



**Summary of the NEA Workshop
on the Application of Remote and Robotic Systems
in Nuclear Back-End Activities
– Way Forward in System Implementation**

30-31 January 2019



BACKGROUND

With the progress of technology, robotic and remote semi-autonomous and autonomous systems are increasingly being used in radioactive waste management and nuclear decommissioning (nuclear back-end). Activities in radioactive waste management and decommissioning projects can be hazardous and occur in dangerous areas. Thus, robotic and remote systems have been developed to address specific technical needs that can solve this issue. As an example, for site characterisation, remotely controlled drones equipped with sophisticated sensors were developed to collect detailed information on site characteristics. Some operations in the process of dismantling and decontamination can be safer by using multifunctional robots with advanced mechanical or other types of tools, which reduce the need for staff engagement. Many projects on waste management and nuclear decommissioning have become safer and more cost-effective thanks to innovative techniques.

Different parties from various countries have expressed the need to organise an international dialogue to discuss amongst them on possible solutions to facilitate the way of the RRS from developer to the implementer. This dialogue can allow all parties to obtain a common understanding and to cooperate in finding a solution on the issue.

The findings and conclusions from this international dialogue can be a bedrock in the development of reports, standards and/or other tools, which will then be proposed to all parties as solutions to better implement systems.

The Nuclear Energy Agency (NEA) organised a workshop and invited a broad range of interested parties in response to the above. The parties were invited to identify the different factors influencing RRS application and to discuss possible methods to resolve these issues that can be applied in a potential international initiative.

SUMMARY WORKSHOP

Host: CEA (France)

Chair: Christine Georges (CEA)

About 60 participants:

(Slovak Rep., Japan, France, Germany, Korea, Italy, UK, Russia, Sweden, China, Spain, Belgium, Finland, EC, Israel, Korea and the US);

Represented:

decision makers, R&D, implementers, suppliers, regulators, users and other parties;

Sponsored by:

EDF (France), Orano (France), Magics Instruments (Belgium), NCNR (Birmingham University, UK)

Technical visit to the CEA Centre in Marcoule (29 January 2019)

On Tuesday 29 January, the workshop participants were invited to visit the CEA facility situated in Marcoule. Before the technical visit, the CEA presented itself and welcomed participants who attended the visit. Then, the workshop sponsors invited participants to their exhibition booths and briefly presented their activities in the RRS development area.

In the afternoon, the CEA presented its facility, samples of RRS and activities regarding the application of the RRS.

OBJECTIVES

The aim of the workshop was to initiate a broad international dialogue between interested parties to identify the different factors influencing the development and of RRS in projects on radioactive waste management, decommissioning and legacy management (the back-end of the nuclear fuel cycle) and to discuss possible methods to resolve these issues in an international initiative for the further application.

WORKSHOP ORGANISATION

The workshop was organised into three sessions

Session 1: «The global situation in the development/implementation of robotic systems in various back-end activities including post-accident radioactive waste management and decommissioning». Chaired by Michel Pieraccini (EDF).

This session intended to get accustomed to the different points of views on the current status of the development and implementation of robotic systems in managing nuclear decommissioning and radioactive waste management. The speakers of this session were invited to demonstrate Robotic/Remote Systems (RRS) development programs, products and applications. They were also invited to share with the audience what the challenges and lessons learned were while developing and implementing the RRS. Different involved parties such as system developers and end-users, regulators and others were able to present their vision of the situation and then discuss amongst each other.

Session 2: «Main factors influencing the implementation of robotic systems in the back end». Co-chaired by Rebecca Tadesse (NEA) and Rustam Stolkin (NCNR, Birmingham University).

During this session, the intention was to exchange opinions between the different parties (developers, users of RRS, decision-makers, regulators and others). The purpose of this session was to examine the main concerns and possible challenges in the implementation of RRS in back-end activities (including post-accident waste management and decommissioning) that could be improved then.

