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Robotic D&D: Smart Robots – 15093

Jeremy Seyssaud *, Cyril Moitrier *, Philippe Girones *, Christian Ducros *, Julien Favrichon *, Yves Soulabaille *
* CEA

ABSTRACT

Project' managers continually seek an ever-greater optimization of time between remote handling operations and those carried out manually; therefore, new technological solutions must be deployed. Robotics offers a great opportunity in this new field of technology to carry out, for example, samplings or remediation in hostile, cluttered surroundings. Teams in charge of dismantling at the CEA have therefore first defined robotizable functions. These functions have been assembled from existing technological blocks to arrive at robots which are operating today [RICAIII, patent: FR 2925702].

Lessons learned, particularly from experience with the RICA robot, have enabled the operating technical specifications to be fine-tuned. A new study phase has been launched applying the same principle of adapting existing, proven means. The growing role of robotics today is unquestioned. Led by research and the academic world; robots such as those equipped with wheels, tracks, feet or even helicopter rotors, are today accessible to the general public, particularly via broadening of the "open source" concept.
Added to these we need tools able to manage large component deconstruction systems, like MAESTRO. Industrialization of such high-potential technological solutions has been aided by:

- Easy use,
- Increasing reliability,
- Flexibility of "open source" solutions,
- Widening skill networks, and therefore greater technical support
- Lower costs.

Decontamination and dismantling (D&D) projects must be able to meet a number of special demands, increasing the number of unit designs, their costs and delivery times. The complexity of dismantling works sites mean that each is a special case to be dealt with almost independently. Such a way of approaching these projects is not on the same wavelength as industry, with tool and method standardization.
The answer to the challenge of operations in difficult environments is an eco-system of functions, performed by a set of inter-connected robots. The first step towards the construction of such robot teams is devoted to functions where strength is not necessary: investigating and clean-up in hostile environments. With this in mind, the CEA Marcoule teams have been given the objective of merging the strengthening commercial robotic world with the needs of D&D, and thus to improve the transversal use of the systems.

INTRODUCTION

The ever-wider use of industrial and service robotics in today's society is generally acknowledged and demonstrated by the growing number of robots available on the market. This democratization of robotics owes much to the arrival of "open source" solutions. At the same time, the expanding nuclear D&D industry has been seeking innovative solutions to meet the requirements for its worksites in extreme environments. The use of robotized systems developed specifically within the industry has been a priority, but the result has been individual developments which have rarely been capitalized on from one project to another, inevitably leading to constantly increasing costs and lead times. This approach to D&D projects does not enable tool standardization or the growing need for lower costs.

Faced with this situation, the CEA teams in charge of nuclear facility D&D have undertaken studies on a combination of the dynamic commercial robotic world with nuclear D&D, in order to establish and improve transversal systems as well as their standardization.
This paper consists of three sections. The first two describe a roadmap towards standardization. Recommendations are made concerning a categorization of D&D robots, with a description of the special constraints associated with the worksites concerned. In the third section, two design strategies are illustrated via 3 robots produced by the nuclear industry (ROV, RICA and a cutting Robot) and 3 from the open market (pusher, Hexapod and H@Ri).

PROPOSITION FOR ROBOT CATEGORIZATION

Faced with the complexity and the special features of nuclear facilities undergoing Dismantling and Decommissioning (D&D), players in this rapidly-expanding industry have expressed high-level functional needs for robotic tools and systems. The basic function is then described in detail by equipment manufacturers in technical specifications for the construction of robots. In response, the production and adaptation of industrial robots gives many options [1] but this offer is widely dispersed. Analysis of the solutions available shows that the complexity of requirements and the formalization of needs as described in functional specifications do not enable clear-cut industrial solutions to come forward. This has been particularly obvious during crisis situations [2] and is the consequence of the absence of standardization, limiting the deployment of robots in D&D operations at the right level.

The approach recommended here is based on a breakdown of D&D operations into missions. It is then described in the form of a robot categorization (Table 1) based on two parameters: the size of the robot and the working environment.

