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Article

Overview and main achievements of the EURANOS project: European approach to nuclear and radiological emergency management and rehabilitation strategies

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ABSTRACT **In June 2009, the 5-year multi-national project EURANOS, funded by the European Commission in its 6th Framework Programme, reached its end, achieving most of the objectives addressed in the work programme. Partners from 23 European countries integrating 17 national emergency management organisations with 33 research institutes, aimed to enhance the preparedness for Europe's response to any radiation emergency and long term contamination. Three handbooks to assist national and local authorities in the management of contaminated food production systems, inhabited areas and contaminated drinking water resources in Europe were developed in conjunction with a wide range of European stakeholders. Further guidance was prepared to support the decision making team in the lifting of early phase countermeasures. A governance framework for the sustainable rehabilitation of long term contaminated territories was developed and tested in France and in Norway. Considerable progress was made in developing a consistent set of models for calculating the best estimate of the current radiological situation in both contaminated agricultural and inhabited areas. These models were integrated in both the ARGOS and the RODOS decision support systems. Decision aiding components were improved to support the selection of management options with the help of multi criteria decision analysis procedures. A mass consistent wind field model was implemented together with a particle model for complex terrain. The migration of RODOS (Real-time On-line Decision Support System) to the operating system LINUX was completed. RODOS was completely re-engineered, taking into account the users' recommendations from the demonstration projects and feedback from its operational use. This new version will build the kernel for the operational RODOS release in 2010 and new research activities related to the future improvement of RODOS.**

1. Introduction

With the emerging nuclear power generation, safety and security of nuclear installations became an European wide area of national and international research

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activities. In particular under the various European Framework Programmes, research activities were initiated to assure state of the art knowledge in emergency management. Despite the fact that considerable progress was made in the 1980's and 1990's, many of these developments were still not fully operational or disseminated all over Europe in the early years of this century. As a consequence, the EURANOS (European Approach to Nuclear and Radiological Emergency Management and Rehabilitation Strategies) project was initiated to increase the coherence and effectiveness of nuclear and radiological emergency management in Europe including the rehabilitation of contaminated areas. The project involved the establishment of an effective working platform of emergency management institutions, Research and Technological Development (RTD) institutes, end-users and other stakeholders with responsibility for initiating application oriented improvements of methods, procedures, guidelines and IT tools, such as the RODOS (real-time on-line decisions support) decision support system (Ehrhardt and Weis, 2000). The project started in April 2004 and was successfully completed in June 2009.

2. Objectives

The ultimate goal of the project was ambituous aiming to develop products that can be applied by the operational community all over Europe in a consistent and harmonised way, reflecting state of the art knowledge, approaches and methods. In particular, cross-border emergency management and rehabilitation in Europe should progressively lead to the establishment of a European Policy in this area.

These objectives could only be realised when those responsible for nuclear or radiological emergency management and rehabilitation strategies within their countries, and the Research Institutes developing methods, IT tools and strategies for a more coherent and efficient emergency response, work closely together. In this sense, the EURANOS project, integrating 17 national emergency management organisations with 33 research institutes, brought together best practice, knowledge and technology (see Fig. 1). Countries not involved from the beginning were able to join the project at any time. The dissemination activities were specifically aimed at attracting more organisations/countries to participate in the project.

3. Work program

When designing the working programme of EURANOS, all potential instruments of FP6 such as research (RTD), demonstration and training, were applied. Demonstration activities, not present in Framework Programme 5 (FP5), played an

