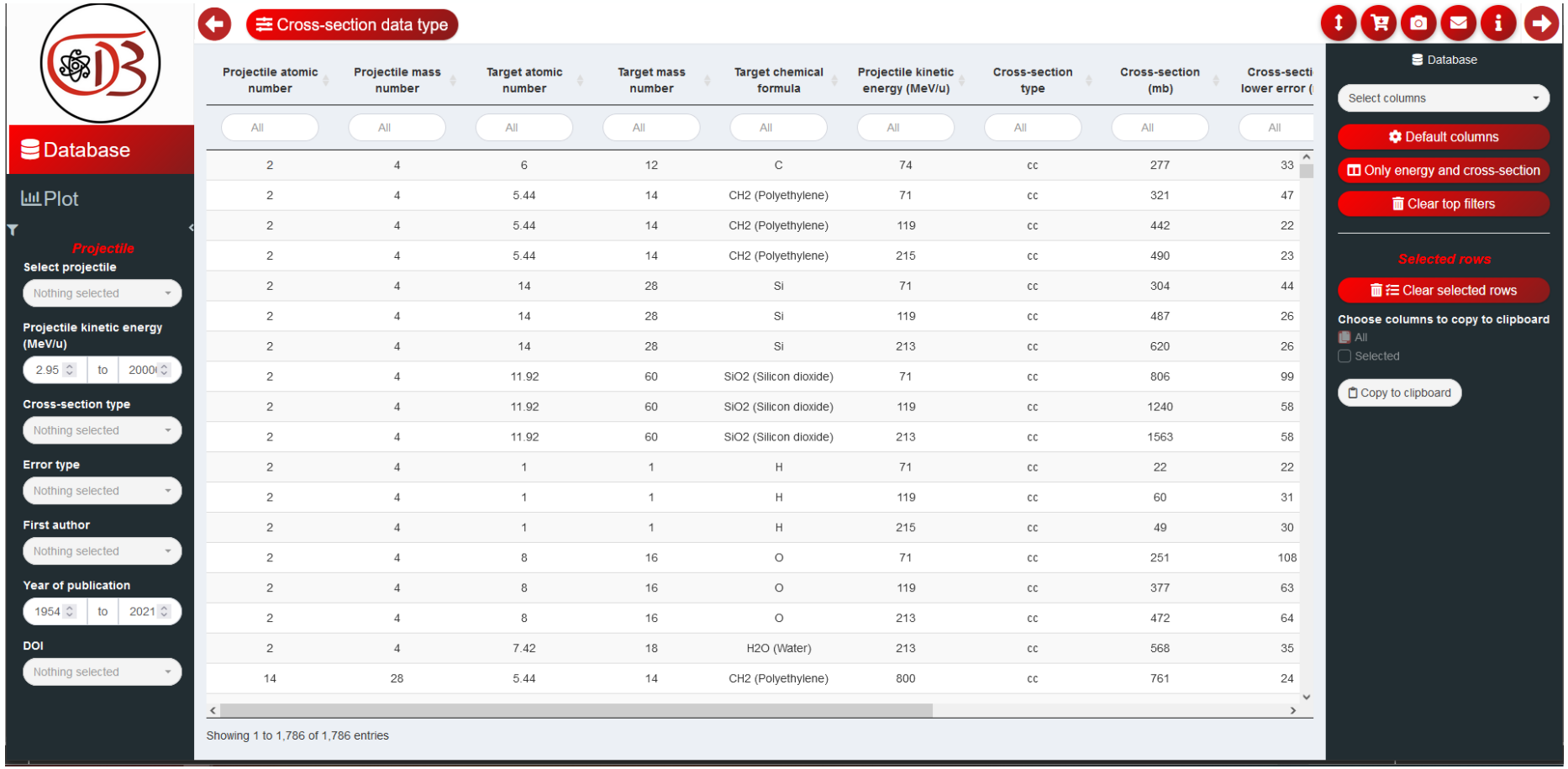


Physics: Protons and Heavy ions (2)

