A Visualisation Framework for MCNP Dose Fields in Radiation Protection

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Introduction

- Monte Carlo radiation-transport calculations are key to radiation protection, informing **shielding design, dose assessment,** and **operational planning** in complex nuclear environments.
- MCNP models are typically defined through **text-based geometry** descriptions and **numerical tally outputs** that can be difficult to interpret spatially, especially for non-specialists.

This work presents a **visualisation framework** that converts **MCNP geometries** and **mesh tally data** into an interactive three-dimensional environment allowing:

- Inspection **radiation fields** in their geometric context.
- Interrogation **local dose** conditions.
- Extending underlying data to **human-relevant dose** assessment using an International Commission on Radiological Protection (ICRP) **anatomical phantom** [1].

Framework Overview

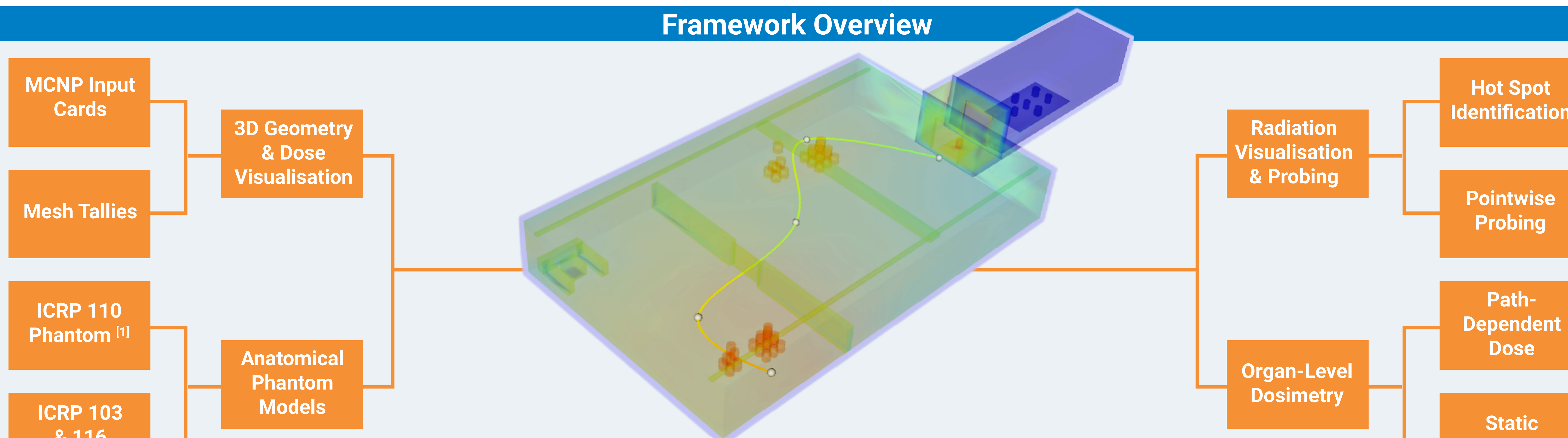

Figure 1: Flow diagram and rendering of a generic waste store using visualisation the framework. The waste store contains 42 active waste-packages. Barrels near door are a lower-energy ^{137}Cs-like source term, while the other sources represent a higher-energy ^{60}Co-like source term.

Dose Calculation Pipeline

Field generation
MCNP mesh tallies define passive and multigroup radiation fields.

Phantom sampling
ICRP-derived voxel phantom samples the field at voxel centres.

Dose conversion
ICRP 116 converts fluence to absorbed and equivalent dose [1].
ICRP 103 combines tissue doses into effective dose [1].

Route accumulation
Repeated poses along a spline route accumulate worker dose.

Figure 2: Rendering of the ICRP 110 female voxel phantom used for dose assessment [1]. The phantom provides an anatomically structured sampling domain.