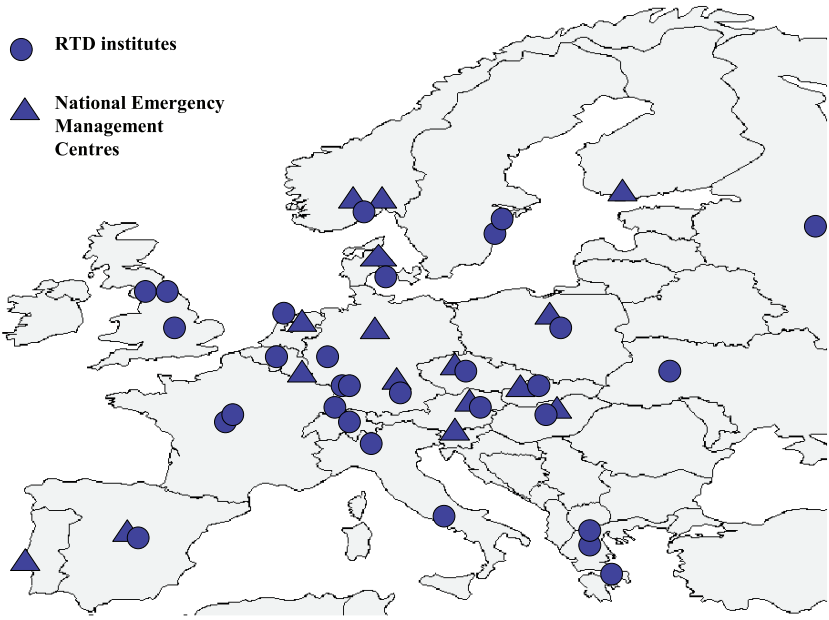

Figure 1 – ***European coverage of the EURANOS project.***

important role in facilitating the interaction between the operational emergency management organisations and the RTD institutes. This feedback was seen as one of the key elements for a successful completion of the proposed work plan as it immediately addressed the views of the operational community on the usefulness of the new methods, IT tools strategies and guidance (see Fig. 2).

The first demonstrations were carried out with those methods and IT tools developed under RTD projects and thematic networks of FP5, which either ended before the start of EURANOS or which overlapped with phase 1 of the work programme. Demonstrations continued in phase 2 with products developed within phase 1. Demonstrations were either carried out as implementation of the tool in nuclear power plants and national emergency centres, or as exercises performed during a given time frame with comprehensive guidance on how to evaluate the findings of the exercise.

The research activities have been subdivided into the following concurrent and closely co-ordinated categories:

- CAT1: all activities related to emergency actions and countermeasures;

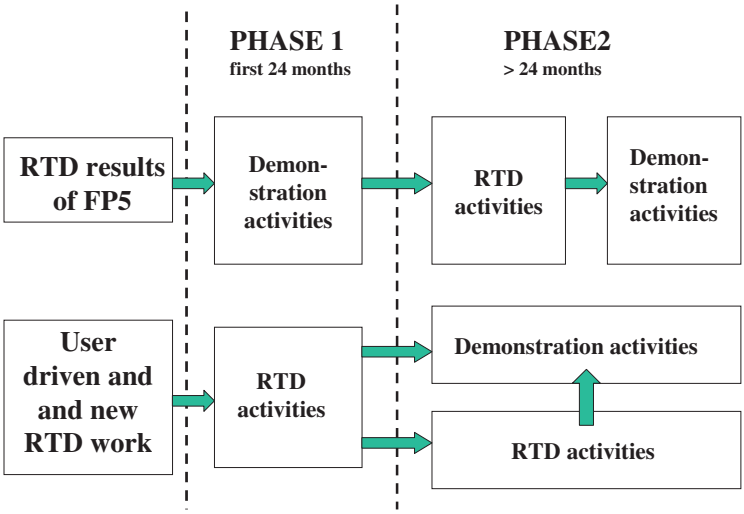

Figure 2 – ***Structure of the interaction between RTD and demonstration activities within phases 1 and 2 of EURANOS.***

- CAT2: all activities related to the further enhancement of decision support systems for operational application;
- CAT3: all activities related to rehabilitation strategies and guidance.

RTD activities, in particular the development of new tools were backed by integrated training programmes providing a sound basis for the use of such a new tool.

4. Management of the project

The management of a project with 50 partners required an efficient management structure. It distinguished the Project Co-ordinator, the Management Committee, the Category Managers of the individual RTD categories, the Demonstration Project Manager, the Lead Contractors and the Advisory Committee. In addition, for each RTD and demonstration activity as well as for the training courses, a Lead Contractor was appointed. The Management Committee (MC) was the kernel of the EURANOS management and the principle decision-making body of the project. The MC decided on and controlled the working programme, the RTD and demonstration projects, and all activities supporting the promotion and dissemination of the project achievements, such as training courses, emergency exercises, seminars and workshops. Being part of the MC, the Category Managers

acted also as interface between the Management Committee and the Lead Contractors of RTD activities. They maintained in particular a continuous oversight of the progress, resource allocation and costs of RTD technical work, demonstration projects and training activities and suggested actions in case of failure of individual contractors. The Demonstration Project Manager, also part of the MC, ensured consistency of goals and results of demonstration projects aiming at different technical issues. Finally, a Lead Contractor assumed the responsibility for co-ordinating an individual activity of the project, such as an RTD project, a demonstration project or a training course.