Table 1: Summary of missions to be accomplished by robotics in cleanup and dismantling

functions	***technical objectives***	***Special technical features***
Investigation	Initial state Remediation operation follow-up	1. Non destructive 2. Destructive (samplings) 3. Intrusive (core drilling)
Clean-up	Nuclear matter mass reduction (n,f) Dose reduction (Gy) Contamination reduction (Bq)	1. Autonomous and continuous
Cutting/Deconstruction /Retrieval	Sources (special points) Components (volume, mass)	1. Remote (teleoperated) 2. Autonomous
Reduction	Physical (size reduction) Radiological (Bq/Package control)	1. Pick and place 2. Coupling of techniques (cutting control)
Storage management	Package waiting list set up Shipment preparation (logistics)	1. Package movements in hostile environment 2. Stock optimization
Final state after clean-up / decommissioning	3D mapping (surface, in-depth migration)	1. Autonomous 2. Large surface (ground, walls, atmosphere)

To simplify the number and the quality of the categorization elements for robots operated in extreme environments, it is suggested that the missions (Table 1) be further described with the addition of the intervention environment data for the "media" concerned, i.e. air, land, or water, as well as the robot's dimensions. A robot's size may range from a nanometric volume up to that of a human, and even far larger in the case for example of systems such as a large crane. This aspect conditions robot capabilities and obviously the means which must be implemented for development. The categorization is therefore built on the basis of three independent items related to major industrial functions in extreme environments and with simplified technical parameters (environment and size) (Table 2).

Table 2: Categorization of the needs

Missions	Media	Robot volume
Inspect Cleanup Cutting Moving	Water Air Land	Nano < 1 cm^3 Micro < 10 cm^3 Human < 1 m^3 > Human

The dose rate and absorbed dose rate also need to be included. For example, it must be remembered that inspection robots are the type most exposed to radioactivity, with levels which may reach dose rates higher than 100 Gy/h. Robots carrying out deconstruction and re-sizing operations must be able to withstand significant absorbed doses (> 100 Gy), it is a minimum for our dismantling applications. A categorization with three levels for the two different missions consolidates the description (Table 3).

Table 3: Suggested absorbed dose limits for robots

Low (L)	Medium (M)	High (H)
< 10^3 Gy	10^3 to 10^4 Gy	> 10^4 Gy

In this paper, only robots useful for missions of inspection, cleanup and cutting within two environments, land and water, and for volumes between micro and human will be presented as examples.

INVENTORY OF THE REQUIREMENTS SPECIFIC TO D&D

The special features of the nuclear dismantling sites [3] in which the robots will have to work mean that an analysis of their specific issues is necessary.
Given the ever-growing numbers of robotized solutions available on the market, it could be thought that the answers to all the industry's technical issues already exist. However the dismantling worksites present challenges which commercially-designed robots cannot completely meet.

A. Size and movement adaptability

The size of the robot is dictated by the dimensions of access-ways and the work zone constraints. The choice of the robot volume basically depends on an analysis of the environment in which it will have to operate. It can be possible to modify the access, for example by core drilling of the walls.
Certain dismantling sites are accessible to operators, meaning that robotized systems smaller than the average human have no difficulty entering. Manual deconstruction is then possible and access ways dimensioned for humans enable the use of relatively large robots.
However highly contaminated and radioactive zones are, by definition, contained and difficult to access. Entrances can be in the form of vertical or horizontal cylindrical tube-like wall piercings, with diameters of a few centimeters up to several tens of centimeters, but may also be pipes, galleries or ventilation shafts (Figure 1). For robots working at floor level, insertion may pose a problem, and it depends on whether the

means to place/remove a robot are available (traveling crane, remote-handled arm, glove connection opening…) or if new means need to be created [4] (access ramp, basket, passage gallery…).

Figure 1: Examples of robot entry for controlled zone work. a) vertical access-way, b) entry airlock, c) horizontal access-way, d) duct [4].