During this exchange of opinions, the participants were able to identify positive factors in implanting RRS. Implementing RRS could provide:

- improvement of economic parameters of projects in the nuclear back-end;
- efficient technical and organisational performance of operations in waste management and decommissioning;
- required or even more elaborated safety measures

Speakers and participants from national research laboratories and industries were able to share their inputs on how beneficial it would be for the development and deployment of robotic systems to integrate end-user guidance in the early stages of development. This would maximise the use of the system.

The participants suggested to open a wider discussing on the following:

- technical factors (e.g. harsh environment, technological challenges, unification, universalisation, reparability, handling, etc.);
- methodological issues (e.g. training, instructions, supporting documents, reproducibility and validation, commonality of terms, etc.);
- organisational issues (availability of skilled staff, corporate support to research/universities, a programme of staff preparation, etc.);
- economic aspects (cost, recoument, others);
- legal issues (e.g. existing regulatory framework and applicable regulations for developing remote/robotic systems; regulatory controls, standards and guideline that will facilitate the development of robots, regulation adaptation and bodies, revision of norms/rules, etc.);
- societal aspects (replacing human operators with machines, etc.);
- and other subjects that were related to the programme.

This session also discussed the regulations and legal requirements/factors that influence the extension of the application of RRS in the nuclear back-end.

Session 3: «International cooperation in the field of development and implementation of robotic systems». Chaired by Leonel Lagos (FIU, US)

The session focused on identifying different initiatives and programmes of cooperation in the area of RRS development that currently exist.

The goal of this session was to see if there was already a (current or established) international programme/initiative that addresses or could address the main challenges for the implementation of RRS in the back-end activities. The NEA Secretariat presented possible forms of the initiative under the NEA auspices.

DISCUSSIONS

The participants discussed potential ways for developing a common understanding on how to address final RRS users' main requests of and for making strategic decisions in order to support the RRS implementation.

The participants also talked about how economic efficiency, advanced technical and organisational skills and elaborate safety measure can be many positive outcomes in implementing RRS. The Workshop Participants emphasised the importance of establishing a common understanding and of harmonising the terminology and approaches in the development and application of RRS. Thus, highlighted the need for organising a dialogue at an international level.

In the first session (see programme¹) ...

... speakers presented to participants an overview of the status of developing and implementing RRS in the nuclear back-end. The RRS industry is connected to the nuclear back-end, and there is room for improvement of a dialogue between these two communities. Participants agreed that there is a need for harmonising and standardising many aspects.

It is still essential to pursue R&D in RRS and to demonstrate to users and other stakeholders (especially, at an international level) what their capacities are. It is also essential to consider existing samples and collected experiences to avoid reinventing the wheel.

Participants talked about possible danger in the handling of detected sources, contaminated areas, facilities and scrap metal yards. They identified plausible emergency situations that can occur such as fire, loss of RW package integrity, leakages and other cases and discussed the necessity to be ready for such incidents.

Furthermore, the participants agreed that to enable further development, it is important to take into account the regulators' views relevant to the RRS application and start a discussion as early as possible.

In regard to the financial and staff management aspects, the speakers and attendees of the workshop all agreed that RRS application should make the nuclear back-end activities "faster, cheaper, safer and less harmful to the environment".

In the second session...

...participants discussed in detail the negative and positive factors that can impact the RRS application.

Speakers from implementers presented and discussed with participants what their experiences and discoveries were from applying advanced remote and robotic systems. It is expected that the implementation of RRS can reduce risks for the personnel and be time and cost efficient.

What the operators have to endure through the repetitiveness of routines and tasks in laborious conditions can not only have serious negative impacts on their health but can also be a nuisance on to the environment. Thus, RRS can be a solution to avoid such issues.

Thanks to equipment that have various tools the RRS can perform many different tasks and is thus flexible for the staff to operate.

