DESMANTELATOR: ROBOTS FOR DISMANTLING



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Who does not remember the iconic line from Blade Runner, spoken by the replicant Roy Batty at the end of that wonderful 1982 film? Forty-four years later, perhaps we could rewrite it as follows:

"I've seen things you people wouldn't believe": **decommissioning nuclear power plants with robots…**

I know, that's not exactly how it went, but it seems like a perfectly fitting adaptation for this article. Forgive my fictional audacity.

Will we see **robots, quadrupeds, drones, and humanoids** decommissioning our nuclear power plants? What would a human, or perhaps a replicant like Roy Batty arriving from the near future, tell us in another forty-four years about the **decommissioning** of today's **nuclear** facilities?

It sounds like science fiction and, admittedly, somewhat crazy. Yet this vision may be closer to reality than we think. Technology, **robotics**, and **automation** are advancing at an extraordinary pace, with new solutions and systems being designed and developed every day. Under human supervision and control, these technologies are increasingly capable of performing **complex autonomous tasks** and optimizing industrial processes. The nuclear and radioactive facility decommissioning sector is no exception. Decommissioning is a particularly complex and unique industrial process that requires tailored technologies and solutions operating within the strict framework of **nuclear safety** and **radiation protection**. **International cooperation** and the development of joint European initiatives, in which ENRESA actively participates, are essential to driving this technological leap and maximizing resources and expertise. Around the world, several initiatives are already applying robotic and remote systems (RRS) in the nuclear back-end sector. Notable examples include Fukushima Daiichi (Japan), Greifswald (Germany), Sellafield (United Kingdom), Ignalina (Lithuania), and several French nuclear power plants.

Responsibility for the decommissioning of nuclear power plants and radioactive facilities in Spain, as well as for the safe management of the associated radioactive waste, lies with ENRESA. Decommissioning projects are highly complex industrial undertakings due to their unique nature and the inherent challenges associated with the terms "nuclear" and "radioactive." They also carry significant social responsibility, as ENRESA must ensure **public safety** while maintaining public **confidence**.

Designing a nuclear decommissioning project requires interaction, coordination, and management of numerous disciplines, technical areas, organizations, companies, contractors, and responsibilities. Decommissioning is approached as an industrial process that generates large quantities of **residual materials**, including radioactive waste, all of which must be managed in an **optimal, efficient, and safe** manner. The design and execution of a decommissioning project, together with continuous improvement throughout its lifecycle, are driven by a commitment to **optimizing** all associated processes. Among these objectives, particular priority is given to minimizing the volume of radioactive waste requiring final disposal at the El Cabril Disposal Facility.

At the same time, ENRESA faces the major challenge of managing the future of Spain's nuclear fleet through a strong commitment to **innovation**, research, **development**, and

collaboration at every level. This approach is guided by a philosophy of continuous improvement and a commitment to safety, quality, and technical excellence.

In this context, ENRESA has developed, in collaboration with national institutions, research centers, and technology companies, advanced solutions for deployment in decommissioning projects. These technologies are already being used in the current Decommissioning and Dismantling Plan of the Santa María de Garoña Nuclear Power Plant. Innovation is being applied to improve project efficiency and optimization, particularly in the field of radiological characterization and measurement for the management and clearance of residual materials generated during decommissioning. The primary objective of these solutions is to minimize the volume of radioactive waste destined for disposal at the El Cabril Disposal Facility while optimizing measurement processes.

Advanced robotic solutions currently available to ENRESA

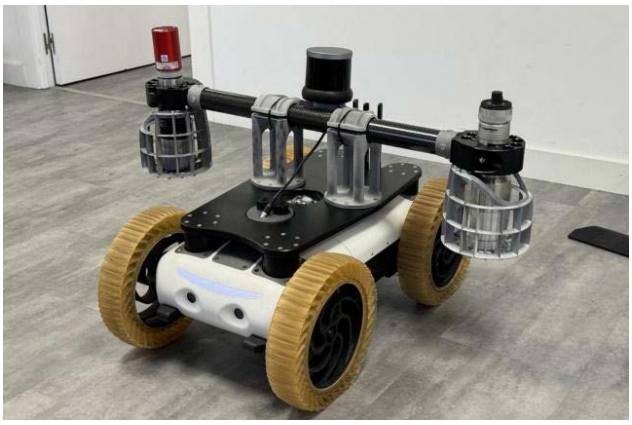
As a result of various R&D programs and collaborative initiatives, ENRESA currently operates several **robotic systems and advanced technological** solutions:

- **Armbot:** Armbot is a four-wheeled platform equipped with a robotic arm carrying a spectrometric detector (NaI or LaBr). The system is designed for surface characterization and spectrometric measurements, providing six degrees of freedom and positioning capabilities in any orientation through GPS and external reference systems. Its measurement software is fully integrated with the positioning and operational software. The robot can operate autonomously through pre-programmed missions and is capable of returning independently to its charging station when battery recharge is required. Designed and manufactured by Star Robotics, Armbot was conceived, among other applications, for clearance measurements of ISO containers at the El Cabril Disposal Facility.