The size of the zones where such robotized equipment will work can be from just a few centimeters to several tens of meters, and of course these dimensions impact the apparatus design decision. The site may be corridors, glove boxes, tanks, ducts etc. (Figure 2). Moreover, many pieces of equipment can be present - piping, technical items etc. – and prevent free movement of the system.
Planning definition of the best-adapted way for the robot to move about can be based on an analysis of the work zone (crawler tracks, wheels, flippers, hexapod, biped…).

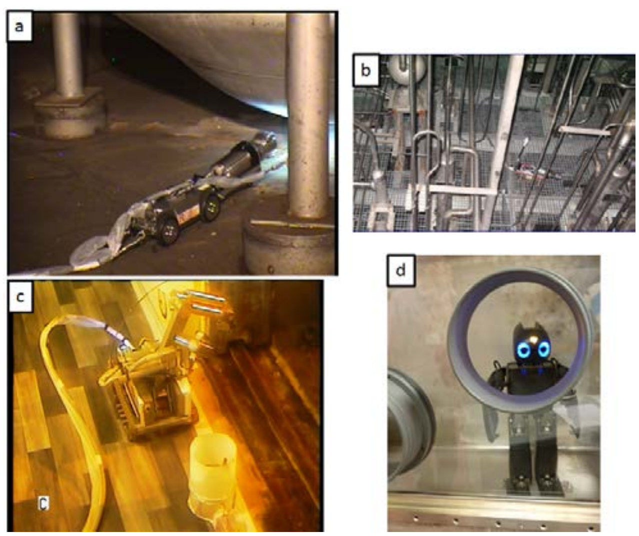

Figure 2: Examples of robot work zones. a) beneath a tank, b) process cell, c) corridor and cell entrance, d) glove box.

Investigation robots are usually small, as the zones they are called on to inspect are difficult to access and the on-board investigation equipment does not require a large carrier (micro category).

B. Robot dose resistance

Hostile nuclear environments are characterized by a given level of contamination, gamma and neutron dose rates [6]. Robots are exposed to dose rates ranging from 0.1 to 250 Gy/h. An analysis of the accumulated dose resistance is indispensable to guarantee that the apparatus will function correctly [5]. Note that by definition, investigation robots work in zones for which very little accurate information is available and can therefore be exposed to the highest dose rates.

In all cases, knowledge of the limits of the on-board equipment is backed up by functional or material unit trials in an irradiator. Special attention is also paid to the components used, particularly the items which form part of the protection against contamination or ensure mechanical functions. The dose rate resistance data produced by these trials can be generalized if the quality of the materials is ensured, which is however rarely the case for active electronic components (Figure 3). The first approach right from the design stage must be to avoid any technologies which do not suit the constraints imposed by the dose rate.

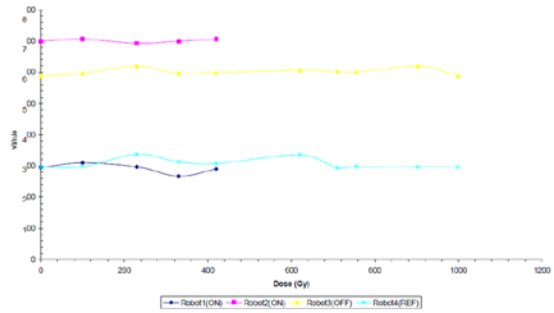

Figure 3: Example of results from a gamma ray flux resistance test on a robot's microcontroller.

Once this data is consolidated and analyzed, several strategies can be envisaged:

- Choice of on-board technologies – right from the design stage
- Acceptability of breakdowns. If ways to retrieve the apparatus are available it may be possible to accept occasional breakdowns, and to retrieve and repair the system.
- Equipment backups. As the effects of irradiation are less on non-polarized electronics, it is possible to set up physical duplicates of the machine's essential functions on board. These backups will only need to start up if a breakdown is detected, and will enable the robot to exit the worksite.
- Physical shielding. This method is widely used to physically protect sensitive equipment, and can consist for example of lead shields. Such protection is however not always feasible for small-sized investigation apparatus.
- Accumulated dose monitoring and preventive maintenance. The electronic board instrumentation enables the accumulated dose to be monitored. This represents an operational dosimeter for the robot. The information acquired, combined with knowledge of the board radiation resistance, enable breakdowns to be predicted and preventive maintenance actions to be scheduled appropriately.