Open (?): Accurate models for low-energy nucl-nucl interactions

Context: **Single Event Effects** in electronics in space environment (component at <100MeV/nuc very important)

Req: Better model for nuclear fragments from nucl-nucl interactions <50MeV/n regime

Source: P. Truscott @Kallisto

Open (?) 2021: Complete lack of reasonable **distribution of ion charged states** after thin targets

Context: 10 MeV O^{4+} through ultra thin Al layer. Codes such as LISE++, ETACHA etc. can model this. Not G4

- Req: Model for reasonable distribution of charge in ion final states

Source: M.Kokkoris @NTU Athens

Open (?) 2021: Neutron production, down to thermal energies from cosmic-ray (protons and HZE particles)

Context: Human exploration missions to Moon and Mars, biological dose and SEE

LRO/CRaTER project (charged-particle sensor aboard Lunar Reconnaissance Orbiter)

- Req: Accurate models for neutrons
- Req: Physics lists: documentation or recommendations for neutron physics and sensor response:

Source: Mark D. Looper @Aerospace Corporation

Physics: Protons and Heavy ions (3)

Open (?) 2020: dE/dx in Si for High Z - High Energy (HZE) particles

Context: Electronic component tests at CERN SPS with Xe 40GeV/n and Pb 150GeV/n

Energy deposition from sub-um up to 500 um thick Silicon sensitive volumes

- EM, 2020, v10.5.p1: discrepancies in dE/dx in Si: DOI:10.1109/TNS.2019.2958746
- Discussion with Vladimir Ivantchenko: theoretical corrections not easy for ion dE/dx at high energy
- Some work done in recent years (Lindhard–Sørensen) – values moved but still incorrect – still ongoing?

Req: Review and improve the current high-energy ion dE/dx models. Include this case in validation suite

Source: S.Gerardin,
M.Bagatin @DEI UniPd

Biasing / scorers

Open (?) 2021: Biasing: plans for implementation of **(cross-section) biasing for charged particles**?

Context: protons and heavier ions for simulations of thin targets (science and electronic components)

> Geant4 doc: *For now, we discuss only the case of neutral particles, i.e., having no continuous energy loss along a step.*
>
> *The case of charged particles is expected to be treated in later releases.*

Req: Enable biasing (e.g. forced interaction) for charged particles

Source: GS @ESA

New : Generic biasing scheme fully compatible with built-in command-based scorer and analysis package

Context: Full simulation of space scenarios through UI commands only

Quick drawing of physics distributions (e.g. energy deposition distribution) when using biasing

“We plan to discuss on this issue during this collaboration meeting”

Req: Integrate generic biasing with scorers / analysis

Source: Makoto Asai @JLab

Scorers

New: Some enhancements to the g4 scorer:

1) add/complete the **spherical grid** option, in addition to the Cartesian and cylindrical options
2) **mesh grid supplied by user**
3) quantities derived from **user supplied fluence-to-quantity** conversion table/curve
4) more output file option, e.g., **json**

Req: Implement new scorer features

Source: Fan Lei @RadMod

Geometry

Open (?) 2021: GDML parser improvements: Fixing xml parser warnings when using GDML

- Req: Remove warnings on material and naming definitions that run fine

Source: Karl Smith @LANL

New: Req: UI to allow user to specify the GDML schema location

Source: Fan Lei @ RadMod

Open (?): Color persistency in GDML models

Source: P. Truscott / GS

- Recognized as general requirement and distributed in G4 example - why not part of GDML standard?