The automated tools are more cost-effective, contrary to a popular misconception regarding robotics. Thus, these automated tools have a minor financial impact on the overall decommissioning project budget. It was suggested that, sometimes, the use of on-shelf automated systems vs specific nuclear R&D-developed tools can allow for a wider application of the RRS and thus improve the value for money on projects, as well as time management. Presenting scenarios that are relevant to decommissioning can be a good start in justifying the application of Robotics and remote systems. The defined scenarios can be achieved through extensive and accurate knowledge of the site and its context, which can be acquired through available means and resources, qualified engineering skills, and collected international feedbacks and lessons. Before considering using RRS application, it is essential to adequately train operators on the tools and physical mock-ups before and

¹ Programme in Annex 1. Page 10

during the project. A presentation was shared to the participants on the evaluation of the application of RRS in decommissioning of Fukushima Daiichi NPP. It is important to consider that ensuring radiological protection for the staff by means of RRS application can be costly. However, RRS application showed an important decrease in dose risks for the personnel. Thus, the overall cost of the project remains comparable, while safety is at the required level or even improved. Severe environmental conditions such as high radiation level, the difficulty in accessing sites, facilities or equipment, and the manipulation of big amounts of material can create challenges for developers of electronic equipment for the application of RRS. However, the considerable reduction of RW volumes due to the use of RRS can prove more viable economically. Platforms created specifically to demonstrate the benefits of this technology could help display its value and relate to the mainstream market. Considering solutions that could solve application challenges across mainstream markets can establish a basis and reference for harmonisation. The participants raised the importance of a standardised electronic platform and noted that a useful roadmap could be developed for its application. The vision of RRS application from their users was discussed. It was pointed out that the use of multifunction systems based on the same principals of control (e.g. master hand) could facilitate RRS adoption. Meanwhile, it is essential to prepare the operators that will adopt such innovative systems, hence the need for adequate training.

To able mass application of RRS, the operations should be standardised as much as possible, which would result in a decrease in the total cost of a project. The more the same type of robotics and remote system is used, the further the cost will decrease and the better the performance will be. This is the reason why standardisation needs to be clearly defined and then followed. The suppliers' point of view was presented. They are eager to better comprehend what are the users' expectations when proposing RRS to the market. Bearing in mind the international nature of the work, RRS producers and suppliers need to understand in addition to the rules, procedures and regulations applied in producing, delivering and operating RRS also how to standardise them so that they can be applied at a global scale. The dialogue with researchers and developers working on RRS elements is important for producers to properly integrate newly developed elements and approaches in a timely fashion. Advocating for an international service certification may facilitate access for service personnel to the customers' equipment.

RRS willingness to be ready for emergencies recognised to be an important factor to focus on in RRS application. Participants discussed the importance of the standardisation of RRS certification. They also addressed how difficult it is to create a standardised approach on advanced RRS.

Artificial intelligence shows promising advantages. However, it is important to evaluate possible problems. The level of autonomy of RRS should be considered, especially when talking about mass production and application. Developing efficient standards for advanced systems remains a challenging issue. There should be a balance between the complex technical level and the price so that it can be beneficial to the final user.

The RRS operators would be inclined to buy the systems only if the products are durable, referable and manageable and also if their cost is reasonable. Thus, users are more likely to be attracted to more elementary solutions than advanced, complex samples.

The participants discussed the role of international educational initiatives and programmes. They agreed that in order to preserve the option of nuclear energy and maintain its credibility it is essential to demonstrate decommissioning at an industrial level and as a final stage of the nuclear life-cycle. As the decommissioning market is progressively

growing, academic and training opportunities are becoming more and more valuable for nuclear back-end projects, especially for the application of RRS.

It is necessary to consider harmonised education criteria when developing and creating new training programmes. It is also necessary to further the collaboration, in the development of the programmes, with all participants that are involved in RRS related activities (i.e. industry, regulators and associated technical support organisations, waste management and decommissioning agencies, research centres and others). The EC ELINDER project was given as an example of an educational and training programme, which considers different aspects of decommissioning and remediation of sites including RRS application.