The MC was supported by the Advisory Committee, which provided an independent strategic look into the project, and advised on the focus or the changes necessary in order for the project to achieve wider objective and assure that the products of the project were suitable for applications.

Having implemented an effective management scheme, the complex structure of the work program and the large number of activities performed in parallel, necessitated additional management effort. The Management Committee introduced a formal risk management system clearly identifying any potential risks for the success of the project. A risk mitigation approach was developed together with a contingency plan. Important here is to mention that for all the risk identified, clear responsibilities were assigned and also indicators when the mitigation approach should be initiated. Having completed this formal risk management process, contingency planning focused on reducing the risk identified.

5. Results

5.1. Cat1: compendia of countermeasures and handbooks

Countermeasure compendia, developed within the FP5 projects STRATEGY (Howard *et al.*, 2002) (Sustainable Restoration and long-term Management of Contaminated Rural, Urban and Industrial Ecosystems) and FARMING (Nisbet and Mercer, 2004) (Food and Agriculture Restoration Management Involving Networked Groups), were further developed within Phase 1 of the EURANOS project, by adding management options (countermeasures) applicable to the pre-deposition and early post accident phase. Datasheets for each management option were adapted to consider radionuclides of importance during the early phase of a nuclear accident (*e.g.* ^{131}I), as well as radionuclides relevant to other types of radiological incident (*e.g.* terrorist use of dirty bombs). Furthermore, compendia for food production systems were extended to consider management options for Mediterranean areas and Fennoscandia.

To assist decision-makers in their choice of options for addressing future nuclear and radiological incidents, generic European handbooks for the management of contaminated food production systems and inhabited areas were developed. These provide guidance on how to select a subset of the most applicable management options on a site and incident specific basis. The handbooks were designed to be used as part of a participatory process involving the affected stakeholders. A first version of the handbooks were completed in 2006/2007 and distributed to interested end users. The handbooks are available from the EURANOS web site. A third document was developed in 2008 to provide guidance of the withdrawal of emergency countermeasures, specifically evacuation and sheltering.

Demonstrations were carried out during 2008 to determine the usefulness and applicability of the handbooks for situations where food production systems and inhabited areas become contaminated as a result of a radiological emergency. Emergency centres not involved in the development of the handbooks were invited to participate in the demonstration activities. Emergency exercises or similar events based on scenarios involving contamination of the food chain or inhabited areas were used. Demonstration activities based on the application of both handbooks in emergency centres concluded that the handbooks were useful for the purposes of contingency planning and accident management but to realise their full potential they should be customised at national, regional and local levels. Feedback on the content of the handbooks was positive with constructive criticism given on how to improve their navigation, structure and format. A need for glossaries and quick guides were identified. For the handbook on food production systems, there were also requests for the inclusion of worked examples, checklists for planning in advance of an incident and the provision of more information on monitoring and measurement strategies. Feedback from the demonstrations also recommended that the drinking water section of the inhabited areas handbook be made into a stand-alone document. All of the key improvements highlighted during the Demonstrations were taken into account and included in version 2 of the handbooks.

A handbook users group was established to serve as a focal point for collecting and assimilating the feedback from the demonstrations and to be a dissemination mechanism related to all aspects of the handbooks.

5.2. Cat2: enhancement of decision support systems

5.2.1. Modelling in food production and inhabited areas

Work performed here concentrated on completing a consistent methodology for calculating the best estimate of current radiological situation in both contaminated

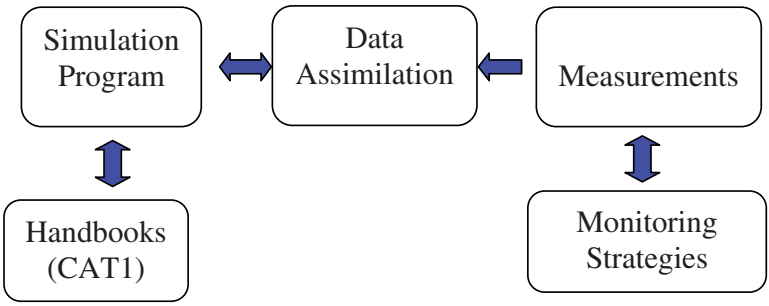

Figure 3 – ***Holistic approach for the modelling of countermeasures in the later phase.***

agricultural and inhabited areas. The underlying approach did not only consider simulation models but tried to include also information from data assimilation and monitoring strategies, with input on countermeasures from the compendia and handbooks developed under CAT1 (see Fig. 3).