The choice of one of these dose resistance management strategies is closely linked to other site-related limitations. For example, access possibilities define the feasible robot volume, which in turn decides the size of the batteries and therefore the maximum mass and level of autonomy.

C. Communication

Compared to market versions often used in different environments, for the nuclear industry communication is considered a challenge. This function, responsible for the transfer of data between the piloting station and the machine, must take into account the system's working zone.

From the physical point of view, the containment of dismantling sites usually ensured by thick walls of concrete or of lead, means that wireless linkups between the inside and outside of these cells is not possible. Moreover, the equipment necessary for such communication often cannot be set up (installation of antennae, relays etc.).

As the data involved is often highly confidential, the networks would have to be secure. Such security is

also essential to prevent any potential takeover of equipment control by unauthorized individuals.
Solutions exist (e.g. cables, beacons set up along the robot's pathway) but complicate work (tether management, beacon management, etc.).
It should also be noted that our designs consider that irradiation has no influence on hertz wave communications.

D. Autonomy

For any system expected to work autonomously this is the major issue, especially in conditions where retrieval of the machine may be impossible. As the safety authorities refuse to consider the use of any system which may be lost, power management is therefore a major consideration.
Depending on the case, it may be possible to power the robot by cable (especially if a communication tether is already part of the design) or to install a charging system in situ and thus limit contacts. A cable power supply has its limits for small-sized robots, which have low traction.

E. Post-use disposal

The design must also take into account post-use options for the systems. Each piece of equipment is destined to be a waste item, and this must be prepared for right from the beginning of a project. The existence of a suitable waste route for these items must be verified, and size-reduction must be simplified if it is going to be necessary.
Moreover, as concerns the dose resistance constraints, a cost study is necessary to compare the impact of frequent item disposal to that of a heightened system protection.

DESCRIPTION OF PROVEN D&D ROBOTS

This multitude of special issues seems to rule against the desire to use "standard" market equipment appreciated by the robotics community. The CEA teams therefore had the task of integrating the best-adapted technological blocks available on the market into robotic systems meeting the challenges of the nuclear environment. Different robot projects reaching these criteria have been and are being developed, using technologies which are both available and proven. They have not required the complexity, costs and time associated with individual-item R&D work.
This section describes two types of robots. The first three (RICAIII [7], a pool ROV and a cutting robot) required developments or adaptations which meant long preparation periods. Each system is a one-off, and a special machine. The desire for standardization has however been applied for the three line-guided, for example through the now generalized use of the Maestro arm or the signal multiplexing approach. Work must be carried out to reinforce this standardization for deeper functions, hence the CEA's studies into robot deployment (pushing robot, Hexapod and the H@Ri project) based on off-the-shelf components. The availability of these components and the size of the robotics community should give further impetus to standardization of at least parts of D&D robots.

A. RICA III

It can be that the information recorded during a facility's process operation is insufficient for dismantling preparation purposes, where interest is on the contamination level in equipment and cells. Radiological investigations must be carried out to provide additional data to complete the facility's technical referential. Such investigations concern two major operational objectives impacting the dismantling scenario and contributing to the safety demonstration as well as to waste management plans:

1. identify concentration points: "special points",
2. draw up a radiological mapping of the whole facility.

The RICA [7] range of robots meets these requirements and includes equipment useful for mapping purposes. The first implementations of these line-guided systems enabled visual inspections to be carried out. The original robots were quickly enhanced with the addition of radiological detectors, leading to the development of Version III. This version is fitted with numerous detectors, including a gamma camera (Figure 4) [7].