Another example is the MEXT Program (2016-2018) on Human Resource Development for Fukushima Daiichi Decommissioning, which focuses on Robotics and Nuclide Analysis. It is a programme that focuses on the preparation of personnel for the work in Fukushima Daiichi NPP decommissioning project including RRS operation. The experience of this programme can be used in other training programmes.

When managing knowledge that has been generated and collected during the performance of projects in the nuclear back-end, it is important to unite efforts. Such collaborations should be acquired and applied in future projects particularly after decommissioning accidents. NEST, an NEA initiative, was highlighted to be a very valuable international programme that allows professionals to manage knowledge and transfer experiences amongst each other.

At the end of the session, participants listed several factors that prove the benefit of joint efforts:

- different regulations; harmonisation as much as possible; readiness of regulator to consider in licensing process situations when the mass application of RRS is planned in projects; standardised approaches to licensing of RRS for application and/or projects with RRS application;
- development of national and international frameworks which facilitate the way from research and development to industrial production and then to final user;
- joint efforts in the development of technical solution as much as possible standardised; discussion of the endpoint of RRS (utilisation routes);
- better communication between RRS developers and regulators, RP service, security end others in order to demonstrate the benefits of RRS application

In the third session...

...the discussion focused on international cooperation and potential forms of cooperation that could be identified to address the needs.

There are several NEA groups that studied the RRS application:

- WPDD and CPD studied RRD Application and formulated the main challenges
- The NI 2050 initiative described RRS application as a crosscutting issue that is important in all stages of the nuclear fuel cycle.

The IAEA IDN WIKI and DAROD projects are also efforts that focus on the decommissioning.

The European Commission organized a number of initiatives also well: EUROBOTICS, SPARC and ROMANS. The SPARC's roadmap for the robotic development in Europe could be a good reference and example for international initiatives on RRS in the nuclear back-end. Other relevant road maps have also been developed in some countries at a national level (e.g. Canada, US), and other initiatives have been organised (NIST activities, DARPA, Fukushima related initiatives and others).

The ISO developed a number of standards, applicable to robotics and is currently developing new standards including robotic vocabulary ([ISO/CD 8373 Robotics](#)) which could be taken considered in a future initiative.

A new initiative by EC (SHARE project) is expected to start in 2019. It will mostly focus on establishing a framework for collaboration on R&D activities related to Decommissioning.

At the conclusion of the workshop, the NEA presented to participants potential activities that would help support the Nuclear Community. The NEA is flexible in addressing requests from members and can propose various formats of activities.

The NEA then briefly talked about the next steps in establishing a new NEA initiative that would focus on the RRS application.

They all agreed that an international framework is essential in order to provide a common outlook on different aspects such as:

- the technology
- the knowledge management
- the competency management
- the criteria on the complexity of RRS and the variety of applications
- others.

To convince countries' decision makers, the participants believed that it would be useful to widen the demonstration of RRS application. And thus, the public would have more confidence in nuclear back-end projects.

OUTCOMES

Participants came to the same agreement that:

- the RRS can be more visible and play a bigger role in nuclear back-end activities. When performing projects in back-end areas, the RRS application is extensive and can not only provide better safety provisions and radiological protection but can also improve the economic parameters.
- for RRS application to become complete and comprehensive, it is necessary to establish dialogues between different parties. These dialogues would focus on the development of common rules (national policies, guidance, standards, road map, etc.).
- In order to develop competent measures that will support the RRS application, it is necessary to consider many factors comprehensively that includes visions of all actors involved.

Conclusions:

- The best way to support the expanded RRS application is to organise an international initiative led by the authoritative organisation with a high level of expertise and advanced skills in the nuclear energy area (OECD NEA). The initiative should engage all interested parties for comprehensive discussions and the development of recommendations for member countries and others.
- The workshop participants appreciated the NEA's efforts in organising the first discussion, which presented the issue from the various points of view.
- They expressed their interest for the NEA to continue supporting the development of a framework, which would establish (when necessary) and improve the communication between the developers and producers of RRS, and the implementers, regulators and decision-makers
- The participants urged for a new initiative, organised by the NEA, on RRS application in nuclear back-end activities.

