EUROPEAN JOINT PROGRAMME FOR THE INTEGRATION OF RADIATION PROTECTION RESEARCH
CONCERT

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PODIUM
Personal Online DosImetry Using computational Methods

EJP-CONCERT

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D9.109 – First Annual Report

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Content

1 WP 0: Management

Objectives: WP0 ensures the day-to-day project management activities

- Take care of all project management activities, including the overall scientific follow-up
- Keep track of the time schedule and the milestones
- Establish the project governance structure and coordinate consortium meetings
- Manage financial, administrative and contractual aspects
- Assess risks in a structured and targeted manner and set up a contingency plan
- Be responsible for the communication with CONCERT
- Ensure IPR and knowledge management as well as ethics management

Task 0.1 : Project management, internal communication, financial and administrative management, meeting coordination

During the first PODIUM year, three meetings were organised:

- Kick off meeting, Mol: 24-26/01/2018
- Second meeting, Munich: 25-26/05/2018
- Third meeting, Malmo: 5-7/11/2018

In between, web meetings were organised with all partners on 7/3, 18/4, 24/5, 4/9 and 18/12.

From each of these meetings extensive minutes were prepared.

The PODIUM management structure was established at the beginning of the project. One representative from each partner forms the Project Management Board (PMB), which is responsible for decision-making during the project. This PMB monitors the progress of the project and the work done by the different partners. It is the PMB that takes important decisions in case of disagreements on the work between partners, and it is the PMB that decides on actions in case a partner does not fulfil their obligations. The PMB has met during each meeting, and separate minutes have been made from these PMB meetings.

From the beginning of the project, a website was established by SCK•CEN. It contains a public part with general information and with links to all public deliverables. It also includes a secure SharePoint part where all working documents are stored and shared between the partners. The secured area also includes a discussion forum where most of the conversations between partners are held.

Because of a shift in responsibilities, the PMB decided to re-allocate 135 k€ for application developer subcontracting from SCK-CEN to UPC. This was approved by CONCERT. During the last meeting, the budget status from each partner was summarised. With 41% of the time elapsed (November 2018), and on average for all partners, we used 25% of the budget.

Task 0.2 : CONCERT communication, reporting, knowledge management, IPR management

The IPR and knowledge management are fixed through the consortium agreement, which was finalised and signed by all partners. As regards exploitation activities, work package 6 will set up an exploitation plan that will guide the consortium in the identification and subsequent leverage of exploitable project results.

This task 0.2 also involves the review and final approval of all deliverables. The following deliverables were submitted and accepted in the first year:

- D9.103: An IPS based on an infrared reflection time-of-flight sensor camera together with the corresponding software (M6).

- D9.105: An IPS based on a developed camera network system and the multi-image acquisition computer system with the corresponding software (M12).
- D9.107, part A: Guidelines for implementing the workplace geometry and the radiation field map in the dosimetry application (M12).
- D9.104: Database of phantoms of different statures and postures (M9).
- D9.101: Report listing all requirements of the software (M1)
- D9.102: Detailed specification of the fields to be used (M3).
- D9.108. Report summarizing the feasibility of the methods, and the accuracy of personal dosimetry in a simple scenario (M12).
- Deliverable 9.107 was split in to part A and B, where part B (on the radiation field map) is to be submitted by M18.
- D9.106 (Prototype of fast MC real time radiation dose estimate application to be tested in hospitals) was shifted to month 24. This time is needed to test and improve the speed and resulting accuracy of several MC simulation codes for workers moving in realistic workplace fields in interventional radiology. This will have no effect on the overall progress of the PODIUM project.

As project coordinator, SCK•CEN is the single point of contact for the CONCERT project for all information exchange, reporting requirements and financial aspects, including the POM status. In October, there was also the stakeholder meeting for all CONCERT projects, where the PODIUM coordinator participated.

Task 0.3 : Risk management

At the beginning of the project, during the kick-off meeting, an exercise was set-up to identify the risks during the project. A standard methodology, also implemented at SCK•CEN, has been used to quantify the risks and to get an importance ranking of the risks. Through a brainstorming exercise, a list of risks was established and scored for importance. For the most important risks, mitigating actions were defined. This list is available in a separate Excel sheet, and will be discussed at every meeting.

2 WP1: Dose simulations input: staff movement monitoring and radiation field mapping

The goal of work package 1 is to provide the required input to simulate the workers’ doses. It has two main tasks: the development of an indoor position system (IPS) capable of identifying and tracking the movement and position of the exposed staff and the mapping of the radiation fields.

Task 1.1: Development of an indoor position system

a.- IPS based on a single Kinect camera

As a first step, an IPS based on an infrared reflection time-of-flight sensor camera together with the corresponding software was set up to perform the tracking of the position and the posture of occupationally exposed workers. The description of this system was given in Deliverable D-9.103. Considering the needs and objectives of PODIUM, the KINECT v.2 TOF camera was first chosen. The KINECT v.2 makes use of two sensors: an RGB camera for acquiring conventional RGB images (for pictures or videos, with a maximum resolution of 1920 × 1080 pixels) and a depth-sensing module.

The depth-sensing module is constituted by an IR laser and by an IR camera with a resolution of 512 × 424 pixels. The laser illuminates the scene by emitting pulsed Infra-Red (IR) light, while the IR camera scores IR photons bouncing back after a reflection. It differs from the most common depth sensing technology (based on structured light) as the KINECT v.2 calculates depth distances by measuring the phase shift associated to the reflected IR light on a pixel-by-pixel basis. The use of an IR illuminator means that the KINECT tracking algorithm can work even when the lighting conditions in the workplace are poor. The phase shift method, also known as TOF, allows the camera to reach a good compromise between range of the depth sensor, spatial accuracy, and high framerate. The camera generates color and depth images with rates up to 30 frames per second, which is much higher than what is needed for tracking radiation workers.

Software, named KINECT Data Acquisition (KDA), developed by SCK•CEN is used to govern the acquisition of RGB and depth images, and the recognition of bodies and body parts. Figure 1.1 shows the start screen, including all the settings, and the main interface of the program during an acquisition. For the moment, KDA is run as a standalone application with its own interface.
The source code of KDA is made of a series of functions governing acquisition and synchronization of RGB and depth data, and the recognition of body parts. Some of the functions are based on the default libraries and examples from the KINECT SDK, while some others were programmed from scratch. While the functions were written in C# language, the graphic interface was written in XAML in order to make use of the Windows Presentation Foundation (WPF) graphical subsystem. Additionally, KDA makes use of some well-known Open Source libraries:
OpenTK: provides several utility libraries, including a math/linear algebra package, a windowing system, and input handling
Emgu CV: is a cross platform .Net wrapper to the OpenCV image processing library. Allowing OpenCV functions to be called from .NET compatible languages such as C#
Office Open XML: is an XML-based format for office documents, including word processing documents, spreadsheets, presentations, as well as charts, diagrams, shapes, and other graphical material
EPPlus: is a .NET library that reads and writes Excel files using the Office Open XML format (xlsx)

Figure 1.1 shows in red the skeleton object obtained by the KDA; this virtual skeleton stores the 3-Dimensional postural data and its variation in time. The skeleton object consists of an array of 25 joints, which are arranged according to a kinematic chain approximating the degrees of freedom of the human body.

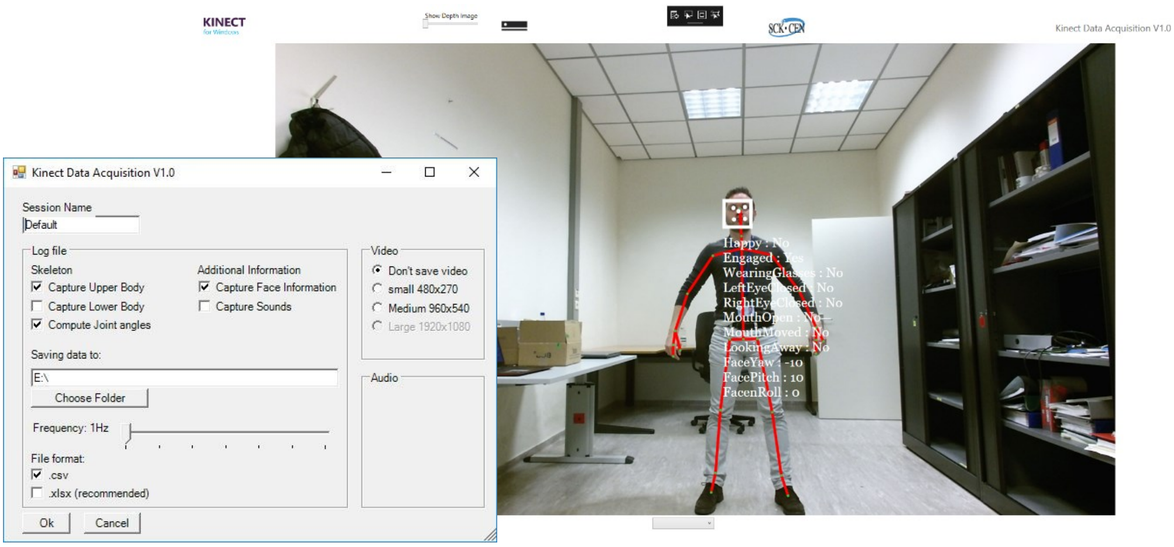


Figure 1.1: *Interfaces of the KINECT Data Acquisition program*

The extracted coordinates of the joints by the IPS are relative to the camera coordinates. Therefore, to obtain real-world coordinates of the workers at different set-ups, a calibration procedure was been developed to transform the Kinect IR coordinates to the real-word coordinates. This calibration process is done only once after fixing the camera location for a given workplace.
The IPS has been successfully tested in simple workplaces within SCK•CEN and UPC, and in a catheterization laboratory (Cath-lab) of UZ Brussels (Vrije Universiteit Brussel), Liège University Hospital and Skåne University Hospital in Malmö. In these scenarios, the system was shown to be reliable when tracking one person or even two people with few inter or self-occlusion. However, several limitations were identified that compromised its extension to a multi-user IPS, i.e. a system that would be able to correctly identify multiple individuals in the scene.

