V&V REPORT

RadMap

Release v3.0.0



radmap.tech

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1 Introduction

This report records the verification and validation of one version of RadMap, named in the summary below. It is generated in the build that produces the version's installer, from the tests that build runs, and published with the version's documentation: every number in it was measured on the software it describes.

RadMap calculates dose rates from radioactive sources and the effect of shielding on them. Its intended use is stated in its licence agreement; what it does not calculate, or calculates only approximately, is listed in the user guide under *Known limitations*. A user qualifying RadMap for their own purpose can base that qualification on this report.

1.1 How the cases are built

Each **V&V case** is an automated test. Most build a project through RadMap's programming interface – sources, shields, materials and dose maps, as a user would – run the same simulation the application runs, and compare the results with expected values; a few check RadMap's own arithmetic, such as turning an activity concentration into a total, without a simulation. The case's text, its references and its checks below are taken from the test itself, so the report and the tests cannot differ.

Each case names the **requirements** it verifies, of two sets. The requirements state what RadMap must get right for its dose rates to be correct; the **safeguard requirements** state what it must guarantee for a dose rate the user reads to belong to the project they built (*Hazards and safeguards* below). The traceability table shows which cases verify each, and lists any that no case verifies yet.

Each case states its **basis**, which says where its expected values come from, and names the published sources it uses; the last chapter lists them in full. The bases are:

- **Published reference.** Every expected value is derived from published data – decay data, attenuation coefficients, buildup factors, conversion coefficients – or, for geometry and arithmetic, worked out by hand. None comes from RadMap.
- **Partly RadMap's own result.** Part of an expected value, which the case's text names, is a result RadMap gave when the case was written. The rest is published data. Such a case shows that the part it takes from RadMap has not changed, not that it is right.
- **Condition.** The case checks a limit, a direction or that something holds – a shield covers the maps it should, a run completes, two runs agree – rather than a value.
- **Measurement.** Every expected value is a published measurement, and the tolerance comes from the experiment's stated uncertainties. Such a case validates RadMap rather than verifying it (*Verification and validation* below).

1.2 Identifiers

Every item the report traces has an identifier that is never changed or given to another item; a withdrawn item's identifier stays unused.

- **R-6**: a requirement on the computation, numbered.
- **S-5**: a safeguard requirement, numbered.
- **H-5**: a hazard, numbered.
- **D-0008**: a defect found in a released version. Those the hazard analysis cites are described under *Defects cited*, which also gives the address of the errata page listing every one.

- **AR-PerMass**, **R6-Sampling**, **S5-Lock**: a V&V case, named by its group and what it tests. A case named after a requirement writes the number without a hyphen, so that **S5-Lock** reads as a case verifying S-5, not as S-5 itself. A few cases from earlier versions begin with a letter and a hyphen followed by a word, such as **S-Seed** and **D-Co60-Cs137**; they keep those names, and are cases, not safeguard requirements or defects.

1.3 Hazards and safeguards

A correct calculation is not enough: the user must also act on the right one. The **hazard analysis** lists the ways a user could act on a wrong dose rate without knowing it is wrong – a fault in RadMap, a damaged installation, a result misread, a calculation set up for another question than the user's – and for each, what controls it and what does not.

Each hazard names its **controls**: the requirements, of either set, whose verification shows it controlled, each with how its cases went in this build. Where a check by hand or the user guide controls it too, the hazard says so. It names the defects found in released versions that came by it, which *Defects cited* describes as they stood when this report was generated. Last, it states what is **open**: what its controls do not cover, the residual risk, and why it is accepted. A safeguard requirement no case verifies yet is listed as unverified.

1.4 Checks and tolerances

Each check compares one result with its criterion: an expected value within a relative tolerance, a limit, or a condition. The tolerances allow for the statistical uncertainty of a Monte Carlo result and for the approximations a derivation makes; each case's text says what its tolerances cover.

A simulated result is shown as its value ± σ, its statistical uncertainty of one standard deviation as RadMap reports it, in the value's own unit (case U-Cs137-Spread checks that it matches the scatter of repeated runs). A check on such a result passes only if the run could tell a pass from a fail: three standard deviations must fit inside the tolerance, and a limit must hold by more than three standard deviations. Otherwise a wrong value could pass by chance. A ratio of two independent results carries both their uncertainties: results of separate runs, or maps in different directions from a source in vacuum, which no photon can reach both of. A ratio of two maps in the same place, such as AP to ROT, is shown without one: in vacuum the maps score exactly the same photons, so the ratio's statistical noise is far below its tolerance, which the derivation alone sets.

The simulations run with a fixed seed, so a case's results vary between runs of the same build only in their last digits, from the order in which threads add their scores; the tolerances therefore guard against changes to RadMap, its data or Geant4, not against run-to-run noise.

1.5 Verification and validation

The cases **verify** RadMap: each shows that RadMap computes what its inputs imply – the decay data, the attenuation and conversion coefficients, the buildup factors – by comparing its results with values derived from published references. Most of those references are themselves calculated, not measured, so a passing case shows that RadMap reproduces accepted reference models, not that the models agree with a measurement.

Validation compares the results with measurements: the cases whose basis is *Measurement*, in ValidationTest. Of the quantities RadMap reports, air kerma is the one that can be measured. Effective dose is a protection quantity, defined on a reference phantom and not measurable; $H^*(10)$ is estimated by instruments calibrated in air kerma. Both are the photon fluence times a published coefficient, a step the cases verify, so validating air kerma validates them too.

The validation cases are the gamma-ray experiments of Kansas State University with radionuclide sources: Cs-137 over a concrete floor, and Co-60 skyshine, which OECD/NEA's SINBAD database holds as an evaluated benchmark. Few photon shielding experiments are documented well enough, in geometry and in stated uncertainties, to compare a calculation with; MCNP's shielding validation suite has the same skyshine experiment and one other photon

experiment. Geant4's published validation of the photon physics RadMap uses is open work; the skyshine case also compares RadMap with LLNL's COG on the same model.

2 Summary

Status
release 3.0.0

RadMap version
3.0.0

Source
`64660deff83b6ace230d7c0fe1e811c47c6e3b5b`

Report generated
2026-11-20 20:18 UTC

V&V cases
121, 121 passed

Checks
530

Requirements
19, 19 verified by at least one case

Safeguard requirements
14, 14 verified by at least one case

Hazards
15, 7 with residual risk

Not in this report: 3 cases of the C API, radmap.dll, which this version does not ship. They are checked and run with every build, and join the report in the version that ships them.

- Published reference: 21 cases
- Partly RadMap's own result: 7 cases
- Condition: 91 cases
- Measurement: 2 cases

3 Requirements

3.1 R-1: Gamma emission

A source emits the gammas of its isotope's decay: those of every excited level of the daughter it reaches, long-lived ones included, with the yields of the decay data.

Verified by: A-Co60-ROT, A-Cs137-ROT, D-Co60-Cs137, B-Co60-Pb, B-Cs137-Pb, E-Cs137-Water, AK-Cs137, AK-Co60, AH-Cs137, AH-Co60, CK-Na22, X-Am241, C-Ru106-Chain, V-KSU-Cs137, V-KSU-Skyshine

3.2 R-2: X-ray emission

The vacancies that electron capture and internal conversion leave in the daughter's atomic shells refill with the X-rays of the atomic data.

Verified by: A-Cs137-ROT, AK-Cs137, AH-Cs137, X-Am241

3.3 R-3: Annihilation

Each positron from beta+ decay annihilates into two 511 keV photons.

Verified by: CK-Na22

3.4 R-4: Activity

A source's dose rates are proportional to its activity, given in any of RadMap's activity units.

Verified by: D-Co60-Cs137, AR-Absolute

3.5 R-5: Activity as a concentration

An activity given per volume or per mass resolves to a total: the concentration times the volume of the source's own material (its solid less the solids placed inside it), and for a mass concentration also times the material's density. An activity that cannot be resolved is refused, not taken as zero.

Verified by: AR-PerVolume, AR-VolumeUnit, AR-PerMass, AR-Children, AR-Refused, AR-NoVolume, AR-Zero

3.6 R-6: Source distribution

A source's decays are spread evenly through its solid's own material, excluding the solids placed inside it.

Verified by: S-Name-0x, S-World, R6-Sampling

3.7 R-7: Several sources

The dose rate from several sources is the sum of their contributions, each at its own activity.

Verified by: D-Co60-Cs137, C-Chain-PerSource, C-Chain-None

3.8 R-8: Decay chain

With *Full chain* on, the radioactive daughters of a source decay as well, each once for every decay of the source.

Verified by: C-Ru106-Chain, C-Chain-PerSource, C-Chain-None

3.9 R-9: Fluence in free air

A dose map scores the photon fluence averaged over its volume, in any orientation. In air the fluence from a point source falls with the inverse square of the distance, reduced only by the attenuation of the air.

Verified by: A-Co60-ROT, A-Cs137-ROT, D-Co60-Cs137, O-Co60-Orientation, AK-Cs137, AK-Co60, AH-Cs137, AH-Co60, CK-Na22, X-Am241, V-KSU-Cs137, V-KSU-Skyshine

3.10 R-10: Attenuation

A shield attenuates the photons crossing it according to the published attenuation coefficients of its material, over the thickness the geometry gives.

Verified by: B-Co60-Pb, B-Cs137-Pb, E-Cs137-Water, BK-Co60-Pb, BK-Cs137-Pb, EK-Cs137-Water, EK-Cs137-WaterInf, G-Box, G-Tube-Phi-0, G-Tube-Phi-180, G-Tube-Phi-Gap, G-Sphere-Phi-10, G-Sphere-Phi-190, G-Sphere-Theta-10, G-Sphere-Theta-0, V-KSU-Cs137, V-KSU-Skyshine

3.11 R-11: Scatter

Photons a shield scatters still reach the dose maps, so the dose behind a shield includes its buildup.

Verified by: B-Co60-Pb, B-Cs137-Pb, E-Cs137-Water, BK-Co60-Pb, BK-Cs137-Pb, EK-Cs137-Water, EK-Cs137-WaterInf, V-KSU-Cs137, V-KSU-Skyshine

3.12 R-12: Geometry

Solids and dose maps reach the simulation as entered: their dimensions, angular segments, positions and rotations, including those inherited from parent solids.

Verified by: O-Co60-Orientation, B-Co60-Pb, B-Cs137-Pb, E-Cs137-Water, S-Name-0x, R6-Sampling, G-Box, G-Tube-Phi-0, G-Tube-Phi-180, G-Tube-Phi-Gap, G-Sphere-Phi-10, G-Sphere-Phi-190, G-Sphere-Theta-10, G-Sphere-Theta-0, T-Translation, T-Rotation, T-Multiaxis, V-KSU-Skyshine

3.13 R-13: Materials

Materials reach the simulation with their composition and density, mixes of other materials included.

Verified by: B-Co60-Pb, B-Cs137-Pb, E-Cs137-Water, M-Mix-Composition, M-Mix-Nested-Composition, M-Name-0x, M-Density-Unit

3.14 R-14: Electrons and bremsstrahlung

With *Simulate electrons* on, electrons from decay are transported and their bremsstrahlung reaches the dose maps; with it off, they contribute nothing.

Verified by: F-Sr90-Toggle, F-P32-Plate

3.15 R-15: Effective dose

Effective dose is converted from fluence with the ICRP 116 coefficients, interpolated in photon energy, for the irradiation geometry chosen.

Verified by: A-Co60-ROT, A-Cs137-ROT, D-Co60-Cs137, B-Co60-Pb, B-Cs137-Pb, E-Cs137-Water, X-Am241, C-Ru106-Chain

3.16 R-16: Ambient dose equivalent

$H^*(10)$ is converted from fluence with the ICRP 74 coefficients, interpolated in photon energy.

Verified by: AH-Cs137, AH-Co60

3.17 R-17: Air kerma

Air kerma is converted from fluence with the ICRP 74 coefficients, interpolated in photon energy.

Verified by: BK-Co60-Pb, BK-Cs137-Pb, AK-Cs137, AK-Co60, AH-Cs137, AH-Co60, EK-Cs137-Water, EK-Cs137-WaterInf, CK-Na22, X-Am241, C-Ru106-Chain, V-KSU-Cs137, V-KSU-Skyshine

3.18 R-18: Statistical uncertainty

Every dose rate is reported with a statistical uncertainty that matches the scatter of repeated runs.

Verified by: U-Cs137-Spread

3.19 R-19: Reproducibility

The same project and seed, run on one thread, give the same results; a different seed gives different ones. Runs on several threads are not reproducible to the bit, because the order in which threads add their scores varies.

Verified by: S-Seed

4 Safeguard requirements

4.1 S-1: The run is the project

What Geant4 receives – geometry, materials, sources, dose maps and run settings – is generated from the project in memory when the run starts, and its geometry is identical to what saving the project writes. Nothing of a run is read from a file.

Verified by: S1-SameAsSave, S1-Unsaved

4.2 S-2: Every entity stays itself

Each solid, material, element and isotope reaches Geant4 as an entity of its own, whatever its name: none is merged with another, renamed into another, or left out.

Verified by: S-Name-0x, S-World, M-Name-0x, S2-References, S2-SharedIsotopes, S2-SharedIsotopeTwo, S2-SharedPartly, S2-SharedMix, S2-AtomsAndMass, S2-IsotopeElementName, S2-OneNameThree, S2-Material0x, S2-Element0x, S2-Isotope0x, S2-Leading0x, S2-AllCharacters, S2-ElementG4Name, S2-MaterialG4Name, S2-Case

4.3 S-3: Input is refused, not changed

A value RadMap cannot use is refused with a message naming what to correct. A material library entry is refused when it is written, naming the fields at fault, and nothing of it is taken. A number its field could not show exactly – with more digits than the field takes, or past its range – is refused when it is written, in the library or the scene, and nothing of that write is taken. Otherwise a solid, source or dose map takes the value as entered and keeps it until the user corrects it; saving or starting a run, whichever needs the value, is refused, naming the entity. RadMap does not clamp, round or replace a value the user entered.

Verified by: S3-AtSave, S3-Numbers, S3-BeforeRun, S3-Library, S3-LibraryFields, S3-ParticleLimit, S3-Sweep

4.4 S-4: Results only from a complete run

A run's results are taken only once the simulation has reported that it finished. A run that fails, crashes, ends without that report, or is cancelled stores none of its results, and one that ends with an error tells the user why. Results cut off part-way are not taken.

Verified by: S4-CutOff, S4-Failed, S4-Cancelled

4.5 S-5: Results freeze their inputs

While a project holds results, every change to what they depend on is refused – the scene, the material library, sources, dose maps and run settings – until the results are discarded. Changes that reach no result, such as colour, stay allowed.

Verified by: S5-Lock, S5-Run, S5-Unpolled

4.6 S-6: Results carry their run

Results are stored with the record of the run that produced them – its run ID, the RadMap version that ran it and its start time – and are saved, loaded and discarded together with it. The run's settings, the number of primary particles among them, stay as the run used them while its results are held (S-5). The report shows the record and the number of primary particles.

Verified by: S10-Report, S6-Record

4.7 S-7: A file reads back as written

A save replaces the file whole or leaves it as it was. A load replaces the project whole or leaves the open one as it was. Numbers are read back exactly as written, on any machine and whatever its regional settings, and a file of an earlier format of 3.0 or later as the version that wrote it read it. A file RadMap cannot read in full – cut off, of a newer format, with results it cannot read – is refused, not read in part, and so is a file saved by RadMap 2.0 or earlier, whose material library holds errors 3.0 corrects.

Verified by: S7-FailedWrite, S7-CutOff, S7-EmptyPart, S7-UnknownUnit, S7-UnknownDensityUnit, S7-BadResults, S7-UnitNames, S7-NewerFormat, S7-EarlierFormat, S7-Geometry, S7-Activity, S7-Locale

4.8 S-8: A fault ends the session

After an exception RadMap's code does not handle, nothing further runs on the project and nothing is saved: the user is told that RadMap must close, and it closes.

Verified by: S8-Wx, S8-WxEnds

4.9 S-9: The installation is the release

A run uses the Geant4 data and libraries installed with RadMap's simulation program, whatever the environment sets, and a simulation program of another version is refused. Each user can check that their installation reproduces the release's results, with projects shipped for it and ranges published for each of their dose rates.

Verified by: S9-Version, S9-InstalledData, S9-Libraries, S9-Verify-Cs137, S9-Verify-Co60, S9-Verify-Na22, S9-Verify-I125, S9-Verify-Sr90

4.10 S-10: Each result says what it is

A dose rate is shown with the unit its dose map scored and with its statistical uncertainty, both read from the run's results, not from the settings in force when it is read; results in a unit RadMap does not know give no dose rate rather than a mislabelled one. The dose map's quantity cannot change while its results are held (S-5).

Verified by: S10-Unit, S10-Report

4.11 S-11: The windows show the project

Every change to the project is reported to the views that show it before the change returns, whichever view or program made it.

Verified by: S11-Run, S11-Structure, S11-Edits, S11-Refused, S11-Load, S11-Library, S11-Settings, S11-View

4.12 S-12: An edit's reach is shown

Before an edit to a library entry that other entries, solids or sources use is applied, the user is shown every one of them it changes.

Verified by: S12-Effect, S12-Replace, S12-Delete

4.13 S-13: A project file is not open to casual editing

A project file is stored in a binary form that cannot be read as text or edited with ordinary tools, such as a text editor or a zip program. Each part of the file carries a checksum of its content, so a file whose content was changed in storage or transfer is refused when it is loaded, even where the changed content would still read.

Verified by: S13-Damage

4.14 S-14: A dose map lies inside the world

A run is refused while a dose map reaches outside the world volume, with a message naming the dose map. The project can still be saved.

Verified by: S14-InsideWorld

5 Hazard analysis

5.1 H-1: A wrong dose computed for the project

The project reaches Geant4 as built, but the dose rate computed for it is wrong: decay data, transport, scoring, conversion coefficients or statistics.

Controls:

- R-1: Gamma emission – 15 cases, all passed
- R-2: X-ray emission – 4 cases, all passed
- R-3: Annihilation – 1 case, passed
- R-4: Activity – 2 cases, all passed
- R-5: Activity as a concentration – 7 cases, all passed
- R-6: Source distribution – 3 cases, all passed
- R-7: Several sources – 3 cases, all passed
- R-8: Decay chain – 3 cases, all passed
- R-9: Fluence in free air – 12 cases, all passed
- R-10: Attenuation – 17 cases, all passed
- R-11: Scatter – 9 cases, all passed
- R-12: Geometry – 18 cases, all passed
- R-13: Materials – 7 cases, all passed
- R-14: Electrons and bremsstrahlung – 2 cases, all passed
- R-15: Effective dose – 8 cases, all passed
- R-16: Ambient dose equivalent – 2 cases, all passed
- R-17: Air kerma – 13 cases, all passed
- R-18: Statistical uncertainty – 1 case, passed
- R-19: Reproducibility – 1 case, passed
- S-14: A dose map lies inside the world – 1 case, passed

Other evidence: none.

Defects: *D-0001*, *D-0002*, *D-0003*, *D-0004*, *D-0005*, *D-0006*, *D-0007*, *D-0008*, *D-0013*, *D-0021*, *D-0027*, *D-0031*, *D-0032*, *D-0033*

Open: none.

5.2 H-2: A run of something other than the project shown

Geant4 is given geometry, materials or sources that differ from what the windows show: a project left as the last save wrote it, or an entity translated wrongly on the way.

Controls:

- S-1: The run is the project – 2 cases, all passed
- S-2: Every entity stays itself – 19 cases, all passed

Other evidence: none.

Defects: D-0014, D-0015, D-0019

Open: none.

5.3 H-3: A project holding other than the user entered

A value the user typed is replaced, rounded or reinterpreted, or an edit reaches entities the user did not mean to change, so the project computed correctly is not the one intended.

Controls:

- S-3: Input is refused, not changed – 7 cases, all passed
- S-7: A file reads back as written – 12 cases, all passed
- S-12: An edit's reach is shown – 3 cases, all passed

Other evidence: checked by hand: an invalid name is marked and refused at saving; a paste that typing could not have entered is refused, in a number field and a name; the user guide, *Set tube dimensions and position*, on entering a full turn.

Defects: D-0008, D-0010, D-0024, D-0026, D-0028, D-0030

Open: a sweep is simulated as entered, so a user who enters a full turn in radians, such as 6.283 rad, gets a solid with a slit too narrow to see in the 3D view; only the user guide warns of it. A number with more decimals than its field shows would be shown rounded and written back rounded by the next edit beside it; RadMap refuses such a number however it is entered (S-3), so a file it writes holds none, and it opens no file of 2.0, whose verification samples held such numbers (D-0030); only a file RadMap did not write could hold one (H-14). The material editor builds the library entry it writes from its windows, and that it writes what they show is checked by hand only: the library refuses an entry it cannot use (S-3), but no automated case reaches the windows, which is how a material mix was saved as a mix of elements (D-0028).

5.4 H-4: Results of an incomplete run taken as complete

A run that stopped part-way, failed or was cancelled leaves results that look like a finished run's.

Controls:

- S-4: Results only from a complete run – 3 cases, all passed

Other evidence: none.

Defects: none.

Open: none.

5.5 H-5: Results attributed to a project changed since the run

The project is edited after a run, and its results are then read, saved or reported as those of the edited project.

Controls:

- S-5: Results freeze their inputs – 3 cases, all passed
- S-6: Results carry their run – 2 cases, all passed

Other evidence: checked by hand: the project is locked once a run has finished.

Defects: none.

Open: none.

5.6 H-6: A report taken for another project or run

A PDF report is matched to the wrong project file or run, or the entities it names cannot be told apart.

Controls:

- S-6: Results carry their run – 2 cases, all passed
- S-10: Each result says what it is – 2 cases, all passed

Other evidence: checked by hand: the report's run ID and dose rates read against the application's. The report and the panels write every number through the same functions (`display`), so they cannot differ in how a value is written.

Defects: *D-0012*

Open: the PDF's layout – that each value stands on the page under its own heading – is checked by hand only; what the report holds is verified without it.

5.7 H-7: A bad state saved

After a fault, a half-changed project is saved and later opened as if it were sound.

Controls:

- S-7: A file reads back as written – 12 cases, all passed
- S-8: A fault ends the session – 2 cases, all passed

Other evidence: checked by hand: after a fault, RadMap shows its message, writes the details to its error log and closes without saving; and the message box itself, which no case can close, shown by a program built on the application's base and closed with OK, the program then ending.

Defects: none.

Open: none.

5.8 H-8: A file read back differently from how it was written

A saved project, volume or library loads with values, entities or results other than those saved – also on another machine, whose regional settings write numbers with a decimal comma.

Controls:

- S-7: A file reads back as written – 12 cases, all passed

Other evidence: checked by hand: a project saved and loaded, with and without results, and a solid saved and loaded with *Save Volume* and *Load Volume*.

Defects: *D-0017*

Open: none.

5.9 H-9: A result read as another quantity, unit or precision

A dose rate is taken for another quantity than its dose map scored, in another unit, or as more precise than its statistical uncertainty allows.

Controls:

- S-10: Each result says what it is – 2 cases, all passed
- R-18: Statistical uncertainty – 1 case, passed

Other evidence: checked by hand: each dose map's quantity, unit and uncertainty in the panel and the report; the user guide, *Choosing what the dose map scores*.

Defects: none.

Open: none.

5.10 H-10: A window showing a state that is not the project's

A panel, list or the 3D view shows an earlier state of the project, and the user checks or reports the geometry or the values from it.

Controls:

- S-11: The windows show the project – 8 cases, all passed

Other evidence: checked by hand: the 3D view against the numbers entered, and the panels during and after a run.

Defects: none.

Open: that each window acts on the changes reported to it is checked by hand only; the automated cases reach the 3D view's drawing, not the panels.

5.11 H-11: An installation that computes differently from the release

The program or data a run uses are not those released – another Geant4 data set, a mismatched DoseAlgorithm, a damaged installation – and give other results.

Controls:

- S-9: The installation is the release – 8 cases, all passed

Other evidence: the user guide, *Verifying your installation*.

Defects: none.

Open: none.

5.12 H-12: The right number for the wrong question

The dose rate is correct for the project, but the project was set up to answer another question than the user's: an irradiation geometry that understates the effective dose of the person assessed, a quantity other than the one the assessment needs, or radiation RadMap does not calculate, such as the beta or neutron dose of a source.

Controls: none in the software.

Other evidence: the user guide, *Known limitations*, *What a dose map measures*, *Choosing what the dose map scores* and *Methods*.