ANNEX 1. AGENDA OF THE WORKSHOP

DAY 0	
SITE TOUR AND RECEPTION– Tuesday 29 January 2019	
9:30	SITE TOUR, CEA Centre
17:00	COCKTAIL RECEPTION
DAY 1 – Wednesday 30 January 2019	
8:30	Check-in <i>If not checked-in the day before</i>
WELCOME SESSION	
9:00	0.1 WELCOME FROM THE NEA <i>Rebecca TADESSE (Head of RWM Division, NEA)</i>
9:10	0.2 WELCOME FROM THE HOST AND THE WORKSHOP CHAIR <i>Christine GEORGES (CEA, France)</i>
9:20	0.3 INTRODUCTION <i>Vladimir LEBEDEV (RWM Division, NEA)</i>
SESSION 1 - THE GLOBAL SITUATION IN THE DEVELOPMENT/IMPLEMENTATION OF REMOTE AND ROBOTIC SYSTEMS IN VARIOUS BACK-END ACTIVITIES INCLUDING POST-ACCIDENT RADIOACTIVE WASTE MANAGEMENT AND DECOMMISSIONING	
<i>Session Chair: Michel PIERACCINI</i>	
9:30	1.1 INTRODUCTION <i>Michel PIERACCINI, Session Chair</i>
9:40	1.2 AN OVERVIEW OF THE DEVELOPMENT OF REMOTE AND ROBOTIC SYSTEMS IN THE NUCLEAR BACK-END <i>Leonel LAGOS (Florida International University, USA)</i>
10:10	1.3 AN OVERVIEW OF THE IMPLEMENTATION OF REMOTE AND ROBOTIC SYSTEMS IN THE NUCLEAR BACK-END <i>Hua ZHANG (Southwest University of Science and Technology, China)</i>
10:40	COFFEE BREAK (30')
11:10	1.4 HOW, AS DECISION-MAKERS, WE CAN ENSURE SUCCESSFUL IMPLEMENTATION OF REMOTE AND ROBOTC SOLUTIONS IN NUCLEAR BACK-END ACTIVITIES <i>Katherine EILBECK (Sellafield Ltd, UK)</i>
11:40	1.5 DISCUSSION AND WRAP-UP <i>Michel PIERACCINI, Session Chair</i>

12:30		LUNCH BREAK (60')	
SESSION 2 - MAIN FACTORS INFLUENCING THE IMPLEMENTATION OF REMOTE AND ROBOTIC SYSTEMS IN THE NUCLEAR BACK-END			
<i>Session Chairs: Rustam STOLKIN & Rebecca TADESSE</i>			
13:30	2.1	INTRODUCTION	<i>Rustam STOLKIN & Rebecca TADESSE, Session Chairs</i>
13:35	2.2	TECHNICAL, TECHNOLOGICAL AND METHODOLOGICAL CHALLENGES, INFLUENCING FACTORS AND ANALYSIS OF THE LEVEL OF FACTORS' INFLUENCE FROM THE IMPLEMENTER'S POINT OF VIEW	<i>Emmanuel WOZNIAK (EDF, France)</i>
14:05	2.3	INTRODUCTION OF ROBOTICS TECHNOLOGY FOR DECOMMISSION OF FUKUSHIMA DAIICHI NUCLEAR POWER PLANT	<i>Koichiro ARAI (TEPCO, Japan)</i>
14:35	2.4	ORGANISATIONAL, STAFF-RELATED AND SOCIETAL CHALLENGES, INFLUENCING FACTORS AND ANALYSIS OF THE LEVEL OF FACTORS' INFLUENCE FROM THE IMPLEMENTER'S POINT OF VIEW	<i>Viktor VOLKOV (Rosenergoatom, Russia)</i>
15:05		COFFEE BREAK (25')	
15:30	2.5	CHALLENGES, INFLUENCING FACTORS AND ANALYSIS OF THE LEVEL OF FACTORS' INFLUENCE FROM THE R&D'S POINT OF VIEW	<i>Jens VERBEECK (MAGICS Instruments, Belgium)</i>
16:00	2.6	CHALLENGES, INFLUENCING FACTORS AND ANALYSIS OF THE LEVEL OF FACTORS' INFLUENCE FROM THE EXPLOITING PERSONNEL'S POINT OF VIEW	<i>Jean-François Thro (Orano, France)</i>
16:30	2.7	REMOTE AND ROBOTIC SYSTEMS PRODUCERS' VISION OF CHALLENGES AND INFLUENCING FACTORS	<i>Anders LABBA (Brokk AB, Sweden)</i>
17:00	2.8	DISCUSSION AND WRAP-UP	<i>Session Chair</i>
18:00		END OF DAY I	