The main limitations are:

- The range of the person tracking algorithm is restricted to about 4.5 meters;
- The Field-Of-View of the Kinect v.2 depth camera is limited to 84 degrees horizontally and 54 degrees vertically;
- The maximum number of tracked people is limited to six by Kinect;
- There might be occlusions affecting the view of the tracked workers;
- There might be a misidentification of the tracked workers;
- The position of the joint coordinates can show some fluctuations and sporadic outliers.

These limitations have been addressed through two different strategies described in deliverable D-9.105 and are summarised in the following paragraphs.

b.- Improved IPS based on a single Kinect camera

The first approach to overcome the limitations identified when testing the initially proposed system is based on the same sensor: a KINECT v.2 with improved software.
We implemented a filter architecture that integrates jitter reduction, as well as statistical smoothing based on Holt Double exponential method (Holt, 1957). This implementation was provided natively in later versions of Microsoft Kinect version 1 SDK, but was yet to be implemented to version 2 SDK. The configuration of the filtration algorithm is highly dependent on the application and the nature of movement. Experimentation is required on an application-by-application basis in order to provide the required level of filtering and smoothing for each case. On the other hand, for our application, we established that one frame per second rate is good enough to estimate doses to workers. Given these considerations, the filter parameters were obtained by trial and error and are shown in Table 1.1.

***Table 1.1**. Double exponential filter parameters used for the selected filtering solution (details about the filter parameters can be found in D-9.105)*

Proposed Filter Parameters	
Smoothing coefficient	0.8
Correction factor	0.1
Prediction coefficient	0.25
Jitter radius	0.5
Max. deviation radius	0.3

The depth images are recorded with a high frequency, i.e. 30 Hz. This high sampling output is filtered and then the one second required output is provided.

Figure 1.2 shows an example of raw data of the hand, together with the output when the double exponential filter is applied, and the final 1 Hz output of the filtered data.

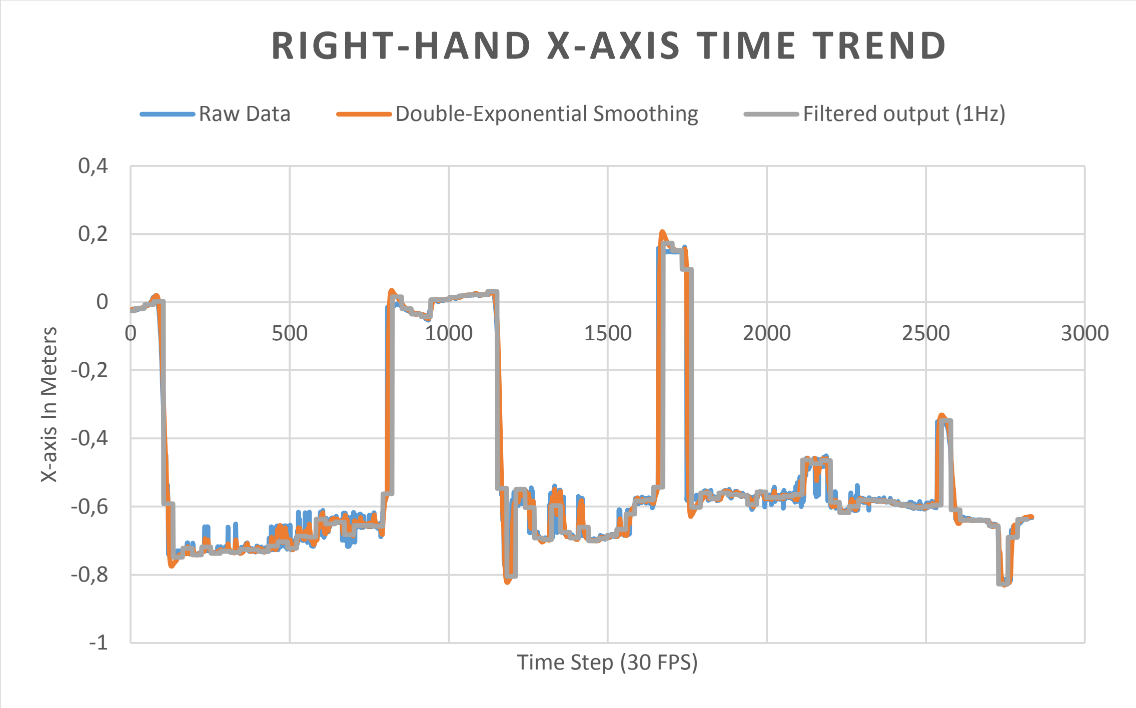


***Figure 1.2**. Example of application of the selected filtering solution to the right hand tracking during a real X-ray procedure*

Another limitation when using a single Kinect is that the current tracking software does not provide an algorithm for identifying individuals, thus recognizing the different users in different locations is a challenging task. The skeleton tracking of the Kinect SDK automatically gives a body ID to different users in the scene, but this body ID is not always consistent over the tracking sequence. The body ID can change when users are overlapping (full body occlusions) or when a user exits the view. Although, performing multiple view skeleton tracking can help retrieving consistent body ID per user along a whole sequence, we investigated different techniques to improve skeleton identification in our single camera IPS.

Facial recognition is particularly difficult in interventional radiology where monitored workers are usually wearing protective glasses and caps. To overcome this problem, we developed an identification algorithm using skeleton joints data based on the specific geometrical configuration found in interventional radiology rooms. The algorithm makes use of skeleton tracking to correlate the relative position of monitored workers to the camera location. In fact, during our tests we observed that the main operator (the doctor) is usually working in a specific space region on the patient side, while the first assistant is positioned close to the main operator but in a separate region compared to the doctor' one. Overlapping between these two regions is unlikely when the x-ray beam is on.

After each procedure, histories of different body joints of different users are recorded and then clustered per user. Hence, the skeleton sequences are modelled as trajectories on 2D plans. This helps identifying monitored users based on their first known geometrical configuration. Skeleton-based person signature can also be used in suitable scenarios. For examples, worker's height can be used as complementary information that helps to identify different users when applicable. Given the fact that in interventional radiology workplaces for this project the KINECT will only see the upper part of the body, it is difficult to rely on a single skeleton-based person signature to identify different users, for example, using the Euclidean distance between feet and neck. Thus, different techniques can be used for different geometrical configurations and for different body size of monitored workers. For now, this procedure is done offline after the procedure is finished.

On the other hand, in neutron workplaces, RGB-based appearance features could be used to identify the monitored workers whenever they do not have to use PPE equipment that cover or partially cover the face.

Table 1.2 summarises the different options for personal identification in PODIUM applications when using a single Kinect v2.

Table 1.2. Personal identification methodology when using a 1 single Kinect

Method	**Workplace**	**Requirement**
RGB-based appearance Facial recognition	Neutron workplaces where workers do not use masks or glasses	- Face frontal view - Good illumination
Single-View Skeleton-based	Interventional Radiology	- Distinctive geometrical configuration
Skeleton-based person signature	Interventional Radiology	- Distinctive feature among tracked users
Multi-view Skeleton-based ID	Neutron workplaces Interventional Radiology	- Multiple cameras

c. Multi-user IPS with multi-view approach

Because of the reported occlusions and FOV limitations, a second tracking approach based on a multi camera solution has also been analysed. We have developed a software to acquire the skeleton data from different view points so that the identification is correctly performed thanks to the data fusion from different sensors. At the moment of writing this report, the software is a beta version and its verification is in progress. The goal of this second tracking approach is to improve the solution presented in the previous paragraph.

The proposed multi-user IPS with multi-view system is based on the use of two Kinect sensors, which require two separate computers and an adapted software consisting of two Windows Presentation Foundation (WPF) applications developed in C#. The first application is the master (or admin) (Figure 1.3). Markers 1 and 2 in Figure 1.3 represent the two columns of data (cameras 1 and 2 respectively). In marker 3, we can see the RGB images coming from cameras and in marker 4, we can see the depth image. In marker 5, we can see some data about how many skeletons is identifying each camera. In marker 6, we can see logs of the program, in this case messages indicating that data is being received. In marker 8, we can see the number of fused skeletons and their position and in marker 7, we can see a 3D plot of the fused data.

Figure 1.3. *View of the two-camera master application.*

The software manages the connection between the cameras, the calibration and the fusion of the data coming from the multiple cameras. The second application is the slave. This software handles the connection with an individual Kinect sensor and sends both the skeletons and the images to the master software (when required by the master). Note that a computer can only handle one Kinect sensor due to the restrictions of the SDK 2.0 provided by Microsoft. The fusion of the data coming from the multiple cameras is the key feature of this software. The master node is in charge of fusing the different information that is receiving from the single-view detectors in the network.

The calibration of the system consists of two different procedures. First of all, the cameras are calibrated with each other, i.e. finding the geometrical transformation between the two of them. Then, the master camera must be calibrated with respect to the world applying the same method used for a single camera system. For future improvements of the software, other approaches can be considered, for instance, improving the fused skeleton by taking into account constraints of bone-lengths.

Preliminary tests in a lab of 5.2 meters length by 3.2 meters wide show promising results in situations with partial occlusions in one of the cameras. Moreover, it is verified that the useful FOV is enlarged compared with using a single camera.

