Institute for Energy Technology
Halden Virtual Reality Centre

Software User Manual

HVRC VRdose Planner User Guide

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HVRC VRdose Planner SUM Issue 2 Revision 1

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Abstract

The HVRC VRdose software comprises of a pair of tools:

- HVRC VRdose Planner: A tool for simulating work scenarios, with radiation visualisation and dose-rate charts for scenario participants
- HVRC VRdose Briefer: A tool for playback of scenarios created using the HVRC VRdose Planner, for training/briefing purposes

This document is the software user manual for the HVRC VRdose Planner software. It provides an overview of the system concept and workflow, as well as reference information for users.

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Contents

1. INTRODUCTION

1.1 The HVRC VRdose Planner

The HVRC VRdose Planner is a real-time software tool for modelling radiological environments, planning a sequence of activities in the modelled environment, optimising protection against radiation, and producing job plan reports with dose estimates. The HVRC VRdose Planner offers the possibility to refine the radiological model to improve the accuracy of estimates and configure the dosimetric output provided. The software can also be used as an aid to producing post-work review reports, with real measurements included. Furthermore, the software provides support for presenting information to different types of users for briefing and decision-making, thus serving as an aid to communication between stakeholders in an intervention.

1.2 Intended readership

The audience for the software user manual is the end-users of the HVRC VRdose software.

1.3 Applicability statement

This issue of the user manual applies to version 2.0 of the HVRC VRdose software.

1.4 Purpose

This document is the software user manual for the HVRC VRdose Planner. It introduces the software and its intended usage, and provides useful reference material for advanced users. Additional information about specific features of the system is available via an online help system.

1.5 How to use this document

This document should be used as a guide to the HVRC VRdose system concept and installation of the software. It also contains some important reference information.

It is intended to provide a general understanding of the capabilities of the software how these capabilities can be accessed.

The Concept and Overview sections describe the general processes and principles supported by the software and the workflow and functionality that the software supports

The Getting Started section explains how to install the software and start using it.

The Reference section provides an overview of main menus and explains configuration options accessible via the user preferences interface. It also provides guidance on preparing 3D models for use in the system and on system administration tasks, including updating the software and taking backups of databases.

A glossary is provided in the appendices, along with a description of the file formats used for importing dose-rate measurements and externally produced dose maps.

1.6 Related documents

ICRP 60	1990 Recommendations of the International Commission on Radiological Protection. ICRP. Publication 60. Ann. ICRP 21 (1–3), 1991.
ICRP 101	Assessing dose of the representative person for the purpose of radiation protection of the public and the optimisation of radiological protection: Broadening the process (ICRP Publication 101). Ann. ICRP 36 (3), 2006.
ICRP 103	The 2007 Recommendations of the International Commission on Radiological Protection (ICRP Publication 103). Ann. ICRP 37 (2-4), 2008.
HWR-896	Comparative Study of Radiation Visualisation Techniques for Interactive 3D Software Applications (HWR-896), OECD Halden Reactor Project, Louka, M. N., et al., 2011.
HWR-982	A Study of Outage Planning under Complex Radiological Conditions using Halden Planner (HWR-982), OECD Halden Reactor Project, Vabø, R., et al. 2011.
HWR-979	Comparative Study of Radiation Visualisation Techniques for Interactive 3D Software Applications (follow-up study) (HWR-979), OECD Halden Reactor Project, Louka, M. N., et al., 2011.
HWR-999	Characterization Implemented in a Virtual Environment (HWR-999), OECD Halden Reactor Project, Vabø, R., et al. 2011.
HWR-1030	New Computational Model for Areal and Personal Monitoring in Nuclear Environments (HWR-1030), OECD Halden Reactor Project, Szőke, I., 2012.
HP-Benchmark	Benchmark test results for validation of the Basic Point Kernel and the Extended Point Kernel dosimetric code units of the Halden Planner, OECD Halden Reactor Project, Szőke, I. et al., 2012.
ISO/IEC 14772-1	Virtual Reality Modelling Language Specification, 1997. Available online on the Web3D Consortium website at http://www.web3d.org/.

1.7 Conventions

File paths, contents of data files, and code are shown using the Courier font – e.g. `c:\planner\examples\model\model.wrl`

The convention “Menu Name > Menu Item” is used to indicate a menu selection from the application’s main menu bar.

Keyboard shortcuts are described as “Command-<Key>” – e.g. “Command-X”.

The command key used for keyboard shortcuts depends on the host platform. For example, the ctrl-key is used on Windows and the cmd-key is used on macOS. The correct command key for shortcuts is always indicated in the menus next to the menu item that the shortcut controls.

Distance units are by default in metres. The Y-axis is up in the 3D coordinate system used by the HVRC VRdose Planner.

1.8 Problem reporting instructions

Please send questions, bug reports, or requests for new features to: vrdose-support@ife.no

When submitting bug reports, please include the following information:

- A description of the result and how it differed from what you expected.
- The conditions or circumstances under which the problem occurred.
- Any other information that could be useful to isolate the problem.

When sending bug reports, please include (if possible) a copy of the technical details in the about box (use the save button in the 'About' window to save it to file). The about box can be accessed via the Help menu.

2. Concept

A significant motivation behind the HVRC VRdose Planner has been to make advanced, radiation exposure situation analysis technology accessible to a broader range of users, who can benefit from an interactive 3D visual representation of radiation risks to support ALARA optimisation. By integrating radiological information with 3D models of nuclear facilities and environments, to facilitate risk-informed planning and work execution, we aim to support the optimisation of radiological protection for activities in nuclear environments and enhance safety culture, by increasing stakeholders' comprehension of radiation risks, thus contributing to improving safety in nuclear facilities.

2.1 Introduction

The purpose of this chapter is to provide a brief introduction to the recommendations for radiological protection published by the International Commission on Radiological Protection (ICRP) in "ICRP 103". The principles and recommendations of the ICRP are important because they serve as the basis for national regulations related to activities in exposure situations, and represent current best practice for radiological protection planning. They are therefore reflected in the design, terminology, and evolution of the HVRC VRdose Planner software, and are thus important to understanding the HVRC VRdose Planner.

The key concept in the field of radiological protection, which has been refined over many years, is that of ALARA ("As Low As Reasonably Achievable"). The goal of radiological protection planning is to optimise the level of risk, by minimising the dose, to achieve a level that is acceptable to the stakeholders involved. The word "reasonable" is the key here, as the goal is *not* to aim for the lowest dose for each individual involved in an exposure situation regardless of social or economic aspects. To explain what this means in practice, the ICRP has developed three key principles, which are described below, and makes recommendations within the framework of these principles on how they should be applied.

2.2 Radiological Protection Principles

ICRP 60 (published in 1991) introduced three fundamental principles for radiological protection:

- Principle of Justification
- Principle of Optimisation of Protection
- Principle of Application of Dose Limits

While these principles are retained in ICRP 103, the latter publication provides revised recommendations on how these principles should be applied. Before explaining each of the principles, and outlining some of the recommendations of ICRP 103, it is necessary to note that all three principles apply only for *planned exposure* situations. For *emergency exposure* and *existing exposure* situations, only the first two principles apply. Except for during (or after) an accident situation, radiological protection activities related to a nuclear power plant, for example, fall into the category of *planned exposure* and it is for ALARA planning of planned, occupational, exposure that the HVRC VRdose Planner is primarily targeted, although it would also be a useful tool to support decision-making in *emergency* or planning activities in *existing exposure* situations too.

To clarify, ICRP 103 defines three exposure situations that are intended to cover all types of exposure situations that can arise.

- *Planned exposure* situations are those involving the "planned introduction and operation of sources".
- *Emergency exposure* situations are "unexpected situations such as those that may occur during the operation of a planned situation, or from a malicious act, requiring urgent attention".
- *Existing exposure* situations are "exposure situations that already exist when a decision on control has to be taken". This typically means situations with significant natural background radiation, but also includes situations resulting from past accidents or other activities such as weapons testing.

In addition to *occupational* exposure to workers, ICRP 103 recognises *public exposure* and *medical exposure* as distinct exposure types. The term *potential exposure is used* to describe exposure that is anticipated but not intended in a planned exposure situation. *Potential exposure*, therefore, describes the exposure that would be received if a planned job goes wrong. The risk of potential exposure should be minimised when producing a plan for acceptable exposure to execute a planned activity. Of course, organisations should strive to understand the causes of potential exposure actually received when a job is done, and communicate lessons learnt that could contribute to reducing the risk of potential exposure when executing similar activities in future.

2.2.1 Principle of Justification

"*Any decision that alters the radiation exposure situation should do more good than harm"* (ICRP 60).

This principle implies that the decision-making process should include an evaluation of whether the net benefit of a change to an exposure situation is positive. The benefits that should outweigh the detriment may be individual or societal. The detrimental risk of radiation exposure may be a small part of the overall equation to determine if the new situation is positive.

2.2.2 Principle of Optimisation of Protection

"The likelihood of incurring exposures, the number of people exposed, and the magnitude of their individual doses should all be kept as low as reasonably achievable, taking into account economic and societal factors" (ICRP 60).

Given that a situation is justified, we should aim to minimise individual doses, but in such a way that we also minimise the number of individuals exposed, following the principle of ALARA. So within dose limit restrictions applied to individuals, we should aim to discover the best, reasonable, level of protection for the individuals that will be exposed. The HVRC VRdose Planner is intended to provide support in the process of identifying the optimal solution for protection for planned exposure, and to identify risks of potential exposure that the stakeholders need to be made aware of to reduce the risk of actually receiving higher doses than planned.

2.2.3 Principle of Application of Dose Limits

"The total dose to any individual from regulated sources in planned exposure situations other than medical exposure of patients should not exceed the appropriate limits specified by the Commission" (ICRP 60).

National laws and regulations on the application of dose limits are generally based on ICRP recommendations. The limits specified by ICRP 103 are primarily intended to guide the application of the optimisation of protection principle

2.3 Recommendations on Applying Radiological Protection Principles

2.3.1 Recommendations on Justification

Within the scope of the HVRC VRdose Planner, radiation protection staff in collaboration with other stakeholders would normally be responsible for justifying a job involving operational exposure, however this is formally within the scope of a high level justification for the operation and maintenance of the facility in which the work will take place, so may not need to be explicitly stated in the preparation of a work permit request, for example. When justifying the introduction of an entirely new facility, the responsibility for justification generally lies with governments and national authorities. As this principle extends beyond the responsibility of radiation protection authorities, the ICRP provides only limited guidance on application of the principle beyond acknowledging that different approaches can be taken for occupational and public exposure depending on whether planned actions can be taken on the source or whether it is only possible to modify pathways of exposure, typically in an emergency or existing exposure situation.

2.3.2 Recommendations on Optimisation of Protection

ICRP 103 provides a general overview of recommendations on optimisation of radiological protection, noting that earlier recommendations continue to apply. The latest detailed guidance from the ICRP can be found in ICRP 101, published in 2005, which focuses on dose assessment issue and the optimisation process. As for ICRP 103, ICRP 101 builds on ICRP 60.

In order to minimise dose, we need to optimise time, distance and shielding, while taking into account other constraints used to determine the scope within which the dose can be justified as reasonably low, such as acceptable risk of potential exposure, and other risks and costs. In addition to restricting the individual dose or risk to a worker, the size of the collective dose to all workers involved in a job is also an important parameter that is taken into account in selecting the best of multiple options.

The optimisation process itself is generally iterative and is focussed on planning ahead. While we are, of course, interested in evaluating performance, to learn from it after a job has been done, optimisation is focussed on minimising risk for planned activities. Effective optimisation in practice requires that stakeholders have a common understanding of the basic principles of radiological protection and that an active safety culture, and learning from past experience, is encouraged.

