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Radiation Dosimetry

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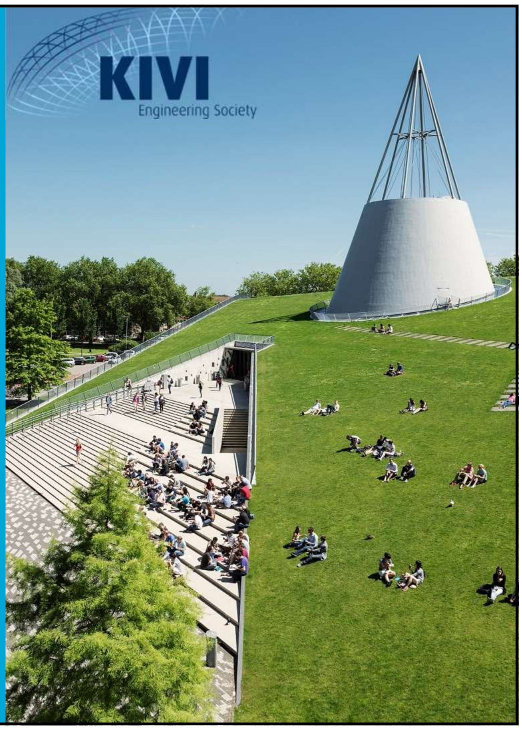
12-2-2026



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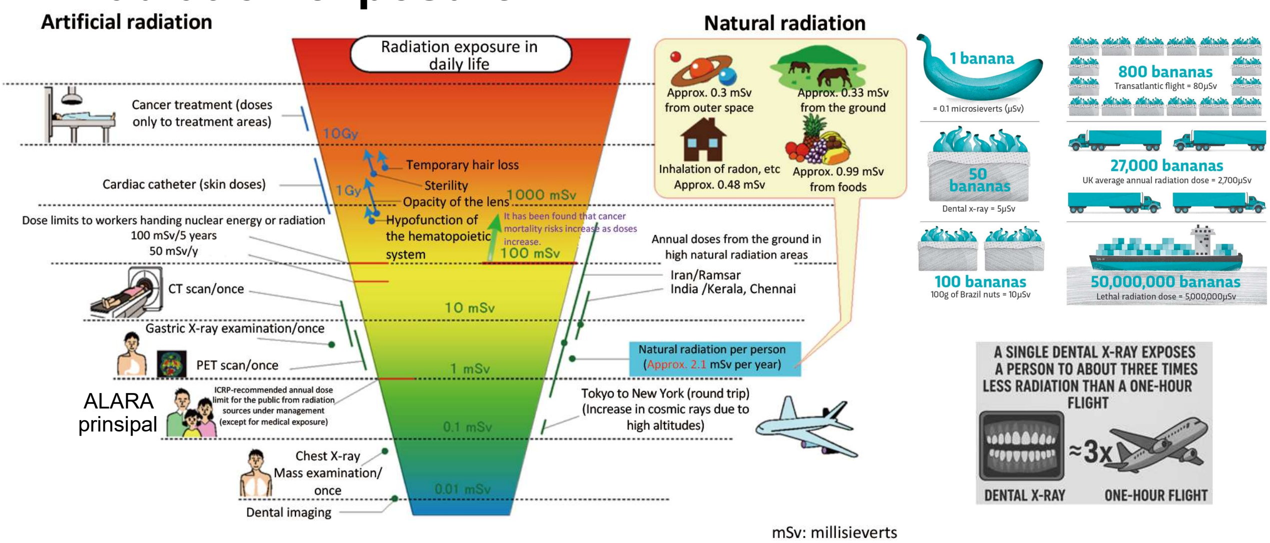
Radiation exposure



mSv: millisieverts

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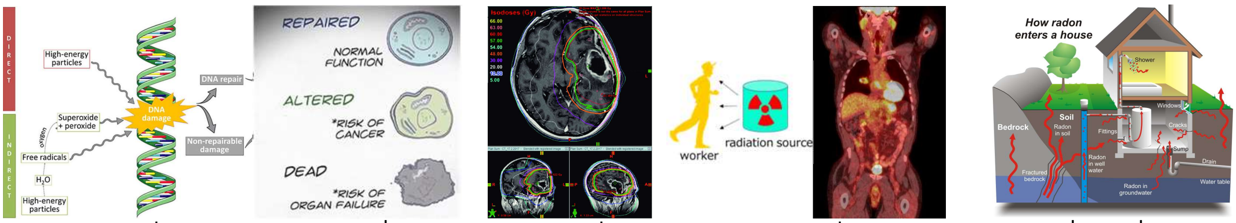
The Multi-Scale Challenge of Dosimetry

- How much dose did the worker receive?



nm scale (DNA) | µm scale (cell) | mm scale (tissue) | cm scale (whole body) | km scale (environment)

- What exactly happens to biological tissue at the molecular level when radiation passes through it?