Defects: *D-0022*

Open: whether a project answers the user's question is the user's judgement, which the EULA's *Intended Use* leaves to them; RadMap can only document what it calculates.

5.13 H-13: A project from an earlier version computed differently

A project made with an earlier version of RadMap is opened or run in this one, and gives other results than it did, or holds results the user takes for this version's. Two kinds of change bring it about: a change in what a file's contents mean, and a change in how RadMap computes – a fix, new data, a new version of Geant4.

Controls:

- S-6: Results carry their run – 2 cases, all passed
- S-7: A file reads back as written – 12 cases, all passed

Other evidence: a change in what a file means raises its format version, and the loader brings an older file to the current meaning before reading it, so the project means what it meant when it was saved. RadMap 3.0 opens no file saved by 2.0 or earlier (S-7): the material library each of them carries holds errors 3.0 corrects (D-0031 to D-0033), which no meaning brought forward could undo. Stored results name the version that computed them, in *Run information* and in the report, and results of a new run name this one. A change in how RadMap computes is

announced, not detected: each version's release notes mark the changes that affect results (**Affects results:**), and the errata page lists the defects of every released version.

Defects: none.

Open: whether a change in computation affects a user's earlier results is theirs to judge from the release notes and the errata page. RadMap does not tell them on opening a project: a notice after every upgrade could not say whether anything affecting that project had changed.

5.14 H-14: A project file changed outside RadMap

A project file is changed after it was saved, by damage in storage or transfer or by someone editing it, and is loaded as the project RadMap saved.

Controls:

- S-7: A file reads back as written – 12 cases, all passed
- S-13: A project file is not open to casual editing – 1 case, passed

Other evidence: none.

Defects: none.

Open: a deliberate change made with tools written for the purpose is not detected. Keeping records that must be shown unchanged, such as a project file or its report, is the job of the user's own quality system.

5.15 H-15: A V&V report showing results that are not its version's

A V&V report presents results from an earlier run of its tests, made on other code, so a user qualifying RadMap relies on evidence that does not describe the version they use.

Controls: none of the requirements: the report itself is the control.

Other evidence: every check a V&V case records carries the identity of the source its test was built from – the commit, and a hash of any change not yet committed – and the report refuses results of any other build, and a release report any build with uncommitted changes. The summary gives the identity. A release's report is also generated in the automated run that builds the release, after every V&V test has run in that run, and the run publishes nothing unless every case ran and passed.

Defects: none.

Open: the report generator's own checks are not V&V cases; they are shown to work by the reports they refuse.

6 Traceability

Requirement	Cases	Refer-ence	Partly own	Condi-tion	Mea-sured
R-1: Gamma emission	15	12	1	0	2
R-2: X-ray emission	4	4	0	0	0
R-3: Annihilation	1	1	0	0	0
R-4: Activity	2	2	0	0	0
R-5: Activity as a concentration	7	4	0	3	0
R-6: Source distribution	3	0	0	3	0
R-7: Several sources	3	1	0	2	0
R-8: Decay chain	3	1	0	2	0
R-9: Fluence in free air	12	10	0	0	2
R-10: Attenuation	17	5	2	8	2
R-11: Scatter	9	5	2	0	2
R-12: Geometry	18	3	1	13	1
R-13: Materials	7	2	1	4	0
R-14: Electrons and bremsstrahlung	2	0	0	2	0
R-15: Effective dose	8	7	1	0	0
R-16: Ambient dose equivalent	2	2	0	0	0
R-17: Air kerma	13	10	1	0	2
R-18: Statistical uncertainty	1	0	0	1	0
R-19: Reproducibility	1	0	0	1	0
S-1: The run is the project	2	0	0	2	0
S-2: Every entity stays itself	19	0	0	19	0
S-3: Input is refused, not changed	7	0	0	7	0
S-4: Results only from a complete run	3	0	0	3	0
S-5: Results freeze their inputs	3	0	0	3	0
S-6: Results carry their run	2	0	0	2	0
S-7: A file reads back as written	12	0	0	12	0
S-8: A fault ends the session	2	0	0	2	0
S-9: The installation is the release	8	0	5	3	0
S-10: Each result says what it is	2	0	0	2	0
S-11: The windows show the project	8	0	0	8	0
S-12: An edit’s reach is shown	3	0	0	3	0
S-13: A project file is not open to casual editing	1	0	0	1	0
S-14: A dose map lies inside the world	1	0	0	1	0

7 V&V cases

7.1 DoseTest

A-Co60-ROT: Co-60 point source in vacuum: effective dose, inverse square and geometry

Result
passed

Verifies
R-1, R-9, R-15

Basis
Published reference – *ICRP 116*, Table A.1; *DDEP Co-60*

Test
DoseTest

A 1 GBq Co-60 source in a 1 mm cube, in a 5 m cube of vacuum. Dose maps score effective dose in the ROT geometry at 0.5 m on the x axis, 1 m on the y axis and 2 m on the z axis, each facing the source and sized with its distance: 200 × 200 × 1 mm at 0.5 m, 400 × 400 × 2 mm at 1 m and 800 × 800 × 4 mm at 2 m. Maps in the same place as the one at 1 m score AP, PA, LLAT, RLAT and ISO.

The expected values sum every photon line of the decay data, each with the coefficient for its energy; none of them comes from RadMap. A coefficient is read from the published table on a natural cubic spline in energy, the interpolation RadMap uses, computed here independently. Below a table's lowest energy, 10 keV, a coefficient is zero, except air kerma's, which keeps its 10 keV value, as the user guide states under *Known limitations*. Lines adding less than 0.01 % are left out of the tables below, not of the sums. The fluence rate 1 m from 1 GBq is $10^9 / (4\pi \times 100^2)$ = 7 957.7 cm^{-2} s^{-1} per photon per decay.

The maps. A map reads the fluence averaged over its volume, so a plate facing a point source reads the mean fluence over its face. Each of these faces is a square 0.4 d on a side at a distance d, and the mean of d^2/r^2 over it, r being the distance to each point, is 0.9743: each map reads 0.9743 of the fluence at its centre. Scaled with its distance, every map subtends the same solid angle, reads the same fraction and counts about the same number of photons. In vacuum nothing scatters or attenuates, and the maps lie in different directions, so no photon reaches two of them: their errors are independent, and the ratio of two carries both their uncertainties. AK-Co60 and AH-Co60 score air kerma and $H^*(10)$ in the same three places, in the same run: the three cases would otherwise simulate the same photons three times.

Dose rate at 1 m (ROT).

Line (keV)	Yield	h_E, ROT (pSv·cm²)
1173.228	0.9985	4.274
1332.492	0.999826	4.757

Per decay, Σ yield × h_E = 9.025 pSv·cm², so at a point 1 m away the dose rate is 7 957.7 × 9.025 × 10^{-12} × 3600 = 258.5 µSv/h, and the map reads 0.9743 of it: 251.9 µSv/h, within ±3 %.

Inverse square. Since the maps are scaled copies of each other, their readings scale exactly as $1/r^2$: the dose rate at 0.5 m is four times that at 1 m, and at 1 m four times that at 2 m, within ±3 %.

The case runs 1 500 000 decays, so that three standard deviations of each result fit inside its tolerance with room to spare.

Irradiation geometry. Maps in the same place score exactly the same photons, so their ratio to ROT varies only with the mix of the two lines among those photons, by well under 0.1 %, and is shown without an uncertainty. It checks that each geometry reads its own column of the table, within ±1 %, which allows for small differences between the decay data Geant4 uses and DDEP's:

Geometry	1173 keV	1332 keV	Ratio to ROT
ROT	4.274	4.757	
AP	5.090	5.608	1.1845
PA	4.411	4.908	1.0318
LLAT	3.725	4.187	0.8761
RLAT	3.522	3.977	0.8303
ISO	3.764	4.217	0.8837

Check	Result	Criterion	Verdict
d(0.5 m) / d(1 m)	4.036 ± 0.030	4 ± 3 %	pass
d(1 m) / d(2 m)	4.013 ± 0.030	4 ± 3 %	pass
d(1 m), ROT	(2.516 ± 0.013) × 10^{-4} Sv/h	2.519 × 10^{-4} Sv/h ± 3 %	pass
AP / ROT	1.185	1.185 ± 1 %	pass
PA / ROT	1.032	1.032 ± 1 %	pass
LLAT / ROT	0.8761	0.8761 ± 1 %	pass
RLAT / ROT	0.8303	0.8303 ± 1 %	pass
ISO / ROT	0.8837	0.8837 ± 1 %	pass

A-Cs137-ROT: Cs-137 point source in vacuum: effective dose, inverse square and geometry

Result
passed

Verifies
R-1, R-2, R-9, R-15

Basis
Published reference – *ICRP 116*, Table A.1; *DDEP Cs-137*

Test
DoseTest

The Co-60 case (A-Co60-ROT), with its maps and its way of deriving the expected values, with a 1 GBq Cs-137 source. It shares its run with AK-Cs137 and AH-Cs137.

Dose rate at 1 m (ROT). Cs-137 emits, through Ba-137m, one gamma line at 661.657 keV with a yield of 0.8499, where ICRP 116's spline gives h_E(ROT) = 2.539 pSv·cm² (2.54 at the table's 0.662 MeV); the line alone gives 61.8 µSv/h at a point 1 m away. It also emits Ba K X-rays, 31.8 to 37.4 keV, 0.0686 per decay, and Ba L X-rays, 4 to 6 keV, 0.0090 per decay. In vacuum both reach the map: the K X-rays add 0.0118 pSv·cm² per decay, 0.55 %, and the L X-rays nothing, being below the table. Per decay, Σ yield × h_E = 2.1695 pSv·cm², so at a point 1 m away the dose rate is 7 957.7 × 2.1695 × 10^{-12} × 3600 = 62.15 µSv/h, and the map reads 0.9743 of it: 60.55 µSv/h, within ±3 %.

Inverse square as in A-Co60-ROT, within ±3 %. With fewer than half the photons per decay of Co-60, the case runs 3 000 000 decays.

Irradiation geometry. As in A-Co60-ROT, within ±1 %. The ratios include the K X-rays, which add 0.4 to 0.8 % to each geometry's sum:

Geometry	h_E at 661.657 keV	Ratio to ROT
ROT	2.539	
AP	3.169	1.2516
PA	2.629	1.0335
LLAT	2.119	0.8338
RLAT	1.969	0.7744
ISO	2.169	0.8540

Check	Result	Criterion	Verdict
d(0.5 m) / d(1 m)	3.963 ± 0.031	4 ± 3 %	pass
d(1 m) / d(2 m)	4.035 ± 0.032	4 ± 3 %	pass
d(1 m), ROT	(6.077 ± 0.034) × 10^{-5} Sv/h	6.055 × 10^{-5} Sv/h ± 3 %	pass
AP / ROT	1.252	1.252 ± 1 %	pass
PA / ROT	1.033	1.034 ± 1 %	pass
LLAT / ROT	0.8338	0.8338 ± 1 %	pass
RLAT / ROT	0.7743	0.7744 ± 1 %	pass
ISO / ROT	0.854	0.854 ± 1 %	pass

D-Co60-Cs137: Two sources at one point: Co-60 1 GBq and Cs-137 3 GBq

Result
passed

Verifies
R-1, R-4, R-7, R-9, R-15

Basis
Published reference – *ICRP 116*, Table A.1; *DDEP Co-60*; *DDEP Cs-137*

Test
DoseTest

Both sources in the same 1 mm cube, with different activities, and the ROT maps of A-Co60-ROT at 0.5, 1 and 2 m. The dose rate at 1 m is the sum of the two cases above, each at its own activity: 251.9 µSv/h for Co-60 at 1 GBq (A-Co60-ROT) and 3 × 60.55 = 181.7 µSv/h for Cs-137 at 3 GBq (A-Cs137-ROT), 433.5 µSv/h in all, within ±3 %. Weighting both sources equally, or dropping one, would miss it by far more. The maps at 0.5 and 2 m check the inverse square law on the combined field, within ±3 %. The case runs 3 000 000 decays, as A-Cs137-ROT does.

Check	Result	Criterion	Verdict
d(0.5 m) / d(1 m)	3.994 ± 0.029	4 ± 3 %	pass
d(1 m) / d(2 m)	4.006 ± 0.029	4 ± 3 %	pass
d(1 m), ROT	(4.342 ± 0.022) × 10^{-4} Sv/h	4.335 × 10^{-4} Sv/h ± 3 %	pass

O-Co60-Orientation: Deep dose maps turned towards a point source read the mean over their volume

Result
passed

Verifies
R-9, R-12

Basis
Published reference – *ICRP 116*, Table A.1; *DDEP Co-60*

Test
DoseTest

The source of A-Co60-ROT, 1 GBq of Co-60 in a 1 mm cube in vacuum, and four deep dose maps 600 mm from it, each scoring effective dose (ROT):

Map	Size (mm)	Centre	Rotation	Facing the source
face	300 × 300 × 300	+x, 600 mm	none	a face
edge	300 × 300 × 300	+y, 600 mm	Z 45°	an edge
corner	300 × 300 × 300	+z, 600 mm	X 35.264°, Y 45°	a corner
box	120 × 240 × 480	−y, 600 mm	X 60°, Y 30°	none

A map reads the fluence averaged over its volume. Within each of these maps the fluence changes several-fold between its nearest and farthest points, so what it reads depends on the region it covers, and on nothing else: not on which of its faces the photons enter by. The thin plates of the other cases cannot tell the two apart: their photons all enter through one large face, and the fluence hardly changes across their thickness.

The expected values are the point dose rate at 600 mm times the mean of d^2/r^2 over each map's volume, with d = 600 mm the distance to its centre and r the distance to each point in it. The point dose rate is that of A-Co60-ROT at 1 m, 258.5 µSv/h, times $(1000/600)^2$: 718.1 µSv/h. The means come from a 64-point Gauss-Legendre rule along each edge of the map, in its own frame, turned as RadMap turns it: a vector turns about Z first, then Y, then X (T-Multiaxis).

Map	Mean of d^2/r^2	Dose rate (µSv/h)	Ratio to face
face	1.01851	731.3	
edge	1.02261	734.3	1.0040
corner	1.02444	735.6	1.0058
box	1.06672	766.0	1.0473

For a cube of side s, the mean is close to $1 + s^2/12d^2$ in any orientation, so the three cubes should read within 0.6 % of each other. The box is not a cube, and its mean depends on how it lies: with its long axis pointing at the source it would read 1.162, with its short axis 0.948. Turned with the rotations in the opposite order, or by its 60° about X only, it would read 1.114, 4.5 % higher than expected, so it checks that the map reaches the simulation turned as RadMap shows it. When the case was written it found a fault: maps were turned by the inverse of their rotation (D-0006), and the box read 1.114. Each dose rate is checked within ±3 %, as in A-Co60-ROT, and each ratio to the face-on cube within ±2 %; the ratios are free of the decay data and coefficients, which cancel.

A scorer that counted the photons entering each map, divided by its area seen from their direction – RadMap's until 2.0 (D-0005) – reads 1.262 face-on, 1.073 edge- on and 0.953 corner-on: the same cube 32 % higher face-on than corner-on, where it should read the same.

The maps lie in different directions from the source, and none can be reached by a photon that reaches another, so their errors are independent. The case runs 1 500 000 decays.

Check	Result	Criterion	Verdict
cube, face-on	$(7.340 \pm 0.027) \times 10^{-4}$ Sv/h	7.313×10^{-4} Sv/h ± 3 %	pass
cube, edge-on	$(7.331 \pm 0.028) \times 10^{-4}$ Sv/h	7.343×10^{-4} Sv/h ± 3 %	pass
cube, corner-on	$(7.333 \pm 0.028) \times 10^{-4}$ Sv/h	7.356×10^{-4} Sv/h ± 3 %	pass
box, turned	$(7.669 \pm 0.034) \times 10^{-4}$ Sv/h	7.660×10^{-4} Sv/h ± 3 %	pass
edge-on / face-on	0.9988 ± 0.0053	1.004 ± 2 %	pass

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Check	Result	Criterion	Verdict
corner-on / face-on	0.9991 ± 0.0053	1.006 ± 2 %	pass
box / face-on	1.0449 ± 0.0060	1.047 ± 2 %	pass

B-Co60-Pb: Co-60 through 21.7 mm of lead: effective dose

Result
passed

Verifies
R-1, R-10, R-11, R-12, R-13, R-15

Basis
Published reference – *ANSI/ANS-6.4.3-1991*, Tables 1a and 3, as reproduced in NUREG/CR-5740; *NUREG/CR-5740*, Table 3; *ICRP 116*, Table A.1; *ICRP 74*, Table A.1; *DDEP Co-60*

Test
DoseTest

A lead slab, 300 × 300 mm and 21.7 mm thick, 100 mm from the Co-60 source of A-Co60-ROT, with the dose map at 1 m behind it. The attenuation coefficients and the buildup factors both come from the standard, so that depth and buildup are counted the same way: in mean free paths without coherent scattering. BK-Co60-Pb scores air kerma in the same place, in the same run; B-Cs137-Pb and BK-Cs137-Pb share one run likewise.

Narrow-beam attenuation. The standard's Table 1a gives μ/ρ for lead of 0.06844 cm^2/g at 1.0 MeV and 0.05102 cm^2/g at 1.5 MeV. Interpolated log-log, at 11.34 g/cm^3, μ = 0.691 cm^{-1} at 1.173 MeV and 0.630 cm^{-1} at 1.333 MeV, so the slab is 1.500 and 1.368 mean free paths thick. Weighting each line by its dose, 4.268 and 4.757 $pSv \cdot cm^2$ per decay (A-Co60-ROT), it passes 0.240 of the unshielded 258.5 μSv/h at a point without scatter: 62.0 μSv/h.

Buildup. Photons the lead scatters still reach the map. The standard's Table 3 gives exposure buildup factors for lead of 1.38 at 1 mfp for both 1.0 and 1.5 MeV, and 1.68 and 1.73 at 2 mfp. Between 1 and 2 mfp lead's factor is close to linear in depth; between the energies it is taken linear in log energy. That gives 1.540 at 1.173 MeV and 1.503 at 1.333 MeV, and 1.519 weighted by the transmitted dose. The expectation is 62.0 × 1.519 = 94.2 μSv/h, within ±10 %.

The case differs from the standard's conditions in two ways, both smaller than the tolerance. The factors are for a point source in an unlimited medium, while this is a finite slab in air: for lead, the report's own comparison (Table 3 of its text, at 1 MeV) puts a slab's factor 1–2 % below the unlimited medium's. And the factors are for exposure, that is air kerma, while the case scores effective dose. Between 0.15 and 1.5 MeV, the energies at which scattered photons get through lead, ICRP 116's effective dose (ROT) per ICRP 74's air kerma stays between 0.80 and 0.88, against 0.84 at Co-60's lines. The scattered photons therefore count nearly alike in both quantities, and the effective-dose factor lies within about 2 % of the exposure factor.

Check	Result	Criterion	Verdict
d(1 m) behind lead, ROT	(9.04 ± 0.26) × 10^{-5} Sv/h	9.420 × 10^{-5} Sv/h ± 10 %	pass

B-Cs137-Pb: Cs-137 through 9.8 mm of lead: effective dose

Result
passed

Verifies
R-1, R-10, R-11, R-12, R-13, R-15

Basis
Published reference – *ANSI/ANS-6.4.3-1991*, Tables 1a and 3, as reproduced in NUREG/CR-5740; *NUREG/CR-5740*, Table 3; *ICRP 116*, Table A.1; *ICRP 74*, Table A.1; *DDEP Cs-137*

Test
DoseTest

The geometry of B-Co60-Pb with the Cs-137 source of A-Cs137-ROT and a 9.8 mm slab, derived as B-Co60-Pb is. The standard's Table 1a gives μ/ρ for lead of 0.1178 cm^2/g at 0.6 MeV and 0.08472 cm^2/g at 0.8 MeV. Log-log at 0.662 MeV, μ = 1.194 cm^{-1}, so the slab is 1.170 mean free paths thick and passes exp(−1.170) = 0.310 of the unshielded 61.8 μSv/h at a point (A-Cs137-ROT) without scatter: 19.2 μSv/h. Table 3 gives exposure buildup factors of 1.28 and 1.34 at 1 mfp, and 1.46 and 1.59 at 2 mfp, for 0.6 and 0.8 MeV; interpolated as in B-Co60-Pb, 1.335. The expectation is 19.2 × 1.335 = 25.6 μSv/h, within ±10 %. The slab and the effective dose differ from the standard's conditions as in B-Co60-Pb; effective dose (ROT) per air kerma is 0.81 at 0.662 MeV.

The case runs 2 000 000 decays. At 500 000 the statistical uncertainty was 4.2 %, too large for the run to tell a value inside ±10 % from one outside it.

Check	Result	Criterion	Verdict
d(1 m) behind lead, ROT	(2.457 ± 0.052) × 10^{-5} Sv/h	2.560 × 10^{-5} Sv/h ± 10 %	pass

E-Cs137-Water: Cs-137 through 230 mm of water, 300 mm wide: effective dose

Result
passed

Verifies
R-1, R-10, R-11, R-12, R-13, R-15

Basis
Partly RadMap's own result – *NIST XCOM*; *ICRP 116*, Table A.1; *DDEP Cs-137*

Test
DoseTest

A water slab, 300 × 300 mm and 230 mm thick, 100 mm from the Cs-137 source of A-Cs137-ROT, with the dose map at 1 m. Water scatters far more than it absorbs at 0.662 MeV, so most of the dose behind it is scattered photons. EK-Cs137-Water scores air kerma in the same place, in the same run.

NIST XCOM gives μ/ρ = 0.0857 cm^2/g, so the slab is 1.971 mean free paths thick and passes exp(−1.971) = 0.139 of the unshielded 61.8 μSv/h at a point (A-Cs137-ROT) without scatter: 8.6 μSv/h. The buildup factor for this finite slab in air, 2.1, is **RadMap's own result**: published factors are for a source inside an unlimited medium, which this geometry is far from – the slab lets scatter escape sideways, and no water lies beyond it to scatter photons back (EK-Cs137-WaterInf checks a published factor in its own geometry). The expectation is 8.6 × 2.1 = 18.1 μSv/h, within ±15 %; without the scattered photons the result would be 8.6 μSv/h and fail clearly. The case runs 1 000 000 decays: at 500 000 the statistical uncertainty was 4.7 %, and three times that barely fitted inside the tolerance.

Check	Result	Criterion	Verdict
d(1 m) behind water, ROT	(1.767 ± 0.060) × 10^{-5} Sv/h	1.810 × 10^{-5} Sv/h ± 15 %	pass

BK-Co60-Pb: Co-60 through 21.7 mm of lead: air kerma

Result
passed

Verifies
R-10, R-11, R-17

Basis
Published reference – *ANSI/ANS-6.4.3-1991*, Tables 1a and 3, as reproduced in NUREG/CR-5740; *NUREG/CR-5740*, Table 3; *ICRP 74*, Table A.1; *DDEP Co-60*

Test
DoseTest

The geometry of B-Co60-Pb, scored as air kerma, the quantity the standard's exposure buildup factors are for. With each line weighted by its kerma, 5.082 and 5.617 pGy·cm² per decay (AK-Co60), the slab passes 0.240 of the unshielded air kerma rate at a point 1 m away, 306.5 µGy/h, without scatter: 73.5 µGy/h. The buildup factor, weighted the same way, is 1.519, so the expectation is 73.5 × 1.519 = 111.6 µGy/h, within ±10 %. The slab differs from the standard's unlimited medium as in B-Co60-Pb.

Check	Result	Criterion	Verdict
air kerma at 1 m behind lead	(1.079 ± 0.031) × 10^{-4} Gy/h	1.116 × 10^{-4} Gy/h ± 10 %	pass

BK-Cs137-Pb: Cs-137 through 9.8 mm of lead: air kerma

Result
passed

Verifies
R-10, R-11, R-17

Basis
Published reference – *ANSI/ANS-6.4.3-1991*, Tables 1a and 3, as reproduced in NUREG/CR-5740; *NUREG/CR-5740*, Table 3; *ICRP 74*, Table A.1; *DDEP Cs-137*

Test
DoseTest

The geometry of B-Cs137-Pb, scored as air kerma, the quantity the standard's exposure buildup factors are for. Without scatter the slab passes 0.310 of the unshielded 75.7 µGy/h at a point 1 m away (AK-Cs137): 23.5 µGy/h. With the buildup factor of B-Cs137-Pb, 1.335, the expectation is 23.5 × 1.335 = 31.4 µGy/h, within ±10 %. It runs 2 000 000 decays, as B-Cs137-Pb does.