The steps of the iterative optimisation process given in ICRP 103 are illustrated in the figure below:

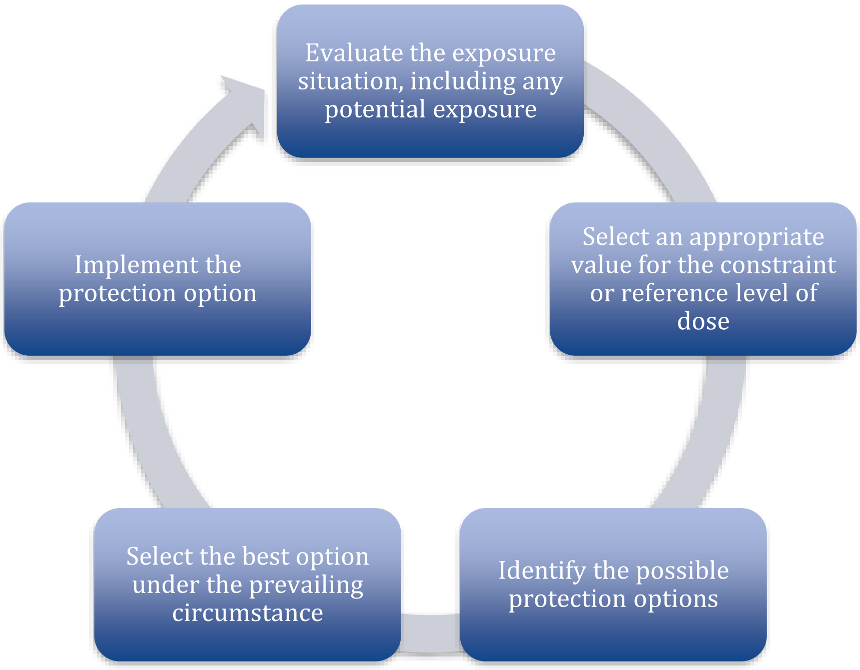


Figure 2.1 ICRP 103 Iterative optimisation process

Considerations to minimise dose in order to identify possible protection options include:

- Less Time → Less Dose
- More distance→ Less Dose
- More shielding → Less Dose
- More shielding → More Time → More Dose…

Effective planning can reduce the time taken to carry out an activity, thus reducing dose. Distance to sources can also be improved through effective briefing of workers and encouragement of a radiation safety mind-set to ensure that workers take breaks in lower dose areas of the work area and move away from sources when carrying out activities that do not require them to be close to a source.

Use of temporary shielding must be justified – is it necessary to comply with the Principle of Application of Dose Limits? If it is not necessary to prevent violation of dose limits, will it contribute to reducing the collective dose of the stakeholder workers, including radiation protection (RP) workers, for the entire planned activity? We should also bear in mind that installation, movement or removal of temporary shielding itself requires spending time in areas of elevated radiation, is normally only allowed to be done with authorisation from responsible RP staff, and planned changes to the exposure situation will often trigger a requirement for control measurements of dose-rate levels, which may significantly increase the time taken to complete a job. Tools such as the HVRC VRdose Planner should be useful for modelling alternative scenarios in order to determine which would give the best result, and also be helpful when briefing workers and documenting why the selected solution is considered optimal.

The best option is not always the one that will give the lowest dose. For example, the option that gives lowest planned dose exposure may involve significantly higher risk for potential exposure, fire, flooding, or some other detrimental result. The lowest dose option might also involve a greater risk of the operation taking significantly longer than planned, again giving increased risk for additional exposure; taking into account the likelihood of receiving greater dose than planned, and the amount of additional dose in that case, what might first appear to be the best option may not be.

2.3.3 Recommendations on Application of Dose Limits

Dose limits are essential to managing the individual health risk to individual workers and are to be treated as absolute constraints on the dose received for planned exposure situations. While many factors can contribute to determining what is *reasonable* in ALARA, when selecting between alternative optimisation plans, the dose limits provide a ceiling for what is an acceptable dose over time. Intentionally breaching the limits is unacceptable and any breach would normally need to be reported to national regulators, and depending on the severity of the breach may have disciplinary consequences for those responsible within the frame of national health and safety laws. Occupational dose limits are significantly lower for pregnant women than other workers, and occupational exposure in aviation and space are also treated as special cases by the ICRP.

Looking at exposure limits only (i.e. not including organ limits) for workers. The ICRP 103 recommended limits for occupational dose are:

- 20 mSv/year averaged over 5 years
- 50 mSv/year in any year
- 100 mSv total in 5 years

Related to the *dose limits* is the *dose constraint,* which is used to guide the optimisation of occupational exposure situations (and public exposure) within the scope of a single planned operation. In an emergency or existing exposure situation the so-called *reference level* is used as the upper limit of dose or risk that an individual could be allowed to receive as part of a planned action. The value to use depends on the exposure circumstances. For planned activities in exposure situations with levels close to the reference value, protective measures would be required. The *residual dose* is the dose expected after protective measures have been implemented, which would contribute to an individual worker's occupational dose.

Note that emergency preparedness should include planning for emergency response, where reference levels are used. Emergency exposure may be permitted (assuming that it is not unavoidable) to exceed the maximum reference level value (100mSv) on a voluntary basis in extreme circumstances only, to save a human life or prevent a disaster – no other circumstance are considered justifiable.

2.4 National Regulations

National regulations on dose limits and radiological protection principle are generally aligned with ICRP recommendations, however national guidelines on the practical application of the principles vary, and individual utilities may also have stricter reporting and documentation requirements than regulators require, hence a software tool to support ALARA planning internationally should ideally aim to be flexible enough to be easily adapted to support established practices, systems and procedures.

An easily accessible example of national regulations and guidelines can be found in the combination of the US NRC 10 CFR Part 20 (and Part 50) and the US Department of Energy Radiological Control Manual. The OECD NEA has published two interesting reports that provide an overview of current challenges and practices, including surveys of national regulations and practices. The first of these is focussed on radiation protection optimisation, and was produced as input to the ICRP during the development of the ICRP 103 report, while the second focuses on work management aspects.

See for example:

- OECD NEA (2005) *Optimisation in Operational Radiological Protection* (NEA Report 5411), ISBN 92-64-01050-5. Report by the Working Group on Operational Radiological Protection of the Information System on Occupational Exposure. Online, URL http://www.oecd-nea.org/html/rp/reports/2005/nea5411-optimisation.pdf (checked 2017.03.06).
- OECD NEA (2009) *Work Management to Optimise Occupational Radiological Protection at Nuclear Power Plants* (NEA Report 6399), ISBN 978-92-64-99089-0. Online, URL http://www.oecd-nea.org/html/rp/reports/2009/nea6399-WorkManagement.pdf (checked 2017.03.06).
- US DOE (1994*) Department of Energy Radiological Control Manual*, DOE/EH-0256T. Online, URL https://www.osti.gov/scitech/biblio/10143998-X3KRUj/native/ (checked 2017.03.06).
- US NRC (1991, 2007) *Standards for Protection Against Ionizing Radiation,* NUREG 10 CFR Part 20, Revision 72 FR 55921, 2007. Online, URL http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/full-text.html (checked 2017.03.06).

3. Overview

3.1 System Overview

The HVRC VRdose Planner is a tool for modelling radiological conditions, planning a sequence of activities in the modelled environment, and producing job plan reports with dose estimates. The software can also be used as an aid to producing post-work review reports, with the possibility to refine the radiological model to improve the accuracy of estimates. Furthermore, the software provides support for presenting information to different types of users for briefing and decision-making, thus serving as an aid to communication between stakeholders in an intervention.

3.2 Applications

The HVRC VRdose Planner is primarily intended to support radiological protection planning, and optimisation of protection within dose constraints for planned activities.

Specifically, it can be used for

- Preparation for jobs in radiological environments
- Preparation of work permit requests and preparation of radiological work permits
- Briefing of staff, contractors, and other stakeholders
- Post-job analysis and reporting
- Education and training in radiation protection and ALARA mind-set
- Testing and visually assessing the results of new dose calculation models

3.3 Key Features

The HVRC VRdose Planner supports near real-time calculation of shielding effects, doses, and relative contributions to dose by different isotopes, enabling the rapid evaluation of alternative protection optimisation or maintenance procedure scenarios. To support the user in interpreting the results of calculations, the HVRC VRdose Planner provides charts, graphs, and 3D radiation visualisation, updated immediately to reflect any changes to the modelled radiological condition, such as changing shielding materials, and human activities over time.

Overview of key features:

- Supports modelling of radiological conditions
- Supports real-time calculation of shielding effects, doses, and relative contributions to dose by different isotopes, enabling the rapid evaluation of alternative job scenarios
- Provides visualisation of potential hazards to support risk-informed decision making
- Supports users in following existing job planning procedures and fulfilling reporting requirements
- Can be interfaced with alternative dosimetry models and calculation codes

Alternative calculation software modules can be used if they can provide appropriate input data and are interfaced using a supplied SDK. This functionality enables the use of calculation methods other than those supplied, and offers a convenient technology for comparing of dose estimates produced using different calculation methods. This enables the software to leverage existing, qualified, calculation methods, and to be used to support the development and testing of new calculation codes.

3.4 System Users

The HVRC VRdose Planner is aimed at three main classes of end-user:

Radiation Protection	use the software to model radiological conditions, optimise the placement of shielding to support work in specific areas of a nuclear facility, and evaluate the radiological consequences of the existence of different isotopes in a nuclear facility over time. Also use measured dose-rate values as an aid to modelling radiological conditions as accurately as possible.
Engineering	uses the software to produce pre-job work descriptions for planned work with descriptions of activities and estimated durations. Use the software to optimise routes, work locations, waiting locations. Provide feedback to Radiation protection if necessary. Also use the software to support the production of post-work experience review reports.
Instructors	use the software to communicate radiological conditions or a job description to staff or students. Instructors may have either (or both) a work planning or radiation protection background.

Radiation Protection and Engineering staff would normally collaborate to agree on the area in which work will take place and to optimise the positioning of shielding and other countermeasures related to the radiation exposure situation. More information on the tasks that the HVRC VRdose Planner supports within a typical workflow is provided later in this chapter.

3.5 System Overview

The software system comprises of the following main components

- *HVRC VRdose Planner*: Main tool with 3D workspace used to add, access, and manipulate data in the database, and produce reports
- *HVRC VRdose Briefer*: A dedicated 3D viewer for presenting scenarios prepared using the HVRC VRdose Planner in briefing situations
- An integrated database, in which data used by the Planner and Briefer is stored

Data is typically imported into the software from files and/or other databases, and include:

- Detailed 3D geometry to visualise a nuclear facility or environment
- 3D geometry representing tools and equipment required to carry out a job
- Isotopic characterisation of sources (historical data, recent surveys, etc.)
- Dose-rate maps (if an external dose modelling system is used to produce dose maps)
- Actual dose-rate measurements

The HVRC VRdose Planner can be used to produce:

- Scenarios with job activities and trajectories that can be replayed as animations
- Dose graphs per worker or dosimeter in a scenario
- Pre-job work reports with a description of a scenario and the associated dose predictions
- Post-job experience review report given the entering of measurement data made when a scheduled job described in a scenario was actually carried out.

In order to define radiological layouts and job scenarios, information is imported from files, entered interactively through direct manipulation of 2D UI components or 3D objects using a mouse, or filling in forms with a keyboard. The user is supported in decision-making and evaluation of alternative scenarios through 2D charts and graphs and 3D plots of radiological conditions. Data entered is stored in a database and subsequent planning activities are thus able to use radiological conditions modelled previously, or expected as the result of planned work that is scheduled, as the starting point for planning further activities. Historical data for jobs that have been completed is available for use by instructors to support the training of staff, learning from past experience, while team leaders can brief workers on planned activities. The combination of graphs, 3D visualisation, and animation of planned work sequences make this a powerful communication aid.

Most data provided to model radiological conditions and to simulate job scenarios are entered interactively using an interactive 3D workspace. Objects in a layout and participants in a scenario are introduced to the workspace using a 3D drag and drop user interface, and some objects have parameters that can be manipulated directly or by entering values. In order to convey a sense of the dimensions of the layout and objects modelled, the user can display a grid with user-configurable spacing and also display the dimensions of selected objects, including routes/trajectories for objects or workers that move during a scenario. Free camera navigation is supported to enable the user to position a virtual camera, and target based travel techniques, including pre-defined and custom viewpoints and “go to selection” are supported.

3.6 3D Geometry Data Management

While the HVRC VRdose Planner can be used to model simple scenes using an empty floor situation to which source and shielding are added, detailed 3D models are normally added to the system database in a geometry interchange format. In the first version of the HVRC VRdose Planner, only the ISO VRML97 geometry data format was supported for importing models to the *Model Bank*. Most CAD systems are capable of exporting 3D models in ISO VRML97 format, and third party geometry conversion tools and services are available for CAD systems that do not support direct export in this format. In version 2.0, models can also be imported in the newer ISO COLLADA/DAE format.

In the Model Bank, we distinguish between *Rooms* (e.g. the nuclear facility itself) and 3D models that can be added to a layout by the user as part of a scenario, such as tools and equipment needed to perform a job. Rooms can be date-tagged in the Model Bank, so the system can determine which of multiple versions of a plant model to use depending on the date associated with a scenario and the date of a model version. In theory, this makes it relatively easy to integrate existing 3D plant databases by importing date-specific plant models as “Rooms” into the HVRC VRdose Planner.

3.7 Radiation Visualisation

Given a set of sources and a shielding configuration, or a set of pre-calculated dose maps, the system enables the user to toggle a 3D visualisation of the radiological conditions in order to support decision-making about the form of the radiological situation.

Several 2D and 3D visualisation techniques are offered that can be user-configured and combined, with a set of default configuration provided based on the results of usability studies. The visualisations are colour coded and the user can select between user-configurable sets of colours, which map radiation levels to colours. The software supports switching between visualisation configurations and colour sets on the fly.