Req: Colors as part of core GDML standard

Closed (?) 2021: Database with realistic Geant4 models for space missions

Source: N. Messios @BISA

Req: Simplified models (no confidential information) for spacecraft, instruments, etc. available to users

- Recent progress: 2022 **Reference Radiation Simulation Scenarios**
  - Via ESSR https://essr.esa.int (also with other Geant4-based tools: GRAS, MULASSIS, etc)
- Produced for ESA by TAS-I (ROSSINI3 project) - including electronic components to simulate TID/SEEs

Closed (?) Visualisation of G4 Boolean Solids

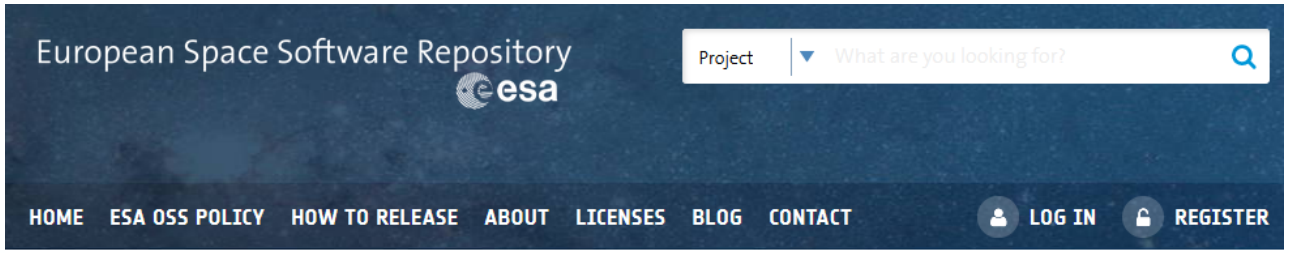
Often only ray-tracing works

Source: P. Truscott @Kallisto

Reference Radiation Simulation Scenarios

European Space Software Repository (ESSR)

https://essr.esa.int



REFERENCE RADIATION SIMULATION SCENARIOS

The Reference Radiation Simulation Scenarios includes models compatible with Monte Carlo simulations for radiation transport, including realistic and detailed geometry models of spacecraft modules, and planetary habitats, and guidelines for high energy radiation environment spectra to be used for the simulations.

Its purpose is to provide access to end-users in the space (exploration) domain to realistic modular geometry elements for their radiation simulations, and at the same time to enable meaningful comparisons, among different teams in the community, of simulation results based on common reference input. It also aims at providing an infrastructure for future augmentation of the scenarios dataset with contributions of additional models by the community, developed under other activities.

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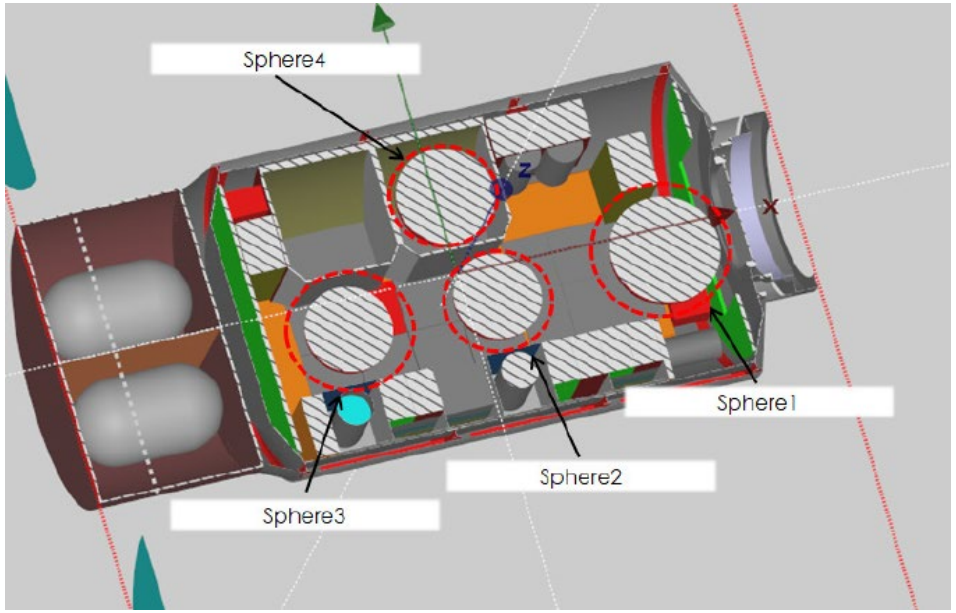
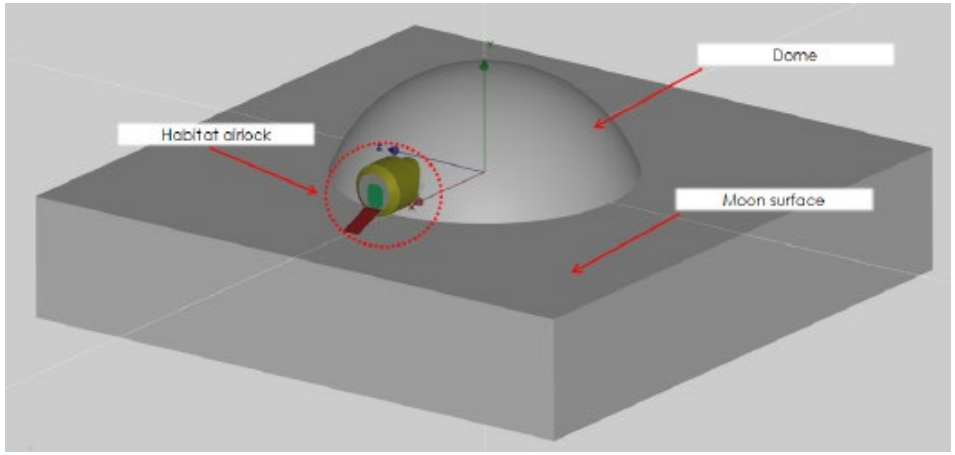
Updated on: 08/04/2022
Created on: 22/02/2022
Owner: TAS-I
Tags: simulation Geant4 Radiation Monte Carlo Radiation shielding GDML Radiation environment Exploration