Route-Based Phantom Assessment

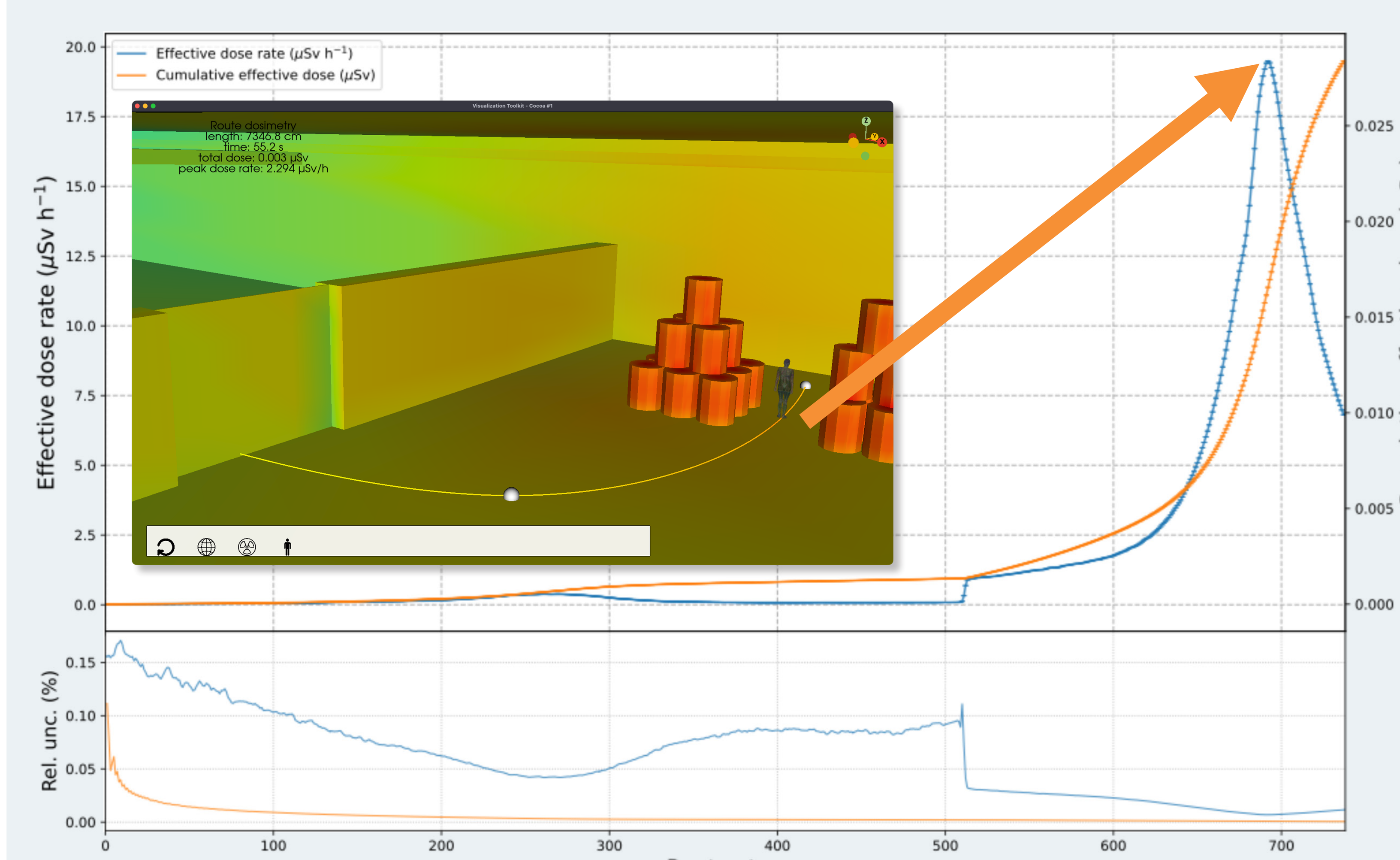

Figure 3: Effective dose rate and cumulative effective dose along the phantom route in the waste-store environment, with the inset identifying the location of the peak dose-rate near the active barrels.

Applications

Task Planning
Assess exposure for maintenance tasks, inspections or reactor area access.

Worker Training
Understanding dose gradients, shielding effects, and optimal standoff distances.

Safety-case
Clearer presentation of dose pathways to engineers and decision makers.

Design Review
Evaluate modifications, shielding improvements, or layout changes.

Future Development

Motion-aware dosimetry:
Introduce gait-cycle based motion into the route model, allowing worker movement to be represented more realistically than rigid-body walking.

VR-based dose estimation:
Virtual-reality support with positional tracking, movement through the 3D scene to estimate exposure along routes.

Path-of-least-exposure planning:
Develop route-optimisation tools to identify lower-exposure paths through complex radiation environments, supporting worker access planning and task optimisation.

References

[1] International Commission on Radiological Protection (ICRP), Publications 103, 110, and 116: tissue weighting, reference computational phantoms, and conversion coefficients for radiological protection.

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