A new state of the art model framework – the European model for inhabited areas ERMIN has been developed and completed. ERMIN brings together a number of models and datasets. Embedding an actual transfer model within ERMIN is one of the main reasons that ERMIN is more flexible than existing systems that rely on predefined libraries of results with a necessarily limited number of countermeasure strategies available. The modelling of indoor weathering and resuspension, long term retention on outdoor surfaces and the modelling of retention of material on and doses from trees are improvements over existing models.

Similar to the inhabited area model, a model for agricultural areas (AgriCP) was developed aiming to provide a much higher flexibility in defining countermeasure strategies than any model has realised so far. This has been achieved by integrating the countermeasure simulation engine into the physical modelling complex of the foodchain module. As new feature, feedback of an agricultural countermeasure on the estimation of the radiological situation has been realised (*e.g.* increasing contamination of feed- and foodstuffs through dispersion of contaminated products like milk in agricultural areas). This required a re-calculation of the activity contamination once the countermeasure is selected. Having implemented such an option in AgriCP, the assessment of waste options will be possible for some foods in future.

Integration of both models into the RODOS and ARGOS (Hoe *et al.*, 2002) decisions support systems has been completed in a first version as part of the overall project.

5.2.2. Data assimilation

Data assimilation combines monitoring information with results from simulation models. Data assimilation tools were developed in the recent years and prototype version of two modules to update the deposited activity and food contamination, were implemented into RODOS. Both data assimilation models have been further developed in the project and their methods were made more robust against erroneous input as only this robustness can assure that the user applies properly these methods in case of a real emergency. However, the final product is still far from operational use, but available for test-operational application.

A data assimilation pre-processor for the inhabited area model was developed allowing to either combine measurements and prognostic information as input to the inhabited area model ERMIN or applying geo-statistical methods to interpolate monitoring information for the further use in the ERMIN model.

During plume passage, the project aimed at developing a methodology that allowed the atmospheric dispersion model the assimilation of the moving cloud. Being successful with tests for simple dispersion situations, complex scenarios and a too course monitoring network prevent so far the operational use of this approach.

5.2.3. Decision aiding components

The decision aiding component, Web-HIPRE (Hämäläinen and Mustajoki, 1998), is an integral part of the RODOS system using results from the late phase models ERMIN and AgriCP to support the decision making team in sorting out the best possible measure for a given situation. The tool can integrate hard facts derived from the RODOS system with soft factors such as socio-economical factors, constraints, feasibility aspects and preferences of the decision making team as its application is an iterative and interactive process.

Improvements were realised mainly in the two areas. Guidance was developed in the decision making for longer term aspects (up to several years) as there decisions taken early might have influences on decisions taken later (sequential decision making). Since such decisions are not always taken independently, but are nested in a series of related decisions, dependencies were derived for the inhabited areas and agricultural countermeasure options. Second, for the first time,

uncertainties which are visualised in RODOS in the various simulation modules and communicated to the decision making team.

5.2.4. Operability of the RODOS system

Besides the many individual research activities identified in the beginning of the project, the improvement of RODOS to a fully operational emergency management tool was one of the key objectives of the EURANOS project. To facilitate this task, the RODOS Users Group (RUG) has been established as a discussion and interaction forum for co-ordinating and managing activities related to the demonstration and enhancement of the RODOS system and for providing essential feedback to the developers. The first result of this communication was the migration from the HP-UX operating system to Linux, which builds a sustainable platform for the forthcoming years. Based on the experiences from this migration process, the end users requested further efforts to assure the full operability of the system:

- In a first step a newly structured user interface was developed using state of the art IT technologies with its implementation in JAVA (object oriented programming language). This new interface facilitates direct error management of the user's input and guides him through a series of easy to understand input frames.
- In a second step a complete re-design of the RODOS system has been initiated, focusing on modern IT-technology and enhancing the system to be used as an information platform for tools related to emergency management and rehabilitation.

The re-engineering process resulted in a first prototype that was distributed to the end users at the end of the EURANOS project. The demonstration of this prototype clearly demonstrated the potential of the new version and it was agreed by the end users. The new Java Based RODOS version (JRODOS) will be the basis for any future further development of the operational system. The delivery to all interested end users will be completed in 2010, following rigorous testing of the system in the German emergency centre for at least 3 months under operational conditions.