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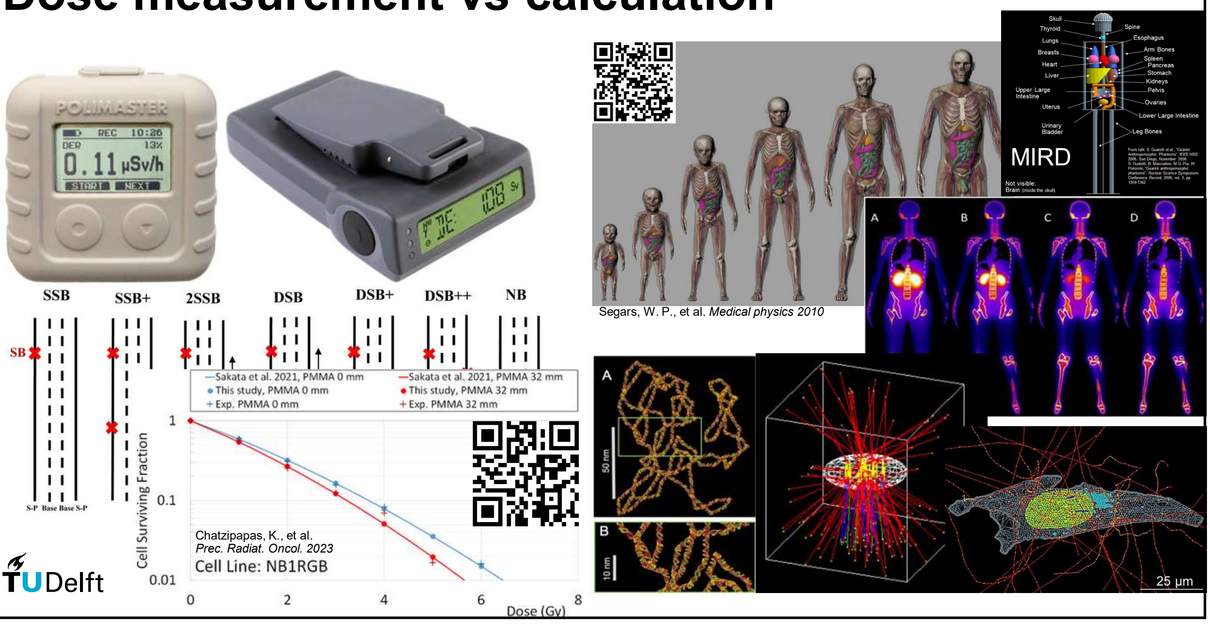
Dose measurement vs calculation



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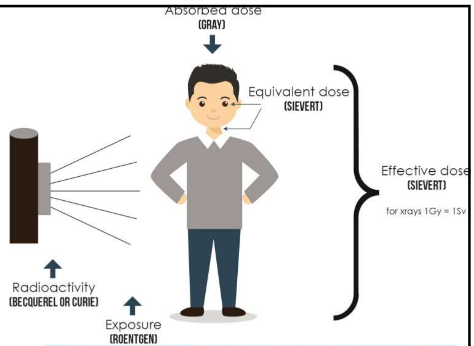
Key Dose Quantities

- **Physical quantities:**
  - Absorbed Dose (D): Energy/mass in Gray [J/kg]
- **Biological quantities:**
  - Equivalent Dose (H_T): Absorbed dose × Quality Factor (radiation type)
  - Quality factor varies: photons QF=1, alpha particles QF=20, neutrons QF=5-20
- **Regulatory quantities:**
  - Effective Dose (E): Sum over organs of (equivalent dose × organ sensitivity weight)
  - Example: 10 mSv to bone marrow + 0.1 mSv to skin = different cancer risks because bone marrow is 100x more radiosensitive
- **Molecular quantities:**
  - Specific energy: Energy deposition in nanometer-scale volumes around DNA targets
  - DNA damage yield (Gy⁻¹): Number of lesions per gray of dose to a cell
  - Repair kinetics and survival probability of cells