Figure 4: RICAIII robot

Another special feature of this apparatus is the data transfer technology to communicate between the hostile environment and the operator. The data transmission and the power supply are carried out via a hardened multiplexed cable link. A single 100 m tether cable means operators have a robot giving reliable information transmission and no autonomy problems, with the only disadvantage being the management of the tether in a contaminated environment. This management requires classical skills and suitable piloting.

Table 4: Categorization of the RICAIII, radiological class (L)

Function	Medium	Robot volume
Inspection	Ground	Human < 1 m^3

Given the successful past results, an arm was added to the equipment, and the robot thus became a sample collector. The original robot was a complete system to carry out mapping under severe conditions. It could then be reconfigured by removing the instrumentation platform and connecting a Romain 50 arm [8] equipped with its tether (Figure 5).

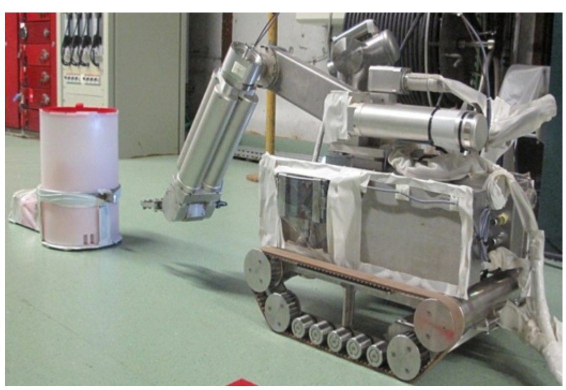

Figure 5: RICA III robot equipped with the Romain 50 arm

The RICA III robot is used to carry out investigations and take samples in extreme environments, and during its 3 years of successful operation it has clearly demonstrated its capabilities.
For the RICA III, the arm and measurement devices are industrial equipment recognized for their efficiency. The multiplexing function was specifically-developed ans will standardize, this element is essential for line-guided robots.

B. Cooling pool Remote Operated Vehicle

To carry out a radiological assessment of a spent fuel storage pool, a submarine robot was adapted and then deployed for the visual and radiological inspection of the inner walls. The pool dimensions were 39.1 m by 19 m for a total surface of 750 m². The low contamination level of the walls and of the water, in which the robot would be working, meant no equipment hardening studies needed to be done. The labile contamination level of the walls was 135 Bq/cm².

Table 5: Categorization of the pool ROV, radiological class (L)

Function	Medium	Robot volume
Inspection	water	Human < 1 m^3

The base unit chosen to carry out the investigation was the ROV Guardian 2.1, made by Subsea Tech. Its technical features met all the required specifications. Briefly, the system is light (< 5 kg), is equipped with a good viewing apparatus and has a 100 m tether.

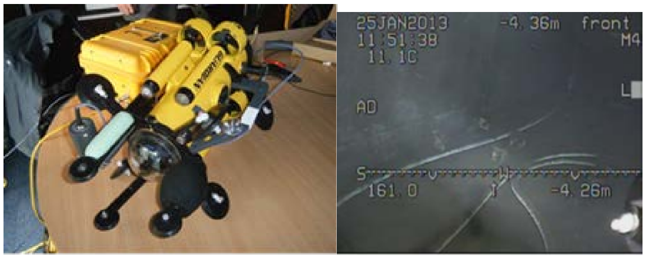

Figure 6: Cooling pool ROV

A dose rate detector and a mechanical system were added to the original ROW equipment. The mechanical system enabled the distance from the wall to the detector to be set by contact. Three configurations were defined:
Lateral configuration: The objective of this configuration is to check the walls in order to locate irradiating zones and for a general inspection. The measurement detector is positioned 95 mm from the wall.
Forward configuration: The ROV is positioned facing the point of interest (static).
Bottom configuration: inspection of the bottom to identify irradiating zones. The measurement detector is positioned at a short distance from the bottom (20mm). The ROV is ballasted to minimize the use of vertical propellers (risk of re-suspending particles).
This system is operational. The images obtained enable the identification of objects and can be used for the analysis of the walls. The good contrast of the dose mapping has supplied useful elements for the scenario: an evaluation of the source term and of the consequences during the pool emptying.
The development of a robot equipped with radiological and position detectors is an obvious next step. It will be based on the works and achievements of the RICAIII.