Geometry: modelling and analysis

Open: GUI for Geant4 geometry and simulation

- Modelling geometry and visualizing trajectories and scorers / analysis
- Convert CAD/STEP files to GDML. Some interesting tools around (e.g. EDGE) but commercial

Req: Have a nice free tool to easily create geometry models / output GDML files / launch simulations

Additional **recent** information / input (**not exhaustive**!)

- **G4CAD**: second version released at https://github.com/drhlxiao/g4cad
  - Bugs fixed / more stable when converting big CAD files

Source: Hualin Xiao @ PSI

- **"STL:** GDML tools development not moving forward. Internally switched to purely using STL for complex equipment.
  - Use in Geant4 via CADMesh. High quality tools to create, convert and/or modify (FreeCAD, Meshmixer, etc) / Easy to reduce computational burden via facet reduction / "Easy" to port to other MC codes (I am aware of user routines for FLUKA etc) In summary: I don't really see any need (and/or future) for GDML"

Source: Christoph Schuy @ GSI

- **FreeCAD GDML plugin**:
  - Can there be an **involvement of the Geant4 collaboration**?
  - Graphical feedback in advanced 3D CAD modelers: any chance of communication of trajectories and analysis objects to **external** tools for live visualization ("streaming"?)

Source: GS @ ESA

Improvement in source spectra

Open: Improvement in internal treatment of user spectrum

- Context: Space applications heavily rely on source energy spectra from external tools
- **Computational accuracy problems in GPS**

Req: Review of GPS algorithms: interpolation, differentiation / integration

Source: Brian Xiaoyu Zhu @JPL
GS@ESA
User forum

Phase space I/O for multi-stage simulations

Open: Phase space information exchange

Context: multi-stage / multi-scale simulations for biological effects (see medical URs) or SEE in electronics

Simulation at subsequent levels:

- spacecraft → unit → component
- accelerator facility → component ground test board
- space habitat → phantom → cell

Req: Definition of a standard, complete, configurable/extensible text/binary format for phase space persistency

Additional information:

Pete Truscott created own phase space format for ESA (AREMBES / HIERRAS projects)

- Prototype made available in GRAS / used in ESA BioRad3 multi-scale Geant4-DNA project
- Possible contribution to Geant4 to develop ideas in that direction
- E.g. flexible format where users can add fields with user-defined tags

