Benefits From R&D For D&D Projects Preparation

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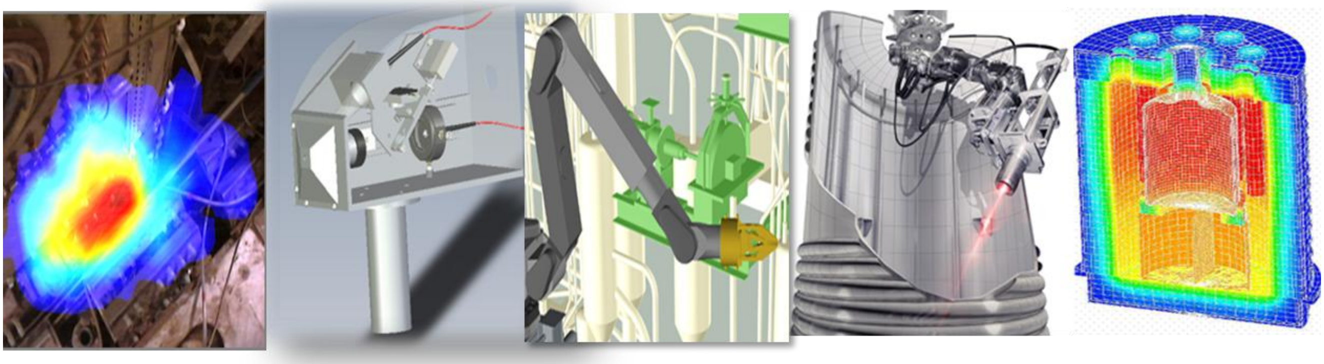
ABSTRACT

CEA (French Alternative Energies and Atomic Energy Commission) is both the operator of important nuclear facilities all over the nuclear cycle, in charge of major new built or Decommissioning and Dismantling (D&D) projects and a R&D group with dynamic policy of technology transfer.
The position of CEA in D&D is unique because of the number and the wide diversity of facilities under decommissioning, with some high level of contamination.
Innovative solutions are being developed in 6 main axes to protect the operators, to minimize the overall costs and the volumes of waste, especially used when preparing D&D operations: Investigations in the facilities, Radiological measurement of waste, Technologies for hostile environment, Decontamination of soils and structures, Waste treatment and conditioning and Methods and Information Technology (IT) Tools for project and waste management .
The last developments are shown and examples of industrial applications given. CEA is willing to share actions in partnership with other operators or with industrials dealing with the same problems to solve.



INTRODUCTION

The position of CEA in decommissioning and legacy waste management is unique because of the numbers of facilities involved (21 nuclear installations are under decommissioning operations out of 43), with contamination levels sometimes very high, and a wide diversity of facilities from laboratory scale to industrial plants: almost all kind of reactors (pool, fast breeders, gas graphite CO2 cooled, …), accelerators and irradiators, laboratories, fuel cycle processing units, Effluent treatment stations, Waste treatment and storage facilities, etc. Almost 800 CEA employees and between 2000 and 2 500 employees from suppliers companies work for CEA programs.
While conducting these very specific and demanding D&D projects, CEA gained skills and feedback in the various management and technical fields involved : project management (cost control, scheduling, risks and opportunities, reporting, etc.), safety and security, waste management, transportation and specific expertise in

remote control operations, measurement of nuclear wastes, characterizations for investigations, process engineering, 3D Models information systems, Nuclear Ventilation, etc.
When solutions were not available on the shelves in the supply chain, CEA had to develop technologies, processes, methods and software by its own, in support of its programs always with the aim to reduce cost, schedule, doses incurred and amount of waste produced and to improve safety and security. CEA took thus advantage of its very specific position, being both operator and research organization and put in place an organization able to develop expertise in the 6 main axes of R&D and expertise for D&D, as detailed in the next chapters:

- Investigations in the facilities,
- Radiological measurement of waste,
- Technologies for hostile environment,
- Decontamination of soils and structures,
- Waste treatment and conditioning
- Methods and Information Technology (IT) Tools for project and waste management.

IMPORTANCE OF PREPARATION

Several issues can affect D&D planning and execution from the lack of initial state knowledge to the evolution of final state definition, including safety exigencies, regulation evolutions, delay in authorization processes, waste management difficulties, upper limit of the financial resources or project management and technical issues.
In order to master these issues, apart from human factor and organization, a pluri-annual strategic vision leading to priorization of the different tasks is necessary and preparation with the help of R&D and expertise is crucial.