Check	Result	Criterion	Verdict
air kerma at 1 m behind lead	(3.017 ± 0.064) × 10^{-5} Gy/h	3.140 × 10^{-5} Gy/h ± 10 %	pass

AK-Cs137: Cs-137 point source in vacuum: air kerma and inverse square

Result
passed

Verifies
R-1, R-2, R-9, R-17

Basis
Published reference – *ICRP 74*, Table A.1; *DDEP Cs-137*

Test
DoseTest

The geometry and maps of A-Cs137-ROT, scored as air kerma, and derived as there. ICRP 74's air kerma table has no point at 0.662 MeV; between its points at 0.600 MeV (2.84 pGy·cm²) and 0.800 MeV (3.69 pGy·cm²) the spline gives 3.111 pGy·cm² at 661.657 keV, and the gamma line alone gives 75.7 µGy/h at a point 1 m away. Air kerma also counts the X-rays: the K X-rays add 0.041 pGy·cm² per decay, and the L X-rays, below the table and counted at its 10 keV value of 7.43 pGy·cm², add 0.067 pGy·cm² – together 3.9 % of the sum. In air the L X-rays would not get past a few centimetres. Per decay, Σ yield × h_K = 2.7514 pGy·cm², so at a point 1 m away the air kerma rate is 7 957.7 × 2.7514 × 10^{-12} × 3600 = 78.82 µGy/h, and the map reads 0.9743 of it: 76.79 µGy/h, within ±3 %. The inverse square law holds within ±3 %, at 3 000 000 decays as in A-Cs137-ROT.

Check	Result	Criterion	Verdict
k(0.5 m) / k(1 m)	3.975 ± 0.031	4 ± 3 %	pass
k(1 m) / k(2 m)	4.014 ± 0.032	4 ± 3 %	pass
air kerma at 1 m	(7.701 ± 0.043) × 10^{-5} Gy/h	7.679 × 10^{-5} Gy/h ± 3 %	pass

AK-Co60: Co-60 point source in vacuum: air kerma and inverse square

Result
passed

Verifies
R-1, R-9, R-17

Basis
Published reference – *ICRP 74*, Table A.1; *DDEP Co-60*

Test
DoseTest

The geometry and maps of A-Co60-ROT, scored as air kerma, and derived as there. Both lines fall between ICRP 74's points at 1.000 MeV (4.47 pGy·cm²) and 1.500 MeV (6.14 pGy·cm²); the spline gives 5.089 pGy·cm² at 1173.228 keV and 5.618 pGy·cm² at 1332.492 keV. Per decay, Σ yield × h_K = 10.700 pGy·cm², so at a point 1 m away the air kerma rate is 7 957.7 × 10.700 × 10^{-12} × 3600 = 306.5 µGy/h, and the map reads 0.9743 of it: 298.6 µGy/h, within ±3 %. The inverse square law holds within ±3 %, at 1 500 000 decays as in A-Co60-ROT.

Check	Result	Criterion	Verdict
k(0.5 m) / k(1 m)	4.036 ± 0.030	4 ± 3 %	pass
k(1 m) / k(2 m)	4.013 ± 0.030	4 ± 3 %	pass
air kerma at 1 m	(2.983 ± 0.015) × 10^{-4} Gy/h	2.986 × 10^{-4} Gy/h ± 3 %	pass

AH-Cs137: Cs-137 point source in vacuum: ambient dose equivalent H*(10)

Result
passed

Verifies
R-1, R-2, R-9, R-16, R-17

Basis
Published reference – *ICRP 74*; *DDEP Cs-137*

Test
DoseTest

The geometry and maps of A-Cs137-ROT, scored as $H^*(10)$ and derived as there, with an air kerma map in the same place as the one at 1 m.

$H^*(10)$ at 1 m. ICRP 74 brackets 661.657 keV between 0.600 MeV (3.44 pSv·cm²) and 0.800 MeV (4.38 pSv·cm²); the spline gives 3.741 pSv·cm². The K X-rays add 0.051 pSv·cm² per decay, 1.6 %, and the L X-rays nothing, being below the table. Per decay, Σ yield × h* = 3.2304 pSv·cm², so at a point 1 m away the dose rate is 7 957.7 × 3.2304 × 10^{-12} × 3600 = 92.54 µSv/h, and the map reads 0.9743 of it: 90.16 µSv/h, within ±3 %. The inverse square law holds within ±3 %, at 3 000 000 decays as in A-Cs137-ROT.

$H^*(10)$ against air kerma. The air kerma map scores exactly the same photons, so the ratio of the two varies by well under 0.1 % and is shown without an uncertainty; it must equal the ratio of the two sums, 3.2304 / 2.7514 = 1.1741 Sv/Gy (AK-Cs137 for air kerma), within ±1 %. For photons the ratio of the coefficients stays between roughly 1 and 2, so a coefficient read from the wrong column of the table cannot satisfy it.

Check	Result	Criterion	Verdict
$H^*(10)$ at 0.5 m / $H^*(10)$ at 1 m	3.963 ± 0.031	4 ± 3 %	pass
$H^*(10)$ at 1 m / $H^*(10)$ at 2 m	4.034 ± 0.032	4 ± 3 %	pass
$H^*(10)$ at 1 m	(9.051 ± 0.050) × 10^{-5} Sv/h	9.016 × 10^{-5} Sv/h ± 3 %	pass
$H^*(10)$ / air kerma	1.175 Sv/Gy	1.174 Sv/Gy ± 1 %	pass

AH-Co60: Co-60 point source in vacuum: ambient dose equivalent $H^*(10)$, two lines

Result
passed

Verifies
R-1, R-9, R-16, R-17

Basis
Published reference – *ICRP 74*; *DDEP Co-60*

Test
DoseTest

The check AH-Cs137 cannot make: two lines per decay, both interpolated, neither at a point of the table. The geometry and maps are those of AH-Cs137, with Co-60, derived as in A-Co60-ROT.

$H^*(10)$ at 1 m. ICRP 74 brackets both lines between 1.000 MeV (5.20 pSv·cm²) and 1.500 MeV (6.90 pSv·cm²); the spline gives 5.819 pSv·cm² at 1173.228 keV and 6.348 pSv·cm² at 1332.492 keV. Per decay, Σ yield × h* = 12.158 pSv·cm², so at a point 1 m away the dose rate is 7 957.7 × 12.158 × 10^{-12} × 3600 = 348.3 µSv/h, and the map reads 0.9743 of it: 339.3 µSv/h, within ±3 %; the inverse square law holds within ±3 %.

$H^*(10)$ against air kerma. As in AH-Cs137, the ratio must equal that of the two sums: 12.158 / 10.700 = 1.1363 Sv/Gy (AK-Co60 for air kerma), within ±1 %.

Check	Result	Criterion	Verdict
$H^*(10)$ at 0.5 m / $H^*(10)$ at 1 m	4.036 ± 0.030	4 ± 3 %	pass
$H^*(10)$ at 1 m / $H^*(10)$ at 2 m	4.013 ± 0.029	4 ± 3 %	pass
$H^*(10)$ at 1 m	(3.390 ± 0.018) × 10^{-4} Sv/h	3.393 × 10^{-4} Sv/h ± 3 %	pass

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Check	Result	Criterion	Verdict
$H^*(10)$ / air kerma	1.136 Sv/Gy	1.136 Sv/Gy ± 1 %	pass

EK-Cs137-Water: Cs-137 through 230 mm of water, 300 mm wide: air kerma

Result
passed

Verifies
R-10, R-11, R-17

Basis
Partly RadMap's own result – *NIST XCOM*; *ICRP 74*, Table A.1; *DDEP Cs-137*

Test
DoseTest

The geometry of E-Cs137-Water, scored as air kerma. Without scatter the slab passes 0.139 of the unshielded 75.7 µGy/h at a point (AK-Cs137): 10.5 µGy/h. In water at this energy scattering dominates, and air kerma and effective dose depend on photon energy alike, so the buildup factor is the same for both: 2.1 for this slab, which is **RadMap's own result** (E-Cs137-Water); no published factor applies to this geometry. The expectation is 10.5 × 2.1 = 22 µGy/h, within ±20 %.

Check	Result	Criterion	Verdict
air kerma at 1 m behind water	(2.166 ± 0.073) × 10^{-5} Gy/h	2.200 × 10^{-5} Gy/h ± 20 %	pass

EK-Cs137-WaterInf: Cs-137 inside water, 2 mean free paths from the maps: air kerma and buildup

Result
passed

Verifies
R-10, R-11, R-17

Basis
Published reference – *ANSI/ANS-6.4.3-1991*, Tables 1a and 3, as reproduced in NUREG/CR-5740; *NUREG/CR-5740*; *ICRP 74*, Table A.1; *DDEP Cs-137*

Test
DoseTest

The standard's buildup factors are for a point source in an unlimited medium, with the response at a point inside it, and the case builds that geometry. The Cs-137 source of A-Cs137-ROT, in a 1 mm cube of water, sits at the centre of a world of water 5 m wide, more than 20 mean free paths to every side: for the photons reaching the maps, the water is unlimited. Six air kerma maps lie 2 mean free paths from the source on ±x, ±y and ±z, and the case checks each.

The standard's Table 1a gives µ/ρ for water of 0.08943 cm^2/g at 0.6 MeV and 0.07856 cm^2/g at 0.8 MeV; log-log at 0.662 MeV, 0.08557 cm^2/g, so 2 mean free paths are 233.7 mm. Unattenuated, the source gives 6 763 photons cm^{-2} s^{-1} at 1 m (A-Cs137-ROT), so 1.238 × 10^5 cm^{-2} s^{-1} at 233.7 mm; with ICRP 74's 3.11 pGy·cm^2 (AK-Cs137) that is 1 386 µGy/h, of which e^{-2} = 0.1353 arrives without interacting: 188 µGy/h. Table 3 gives exposure buildup factors at 2 mfp of 4.49 at 0.6 MeV and 3.96 at 0.8 MeV; linear in log energy, 4.31 at 0.662 MeV. The expectation is 188 × 4.31 = 810 µGy/h, within ±10 %.

The maps are plates, 40 × 40 mm and 1 mm thick, facing the source. A map reads the fluence averaged over its volume, and across a plate's 40 mm that mean lies about 0.5 % below the value at its centre.

Measured when the case was written, the same six maps at 1, 2 and 3 mean free paths, each depth in a run of its own with 2 000 000 decays, gave buildup factors of 2.22 to 2.27 (σ 0.019 for each map), 4.20 to 4.39 (σ 0.08) and 6.70 to 7.36 (σ 0.23 to 0.30), against the standard's 2.28, 4.31 and 7.04.

Check	Result	Criterion	Verdict
air kerma at 2 mfp, +x	(7.90 ± 0.15) × 10^{-4} Gy/h	8.100 × 10^{-4} Gy/h ± 10 %	pass
air kerma at 2 mfp, -x	(8.24 ± 0.16) × 10^{-4} Gy/h	8.100 × 10^{-4} Gy/h ± 10 %	pass
air kerma at 2 mfp, +y	(7.94 ± 0.16) × 10^{-4} Gy/h	8.100 × 10^{-4} Gy/h ± 10 %	pass
air kerma at 2 mfp, -y	(7.88 ± 0.15) × 10^{-4} Gy/h	8.100 × 10^{-4} Gy/h ± 10 %	pass
air kerma at 2 mfp, +z	(8.02 ± 0.16) × 10^{-4} Gy/h	8.100 × 10^{-4} Gy/h ± 10 %	pass
air kerma at 2 mfp, -z	(8.01 ± 0.16) × 10^{-4} Gy/h	8.100 × 10^{-4} Gy/h ± 10 %	pass

CK-Na22: Na-22 in an aluminium capsule: air kerma, annihilation photons included

Result
passed

Verifies
R-1, R-3, R-9, R-17

Basis
Published reference – *ICRP 74*, Table A.1; *DDEP Na-22*; *NIST SRD 126*

Test
DoseTest

A 1 GBq Na-22 source in a 0.4 mm aluminium cube at the centre of a 2 mm aluminium cube, its capsule, in vacuum, scored as air kerma at 0.5, 1 and 2 m by the maps of A-Co60-ROT, on the capsule's axes, and derived as there. Aluminium stops the positrons within 0.6 mm, and every decay is at least 0.8 mm from the capsule's face, so both annihilation photons start at the source; without the capsule the positrons would range out over tens of centimetres of air, and in vacuum would not stop at all.

Na-22 decays by beta+ (90.36 %) or electron capture (9.64 %), all but 0.06 % of decays to the 1.2745 MeV level of Ne-22, so each decay gives a 1.2745 MeV gamma (yield 0.9994) and 1.807 annihilation photons at 0.511 MeV. Its Ne K X-rays, at 0.85 keV, do not leave the capsule. The spline gives ICRP 74's air kerma coefficients as 5.4297 and 2.4321 pGy·cm². The air kerma rate at a point 1 m away is (0.9994 × 5.4297 + 1.807 × 2.4321) × 10^{-12} × 7 957.7 × 3600 = 281.4 µGy/h, and the map reads 0.9743 of it: 274.2 µGy/h. Without the annihilation photons it would be 151.6 µGy/h.

The capsule's 1 mm of aluminium, at 2.70 g/cm³, takes 2.3 % of the 511 keV photons and 1.5 % of the 1.27 MeV photons crossing it, with mass attenuation coefficients of 0.0837 and 0.0544 cm²/g (NIST SRD 126, interpolated log-log): 1.8 % of the air kerma, less the photons it scatters forward. The tolerance, ±4 %, covers that loss and three standard deviations at 1 500 000 decays. The inverse square law holds within ±3 %.

Check	Result	Criterion	Verdict
k(0.5 m) / k(1 m)	3.969 ± 0.026	4 ± 3 %	pass
k(1 m) / k(2 m)	4.001 ± 0.027	4 ± 3 %	pass

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Check	Result	Criterion	Verdict
air kerma at 1 m	(2.748 ± 0.013) × 10^{-4} Gy/h	2.742 × 10^{-4} Gy/h ± 4 %	pass

X-Am241: Am-241 point source in air: X-rays, air kerma and effective dose

Result
passed

Verifies
R-1, R-2, R-9, R-15, R-17

Basis
Published reference – *DDEP Am-241*; *NIST XCOM*; *ICRP 74*, Table A.1; *ICRP 116*, Table A.1

Test
DoseTest

A 1 GBq Am-241 source in a 1 mm cube of air, scored as air kerma and as effective dose (ROT) at 1 m. Am-241's alpha decay leaves Np-237 excited, and the internal conversion of its low-energy transitions empties L shells, which refill with Np L X-rays. This is the only case scored mainly on X-rays.

Photons per decay, from DDEP:

Photons	Energy (keV)	Per decay
gamma	59.54	0.3592
gamma	26.34	0.0231
gamma	33.20	0.0012
L X-rays, Ll	11.89	0.0084
L X-rays, Lα	13.9	0.1302
L X-rays, Lη	15.88	0.0038
L X-rays, Lβ	about 17.5	0.1858
L X-rays, Lγ	about 21.1	0.0483

Group energies are the intensity-weighted means of their lines. One metre of air (0.1205 g/cm²) passes 0.79 of the Lα, 0.86 of the Lβ and 0.98 of the 59.5 keV photons (NIST XCOM). Summing over the lines with the ICRP 74 and ICRP 116 coefficients and the point-source fluence gives 27.8 µGy/h of air kerma, 87 % of it from the X-rays, and 3.28 µSv/h of effective dose, 21 % from the X-rays. Without X-rays the air kerma would fall about eightfold.

Tolerances. Measured when the case was written: +9.4 % on the air kerma and +2.4 % on the effective dose, with statistical uncertainties of 1.3 % and 1.1 %. The air kerma's excess has two known parts. Geant4's L X-ray yields total 0.372 against DDEP's 0.377 but put more in Lα and less in Lβ and Lγ, worth +3.5 % with a coefficient this steep. The rest is air scatter, which the derivation removes in full although much of it still reaches the map. Hence ±15 % on the air kerma and ±10 % on the effective dose. The case runs 5 000 000 decays, because the map scores few X-rays and 500 000 left it about 5 % noisy.

Nothing below 10 keV, where the coefficient tables stop, reaches 1 m: the Np M X-rays (3.2 to 3.7 keV) travel about 6 cm in air.

Check	Result	Criterion	Verdict
air kerma at 1 m	(3.039 ± 0.041) × 10^{-5} Gy/h	2.780 × 10^{-5} Gy/h ± 15 %	pass

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Check	Result	Criterion	Verdict
effective dose at 1 m	(3.360 ± 0.036) × 10^{-6} Sv/h	3.280 × 10^{-6} Sv/h ± 10 %	pass

C-Ru106-Chain: Ru-106 with Full chain on and off: its daughter Rh-106 decays only when on

Result
passed

Verifies
R-1, R-8, R-15, R-17

Basis
Published reference – *DDEP Ru-106*; *DDEP Rh-106*; *ICRP 116*, Table A.1; *ICRP 74*, Table A.1

Test
DoseTest

A 1 GBq Ru-106 source in vacuum, scored at 1 m as effective dose (ROT) and as air kerma, run once with *Full chain* on and once with it off. Vacuum (hydrogen at 10^{-25} g/cm³, as Geant4 models it) leaves nothing between source and map but the inverse square law, so the comparison is of the emission, the chain and the conversion alone.

Ru-106 (half-life 372 d) decays by beta− with an endpoint of 39.4 keV straight to the ground state of Rh-106 and emits no photons. Its daughter Rh-106 (30 s) decays by beta− to excited levels of Pd-106 and gives off 0.342 gammas per decay, over some ninety lines. So the photons come entirely from the daughter: with *Full chain* off RadMap must stop at Rh-106 and score nothing, and with it on Rh-106 must decay once for each decay of Ru-106. The daughter's ground state is what makes this a test of the chain: excited and metastable daughters decay either way.

Chain on. Summing every Rh-106 line DDEP lists, each with its ICRP 116 (ROT) and ICRP 74 coefficients as RadMap interpolates them, over the point-source fluence at 1 m, gives 22.3 µSv/h of effective dose and 27.4 µGy/h of air kerma. Three lines carry most of it:

Line (keV)	Per decay	Share of the effective dose
511.85	0.2052	52 %
621.90	0.0987	30 %
1050.39	0.0149	7 %

Measured when the case was written, with 10 000 000 decays: +0.6 % on the effective dose and +0.9 % on the air kerma, each with a statistical uncertainty of 1.0 %. Geant4's Rh-106 yields run 1 to 6 % above DDEP's, about +1.5 % weighted by dose. At 2 000 000 decays, with an uncertainty of about 2.2 %, one run read +4.5 %, which is why the case runs five times as many. The tolerance, ±5 %, covers both; a daughter decaying twice, or not at all, misses it by far.

Chain off. The dose rate must be below 1 % of that with the chain on; only stray photons from the betas could give any.

Check	Result	Criterion	Verdict
effective dose at 1 m, chain on	(2.251 ± 0.022) × 10^{-5} Sv/h	2.230 × 10^{-5} Sv/h ± 5 %	pass
air kerma at 1 m, chain on	(2.764 ± 0.027) × 10^{-5} Gy/h	2.740 × 10^{-5} Gy/h ± 5 %	pass

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Check	Result	Criterion	Verdict
effective dose, chain off / on	0 ± 0	below 0.01	pass

C-Chain-PerSource: Full chain applies only to the isotope it is set on

Result
passed

Verifies
R-7, R-8

Basis
Condition

Test
DoseTest

Each simulation thread decays a project's sources one after another, so one source's *Full chain* setting must not carry over to the next decay (D-0013).

1 GBq each of Te-132, with *Full chain* off, and Ru-106, with it on, share one 1 mm cube of air, with an effective dose map (ROT) at 0.5 m. Were Ru-106's setting to leak, Te-132's daughter I-132, which emits far more photons than Te-132, would decay too. The two together must read the sum of each run alone, within ±5 %; with the fault put back they read 5.9 times the sum.

Check	Result	Criterion	Verdict
together / sum of the two alone	0.9953	1 ± 5 %	pass

C-Chain-None: Full chain changes nothing for an isotope with no chain

Result
passed

Verifies
R-7, R-8

Basis
Condition

Test
DoseTest

For an isotope whose daughters do not decay further, RadMap keeps *Full chain* off, since it could change nothing. Cs-137 is one: its daughter Ba-137m is followed in any case, as an excited state, and the ground state it falls to is stable. So the setting, on or off, must not move the dose rate.

1 GBq of Cs-137 in a 1 mm cube of air, with an effective dose map (ROT) at 0.5 m, run with the setting off and on. The API refuses to turn it on for such an isotope, so the case sets it on the model's source directly. The two must agree within ±5 %.

Check	Result	Criterion	Verdict
on / off	1	1 ± 5 %	pass

S-Name-0x: A source stays in its solid whatever the solid is called

Result
passed

Verifies
R-6, R-12, S-2

Basis
Condition

Test
DoseTest

A name may hold "0x", as `Block100x100` does, where Geant4's reader of geometry files cuts names by default. The source's confinement then found no volume, and decays spread through the box around the solid, children included (D-0014).

A 200 mm cube of air holds a 190 mm cube of lead, with 1 GBq of Cs-137 in the air, so its decays lie in a 5 mm shell outside the lead. With an effective dose map (ROT) at 0.5 m, the same project and seed must read the same under both names, within ±5 %. Before the fix `Block100x100` read 3.9 times lower, with most decays inside the lead.

Check	Result	Criterion	Verdict
Block100x100 / Block	1	1 ± 5 %	pass

S-World: A source in the world volume stays out of the world's children

Result
passed

Verifies
R-6, S-2

Basis
Condition

Test
DoseTest

The world volume is placed by Geant4, not by a line of the geometry file, so a source's confinement once found no volume by the name RadMap asks for, and decays spread through the whole world, children included (D-0019).

A 1200 mm cube of air holds a 1000 mm cube of lead, with 1 GBq of Cs-137 in the air, so its decays lie in a 100 mm shell outside the lead. The cube of air is the world in one run, and a solid in a larger world in the other, and an effective dose map (ROT) sits at the same place in the shell. The two must agree within ±5 %. They share a seed, so their errors are correlated and the ratio gets no σ. With the fault put back it read 0.47.

Check	Result	Criterion	Verdict
in the world / in a solid	0.9996	1 ± 5 %	pass

U-Cs137-Spread: The reported uncertainty matches the spread of repeated runs

Result
passed

Verifies
R-18

Basis
Condition

Test
DoseTest

RadMap reports each dose rate with a statistical uncertainty: the standard error of the mean of the doses the individual decays deposit, one standard deviation. The case checks that number against what it claims to predict, the scatter of the dose rate between independent runs.

A 1 GBq Cs-137 source in a 1 mm cube of air, with effective dose maps (ROT) at 0.5, 1 and 2 m, is run 20 times with 100 000 decays each, every run with its own seed. For each map, the standard deviation s of the 20 dose rates is compared with the mean uncertainty σ RadMap reported for them. If σ is right, $(s/\sigma)^2$ follows a χ^2 distribution with 19 degrees of freedom divided by 19, which puts s/σ between 0.55 and 1.5 with a probability of 99.8 %. An uncertainty reported twice too large or too small fails. The three maps catch about 1 100, 270 and 70 photons a run, so the check holds from well-sampled maps to sparse ones.

Scaling. The same project with 400 000 decays, four times as many, must report a relative uncertainty half as large: the mean of the 20 relative uncertainties at 100 000 decays over the one at 400 000 is 2, within ±10 %, which covers the scatter of the uncertainty estimates themselves.

Every map must report an uncertainty above zero in every run.

Measured when the case was written: s/σ of 0.88, 1.10 and 0.86 at 0.5, 1 and 2 m, and uncertainty ratios of 2.02, 2.01 and 2.07. The 21 runs take about 40 s.

Check	Result	Criterion	Verdict
every map reports an uncertainty above zero	holds	holds	pass
s / sigma at 0.5 m	0.8869	above 0.55	pass
s / sigma at 0.5 m	0.8869	below 1.5	pass
rel. sigma, 100k / 400k decays, 0.5 m	2.016	2 ± 10 %	pass
s / sigma at 1 m	1.107	above 0.55	pass
s / sigma at 1 m	1.107	below 1.5	pass
rel. sigma, 100k / 400k decays, 1 m	2.015	2 ± 10 %	pass
s / sigma at 2 m	0.8518	above 0.55	pass
s / sigma at 2 m	0.8518	below 1.5	pass
rel. sigma, 100k / 400k decays, 2 m	2.071	2 ± 10 %	pass

F-Sr90-Toggle: Sr-90 in a lead container: bremsstrahlung only with electron transport

Result
passed

Verifies
R-14

Basis
Condition – *DDEP Sr-90*

Test
DoseTest

Sr-90 decays by beta− (endpoint 0.546 MeV) straight to the ground state of Y-90: no gamma lines, and *Full chain* is off, so Y-90 does not decay. A 3.7 GBq source in a 1 mm cube of air sits inside a 3 mm lead cube with 1 mm walls; the betas stop within 0.1 mm of lead. The dose map, 200 × 200 × 1 mm, is at 0.5 m.