It is planned to complete the verification of this system in the next months, and in particular to test it against the improved KDA single Kinect software described in paragraph b. The main steps planned are:

1. Continue the software improvement and verification.
2. Comparison of 1 Kinect / 2 Kinect, examples of realistic movements in UPC lab.
3. Verification in realistic workplaces.

Based on the actual results, it was decided that the improved one camera IPS solution (paragraph b) would be easy and convenient to be installed in interventional radiology and neutron workplaces, in the framework of WP4 and WP5 measurements.

The two-camera solution based on the use of two Kinect 2.0 depth sensor cameras and an adapted software which is capable to fuse the images of the two cameras and thus reduce occlusion problems and increase the field of view of the cameras is still in progress and will be compared to the first one for some workplaces, in particular, in those cases where a longer range of person tracking is required or where occlusions are not satisfactorily solved by the proposed improved single camera solution. This solution is more expensive since it needs as many computers as cameras.

The tracking system has a central role in the online dosimetry system of PODIUM. Its output, i.e. the worker(s) position and posture, constitute the input for the dose calculation modules. It is foreseen that the tracking software will be run as a background batch process in the PODIUM web-app, which is being developed in WP3.

Task 1.2 Geometry input and radiation field mapping

This task deals with providing guidelines for implementing the workplace geometry and the radiation field map in the dosimetry application, it is divided in two parts. First the general methodology for implementing the workplace geometry and, secondly, the methodology for obtaining the radiation field map. Deliverable D-9.107 Part A describes the definition of the most important elements characterizing the workplaces geometry. The second part about the radiation field map is in progress.

A method based on the use of Structure sensors (Occipital Inc.), i.e., a 3D camera attached on an iPad has been tested in an interventional radiology room in Malmö. The camera uses the RAM-memory to create a 3D mesh of the filmed geometry. The created 3D mesh environment was generated using the app Canvas. The 3D mesh is then post-processed by the additional “Scan To CAD” service ($29.00 per scan) in the Canvas app, which converts the generated 3D mesh into an editable CAD file.

Guidelines on the placement of the IPS camera are provided in D.9.107 and summarised in this paragraph. For achieving an optimal tracking accuracy, the IPS camera should be placed following a series of ideal criteria. Unfortunately, in some cases, it could become necessary to compromise some criteria to reduce both the intrusiveness and the possibility of obstructions. One priority in the placement of the IPS is its discreteness, i.e. we must assure that the work of the staff is not hindered during the course of their work. All the components of the IPS, including the Kinect, the cables and the acquisition PC controlling the IPS, must be placed safely and out of highly trafficked areas. The first condition for an optimal positioning is that the Kinect should have a front facing view of the staff. With a front facing view, the IPS will deliver the most accurate tracking of chest, head, and of both arms and both hands. Table 1.3 summarises the criteria to be considered for the Kinect, based on some tests performed in the Malmo Hospital room number 105.

Table 1.3: *Comparison of advantages/drawbacks of the proposed locations for the placement of the camera in room 105 of Malmo Hospital*

Position	FOV	Distance Kinect-Doctor	Tilt angle	Horizontal angle	Occlusions	Calibration
1: Kinect mounted on a closet on the side of the C-Arm.	Good. It covers the whole region of interest.	Not good. The camera is far from the monitored area.	Good. The height at about 2.1 m implies a tilt angle smaller than 20°.	Not good. The horizontal position requires angle of rotations larger than 20°.	High probability of occlusions with the C-Arm when rotated.	Complex due to large distances and relatively hard tilt and horizontal angles.
2: Kinect hanging right below the ceiling on the same side of the C-Arm	Good. It covers the whole region of interest.	Not good. The camera is far from the monitored area.	Not good. The height at about 2.7 m implies a tilt angle higher than 25°.	Ideal. The Kinect has a front facing view of the doctor.	Medium probability of occlusion with C-Arm when rotated	Complex due to large distances and relatively hard vertical and horizontal angles.
3: Kinect hanging right below the ceiling at the center of the bed	Good. It covers the whole region of interest.	Good. The camera is not too far from the monitored area.	Not good. The height at about 2.7 m implies a tilt angle higher than 25°.	Ideal. The Kinect has a front facing view of the doctor.	Low probability of occlusion from tv screen and C-Arm when rotated.	Easy, thanks to the ideal distances and to the good vertical and horizontal angles.
4: Kinect mounted on a wall light at about 2.3 meters of height	Good. It covers the whole region of interest.	Not ideal. The camera is far from the monitored area.	Mediocre. The vertical position at about 2.3 m of height implies a tilt angle of about 20°.	Ideal. The Kinect has a front facing view of the doctor.	Medium probability of occlusion from tv screen and C-Arm when rotated.	Easy, thanks to the ideal distances and to the good vertical and horizontal angles.
5: Kinect placed above the closet on the right side of the room	Good. It covers the whole region of interest.	Not good. The camera is far from the monitored area.	Good. The vertical position at about 2.1 m of height implies a tilt angle smaller than 20°.	Not good. The horizontal position requires angle of rotations larger than 20°.	Medium probability of occlusion from tv screen if rotated.	Complex due to large distances and relatively hard vertical and horizontal angles.
6: Kinect mounted on the imaging screen	Excellent, doctor during procedure always look screen so even if moved it will always track doctor.	Excellent. The camera is at ideal distance to allow high accuracy and good view of the scene.	Good. The vertical position at about 2 m of height implies a tilt angle smaller than 20°.	Ideal. The Kinect has a front facing view of the doctor.	Very low risk of occlusions.	Complex. If the monitor is moved frequently, it will require an automated calibration procedure
7: Kinect hanging on the ceiling thought a mounting rack	Good. It covers the whole region of interest.	Excellent. The camera is at ideal distance to allow high accuracy and good view of the scene	Mediocre. The vertical position at about 2.2 m of height implies a tilt angle of about 20°.	Ideal. The Kinect has a front facing view of the doctor.	Very low risk of occlusions.	Easy, thanks to the ideal distances and relatively hard vertical and horizontal angles.

References:

Holt, C.C. (1957). Forecasting trends and seasonals by exponentially weighted averages, Carnegie Institute of Technology, Pittsburgh ONR memorandum no. 52.

3 WP2: Dose simulations using computational phantoms and Monte Carlo methods

The aim of WP2 is to provide fast dose calculations for workers moving in realistic workplace fields.

Task 2.1: **Development of phantoms that can be used in the Monte Carlo calculations**

Three computational phantoms were selected based on the requirements of PODIUM. First, these phantoms represent a good variety of anatomies, including both sexes. Secondly, they belong to two different generations of phantoms, where each generation has complementary advantages and disadvantages. Lastly, two partner institutes with experience in computational phantom modeling developed them. This allowed us to make specific modifications to the phantoms, such as adding of lead aprons. On one hand, we use two female phantoms from the well-established HMGU family of voxel phantoms, developed in the Helmholtz Zentrum München. These phantoms were selected because they represent female doctors and nurses with a realistic range of body statures. On the other hand, we are also making use of the recently developed Realistic Anthropomorphic Flexible (RAF) adult male phantom, which is characterised by a high level of flexibility. In this case, the phantom is representing male doctors and nurses with body dimensions close to that of the ICRP reference man (ICRP 2002) and can assume various postures.

The Realistic Anthropomorphic Flexible phantom belongs to the Boundary Representation (B-Rep) generation of computational phantoms. The Polygonal Mesh (PM) representation is, by far, the most widespread computer graphic modeling technique. For this reason, modern computer hardware was evolved and optimised to work with PM. GPUs can process billions of polygons per seconds, making it possible to apply complex mathematical operations to deform the mesh surfaces in real-time.

Nevertheless, making use of RAF phantom in PODIUM applications would have not been practical, as it requires specialised software and experience in B-Rep modeling. For this reason, a software tool, named Interactive Posture Program (IPP), was developed which allows making use of the RAF phantom through a simple interactive user interface, illustrated in figure 2.1a. With IPP, nine selectable objects, called end-effectors, control the posture of the RAF phantom. Five end-effectors are used to define the point that needs to be reached by each limb (hands, feet and head of the phantom). Additionally, four end-effectors can be turned on to adjust finely the orientation of elbows and knees. Thanks to IPP, the RAF phantom can be shared among PODIUM partners, who will be able to create phantom versions mimicking realistically the workers posture. For assessing correctly doses to medical staff in Interventional Radiology, protective garments are included in our simulations. For this reason, in IPP the RAF phantom can also be equipped with an apron, a thyroid collar and a cap (all 0.5 mm thick). The garments are activated through a toggle in the IPP interface (figure 2.1b).

Another aspect that needs to be taken into account with B-Rep is that polygonal mesh surfaces, by definition, do not enclose fixed volumes, so they can overlap each other. For this reason, we developed a special process within IPP, in which the polygonal surfaces are attributed to a volume. This process can be performed in two ways, depending on the MC transport code that is used.

They consist in:

- converting the RAF phantom to mesh files compatibles with Geant4, and in
- converting the RAF phantom to a voxel phantom, compatible with most MC transport codes (MCNP, EGS, Penelope, Geant4).

1a 1b

Figure 2.1: *a) graphical interface of the Interactive Posture Program (IPP) for controlling the posture of the RAF phantom, and b) RAF phantom equipped with protective garments.*

Due to the large experience in the consortium with MCNP, EGS and Penelope within WP2, the voxelised version of the RAF phantom is the one of greater interest for PODIUM. The resolution of the voxelization process can be selected depending on the application and on the anatomical accuracy required for the phantom. It is important to underline that, on one hand, the voxel resolution affects the mass and the thickness of the tissues. The higher the resolution, the more accurate masses and thicknesses are. On the other hand, high voxel numbers require higher computational performances and require larger memory, which could reduce dramatically the number of simulations that could be performed within short timeframes, needed for PODIUM. Ideally, for not compromising the anatomical accuracy of the RAF phantom and for maintaining reasonable computing performances, the voxel dimension should be kept between 1 and 3 mm in the axial plane, and between 2 and 4 mm along the longitudinal axis of the phantom.