Besides the improvements in the operational applicability, new simulation models were also developed and integrated into RODOS. This comprises an atmospheric dispersion model for complex terrain, an improved wind field modelling and extensions of the data base and models to cover radiological events and transport accidents. With the new wind field and the particle model, it is now possible to apply the RODOS system also in complex terrain such as in mountain areas or even the Alps with Swiss NPPs located there. An extension of the existing Gaussian type transport and dispersion model allows to perform calculation for

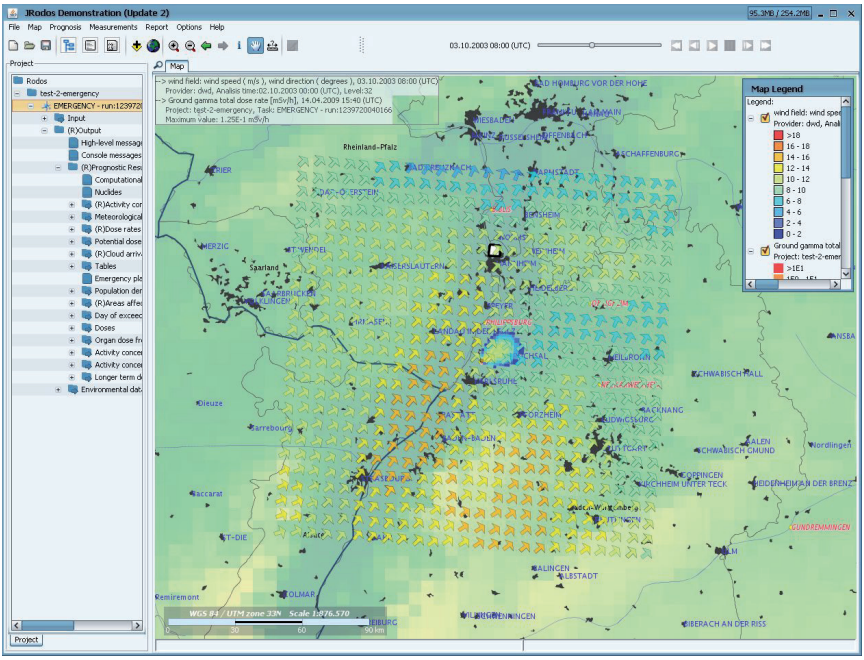

Figure 4 – ***Visualisation of the dispersion of a radioactive cloud together with its underlying wind filed in the re-engineered RODOS system.***

several hundreds of kilometres and in this way improves the operability of the system for releases from neighbouring countries.

Also the long range atmospheric transport and dispersion model in RODOS was further improved being now able to consider weather forecast data from many national and international providers, using further information from these data sets, running now with an extended set of radionuclides and finally has an interface to the source term module in the same way as the near range dispersion models.

A first attempt was also made to expand RODOS for the use for transport accidents and radiological events such as the explosion of radiological dispersal devices (RDD), however, this was limited to an extension of the data base containing now nuclides which might be relevant for the use in a RDD event and the extension of one dispersion model with a sub-module describing the initial blast of an explosion in terms of explosive equivalents.

5.3. Cat3

The governance framework developed for the sustainable rehabilitation of long term contaminated territories has been tested in a pilot study implemented in the French context where authorities and experts are questioning and reconsidering their strategies and operational tools for post-accidental management. The objective of the Pilot Study was to take advantage of this situation to initiate and accompany a process of change involving local and national concerned parties with the objective to give the ability to potentially affected French territories to contribute actively to the development of strategies and guidance for the sustainable rehabilitation of living conditions in case of long term radioactive contamination. The implementation of this first step in France and in Norway has been completed successfully. As results, a guidance document was developed supporting further European Member States to implement this framework in their own context.

The second step of the framework consists of the development of a national platform integrating national authorities and local communities with their respective stakeholders. This work has started in France. As part of the development of the French platform on rehabilitation, the work with the Community of Municipalities of Montbéliard in the East part of France was established with the objective to explore how it could be possible to adapt the EURANOS tools (handbooks, RODOS, rehabilitation framework…) to the needs of local communities. A recommendation for RODOS was issued at the end of EURANOS.

Finally, a users group for the long term rehabilitation (LTRUG) has been established with the objectives to provide information to interested parties, facilitate dialogue between members of the users group, diffuse the EURANOS Framework for long term rehabilitation preparedness and act as a focus for exchange of experience on this issue.

5.4. Demonstrations

Close to 20 different demonstrations were carried out on CAT1 and CAT2 methodologies and tools. In the first phase, the demonstrations focused on either tools developed in FP5 such as source term estimation from in plant data, visualisation of real-time data, data exchange between neighbouring countries, user requirements and user interfaces.