DAY 2 – Thursday 31 January 2019

SESSION 2 - MAIN FACTORS INFLUENCING THE IMPLEMENTATION OF REMOTE AND ROBOTIC SYSTEMS IN THE NUCLEAR BACK-END

Session Chairs: Rustam STOLKIN & Rebecca TADESSE

9:00 2.10 INTRODUCTION
Rustam STOLKIN & Rebecca TADESSE, Session Chairs

9:05 2.11 NEEDS IN STANDARDISED APPROACHES TO THE DEVELOPMENT, TESTING AND CERTIFICATION OF REMOTE AND ROBOTIC SYSTEMS FOR THE IMPLEMENTATION IN THE BACK-END ACTIVITIES
Rustam STOLKIN (University of Birmingham, UK)

9:35 2.12 NEEDS IN EDUCATIONAL AND STAFF TRAINING PROGRAMMES, CENTRES FOR PREPARING THE EXPLOITING PERSONNEL
Pierre KOCKEROLS (JRC, EC)

10:05 2.13 NEEDS IN JOINT ACTIVITIES/INSTITUTIONS ON THE INFORMATION, DATA AND KNOWLEDGE COLLECTION, ANALYSIS AND APPLICATION FOR SUPPORT THE REMOTE AND ROBOTIC SYSTEMS IMPLEMENTATION
Koji OKAMOTO (CLADS/JAEA, The University of Tokyo, Japan)

10:35 *COFFEE BREAK (25')*

11:00 2.14 DISCUSSION AND WRAP-UP
Session Chairs

12:30 *LUNCH BREAK (60')*

SESSION 3 - INTERNATIONAL COOPERATION IN THE FIELD OF THE DEVELOPMENT AND IMPLEMENTATION OF REMOTE AND ROBOTIC SYSTEMS. PROSPECTS.

Session Chair: Leonel LAGOS

13:30 3.1 INTRODUCTION
Leonel LAGOS, Session Chair

14:00 3.2 AN OVERVIEW OF INTERNATIONAL INITIATIVES/ACTIVITIES AND THEIR READINESS TO ADDRESS THE NEEDS IN SUPPORT THE IMPLEMENTATION OF REMOTE AND ROBOTIC SYSTEMS IN THE BACK-END
Christine GEORGES (CEA, France)

14:30 3.3 PROPOSED INTERNATIONAL UNDERTAKINGS UNDER THE AEGIS OF THE NEA
Vladimir LEBEDEV (NEA)

15:00 3.4 DISCUSSION AND WRAP-UP
Leonel LAGOS, Session Chair

CLOSING SESSION

16:00 **4.1** **SUMMARY AND CLOSURE OF WORKSHOP**

Christine GEORGES, Workshop Chair

Rebecca TADESSE, NEA

16:30

ADJOURN

ANNEX 2. FOR FURTHER INFORMATION

CONTACT

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WEBPAGES

- The Nuclear Energy Agency:
 - <http://www.oecd-nea.org/>
- The Radioactive Waste Management and Decommissioning:
 - <http://www.oecd-nea.org/rwm/>
- Link to the Workshop:
 - <https://www.oecd-nea.org/rwm/workshops/2019/robsysnba/>