C. Cutting robot

For the dismantling of the Petrus line at the CEA Fontenay-aux-Roses site, and in particular of the technical gallery where the space was limited (width 1.24 m and height 1.84 m), it was decided to work with a public works-type machine already commonly used for nuclear work sites, the BROKK [9]. It was fitted it with a hydraulic arm developed in a collaboration between the CEA and Cybernétix [10], the MAESTRO [11]. This arm has an irradiation resistance tested at 10 kGy [12] and will be validated for a level of > 50 kGy. It is therefore part of the equipment in the radiological category M.

Figure 7: a) Brokk 90 equipped with an on-board controller and the Cybernétix Maestro arm; b) the machine in the technical gallery mock-up; c) in action with a nibbler.

Once the equipment chosen (carrier, arm, cutting tools) had been tested on a mock-up and the main steps planned for the cutting work were validated, the site was handed over to the Cybernétix team.
Because a single hydraulic center was used together with an on-board controller ensuring the multiplexing of signals for the arm, camera and on-board cutting tools, communication via a tether was possible (Figure 11).

Figure 8: Cybernétix industrial version of a Brokk 90 equipped with an on-board controller and the Maestro arm. Tool rack on the front of the machine.

The autonomy of the remotely controlled machine is guaranteed because of the use of a tether. Back-up modes can be implemented, with a final option of using a second machine to retrieve the first if necessary.

Table 6: Categorization of the Brokk + arm

Function	Medium	Robot volume
Cutting	Ground	> Human

D. Pushing robot

In operations prior to the dismantling of High Level (HL) cells, it is often necessary to move small objects located on the cell floor and inaccessible to the in-situ means available.
According to studies, the main limiting factors include:

- Volume and working zone. The system must be suitable for cell entrance by PADIRAC cask + CTPE container + PODEC (Figure 1-b). This means a maximum diameter of 230mm and height of 300mm. Remote handling is used to move the system, via master-slave arms. Its design will therefore take into account this aspect, especially as concerns gripping and deconstruction or the attachment of connectors.
- Power autonomy. The robot will have a cable power supply via a duct to the outside of the cell.
- Communication. The robot will be permanently connected to the control station outside the cell. This cable connection will enable the transfer of detector data and carrier piloting, as well as remote re-programming of the microcontroller.
- Dose resistance. It is essential to know the system's operating limits in terms of dose resistance. This information means maintenance can be scheduled and contributes to the appropriate preparation of worksites (fallback position, system power supply…). The atmospheric dose rate is 250 mGy/h with hot spots of 3 to 5 Gy/h.
- Cost and scheduling. Another objective of this project is to demonstrate the feasibility of such a combination in a short period (less than one year) and at a low cost (under €1000).

Sumo-type robots, initially designed for student robotic competitions, were chosen. The ZUMO platform marketed by Pololu [10] is able to push relatively heavy loads compared to its own weight, and has small dimensions. The ZUMO kit, compatible with Arduino [11], includes a crawler base, 2 micro motors and their driver as well as a 3-axis accelerometer-magnetometer.

Figure 9: Zumo robot

The use of the Arduino board to command the robot and the detector interface means highly flexible programming is possible. A webcam with a fish-eye lens completes the robot set-up, and a video game joystick is used for piloting. The cleanup function is via a waste collection shovel resembling that of a snow-plow and completed by a bucket-wall system mounted on a servomotor. It is set up on the front of the robot within the webcam viewing field.