The IPP program will be distributed to PODIUM partners through the restricted section of the PODIUM website.

Furthermore, the following voxel phantoms from the HMGU phantom family (Fill et al., 2004; Zankl, 2010) are used for the PODIUM project: Irene and Donna. Irene is a slim person (51 kg, 163 cm), and Helga is large (79 kg, 176 cm). Furthermore, RCP-AM and RCP-AF, the ICRP/ICRU reference adult male and female computational phantoms (73 and 60 kg, 176 and 163 cm, respectively), are also used (ICRP, 2009). The main characteristics of these voxel phantoms are given in Table 2.1.

For the simulations in interventional radiology workplaces, the phantoms Donna and Irene have been equipped with protective garment (apron and collar). One voxel layer of protective material surrounding the phantom outline (see Fig. 2.3) represents this garment. The material and density of this voxel layer has to be assigned in the MC simulations such that the voxel dimension properly reflects the material and thickness of the protective garment. For Donna and Irene, whose voxel in-plane resolution is 1.875 mm, a “modified” lead density of 3.0267 g cm^{-3} should be used to simulate 0.5 mm of lead (compared to the physical lead density of 11.35 g cm^{-3}).

Table 2.1: Main characteristics of voxel phantoms Donna, Irene, RCP-AM and RCP-AF

	Donna	Irene	RCP-AM	RCP-AF
Height (cm)	176	163	176	163
Mass (kg)	79	51	73	60
Slice thickness (voxel height, mm)	10	5	8	4.84
Voxel in-plane resolution (mm)	1.875	1.875	2.137	1.775
Voxel volume (mm^3)	35.2	17.6	36.54	15.25

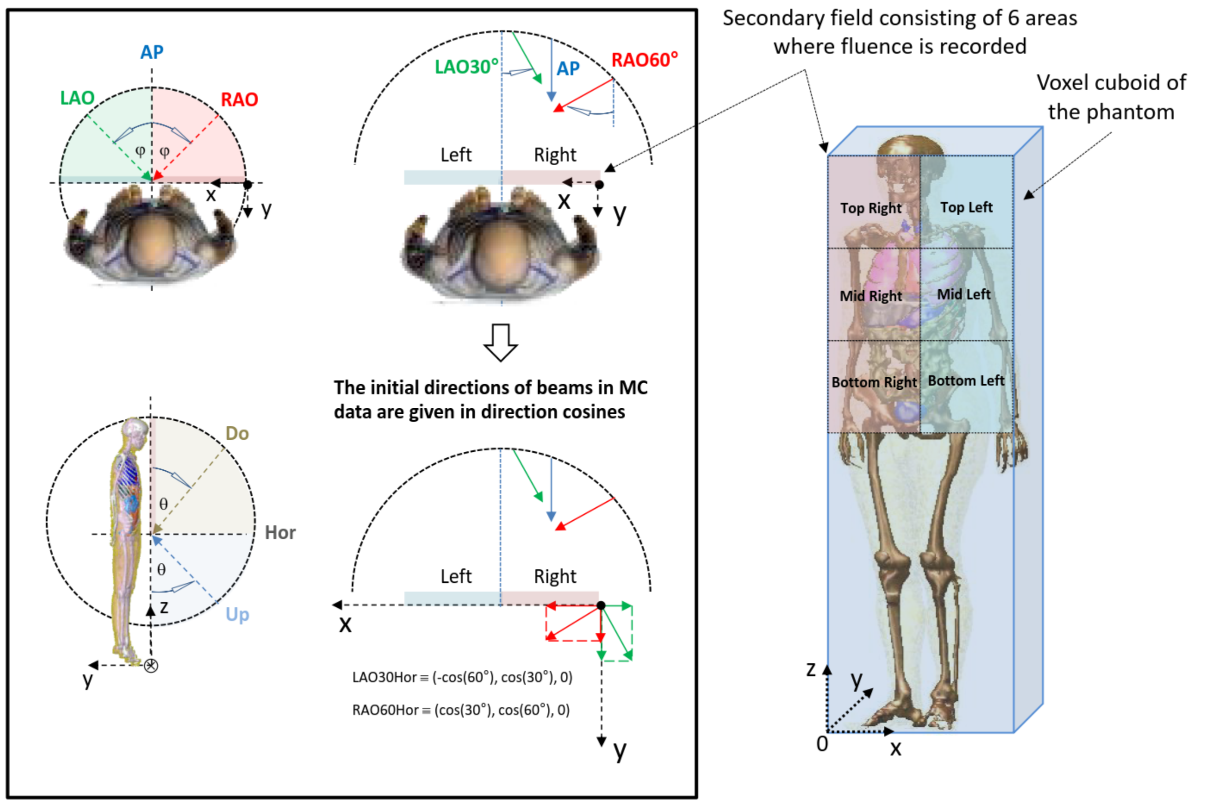
***Figure 2.2**: Transversal slice of Donna at height of the breast with added voxel layer representing a protective apron.*

Task 2.2: Establishment of a pre-calculated database of fluence to dose conversion coefficients for photons and neutrons for different phantom positions, postures, and statures and for different irradiation geometries and energies

SCK•CEN have made available their results for organ and effective doses for the ICRP reference adult male phantom with and without protective garment for whole-body irradiation with monoenergetic photon beams under various angles of incidence. HMGU have performed calculations for whole-body irradiation with parallel monoenergetic photon beams in AP geometry with their Donna phantom with and without protective garment.

Concerning the simulation of realistic fields, HMGU have incorporated source incidence at arbitrary angles into their EGSnrc user code. Calculations of organ dose conversion coefficients at various horizontally impinging angles (AP, left and right oblique incidence at 15°, 30°, 45°, and 60°) on six sub-regions of the anterior side of the trunk of Donna have been performed. A sketch of the sub-regions and the labelling of incidence angles can be seen in Figure 2.3.

For the neutron calculations, due to the large amount of neutron energies from 1 meV to 20 MeV, only broad parallel beams will be considered with an incident angle of 0° (AP), 45°, 90° (RLAT), 135°, 180° (PA), 225°, 270° (LLAT), and 315°. For neutron exposures the protective garment is in practice not used and will therefore not be simulated.



RAO = **R**ight **A**nterior **O**blique, **LAO** = **L**eft **A**nterior **O**blique, **AP** = Anteroposterior
For the non horizontal, non-zero z-direction, Up(θ) and Do(θ) with the polar angle θ are also defined
File naming: **LAO30Do15ML** (LAO30HorML if horizontal, θ=0°) – **L**eft **A**nterior **O**blique with the azimuthal angle φ of **30**°, **Do**wnwards with polar angle θ of **15**° from the **M**iddle **L**eft area in the secondary field

Figure 3: *Characterization of the six sub-regions on the trunk of the body and the nomenclature for the angles of incidence.*

Task 2.3: Feasibility study towards application and improvement of fast MC codes for online dosimetry in interventional radiology

Progress has been made on using MC-GPU to speed up calculations of doses to staff. MC-GPU (Badal, 2009) has been successfully compared with PENELOPE (Salvat, 2015) calculations and TLD measurements. The use of accelerated simulations with standard codes has been tested by using a new tally for fast simulations with Penelope/penEasy (photon fluence point, detection forcing). PenEasy (Sempau, 2011) is a general-purpose main program for PENELOPE. It provides users with a set of source models, tallies and variance reduction techniques that are invoked from a structured code.

To test the performance and accuracy of the different approaches, some experimental measurements of staff doses in simplistic situations (see Figure 2.4) have been used as a reference. The results of the full MC simulation of the problem with PENELOPE, by using the photon fluence point approach (detection forcing) from PENELOPE/penEasy and MC-GPU have been compared against the experimental results.

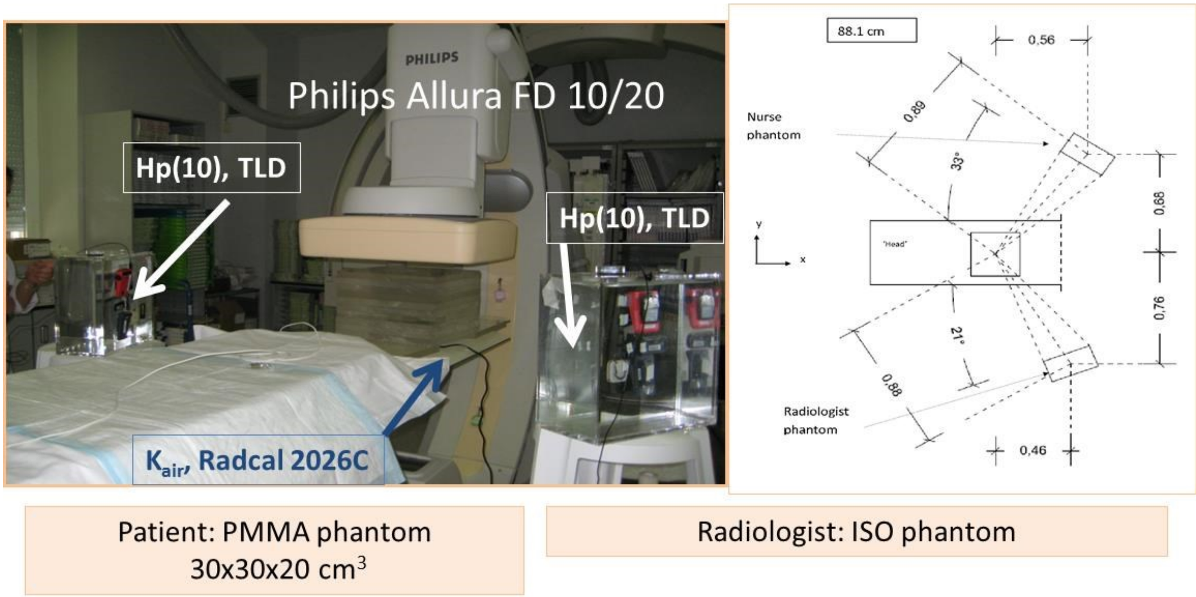


Figure 2.4: *Experimental measurements at the San Carlos University Hospital (Spain)*