With *Simulate electrons* on, the betas' bremsstrahlung in the lead reaches the map; with it off, nothing does. The check is that the dose rate with electrons off is below 1 % of that with them on.

Check	Result	Criterion	Verdict
dose, electrons off / on	0 ± 0	below 0.01	pass

F-P32-Plate: P-32 behind a thin plate: more bremsstrahlung from lead than from PMMA

Result
passed

Verifies
R-14

Basis
Condition – *DDEP P-32*

Test
DoseTest

The situation radiation-protection guidance warns about: a beta source held behind a thin, dense absorber. P-32 decays by beta− (endpoint 1.711 MeV) with no gamma lines, so every photon reaching the map is bremsstrahlung. A 1 GBq source in a 1 mm cube of air sits 5 mm in front of a 100 × 100 mm plate: once 1 mm of lead, once 10 mm of PMMA, the plastic shield recommended for P-32. An effective dose map (ROT, photons), 200 × 200 × 1 mm, is at 30 mm, close behind the plate. Electron transport is on.

Bremsstrahlung grows with the atomic number of the absorber, so the lead plate gives the higher photon dose rate. Lead also absorbs much of its own soft bremsstrahlung, so the dose ratio is far smaller than the ratio of the yields: at 200 000 decays per run the case reads 2.09 ± 0.13, at 187 ± 8 µSv/h behind the lead. Four seeds at 1 000 000 decays per run gave 2.02 ± 0.05, 1.99 ± 0.06, 1.92 ± 0.10 and 1.97 ± 0.07. No published ratio for this geometry is known, so the check is a direction: lead gives more than PMMA, held by about 8σ.

Check	Result	Criterion	Verdict
dose, lead / PMMA plate	2.09 ± 0.11	above 1	pass

7.2 SourceDistributionTest

R6-Sampling: Decays fill the source's volume evenly, whatever its shape and placement

Result
passed

Verifies
R-6, R-12

Basis
Condition

Test
SourceDistributionTest

A source's volume is its solid less the solids placed inside it. Where its decays happen is decided in Geant4's source sampler: RadMap gives it a box enclosing the source solid, in world coordinates, and the sampler samples positions evenly in that box and keeps those that Geant4's navigator places in the source's volume – a position inside a child solid is placed in the child and rejected. So decays are even in the source's volume by construction, provided the box RadMap computes really encloses the solid. That box depends on the solid's shape, its rotation and every parent's position and rotation, and getting it wrong leaves part of the source without decays, or all of it, which a dose at a distance would barely show. This case looks at the decays themselves.

Three Sr-90 sources of 1 GBq each, in vacuum, chosen to make that box hard to get right:

Source	Shape	Placement
A	box 200 × 120 × 80 mm, containing a half sphere, a tube segment and a small box	inside a parent box moved to (300, 200, −100) mm and rotated (20°, 0°, 35°), itself moved and rotated (0°, 25°, 0°) in it
B	tube segment, radii 20 and 80 mm, 120 mm long, from 30° over 220°	rotated (30°, 45°, 0°), moved to (−300, 0, 100) mm
C	sphere segment, radii 10 and 70 mm, φ from 0° to 90°, θ from 0° to 60°	rotated (0°, 30°, 60°), inside a parent moved to (0, −450, 0) mm and rotated (40°, 0°, 50°)

The segments' bounding boxes are off-centre – source C's by about 60 mm – and the solids rotated, so the sampling box must turn its offset with them, and source C's with its parent's rotation too, composed in the right order; source A's box must follow two levels of transform. The case runs DoseAlgorithm on exactly the geometry and macro RadMap generates for the project, with 30 000 decays, and reads every decay's starting point from Geant4's own trace (/tracking/verbose 1).

Each point is taken back into the frame of the source it belongs to, with the positions and rotations as entered and RadMap's rotation order (an offset turns about Z, then Y, then X), and tested against the shape as defined – written out here, not taken from RadMap. The trace gives positions to three significant figures, ±0.5 mm at a few hundred millimetres, so a point counts as inside a solid within 1 mm of it, and inside a child only when more than 1 mm into it. The checks:

- each source's sampling box, as the macro gives it to Geant4, encloses the whole source: points spread densely over the shape as defined, placed in the world by the test's own transforms, lie no further outside the box than the macro's rounding allows (5 µm). This finds a box short by far less than the trace or the statistics below can show – a box fitted to the drawing mesh, which stops short of a curved surface between vertices, failed it by 30 µm;
- every decay lies inside one of the three sources;
- no decay lies inside a child of source A;
- each source receives a third of the decays, as their activities are equal;
- within each source, the decays fall into the cells of a 4 × 4 × 4 grid over the shape's extent in its own frame in proportion to each cell's share of the source's volume, which the test finds by sampling the shape evenly itself. The comparison is a χ^2 test against its 99.9 % point for the number of cells used, leaving out cells holding almost none of the volume, as χ^2 requires. A sampling box that misses a few centimetres of a source empties the cells there and fails it.

The case was checked against three wrong ways of placing the sampling box: with its offset not rotated, rotated the wrong way, and rotated by the source's own rotation without its parent's. Each fails it.

Check	Result	Criterion	Verdict
sampling box overreach, source A	4.263×10^{-14} mm	below 0.005 mm	pass
sampling box overreach, source B	5.684×10^{-14} mm	below 0.005 mm	pass
sampling box overreach, source C	5.684×10^{-14} mm	below 0.005 mm	pass
every decay inside one of the sources	holds	holds	pass
no decay inside a child of source A	holds	holds	pass
share of decays, source A	0.34	0.3333 ± 4.08 %	pass
grid chi2, source A	55.78	below 103.5	pass
share of decays, source B	0.3275	0.3333 ± 4.08 %	pass
grid chi2, source B	60.98	below 82.8	pass
share of decays, source C	0.3325	0.3333 ± 4.08 %	pass
grid chi2, source C	45.15	below 74.83	pass

7.3 GeometryShieldingTest

G-Box: Lead box: its width casts the expected shadow

Result
passed

Verifies
R-10, R-12

Basis
Condition

Test
GeometryShieldingTest

A Co-60 source and a lead shield in air, with effective dose maps (ROT) some of which the shield should cover. The expectation is geometry alone: a map the shield covers scores less than one it does not, which holds only if the shield's dimensions and angles reach Geant4 as RadMap describes them.

The source sits 100 mm in front of a 100 × 100 × 20 mm lead slab; three 30 mm maps lie 50 mm behind it, at x = 0, 40 and 90 mm. From the source, the slab's edge casts its shadow out to x ≈ 68 mm at the maps, so the maps at 0 and 40 mm are covered and the one at 90 mm is not. A slab of half the width would leave the map at 40 mm uncovered, and one of twice the width would cover the map at 90 mm, so the case also catches a halved or doubled dimension.

Check	Result	Criterion	Verdict
covered at x = 0 / uncovered	0.4379	below 1	pass
covered at x = 40 / uncovered	0.3923	below 1	pass

G-Tube-Phi-0: Lead tube sector from 0° to 180°: covers +Y only

Result
passed

Verifies
R-10, R-12

Basis
Condition

Test
GeometryShieldingTest

A Co-60 source and a lead shield in air, as in G-Box: a map the shield covers must score less than one it does not.

A half tube (radii 25 and 100 mm, 500 mm long) spans φ = 0° to 180°, the +Y side. Of two maps 300 mm from the source, the one at +Y is covered and the one at −Y is not.

Check	Result	Criterion	Verdict
+Y / -Y	0	below 1	pass

G-Tube-Phi-180: Lead tube sector from 180° to 360°: covers −Y only

Result
passed

Verifies
R-10, R-12

Basis
Condition

Test
GeometryShieldingTest

A Co-60 source and a lead shield in air, as in G-Box: a map the shield covers must score less than one it does not.

G-Tube-Phi-0 with the sector starting at φ = 180°: now the map at −Y is covered and the one at +Y is not, so the start angle is read as well as the span.

Check	Result	Criterion	Verdict
-Y / +Y	0	below 1	pass

G-Tube-Phi-Gap: Lead tube with a 20° gap: maps either side of its edge

Result
passed

Verifies
R-10, R-12

Basis
Condition

Test
GeometryShieldingTest

A Co-60 source and a lead shield in air, as in G-Box: a map the shield covers must score less than one it does not.

The tube spans φ = 10° to 350°, leaving a 20° gap around +X. A map at φ = 0° sees the source through the gap; maps at φ = ±25°, 15° inside the tube's ends, are covered.

Check	Result	Criterion	Verdict
phi = -25 deg / gap	0.08595	below 1	pass
phi = +25 deg / gap	0.001242	below 1	pass

G-Sphere-Phi-10: Lead sphere shell with a 20° azimuthal gap at +X

Result
passed

Verifies
R-10, R-12

Basis
Condition

Test
GeometryShieldingTest

A Co-60 source and a lead shield in air, as in G-Box: a map the shield covers must score less than one it does not.

A shell of radii 1 and 10 mm spans φ = 10° to 350° and all of θ, leaving a 20° gap around +X; the source sits in its hollow. Six small maps lie 11 mm from the centre in the XY plane, at φ = 0°, ±15°, 180° and 180° ± 15°. Only the one at φ = 0° is in the gap; the ones at ±15°, 5° past its edges, are covered.

Check	Result	Criterion	Verdict
phi = +15 deg / gap	0.6385	below 1	pass
phi = -15 deg / gap	0.5721	below 1	pass
phi = 180 deg / gap	0.6609	below 1	pass
phi = 165 deg / gap	0.6343	below 1	pass
phi = 195 deg / gap	0.6356	below 1	pass

G-Sphere-Phi-190: Lead sphere shell with a 20° azimuthal gap at −X

Result
passed

Verifies
R-10, R-12

Basis
Condition

Test
GeometryShieldingTest

A Co-60 source and a lead shield in air, as in G-Box: a map the shield covers must score less than one it does not.

G-Sphere-Phi-10 with the shell starting at φ = 190°, which moves the gap to −X: now only the map at φ = 180° is uncovered.

Check	Result	Criterion	Verdict
phi = 0 deg / gap	0.6015	below 1	pass
phi = +15 deg / gap	0.6122	below 1	pass
phi = -15 deg / gap	0.5744	below 1	pass
phi = 165 deg / gap	0.5892	below 1	pass
phi = 195 deg / gap	0.5921	below 1	pass

G-Sphere-Theta-10: Lead sphere shell with a 10° polar gap at +Z

Result
passed

Verifies
R-10, R-12

Basis
Condition

Test
GeometryShieldingTest

A Co-60 source and a lead shield in air, as in G-Box: a map the shield covers must score less than one it does not.

A shell of radii 1 and 10 mm spans θ = 10° to 180° and all of φ, leaving a 10° cap open around +Z; the source sits in its hollow. Six small maps lie 11 mm from the centre, at θ = 0°, 15° (twice), 180° and 165° (twice). Only the one at θ = 0° is in the gap; the ones at 15°, 5° past its edge, are covered.

Check	Result	Criterion	Verdict
theta = 15 deg, +X / gap	0.4671	below 1	pass
theta = 15 deg, -X / gap	0.6322	below 1	pass
theta = 180 deg / gap	0.5725	below 1	pass
theta = 165 deg, +X / gap	0.6212	below 1	pass
theta = 165 deg, -X / gap	0.6264	below 1	pass

G-Sphere-Theta-0: Lead sphere shell with a 10° polar gap at −Z

Result
passed

Verifies
R-10, R-12

Basis
Condition

Test
GeometryShieldingTest

A Co-60 source and a lead shield in air, as in G-Box: a map the shield covers must score less than one it does not.

G-Sphere-Theta-10 with the shell spanning θ = 0° to 170°, which moves the gap to −Z: now only the map at θ = 180° is uncovered.

Check	Result	Criterion	Verdict
theta = 0 deg / gap	0.6688	below 1	pass
theta = 15 deg, +X / gap	0.5289	below 1	pass
theta = 15 deg, -X / gap	0.7033	below 1	pass
theta = 165 deg, +X / gap	0.6568	below 1	pass
theta = 165 deg, -X / gap	0.6787	below 1	pass

7.4 GeometryTransformTest

T-Translation: Dose maps attached to a solid follow its position

Result
passed

Verifies
R-12

Basis
Condition

Test
GeometryTransformTest

Dose maps attached to a solid must land where the solid's transform puts them, and the check is exact. Each pair is two dose maps that should end up in the same place: one placed directly in the world at a position and rotation worked out by hand, the other attached to a source solid and placed relative to it, so that RadMap has to compose the solid's transform with the map's own. With a fixed seed on one thread (R-19), two maps in the same place score the same photons and must report identical results to the last digit; a map composed even slightly wrong does not.

Each map sits at its solid's origin, so it must land where the solid is: four solids at different positions, one unrotated and three rotated about X, Y and Z.

Check	Result	Criterion	Verdict
pair 1 — pure translation: source=(100,50,30) no rotation	holds	holds	pass
pair 2 — translation + RX(30°): source=(-100,-50,-30)	holds	holds	pass
pair 3 — translation + RY(45°): source=(0,60,0)	holds	holds	pass
pair 4 — translation + RZ(45°): source=(0,0,60)	holds	holds	pass

T-Rotation: A solid's rotation turns the offsets of its dose maps

Result
passed

Verifies
R-12

Basis
Condition

Test
GeometryTransformTest

Pairs of dose maps, one placed by hand and one through a solid, as in T-Translation: the two must report identical results to the last digit.

Each map is offset from its solid, and the solid's rotation must turn that offset into the world: no rotation, then 90° about X, Y and Z in turn. A fifth pair composes a solid's rotation of 30° about X with the map's own 30° about X, which must give 60°.

Check	Result	Criterion	Verdict
pair 1 — DM local X offset, no solid rotation: dm_local=(30,0,0) → world (110,0,0)	holds	holds	pass
pair 2 — RX(90°) rotates dm_local=(0,50,0) → (0,0,50): world (0,60,50)	holds	holds	pass
pair 3 — RY(90°) rotates dm_local=(50,0,0) → (0,0,-50): world (0,-60,-50)	holds	holds	pass
pair 4 — RZ(90°) rotates dm_local=(50,0,0) → (0,50,0): world (0,50,60)	holds	holds	pass
pair 5 — solid RX(30°) composed with DM local RX(30°) → world rot RX(60°)	holds	holds	pass

T-Multiaxis: Rotations about two axes compose in RadMap's order

Result
passed

Verifies
R-12

Basis
Condition

Test
GeometryTransformTest

Pairs of dose maps, one placed by hand and one through a solid, as in T-Translation: the two must report identical results to the last digit.

Each solid is rotated about two axes, X and Z, Y and Z, X and Y, and offsets its map. Rotations about different axes do not commute, so the hand-worked positions follow RadMap's order – an offset turns about Z first, then Y, then X – and the opposite order would put the maps elsewhere.

Check	Result	Criterion	Verdict
pair 1 — RX(90°)+RZ(90°): dm_local=(50,0,0) →RZ→(0,50,0) →RX→(0,0,50): world (0,0,50)	holds	holds	pass
pair 2 — RY(90°)+RZ(90°): dm_local=(50,0,0) →RZ→(0,50,0) →RY→(0,50,0): world (0,110,0)	holds	holds	pass
pair 3 — RX(90°)+RY(90°): dm_local=(0,0,50) →RY→(50,0,0) →RX→(50,0,0): world (50,-60,0)	holds	holds	pass

7.5 MaterialMixTest

M-Mix-Composition: A mix of two materials shields like its elements written out

Result
passed

Verifies
R-13

Basis
Condition

Test
MaterialMixTest

A mix reaches the simulation as a material made of other materials, which Geant4 builds into one homogeneous material from their compositions. The case runs the same geometry twice, changing only the shield's material: once the mix, and once a material written element by element with the composition the mix should have, at the same density. The shield is one box of one material, with nothing inside it. If the mix reaches Geant4 with its composition and density, the two shields are the same material and the dose rates behind them agree within their statistical uncertainty.

The mix is 30 % water and 70 % lead by mass, at 2.2 g/cm³. Each element's mass fraction is the sum over the mix's materials of the material's fraction times the element's fraction in it: hydrogen 0.3 × 0.1119 = 0.03357, oxygen 0.3 × 0.8881 = 0.26643, lead 0.7.

An Am-241 source in air sits 100 mm in front of a shield, 400 × 400 × 2 mm, and an effective dose map (ROT), 200 × 200 mm, lies 100 mm behind it; 10^6 decays per run. The shield lets about a sixth of the dose through. At Am-241's 59.5 keV gamma ray, lead attenuates about 25 times

more per gram than water, so the dose rate shows the composition as well as the density; at Co-60's energies the two differ by less than a tenth and the case could not tell them apart. The two runs use different seeds, so their results are independent; they must differ by less than 4 standard deviations of the difference.

Measured when the case was written, with the mix written wrongly: with its fractions swapped the dose rate is 2.4 times higher, and with its density 10 % higher it is 14 % lower, 7 standard deviations away. Either fails the case.

Check	Result	Criterion	Verdict
|mix - elements| / sigma	1.66	below 4	pass

M-Mix-Nested-Composition: A mix containing a mix shields like its elements written out

Result
passed

Verifies
R-13

Basis
Condition

Test
MaterialMixTest

As M-Mix-Composition, for a mix one of whose materials is itself a mix: half air and half the mix of M-Mix-Composition, by mass, at 1.1 g/cm³. Its elements, by the same sum taken twice: hydrogen 0.016785, carbon 0.000062, nitrogen 0.377634, oxygen 0.249106, argon 0.0064135, lead 0.35. The source, geometry and check are those of M-Mix-Composition, except that the shield is 8 mm thick in both runs. Holding a quarter of the lead per volume, it then attenuates as much as the 2 mm shield of M-Mix-Composition; at 2 mm a density 10 % off would change the dose rate by only 4 %, too little to tell from the statistics. No result is compared between the two cases.

Measured when the case was written, with the mix written wrongly: with its density 10 % higher the dose rate is 16 % lower, 8 standard deviations away, and with the air left out (the inner mix alone at 1.1 g/cm³) it is 4.6 times lower. Either fails the case.

Check	Result	Criterion	Verdict
|mix - elements| / sigma	2.281	below 4	pass

M-Name-Ox: Two materials named alike up to "Ox" stay two materials

Result
passed

Verifies
R-13, S-2

Basis
Condition

Test
MaterialMixTest

A name may hold “0x”, as `Mix50x50` does, where Geant4 cuts the names of materials, elements and isotopes when it reads a geometry file, in their definitions and where they are used. Two names alike up to it became one, and every solid of either got the first definition, with no message (D-0015). RadMap now writes such a name so that Geant4 sees no “0x”, and restores it on loading.

The source, geometry and check are those of M-Mix-Composition. `WALL0xB` is the mix’s composition at the mix’s density, written element by element, and is the shield’s material. `WALL0xA` is water, and a solid of it stands out of the beam, written to the file first so that its definition comes first: the one Geant4 kept for both names before the fix. The shield must read as `MIX_ELEMENTS` does, which is the same material under a name with no “0x”.

Measured when the case was written, without the fix: the shield took water’s definition, and the dose rate was 6.1 times higher, 138 standard deviations away.

Check	Result	Criterion	Verdict
|WALL0xB - MIX_ELEMENTS| / sigma	1.66	below 4	pass

M-Density-Unit: A density reaches the simulation the same in every unit

Result
passed

Verifies
R-13

Basis
Condition

Test
MaterialMixTest

RadMap hands Geant4 every density in g/cm³, converted from the unit the user chose. Until 2.0 it passed the unit’s name through, and Geant4 refused one it did not know: a material in kg/cm³ stopped the run (D-0009). The case runs the geometry of M-Mix-Composition twice, with a lead shield 0.2 mm thick: once of lead at 11.34 g/cm³, once of the same lead given as 11340 mg/cm³. Both runs must finish, and since the shields are the same material, the dose rates behind them must agree within their statistical uncertainty: less than 4 standard deviations of the difference, the runs having different seeds. A density reaching Geant4 a thousand times off would let almost everything or almost nothing through.

Check	Result	Criterion	Verdict
|g/cm3 - mg/cm3| / sigma	0.3826	below 4	pass

7.6 ValidationTest

V-KSU-Cs137: Cs-137 over a concrete floor: air kerma measured at 2 to 18 m

Result
passed

Verifies
R-1, R-9, R-10, R-11, R-17

Basis
Measurement – *Roseberry (1980)*; *LLNL-TR-838615*; *ICRU 90*; *SINBAD NEA-1517/91*

Test
ValidationTest

A validation case: the expected values are measurements, made at Kansas State University in 1979-80 with Cs-137 sources above a concrete floor (Roseberry), as LLNL documented them in 2022 to benchmark its own code (LLNL-TR-838615). A source 5.08 cm above a 22.86 cm concrete floor on ground, and an ion chamber 91.44 cm above the floor at 2 to 18 m from it: the dose rate comes from the photons that reach the chamber directly, attenuated by the air, and those the floor and the air scatter towards it – what RadMap computes in everyday use. The same programme's Co-60 skyshine measurements are the one gamma benchmark with a radionuclide source in SINBAD, the OECD/NEA archive of evaluated shielding experiments.

The model. The experiment did not record the materials, so the case takes LLNL's assumptions: ordinary concrete (NIST composition) at 2.17 g/cm³, ground of hydrogen, oxygen, silicon and aluminium (16, 57, 19 and 8 atoms in 100) at 1.7 g/cm³ under it, 76.2 cm deep, and dry air at the measured 1.142 mg/cm³. The floor and the air are 400 m square, where LLNL's model is 1 km; at 662 keV a photon's mean free path in this air is 113 m, so what lies beyond 200 m adds far less than the experiment's uncertainty at 18 m. The source is a bare 1 GBq of Cs-137: the experiment does not describe its capsule, which would have absorbed the Ba K X-rays, about 1.5 % of the air kerma a bare source gives. Each chamber is an air kerma map 91.44 cm above the floor on the x axis, a box 0.2 × the distance wide, and 0.2 × the distance, at most 0.8 m, deep and high: averaging the direct photons over it shifts its reading by under 0.5 %.

The measurements are exposure rates per mCi. With 1 R = 2.58 × 10^{-4} C/kg and W/e = 33.97 J/C for air (ICRU 90), 1 R is 8.764 mGy of air kerma, so 1 µR/h per mCi is 0.2369 µGy/h per GBq:

Distance (m)	Exposure rate (µR/h per mCi)	Air kerma rate (µGy/h per GBq)	Tolerance
2	79.77 ± 0.26	18.90	±10.0 %
4	22.53 ± 0.05	5.337	±10.0 %
5	14.68 ± 0.06	3.477	±10.1 %
7	7.44 ± 0.06	1.762	±10.2 %
8	5.62 ± 0.04	1.331	±10.1 %
10	3.78 ± 0.06	0.8954	±10.7 %
12	2.48 ± 0.04	0.5874	±10.7 %
14	1.81 ± 0.04	0.4287	±11.3 %
18	0.99 ± 0.04	0.2345	±13.7 %

Tolerances, set before the case was first run: twice the experiment's combined standard uncertainty – 3.5 % on the source strength and each reading's own – plus 3 % for what the experiment did not record: the concrete's composition and density and the source's capsule. LLNL's own model of the experiment emits one photon per decay where Cs-137 gives 0.85, which accounts for most of its 6 to 19 % excess; the case takes the measurements, not that model.