Examples of the kinds of 3D visualisation techniques supported by the software are illustrated below. For volumetric rendering techniques such as the "isosurfaces", it is usually helpful to turn on value-dependent transparency, so that the shape of the highest dose levels is more easily visible through the lower levels. A perceptual colour map (based on a blue to yellow heat scale) selected (Figure 3.1, Figure 3.2, Figure 3.3, Figure 3.4, Figure 3.5).

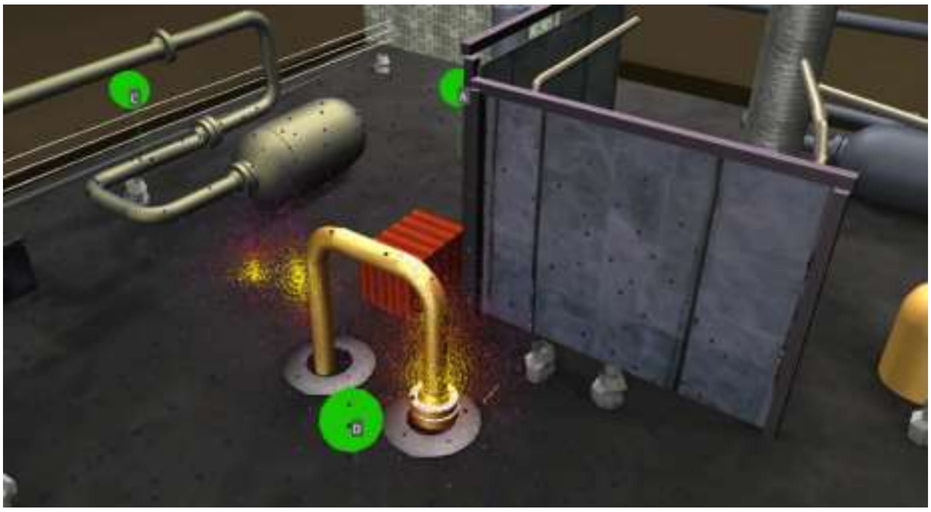


Figure 3.1 Point cloud with Density Proportional to Radioactivity Level.

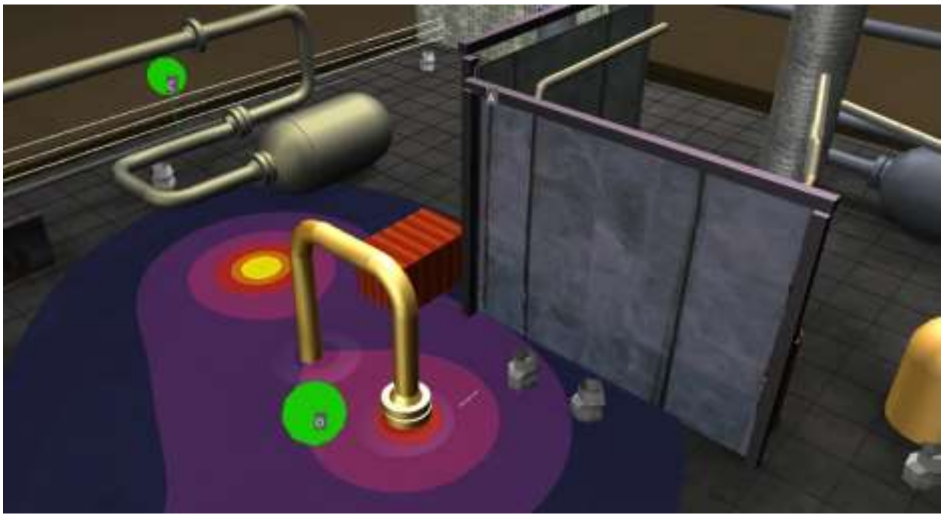


Figure 3.2 2D slice cross-section of 3D data.

Figure 3.3 Scalar field comprising of a grid of boxes.

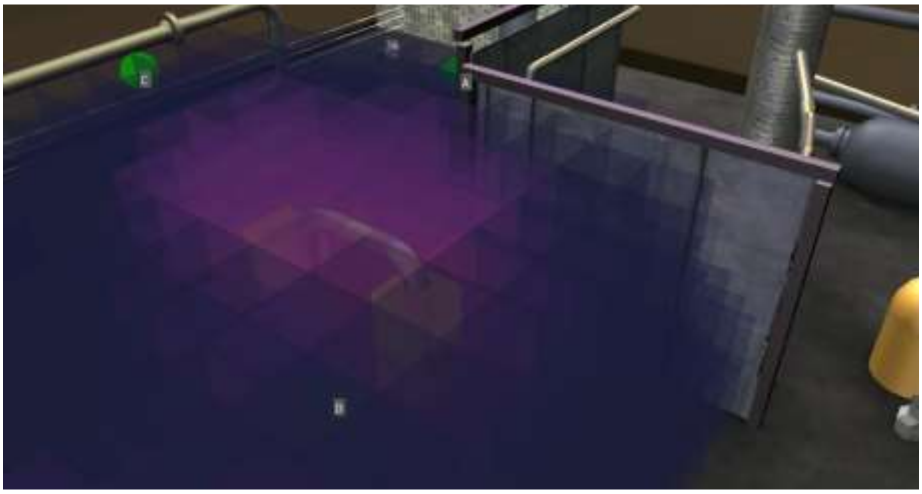


Figure 3.4 Volumetric visualisation technique.

Figure 3.5 View Dependent smooth isosurfaces in combination with a point cloud, showing the boundary between the radiation level at the current location and the next level.

3.8 Workflow

In this section, an overview of the general radiological protection planning, optimisation and monitoring workflow supported by HVRC VRdose is presented. The following sections briefly explain how HVRC VRdose supports each of the activities illustrated.

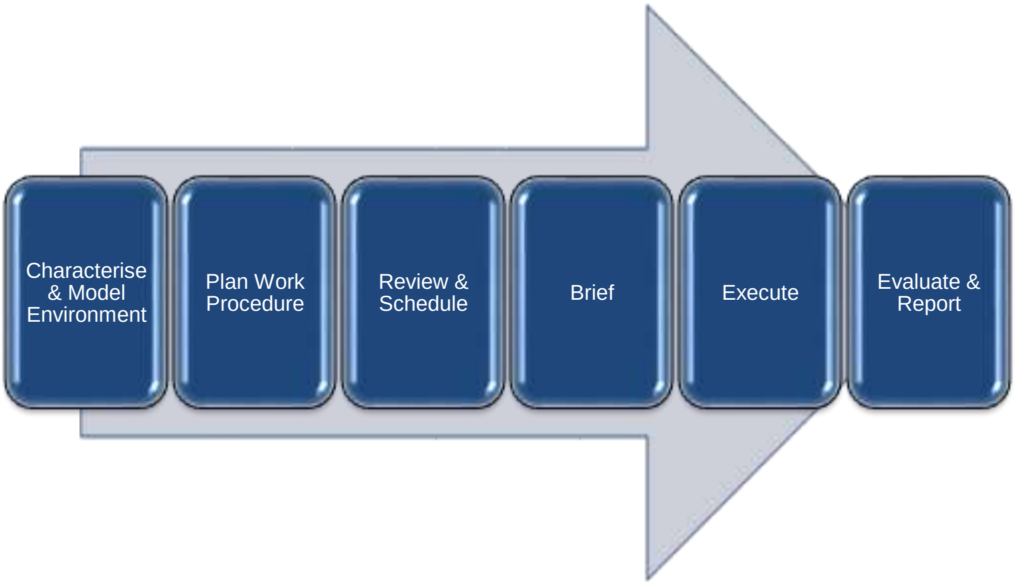


Figure 3.6 Workflow Diagram

When planning a job in a radiological complex situation, we need to be able to transfer information between each planning activity and to explain how that is done we must introduce a handful of concepts that are used to manage the information flow in the workflow (Figure 3.6). The following concepts are referred to frequently in the sections that follow, and in some cases more detailed explanations are provided later:

- Scenario: A collection of *participants* that perform actions over time in a *room*. A scenario always has a specified start and end date, and a status (draft, scheduled, completed etc.)
- *Participant*. An object that can be added to a room, thus participating in a scenario
- *Room*: A virtual environment in which a scenario takes place. It is typically represented as a single static 3d model representing a building. While static within the scope of a single scenario, there may be multiple variants of a room model representing the (planned or actual) state of the building at specific dates/times
- *Layout*: A static representation of the virtual radiological environment that represents a snapshot at a specific time that can be used as a reference scene configuration for new scenarios. Typically comprises of room + sources + shielding, but sometime other equipment left as the end state of a related job (e.g. a job is spread over several days represented by separate scenarios)
- *Project* is a collection of related *scenarios* and *layouts*, with additional common project meta-data (expected start date, expected end date, description, references)

These and other definitions can also be found in the appendix.

3.9 Supporting Characterisation and Modelling the Environment

A layout can contain known radionuclide sources, which can have different shapes or forms. In the current version of the HVRC VRdose Planner, sources can have the forms of lines, points, quads, or closed volumetric meshes.

The radionuclides supported by the included calculators include 60Co, 58Co, 110mAg, 137Cs, although two of the calculators include additional radionuclides. Sources have a date associated with the values of the properties that describe its character. This enables the software to consider decay, using a simplistic model based on half-life over time.

Shielding can be introduced into a layout, and be moved as part of a work scenario. At present, shield composition is limited to iron, lead, water, concrete and sand. Rectangular, cylindrical, and volumetric mesh shield geometry are supported with user-configurable dimensions.

3.9.1 Measured Dose-rate Data

Measured dose-rate measurements associated with specific dates and times collected during a radiological survey can be stored in the database, and are useful as an aid to characterisation, planning and review. These measurements can be visualised with colour-coded values at the location of the measurement within a user-configured timeframe relative to the “current scenario time” in a scenario, to see the most recent measurements relative to the planned time of a scenario. If a layout contains sources or a dose map then you can also access a table of showing the estimated value (at scenario time) at each measurement location, the measured value, and the %deviation (+/-).

3.9.2 Radiation and Dose Calculation

The HVRC VRdose Planner is supplied with three calculators. Two of these are point-kernel based calculators for estimating the dose, isotopic contribution to dose, and shielding effects, while the third is a pseudo-calculator that does not compute dose maps itself but uses data from imported dose maps to estimate the dose at any location within the dose mapped space.

By default, we expect users to use the supplied point-kernel calculators for most planning and optimisation purposes, but with the option to import data from other offline calculators for plans that are to be scheduled, typically because the offline calculator has been qualified for use or because more complex methods (such as monte-carlo simulation) are required by company or national regulations.

The supplied point-kernel calculators have the advantage of being reasonably accurate and being able to cope well with dynamically changing situations with close to real-time response. Changes to sources and shielding conditions or properties trigger an immediate update of the radiological situations, and any associated visualisations. The HVRC VRdose Planner calculates accumulated dose equivalents for virtual dosimeters using either real-time or pre-calculated dose-map data as basis for calculations.

Both point-kernel (pk) calculators are documented in detail in a Halden Work Report (HWR-1030), available to HVRC VRdose Planner users on request. A benchmark comparison between results from the supplied calculators and reference calculations is provided in the HVRC VRdose Planner system documentation. The two pk-calculators are labelled *basic* and *extended*, where the basic model is relatively simple and very fast, but not applicable to all situations, while the extended calculator is significantly more accurate in a much broader range of situations, but is also significantly slower. In comparison with monte-carlo based methods, it is unfair to describe either method as *slow,* as the difference between the two pk-calculators is essentially a question of how many re-computations we can achieve per second while multiple sources or shields are moving.

3.10 Supporting Work Procedure Planning

3.10.1 Scenarios

The fundamental building block for the simulation of a work procedure in the HVRC VRdose Planner is the scenario. A scenario comprises of a set of participants that perform actions in a sequence in a room

- *Room:* The modelled space in which a job takes place – typically a model of part of a nuclear facility. Although the model may change over time (especially in a decommissioning setting), it is generally static within the scope of a single job.
- *Participants*: manikins or other objects, such as tools, sources, shields, vehicles
- *Actions*: walking, lying down, crouching, waiting, working, etc.

Actions take place on a trajectory or path through the room and represent a participant's position in the scene at a specific time as dictated by a participant's actions. Sets of actions can be grouped as *steps* with a description entered by the user, thus enabling the organisation of sets of actions into a *work plan*. Steps can reference standardised procedures that specify in detail how a specific work task should be done but the details of that are not usually modelled in the HVRC VRdose Planner, where the focus is primarily on where a task is done and for how long rather than on producing a detailed animation of the micro-actions of the procedure itself. For example, a work step might be "remove the screws using a screwdriver", where the user is simply "working" (action) for an estimated duration of time at a specified location using the object *screwdriver.*

A visual timeline provides an overview of a scenario, listing participants and showing a schedule of actions and a visual representation of the work plan is also provided to enable the easy grouping of actions into work steps.