In the second period, the decision aiding component, the usefulness and applicability of the hydrological model chain and the application of the MOIRA

system (Monte *et al*., 2009) for the long term contamination of water catchments were demonstrated by the end users. Further demonstrations focused on small scale applications dealing with releases other than from a nuclear power plant and the two handbooks on assisting in the management of contaminated food production systems and contaminated areas. In these demonstrations of the generic handbooks not only the final product was exercised but also the process how to establish the best environment for the usage of these handbooks. This comprises the set-up of stakeholder panels which are an integral part of the successful application of the handbooks following a nuclear or radiological emergency. The two handbook demonstrations provided valuable feedback for the further improvement of the final documents available by the end of the EURANOS project.

The re-engineering of the RODOS system was also closely followed by the operational community and each prototype released was immediately examined by the emergency management centres. The final demonstration with more than 15 participants was devoted to the re-engineered RODOS system and provided some final feedback that will be considered in the next operational version of the system.

5.5. Training

Training was always an integral part of the EURANOS project. Training was used to promote and disseminate the project achievements. All end products developed within EURANOS were supported by training courses. In particular training courses for operators and users of decision support systems were either refined or developed from new. Feedback obtained from the participants was immediately included in the research activities when relevant. Training courses were conducted on the administration, operation and application of the RODOS system, on the evaluation tools and methods for supporting the off-site emergency management team and on strategies and guidance for the rehabilitation of living conditions in long term contaminated territories. In addition training on preparedness and response for nuclear or radiological emergencies was provided and forms the basis for any professional working in the area of emergency response.

The close relationship between research and the training courses resulted in the continuous update and refinement of the courses taking into account any new results from the RTD projects. This assured the outstanding quality of the proposed courses. In addition to the training program, a Web Site (http://www.eu-neris.net) was developed as a European portal for information and knowledge relevant for radiological and nuclear off-site emergency management and rehabilitation.

6. Conclusions

The EURANOS project clearly demonstrated the benefit of a large integrated project. Management of this project required an efficient management structure with a formal risk management system. The success of the project with 50 partners from 23 different countries involved in numerous RTD tasks clearly demonstrated the usefulness of such an approach and indicates its importance for any large scale research project.

The EURANOS project has achieved one of its major objectives in terms of establishing a European wide network, integrating operational emergency management organisations and the research community. This provides an ideal basis for better harmonisation and coordination of emergency management and long term rehabilitation in Europe for the future. Although the EURANOS project could not address the political level, harmonisation was reached to some extent by providing end products that can be widely used by the operational community. Of particular importance were the development of common tools and methods which were designed to be used all over Europe. This achievement is far beyond that which could have been reached by national projects.

The demonstrations and very strong user interaction has significantly influenced the structure and content of the work program and has resulted in a coherent system of inter-related components comprising:

– A set of European handbooks developed in co-operation with key end-users and stakeholders integrating the existing knowledge and know-how on all the instruments (methods, tools, procedures and guidelines) necessary for emergency and rehabilitation preparedness and management. These handbooks cover food production systems, inhabited areas and drinking water for all accident phases. Separate guidance on the lifting of emergency countermeasures was also produced in conjunction with a wide range of stakeholders.
– A robust and effective RODOS DSS for emergency and rehabilitation management structured in a way that it addresses the needs of the end-user with different interests and capabilities.
– An inclusive governance framework for both emergency and rehabilitation preparedness and management favouring the engagement of key end-users and stakeholders *i.e.* RODOS and non RODOS based emergency centres, authorities (national, regional and local), expert bodies, administrations (national, regional and local), professional bodies, NGOs.
– A demonstration programme and an international mechanism to regularly test the tools and governance processes developed within the RTD activities.

– A coherent and effective training and information infrastructure to ensure the transmission of the know-how to experts, professionals and authorities, and the diffusion of the relevant radiological protection culture within all segments of the society.
– A set of users groups for all the major products developed within EURANOS aiming to reach sustainability beyond the lifetime of the project.

The products and partnerships developed by EURANOS will extend well beyond the end of the project. Existing networks have been strengthened and the establishment of three users groups for the handbooks, long term rehabilitation and the RODOS system will continue to operate in future. Furthermore, at the final meeting of the project the vision of a platform on nuclear and radiological emergency management was presented and consensus reached to explore the establishment of such a platform following the end of the project. This will maintain the momentum of the successfully completed EURANOS project.

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