The results of the simulations show very low statistical uncertainty and agree well between full MC, detector forcing, MC-GPU and experimental results (within 30%), with MC-GPU providing very good results within 90 seconds computation time. While the runtimes were initially relatively long (1200 seconds), by optimizing the distribution of the workload among cores, the MC-GPU calculation speed was significantly improved. Very low uncertainties (below 2%) can be achieved after 200 seconds with the improved MC-GPU calculation speed, even for a single thin voxel of air. Simulations for a specific interventional room in Malmö university hospital achieved good statistics in fluence (calculated free in air) within 60 or even 30 seconds. In summary, it can be stated that calculations can be done within 1-2 minutes.

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4 WP3: Development of the Dosimetry online Calculation Application

The goal of WP3 is to integrate the developments of the different work packages in a user-friendly online application called Dosimetry online Calculation Application (DCA). This work package consists of four tasks.

Task 3.1: Listing all requirements of the software

The goal of this task is to make a list of the DCA requirements based on the experience of the different partners.

The DCA requirements were listed in a document as deliverable 3.1. This document was also sent to possible subcontractors for the software development. Of course, the requirements will be further updated during the project based on the input from the other work packages.

In summary, the DCA is an online application that functions as the user interface and works with a database for storage and retrieval of all relevant data and different external technical modules that allow controlling the camera's for tracking, calculation of the radiation field and calculation of the worker doses.

Task 3.2: Identification of an appropriate subcontractor

The goal of this task is to find an appropriate subcontractor for the development of the software.

During task 3.1 it was decided that the subcontractor will develop the front-end online application, the database and the back-end to allow communication between the web application, the database and the technical modules that will be developed by the PODIUM partners.

Two possible Belgian subcontractors have been contacted: RealDolmen and Cronos. The software requirements document from task 3.1 was provided to them as first information. Several meetings have been organised and more detailed information has been provided to give the subcontractors sufficient information to make a price offer. The price offer that we received was significantly above the foreseen budget. It was not possible to decrease the price to fit within the budget because this would mean that we had to exclude essential elements from the application. Therefore, an alternative solution was chosen. The budget for subcontracting was transferred from SCK•CEN to UPC. UPC hired Ariel von Barnekow, an ICT specialist with which UPC had good experience in the past. He will work fulltime on the development of the DCA during the whole PODIUM project and will also participate in the project meetings. This will allow us to stay within the budget, keep our time schedule and closely follow up the development.

Task 3.3: Development and updating of a test version of the software

The development of the online application has started in October 2018. Regularly new prototype versions with new features are being released. Development, version control and issue tracking of the source code is done in a Gitlab environment setup by UPC (fig. 3.1).

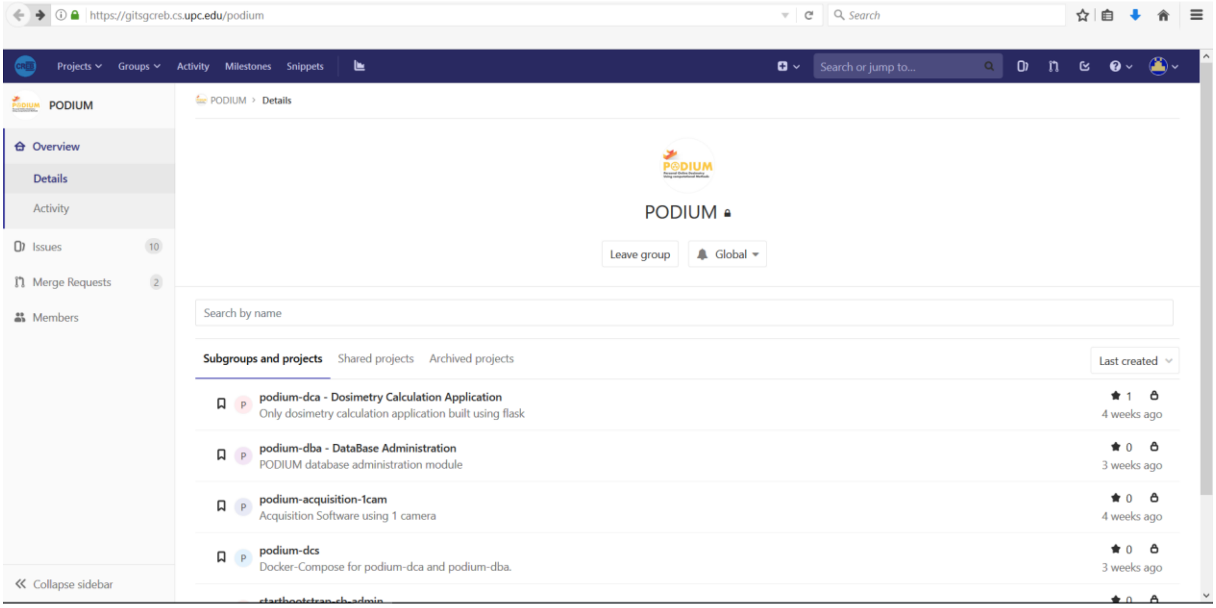


Fig. 3.1: *Gitlab environment for development, version control and issue tracking of the source code*

In December 2018, a second prototype version has been released. Many of the required functionalities of the online application have already been implemented:

- Login screen with different roles with different functionalities
- Creation of rooms
- Procedure handling: procedure creation, start/pause/resume/finish tracking, start dose calculation
- Procedures overview
- Administrator area for editing/creating/exporting data in the database
- Uploading of radiation source log

As an example, fig. 3.2 shows one of the screens for procedure handling. The remaining required DCA functionalities are now being implemented.

The external technical modules that are currently being developed by different PODIUM partners will also need to be integrated within the DCA. For this, the application will make use of so-called runners. A runner executes tasks on external modules using information provided by the DCA. The runners communicate with the DCA through HTTPS by using an Application Programming Interface (API). The API is used to register the runners and to obtain and store data in the database. The communication is always from the runners to the DCA. At regular time intervals, the runners poll for required operations.

The development and integration of the external technical modules is quite challenging. To facilitate the process, an example runner is now being developed which can be used as a starting point for developing the runners of the different technical modules. In addition, an Excel sheet was setup to clearly define the responsibilities for the development of the technical modules. This Excel sheet is also used to define the data flow within the application. This will help in clarifying which data are required and in which format as input for the different technical modules and thus have to be provided by one of the other technical modules. This information is also essential for setting up the structure of the database, which will be based on PostgreSQL.

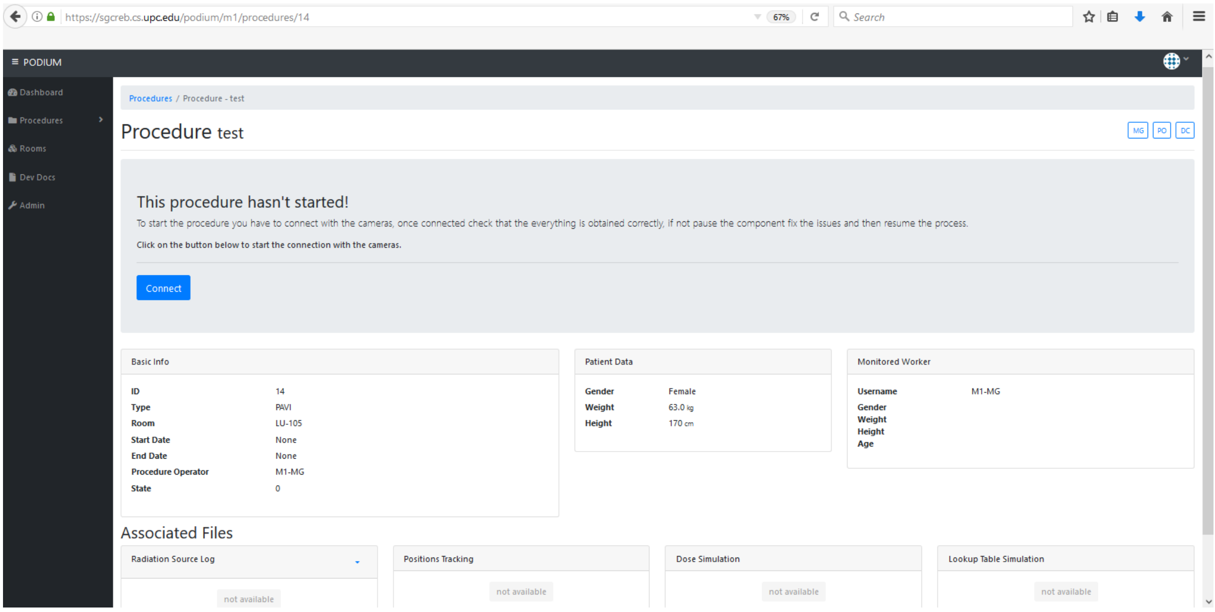


Fig. 3.2: *One of the DCA screens for procedure handling*

Task 3.4: Development of a final user-friendly version of the software

This task will only start in the final stage of the PODIUM project.