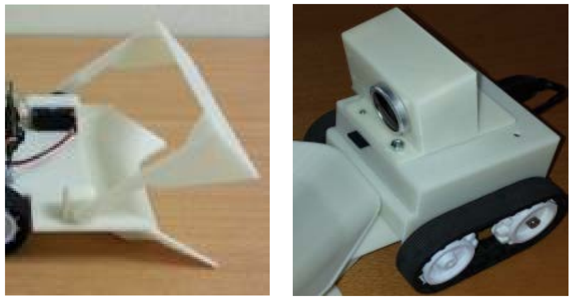

Figure 10: prototyping of the pushing robot

As concerns robot categorization, this “tank”-type robot includes on-board functions useful in investigation and for clean-up, works on the “ground”, and has a “micro” size. 3 main functions are listed:

- Retrieval and movement of objects at floor level via remote handling,
- Real time viewing of the retrieval zone,
- Atmospheric radiological measurements in real time.

Table 7: Categorization of the pushing robot, radiological class (M)

Function	Medium	Robot volume
Inspection Clean-up	Ground	Human < 1 m^3

The pushing robot is the result of assembling off-the-shelf components, constructed in just a short time [13]. The robot was created in less than three months, for operations in a High Level cell and for a cost objective of under 1000 €.

This project is a simple and efficient solution using components from the open source community. Construction takes just a short time and the ability to work in a general public or gaming environment can also be possible. This opens up the prospect of a wide deployment of robotized equipment for inspection and clean-up missions.

E. Hexapod

Facilities undergoing dismantling works are complex environments, for example during the decommissioning phase when the treatment of concrete floors gives surfaces which may not be completely flat. These surfaces need to be checked. The checking equipment can be carried by robots like RICAIII.

Lessons learned [1] from work with tracked carriers and trials with bipeds for investigations and clean-up have shown the problems posed by movement in a cluttered environment. Systems with wheels, tracks or flippers rapidly reach their limits [12]. Given this, the hexapod seems an obvious solution with *a priori* greater movement and agility abilities.

With the focus on “open space” equipment in mind during technical prospection phase, the choice of the foundation item was a PhantomX hexapod [13]. It has classical architecture: a PCDuino3 enables communication management with the user, the movement algorithms and the interface with the on-board detectors. The actuators are dynamixels [14]. The hexapod is fitted with a low-capacity arm with X axes, to handle small-size objects.

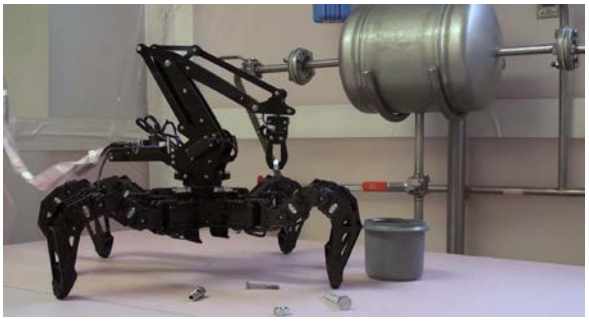

Figure 11: Hexapod + arm

Table 8: Categorization of the Hexapod robot, radiological class (L)

Function	Medium	Robot volume
Inspection Clean-up	Ground	Human < 1 m^3

F. H@RI Project - A solution

One last example of a platform and construction made possible through the use of “open source” components. Humanoid robots have not yet made their presence felt in the fields of research or of the nuclear industry. The H@RI project (or Robotized Assistance Humanoid for Investigation), can be mentioned in the future for investigation tasks (visual and radiological), clean-up and sample collection in hostile environments (ionizing radiation).

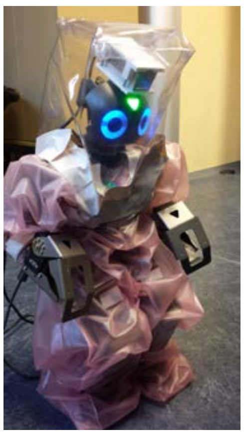

Figure 12: H@Ri in protective suit

The project has several objectives. The first is to explore la the possibilities for humanoid robotics in the nuclear field in order to overcome the limitations and technical deadlocks of crawler-tracked platforms in work sites where there are obstacles or a need for literally manual operations. The second objective is to set up an architecture enabling robotic platforms to share functions developed in the form of software blocks.