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- **Landbot:** Landbot is a robot built on the same rover platform as Armbot and was also designed and manufactured by Star Robotics, but specifically for land characterization applications. It incorporates the same positioning and data acquisition capabilities and features two downward-facing spectrometric detectors capable of performing scanning operations as well as dynamic and static measurements. Together, the detectors cover an area of approximately 2 m^2. The system is currently being used within the José Cabrera NPP Decommissioning Project to perform measurements associated with site release activities. ENRESA currently operates two units of this equipment.



- **Spot PRT ENRESA:** Spot PRT ENRESA is a quadruped robotic platform based on Boston Dynamics’ Spot robot and customized specifically for ENRESA. It was jointly designed and developed by Alisys and GDES to perform spectrometric and non-spectrometric measurements in decommissioning environments, particularly in areas with difficult access or elevated radiation dose rates. The robot incorporates a robotic arm specifically configured for ENRESA’s operational requirements and can accommodate both spectrometric detectors and contamination monitors. This versatility enables measurements on materials, localized points, and larger surfaces. The system can autonomously execute missions using advanced navigation and positioning sensors, operate continuously with automatic recharging, or be teleoperated when necessary. It is also capable of generating 3D physical maps of its surroundings and radiological maps for the identification of radioactive contamination and hot spots. ENRESA currently operates one unit of this system.





- **Drones:** Through a service contract, ENRESA operates drones developed by Enusa and Hovering that are equipped with spectrometric capabilities for surface characterization and measurements at clearance levels, particularly for land surveys. The project was developed with the ambitious objective of employing lightweight, high-efficiency spectrometric detector systems mounted on drones, capable of performing highly accurate measurements at clearance levels. The systems can be deployed both outdoors and within buildings or enclosed spaces. They support dynamic and static measurements, autonomous operation through pre-programmed missions, and manual piloting when required. ENRESA has successfully completed the commissioning phase of these systems and is currently using them for radiological characterization campaigns at the Vandellós I site and the Santa María de Garoña Decommissioning and Dismantling Project.





Artificial Intelligence: supporting human expertise

Artificial intelligence will never replace **human oversight**, supervision, and final decision-making in decommissioning projects or in the processes associated with radioactive waste management throughout the entire waste management lifecycle. Instead, it should serve as a tool that supports project objectives and enhances process optimization. **AI** can provide significant benefits in this field through its capabilities in spatial reconstruction, data analytics, and large-scale information processing. It can also **optimize** planning and operational activities through simulations, **digital twins**, and integration with Building Information Modelling (BIM) environments. In addition, AI can facilitate **process control**, manage data flows across multiple workstations, and coordinate fleets of robots and autonomous systems. One of the most valuable contributions of **AI** lies in optimizing work planning under ALARA principles and enhancing worker safety by minimizing occupational radiation exposure. In this context, AI should be employed as a technology that actively **supports radiation protection** objectives.

The potential of **AI** to improve and optimize decommissioning activities is unquestionable. However, its implementation will always require what might be called Natural Intelligence behind the controls, guiding and governing its application.

Likewise, virtual reality is already a proven and valuable tool for **process enhancement and optimization**. It enables project planning, safety studies, risk analyses, operational scenario simulations, and ALARA-based training activities, representing a significant qualitative leap forward for the sector.

Although **AI** has not yet been fully implemented operationally within ENRESA's decommissioning activities, in such a complex, sensitive, and highly regulated environment, it is undoubtedly knocking at the door and requesting entry.

A promising **future** lies ahead for the development and integration of new technologies and **artificial intelligence** within the nuclear sector. This represents a key challenge for ENRESA and its technology partners, whose goal is to **optimize decommissioning** projects while maintaining the highest standards of safety, quality, and technical excellence.

We possess the capabilities, the expertise, the scientific and technological talent, and the commitment to research, development, and innovation needed to achieve this objective.

So, how do you imagine the future of nuclear decommissioning? Let's allow our imagination to land gently and find out... ■