Check	Result	Criterion	Verdict
air kerma at 2 m	(1.879 ± 0.010) × 10^{-5} Gy/h	1.890 × 10^{-5} Gy/h ± 10 %	pass
air kerma at 4 m	(5.243 ± 0.028) × 10^{-6} Gy/h	5.337 × 10^{-6} Gy/h ± 10 %	pass
air kerma at 5 m	(3.350 ± 0.020) × 10^{-6} Gy/h	3.477 × 10^{-6} Gy/h ± 10 %	pass
air kerma at 7 m	(1.685 ± 0.012) × 10^{-6} Gy/h	1.762 × 10^{-6} Gy/h ± 10.2 %	pass
air kerma at 8 m	(1.285 ± 0.010) × 10^{-6} Gy/h	1.331 × 10^{-6} Gy/h ± 10.1 %	pass

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Check	Result	Criterion	Verdict
air kerma at 10 m	(8.164 ± 0.072) × 10^{-7} Gy/h	8.954 × 10^{-7} Gy/h ± 10.7 %	pass
air kerma at 12 m	(5.621 ± 0.055) × 10^{-7} Gy/h	5.874 × 10^{-7} Gy/h ± 10.7 %	pass
air kerma at 14 m	(4.085 ± 0.043) × 10^{-7} Gy/h	4.287 × 10^{-7} Gy/h ± 11.3 %	pass
air kerma at 18 m	(2.407 ± 0.029) × 10^{-7} Gy/h	2.345 × 10^{-7} Gy/h ± 13.7 %	pass

V-KSU-Skyshine: Co-60 in an open silo: skyshine air kerma measured at 50 to 400 m

Result
passed

Verifies
R-1, R-9, R-10, R-11, R-12, R-17

Basis
Measurement – *SINBAD NEA-1517/91*; *LLNL-TR-838835*; *ICRU 90*

Test
ValidationTest

A validation case for skyshine: radiation that leaves a shield upwards and reaches the ground far away only because the air scatters it back down. Kansas State University measured it in 1977 with Co-60 in a concrete silo, open to the sky through a collimator, with an ion chamber 1 m above the ground at 50 to 700 m; the walls stop every photon headed for the chamber directly. SINBAD, the OECD/NEA archive of shielding benchmarks, evaluates the experiment, and LLNL documents its geometry (LLNL-TR-838835). This case takes the points at 50, 100 and 200 m, measured with a 10.33 Ci source, and at 300 and 400 m, measured with a 229.1 Ci source. SINBAD judges the reading at 300 m an anomaly of the measurement; the case keeps it, as LLNL does.

The model. As LLNL models it, with RadMap's shapes:

- the silo, 228.6 cm high on a 22.86 cm concrete pad: twelve-sided, 91.44 cm walls, here a tube of the same cross-section, 125.9 and 218.4 cm in radius;
- the collimator: 48 concrete wedges at 1.93 g/cm³ on the silo's rim, from 124.46 to 185.42 cm out, their tops rising from 231.14 to 248.60 cm, which shape a cone 150.5° wide; here 24 concentric rings stepped to that slope, each as high as the slope at its outer edge, and without the narrow gaps between the wedges;
- the sources as bare points, their casks not being described: the 10.33 Ci source 5.08 cm above the collimator's apex, 203.2 cm above the pad, as LLNL reads Roseberry's "2 in from the apex", and the 229.1 Ci source at the apex, 198.12 cm, where Roseberry puts the midpoints of the larger sources;
- the steel plate in the pad's top; the thinner pads around the silo, 10 cm of concrete lying on the ground, are left out;
- ground at 1.7 g/cm³ and dry air at the measured 1.096 mg/cm³, 2 km across and 1 km above the ground, the extent LLNL uses.

Each source is a run of its own, of 5 000 000 decays. Each chamber is four air kerma maps, 90° apart round the silo, 0.2 × the distance wide and 1.2 m high, centred 1 m above the ground, and deep along the radius: 4 m at 50 to 200 m, 8 m at 300 and 400 m, where the readings are fainter. The case averages the four. No photon is likely to reach two of them, so the average carries their combined uncertainty. A run scores at most 15 maps, so the fainter points get deeper maps, not more of them. Depth costs no accuracy: along it the reading changes almost

linearly, which the average cancels, and what is left, about $d^2(\dot{X}'/\dot{X})^2/24$ of the reading, is under 0.1 %. It buys only part of the precision its volume suggests: photons entering a map through its top and sides grow in number with its depth, while those entering through the face towards the silo cross it once however deep it is. A wider box would cost accuracy: its ends lie further from the silo than its middle.

The measurements are exposure rates per Ci; with 1 R = 8.764 mGy of air kerma (ICRU 90), 1 µR/h per Ci is 2.369×10^{-4} µGy/h per GBq:

Distance (m)	Source (Ci)	Exposure rate (µR/h per Ci)	Air kerma rate (nGy/h per GBq)
50	10.33	27.49 ± 0.04	6.511
100	10.33	10.97 ± 0.07	2.598
200	10.33	2.72 ± 0.04	0.6443
300	229.1	0.842 ± 0.004	0.1994
400	229.1	0.340 ± 0.002	0.08054

Tolerance, set before the case was first run: ±21 %, twice SINBAD's combined standard uncertainty of about 8 % – 5 % on the source's activity, about 4 % on the source's correction factors, and the atmosphere – plus 5 % for the simplified geometry: the collimator's rings, the missing pads and casks. The 300 and 400 m points have the same tolerance, also set before they were first run.

Measured when the case was written: RadMap reads 0.85, 0.83, 0.93, 0.95 and 0.97 of the measurements at 50, 100, 200, 300 and 400 m, with statistical uncertainties of 1.9, 2.2, 3.0, 3.6 and 5.2 %: 3 to 17 % low, inside the tolerance.

Why it reads low. The difference lies in the model of the experiment, not in the transport, as a comparison with LLNL's code shows. It was made, like the sensitivities below, with the 10.33 Ci source's points alone, in single runs of 10 000 000 decays with chambers 2 m deep, in which RadMap read 0.86, 0.84 and 0.93 of the measurements, ±1.4 to 2.1 %. COG reads 0.92, 0.88 and 0.97, but LLNL's model places the chambers 2.21 m above the ground, 198.12 cm above the pad, where this case follows SINBAD's 1 m. With LLNL's chambers – rings of 30.48 cm radius at that height, here boxes 61 cm on a side – RadMap reads 0.91, 0.87 and 1.03 of the measurements, ±2.2, 2.6 and 3.4 %: the two codes agree within RadMap's uncertainty at 50 and 100 m, and within 2σ at 200 m. Both therefore leave about 10 % at 50 and 100 m to what the experiment's description leaves open, and SINBAD's MCNP evaluation agrees within its 8 %. How much the description leaves open: placing the source 5.1 cm lower, at the collimator's apex, where SINBAD's description puts the sources, lowers every reading by 7 to 9 %; 12 rings instead of 24 lower them by up to 2 %. The geometry as documented thus leaves an uncertainty about as large as the difference, and larger than the 5 % the tolerance allowed for it. At 300 and 400 m, with the 229.1 Ci source at the apex in both codes, COG reads 1.02 and 1.01; RadMap with LLNL's chambers, in one run of 5 000 000 decays, reads 1.02 and 0.92, ±4.1 and 5.3 %: the same at 300 m, and within 2σ at 400 m.

Check	Result	Criterion	Verdict
air kerma at 50 m	$(5.51 \pm 0.10) \times 10^{-9}$ Gy/h	6.512×10^{-9} Gy/h ± 21 %	pass
air kerma at 100 m	$(2.167 \pm 0.048) \times 10^{-9}$ Gy/h	2.598×10^{-9} Gy/h ± 21 %	pass
air kerma at 200 m	$(5.98 \pm 0.18) \times 10^{-10}$ Gy/h	6.443×10^{-10} Gy/h ± 21 %	pass
air kerma at 300 m	$(1.893 \pm 0.069) \times 10^{-10}$ Gy/h	1.994×10^{-10} Gy/h ± 21 %	pass
air kerma at 400 m	$(7.84 \pm 0.40) \times 10^{-11}$ Gy/h	8.054×10^{-11} Gy/h ± 21 %	pass

7.7 DoseAlgorithmSeedTest

S-Seed: The same seed on one thread reproduces a run; another seed does not

Result
passed

Verifies
R-19

Basis
Condition

Test
DoseAlgorithmSeedTest

One project, a fixture with a source and dose maps, is run five times: twice with seed 42 on one thread, once with seed 42 on four threads, and with seed 99 on one and on four threads. The two single-thread runs with seed 42 must give identical results files, byte for byte; changing the seed must change the results, on one thread and on four.

Runs on several threads with the same seed are not compared: Geant4 adds the threads' scores in whatever order the threads finish, so their sums differ in the last digits from run to run.

Check	Result	Criterion	Verdict
seed 42, one thread, twice: identical results	holds	holds	pass
seed 42 and seed 99, one thread: different results	holds	holds	pass
seed 42 and seed 99, four threads: different results	holds	holds	pass

7.8 ActivityResolverTest

AR-Absolute: A total activity is taken as entered, in its unit

Result
passed

Verifies
R-4

Basis
Published reference – none needed: geometry or arithmetic alone

Test
ActivityResolverTest

5 MBq entered as a total activity resolves to 5 MBq, whatever the source's solid or material, because a total depends on neither.

Check	Result	Criterion	Verdict
5 MBq / 5 x the MBq factor	1	1 ± 0.001 %	pass

AR-PerVolume: A volume concentration times the solid's volume

Result
passed

Verifies
R-5

Basis
Published reference – none needed: geometry or arithmetic alone

Test
ActivityResolverTest

RadMap's own arithmetic, checked against hand calculation. Each expected value is the same activity entered as a total and resolved by RadMap, not a number in RadMap's internal unit, so the check holds whatever scale RadMap keeps activities on. The cube is 10 cm on a side, 1000 cm^3, and filled with water at exactly 1 g/cm^3, so it holds 1000 g.

5 MBq/cm^3 in 1000 cm^3 is 5000 MBq.

Check	Result	Criterion	Verdict
5 MBq/cm3 in 1000 cm3 / 5000 MBq	1	1 ± 0.001 %	pass

AR-VolumeUnit: The volume unit of a concentration scales the total

Result
passed

Verifies
R-5

Basis
Published reference – none needed: geometry or arithmetic alone

Test
ActivityResolverTest

RadMap's own arithmetic, checked against hand calculation. Each expected value is the same activity entered as a total and resolved by RadMap, not a number in RadMap's internal unit, so the check holds whatever scale RadMap keeps activities on. The cube is 10 cm on a side, 1000 cm^3, and filled with water at exactly 1 g/cm^3, so it holds 1000 g.

1 MBq/m^3 in the cube is a millionth of 1 MBq/cm^3 in it, since 1 m^3 is 10^6 cm^3.

Check	Result	Criterion	Verdict
per m3 / per cm3	1.000×10^{-6}	1.000×10^{-6} ± 0.001 %	pass

AR-PerMass: A mass concentration times the volume and the material's density

Result
passed

Verifies
R-5

Basis
Published reference – none needed: geometry or arithmetic alone

Test
ActivityResolverTest

RadMap's own arithmetic, checked against hand calculation. Each expected value is the same activity entered as a total and resolved by RadMap, not a number in RadMap's internal unit, so the check holds whatever scale RadMap keeps activities on. The cube is 10 cm on a side, 1000 cm^3, and filled with water at exactly 1 g/cm^3, so it holds 1000 g.

5 MBq/g in 1000 g of water is 5000 MBq; 5 MBq/kg is a thousandth of that.

Check	Result	Criterion	Verdict
5 MBq/g in 1000 g / 5000 MBq	1	1 ± 0.001 %	pass
per kg / per g	0.001	0.001 ± 0.001 %	pass

AR-Children: Solids placed inside the source are left out of its volume

Result
passed

Verifies
R-5

Basis
Published reference – none needed: geometry or arithmetic alone

Test
ActivityResolverTest

RadMap's own arithmetic, checked against hand calculation. Each expected value is the same activity entered as a total and resolved by RadMap, not a number in RadMap's internal unit, so the check holds whatever scale RadMap keeps activities on. The cube is 10 cm on a side, 1000 cm^3, and filled with water at exactly 1 g/cm^3, so it holds 1000 g.

A 5 cm cube inside the source takes 125 cm^3 of it, leaving 875 cm^3: 1 MBq/cm^3 and 1 MBq/g both resolve to 875 MBq. Their agreeing also shows that the volume and the mass paths subtract the same.

Check	Result	Criterion	Verdict
1 MBq/cm3 / 875 MBq	1	1 ± 0.001 %	pass
1 MBq/g / 875 MBq	1	1 ± 0.001 %	pass

AR-Refused: A concentration that cannot be resolved is refused, not taken as zero

Result
passed

Verifies
R-5

Basis
Condition

Test
ActivityResolverTest

A concentration needs a solid to measure, and a mass concentration a material of known density. Without them RadMap must report that it has no total, so that the simulation refuses the source, rather than run it at zero. Each section takes one thing away: the solid's material, the material's entry in the library, the solid itself. A total activity needs none of these and is never refused.

Check	Result	Criterion	Verdict
no material: per mass refused	holds	holds	pass
material not in library: per mass refused	holds	holds	pass
no solid: per mass refused	holds	holds	pass
no solid: per volume refused	holds	holds	pass
total activity: never refused	holds	holds	pass

AR-NoVolume: A solid that describes no volume leaves the concentration unresolved

Result
passed

Verifies
R-5

Basis
Condition

Test
ActivityResolverTest

A solid part-way through being set up can describe no volume: a flattened box has none, and a tube whose inner radius exceeds its outer one would have a negative one. A concentration in it, or around a child that has no volume, or around a child larger than the source, must stay unresolved rather than give a total that looks right. A total activity depends on no geometry and still resolves.

Check	Result	Criterion	Verdict
flat source: per mass unresolved	holds	holds	pass
flat source: per volume unresolved	holds	holds	pass
flat child: per mass unresolved	holds	holds	pass
flat child: per volume unresolved	holds	holds	pass
total activity: resolved	holds	holds	pass
child larger than source: per mass unresolved	holds	holds	pass
child larger than source: per volume unresolved	holds	holds	pass

AR-Zero: A zero concentration resolves to zero, not to nothing

Result
passed

Verifies
R-5

Basis
Condition

Test
ActivityResolverTest

A concentration the user set to zero is a total of zero, which the simulation then refuses as a zero activity; it is not the same as a concentration that cannot be resolved at all.

Check	Result	Criterion	Verdict
0 MBq/g resolves to exactly zero	holds	holds	pass

7.9 ProjectTest

S4-CutOff: Results cut off part-way are not taken

Result
passed

Verifies
S-4

Basis
Condition

Test
ProjectTest

A run's results arrive as one document. One that ends part-way – here inside a dose map's values – is taken as no results at all, not as the part that was read: a dose map whose value was cut short could otherwise show a wrong number.

Check	Result	Criterion	Verdict
results cut off part-way are not taken	holds	holds	pass

S1-SameAsSave: The geometry a run is given is the geometry a save writes

Result
passed

Verifies
S-1

Basis
Condition

Test
ProjectTest

A run's geometry is generated from the project when the run starts; a save writes the geometry into the project file by the same steps. The case builds a project with a source, generates the

geometry a run would be given, saves the project, and reads the geometry back from the file: the two are identical, character for character. So the geometry checked by every save is the geometry simulated, and the two cannot drift apart unnoticed.

Check	Result	Criterion	Verdict
the run's geometry identical to the saved geometry	holds	holds	pass

S10-Unit: A dose rate carries the unit and uncertainty its run recorded

Result
passed

Verifies
S-10

Basis
Condition

Test
ProjectTest

Effective dose is scored in sieverts and air kerma in grays, and nothing in the numbers tells them apart. Results recorded in pSv are read as sieverts, and the same numbers recorded in pGy as grays, with the same value: the unit comes from the results, not from the dose map's settings. A unit RadMap does not know, or none, gives no result rather than one with a wrong label. The uncertainty read is the one the run recorded with the value.

Check	Result	Criterion	Verdict
pSv read as sieverts	holds	holds	pass
the uncertainty the run recorded	holds	holds	pass
pGy read as grays	holds	holds	pass
the unit does not change the value	holds	holds	pass
an unknown unit gives no result	holds	holds	pass
no unit gives no result	holds	holds	pass

S7-FailedWrite: A save that cannot be completed leaves the file as it was

Result
passed

Verifies
S-7

Basis
Condition

Test
ProjectTest

A project is saved, and its file made read-only. The project is then changed and saved to the same file again, which cannot succeed. The save reports a failed write, the file holds exactly the

bytes of the first save, and no temporary file is left beside it: a save replaces the file whole or not at all, so a failure part-way never leaves a file that is half old and half new.

Check	Result	Criterion	Verdict
the failed save reported	holds	holds	pass
the file as it was, byte for byte	holds	holds	pass
no temporary file left	holds	holds	pass

S13-Damage: A project file damaged in any of its parts is refused

Result
passed

Verifies
S-13

Basis
Condition

Test
ProjectTest

A project file is a zip archive of four parts – geometry, properties, material library and results – each stored with a checksum of its content. A project holding results is saved, and the file is damaged one byte at a time, as storage or a transfer can damage it: in turn, about 50 bytes spread over each part's stored content are changed. Every file whose content the damage changed is refused as unreadable, and the project open when it is loaded stays. Some of the damaged parts still decode to a well-formed document, which would have been read without the checksum; they are refused too. (A changed byte can leave the content as it was, when it falls in the spare bits that end a compressed part; such a file holds the project unchanged, and is not counted.)

Each part, extracted as a zip program extracts it, is not text: its content does not read as the document it holds.

Check	Result	Criterion	Verdict
geom.cry extracted is not readable text	holds	holds	pass
prop.xml extracted is not readable text	holds	holds	pass
matlib.mlb extracted is not readable text	holds	holds	pass
results.xml extracted is not readable text	holds	holds	pass
geom.cry: every change to its content refused, the open project kept	holds	holds	pass

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Check	Result	Criterion	Verdict
prop.xml: every change to its content refused, the open project kept	holds	holds	pass
matlib.mlb: every change to its content refused, the open project kept	holds	holds	pass
results.xml: every change to its content refused, the open project kept	holds	holds	pass
some damage still read as well-formed XML, and was refused all the same	holds	holds	pass

S7-CutOff: A cut-off project file is refused, and the open project stays

Result
passed

Verifies
S-7

Basis
Condition

Test
ProjectTest

A saved project file is cut to half its length, as a copy or transfer stopped part-way would leave it, and loaded over an open project. The load is refused as unreadable, and the open project is still the one in place: a load replaces the project whole or leaves it as it was, never with what part of a file held.

Check	Result	Criterion	Verdict
the cut-off file refused	holds	holds	pass
the open project stays	holds	holds	pass

S7-EmptyPart: A project file with a part that holds nothing is refused

Result
passed

Verifies
S-7

Basis
Condition

Test
ProjectTest

A project file is written whose material library is present but holds nothing. Loading it is refused as unreadable: a part that holds nothing is a damaged file, not an empty library.

Check	Result	Criterion	Verdict
the file with an empty part refused	holds	holds	pass

S7-UnknownUnit: A project file naming a unit RadMap does not know is refused

Result
passed

Verifies
S-7

Basis
Condition

Test
ProjectTest

A project file is written whose solid gives its dimensions in a unit no RadMap has. Loading it is refused as unreadable, and the open project stays. Any unit RadMap chose in its place would give the value a scale the file does not: read as zero, a position would put its solid at the origin, where it would save and simulate without a word.

Check	Result	Criterion	Verdict
the file with an unknown unit refused	holds	holds	pass
the open project stays	holds	holds	pass

S7-UnknownDensityUnit: A library naming a density unit RadMap does not know is refused, not guessed

Result
passed

Verifies
S-7

Basis
Condition

Test
ProjectTest

A project's material library gives each density with its unit's name. A project file is written whose library gives a material's density in a unit no RadMap has. Loading it is refused as unreadable, and the open project stays; the same library in a volume file is refused too, and nothing of the volume joins the scene. Any unit RadMap chose in its place would scale the density, and every dose behind that material with it.

Check	Result	Criterion	Verdict
the project refused	holds	holds	pass
the open project stays	holds	holds	pass
the volume refused	holds	holds	pass
nothing of it joins the scene	holds	holds	pass

S7-BadResults: A project file whose results cannot be read is refused, not opened without them

Result
passed

Verifies
S-7

Basis
Condition

Test
ProjectTest

A project file is written whose results are not readable results. Loading it is refused as unreadable. Opening the project without its results instead would show it as never run, and the next save would delete the results from the file.

Check	Result	Criterion	Verdict
the file with unreadable results refused	holds	holds	pass

S7-UnitNames: A file names each unit for its value, and reads back as written

Result
passed

Verifies
S-7

Basis
Condition

Test
ProjectTest

XML forbids two attributes of one name on an element, so each unit is an attribute named for its value: `x="5" x_unit="cm"`. A project is built with a box, a tube, a sphere and a dose map, their values in several units: centimetres, metres, radians beside millimetres and degrees. Its file is written, and no element in it has two attributes of one name. The file loads, and its scene, written out again, is the scene it was saved from, every value in its unit.

Check	Result	Criterion	Verdict
no element of the file has two attributes of one name	holds	holds	pass

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Check	Result	Criterion	Verdict
the file's scene is the scene it was saved from	holds	holds	pass

S7-NewerFormat: A file of a newer format is refused, not read in part

Result
passed

Verifies
S-7

Basis
Condition

Test
ProjectTest

A file written by a later version of RadMap may hold what this version does not know, or mean something else by what it does. A project file whose format is newer than this version's, and one whose material library's format is, are each refused, with the reason given as a newer format.

Check	Result	Criterion	Verdict
a newer project format refused as such	holds	holds	pass
a newer material library format refused as such	holds	holds	pass

S7-EarlierFormat: A file saved by RadMap 2.0 or earlier is refused, and the project stays

Result
passed

Verifies
S-7

Basis
Condition

Test
ProjectTest

The material library RadMap 2.0 and earlier shipped, which every project, volume and library file of theirs carries a copy of, held wrong atomic weights, densities and compositions (defects D-0021, D-0031, D-0032 and D-0033). RadMap 3.0 therefore opens no file of their formats: project format 5 and older, library format 2 and older. A project is saved, then written again labelled format 2, the format RadMap 2.0.0 wrote; as a volume file labelled format 5, the newest refused; and its material library alone labelled format 2. Each is refused as from an earlier RadMap, and the open project is the one it was before.

Check	Result	Criterion	Verdict
a project of format 2 refused as from an earlier RadMap	holds	holds	pass
the open project unchanged	holds	holds	pass
a volume of format 5 refused as from an earlier RadMap	holds	holds	pass
the open project unchanged	holds	holds	pass
a library of format 2 refused as from an earlier RadMap	holds	holds	pass

7.10 RadMapApiLockTest

S5-Lock: A project holding results refuses every change its results depend on

Result
passed

Verifies
S-5

Basis
Condition

Test
RadMapApiLockTest

A project file holding results is loaded through RadMap's programming interface, as a user opens one. The case then tries each kind of change, every one through the same calls the application makes, and checks the answer:

- placement, dimensions and names of solids, adding and deleting solids, sources and dose maps, the project's material library and the run settings are refused, and the refused value is not taken;
- a second run is refused while the results are held;
- colour, wireframe and the coordinate-system axes are allowed: they are saved with the project but never reach the simulation, so no result depends on them;
- a material library that is not the project's is not locked;
- discarding the results releases the lock, and the same change is then taken.

The results are read back from the project, so the lock holds results the project owns, not only those of a run still in memory.

Check	Result	Criterion	Verdict
a solid's position refused	holds	holds	pass
a solid's dimensions refused	holds	holds	pass
a library edit: answered with the refusal	holds	holds	pass

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Check	Result	Criterion	Verdict
replacing the library: answered as locked	holds	holds	pass
deleting a material: answered as locked	holds	holds	pass
deleting an element: answered as locked	holds	holds	pass
deleting an isotope: answered as locked	holds	holds	pass
a solid's name refused	holds	holds	pass
the refused name not taken	holds	holds	pass
colour allowed	holds	holds	pass
wireframe allowed	holds	holds	pass
coordinate-system axes allowed	holds	holds	pass
adding a solid refused	holds	holds	pass
adding a source refused	holds	holds	pass
adding a dose map refused	holds	holds	pass
deleting solids refused	holds	holds	pass
the project library refused	holds	holds	pass
another library allowed	holds	holds	pass
the run settings refused	holds	holds	pass
the refused settings not taken	holds	holds	pass
resetting the run settings refused	holds	holds	pass
a second run refused	holds	holds	pass
after discarding, the change taken	holds	holds	pass

7.11 ReportContentTest

S10-Report: The report shows each dose map's own result, with its unit, uncertainty and run

Result
passed

Verifies

S-6, S-10

Basis
Condition

Test
ReportContentTest

A Cs-137 source of 1 GBq in air, and three dose maps at different distances from it, scoring different quantities: effective dose (ROT) at 800 mm, air kerma at 300 mm and $H^*(10)$ at 500 mm, created in that order and named so that alphabetical order differs from it. The project is simulated with 20 000 primary particles, and its dose rate report's content is built from the project as the PDF report is, without any window.