3.10.2 Radiological Environment Analysis

The radiation visualisation capabilities of the system are very useful for rapidly identifying optimal wait areas or areas to avoid unless absolutely necessary. For any scenario, the expected total dose per worker, collective dose, and maximum and minimum dose are also readily available to the user, but a number of additional features are also provided to assist in the optimisation of shielding.

For example, you can:

- Display the collective dose history for all virtual dosimeters for the time interval represented by the scenario, or for a single selected virtual dosimeter
- Display shielding effects information per virtual dosimeter for the radiological situation at the current scenario time
- Display the per isotope contribution to dose-rate per virtual dosimeter

The second two examples above are only available if using a calculator that supports the provision of this information (e.g. in the standard package, this data is not available if imported dose maps are used instead of one of the two point-kernel calculators).

3.11 Supporting Review and Scheduling Process

An Annotation Manager function supports adding feedback and comments to a scenario. Annotations are also used to highlight key things in a scenario, such as hazards, access ways, that can be displayed during a briefing session, and are required for pre-job reporting. The annotation manager can also be used to handle checklists.

It is possible to compare the “vital statistics” of scenarios in the database, such as the duration, max/min dose-rate, accumulated dose, etc., which is useful for quickly comparing alternative plans, or comparing a proposed plan with a similar “historic” scenario that has been completed in the past. This information is provided in both tabular and graphic form and can be exported as a report from the system. The table itself can also be exported as raw data for use in spreadsheet or statistical software.

3.11.1 Pre-Job Work Plan Reports

Pre-job work plan reports can be exported from the HVRC VRdose Planner, including report elements selected by the user to configure what information should be included. It can therefore be used to produce report data required for producing work permit applications, work permits, safety cases, pre-job reports, etc. (see for example the US Department of Energy Radiological Control Manual for examples of information elements that should be included in various report types).

Examples of information elements that can be included in a report from the HVRC VRdose Planner are:

- Timeline
- Work steps
- Maps and routes
- Overview of estimates for doses with charts
- Annotations

Other information that should be included in reports can be added (or referenced) and stored in the database, primarily via the annotations system, enabling practically all report elements recommended by the ICRP, national regulators or authorities to be included, if desired.

3.12 Supporting Briefing

HVRC VRdose Briefer is a dedicated presentation tool can load scenarios produced using the HVRC VRdose Planner. It can be used by instructors to step through animated work procedures and visualise radiological conditions, and can also be used for personal study. It is used to present scenarios “full-screen” with limited functionality in comparison with the HVRC VRdose Planner.

Specifically, the HVRC VRdose Briefer can be used to:

- Present and explain steps of work procedures
- Highlight potential issues and hazards
- Illustrate radiological conditions

A significant restriction of the HVRC VRdose Briefer is that scenarios cannot be modified using it, and it does not provide access to dose charts and other detailed information, however the HVRC VRdose Planner can, of course, also be used for briefing where more detailed information, complex alternatives, or “what-if” cases need to be explained.

3.13 Supporting Execution of the Scheduled Plan

The HVRC VRdose Planner currently supports execution of a scheduled plan in that it can be used to produce printouts of job plans, estimated values, dose maps, and so forth that can be carried by individual workers. Immediately after a job has been completed, a scenario can be annotated with comments and actual measured values, which can then be used for experience review (see below).

3.14 Supporting Experience Review

The HVRC VRdose Planner provides flexible support as part of the preparation of post-work experience review reports and visual support for debriefing. In many ways, this activity is similar to pre-work briefing and reporting, but can include actual values for personal dose equivalents and dose-rates logged at control points during the job. To support organisational learning and debriefing it is useful to be able to annotate completed jobs to note and compare the actual durations of major work steps, expected and measured doses, and to record explanations for significant deviations. If a serious incident took place during the execution of a job then the software may be useful to help stakeholders discover the reason and to produce any additional data or explanations, with illustrations, required to provide genuinely useful information when reporting the incident.

3.15 Supporting Organisational Learning

Once scenarios have been prepared and the planned work has been executed, they can be useful for preparing case studies to teach best practices for educational purposes, and the radiation visualisation capabilities can be excellent for training new employees and contractors. Furthermore, over time, the historical data accumulated in the database can serve as a useful digital archive which, given sufficient amounts of data, may be useful for statistical analysis and other data mining activities to support organisational learning.

3.16 Interfaces for Customisation, Integration, and Extension

The software is designed to support easy extension to support new functionality, and to integrate into existing information architectures. While the standard system uses an embedded SQL database, customisation of the software is possible through custom development in collaboration with IFE, to bridge to alternative data sources, in particular for plant geometry data or historical radiological data. A Java-based plugin interface is provided to enable alternative radiation/dose calculators to be wrapped and integrated. An SDK for producing calculator plug-ins is included with the software installation and can be used without assistance from IFE.

4. Getting Started

4.1 System Requirements

The minimum recommended requirements for the system are:

- Intel Core i5 x64 processor or similar
- 6GB RAM
- Microsoft Windows 7 64-bit or Mac OS X 10.8 Mountain Lion
- 3D Graphics accelerator card with OpenGL 3.3 support
- A three-button mouse (or a two-button mouse with scroll-wheel "button")

The software can sometimes be used on a less powerful hardware however system performance will not be optimal.

The recommended requirements for the system are:

- Intel Core i7 x64 processor or similar
- 16GB RAM
- 64-bit Microsoft Windows 10 or macOS 10.12
- Discrete AMD or NVIDIA 3D Graphics accelerator with OpenGL 4.2 support
- A three-button mouse (or a two-button mouse with scroll-wheel "button")

The software is easiest to use with a three-button mouse (including two-button mice with a scroll wheel "button"). If used with a two-button mouse, use the alt-key on your keyboard in combination with the left mouse button to simulate the middle mouse button.

4.2 Installation

Important: See System Requirements above before installing.

The application called "HVRC VRdose Installer" installs the HVRC VRdose software.

Double-click on the installer and follow the instructions.

4.3 Starting HVRC VRdose Planner

To run the HVRC VRdose Planner, open the HVRC VRdose Planner folder, which was created when the software was installed, and double-click on the HVRC VRdose Planner application.

Depending on which options were selected when running the installer, you may also be able to start the application by double-clicking on an icon on the Microsoft Windows desktop or by selecting it from the Start menu (in the "HVRC VRdose" group).

The information above assumes that you are running on a Microsoft Windows platform. On other platforms, the installer follows the conventions of the host platform to support convenient execution of the software.

Please note that the HVRC VRdose Planner software requires a license key file. The first time you start the HVRC VRdose Planner, it will ask you to locate the license file. If you haven’t received a license file please contact vrdose-support@ife.no.

4.4 User Interface overview

The appearance of some user interface elements varies depending on the host operating system, but the general layout and functionality is the same for all platforms.

When HVRC VRdose Planner has been started, it initially appears as shown in Figure 4.1:

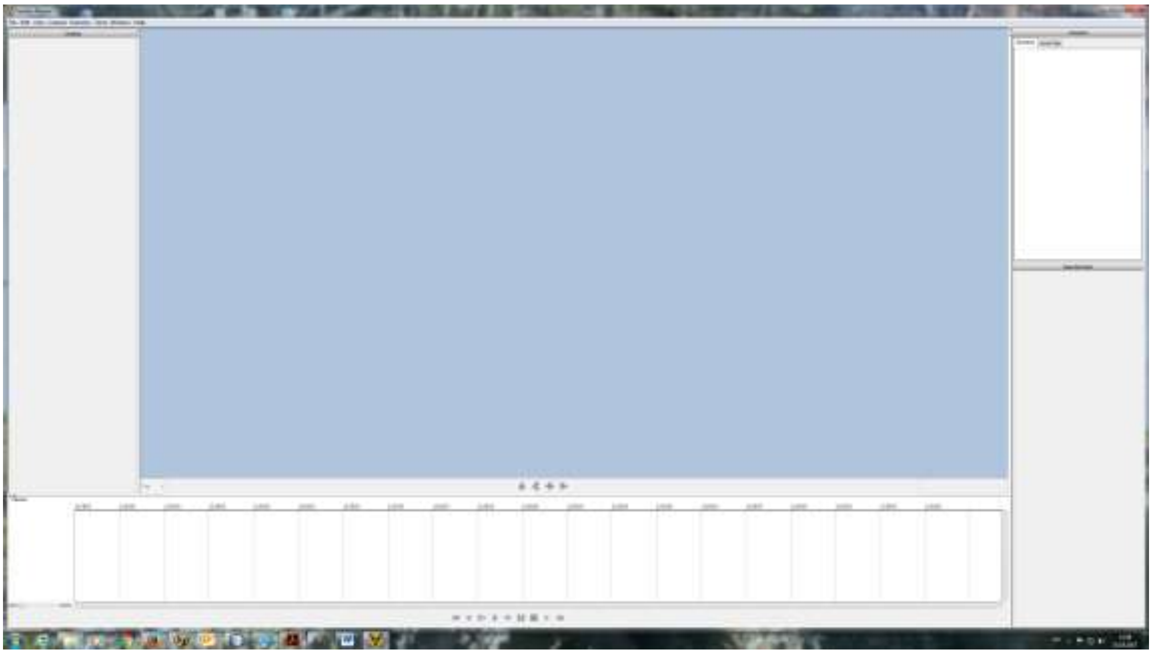
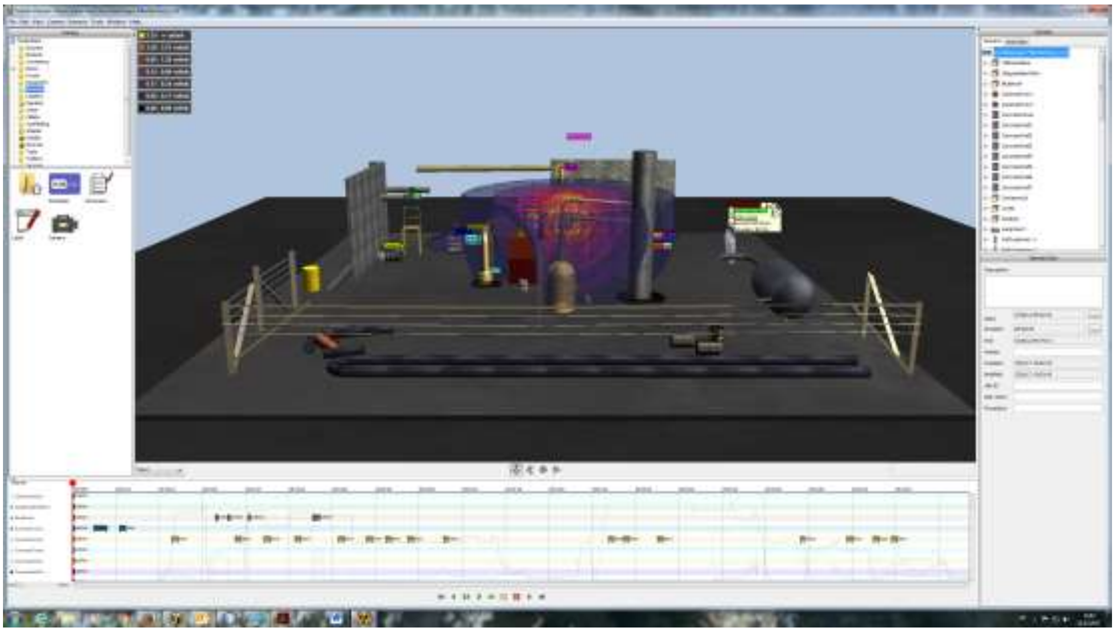


Figure 4.1 User Interface

The user interface consists of a main menu bar at the top, an object catalogue to the left, the 3D view, with toolbar, in the middle, a scenario (and work plan) overview to the right and a graphical scenario timeline, with toolbar, at the bottom of the user interface. An overview of the colour key used for the visualisation is displayed in a head-up display in the 3D view.

After a scenario has been created or opened, the user interface typically looks like this:



4.4.1 Projects and scenarios

Create new projects and scenarios, or open an existing scenario, from the 'File' menu.

4.4.2 Adding objects

Add objects to a scenario by dragging them in from the model bank catalogue on the left into the 3D view. For all projects except for the default project, a project-specific room will be added automatically when a new scenario is created. The first object in a scenario is always a (one) room. The added objects will be shown in the Scenario overview to the upper right of the main window.
Not all objects in the catalogue represent physical entities. The General category contains objects that enable you to insert virtual dosimeters, documents, labels, or camera views into a scenario.

4.4.3 Positioning objects

Hold the Shift key to move objects and Alt-Shift to rotate objects.