5 WP4: Assessment and validation of the online dosimetry application in hospitals

The work package concerns validation of online dosimetry in interventional radiology, the field of medicine for which the system may be particularly useful. The work package consists of three tasks.

Task 4.1: The validation of the application in a controlled experiment set-up in a hospital.

The first task (4.1) - preparing to be able to perform measurements in hospitals - has been completed. The first challenge was to establish contact with managers and clinical staff to access equipment and make measurements in the clinic. Another challenge was to get ethical approval for the clinical studies. Ethical approval for clinical measurements has been obtained for the participating hospitals in Sweden and Ireland. A significant amount of work has been done to communicate with the clinical staff to establish good relationships. These tasks are crucial for the success of the project.

Within this task, a validation plan has been developed. The validation process - how to perform the sub-tasks and when the different subtasks are to be performed are defined in this plan. The plan also includes sharing the main tasks for partners participating in the work package. The validation plan is given in Figure 4.1.

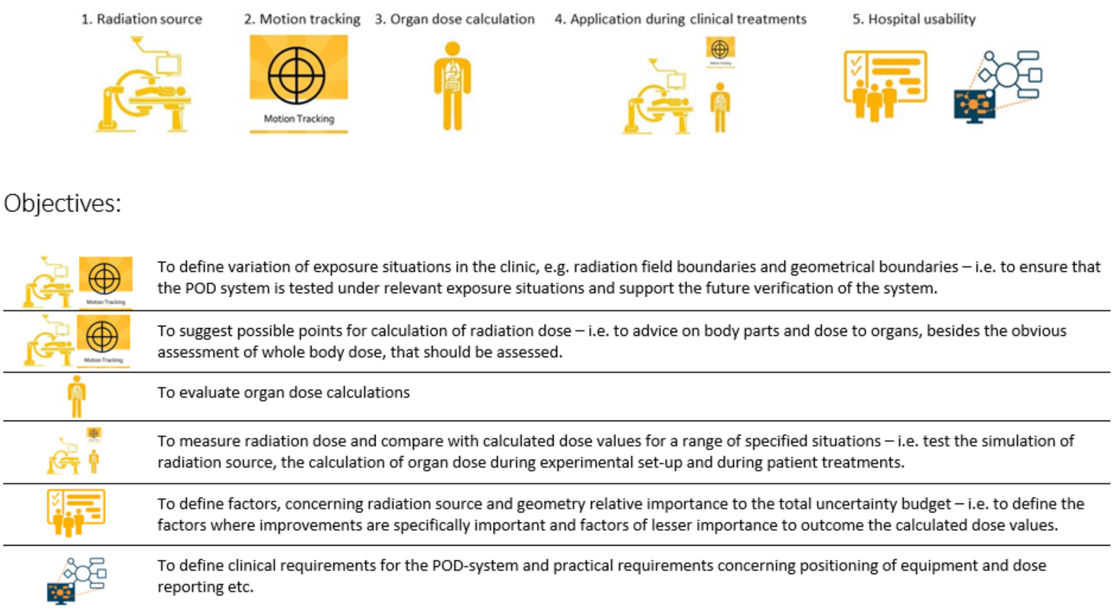


Figure 4.1*: Validation plan*

A series of experiments have been conducted to test the IPS system in a systematic manner. These experiments have been performed using the second version of the system. Some parts of the system have been tested in the clinical environment but not the entire online dosimetry application as it is still in development.

The indoor positioning system has been tested on site in hospitals in Belgium and Sweden. The following issues have been identified:

- <u>Camera positioning is crucial</u>. A standardised optimised position has been difficult to identify, as each procedure room is unique. Therefore, careful instructions must be developed if the positioning of the current technical solution is chosen. The working range of the camera - including an assessment of the uncertainty - is about 5 meters. This can be a limiting factor for some clinical applications as these are performed in large operating rooms.
- <u>Each operator should be uniquely identified</u>. The system must be able to consistently track the person of interest, even if occlusion occurs or the person leaves and returns to the camera's field of view. This is a small issue for standardised treatments such as cardiac treatments, where the operator and assistant staff work in a static way. However, for other types of treatments, the clinical team consists of several people work in more dynamic processes and their identification can be a problem.

The availability of data for the estimates of scattered radiation has been investigated, including information from suppliers and several hospitals. Technical parameters of X-ray equipment are crucial for calculating scattered radiation, but also for defining coordinates to define the scattered radiation positions in space. In this context, data variation during the clinical treatments has been confirmed. The number of irradiation events may be several hundreds during a treatment and the technical data may vary at each event. This variation has been studied on a small scale together with the investigation of the quality of the data itself. The technical parameters that define X-ray energy distribution, field size and radiation dose appear to be retrievable and easy to use. However, one factor that needs to be further investigated is the geometric data from the X-ray machine - such as the couch position etc. This information is required to get the position parameter of the irradiated volume, which in turn is necessary to define the operator's relative position in the spread field. These data do not seem to be readily available from the X-ray device. This issue is schematically illustrated in figure 4.2.

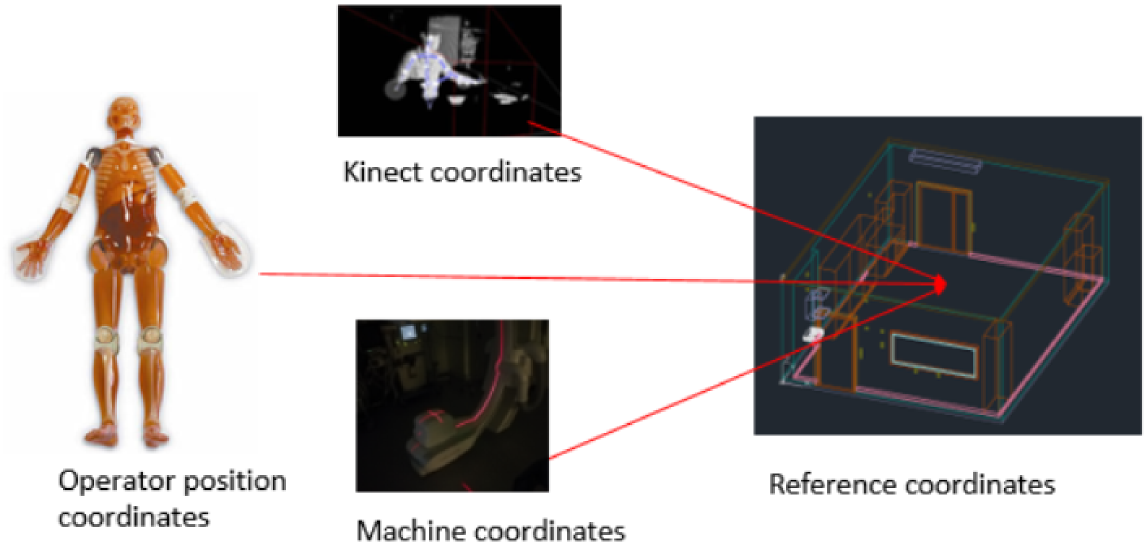


Fig 4.2. *A schematic illustration of the issue creating reference coordinates from different data sources.*

Experiments, where anthropomorphic phantoms have been used for the operator and patient have been performed. During these experiments, detailed measurements have been conducted for different positions with both active and passive dosemeters to validate the calculated doses. The results are not complete yet. The results will be included in the delivery report that covers this task due M14 (D4.1). This part of the validation will provide information useful for improving simulations, source specification and geometric mapping.

Task 4.2: Perform feasibility study during patient treatments in the hospital

Small-scale measurements during patient treatments in Belgium and Sweden have been performed. These measurements have not been evaluated yet. A full-scale feasibility trial in clinical settings under real patient treatment in hospitals is currently being planned. Two categories of procedure ((i) Interventional Cardiology (Coronoary Angiograms (CA) or Percutaneous Coronary Intervention (PCI) and (ii) Endovascular Aneurysm Repair Treatment (EVAR)) have been selected for the feasibility study. The measurements will be performed in University of Lund and at St James Hospital in Dublin. The staff will use both active and passive dosemeters – the type and number have been discussed – at the relevant locations of the operators. These clinical measurements are necessary to gather appropriate information on the performance of an online dosimetry application at the hospital.

Task 4.3: Identify future improvement needs

The experimental and clinical tests will indicate developmental needs to obtain the full clinical relevance of the online dosimetry application. This will only begin in the final phase of the PODIUM project, but contributions to this task are ongoing.

6 WP5: Assessment and validation of the online dosimetry application in mixed neutron-gamma workplace fields

Objectives

The main aim of this work package is to perform a proof-of-concept study of the online dosimetry in a mixed neutron-gamma workplace field. The work is divided into four main tasks. Firstly, the possible fields used to test the system were identified. Secondly, the optimization of the tools will be done in a simulated field representative of a workplace, before then moving to a real workplace. Finally, online simulations will be tested to evaluate their accuracy with present computational tools. Progress in the first two tasks is described below; the third and fourth tasks will progress mainly in the second year of the PODIUM project.

Task 5.1: Selection of the real and simulated workplaces that are to be used

To be useful to the PODIUM project, the fields in which the system is tested need not only to be representative of real workplaces but also have relatively high dose rates to facilitate measurements. Real neutron workplace fields are also mixed, so dosimetry of both the neutrons and photons will need to be performed in parallel. At the proposal stage, it was realised that the first stage of the experimental measurements needed to be one with guaranteed access, so a modified calibration laboratory at PHE was selected.