Source: Pete Truscott @ Kallisto GS @ ESA

User documentation for Tasking

New: Support to parallelization of user application

Tasking not as documented as MT

Req: Improve documentation for Tasking

Source: Michail Axiotis @ Democritos
Dimitris Lenis @ IASA

Docker support

Open: Installation / distribution via docker – starting point for users

Widely used by users but not supported / documented

Source: Dávid Lucsányi & CERN R2E
Pete Truscott @ Kallisto
Neophytos Messios @BISA
GS @ ESA

Req: Provide official Docker support

- Distribute a few standard images – ready for download, users can run examples etc
- Provide scripts for Geant4 containers (including baseline and additional user configurable options)
- Provide guidelines / tips for packaging additional space applications
- Provide instructions for using the G4 libs / running the G4-based apps from a Docker image

Additional information

Recent development at ESA:

- **g4spaceapps** docker container – developed by Pete Truscott for ESA – layered approach
- Now in ESA gitlab repo – standard Geant4 licence conditions – can be input to the collaboration
- Form a small group of interested contributors?

A very active user community in space

For example: some papers from COSPAR 2022 that explicitly use Geant4 one way or another

Modeling Mercury's particles sputtering from surface using Geant4 - N Chirskaia et al

GRAPPA - A New Geometry Generation Tool for Simulating Martian and Lunar Radiation Environments with Geant4 - P Truscott et al

Challenges of Measuring Energetic Particles in the Inner Belt: Geant4-Based Design of Relativistic Electron Proton Telescope integrated little experiment-2 (REPTile-2 … X Li et al

ESA's Human Interplanetary Exploration Radiation Risk Assessment System (HIERRAS) D Heynderickx et al

Solar Energetic Particle Radiation Dosage around a Simple Lunar Crater P Phipps et al,

Canadian Space Radiation Monitoring and Risk Mitigation in Deep Space: Directional Analysis of SEPs and Astronaut Protection at the Lunar Gateway K Ball et al

The biological effectiveness of neutrons on the Mars surface A Mentana et al

The REDMoon model: Radiation Environment and Dose rates on the lunar surface and subsurface M Dobynde et al

Modeling of the Earth atmosphere responce on the cosmic ray particles E Maurchev et al

Space radiation dosimetry at the exposure facility of the International Space Station S Kodaira et al

Mars Radiation Environment under Different Atmospheric and Regolith Depths and the Implication for Shielding Protection of Future Habitats J Zhang et al

Extending SOHO-EPHINs energy range for Helium nuclei M Hörlöck et al

The evaluation of the Earth's atmosphere ionization by solar cosmic rays particles and the equivalent dose calculation E Maurchev et al

Electron flux measurements from ESA Next Generation Radiation Monitor on-board GEO EDRS-C satellite S Aminalragia-Giamini et al

Latest result on Searching for fractionally charged particles with the DAMPE experiment Y Wei et al

Ready function to evaluate the dose distribution of the deep space radiation in human brains S Khaksarighiri et al

Simulation of the planetary environments of the icy giants with PLANETOCOSMICS C Tsironis et al

Radiobiological Significance of Cosmogenic Radionuclides Induced in the Human Body from Space Radiation A Roy et al

METU-DBL: A Cost Effective Proton Irradiation Facility M Bilge Demirköz

Comprehensive radiation monitor package for Lunar mission C Lambropoulos et al

Stellar Energetic Particle-driven Production of Biologically Relevant Molecules in Atmospheres of Young Earth-like Exoplanets G Gronof et al

Microdosimetry Based Radiation Monitoring System for Space Missions A Rosenfeld et al

SIMULATION OF SOLAR NEUTRON FLUX IN THE EARTH'S ATMOSPHERE F Monterde-Andrade et al

Summary – Users' workshop

- Heavy ions
  - cross sections
  - dE/dx
  - biasing
  - neutron production
- Usability
  - biasing / scorers
  - phase space
  - geometry GUI / GDML
  - source spectra
  - tasking
  - docker

Space users' workshop:

Next event (physical meeting) under discussion for 2023