- ***Equivalent dose in a tissue or organ***

$$H_T = \sum_R w_R D_{T,R}$$

- ***Effective dose***

$$E = \sum_T w_T \sum_R w_R D_{T,R}$$

$D_{T,R}$: Mean absorbed dose from radiation R in a tissue or organ T
w_R : Radiation weighting factor
w_T : Tissue weighting factor

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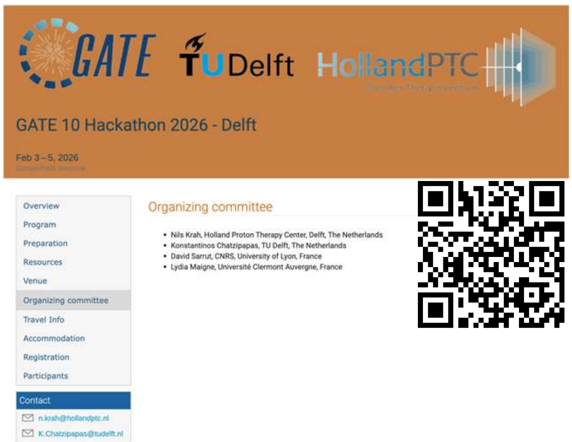
Computational Dosimetry - Monte Carlo & AI (1/3)

- **GATE**
- Personalised dosimetry
  - Medical applications
  - External beams/ radiotherapy (p/γ)
  - Radionuclide therapy (PBPK)
  - Medical Imaging
  - Shielding (Medical/ Nuclear facilities)



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Computational Dosimetry - Monte Carlo & AI (2/3)

- **Geant4** and **Geant4-DNA**
- ESA / TU_Delft
- Micro and nano-dosimetry
- Investigation of cellular damage to predict the outcome of irradiated persons (low dose conditions) (space/ workers)

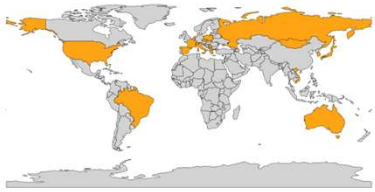
Collaboration

The Geant4-DNA project was initiated by **P. Nieminen** at ESA/ESTEC, The Netherlands.

The Geant4-DNA collaboration is managed by a **Steering Committee (SC)** and **Activity representatives** are members of the Geant4-DNA Steering Committee. The Geant4-DNA project is coordinated by IN2P3/CNRS since 2008. It is a full activity of the Electromagnetic Physics working group of the Geant4 collaboration. Our collaboration rules have been adopted in 2014 and they are updated every three years.

For the **2023-2026 collaboration cycle**, the following collaborators are members of the Geant4-DNA collaboration.

Geant4-DNA World map of collaborators in 2023-2026



Steering Committee members are

- « Physics » activity : **I. Kyriakou**, Ioannina U., Greece
- « Chemistry » activity : **H. N. Tran**, LP2i/IN2P3/CNRS, France
- « Biological damage and repair » activity : **Y. Perrot**, ASNR, France
- « Applications and G4-Med » activity : **S. Guatelli**, Wollongong U., Australia
- « Documentation and outreach » activity : **D. Sakata**, Osaka U., Japan
- « Computing & testing » activity : **V. Ivantchenko**, CERN & Tomsk U.
- Technical Coordinator : **H. N. Tran**, LP2i/IN2P3/CNRS, France
- ESA representatives : **P. Nieminen** and **G. Santin**, ESA/ESTEC, The Netherlands
- Geant4 representative : **V. Ivantchenko**, CERN & Tomsk U.
- Geant4-DNA coordination : **S. Incerti**, LP2i/IN2P3/CNRS, France (spokesperson), **D. Sakata**, Osaka U., Japan (deputy spokesperson)

The following collaborators are contact point for specific research topics

- AI : **K. Chatzipapas**, T. U. Delft, The Netherlands
- Flash irradiation : **S. Fattori**, LNS/INFN, Italy
- Space applications : **J. M. C. Brown**, Swinburne U., Australia
- Geant4-DNA database: **S. Fattori**, LNS/INFN, Italy