The dose map table lists the three maps in the order they were made. Each row's dose rate, read back from its text, equals that map's own simulated result and its statistical uncertainty to within the report's rounding to three significant digits (0.5 %), so no row shows another map's number. Each unit is the one its quantity is scored in, decided from the quantity, not read from the result: Gy/h for air kerma, Sv/h for effective dose and $H^*(10)$. The report's run line names the run the results come from – the RadMap version that ran it, its start time to the minute and its run ID – and its text gives the number of primary particles.

Check	Result	Criterion	Verdict
the dose maps in the order they were made	holds	holds	pass
z_effective_far: the dose rate shown is its own	9.040×10^{-5} Sv/h	9.037×10^{-5} Sv/h ± 0.5 %	pass
z_effective_far: the uncertainty shown is its own	1.010×10^{-5} Sv/h	1.013×10^{-5} Sv/h ± 0.5 %	pass
z_effective_far: shown in Sv/h	holds	holds	pass
a_kerma_near: the dose rate shown is its own	8.300×10^{-4} Gy/h	8.302×10^{-4} Gy/h ± 0.5 %	pass
a_kerma_near: the uncertainty shown is its own	3.380×10^{-5} Gy/h	3.382×10^{-5} Gy/h ± 0.5 %	pass
a_kerma_near: shown in Gy/h	holds	holds	pass
m_hstar_mid: the dose rate shown is its own	3.600×10^{-4} Sv/h	3.601×10^{-4} Sv/h ± 0.5 %	pass
m_hstar_mid: the uncertainty shown is its own	2.440×10^{-5} Sv/h	2.444×10^{-5} Sv/h ± 0.5 %	pass
m_hstar_mid: shown in Sv/h	holds	holds	pass
the run line names the run's ID	holds	holds	pass
the run line names the RadMap version that ran it	holds	holds	pass

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Check	Result	Criterion	Verdict
the run line gives the run's start to the minute	holds	holds	pass
the text gives the number of primary particles	holds	holds	pass

7.12 RunLockTest

S5-Run: A run locks the project from its start until its results are discarded

Result
passed

Verifies
S-5

Basis
Condition

Test
RunLockTest

A project is built and run through RadMap's programming interface, with a stand-in for the simulation that writes results after a delay, so the run can be observed in flight. A change to a solid is tried while the run is going, after its results are stored, after an attempt to cancel the finished run, and after the results are discarded. It is refused in the first three states and taken only in the last: the lock begins when the run starts, not when its results arrive, and cancelling cannot release results already stored.

Check	Result	Criterion	Verdict
locked while the run goes	holds	holds	pass
a change refused while the run goes	holds	holds	pass
locked once its results are stored	holds	holds	pass
cancelling a finished run leaves it locked	holds	holds	pass
cancelling a finished run keeps its results	holds	holds	pass
unlocked once the results are discarded	holds	holds	pass
the results gone	holds	holds	pass
the change then taken	holds	holds	pass

S5-Unpolled: A run that has ended but whose results are not yet collected still locks

Result
passed

Verifies
S-5

Basis
Condition

Test
RunLockTest

The simulation is a separate program, and RadMap collects its results when it next asks how the run is going. Between the program ending and that question, the project must stay locked, or a change could slip in before results that describe the earlier project are stored. The case starts a run, waits until the stand-in for the simulation has ended, and tries a change before collecting the results: it is refused.

Check	Result	Criterion	Verdict
locked before the results are collected	holds	holds	pass
a change refused before the results are collected	holds	holds	pass

S11-Run: A run's start, end, results and their discarding are reported

Result
passed

Verifies
S-11

Basis
Condition

Test
RunLockTest

A listener is attached and a project is run through RadMap's programming interface, with a stand-in for the simulation. A run that stores results reports that it started, that results were stored and that it ended, and discarding the results is reported too; a run that fails, and one that is cancelled, report that they started and ended, and no results. So the windows that show the results, and lock the project while it holds them, follow the run.

Check	Result	Criterion	Verdict
results stored, then discarded: each reported	holds	holds	pass
a failed run: started and ended, no results	holds	holds	pass

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Check	Result	Criterion	Verdict
a cancelled run: started and ended, once	holds	holds	pass

S4-Failed: A run that fails, crashes or does not finish stores no results, and says why

Result
passed

Verifies
S-4

Basis
Condition

Test
RunLockTest

The simulation is a separate program that reports its progress line by line and ends by reporting that it has finished; only then are all its results written. A stand-in for it is run through RadMap's programming interface in three ways that must not give results:

- it reports an error and stops;
- it crashes, as Geant4 does on a fatal error, leaving only Geant4's message;
- it writes a results file and ends without an error, but never reports that it finished – the results may be incomplete, so they must not be taken.

Each time the run ends with an error, the error carries a message for the user (Geant4's own text where there is one), the project holds no results, and the project is unlocked so the cause can be corrected.

Check	Result	Criterion	Verdict
an error reported ends the run with an error	holds	holds	pass
the algorithm's error reaches the user	holds	holds	pass
no results stored	holds	holds	pass
the project unlocked	holds	holds	pass
a change then taken	holds	holds	pass
a crash ends the run with an error	holds	holds	pass
Geant4's message reaches the user	holds	holds	pass
no results stored	holds	holds	pass
the project unlocked	holds	holds	pass
a change then taken	holds	holds	pass

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Check	Result	Criterion	Verdict
an unfinished run ends with an error	holds	holds	pass
the user is told it did not finish	holds	holds	pass
no results stored	holds	holds	pass
the project unlocked	holds	holds	pass
a change then taken	holds	holds	pass

S6-Record: A run's record arrives with its results and goes with them

Result
passed

Verifies
S-6

Basis
Condition

Test
RunLockTest

A project is run through RadMap's programming interface, with a stand-in for the simulation. Before a run, and after a run that fails, the project has no run record. After a run that stores results, the record holds a run ID of 12 hexadecimal digits, the time the run started in UTC, and the RadMap version that ran it. Discarding the results removes the record with them, and running the unchanged project again gives a new ID: a run ID names one run, never a project.

Check	Result	Criterion	Verdict
no record before a run	holds	holds	pass
no record after a failed run	holds	holds	pass
no record before a run	holds	holds	pass
a run ID of 12 hexadecimal digits	holds	holds	pass
the start time, between starting the run and its end	holds	holds	pass
the RadMap version that ran it	holds	holds	pass
the record gone with the results	holds	holds	pass
no record before a run	holds	holds	pass
a run ID of 12 hexadecimal digits	holds	holds	pass
the start time, between starting the run and its end	holds	holds	pass

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Check	Result	Criterion	Verdict
the RadMap version that ran it	holds	holds	pass
a new run of the same project gets a new ID	holds	holds	pass

S4-Cancelled: A cancelled run stores no results

Result
passed

Verifies
S-4

Basis
Condition

Test
RunLockTest

A run is started through RadMap's programming interface with a stand-in for the simulation that would write results, but only after a delay, and is cancelled while it is going. The project holds no results, is unlocked at once, and takes a change: nothing of the cancelled run remains.

Check	Result	Criterion	Verdict
no results stored	holds	holds	pass
the project unlocked at once	holds	holds	pass
a change then taken	holds	holds	pass

7.13 ProjectXmlTest

S7-Geometry: Dimensions and positions are written as typed and read back exactly

Result
passed

Verifies
S-7

Basis
Condition

Test
ProjectXmlTest

A box is given dimensions and a position with decimals that a binary number cannot hold exactly – 228.6, 0.4, 1234.567 and -114.3 mm. The project file holds each as the decimal typed, and reading it back gives exactly the same number, not one off in its last digits. Solids placed to touch depend on it: Geant4 reports two faces as overlapping if they miss each other by more than half a nanometre.

Check	Result	Criterion	Verdict
228.6 written as 228.6	holds	holds	pass
0.4 written as 0.4	holds	holds	pass
1234.567 written as 1234.567	holds	holds	pass
25.4 written as 25.4	holds	holds	pass
228.6 read back exactly	holds	holds	pass
0.4 read back exactly	holds	holds	pass
1234.567 read back exactly	holds	holds	pass
-114.3 read back exactly	holds	holds	pass

S7-Activity: An activity is written as typed and read back exactly

Result
passed

Verifies
S-7

Basis
Condition

Test
ProjectXmlTest

Sources are given activities of 1.234, 999.999, 0.001 and 123456789.123 Bq, written to a project file and read back. Each is written as the decimal typed and read back as exactly the same number.

Check	Result	Criterion	Verdict
1.234 Bq written as typed	holds	holds	pass
1.234 Bq read back exactly	holds	holds	pass
999.999 Bq written as typed	holds	holds	pass
999.999 Bq read back exactly	holds	holds	pass
0.001 Bq written as typed	holds	holds	pass
0.001 Bq read back exactly	holds	holds	pass
123456789.123 Bq written as typed	holds	holds	pass
123456789.123 Bq read back exactly	holds	holds	pass

S7-Locale: A file reads back the same under a locale with a decimal comma

Result
passed

Verifies
S-7

Basis
Condition

Test
ProjectXmlTest

A file must read the same on every machine, whatever its regional settings. The case sets the program's numeric locale to German, whose decimal separator is a comma, and then writes and reads back a box's dimensions (228.6, 0.4 and 0.0015 mm), a material's density and atomic mass (7.874 g/cm3, 55.845 g/mol), and the total activity stored results are normalised by (1.25e9 Bq). Each is written with a point, as on any other machine, and read back exactly.

Check	Result	Criterion	Verdict
the locale's decimal separator is a comma	holds	holds	pass
228.6 written with a point	holds	holds	pass
228.6 read back exactly	holds	holds	pass
0.4 read back exactly	holds	holds	pass
0.0015 read back exactly	holds	holds	pass
density 7.874 read back exactly	holds	holds	pass
atomic mass 55.845 read back exactly	holds	holds	pass
total activity 1.25e9 read back exactly	holds	holds	pass

7.14 MaterialCombinationsTest

S2-References: The lead and the oxygen shields the other cases compare with give clearly different doses

Result
passed

Verifies
S-2

Basis
Condition

Test
MaterialCombinationsTest

The other S2- cases tell a shield of lead from one of oxygen by the dose rate behind it. Am-241's 59.5 keV photons pass the thin oxygen shield more easily: the dose behind it is more than twice the dose behind the lead one, so a run that took one material for the other could not pass them.

Check	Result	Criterion	Verdict
plain oxygen's dose / plain lead's	21.48	above 2	pass

S2-SharedIsotopes: Two elements of one material built from the same isotopes

Result
passed

Verifies
S-2

Basis
Condition

Test
MaterialCombinationsTest

Each case runs a source of Am-241 behind a 2 mm shield, with a second material in a solid out of the beam, and compares the dose rate behind the shield with that behind a plainly named shield of the same composition, run separately. The two must agree within 4 standard deviations of their difference. Here two elements of one lead material are built from the same two isotopes in different proportions: each isotope must reach Geant4 once, defined before either element uses it.

Check	Result	Criterion	Verdict
the shield: |dose - plain shield's| / sigma	1.576	below 4	pass

S2-SharedIsotopeTwo: Elements of two materials share an isotope

Result
passed

Verifies
S-2

Basis
Condition

Test
MaterialCombinationsTest

Each case runs a source of Am-241 behind a 2 mm shield, with a second material in a solid out of the beam, and compares the dose rate behind the shield with that behind a plainly named shield of the same composition, run separately. The two must agree within 4 standard deviations of their difference. Here the elements of two different lead materials share an isotope, so the isotope is used by both and must be defined once.

Check	Result	Criterion	Verdict
the shield: |dose - plain shield's| / sigma	0.579	below 4	pass

S2-SharedPartly: Three elements share isotopes, partly and in a different order

Result
passed

Verifies
S-2

Basis
Condition

Test
MaterialCombinationsTest

Each case runs a source of Am-241 behind a 2 mm shield, with a second material in a solid out of the beam, and compares the dose rate behind the shield with that behind a plainly named shield of the same composition, run separately. The two must agree within 4 standard deviations of their difference. Here three elements share isotopes in part, each listing them in a different order.

Check	Result	Criterion	Verdict
the shield: |dose - plain shield's| / sigma	1.576	below 4	pass

S2-SharedMix: Two mixes share a material, and a solid uses that material itself

Result
passed

Verifies
S-2

Basis
Condition

Test
MaterialCombinationsTest

Each case runs a source of Am-241 behind a 2 mm shield, with a second material in a solid out of the beam, and compares the dose rate behind the shield with that behind a plainly named shield of the same composition, run separately. The two must agree within 4 standard deviations of their difference. Here two material mixes include the same material, and a solid uses that material on its own: it must reach Geant4 once, and each mix must keep its own composition.

Check	Result	Criterion	Verdict
the shield: |dose - plain shield's| / sigma	0.7629	below 4	pass

S2-AtomsAndMass: A material by atom count shares its element with one by mass fraction

Result
passed

Verifies
S-2

Basis
Condition

Test
MaterialCombinationsTest

Each case runs a source of Am-241 behind a 2 mm shield, with a second material in a solid out of the beam, and compares the dose rate behind the shield with that behind a plainly named shield of the same composition, run separately. The two must agree within 4 standard deviations of their difference. Here one material is given by atom count and another by mass fraction, both of the same element.

Check	Result	Criterion	Verdict
the shield: |dose - plain shield's| / sigma	0.7629	below 4	pass

S2-IsotopeElementName: An isotope and its element have the same name

Result
passed

Verifies
S-2

Basis
Condition

Test
MaterialCombinationsTest

Each case runs a source of Am-241 behind a 2 mm shield, with a second material in a solid out of the beam, and compares the dose rate behind the shield with that behind a plainly named shield of the same composition, run separately. The two must agree within 4 standard deviations of their difference. Here an isotope and the element made of it have the same name, which the material library allows: each must stay what it is.

Check	Result	Criterion	Verdict
the shield: |dose - plain shield's| / sigma	0.6049	below 4	pass

S2-OneNameThree: A material, an element and an isotope all have the same name

Result
passed

Verifies
S-2

Basis
Condition

Test
MaterialCombinationsTest

Each case runs a source of Am-241 behind a 2 mm shield, with a second material in a solid out of the beam, and compares the dose rate behind the shield with that behind a plainly named shield of the same composition, run separately. The two must agree within 4 standard deviations of their difference. Here a material, its element and that element's isotope all have the same name.

Check	Result	Criterion	Verdict
the shield: |dose - plain shield's| / sigma	0.579	below 4	pass

S2-Material0x: Two materials named alike up to "0x" stay two materials

Result
passed

Verifies
S-2

Basis
Condition

Test
MaterialCombinationsTest

Each case runs a source of Am-241 behind a 2 mm shield, with a second material in a solid out of the beam, and compares the dose rate behind the shield with that behind a plainly named shield of the same composition, run separately. The two must agree within 4 standard deviations of their difference. Geant4 cuts a name at "0x" when it reads one, so Wall0xA and Wall0xB would both become Wall. Here Wall0xA is lead and Wall0xB is oxygen, each run as the shield with the other beside it, written to the file before and after it: each shield reads as its own material (defect D-0015).

Check	Result	Criterion	Verdict
Wall0xA, Wall0xB written before it: |dose - plain shield's| / sigma	0.7629	below 4	pass
Wall0xB, Wall0xA written before it: |dose - plain shield's| / sigma	0.4298	below 4	pass
Wall0xA, Wall0xB written after it: |dose - plain shield's| / sigma	1.288	below 4	pass
Wall0xB, Wall0xA written after it: |dose - plain shield's| / sigma	0.1385	below 4	pass

S2-Element0x: Two elements named alike up to “0x” stay two elements

Result
passed

Verifies
S-2

Basis
Condition

Test
MaterialCombinationsTest

Each case runs a source of Am-241 behind a 2 mm shield, with a second material in a solid out of the beam, and compares the dose rate behind the shield with that behind a plainly named shield of the same composition, run separately. The two must agree within 4 standard deviations of their difference. As S2-Material0x, for two elements, El0xA of lead and El0xB of oxygen.

Check	Result	Criterion	Verdict
Heavy, Light written before it: |dose - plain shield’s| / sigma	0.7629	below 4	pass
Light, Heavy written before it: |dose - plain shield’s| / sigma	0.4298	below 4	pass
Heavy, Light written after it: |dose - plain shield’s| / sigma	1.288	below 4	pass
Light, Heavy written after it: |dose - plain shield’s| / sigma	0.1385	below 4	pass

S2-Isotope0x: Two isotopes named alike up to “0x” stay two isotopes

Result
passed

Verifies
S-2

Basis
Condition

Test
MaterialCombinationsTest

Each case runs a source of Am-241 behind a 2 mm shield, with a second material in a solid out of the beam, and compares the dose rate behind the shield with that behind a plainly named shield of the same composition, run separately. The two must agree within 4 standard deviations of their difference. As S2-Material0x, for two isotopes, Iso0xA of lead and Iso0xB of oxygen.

Check	Result	Criterion	Verdict
Heavy, Light written before it: |dose - plain shield's| / sigma	0.579	below 4	pass
Light, Heavy written before it: |dose - plain shield's| / sigma	0.4298	below 4	pass
Heavy, Light written after it: |dose - plain shield's| / sigma	1.458	below 4	pass
Light, Heavy written after it: |dose - plain shield's| / sigma	0.1385	below 4	pass

S2-Leading0x: Names that begin with "0x" are kept whole

Result
passed

Verifies
S-2

Basis
Condition

Test
MaterialCombinationsTest

Each case runs a source of Am-241 behind a 2 mm shield, with a second material in a solid out of the beam, and compares the dose rate behind the shield with that behind a plainly named shield of the same composition, run separately. The two must agree within 4 standard deviations of their difference. Here the isotope, element and material are named 0x1, 0x2 and 0x3: cut at "0x", each name would be nothing at all.

Check	Result	Criterion	Verdict
the shield: |dose - plain shield's| / sigma	0.579	below 4	pass

S2-AllCharacters: Names holding every character the library allows

Result
passed

Verifies
S-2

Basis
Condition

Test
MaterialCombinationsTest

Each case runs a source of Am-241 behind a 2 mm shield, with a second material in a solid out of the beam, and compares the dose rate behind the shield with that behind a plainly named

shield of the same composition, run separately. The two must agree within 4 standard deviations of their difference. Here the isotope, element and material have names that use every kind of character the library accepts: digits, a comma, a hyphen, an underscore and a full stop.

Check	Result	Criterion	Verdict
the shield: |dose - plain shield's| / sigma	0.579	below 4	pass

S2-ElementG4Name: An element named like one of Geant4's own materials stays the user's

Result
passed

Verifies
S-2

Basis
Condition

Test
MaterialCombinationsTest

Each case runs a source of Am-241 behind a 2 mm shield, with a second material in a solid out of the beam, and compares the dose rate behind the shield with that behind a plainly named shield of the same composition, run separately. The two must agree within 4 standard deviations of their difference. Geant4 looks a name up among its own materials before it reads it as an element. Here an element of oxygen is named G4_Pb, Geant4's name for lead: the shield must read as oxygen.

Check	Result	Criterion	Verdict
the shield: |dose - plain shield's| / sigma	0.6239	below 4	pass

S2-MaterialG4Name: A material named like one of Geant4's own materials stays the user's

Result
passed

Verifies
S-2

Basis
Condition

Test
MaterialCombinationsTest

Each case runs a source of Am-241 behind a 2 mm shield, with a second material in a solid out of the beam, and compares the dose rate behind the shield with that behind a plainly named shield of the same composition, run separately. The two must agree within 4 standard deviations of their difference. Here a material of oxygen is named G4_Pb, Geant4's name for lead: the shield must read as oxygen.

Check	Result	Criterion	Verdict
the shield: |dose - plain shield's| / sigma	0.6239	below 4	pass

S2-Case: Names that differ only in case stay apart

Result
passed

Verifies
S-2

Basis
Condition

Test
MaterialCombinationsTest

Each case runs a source of Am-241 behind a 2 mm shield, with a second material in a solid out of the beam, and compares the dose rate behind the shield with that behind a plainly named shield of the same composition, run separately. The two must agree within 4 standard deviations of their difference. Here WALL is lead and wall is oxygen, made of elements EL and el, run both ways round and in both orders in the file.

Check	Result	Criterion	Verdict
WALL, wall written before it: |dose - plain shield's| / sigma	0.7629	below 4	pass
wall, WALL written before it: |dose - plain shield's| / sigma	0.4298	below 4	pass
WALL, wall written after it: |dose - plain shield's| / sigma	1.288	below 4	pass
wall, WALL written after it: |dose - plain shield's| / sigma	0.1385	below 4	pass

7.15 RunInputsTest

S1-Unsaved: A run is given the project in memory, not the file last saved

Result
passed

Verifies
S-1

Basis
Condition

Test
RunInputsTest

A project is built through RadMap's programming interface and saved. Then, without saving again, a solid's dimension is changed to 137.5 mm and the dose map is moved to 433.25 mm, and the saved file is deleted. The run is started with a stand-in for the simulation that keeps a copy of the geometry and the instructions it is given.

The run starts although the file is gone, the geometry it was given holds the changed dimension, and its instructions place the dose map where it was moved: what a run simulates is the project as it is when the run starts, whatever was saved.

Check	Result	Criterion	Verdict
the run starts with the saved file gone	holds	holds	pass
the geometry holds the unsaved dimension, 137.5 mm	holds	holds	pass
the instructions place the dose map where it was moved, 433.25 mm	holds	holds	pass

7.16 RadMapApiValidationTest

S3-AtSave: Values a save cannot take are kept as entered, and the save names them

Result
passed

Verifies
S-3

Basis
Condition

Test
RadMapApiValidationTest

A solid is renamed "vial 2", with a space, which a name may not hold, and its source's activity is set to 0. Both are taken as entered, so the windows keep showing what was typed: the project is a document mid-edit, and refusing the keystroke would leave the window showing one value while the project held another. Saving is refused; the message names the solid and the source, and no file is written. Once both are corrected, the save succeeds.

Check	Result	Criterion	Verdict
an invalid name taken as entered	holds	holds	pass
a zero activity taken as entered	holds	holds	pass
the save refused	holds	holds	pass
the message names the solid	holds	holds	pass
the message names the source	holds	holds	pass
no file written	holds	holds	pass
the values still as entered	holds	holds	pass

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Check	Result	Criterion	Verdict
once corrected, the save succeeds	holds	holds	pass

S3-Numbers: A number its field could not show is refused at the write, unchanged

Result
passed

Verifies
S-3

Basis
Condition

Test
RadMapApiValidationTest

A field shows a number to six decimals and below 1000 in its unit, the rule the API reports for the windows to build their fields from. A number past it would show rounded, and the next edit beside it would write the rounded number back (defect D-0026). So the write refuses it, and changes nothing: a position with one coordinate of seven decimals, a dimension of 1000 and an activity that is not a number are each refused, and the solid and the source keep what they held. A coordinate of exactly six decimals, and a dimension just below 1000, are taken, and read back as they were sent.

Check	Result	Criterion	Verdict
the rule reported: below 1000, six decimals	holds	holds	pass
a coordinate of seven decimals refused	holds	holds	pass
the whole position kept	holds	holds	pass
a dimension of 1000 refused	holds	holds	pass
the dimensions kept	holds	holds	pass
an activity that is not a number refused	holds	holds	pass
the activity kept	holds	holds	pass
six decimals taken	holds	holds	pass
just below 1000 taken	holds	holds	pass

S3-BeforeRun: A source that cannot be simulated is refused before the run, by name

Result
passed

Verifies
S-3

Basis
Condition

Test
RadMapApiValidationTest

A complete project is given a source of Ba-132, an isotope whose ground state Geant4 has no decay for: it would emit nothing, and every dose map would read zero (defect D-0004). The project can still be saved, since nothing in it is malformed, but the run is refused before it starts, with a message naming the source and its isotope. The source keeps its isotope until the user changes it.

Check	Result	Criterion	Verdict
the project still saves	holds	holds	pass
the message names the source and its isotope	holds	holds	pass
no run started	holds	holds	pass
the isotope still as entered	holds	holds	pass

S14-InsideWorld: A dose map reaching outside the world is refused before the run, by name

Result
passed

Verifies
S-14

Basis
Condition

Test
RadMapApiValidationTest

Nothing is simulated outside the world volume, so the part of a dose map outside it scores nothing, while the map's reading is averaged over its whole volume: it reads too low by the fraction outside (defect D-0027; in a run, a box half outside the world read half what a box of its inside half alone read).