4.4.4 Producing a scenario and work plan

Produce a scenario by adjusting the time in the scenario timeline before adding new actions. Adjust properties of participants and actions, and add new actions using the user interface on the right side of the main window.
Actions can be grouped into descriptive steps using the Work Plan overview to the upper right of the main Window. The resulting work plan can be used to generate informative reports and to support the presentation of the scenario to stakeholders.

4.4.5 Online Help

Please refer to the online help found in the 'Help' menu for more details.

5. Reference

5.1 Menus

This chapter provides an overview of the main menus in the HVRC VRdose Planner. Keyboard shortcuts are available for the most frequently used menu actions and are displayed next to menu items with shortcuts.

5.1.1 File Menu

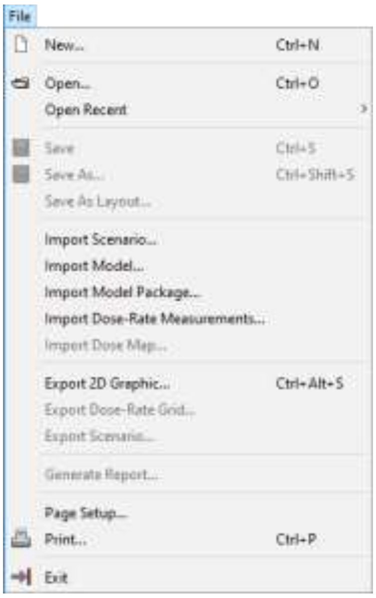


Figure 5.1 File Menu

The File menu provides functionality for creating, opening, and saving scenarios and layouts. It also provides functionality for importing data into the HVRC VRdose Planner database. In addition, it is used to generate reports and export data, including scenarios and images to file.

New…	Create a new scenario
Open ...	Open an existing scenario or layout from the database
Open Recent	Open a recently used scenario or layout
Save	Save the current scenario to the database
Save As...	Save the current scenario with a new name to the database
Save As Layout…	Save the current scenario as a layout
Import Scenario…	Import an existing scenario from the file system
Import Model…	Import a model into the model bank
Import Model Package	Import a set of models into the model bank
Import Dose-Rate Measurements…	Import dose-rate measurement from the file system (XML)
Import Dose Map…	Import a dose map into the current scenario
Export 2D Graphic…	Export a snapshot of the 3d view as an image file (JPEG or PNG)
Export Dose-Rate Grid…	Export a grid of estimated dose-rates at the current scenario time (within the visualised bounds) to an MS Excel workbook (xlsx)
Export Scenario…	Export the current scenario to the file system
Generate Report…	Generate a report describing the current scenario (HTML)

Page Setup…	Set the page orientation and paper size for printing the 3D view
Print…	Print the current 3D view
Exit	Exit the Planner. If you are using macOS then the Quit menu item is located in the application menu.

5.1.2 Edit Menu

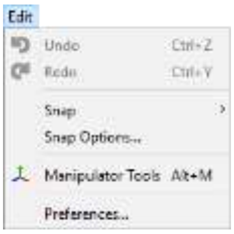


Figure 5.2 Edit Menu

The Edit menu is primarily used to control editing of a layout or scenario. Note that most editing functions in this software are provided via a drop-down menu shown when a scenario participant or other time is right-clicked on.

Undo	Undo last action performed in the Planner
Redo	Redo an action that has been undone
Snap	Set the snapping policy for positioning of objects. • None - No snapping (the default) • Snap to Grid - Snap to the visual grid • Snap to Bounding Box - Snap by aligning bounding boxes
Snap Options…	Configure snapping behaviour
Manipulator Tools	Toggle use of manipulator tools for moving and rotating objects.
Preferences…	Configure the Planner (see section 5.2). If you are using macOS then this menu item is located in the application menu.

5.1.3 View Menu

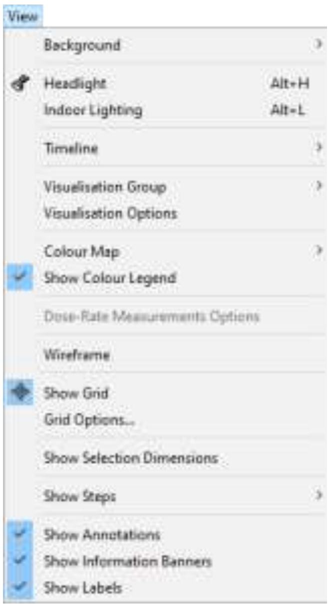


Figure 5.3 View Menu

The View menu is used to configure the user interface. The effect is global rather than stored in the scenario or layout.

Background	
➢ Set Background Colour...	Set the background colour for the 3D view
Headlight	Toggle headlight on and off. The headlight is a light attached to the view - useful for viewing dark scenes.
Indoor Lighting	Toggle indoor lighting on and off. Indoor lighting is a set of light designed to illuminate indoor environments that otherwise have no lights in the model.
Timeline	
➢ Tasks	Toggle displaying tasks in the timeline
➢ Dose graphs	Toggle displaying dose graphs in the timeline
➢ Dose graphs	
➢ ➢ Dose-rate	Show dose-rates graphs
➢ ➢ Accumulated dose	Show accumulated dose graphs
➢ Compact	Toggle between normal and compact display mode
➢ Filtering	Limit type of participants to show in timeline
Visualisation Group	
➢ Slice	Use Slice visualisation
➢ Scalar Field	Use Scalar Field visualisation
➢ Particle Cloud	Use Particle Cloud visualisation
➢ Isosurface	Use Isosurface visualisation
➢ Smooth Isosurface	Use Smooth Isosurface visualisation
➢ View-Dependent Isosurface	Use View-Dependent Isosurface visualisation
➢ Slice – Point Cloud	Use Slice – Point Cloud visualisation
➢ Add…	Add a new visualisation group based on current visualisation options
➢ Remove	Remove a visualisation group
Visualisation Options	Select and configure radiation visualisation options
Colour Map	
➢ Spectrum	Use Spectrum (rainbow) colour map
➢ Perceptual	Use Perceptual (heat) colour map
➢ Traffic Lights	Use Traffic Lights colour map
➢ Configure…	Create or modify a custom colour map
Show Colour Legend	Toggle display of the Colour Legend
Show Dose-rate Measurements	Toggle display of Dose-rate Measurements in the 3D view
Dose-Rate Measurements Options…	Open the Dose-rate Measurements options dialog
Wireframe	Toggle Wireframe rendering of the 3D scene
Show Grid	Toggle a visual grid
Grid Options…	Configure spacing and colour of the visual grid

Show Selection Dimensions	Toggle display of the dimensions for the currently selected scenario participant in the 3D view
Show Steps	Display the name or description of the current step in a work plan in the 3D view
Show Annotations	Toggle display of annotations in the 3D view.
Show Information Banners	Toggle display of information banners above participants in the 3D view.
Show Labels	Toggle labels for participants in the 3d view. If selected then labels set to be visible are shown. If not selected then labels set to visible are not shown.

5.1.4 Camera Menu

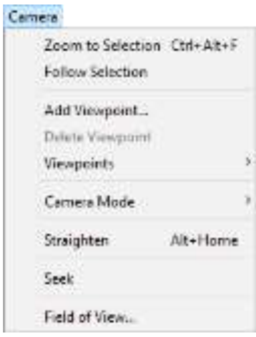


Figure 5.4 Camera Menu

The Camera menu consists of features for aiding navigation as well as management of viewpoints and other camera related properties such as projection modes and field of view.

Zoom to Selection	Move the camera to fit the view to the currently selected objects
Follow Selection	When selected the camera will follow the selection. Note that normal camera navigation is disabled when this is menu option is selected.
Add Viewpoint…	Add a user-defined viewpoint based on the current camera view
Delete Viewpoint	Delete the currently selected user-defined viewpoint
Viewpoints	Move the camera to a pre-defined or user-defined viewpoint in the 3D scene by selecting it in the sub-menu.
Camera Mode	
➢ Perspective	Set the camera to use perspective projection
➢ Orthographic	Set the camera to use orthographic projection
Straighten	Level the camera relative to the ground plane
Seek	Move the camera to immediately in front of a point clicked on in the scene after selecting this command
Field of View…	Adjust the field of view of the camera

5.1.5 Scenario Menu

Figure 5.5 Scenario Menu

The Scenario menu is primarily used to control the playback of a scenario.

Cue to Start	Cue the current scenario time to the start of the scenario
Cue Backward	Cue the current scenario time to the start of the previous action in the scenario. If there is more than one action at the current time, the cue is set to the one who ends first.
Slow Playback	Play the scenario at half speed
Play	Play the scenario.
Fast Playback	Play the scenario at double speed
Pause	Pause playback. Cue Buttons are locked.
Stop	Stop scenario playback
Cue Forward	Cue current scenario time to the beginning of the current action. If there is more than one action at the current scenario time, the cue is set to the one that starts first.
Cue To End	Cue the current scenario time to the end of the scenario
Insert Time Period…	Insert a time period at the current scenario time
Remove Time Period…	Remove a time period from the scenario at the current scenario time

5.1.6 Tools Menu

Figure 5.6 Tools Menu

The Tools menu is used to access features that support working with a scenario but do not modify the scenario itself.

Dosimeter Tool	Toggle the Dosimeter Tool, which enables you to click on a surface in the 3D scene to look up the dose-rate at the clicked point
Compare Scenarios…	Compare the vital statistics about the current scenario with other scenarios
Grid Control	Display a dialog to control the grid orientation and position

5.1.7 Windows Menu

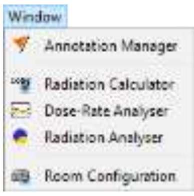


Figure 5.7 Windows Menu

The Window menu gives access to secondary windows that can be used to view information about a scenario and to perform scenario-specific configurations and analyses.

Annotation Manager	Open the Annotation Manager, which is used to edit or add annotations about the current scenario. The annotations are used for information purposes and to add documentation that is output when reports are generated.
Radiation Calculator	Open the Radiation Calculator configuration window, which is used to select and configure the calculator to use to calculate doses.
Dose-Rate Analyser	Open the Dose-Rate Analyser, which is used to displays dose charts in a secondary window.
Radiation Analyser	Open the Radiation Analyser, which is to display a breakdown of the contributors to a dose
Room Configuration	Open the Room Configuration, which is used to toggle visibility of named components (if any) in the geometry hierarchy of the Room model.

5.1.8 Help Menu

Figure 5.8 Help Menu

The Help menu provides access to copyright information about this software and to online help.

About…	Display system, copyright, and licensing information about this software. If you are using macOS then this menu item is located in the application menu.
Startup Tips	Display the Startup Tips dialogue
Check for Update	Check if a newer version of the software is available
Help	Access the online user guide

5.2 Configuring User Preferences

This section describes the options available in the User Preferences dialog. These enable fine-tuning of the user experience and 3D rendering.

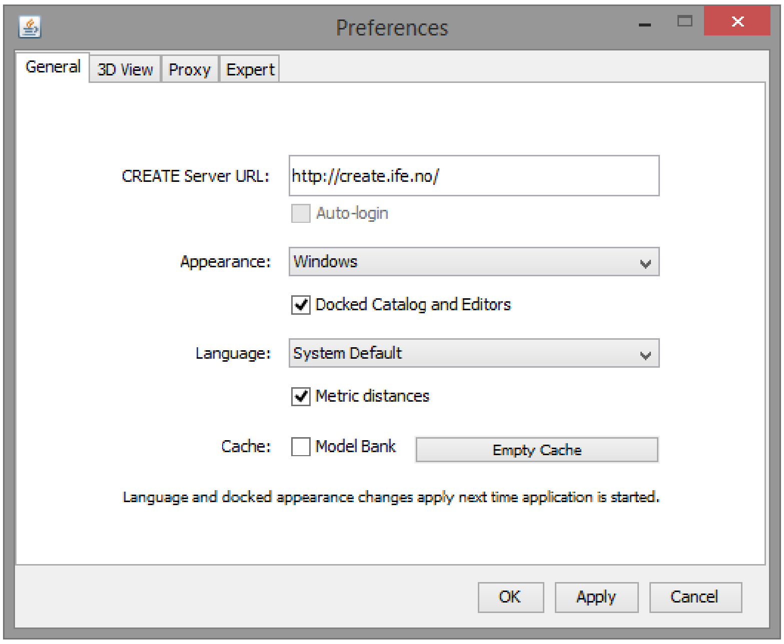


Figure 5.9 The Preferences Window

You can adjust your personal configuration via the options in the Preferences Window.

The Preferences Window can be accessed from the main menu bar's Edit > Preferences… menu item (or in the Application menu on macOS). The keyboard shortcut to open the Preferences Window is ctrl-comma (or command-comma).

Changes to preferences are global and therefore affect all your work with the HVRC VRdose Planner, however they are also personal and will not affect any other users of software that share a computer as long as you are not sharing a computer user account.