Simulated workplace field at PHE

The PHE neutron calibration laboratory is a low-scatter environment routinely used to perform Secondary Standards certified exposures to an ^{241}Am-Be source, and is readily accessible and modifiable as required for the purposes of PODIUM. To generate a field more representative of a workplace, water shields were used to moderate the source. These shields only partially obscure the neutron source, so there are significant dose rate and field hardness gradients in the room: the field is a mix of fast neutrons from the partially moderated source, and lower energy neutrons from scatter with the shield and calibration room, making the environment dosimetrically interesting from the perspective of testing PODIUM. It is representative of typical reactor and nuclear fuel cycle fields where the moderation is optimised.

A schematic of the moderator set-up is shown in Figure 5.1. The room is of dimensions of 8.1 (l) x 5.2 (w) x 2.7 (h) m^3, which is coverable by two Kinect cameras placed in opposite corners.

Real workplace

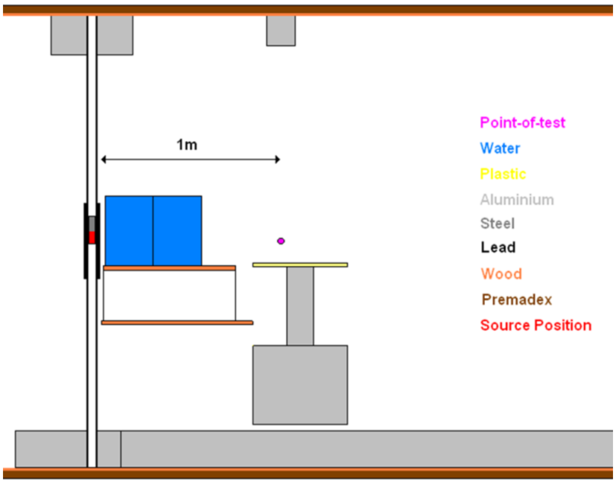
The options for real workplaces were reviewed, with many possibilities considered and contact made with a number of potential sites within the nuclear, security and medical sectors. Some of the options were unsuitable due to energy characteristics or dose rates; for those that were considered dosimetrically suitable, security issues would have made access too problematic. For these reasons, the real workplace field selected was that around a fuel flask at SCK-CEN: this has significant neutron dose rates, a geometry that is suitable for PODIUM in terms of worker movement and the Kinect system, and is relatively easy to access by members of the PODIUM consortium.

Real time calculations in workplaces

Effective dose is the primary quantity required for the PODIUM system. The options for performing coupled neutron-photon calculations of effective doses in a realistic workplace have therefore been reviewed. The conclusion is that the current status of computing capability will not permit this in real-time, because: the CPU and memory requirements for neutron Monte Carlo are too high; it is not possible to use GPUs with current neutron Monte Carlo codes; and it is not possible to calculate neutron effective doses directly using anthropomorphic phantoms embedded into a facility, due to problems associated with correctly assigning radiation weighting factors.

Instead, other ways of achieving the same outcome have been thoroughly investigated. As a practical solution, the favoured approach for a system that could be used for online dosimetry incorporates “look-up tables” of dose rate maps that will be dependent on the location and orientation of the individual and, in the future, also potentially on their posture and stature. The intention is that the position of the centre of the individual and the direction in which they are facing will be tracked in real time, and will be ‘snapped’ to the closest position and orientation that is defined on the adopted grid. The data at that point on the field map will then be used to derive the dose to the individual for the duration for which they can be considered at that location and orientation. Methods for generation of these dose rate maps for the simulated and workplace fields is therefore a major objective for the work package.

Figure 5.1. *The PHE calibration laboratory, with water tank moderators used to produce a field at the 1 m reference position similar to a nuclear power plant*.



Task 5.2: Study using a simulated workplace field in a calibration laboratory

The overall goal is to demonstrate that the PODIUM method can improve current personal dosimetry techniques for mixed neutron/photon fields. Task 5.2 has split into two inter-dependent sub-tasks: Monte Carlo modelling of the PHE simulated workplace field to produce sets of dose rate maps; and measurements in the field to contrast and corroborate the modelled results. In fact, several dose rate maps are of interest, relating to different relevant dose quantities:

- Ambient dose equivalent, to compare against data measured using neutron survey instruments;
- Photon air kerma, which can be compared against measurements by ionization chambers;
- Personal dose equivalent, which can be compared against on-phantom measurements using personal dosemeters;
- Effective dose, which is the primary quantity required for the PODIUM look-up tables, but cannot be evaluated non-computationally so cannot directly be compared with measurements.

The modelling was performed using MCNPX (Pelowitz 2005) and MCNP6 (Pelowitz 2013). The simulated workplace field developed at PHE incorporates an 241Am-Be source located at 1.25 m from the floor of the facility, so this provided an obvious natural height at which to produce the dose maps. The modelling and measurements used a regular 1 m $\times$ 1 m grid of points extending over the whole calibration room.

Ambient dose equivalent rate, Ḣ*(10)

The total ambient dose equivalent rate has been determined at each location of the grid. The primary motivation for this was to corroborate the model using measurements: if the *H**(10) map can be verified, it gives confidence that the effective dose map may be reliable. The final *H**(10) map (Figure 5.2) shows strong dependence of the dose rate on location, with the water tanks significantly perturbing the field as anticipated.

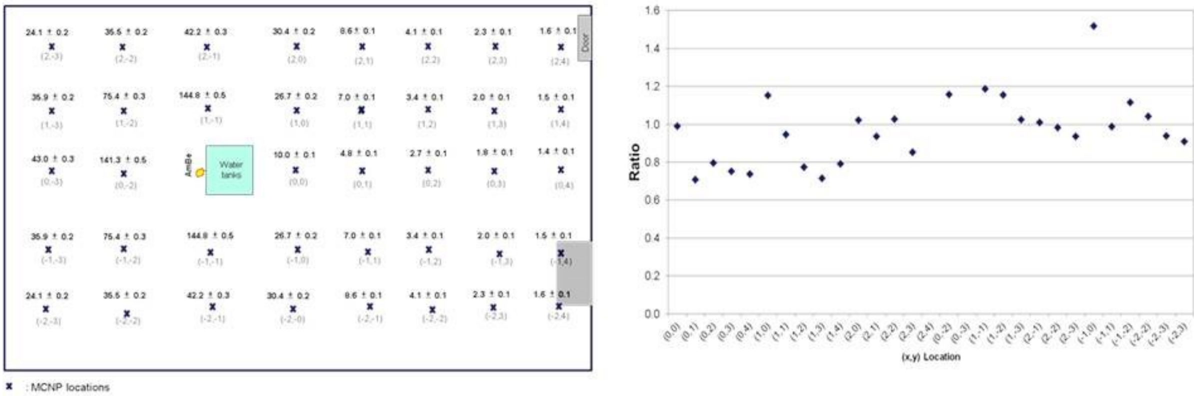


Figure 5.2*. (Left) Modelled H*(10) dose rate map at a height of 1.25 m; quoted uncertainties are one standard deviation on the MCNP result. (Right) Ratio of the MCNP calculated H*(10) neutron rate to the measured H*(10) rate. The measured data are the average of the GNU and Tracerco T405 results.*

Validation of the modelling at all points on the *H**(10) grid map has been obtained using a set of survey instruments, three for neutrons and one for photons. These were: a Guided Neutron Unit (GNU) (Eakins, Hager et al. 2017); a Tracerco T405 (Leake, Lowe et al. 2004); a Ludlum Model 23-63/ Prescila (neutron and gamma) (Olsher, Seagraves et al. 2004); and a Tracerco T406 for photons. Generally, there was relatively good agreement between the various results for the measured neutron *H**(10) dose rates, with some differences exhibited due to the different constructions (and hence response characteristics) of the instruments. The measured photon dose rates were too low in places to determine statistically valid results, with the highest being ~7% of the neutron dose rate.

The measured results generally showed good agreement with the MCNP results (Figure 5.2) for data corresponding to the averages of the GNU and Tracerco T405 measurements. There is one anomalous result where the MCNP result is over 50% higher than the measured result, which could reflect either a low measurement or a high MCNP result and merits further investigation.

Personal dose equivalent rate, Ḣp(10)

The PODIUM project outcomes will ultimately be compared with personal dosimetry. The exposure of personal dosemeters in the workplace fields is hence an important part of the project. Moreover, effective doses in the workplace can neither be measured nor calculated without applying approximations, so exposures of personal dosemeters provide the best available surrogate.

To calculate the personal dose equivalent map, a 30 cm x 30 cm x 15 cm slab of ICRU 4-element tissue was located and orientated as required, and the average kerma factors and quality factor method of Siebert and Schuhmacher was applied (Siebert and Schuhmacher 1995). The $H_p(10)$ rate for both the front and rear of the slab was calculated, simultaneously representing either AP or PA exposures of individuals facing either towards or away from the source. In the measurements, the slab was replaced by an ISO water-filled slab of the same dimensions, with dosemeters placed on its both front and rear faces. Two types of neutron personal dosemeters were exposed: the PHE PADC passive neutron dosemeter, and the Thermo Fisher EPD N2 neutron / photon active dosemeter. The low sensitivity of both types of dosemeter has so far limited the number of locations that can be used for experimental determinations to three, for which Monte Carlo data were in turn also determined for comparison.

The results for the PADC and EPD N2 at the three locations have been compared with the MCNP results (Figure 5.3). In general, the modelled data agree with the PADC measurements to within a few 10s of percent, which is encouraging, but less well with the EPD results. This latter observation is perhaps as anticipated, because the EPD is expected to exhibit a poorer response in the PHE set-up, and demonstrates one advantage of the PODIUM approach relative to the use of physical dosemeters. However, the lack of agreement for photons could also indicate a limitation in the model for that component of the field. Additional $H_p(10)$ measurements for photons have therefore be made using the PHE β/γ thermoluminescence dosemeter (TLD), which incorporates Harshaw TLD700H ^{7}LiF:Mg,Cu,P and is routinely issued to provide accurate estimates of photon personal dose equivalent. These latter results will be analysed and compared in due course.