A complete project with a world of 2 m by 1 m by 2 m is given dose maps in turn, and each time a run is started. A map well inside the world, and one whose face lies on the world's, are accepted; a map half outside is refused, and the message names it. The project with that map can still be saved. A map is placed as the run places it: a cube inside the world unturned is refused once turned so that a corner reaches out; a map placed inside by its own position is refused when the solid it is attached to moves it out; and one placed inside along the world's long side is refused when its solid turns it onto the short side.

Each run is also refused for a source whose isotope cannot be simulated, so that nothing is launched; the case reads from the message whether the dose map is among the problems.

Check	Result	Criterion	Verdict
a map well inside accepted	holds	holds	pass
a map touching the world's face accepted	holds	holds	pass

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Check	Result	Criterion	Verdict
a map half outside refused	holds	holds	pass
the message names it	holds	holds	pass
the project still saves	holds	holds	pass
a map well inside accepted	holds	holds	pass
a map turned so a corner reaches out refused	holds	holds	pass
a map well inside accepted	holds	holds	pass
a map moved out by its solid refused	holds	holds	pass
a map well inside accepted	holds	holds	pass
a map turned out by its solid refused	holds	holds	pass

7.17 RadMapApiMaterialTest

S3-Library: A material entry RadMap cannot use is refused, naming each field at fault

Result
passed

Verifies
S-3

Basis
Condition

Test
RadMapApiMaterialTest

A material library is a set of entries that the simulation reads as they stand, so an entry is checked when it is written, not later. A material with a density of 0 and an atomic mass below its atomic number is added to a library. The write is refused, the refusal names both the density and the mass as the fields to correct, and the library holds no such entry: nothing of it was taken, in part or altered.

Check	Result	Criterion	Verdict
the density named	holds	holds	pass
the mass named	holds	holds	pass
nothing written to the library	holds	holds	pass

S3-LibraryFields: A library value or name its field could not show is refused at the write

Result
passed

Verifies
S-3

Basis
Condition

Test
RadMapApiMaterialTest

The material editor shows a number to eleven decimals and a name up to a length for each kind of entry, the rules the API reports for the editor to build its fields from. A value past them would show rounded, or cut, and saving the entry would write that back (defect D-0026: a mass of eleven decimals shown to nine). An isotope with H1's mass of eleven decimals is taken as it is; one with a mass of twelve is refused, naming the mass, and so is an element named longer than an element's name may be; neither is written.

Check	Result	Criterion	Verdict
the rule reported: eleven decimals	holds	holds	pass
eleven decimals taken	holds	holds	pass
twelve decimals refused, naming the mass	holds	holds	pass
that isotope not written	holds	holds	pass
a name too long refused, naming the name	holds	holds	pass
that element not written	holds	holds	pass

S12-Effect: Before an edit to a shared library entry, everything it changes is listed

Result
passed

Verifies
S-12

Basis
Condition

Test
RadMapApiMaterialTest

A project library holds an isotope of iron, an element made of it, steel made of the element, concrete containing the steel and a wall containing the concrete, and water. Solids are made of steel, of wall and of water, with sources whose activity is given per mass, per volume and in total. For each kind of edit, the case asks what the edit would change, as the material editor does before applying it:

- an edit to the isotope reaches the element, the steel, concrete and wall, and the solids made of them;
- a new density for the steel reaches the steel's own solid and the one source whose total comes from that density: the per-mass source in the steel solid, not the per-volume or absolute ones; not the mixes containing the steel, nor their solids, nor the per-mass source in the wall – a mix is made of its components' elements, whatever their densities, and keeps its own;
- the same density written in other units reaches nothing;

- a new composition for the steel reaches the mixes containing it and their solids, but no source's total;
- an edit that changes nothing reaches nothing; one the library would refuse, and one to a name the library does not hold, are answered with the very issues the update refuses them with;
- an entry nothing else uses reaches only its own solid, and in a library that is not the project's a new composition reaches the mixes but no solid or source.

Check	Result	Criterion	Verdict
an isotope: the elements it reaches	holds	holds	pass
an isotope: the materials it reaches	holds	holds	pass
an isotope: the solids it reaches	holds	holds	pass
an isotope: the sources it reaches	holds	holds	pass
an element: the elements it reaches	holds	holds	pass
an element: the materials it reaches	holds	holds	pass
an element: the sources it reaches	holds	holds	pass
a density: no mix of it reached	holds	holds	pass
a density: its own solid alone	holds	holds	pass
a density: the sources it reaches	holds	holds	pass
the same density in other units: nothing reached	holds	holds	pass
a composition: the mixes it reaches	holds	holds	pass
a composition: the solids it reaches	holds	holds	pass
a composition: the sources it reaches	holds	holds	pass
an unchanged entry: reaches nothing (Steel)	holds	holds	pass
an unchanged entry: reaches nothing (Fe)	holds	holds	pass
an unchanged entry: reaches nothing (Fe56)	holds	holds	pass
a refused edit: answered with the update's issues	holds	holds	pass

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Check	Result	Criterion	Verdict
a refused edit: answered with the update's issues (a material made of itself)	holds	holds	pass
an unknown name: answered with the update's issues	holds	holds	pass
an entry nothing uses: the materials it reaches	holds	holds	pass
an entry nothing uses: the solids it reaches	holds	holds	pass
another library: the materials it reaches	holds	holds	pass
another library: the solids it reaches	holds	holds	pass
another library: the sources it reaches	holds	holds	pass

S12-Replace: Before the project library is replaced, every material in use it changes is listed

Result
passed

Verifies
S-12

Basis
Condition

Test
RadMapApiMaterialTest

The project library holds an isotope of iron, an element made of it, steel made of the element, concrete containing the steel and a wall containing the concrete, water, and a material no solid uses. Solids, 100 mm cubes, are made of steel, of wall and of water, and one more of water has no dimensions; their sources are given per mass and per volume. For each replacement library – a copy of the project's, edited – the case asks what replacing the project's library with it would change, as Import and Reset do before replacing it:

- an unchanged copy changes nothing;
- a copy with another mass for the isotope, deep inside the mixes, changes the steel and the wall – the materials in use made of it – and their solids, but no source's total, as no density changes;
- a copy with another density for the steel changes the steel, its solid, and the total of the per-mass source in it only: not the wall made of it, whose composition and own density stay, nor the per-volume source, nor the per-mass source in the wall;
- a copy without the water clears the solids made of water – they are left with no material – and lists the per-mass source in the one with a volume, whose total can no longer be worked out, but not the one in the solid without dimensions, whose total was undefined before and stays so; it changes no other material, solid or source;
- a copy with the unused material changed changes nothing: no solid is made of it.

Check	Result	Criterion	Verdict
an unchanged copy: nothing listed	holds	holds	pass
an isotope: the materials in use it changes	holds	holds	pass
an isotope: their solids	holds	holds	pass
an isotope: no source's total	holds	holds	pass
an isotope: no solid loses its material	holds	holds	pass
a density: the material in use it changes, not the mix of it	holds	holds	pass
a density: its solid	holds	holds	pass
a density: the per-mass source in that material's own solid	holds	holds	pass
a lacking material: the solids left without it	holds	holds	pass
a lacking material: the per-mass source whose total it was, not the one in a solid with no volume	holds	holds	pass
a lacking material: no material or solid changed	holds	holds	pass
an unused material: nothing listed	holds	holds	pass

S12-Delete: Before a material is deleted, the solids that lose it, or the delete's refusal, are known

Result
passed

Verifies
S-12

Basis
Condition

Test
RadMapApiMaterialTest

The project library holds water, an element mix, and steel inside concrete, a material mix. Solids are made of water (with a source given per mass and one in total), of water again but without dimensions (with a source given per mass), of concrete, and one of nothing. The case asks what deleting each would do, as the material editor does before deleting it:

- the water would be deleted, leaving its solids with no material: the per-mass source in the one with a volume gets a total that can no longer be worked out; the per-mass source in the solid without dimensions, whose total was undefined before, and the source given in total stay as they were;
- the steel would be refused, as the concrete contains it, which the answer names, and so changes nothing;
- a material no solid is made of would be deleted and change no solid; a name the library does not hold would not be found; a material of a library that is not the project's reaches no solid or source.

Then the materials are deleted: each delete decides as it was answered – the steel refused, the water deleted with the very solid cleared that the answer listed.

Check	Result	Criterion	Verdict
water: the solids left without a material	holds	holds	pass
water: the per-mass source whose total it was, not the one in a solid with no volume	holds	holds	pass
water: no material or other solid changed	holds	holds	pass
steel: refused, as a material contains it	holds	holds	pass
steel: the material that contains it is named	holds	holds	pass
a material no solid uses: deleted, reaching nothing	holds	holds	pass
a name the library does not hold: not found	holds	holds	pass
another library: no solid or source reached	holds	holds	pass
the delete refuses as answered	holds	holds	pass
the delete goes ahead as answered, clearing the solids listed	holds	holds	pass

7.18 RadMapApiSettingsTest

S3-ParticleLimit: A run over the licence's particle limit is refused, not cut down to it

Result
passed

Verifies

S-3

Basis
Condition

Test
RadMapApiSettingsTest

A licence may limit the number of primary particles a run may use. The case sets the number to the limit and to one more. Each is kept as entered; the run at the limit is not refused for it, and the run over it is refused with a message saying it exceeds the limit. RadMap never runs fewer particles than were entered, which would change the statistical uncertainty of every result. Under a licence with no limit, the largest number the field can hold is checked instead, and not refused.

Check	Result	Criterion	Verdict
the number of particles kept as entered	holds	holds	pass
no limit: the largest number not refused for it	holds	holds	pass

7.19 GeometryDimensionsTest

S3-Sweep: An angle reaches Geant4 as typed, even one just short of a full turn

Result
passed

Verifies
S-3

Basis
Condition

Test
GeometryDimensionsTest

A tube is given a sweep of 6.283 rad, the nearest three decimals come to a full turn in radians, and a sphere a theta range from 30.123 to 180 degrees, entered as 30.123 and 149.877. The tube reaches Geant4 swept 6.283 rad, 0.011 degrees short of a turn, not closed to a full one: RadMap does not change an angle to what it guesses was meant. The sphere reaches Geant4 with the range typed, which ends at the pole. The project keeps 6.283 rad.

Check	Result	Criterion	Verdict
the tube's sweep, as given to Geant4	360 deg	360 deg ± 1e-10 %	pass
the sphere's full turn, 360 degrees	holds	holds	pass
the sphere's theta range as typed, 149.877 degrees	holds	holds	pass
the project keeps 6.283 rad	holds	holds	pass

7.20 FaultHandlingTest

S8-Wx: After a fault, the application runs no more of its code, logs it and says so

Result
passed

Verifies
S-8

Basis
Condition

Test
FaultHandlingTest

The parts the application's handler for a fault is made of, as it runs them. An exception caught there is read, its type and its message, and one of a kind RadMap's code never throws is still recognised as caught. Then every event is dropped: an event sent to a handler afterwards, directly or queued, does not reach it, so no handler of RadMap's – no save, no paint, no click – runs on the project the failed operation may have left half changed. The details are appended to the error log, which is created if it is missing, and the message tells the user that RadMap must close and that the project file is as last saved, and where the details are; when the log cannot be written, the message holds the details itself. That the application's base calls these parts when a fault is caught, and that the session then ends, is S8-WxEnds.

Check	Result	Criterion	Verdict
the exception's type read	holds	holds	pass
its message read	holds	holds	pass
an exception of no standard kind still caught	holds	holds	pass
after the fault no event reaches a handler, sent or queued	holds	holds	pass
the details logged, the log's folder made	holds	holds	pass
a second fault appended, the first kept	holds	holds	pass
the log names the version, the type and the message	holds	holds	pass
the user told RadMap must close	holds	holds	pass
the user told the project file is as last saved	holds	holds	pass
the user told where the details are	holds	holds	pass

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Check	Result	Criterion	Verdict
a log that cannot be written reported	holds	holds	pass
the message then holds the details	holds	holds	pass

S8-WxEnds: A fault in the application's code ends the session it happens in

Result
passed

Verifies
S-8

Basis
Condition

Test
FaultHandlingTest

A program built on the application's own base, which catches every fault wx catches, throws an exception as a fault would: once from an event handler, and once from its start-up, where wx catches it outside the event loop. Each time the program ends at once with the code of an ended session, 1, not by returning; the details are in its error log; and the message it would show says that it must close. While the message is up a save is sent, as a click would send it, and it does not run. The program records the message where the application shows it in Windows' message box, which waits for the user and so cannot be run here: that the application hands the text to the message box is checked by hand.

Check	Result	Criterion	Verdict
a fault in an event handler: the session ended, code 1	holds	holds	pass
a fault in an event handler: the details logged	holds	holds	pass
a fault in an event handler: the user told it must close	holds	holds	pass
a fault in an event handler: a save sent meanwhile not run	holds	holds	pass
a fault at start-up: the session ended, code 1	holds	holds	pass
a fault at start-up: the details logged	holds	holds	pass
a fault at start-up: the user told it must close	holds	holds	pass

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Check	Result	Criterion	Verdict
a fault at start-up: a save sent meanwhile not run	holds	holds	pass

7.21 SimulationRunnerTest

S9-Version: A simulation program of another version is refused

Result
passed

Verifies
S-9

Basis
Condition

Test
SimulationRunnerTest

RadMap and the simulation program it runs agree on how a project is described to the simulation and how results come back. A stand-in for the program reports a version other than the one RadMap was built with. The run ends with an error, and the message names the version: results from a program RadMap was not built for are never taken.

Check	Result	Criterion	Verdict
the run ends with an error	holds	holds	pass
the message names the version	holds	holds	pass

S9-InstalledData: A run uses the data installed with RadMap, whatever the environment says

Result
passed

Verifies
S-9

Basis
Condition

Test
SimulationRunnerTest

Geant4 finds its physics data through environment variables, and a computer with its own Geant4 installation may have them set to other data. A stand-in for the simulation program is installed as RadMap installs it, beside its data folder, in a folder whose name holds letters no single Windows code page has together. With G4LEDATA already set to another folder, the program is started and reports the environment it was given: G4LEDATA names the data installed with RadMap.

Check	Result	Criterion	Verdict
G4LEDATA names the installed data	holds	holds	pass

S9-Libraries: A run loads the libraries installed with RadMap

Result
passed

Verifies
S-9

Basis
Condition

Test
SimulationRunnerTest

The simulation program loads Geant4's libraries from the folders on its search path. A stand-in for the program, installed as RadMap installs it, is started twice and reports the search path it was given: it begins with the program's own folder, where RadMap installs the libraries, so they are found before any others; and the second run's path is the same as the first's, not lengthened by it.

Check	Result	Criterion	Verdict
the search path begins with the program's folder	holds	holds	pass
a second run gets the same path	holds	holds	pass

7.22 VerificationTest

S9-Verify-Cs137: The installation check passes: Cs-137 in air, at three dose quantities

Result
passed

Verifies
S-9

Basis
Partly RadMap's own result

Test
VerificationTest

The installation verification lets each user check their own installation: they run the projects shipped in Samples\Verification and compare each dose rate with the range the installation guide publishes. The ranges come from reference runs of this version, with 20 million primary particles, widened to allow for the statistics of the user's shorter run; so they rest on RadMap's own earlier result, and the case guards that it has not changed. It runs the shipped project as a user does, from its file, with the number of particles saved in it, and checks every dose map against its published range: the check the user is offered passes on the build being released.

This project: Cs-137 in air, at three dose quantities.

Check	Result	Criterion	Verdict
Effective_dose_ROT, the published range's low end	4.917×10^{-4} Sv/h	above 4.870×10^{-4} Sv/h	pass

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Check	Result	Criterion	Verdict
Effective_dose_ROT, the published range's high end	4.917 × 10^{-4} Sv/h	below 4.960 × 10^{-4} Sv/h	pass
Ambient_dose_H10, the published range's low end	7.330 × 10^{-4} Sv/h	above 7.260 × 10^{-4} Sv/h	pass
Ambient_dose_H10, the published range's high end	7.330 × 10^{-4} Sv/h	below 7.390 × 10^{-4} Sv/h	pass
Air_kerma, the published range's low end	6.101 × 10^{-4} Gy/h	above 6.050 × 10^{-4} Gy/h	pass
Air_kerma, the published range's high end	6.101 × 10^{-4} Gy/h	below 6.150 × 10^{-4} Gy/h	pass

S9-Verify-Co60: The installation check passes: Co-60 behind a lead shield

Result
passed

Verifies
S-9

Basis
Partly RadMap's own result

Test
VerificationTest

The installation verification lets each user check their own installation: they run the projects shipped in Samples\Verification and compare each dose rate with the range the installation guide publishes. The ranges come from reference runs of this version, with 20 million primary particles, widened to allow for the statistics of the user's shorter run; so they rest on RadMap's own earlier result, and the case guards that it has not changed. It runs the shipped project as a user does, from its file, with the number of particles saved in it, and checks every dose map against its published range: the check the user is offered passes on the build being released.

This project: Co-60 behind a lead shield.

Check	Result	Criterion	Verdict
Ambient_dose_H10, the published range's low end	9.129 × 10^{-4} Sv/h	above 9.010 × 10^{-4} Sv/h	pass
Ambient_dose_H10, the published range's high end	9.129 × 10^{-4} Sv/h	below 9.190 × 10^{-4} Sv/h	pass

S9-Verify-Na22: The installation check passes: Na-22, whose positrons annihilate

Result
passed

Verifies
S-9

Basis
Partly RadMap's own result

Test
VerificationTest

The installation verification lets each user check their own installation: they run the projects shipped in Samples\Verification and compare each dose rate with the range the installation guide publishes. The ranges come from reference runs of this version, with 20 million primary particles, widened to allow for the statistics of the user's shorter run; so they rest on RadMap's own earlier result, and the case guards that it has not changed. It runs the shipped project as a user does, from its file, with the number of particles saved in it, and checks every dose map against its published range: the check the user is offered passes on the build being released.

This project: Na-22, whose positrons annihilate.

Check	Result	Criterion	Verdict
Ambient_dose_H10, the published range's low end	0.002597 Sv/h	above 0.00257 Sv/h	pass
Ambient_dose_H10, the published range's high end	0.002597 Sv/h	below 0.00261 Sv/h	pass

S9-Verify-I125: The installation check passes: I-125, whose photons are mostly X-rays

Result
passed

Verifies
S-9

Basis
Partly RadMap's own result

Test
VerificationTest

The installation verification lets each user check their own installation: they run the projects shipped in Samples\Verification and compare each dose rate with the range the installation guide publishes. The ranges come from reference runs of this version, with 20 million primary particles, widened to allow for the statistics of the user's shorter run; so they rest on RadMap's own earlier result, and the case guards that it has not changed. It runs the shipped project as a user does, from its file, with the number of particles saved in it, and checks every dose map against its published range: the check the user is offered passes on the build being released.

This project: I-125, whose photons are mostly X-rays.

Check	Result	Criterion	Verdict
Ambient_dose_H10, the published range's low end	2.851×10^{-4} Sv/h	above 2.830×10^{-4} Sv/h	pass
Ambient_dose_H10, the published range's high end	2.851×10^{-4} Sv/h	below 2.870×10^{-4} Sv/h	pass

S9-Verify-Sr90: The installation check passes: Sr-90, whose beta particles give bremsstrahlung

Result
passed

Verifies
S-9

Basis
Partly RadMap's own result

Test
VerificationTest

The installation verification lets each user check their own installation: they run the projects shipped in Samples\Verification and compare each dose rate with the range the installation guide publishes. The ranges come from reference runs of this version, with 20 million primary particles, widened to allow for the statistics of the user's shorter run; so they rest on RadMap's own earlier result, and the case guards that it has not changed. It runs the shipped project as a user does, from its file, with the number of particles saved in it, and checks every dose map against its published range: the check the user is offered passes on the build being released.

This project: Sr-90, whose beta particles give bremsstrahlung.

Check	Result	Criterion	Verdict
Ambient_dose_H10, the published range's low end	1.319×10^{-4} Sv/h	above 1.270×10^{-4} Sv/h	pass
Ambient_dose_H10, the published range's high end	1.319×10^{-4} Sv/h	below 1.360×10^{-4} Sv/h	pass

7.23 RadMapApiChangeTest

S11-Structure: Adding and removing an entity, and replacing the project, are reported at once

Result
passed

Verifies
S-11

Basis
Condition

Test
RadMapApiChangeTest

Every view of the project – the solid tree, the lists of sources and dose maps, the 3D view – learns of changes by listening for them, so a change that is not reported leaves a view showing what is no longer there. A listener is attached and the project's structure is changed through RadMap's programming interface: a solid, a source and a dose map are added, each is deleted, a solid's children are deleted at once, and the project is replaced by a new one. Each change is reported before the call that made it returns, once, about the entity it concerns and under its parent; a removal is announced while the entity can still be read, so a view can find what to take away.

Check	Result	Criterion	Verdict
createSolid: reported as entity added	holds	holds	pass
createSolid: about the solid	holds	holds	pass
createSolid: under the world	holds	holds	pass
createSource and createDoseMap: reported as entity added	holds	holds	pass
createSource and createDoseMap: about the source	holds	holds	pass
createSource and createDoseMap: under the world	holds	holds	pass
createSource and createDoseMap: about the dose map	holds	holds	pass
deleteSolid: still in the scene when announced	holds	holds	pass
deleteSolid: about the solid being deleted	holds	holds	pass
deleteSolid: reported as entity removing	holds	holds	pass
deleteChildren: one report, for the first child	holds	holds	pass
deleteChildren: one report, for the second child	holds	holds	pass
deleteSource and deleteDoseMap: reported as entity removing	holds	holds	pass
deleteSource and deleteDoseMap: about the source	holds	holds	pass
deleteSource and deleteDoseMap: about the dose map	holds	holds	pass
newProject: reported as project replaced	holds	holds	pass

S11-Edits: Each edit to an entity is reported, with what about it changed

Result
passed

Verifies
S-11

Basis
Condition

Test
RadMapApiChangeTest

A listener is attached, and a solid, a dose map and a source are edited through RadMap's programming interface: dimensions, position and rotation, colour and wireframe, name, material and settings, and a material removed from under the solids using it. Each edit is reported before it returns, about the entity it changed, with the aspect that changed – shape, placement, appearance or properties – so each view can tell whether it shows what changed. A solid's first usable dimensions are reported as making it drawable, later ones are not.

Check	Result	Criterion	Verdict
dimensions: with the aspect shape	holds	holds	pass
dimensions: reported as having become drawable	holds	holds	pass
dimensions: not reported as having become drawable	holds	holds	pass
a dose map's dimensions: with the aspect shape	holds	holds	pass
a dose map's dimensions: about the dose map	holds	holds	pass
position and rotation: with the aspect placement	holds	holds	pass
position and rotation: with the aspect placement	holds	holds	pass
appearance: with the aspect appearance	holds	holds	pass
appearance: about the dose map	holds	holds	pass
name and material, dose map and source settings: with the aspect properties	holds	holds	pass

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Check	Result	Criterion	Verdict
name and material, dose map and source settings: with the aspect properties	holds	holds	pass
name and material, dose map and source settings: with the aspect properties	holds	holds	pass
name and material, dose map and source settings: about the dose map	holds	holds	pass
name and material, dose map and source settings: about the source	holds	holds	pass
a material deleted from the project library: with the aspect properties	holds	holds	pass
a material deleted from the project library: about the solid	holds	holds	pass
a material deleted from the project library: reported as library changed	holds	holds	pass

S11-Refused: A change that is refused is not reported

Result
passed

Verifies
S-11

Basis
Condition

Test
RadMapApiChangeTest

A listener is attached, and a change the project refuses is made. Nothing is reported: a view acting on a report of a refused change would show something the project does not hold.

Check	Result	Criterion	Verdict
nothing reported	holds	holds	pass

S11-Load: Loading a project is reported; a load that fails is not

Result
passed

Verifies
S-11

Basis
Condition

Test
RadMapApiChangeTest

A listener is attached and a project is loaded from a file: the project is reported replaced, so every view shows the loaded project. A load that fails reports nothing, as the open project stays.

Check	Result	Criterion	Verdict
a successful load: reported as project replaced	holds	holds	pass
a failed load: nothing reported	holds	holds	pass

S11-Library: Changes to the project's material library are reported, and only those

Result
passed

Verifies
S-11

Basis
Condition

Test
RadMapApiChangeTest

A listener is attached, and entries of the project's material library – materials, elements and isotopes – are added, edited and deleted, and a library is copied into it. Each change is reported as a change of the library, so the material choices on screen follow it. A refused change reports nothing, and a change to a library that is not the project's, such as one being edited for export, reports nothing either.