There are three sets of preferences in the Preferences Window. The individual sets and the options they contain are described in the subsections below.

The Preferences Window has three buttons:

- OK is used to update the preferences and close the window
- Apply is used to set the update the preferences but not close the window
- Cancel is used to dismiss the window without making any changes

Clicking Apply followed by Cancel is equivalent to clicking OK.

A configuration file containing your preferences is created in your home directory and will be applied the next time you run the software.

Closing the window by clicking on the close box (top right of the window) or hitting the escape key is equivalent to clicking on the Cancel button.

5.2.1 General Preferences

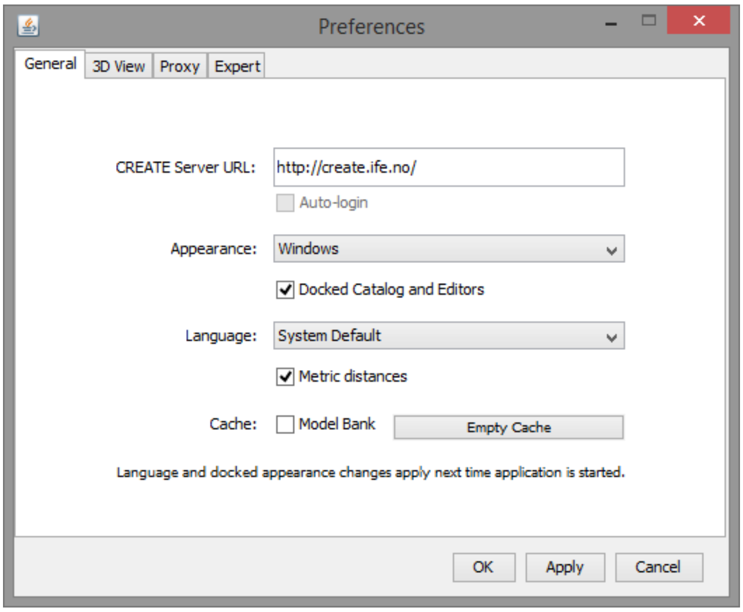


Figure 5.10 The General Preferences section of the Preferences Window

The General Preferences section of the Preference Window is used to overall preferences for the user interface.

The General options are described below:

Appearance	The default Appearance is that of the host operating system. The host operating system appearance normally gives the software a look similar to that of other applications on your computer. The cross-platform setting provides a consistent user interface look and feel regardless of whether you are running the software on Windows, Linux, macOS, or some other operating system.
Language	The text of the user interface can be displayed in may be English, US English, Norwegian, or Russian. By default this option is set to system default, enabling the software to select the language automatically depending on your operating system language settings. However, you can also select the language specifically. For example, this can be useful if you are working on an international project where English is the project language, but your personal computer is otherwise configured to use a non-English language. Other language options may be offered in future.
Metric distances	If you want distances to be displayed using U.S. measurement units then you can turn this option off, otherwise distances are displayed in metric units. *Note that this changing this option is not permitted in version 2.0.*

5.2.2 3D View Preferences

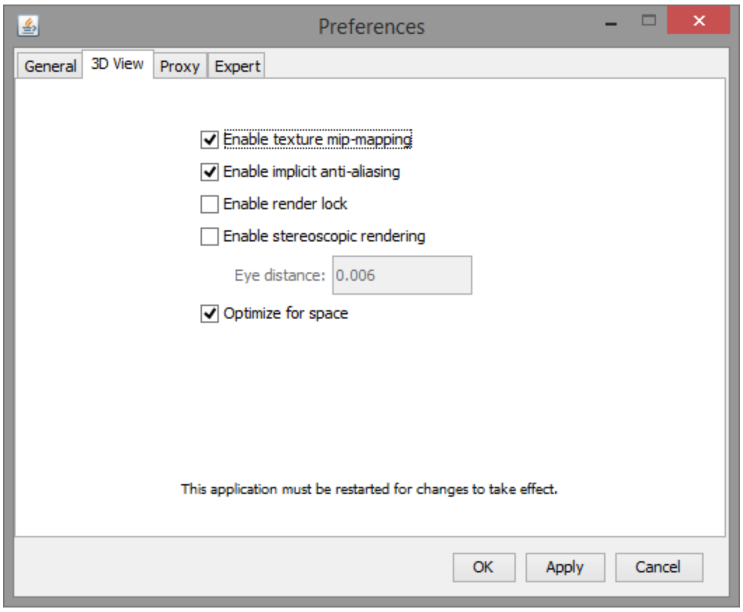


Figure 5.11 The 3D View Preferences section of the Preferences Window

The 3D View Preferences offer control over the way in which the 3D graphics are rendered. These options generally have no effect until the application has been restarted as they affect the way in which the 3D view is initialised.

The 3D View options are described below:

Enable texture mip-mapping	Enable generation of multi-resolution textures when textured models are loaded. This option improves the appearance and performance of textures, however some graphics cards may not support this feature and the loading of textured models may be significantly slower if this option is enabled.
Enable implicit anti-aliasing	Allow the display driver to control full-screen anti-aliasing settings. If you have a graphics card with support for anti-aliased rendering then this option enables will cause the tool to acknowledge your anti-aliasing set-up. This option can greatly improve the visual appearance of the 3D view but there may be a significant performance loss, and some graphics cards do not support this feature.
Enable stereoscopic rendering	Enable initialisation of 3D views in stereo mode. This option will only have an effect if you have a graphics card that supports active stereoscopic rendering. Unless you are actually using stereoscopic hardware, you should not enable this option as stereoscopic rendering will decrease the overall performance of the 3D view as it requires more effort of the graphics card. Default off.
Enable render lock	Controls rendering execution. Try changing this if you have driver problems. In general, you should leave it off. This option is offered only because it can resolve graphics driver problems in some special cases. Default off.

Optimize for space	Optimize 3D geometry to use less memory at the expense of slower performance. Only disable this if you have lots of memory and need to squeeze out a little more performance. In most cases the difference is hard to detect so we recommend leaving it on. Default on.

5.2.3 Input Configuration

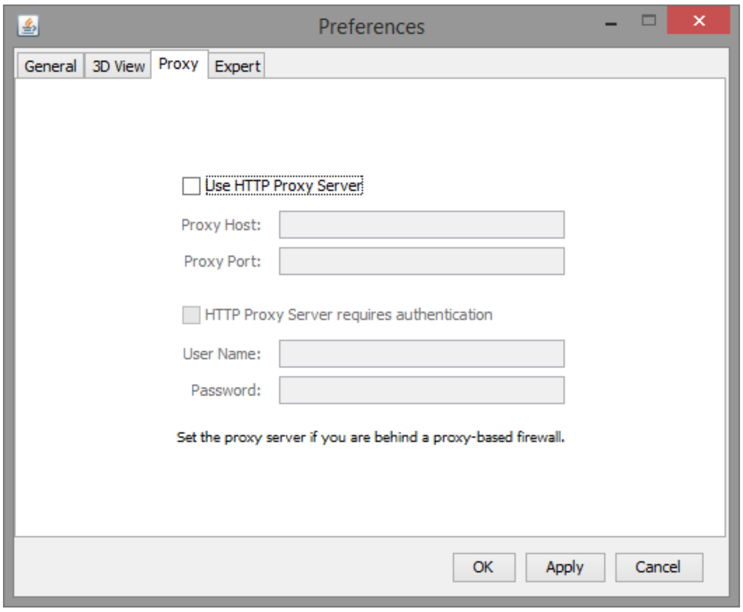


Figure 5.12 The Input Configuration section of the Preferences Window

The Input Configuration options allow you to set the default speed to use when new participants are added to a scenario, and whether new participants should be automatically rotated to face the view when added.

The Input Configuration options are described below.

Manikin walk speed	Default walking speed in m/s for new manikins.
Object move speed	Default movement speed in m/s for new objects.
Auto-rotate objects	Option to automatically rotate objects added so that they face the current view. If this is not selected then objects are placed with their default rotation relative to the global origin of the 3D scene.

5.2.4 Expert Preferences

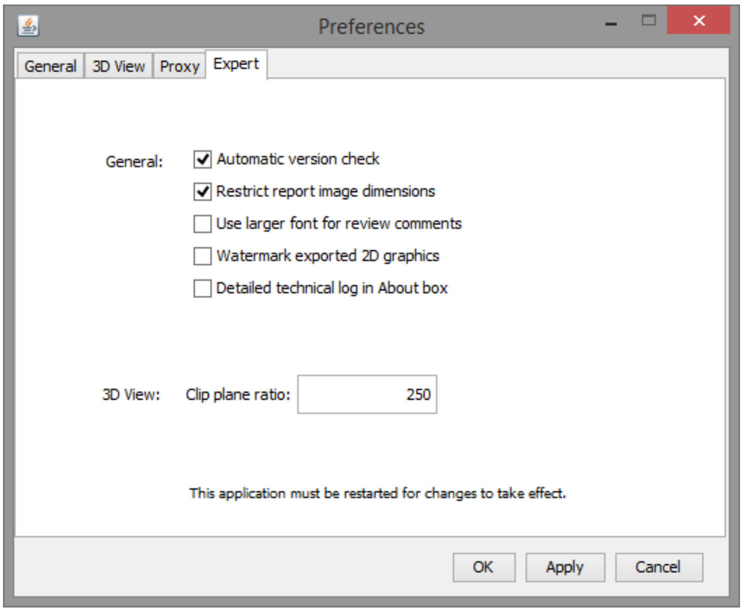


Figure 5.13 The Expert Preferences section of the Preferences Window

The Expert preferences provide access to additional options, described below:

Automatic version check	Turn off the automatic daily checking for a new release of the software. If you turn this off then you will not be informed automatically of new updates, but can still check for updates manually via the Help-menu (Help > Check for Update). Default on.
Watermark exported 2D graphics	If this option is enabled then "HVRC VRdose Planner" and the name of the licensee is inserted at the top left on exported images. In the demo version then this cannot be turned off. Default off.
Detailed technical log in About box	Select to enable detailed technical logging of system behaviour in the log in the About box. This is useful for troubleshooting if you experiencing technical issues with the software, and you need to contact support for assistance. Enabling this option has a small negative effect on the system performance. Default off.
Enable experimental 3D loaders	Select this to enable experimental 3D loaders, to support importing 3D models in LWO, OBJ, PLY, and SCENE (Ogre3D) formats. Default off.
3D View Clip plane distances	If you experience tearing effects in the 3D view then this may be because your graphics processor is unable to draw surfaces with sufficient precision. The near (front) and far (back) clip planes (and the field of view) specify the camera view frustum that is rendered. To increase rendering precision, try increasing the front clip distance and/or decreasing the back clip distance.

5.3 Preparing 3D Models

This section provides guidance on producing 3D models for use in the HVRC VRdose Planner. The Model Bank database supports version control for individual objects, as well as alternative "room" versions to enable variations of a room model to be selected by date.

5.3.1 File format

The internal file format used for 3D models in the Model Bank is ISO VRML97 (Virtual Reality Modelling Language). VRML files can be exported from most high-end CAD and 3D modelling packages, including the free 3D modelling tool Blender. Details about ISO VRML97 can be found on the Web 3D Consortium website: http://www.web3d.org/. VRML units are metres.

You can also import models stored in the increasingly popular COLLADA (DAE – Digital Asset Exchange) and KMZ formats. Many CAD and 3D modelling packages can export data in these formats, including Trimble SketchUp. Most online 3D model archives offer models in at least one of these three supported formats. Additional "experimental 3D loaders" (ie not guaranteed to always work) can be enabled in the User Preferences for the HVRC VRdose Planner. The experimental loaders include LWO, OBJ, PLY, and SCENE (Ogre3D) formats.

If you are producing or converting models yourself then it is useful to be aware of the 3D modelling practices that can make your model more efficient and trigger special features in the HVRC VRdose Planner. Please contact technical support for advice on conversion from specific formats as we can give guidance on free or commercial tools for conversion and on the best intermediate formats to use to exchange data.

Regardless of the format used to transfer a 3D model into the Model Bank, the same basic rules apply in order to produce models that are optimised for use in the HVRC VRdose Planner. These are described in the following sections.

5.3.2 The origin and centre of rotation

When a model is dropped on a surface in the HVRC VRdose Planner, the origin is the point where the model will initially be attached to the surface. When that model is rotated then it is by default rotated around the Y-axis around the origin. Using an appropriate origin is therefore important. For example, a model of a chair would normally have its origin at floor level with the Y-axis passing through the centre of the model.