Effective dose rate Ė

Due to the difficulties in calculating effective doses precisely in real workplace fields, a number of different methods and approximation schemes have been trialled in order to provide a workable solution. The approach finally chosen employs a system based on defining tallying cones to limit the fluence contribution to a restricted direction. Several planes and cones are then used to determine the various fluence components (Figure 5.4), from combinations of which effective doses may be derived; a family of calculations is thus performed at each location on the grid. This compromise approach will be reviewed fully for accuracy in due course, but the calculations currently require more conversion coefficient data from WP2 before they can proceed further.

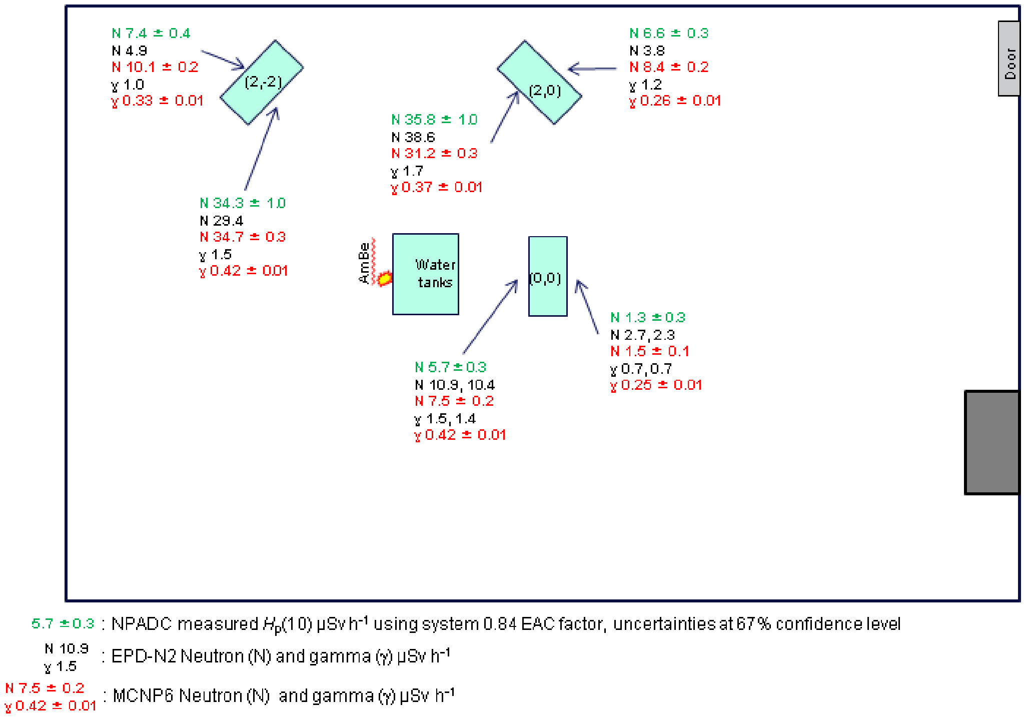


Figure 5.3.*Measured and modelled H_p (10) rates at three different locations and orientations within the PHE simulated workplace field.*

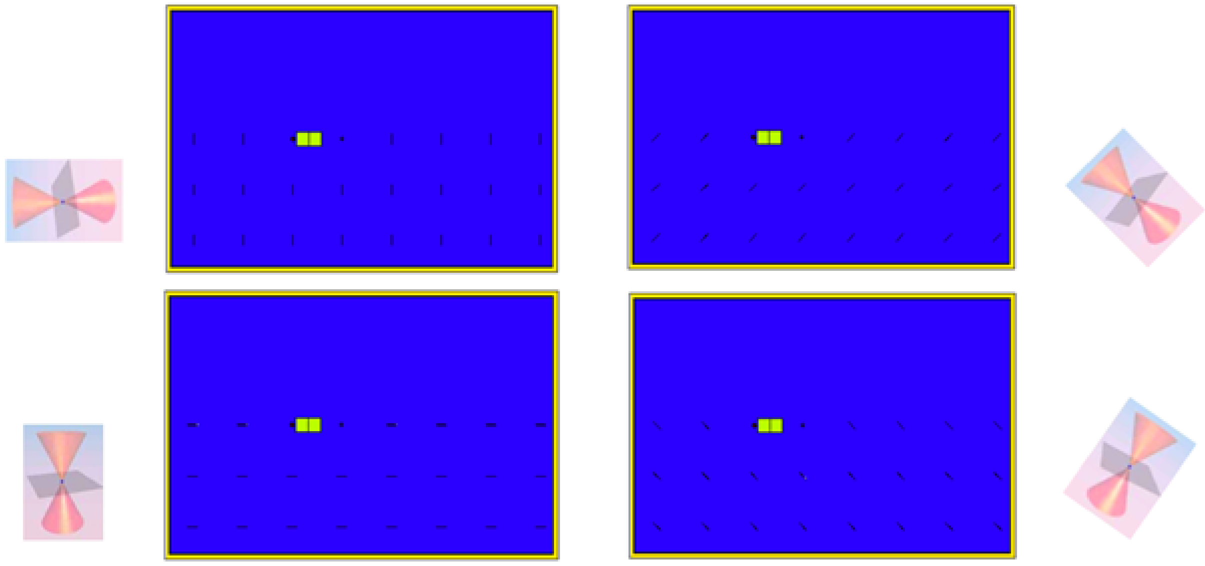


***Figure 5.4**. Modelled geometries of the PHE simulated workplace fields, showing a 1 m $\times$ 1 m grid of tally discs, upon which angle binning is achieved using forward- and rear-facing cones to build an effective dose rate map as a function of location and orientation.*

Summary

Much effort has been directed at determining whether real-time calculations are feasible for neutrons. In the absence of any exact solution, a look-up table approach is therefore instead proposed for use within the PODIUM system. A protocol for the estimation of effective dose rates has been established to generate the data necessary to populate these tables. In preparation for this, and to contribute to an analysis of its accuracy, the PHE calibration room with the water moderators has been characterised via measurement and modelling. The initial results for the ambient dose equivalent and personal dose equivalent calculations versus measurements are generally encouraging, with further work planned to investigate the few discrepancies.

Evaluation of a Kinect tracking system in the PHE simulated field will commence shortly, in parallel with analogous characterization and testing in a real workplace field, i.e. around a fuel flask at SCK-CEN (Task 5.3). Fuller analyses of the PODIUM system for mixed neutron/photon dosimetry can then be performed (Task 5.4).

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7 WP 6: Dissemination of the project results

A dedicated Work Package is set up in the project in order to achieve the maximum impact of the online application in combination with the ALARA principle in occupational dosimetry. The tasks of this work package and the respective progress is described below.

Task 6.1: Advisory board set up

An advisory board has been set up in order to guide the orientation of the project and to assess its implementation. Representatives from European and international organisations, (HERCA, EC, ICRP, and ILO) with experience in dosimetry and occupational exposure were contacted to give input and guidance to the project partners. The board members that have accepted the invitation to be part of the advisory group are:

- *An Fremout from Federal Agency for Nuclear Control (Brussels, Belgium)*
- *Stefan Mundigl from European Commission (Luxembourg, Luxembourg)*
- *Shengli Niu from International Labour Office (Geneva, Switzerland) and*
- *Volodymyr Berkovskyy from Ukrainian Radiation Protection Institute (Kyiv, Ukraine)*

Upon their acceptance, they were informed in writing about the progress of the project and invited in a meeting with the WP leaders. The meeting was held in Malmö, Sweden, on 7th of November 2018, one day after the 3rd Podium meeting. A draft outline of each work package focused on the progress was presented to the Advisory group. A detailed discussion was held afterwards with. Minutes were kept so that all partners are informed of the Advisory's group comments and more specifically about their ideas on the problems discussed and the possible solutions.

For the future, the plan is that there is a close contact with the Advisory Group and they will be invited in the project's workshop to be held in Athens in November 2019.

Task 6.2: Exploitation plan

The results of the project will be incorporated into an application, which will be useful for on line personal dosimetry in different fields. The consortium will set out a roadmap for the further development of the application. Contacts have been made with a commercial company (RayXpert) and a research group from Strasbourg. The status of the PODIUM project to date was presented. Some initial ideas have been exchanged and the communication will be enhanced as the project is progressing. The business development group of SCK-CEN will also be involved in this task.

An initial action plan for the exploitation plan has been drafted and a task group for this specific task has been formed in order to progress with this task.

Task 6.3: Establishment of approval criteria for online dosimetry as legal dosimetry methodology

Within this task, an action related to finding criteria for the approval of online dosimetry as legal system has been initiated. Up to now, there has been a collection of various approval criteria of dosimetry services in many counties. This action was discussed in depth during the meeting with the advisory group. The output of the discussion needs to be incorporated into the next project meeting.

Task 6.4: Preparation of a 2-day workshop

The main aim of the workshop will be to present the advantages of online dosimetry systems in routine practice in the framework of the ALARA principle. The Project coordinator and WP6 leader are in contact with the European ALARA network in order to jointly organise a workshop in Athens. The workshop is planned to be held in Athens by the end of November. The 1st announcement has been drafted and will be distributed shortly.

Task 6.5: Scientific dissemination (EEAE, all) (M12-24)

To date, one presentation of the project has been made in the 3rd European Radiological Protection Research Week Rovinj, Croatia, 1-5 October 2018.