Check	Result	Criterion	Verdict
add, update and delete, of each entry kind: reported as library changed	holds	holds	pass
add, update and delete, of each entry kind: reported as library changed	holds	holds	pass

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Check	Result	Criterion	Verdict
add, update and delete, of each entry kind: reported as library changed	holds	holds	pass
add, update and delete, of each entry kind: reported as library changed	holds	holds	pass
add, update and delete, of each entry kind: reported as library changed	holds	holds	pass
add, update and delete, of each entry kind: reported as library changed	holds	holds	pass
add, update and delete, of each entry kind: reported as library changed	holds	holds	pass
copyLibrary into the project library: reported as library changed	holds	holds	pass
a refused write reports nothing: nothing reported	holds	holds	pass
a standalone library is not part of the project: nothing reported	holds	holds	pass

S11-Settings: Changes to the run's settings, the dose settings and saving are reported

Result
passed

Verifies
S-11

Basis
Condition

Test
RadMapApiChangeTest

A listener is attached. The simulation settings are set and reset, the dose settings are changed, and the project is saved: each is reported, so the windows showing them and the title showing whether the project is saved follow. A save that fails reports nothing.

Check	Result	Criterion	Verdict
simulation settings, set and reset: reported as simulation settings changed	holds	holds	pass
simulation settings, set and reset: reported as simulation settings changed	holds	holds	pass
dose settings: reported as dose settings changed	holds	holds	pass
a save that succeeds, and one that does not: reported as saved	holds	holds	pass
a save that succeeds, and one that does not: nothing reported	holds	holds	pass

7.24 RadMapViewTest

S11-View: The 3D view drops what was removed and redraws a replaced project

Result
passed

Verifies
S-11

Basis
Condition

Test
RadMapViewTest

The 3D view listens for changes like every other view, and keeps a drawing of each solid and dose map. With a renderer that records what it is told, a project is replaced, a solid with a child and a dose map is deleted, a solid's children are deleted, and a dose map is deleted. The view rebuilds its drawing for the new project, and names each deleted solid and dose map to the renderer, so none is drawn after it is gone. The drawing itself needs a graphics card; what the view does with each change does not.

Check	Result	Criterion	Verdict
a new project: the drawing rebuilt	holds	holds	pass
a deleted solid: named to the renderer	holds	holds	pass
a deleted solid: its dose map goes with its subtree	holds	holds	pass

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Check	Result	Criterion	Verdict
deleted children: each named	holds	holds	pass
a deleted dose map: named to the renderer	holds	holds	pass
a deleted dose map: no solid named	holds	holds	pass

8 Checks by hand

The user interface and the PDF report are not covered by automated cases. Every change states whether it alters what a user sees; one that does is checked by hand when it is made, for what it touches, and its commit message records the check. The libraries behind them, wxWidgets and wxPdfDocument, are evaluated in the software development plan's component register. The installation verification is each user's own check of the whole chain, from the computed dose rate to the screen and the report.

Changes since release v2.0.0: 125. 51 changed what a user sees.

Commit	Date	Change	Checked by hand
8c32178	2026-11-07	Renderer calls GL only while drawing	load project, edit dimensions, delete a solid with children, Load Volume, dose map box, File > New, PDF scene image
43a843e	2026-11-07	Renderer draws the scene it is handed and knows nothing of the view	start and close, load project, move and rotate a solid with children, add a solid, Load Volume,
d58acf2	2026-11-07	Front ends include only the API, the view, radmap_types and the renderer's host header	Help > About version, solid dimensions and position, source activity, Preferences half-life
9f4fd96	2026-11-07	The 3D view is its own component above the project	start, load project, orbit and pan, highlight, PDF scene image, close
66dbdfe	2026-11-07	Avalonia pilot step 2: C API and an Avalonia app that shows a project	Avalonia pilot: open project, orbit, pan, zoom, arrows, fit all, resize, second screen, close
22b0680	2026-11-09	A fault ends the session in wx; a run ends with RadMap	a full run, a cancelled run, RadMap ended from Task Manager during a run (DoseAlgorithm ends with
2fc7c93	2026-11-09	V&V report: hazard analysis, safeguard requirements, defects cited	V&V report PDF – summary, hazard chapter and Defects cited appendix
d55af84	2026-11-10	Sweeps simulated as entered; project format 3 keeps 2.0's full turns	a 2.0-format tube of 6.283 rad opens as 360
a772b3a	2026-11-11	wx: a paste goes into a field whole, as if typed, or not at all (D-0024)	pasting into position fields, a name and the material editor
9713410	2026-11-11	Simulation: a refused save lists all its problems under one headline (D-0025)	simulation start and File → Save of a project with an invalid world

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Commit	Date	Change	Checked by hand
ed9a5fd	2026-11-11	View: wheel zoom and right-drag pan; no step size; API 2.0.0	Focus and fit with orbits on the Mössbauer lead_collimator, zooming through a dose map and back out, in the wx and Avalonia apps
8467e4e	2026-11-11	View: a selected wireframe solid is drawn by its highlight alone	the world selected in the Mössbauer example, before and after orbiting (solid cyan outline), and back to red when another solid is selected
ea3a5a3	2026-11-11	Fields show exactly what the project holds: the API's field rules (D-0026)	position and dimension fields at 6 decimals (-999.999999 fits, minus stays in view), pasting a
9d744ee	2026-11-11	wx: a fault's ending tested for real; H-7 has no open item	the fault message box shown by FaultHelper show (title, icon, text, log path), closed with OK,
d1b6d12	2026-11-12	API: remove getResultsXml, called only by tests	unchange
575599a	2026-11-12	Refuse a run while a dose map reaches outside the world (D-0027)	a run refused with a dose map partly outside the world, naming it; the project still saves
7e74a98	2026-11-13	Name fields sized from the API's rule; measurements show one decimal	material editor fits the screen at 150 %; Solid properties name field holds 16 M's (20 average capitals); 228 typed in a dimension shows 228.0
813f24f	2026-11-13	Number fields sized with GetSizeFromText	-999.999999 in a position field and 9.9999999999e-308 in a density show whole
c68d378	2026-11-13	Material editor: a mix keeps the kind it was saved as (D-0028)	New, Material mix, add, Apply, Element mix empties the grid; back to Material mix restores the
cff2655	2026-11-13	Material editor: materials, elements and isotopes on tabs	the three tabs at 150 % unclipped; an edit kept across tab changes; red field clears on typing; Apply, New and Delete on each tab; element and material added to a mix
28d7940	2026-11-13	Material editor: right-click a mix's row to open it on its tab	right-click opens an element from an element mix, an isotope from an isotope mix and a material from a material mix on their tabs; an empty row does nothing
60b93f0	2026-11-13	display: one place for how RadMap writes a number for people	fields in each panel (228 shows 228.0, emptied

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Commit	Date	Change	Checked by hand
c692fe2	2026-11-13	Run start time as a time, not text; names a reader can follow	Run information Started and the PDF header after a new run; a per-mass source's Specific activity
4d81002	2026-11-13	display: the rest of RadMap's number text; D-0029 recorded	isotope dropdown half-lives; isotope filter note; Isotope info half-life, branching, gamma
e900918	2026-11-14	Report PDF renders report::Content; no window supplies its tables	PDF of a project with 15 dose maps and 45 sources: header and run line, particle note, Dose maps,
de8118a	2026-11-14	Library changes ask once, listing what they change in the project (D-0029)	Reset after editing a used material lists it and its solid in one dialog; import of an identical
f3ec278	2026-11-15	Library write queries answer as their writes would; sources listed exactly	Delete of a contained material logs what contains it with no dialog; Delete of a used material
4aed4f2	2026-11-15	Library change effects compare materials by what a simulation uses	density change of a mix component lists only its own solid; composition change lists the mix and
95a2835	2026-11-15	Material editor: no log; every delete asked from the API, unused parts included	delete refusals (one holder named with its type, several in a table, isotope held by elements);
e6fc342	2026-11-15	Material editor: a star marks a tab with changes not applied; closing asks	stars and Apply enabling on typing, unit, radios and grid edits, cleared by Apply or by undoing
92e438b	2026-11-15	Material library refusals read as the editor's fields; "made of itself", not cycles	a material made of itself (chain named, row red); fractions not adding up to 1 (sum shown);
bade71f	2026-11-16	Preferences: half-life limits accept e-notation without turning red mid-typing	Preferences limits typed in e-notation, minimum above maximum, density field in the material
ac958b8	2026-11-16	Model reads numbers from files the same under any locale	a project loaded
18fbae5	2026-11-16	Update TODO.md	a project loaded and saved
42d8cdc	2026-11-16	One unit catalogue in radmap_types, units typed per kind	unit dropdowns (position, rotation, dimensions), Preferences half-life limits
c905983	2026-11-16	Worked-out activity total keeps the concentration's digits; TBq concentrations	worked-out total display, TBq in the per-mass and per-volume unit lists

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Commit	Date	Change	Checked by hand
50e4390	2026-11-17	● Units: no “no unit”; unknown unit names refuse the file	concentration unit lists, material density unit, material conflict dialog on Load Volume,
130fd65	2026-11-17	Units: a value and its unit as one Measure	box, tube and sphere dimensions, position and rotation panels, save and reload
83a109c	2026-11-17	Units named per value (project format 4); a file’s values fit their fields (D-0030)	an older project and volume load, save and reload with their geometry and units; 2.0’s
a0e7b68	2026-11-17	Retire Units.h; activity in becquerels (project format 5)	2.0 verification sample’s dose rates against the user guide’s table, panel and PDF report; total
3089514	2026-11-17	DEFECTS: D-0030 fixed in 83a109c	unchange
2363245	2026-11-17	Degrees become radians one way: radiansOf	tubes and spheres with partial sweeps and rotated solids in the 3D view; a concentration’s total
bf24078	2026-11-17	One unit dropdown per kind; the shipped library’s density units checked	box, tube and sphere dimensions, position and rotation of a solid and a dose map, the material
1a695a3	2026-11-18	A material’s density is a DensityMeasure; an unknown density unit refused at load	material editor in mg/cm3 and g/cm3 (open, change unit,
0b4b146	2026-11-18	A full licence names its licensee, under one signature; 2.0 files refused	Help > License on the free tier with a 2.0 file
8ab56ac	2026-11-18	Help > License: renewing asks for the licensee too	Help > License and the PDF report with a full licence
6bc8a49	2026-11-19	RadMap 3.0 opens no 2.0 file; default material library corrected (D-0031 to D-0033)	the earlier-RadMap refusal for a project, a solid file,
2a7862d	2026-11-19	Title bar shows the RadMap version; one style for a refused file	the title bar with and without a saved project; the
a1e2f14	2026-11-19	Example projects written by a program: Co-60 behind lead, Cs-137 in a water tank	both examples opened and run from Samples\Examples
1978db5	2026-11-20	Pre-release review: activity text as the field shows it; stale doc claims	an activity of 0.0001 MBq shows in plain decimals in the source panel’s total and the report
53cb87f	2026-11-20	Release 3.0.0	title bar and Help → About show 3.0.0.

9 Defects cited

The defects in released versions that the hazard analysis cites, as the defect log held them when this report was generated. The errata page, https://radmap.tech/documentation/errata.html, holds their current state and every defect found since.

D-0001: Sources in a moved parent, or rotated tube segments, sampled in the wrong place.

Versions affected
1.1.0

Effect on results
For a source in a solid that sits inside a moved solid, at any depth, and for a source in a rotated tube segment. Either the run stopped at its first decay, with an error or a crash, or it completed with decays in only part of the source's volume, the part the sampling box happened to overlap. The dose rates of such a run describe a source of the right activity in the wrong place: too high near the part that had decays and too low elsewhere, by an amount that depends on the geometry. Sources in solids placed directly in the world volume, and full tubes, were not affected.

Fixed in
2.0.0

D-0002: Sampling box of a curved source fitted to its drawing mesh, slightly too small.

Versions affected
1.1.0

Effect on results
Negligible. For sources in tubes and spheres, thin slivers at the curved surfaces, at most about 0.2 % of the radius deep and together about 2 parts in 10 000 of the source's volume, never had decays. The activity was not lost but spread over the rest of the source, a few millimetres away, so dose rates changed by far less than 0.1 %, well within the statistical uncertainty of any run. Sources in boxes were not affected. No recalculation is needed.

Fixed in
2.0.0

D-0003: Effective dose used ICRP 116's coefficients without their 2015 corrections.

Versions affected
1.1.0

Effect on results
Effective dose from photons, in every irradiation geometry. At the energies radionuclides emit, up to 10 MeV, RadMap's coefficients were up to 1.7 % high in LLAT, 1.2 % high in RLAT, 1.2 % low in PA, 0.9 % low in ROT, and within 0.6 % in ISO and AP, depending on the energy; a dose rate differs by at most as much. Air kerma and $H^*(10)$ are not affected. Only an effective dose result used within about 2 % of a limit needs recalculating.

Fixed in
2.0.0

D-0004: Isotopes offered whose ground state has no decay data emitted nothing.

Versions affected
1.1.0

Effect on results

For a source of Ag-94, Bi-198, Lu-154, Nb-85, Po-193, Ra-201, Re-194, Se-82 or Tl-186 only. The source emitted no radiation, and every dose map read zero, without a warning. Of these, only Bi-198 (half-life 11.6 minutes) is a likely choice: Se-82 is practically stable and the others have half-lives under 12 seconds. Results of a project with such a source should be recalculated with another isotope.

Fixed in

2.0.0

D-0005: Deep dose maps read the radiation where it entered them, not their mean.

Versions affected

1.1.0

Effect on results

For dose maps deep along the direction the radiation comes from, where it changes across them: close to a source, or at the edge of a shield's shadow. A box facing a small source read high by about half its depth divided by its distance: 5 % for a 10 cm cube at 1 m, 15 % for a 30 cm cube. Turned with a corner towards the source, the same cubes read 0.2 % and 2.4 % low. Plates facing the source changed little: 0.1 % for a plate 2 mm thick at 1 m. A dose map enclosing a source, or part of one, did not count the photons emitted inside it and read low, by an amount depending on how much of the source it held. Results from dose maps deeper than a few per cent of their distance from a source, or enclosing one, should be recalculated.

Fixed in

2.0.0

D-0006: Rotated dose maps simulated turned the opposite way.

Versions affected

1.1.0

Effect on results

For a dose map with a rotation of its own, or attached to a rotated solid. The map was in the right place but turned the opposite way from the one RadMap showed: about one axis, by the angle with its sign reversed; about several, by the inverse rotation. The map then covered a different region from the one drawn, and for a deep map near a source its reading also changed with its orientation (D-0005). The effect is negligible for a map small compared with its distance from sources and shield edges, and grows with its size: a 120 × 240 × 480 mm box turned about two axes, 600 mm from a source, covered a region where the mean dose rate is 4.5 % higher. Results from large rotated dose maps near sources or shield edges should be recalculated.

Fixed in

2.0.0

D-0007: Dose maps turned close to a quarter turn about Y simulated up to 1° off.

Versions affected

1.1.0

Effect on results

Negligible. For a dose map whose overall rotation, its own combined with its solids', came within about 1.15° of a quarter turn about Y – for instance a map turned 89.5° about Y – the map was simulated as if turned the full quarter turn, tilted by up to 1.15° from the orientation shown. Turned exactly 90°, it was simulated as shown. A tilt of 1.15° changes the region a map covers so little that a 30 cm cube reads within 0.02 %, and a 120 × 240 × 480 mm box 600 mm from a source within 0.4 %. No recalculation is needed.

Fixed in
2.0.0

D-0008: A full turn of a tube or sphere entered in radians left a slit.

Versions affected
1.1.0

Effect on results
For a tube or sphere whose sweep was meant as a full turn but entered in radians, or a sphere meant to reach a pole in radians. The fields keep three decimals, so a full turn could not be entered exactly: 6.283 rad, the nearest, is 0.011° short of it, and the solid was simulated with a slit that wide running through it, 0.19 mm at a radius of 1 m; 6.284 rad was refused. Photons heading into the slit crossed the solid unattenuated. The effect depends on the geometry: it is largest for a thick shield, at points behind it in line with the slit. Angles entered in degrees were not affected. Results from shields whose sweep was entered in radians should be recalculated.

Fixed in
2.0.0

D-0010: A solid's material could change to one whose name differs only in case.

Versions affected
1.1.0

Effect on results
Only in a project whose material library holds two materials whose names differ only in upper and lower case, such as *Lead* and *LEAD*, which RadMap's own library does not. A solid given the second of them was shown with the first, and editing anything else about that solid – its name, colour, wireframe or axes – gave it the first: it was then simulated in a material the user had not chosen. Results from projects whose library holds such a pair should be checked: each solid's material is shown correctly from 2.0.0, and a solid showing the wrong one should be recalculated.

Fixed in
2.0.0

D-0012: A name in a non-Latin script prints as question marks in the PDF report.

Versions affected
1.1.0

Effect on results
None. The numbers are right, but which dose map or source a row belongs to may not be readable, and two names can print the same.

Fixed in
2.0.0, in part: the report warns; the characters still print as question marks

D-0013: *Full chain* on one source also applies to the other sources.

Versions affected
1.1.0

Effect on results
For a project with *Full chain* on for one source and off for another whose daughter is radioactive in its ground state. The other source's daughters decay too, so its dose rate is too high, by an amount that depends on the isotopes. Measured: 100 MBq of Te-132 with *Full chain* off beside 100 MBq of Cs-137 with it on gave 3.3 times the sum of the two run alone, because Te-132's daughter I-132 emits far more photons. Projects where every source has the same setting are not affected.

Fixed in
2.0.0

D-0014: A source in a solid with “0x” in its name is not confined to the solid.

Versions affected
1.1.0

Effect on results
For a source in a solid whose name contains “0x”, such as `Plate100x50`. Decays are placed anywhere in the box around the solid: also inside its child solids, and outside a tube or sphere. Dose rates can be too high or too low, depending on the geometry. Measured: a source in a 5 mm air shell around a lead core gave a dose rate 3.9 times lower with a name containing “0x”, as most decays landed in the lead. A box with no children is not affected. Nothing warned of it.

Fixed in
2.0.0

D-0015: Materials named alike up to “0x” are simulated as one material.

Versions affected
1.1.0

Effect on results
For a project using two materials, two elements or two isotopes whose names are the same up to a “0x”, such as `Wall0xA` and `Wall0xB`. Both are simulated as whichever was defined first, so dose rates can be wrong by any amount, in either direction. Measured: a vacuum shield beside a lead material of such a name gave a dose rate 187 times too low. Nothing warned of it. One such name on its own, with no other that matches it, is not affected.

Fixed in
2.0.0

D-0017: Save Volume writes a file that loses solids when names repeat.

Versions affected
None. The fault was made and found during the development of 2.0.0, and fixed before its release; 1.1.0 checked the names.

Effect on results
None directly: the solids missing after *Load Volume* can be seen.

Fixed in
2.0.0

D-0019: A source in the world volume is not confined to it.

Versions affected
1.1.0

Effect on results
For a source in the world volume of a project with solids in the world. Decays are placed anywhere in the world: also inside the solids, not only around them. Dose rates can be too high or too low, depending on the geometry. Measured: a source in the 100 mm of air around a lead cube gave a dose rate 2.1 times lower, as most decays landed in the lead. A world with no solids in it is not affected. Nothing warned of it.

Fixed in
2.0.0

D-0021: Argon and potassium had each other’s atomic weight in the default library.

Versions affected
1.1.0

Effect on results
Not measured. Argon was given 39.0983 instead of 39.948, and potassium the reverse, so each element's number of atoms per gram was about 2 % off: argon in AIR, and potassium in the twelve materials holding it, among them tissue-equivalent ones and POTASSIUM_IODIDE. The attenuation by these elements changes by as much; a material's density is not affected.

Fixed in
2.0.0

D-0022: The user guide recommended ROT, not AP, as the body orientation for one source.

Versions affected
2.0.0

Effect on results
RadMap calculates every orientation correctly; the advice chose the wrong one. A dose map set to *Effective dose (ROT)* for a person facing one source reads lower than *Effective dose (AP)*: by 15 % for Co-60, 20 % for Cs-137 and about 36 % for Am-241.

Fixed in
3.0.0, commit 41812aa

D-0024: A pasted value was changed instead of refused.

Versions affected
1.1.0 to 2.0.0

Effect on results
Only for a number pasted into a field with more decimals than the field shows, three, after which another value in the same window was edited. The pasted number was then replaced by its rounding to three decimals: a position or dimension moved by at most 0.0005 of its unit, 0.5 mm in metres, and a number below 0.0005 became 0. An angle sweep pasted as 6.2831853 rad became 6.283 rad, leaving a slit in a full turn. A number typed, never pasted, was not affected. A name cut short changed no result.

Fixed in
3.0.0, commit a772b3a

D-0026: An isotope's atomic mass was rounded when the isotope was saved.

Versions affected
1.1.0 to 2.0.0

Effect on results
Negligible. The atomic mass changed by less than $5 \cdot 10^{-10}$ u in 2.0.0, and by less than 10^{-6} u in 1.1.0, far below anything a dose rate depends on.

Fixed in
3.0.0, commit ea3a5a3

D-0027: A dose map reaching outside the world volume read too low.

Versions affected
1.1.0 to 2.0.0

Effect on results
A dose map lying partly outside the world read too low, by the fraction of its volume outside: half outside, it read half the dose rate in the part inside. A dose map wholly outside read zero. Maps inside the world were not affected.

Fixed in
3.0.0, commit 575599a

D-0028: The material editor could save a material mix as a mix of elements.

Versions affected
2.0.0

Effect on results
A material saved this way was made of the elements named like its materials, in the same mass fractions. Where each of those materials is the pure element of its name, as every such material in the default library is, the composition was the same. Otherwise it changed as far as those materials differ from those elements, and so did every dose rate computed with it. A mix holding a material that no element is named like was refused, as it should be.

Fixed in
3.0.0, commit c68d378

D-0030: A value a file held beyond its field was replaced by the field's limit.

Versions affected
2.0.0

Effect on results
Only for a project whose file held a position, rotation, dimension or activity beyond what its field shows – past its range, or with more than three decimals – after which the field was clicked and another value in the same window was edited. The value was then replaced by the end of the field's range, or rounded to three decimals: the 2.0 verification samples' world, 2000 mm wide, became 1000 mm. Such values come only from files RadMap's fields did not write: 2.0's own verification samples, and projects a script built through the API. A project whose every value was typed into RadMap was not affected.

Fixed in
3.0.0, commit 83a109c; since RadMap 3.0 by opening no file of 2.0 (D-0031 to D-0033)

D-0031: Ten elements had a neighbour's atomic weight in the default library.

Versions affected
1.1.0 to 2.0.0

Effect on results
Not measured; negligible for dose rates. Five pairs of neighbouring elements had each other's atomic weight: cobalt and nickel, tellurium and iodine, thorium and protactinium, uranium and neptunium, plutonium and americium – uranium 237 instead of 238.03, iodine 127.6 instead of 126.90. Each element's number of atoms per gram was 0.4 to 0.55 % off, and the attenuation by it changes by as much: the pure elements, and the fifteen materials holding one, among them SODIUM_IODIDE, CESIUM_IODIDE, POTASSIUM_IODIDE, CADMIUM_TELLURIDE, URANIUM_OXIDE, PLUTONIUM_DIOXIDE and STAINLESS-STEEL. A material's density is not affected.

Fixed in
3.0.0

D-0032: Aluminium oxide and carbon dioxide had no density in the default library.

Versions affected
1.1.0 to 2.0.0

Effect on results
A solid of ALUMINUM_OXIDE or CARBON_DIOXIDE from the default library was simulated as vacuum: whatever it attenuates was missing, so dose rates behind it were too high – for aluminium oxide, 3.97 g/cm³, by as much as its attenuation. The material editor showed the density as 0. A source in such a solid with its activity per mass resolved to no activity, and was refused.

Fixed in
3.0.0

D-0033: Four compositions in the default library were those Geant4 later corrected.

Versions affected
1.1.0 to 2.0.0

Effect on results
Not measured. STAINLESS-STEEL held 8 % chromium and 18 % nickel by atoms, the reverse of 18/8 steel; at photon energies above a few hundred keV it attenuates within about 1 % of the right steel, and below them more strongly, so dose rates behind it were too low there. TERPHENYL, POLYCHLOROSTYRENE and POLYVINYL_BUTYRAL had the hydrogen content of another molecule: their attenuation is off by about 1 %.

Fixed in
3.0.0

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