The Darwin-OP (Dynamic Anthropomorphic Robot with Intelligence–Open Platform) humanoid platform was used for this study. It was developed jointly by the robotics and mechanisms laboratory (RoMeLa) at Virginia Tech USA), the University of Pennsylvania, and Purdue University as well as the Korean company ROBOTIS [9].

This open-source robot was designed to be highly adaptable, enabling the addition of new functions and of the modifications necessary for its missions in the field of nuclear industry applications.

During the first phase, the development architecture and the implementation of basic functions such as viewing and simple teleoperation were defined.

For this, remote piloting from a computer station and real time camera viewing were prepared based on the native Darwin-OP Framework. This development, closely linked to the platform Framework, is difficult to transfer to other platforms. This situation reinforced the objective of defining shared inter-platform standards in terms of development and of communication. The study was therefore oriented towards a "middleware"-type architecture, which would enable these expectations to be met. Attention was drawn to the Robot Operating System (ROS) which offers an extensive range of tools, of libraries and of conventions enabling complex, robust robot behavior management via a wide variety of robotic platforms. This new development architecture required an adaptation of the DARWIN-OP platform in terms of resources and systems: migration of the operating system to Ubuntu 12.04LTS and extension of the storage capacity.

Once the H@RI platform architecture was defined, a second phase was launched to meet the operational objective, the inspection/radiological analysis of a glove box. This action required specific movements, for example taking wipes in 2 (flat surface, window) or 3 dimensions (piping) as well as the addition of a detector. Three types of teleoperation interface were developed, each specific to an element of the robot and all integrated in the ROS. The first, piloting the robot arms, required the development of suitable remote control. A Kinect-type interface was chosen as it enables the imitation of the operator's movements appropriate to a situation.

The second, piloting the grippers, was set up with a glove equipped with FlexSensor-type [18] variable resistances interconnected via an Arduino Nano board. The last interface, for the apparatus movement function, is controlled by a Nunchuk joystick. The measurement actions are carried out by a gamma spectroscopy probe interfaced via the ROS. The spectra obtained are displayed on the computer station on a human-machine interface with RQt plugins.

For this system, future developments will focus on walking movements and balance, in order to meet the safety requirements and the limitations imposed by the working environment. This work will require the motor systems and the inertial center to be integrated in the ROS.

Table 9: Categorization of the H@RI platform, radiological class (L)

Function	Medium	Robot volume
Inspection Clean-up	Ground	Human < 1 m^3

CONCLUSION AND PERSPECTIVES

Changes to the D&D paradigm which are accelerating the mutation of a niche activity into a mass industry are on the way. This is the consequence of a young industry which in the CEA is based on the issues raised by facilities constructed in the early days of the nuclear industry and which are now reaching the end of their lifetimes. Robot technology can be one vector speeding up the industrialization of all phases of today's D&D if, and only if, standards are agreed on.

The principle which places robot categorization among the accelerators of D&D system standardization has yet to be demonstrated. The level of standardization achieved from the examples of operations carried out in CEA facilities have shown that all robots are, and remain, an assembly of components. Standardization must therefore begin with nuclear-compatible unitary components. This is the approach which has led to the development of the Maestro and also the RICA III robot. The component assembly concept, faced with the needs of D&D operations, demands new design and construction modalities in order to provide the quality and quantity called for by the market while reducing customized technical solutions as much as possible.

The combination of a strong demand for D&D industrialization with the emergence of a new way to design complex systems is an opportunity. Through a few examples given in this paper, the design trend to meet today's needs has been indicated. While a few years ago each specific situation was addressed by a single team, solutions are now sought from a wide community. The standard chosen by the CEA, following this

work, of the development platform or of the on-board operating system illustrate the dynamic and the relevance of this type of approach.
Combining the results of work requiring heavy equipment and solutions from the "open source" world is the way forward for D&D robotization. Such is the choice of more and more teams, including those of the CEA/DEN.

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