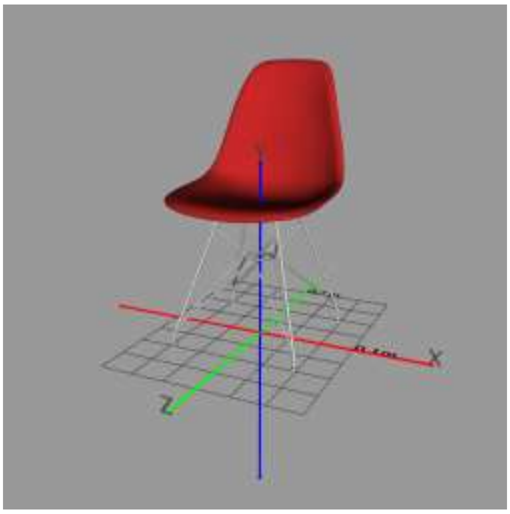


Figure 5.14 Centre of rotation OK

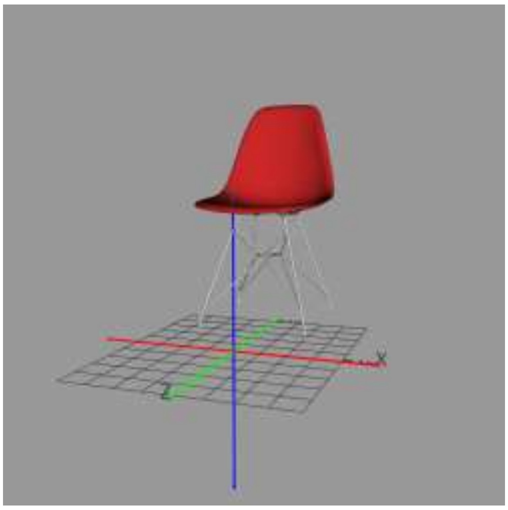


Figure 5.15 Centre of rotation not OK

Above are two pictures of the same model. In the first picture, the model's centre of rotation is correct, while in the second picture, the centre of rotation represents an example of a location that would be difficult to work with interactively as the object will be positioned and rotated relative to that position when the user moves the object in the HVRC VRdose Planner.

For objects that will be attached to walls and ceilings then the model’s Y-axis should be defined as if the object were to be placed flat on the floor. This ensures that the correct orientation is obtained when the object is placed on a wall or the ceiling. For example, a wall sign should be modelled with the front face facing up and a ceiling lamp should be modelled upside down. To see examples, have a look at existing objects in the Model Bank that are intended to be placed on walls or the ceiling.

In special cases you may want the origin to be somewhere other than the middle of the base of the model, but this is rare for typical HVRC VRdose Planner use-cases.

5.3.3 Orientation

Models should be produced so that they are flat in the XZ-plane and with orientation around the Y-axis set to neutral (0). When a HVRC VRdose Planner user rotates an object interactively, it is rotated around the y-axis of the model relative to the centre of rotation (origin) of the object, relative to the surface on which the object is placed, although the user can opt to rotate an object freely by turning on Manipulator Tools in the Edit menu.

Below are two pictures of the same model of a chair. In the first picture, the model's orientation is correct (with the legs on the group plane, which is the XZ-plane), while the orientation of the chair in the second image is, of course, inappropriate. When you load a model into the HVRC VRdose Planner then it should normally face the user, if it is an object that is placed on the floor, e.g. a chair or a shelving unit that stands on the floor. While there is no harm in such units being oriented differently around the Y-axis, since the Y-rotation can be modified in the HVRC VRdose Planner, it is easier for the end-user if the initial direction that objects face in is consistent.

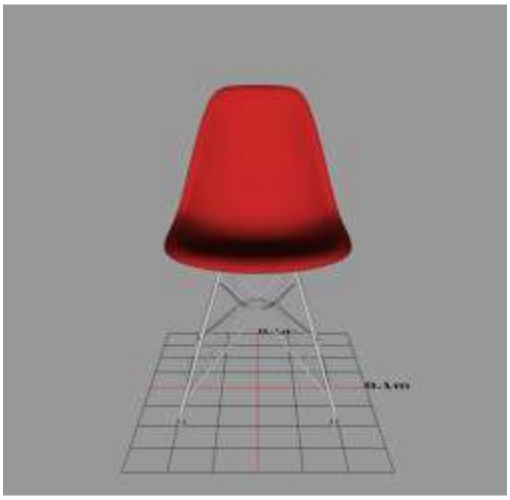


Figure 5.16 Orientation OK

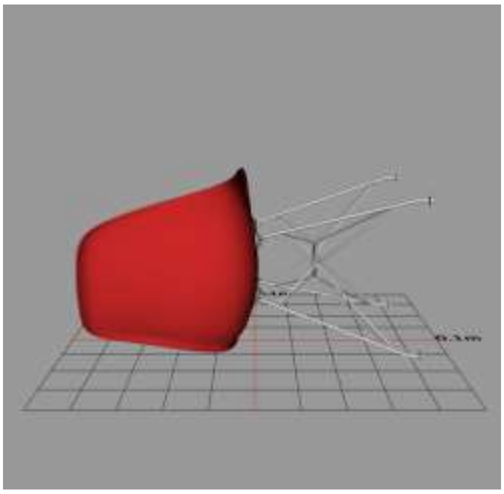


Figure 5.17 Orientation not OK

5.3.4 Lights

3D models representing lights can be used for "light" models and are permitted to contain 3D lights that cast light. All other models that would not naturally cast light should not contain lights. Room models may contain lights. But that is not required as the HVRC VRdose

Planner provides a general 'indoor lighting' option which is normally preferable. 3D models added to the Model Bank can have realistic lighting effects baked into their textures, however these will, of course, not affect other models added to a layout. A baked room can be very effective for showcasing a plan (e.g. for training or briefing) but takes more time to prepare.

5.3.5 Inline files

A 3D model file (VRML97, DAE, KMZ) imported into the Model Bank may contain internal references to other 3D data files, image files for textures, and other resources. If the referenced files are not in the same directory (or a sub-directory) as the main model file, the HVRC VRdose Planner will attempt to copy them and reorganise the file structure of copy of the model that will be added to the database, so the resulting model in the Model Bank is guaranteed to be complete.

5.3.6 Textures

Textures should follow usual conventions for 3D models intended for interactive applications. Textures should not be larger than necessary to conserve texture memory -- it is rarely necessary for textures to be larger than 1024x1024 in size, and it is generally good practice to provide images using powers of 2 (i.e. 4x4, 8x8, 16x16, 32x32, etc.) pixel dimensions for optimal performance. Most graphics cards do not support textures larger than 4096 x 4096 at all.

We recommend using PNG-format for textures to avoid compression artefacts, although for photographic-type images, JPEG may give adequate results with smaller file sizes. PNG is preferable to GIF when using transparency as it supports finer control of transparency levels.

The colour of surfaces and the textures are blended, so you should normally use white materials “under your textures” if you want the texture’s own colour to dominate.

5.3.7 Supported features

Only static geometry is supported. Animations, scripted, or interactive features are generally ignored.

5.3.8 Creating manikins

Manikins are modelled using the ISO/IEC FCD 19774 H-ANIM 1.x standard, however the current version of the HVRC VRdose Planner does not provide tools for end-users to import manikins.

IFE can supply or convert custom-specified manikins, Please contact HVRC VRdose Support for assistance. When new manikin models are prepared by IFE then they are supplied in the form of a Model Package that can be imported into the HVRC VRdose Planner by an end user.

5.3.9 Creating rooms

Rooms can be modelled in the HVRC VRdose Planner itself (using primitive shapes or shield objects from the object Catalogue) or in a 3D modelling package for inclusion in the Model Bank. This section concerns rooms created in a 3D modelling tool that will be added to a Model Bank.

Rooms can be modelled in a way that makes it possible to hide and show parts of the room to make viewing and editing easier. In most cases, at least the ceiling should be identified to enable the user to hide it and more easily access the contents of the room.

To make part of a room identifiable, that part (node) has to be named in the model data. Note that when part of a room is hidden or shown, any children of that part will also be toggled. The model should therefore be structured appropriately.

VRML97 Example:

```
#VRML V2.0 utf8
DEF Room Group {
  children [
    DEF Floor   Transform { … }
    DEF Ceiling Transform { … }
    DEF Walls   Transform { … }
    …
  ]
} # end of Room
```

Note that …in this example indicates additional code.

5.4 System Administration

This section provides guidance on administration of the software by system administrators or advanced users.

5.4.1 Customising installation

The HVRC VRdose Planner by default stores all its data and settings in a folder named '.haldenvr' under your user profile - e.g. 'C:\Users\<username>\.haldenvr' on a Windows computer. Under macOS, the data located in '.haldenvr" in the user's home folder, while the settings are located in ~/Library/Preferences/haldenvr.

The first time you start the HVRC VRdose Planner you will be asked if you wish to store data in an alternative location.

If you need to move your data to a new location after the first run:

1. Ensure that the HVRC VRdose Planner is not running.
2. Copy the 'haldenvr_data' directory to the new location.
3. Locate the settings file 'haldenvr.properties'.
4. Open 'haldenvr.properties' in a text editor.
5. Search for the property ''hvrc.data' and adjust the specified location accordingly.

5.4.2 Backing up data

It is strongly recommended that the data directory is regularly backed-up to reduce the risk of data loss.

In order to back up or move data to another computer or disk, you can simply copy the data folder ('haldenvr_data') from the location described above under Customising installation.

5.4.3 Installing software updates

The software installer supplied can be used both to install a new copy of the software and to update an existing one. If you run the installer on a system with an older version installed previously then any existing settings and data are kept.

Uninstalling the HVRC VRdose Planner will not delete the settings and data.

5.5 Dosimetric Models

5.5.1 Advantages of Real-Time Dosimetric Models

HVRC VRdose Planner is based on a highly optimized dosimetric package, especially designed to enable reasonably accurate *real-time 3D dosimetric computation* using a well-documented point-kernel approach.

- Real-time response enables very *efficient optimization of work strategies*, by facilitating users to rapidly explore and compare alternative scenarios (e.g. biological shielding configurations).
- We can simulate *radiation risk assessment in dynamically changing environments*, where the radiation situation is dynamically altered by changes to radiation sources and biological shields. While useful for planning non-routine activities during the operational phase of a nuclear facility, it is especially useful during the decommissioning phase where the environment is continuously changing.
- Real-time risk assessment can be used during a radiological accident situation to *support decision-making in a stressful situation*.
- During training or briefing, the consequences of actions can be demonstrated in real-time.

While non-real time tools can provide a high level of accuracy in theory, we believe that real-time tools are more suitable for the tasks listed above. To achieve real-time capabilities, great demands are made for the performance of the radiation transport techniques applied, limiting the options to those techniques capable of high-speed calculation while still yielding reliable results. This requirement effectively rules out sophisticated radiation transport models such as those based on precise Monte-Carlo techniques, but is also demanding for deterministic radiation transport techniques.

5.5.2 Flexibility and Extensibility

It is not always possible or advisable to use a point-kernel based radiation transport model, so you need to bear in mind the following points:

- Radiation transport simulation requires adequate knowledge about the radiation sources in a scene. In situations where such data is missing, radiation risk assessment is still possible, if suitable scattered data (a set of dose measurements) are available.
- Deterministic radiation transport techniques become increasingly unreliable for calculating dose with increasing contribution of scattered radiation. In such situations measurements, quantifying the contribution of multiply scattered photons, can be taken into account in addition to the radiation transport calculations.
- There are additional efficient dosimetric methodologies that can be applied in transitional situations, where some knowledge about the radiation sources is available in addition to measurements.

Therefore, in addition to radiation transport techniques, the software also supports the use of other dosimetric models, based on interpolation and other techniques, in order to be able to adapt the software to using the best radiological input data available. HVRC VRdose Planner includes an open programming interface that can be used to develop plugin-in software modules to integrate additional dosimetric models into the system. It can also import sets of dose-maps produced entirely independently using other software, in addition to dose-rate measurements registered in the field.

5.5.3 Further Reading

The following articles describe the methods applied in this software and it's long history:

Szőke, I., Louka, M.N., Bryntesen, T.-R., Bratteli, J., Edvardsen, S.T., Rø Eitrheim, K.K., and Bodor, K. (2014) Real-time 3D radiation risk assessment supporting simulation of work in nuclear environments. *Journal of Radiological Protection*, 34 389–416 (2), doi:10.1088/0952-4746/34/2/389

Chizhov, K., Sneve, M. K, Szőke, I. et al. (2014) 3D simulation as a tool for improving the safety culture during remediation work at Andreeva Bay, *Journal of Radiological Protection,* 34 755–773, doi:10.1088/0952-4746/34/4/755

Szőke, I., Louka, M.N., Bryntesen, T.-R., Edvardsen, S.T., and Bratteli, J. (2014) Comprehensive support for nuclear decommissioning based on 3D simulation and advanced user interface technologies. *Journal of Nuclear Science and Technology*, doi:10.1080/00223131.2014.951704

Szőke, I., Louka, M.N., Mark, N.K., Bryntesen, T.R., Bratteli, J., Edvardsen, S.T., Gustavsen, M.A., Toppe, A.L., Johnsen, T. Rindahl, G. (2012) New software tools for dynamic radiological characterisation and monitoring in nuclear site. In *Proceedings of OECD NEA Workshop on Radiological Characterisation for Decommissioning, Studsvik, Sweden 17-19 April 2012*. Paris, France: OECD Nuclear Energy Agency.