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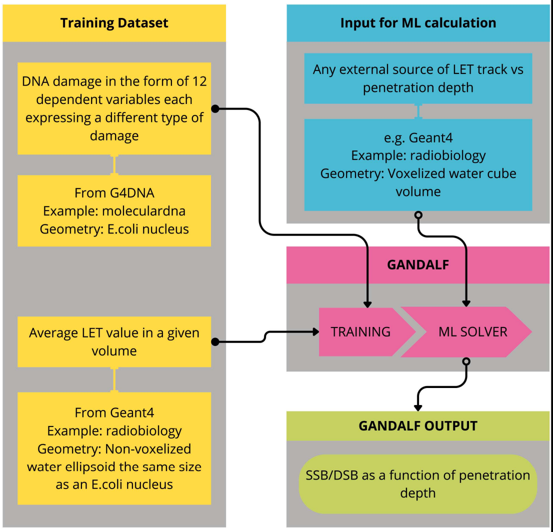
Computational Dosimetry - Monte Carlo & AI (3/3)

- Fast Prediction to enable real-time decision-making in medical and nuclear facilities.
- **GANDALF**
  - a neural network trained on Geant4-DNA simulation outputs to predict DNA damage
  - feeding a dose distribution to predict DNA damage patterns and cellular risk.
  - This enables real-time decision-making in nuclear and medical facilities:
  - Worker planning a maintenance task in a reactor pool
  - Optimisation of shielding in both nuclear facilities and clinical environment
  - Optimise biological result of therapeutic procedures



Sciuto A., Chatzipapas K. et al. *Physica Medica 2025*

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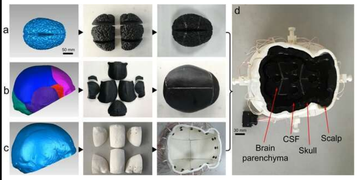
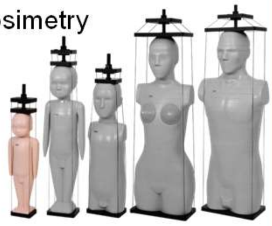
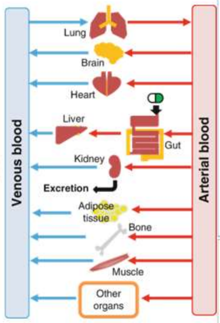
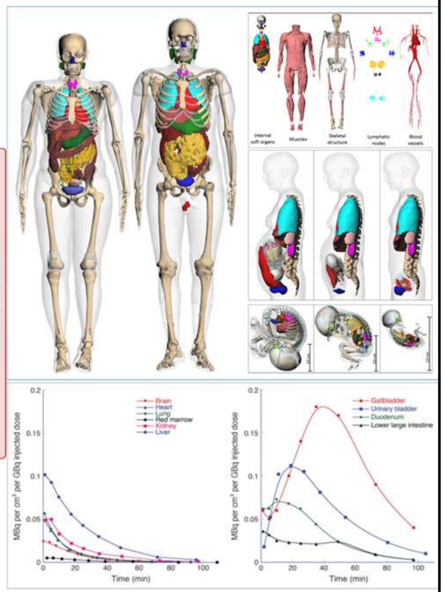
Personalized dosimetry

- Beyond the average person
- Physiologically-Based Pharmakokinetic Modeling (PBPK)
- 3D Bioprinting for Dosimetry









- **Applications Beyond Nuclear Industry:**
- **Medical imaging- Radiotherapy- Space radiation- Occupational dosimetry**

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Digital Twins & Future of Nuclear Dosimetry

- Virtual Environment for Reactor Applications (VERA).
- VERA can solve a variety of reactor performance challenges by modeling multiphysics phenomena.

3). Spinger Nature.
/978-3-031-21343-4_31

- A virtual reality digital twin model of the ORNL's liquid-salt test loop facility, displaying embedded technical information with simulated walk-downs to optimize work planning

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Future Directions & Call to Collaboration

- Research frontiers at TU_Delft and the RID
- Real-time AI dosimetry
- Lunar/Space radiation dosimetry
- Advancing molecularDNA
- Integration with medical physics
- International collaboration

- Contact us for future collaboration

Applied Radiation & Isotopes (ARI) Group
Department of Radiation Science and Technology (RST)
Faculty of Applied Sciences, TU Delft

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