Szőke, I. and Louka, M.N. (2011) New dosimetric model for real time radiation visualization and work planning and monitoring in nuclear environments. Part 1: External gamma dosimetry. In *Proceedings of the Man-Technology-Organisation Sessions at the 2011 Enlarged Halden Programme Group Meeting, Sandefjord, Norway*. Halden, Norway: OECD Halden Reactor Project.

Louka, M.N. and Rindahl, G. (2010) A Comparative Study of Radiation Visualization Techniques for Interactive 3D Software Applications. In *Proceedings of the Seventh American Nuclear Society International Topical Meeting on Nuclear Plant Instrumentation, Control and Human-Machine Interface Technologies, NPIC&HMIT 2010, Las Vegas, Nevada, November 7-11, 2010.* LaGrange Park, IL: American Nuclear Society.

Vabø, R., Piotrowski, L & Rindahl, G. (2010) 3D representation of radiosotopic dose rates within nuclear plants for improved radioprotection and plant safety. In *International Journal on Nuclear Safety and Simulation*, Vol. 1, No. 2, pp. 127-133, (June 2010).

Rindahl, G. and Mark, N.-K. F. (2008) VRDose™ and Emerging 3D Software Solutions to Support Decommissioning Activities: Experiences and expectations from development and deployment of innovative technology. In *Innovative and Adaptive Technologies in Decommissioning of Nuclear Facilities (IAEA-TECDOC-1602).* Vienna, Austria: IAEA.

Piotrowski. L. and Rindahl, G. (2008) 3D Representation of Isotopic Gamma-Radiation Exposures within Nuclear Plants for Improved Radioprotection and Plant Safety. In *Proceedings of International Symposium on Symbiotic Nuclear Power 2008*. Harbin, China: Harbin Engineering University. Vol.1, pp. 3–9.

Rindahl, G., Johnsen, T., Mark, N-Kr. F., and Meyer, G. (2006) Virtual Reality in Planning and Operations from Research Topic to Practical Issue. In *Proceedings of 5th International Topical Meeting on Nuclear Plant Instrumentation, Controls, and Human Machine Interface Technology (NPIC&HMIT 2006)* at the American Nuclear Society 2006 Meeting, 12-16 November 2006, Albuquerque, NM, USA: American Nuclear Society.

Rindahl, G., Mark, N.K.F., and Meyer, G. (2006) VR in decommissioning projects Experiences, lessons learned and future plans. On CD-ROM accompanying *Proceeding of International Conference on Lessons Learned from Decommissioning of Nuclear Facilities and the Safe Termination of Nuclear Activities*, IAEA, Athens.

Iguchi, Y., Kanehira, Y. Tachibana, M., and Johnsen, T. (2004) Development of Decommissioning Engineering Support System (DEXUS) of the Fugen Nuclear Power Plant. In *Journal of Nuclear Science and Technology*, Vol. 41, No.3, pp. 367-375. Tokyo, Japan: Atomic Energy Society of Japan.

Iguchi, Y., Louka, M. N., and Johnsen, T. (2004) VRdose: An Exposure Dose Evaluation System based on Virtual Reality Technology - Current Status and Future Possibilities, In *Proceedings of 2004 Enlarged Halden Programme Group Meeting*. Halden, Norway: OECD Halden Reactor Project.

Rindahl, G., Johnsen, T., Øwre, F.and Iguchi, Y. (2002) Virtual Reality Technology and Nuclear Decommissioning In *Proceeding of an International Conference on Safe Decommissioning for Nuclear Activities Organized by the International Atomic Agency*, 14–18 October 2002. Berlin, Germany: IAEA. pp.223–238.

Rindahl, G., Iguchi, Y. (2001) Virtual Reality Technology for Application In Nuclear Decommissioning Process, In *Proceedings of 2001 Enlarged Halden Programme Group Meeting Meeting. Session C3-8, March 2001*. OECD Halden Reactor Project, Halden, Norway.

Iguchi, Y. and Sundling, C.-V. (1999) Using Virtual Reality Technology for the Planning of Decommissioning of Fugen NPS. In *Proceedings of 1999 Enlarged Halden Programme Group Meeting Meeting Session C2, no 9, May 1999*. Halden, Norway: OECD Halden Reactor Project.

6. Appendix

6.1 Glossary

Action	In the context of a scenario, an activity that a participant can perform, such as moving, waiting, working, and so forth.
Administrator	The user that is responsible for the management of the software installation.
COLLADA	See DAE.
DAE	Digital Asset Exchange; an ISO-standard file format for exchange of digital assets, including 3D models between software systems (ISO/PAS 17506:2012).
Developer	A programmer using the software to implement extensions to it
GPU	Graphics Processing Unit. A dedicated processor that is highly efficient and manipulating graphics and images. Usually employ a highly parallel architecture that can also support the execution of general-purpose parallel computing algorithms.
VRdose Planner	3D job planning tool with radiation visualisation and dose estimation.
HTML	Hypertext Mark-up Language.
HVRC	Halden Virtual Reality Centre – IFE's VR research centre in Halden.
IFE	Institute for Energy Technology (Institutt for energiteknikk). A research foundation in Norway located at Kjeller and Halden.
Instructor	A user that is using the software for teaching or briefing purposes.
JPEG	An image format with lossy compression.
Layout	A static representation of the virtual radiological environment that represents a snapshot at a specific time that can be used as a reference scene configuration for new scenarios.
Manikin	A virtual human. A 3D model of a human used to simulate and evaluate jobs. Usually represents a worker.
Model Bank	a hierarchically organised model database that supports the storage and access to 3D models with meta-data and version control of models
Participant	An object in a scene that can perform actions, thus participating in a scenario.
PNG	An image format that supports efficient lossless compression.
Project	A collection of related scenarios and layouts, with additional common project meta-data (expected start date, expected end date, description, and references.)
Room	The virtual environment in which a scenario takes place. It is typically represented as a single static 3d model representing a building. While static within the scope of a single scenario, there may be multiple variants

	of a room model representing the (planned or actual) state of the building at specific dates/times.
Scenario	A collection of participants that perform actions over time in a virtual radiological environment. A scenario always has a specified start and end date.
Scene	The view of a layout displayed in a 3D view, comprising of a hierarchy of participants in a room.
SDK	Software development kit. A code framework for extending the functionality of the software system.
SQL	Structured Query Language; A standard language for querying relational databases.
UI	User interface.
User	The end-user of the software system.
XML	Extensible Mark-up Language; A set of rules for encoding arbitrary data and documents in a machine-readable form.
VR	Virtual reality. Interactive 3D visualisation, ideally displayed full-scale.
VRML	Virtual Reality Modeling Language. VRML 97 is an ISO standard 3D file format (ISO/IEC 14772-1:1997).

6.2 File Formats

6.2.1 Dose-rate measurement data

6.2.1.1 Description

A measurements file is used to import measurements into HVRC VRdose Planner from data logging systems. The contents of a measurements data file are formatted using XML and are otherwise text files that can be read and edited using a text editor and are thus easy to produce.

A measurements data file contains a `measurements` element enclosing 0 or more `measurement` elements.

6.2.1.2 Example File

```
<measurements>
  <measurement>
    <date>2011-10-24T15:29:42</date>
    <position>0 2 2</position>
    <doseRate>10</doseRate>
    <unit>mSv/h</unit>
  </measurement>
  <measurement>
    <date>2011-10-24T15:29:30</date>
    <position>0 2 -2</position>
    <doseRate>1</doseRate>
    <unit>mSv/h</unit>
  </measurement>
</measurements>
```

6.2.1.3 <measurements> Element

Syntax

```
<measurements>
  <!-- 0 or more measurement elements -->
</measurements>
```

Description

An encapsulation element for grouping a set of `measurement` nodes.

6.2.1.4 <measurement> Element

Syntax

```
<measurement>
  <!-- dateTime -->
  <date>...</date>
  <!-- 3 space separated floats -->
  <position>...</position>
  <!-- float -->
  <doseRate>...</doseRate>
  <!-- string -->
  <unit>...</unit>
</measurement>
```

Description

Defines a single measurement node encapsulating the following data elements: `date`, `position`, `doseRate`, and `unit`.

<date>	The date and time of the measurement. The dateTime is defined according to XML Schema and can be expressed as *yyyy-mm-ddThh:mm:ss[Z|(+|-)hh:mm]*
<position>	Where the measurement was taken in the coordinate system of the room in metres (e.g. `0 0 0`, if at the origin of the coordinate system)
<doseRate>	The value of the measurement (e.g. `0.1`)
<unit>	The unit of the measurement (e.g. `mSv/h`, `nR/s`, `pGy/y`). The unit can be expressed as [scale]Symbol/rate. Scale must be one of m (milli), mu (micro), n (nano) or p (peta). The scale can be omitted, in which case 1 is used. Symbol can be any string, except it cannot have the same prefix as any of the predefined scale values. The rate specifies the time and must be one of y (year), h (hour) or s (second).

6.2.2 Dose map data

6.2.2.1 Description

A dose map file is used to import dose map data into HVRC VRdose Planner. The file contains a set of time-specified snapshots, enabling for the dose map to change over time. A right-handed coordinate system is used where the *y*-axis is up.

6.2.2.2 Example File

```
<dosemap>
  <unit>mSv/h</unit>
  <snapshot>
    <date>2012-02-15T10:30:15</date>
    <grid>
      <lower>-10.0 0.0 -10.0</lower>
      <upper>10.0 2.0 10.0</upper>
      <elements>3 2 3</elements>
    </grid>
    <data>0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17</data>
  </snapshot>
  <snapshot>
    <date>2012-02-15T10:31:00</date>
    <grid>
      <lower>-10.0 0.0 -10.0</lower>
      <upper>10.0 2.0 10.0</upper>
      <elements>3 2 3</elements>
    </grid>
    <data>10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27</data>
  </snapshot>
</dosemap>
```

6.2.2.3 <dosemap> Element

Syntax

```
< dosemap>
  <!-- string -->
  <unit>...</unit>

  <!-- 0 or more snapshot elements -->
</dosemap>
```

Description

Contains a list of `snapshot` elements at specific times in the scenario. All values in all snapshots must use the same unit specified by the `unit` element.

6.2.2.4 <unit> Element

Syntax

```
<unit>...</unit>
```

Description

The unit of the dose-rate values in the grid of data in the snapshots (e.g. `mSv/h`).

6.2.2.5 <snapshot> Element

Syntax

```
<snapshot>
  <!-- dateTime -->
  <date>...</date>
  <grid>
    <!--  floats (x y z) -->
    <lower>...</lower>
    <!-- floats (x y z) -->
    <upper>...</upper>
    <!-- integers (x y z) -->
    <elements>...</elements>
  </grid>
  <!-- x y z floats -->
  <data>...</data>
</snapshot>
```

Description

Defines a regular grid of dose-rate values for a specific time.

<date>	The date and time of the measurement. The date and time (*dateTime*) is defined according to XML Schema and can be expressed as *yyyy-mm-ddThh:mm:ss[Z|(+|-)hh:mm]*
<grid>	Defines the number of sample points in the grid and the position of each point. The lower element specifies the position of the point with the lowest x, y and z values. The upper element specifies the position of the point with highest x, y and z values. The `elements` element specifies the dimensions of the grid, being the number of sample points in each direction (e.g. 2 2 2 for a grid comprising of eight points and one cell).
<data>	The dose-rate values of the grid. The number of values is given by the grids elements x*y*z. There have to be one space between each value.
<unit>	The unit of the measurement (e.g. `mSv/h`, `nR/s`, `pGy/y`). The unit can be expressed as [scale]Symbol/rate. Scale must be one of m (*milli*), mu (*micro*), n (*nano*) or p (*peta*). The scale can be omitted, in which case 1 is used. Symbol can be any string, except it cannot have the same prefix as any of the predefined scale values. The rate specifies the time and must be one of y (*year*), h (*hour*) or s (*second*).

Code to generate a position for each value for the grid can be written as follows:

```
for (int zIdx = 0; zIdx < elements.x; zIdx++) {
  for (int yIdx = 0; yIdx < elements.y; yIdx++) {
    for (int xIdx = 0; xIdx < elements.z; xIdx++) {
      float x = lower.x + (xIdx / (elements.x - 1f)) * (upper.x - lower.x);
      float y = lower.y + (yIdx / (elements.y - 1f)) * (upper.y - lower.y);
      float z = lower.z + (zIdx / (elements.z - 1f)) * (upper.z - lower.z);
    }
  }
}
```