DEVELOPMENTS FOR INVESTIGATIONS IN THE FACILITIES

Characterization of the radiological and physical states of the facilities is a key point in D&D, including historical waste management, to provide right data for scenarios, to minimize hazards during workshops and thus save time and money and work safer or to avoid overestimating associated waste facilities. Investigations with sampling operations and in situ characterization are then necessary for assessment of the initial state in order to prepare workshops:

- for comprehensive measurement and mapping of the residual radioactivity, with level of radioactivity and type of emission.
- to quantify residues / deposits / sludges located in the components, to obtain reliable data (activities, dose rate, quantities) for waste management studies
- to launch soon enough inventories, feasibility studies and waste management report in order to anticipate technical difficulties and waste intermediate storage needs, etc.
- to Anticipate R&D needed to develop conditioning matrices .

Methods and tools have been developed. These tools are necessary from the identification of characterization objectives through to the final physical and radiological inventory.
Coming from complex in situ measurement issues on its own D&D & R workshops, CEA gained experience in analysis of characterization needs, choice of appropriate measurement systems or measurement method in order to validate and optimize a characterization process. A major challenge for developments in this field is to minimize destructive analysis in order to minimize doses integrated by workers and to relieve congested sites laboratories.

From design to integration and qualification of complex measurement systems

CEA developed new in situ techniques to map facilities and soil, to localize hot spots, to identify radionuclides, to estimate radioactivity, and to minimize and sometime prevent the number of samplings necessary or to process numerous radiochemical analyses simultaneously. These techniques are already used on CEA D&D workshops, some being already commercialized (Ex: Geostatistics, others being at prototype scale, on the way to industrialization, Ex: Gamma camera (Fig. 1.), Alpha camera (Fig. 2.) or Auto-radiography (Fig. 3.) for Beta emitters, LIBS technology, etc.

Fig. 1. Gamma camera.

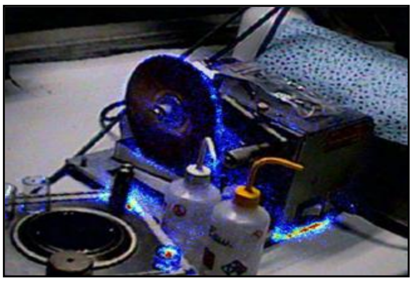


Fig. 2. Alpha camera.

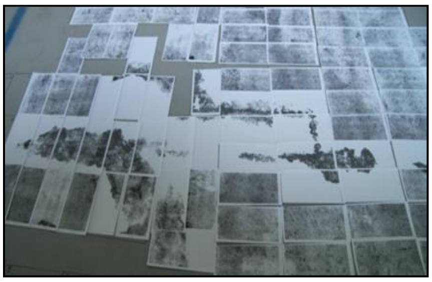


Fig. 3. Auto-radiography.

CEA also works on the coupling of measurement tools and on the integration on carriers, ex: Robot RICA (Fig 3) with Gamma Camera.

CEA owns several laboratories equipped for nuclear instrumentation (Gamma camera, gamma spectrometry probes, means dedicated to calculation, LIBS, radioactive sources, calibration setups) and test platforms to accommodate large systems or to train operators to the use and interpretation of measurement systems

Fig. 4. Investigation Robot.

DEVELOPMENTS FOR WASTE MEASUREMENT

From its management as operator of various nuclear facilities and from R&D developments, CEA gained experience both in destructive (Beta long live) and non-destructive analysis (X, γ and α imaging, γ spectrometry, Neutronic measurement). This knowledge is very useful for D&D & R projects where optimization and validation of waste characterization strategy is needed:

- drawing up objectives for radiological, physical and elementary waste characterization.
- choice of equipment and scenarios to implement (Ex: Fig. 5.)
- optimization of characterization procedures
- high-performance modeling and simulation tools to enable optimization of measurement equipment and scenarios (fig. 6.)

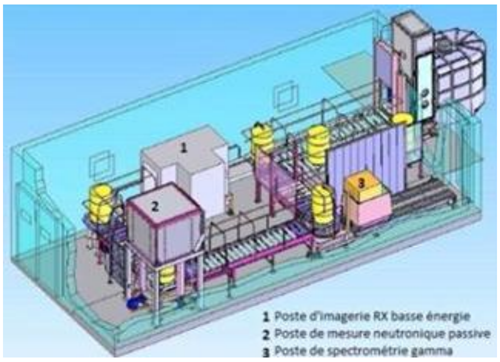


Fig. 5. Method coupling for waste retrieval

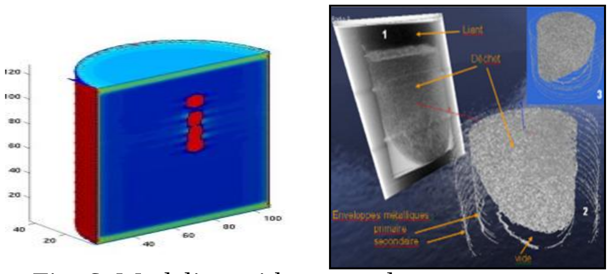


Fig. 6. Modeling with pre- and post-measurement imagery

Design, qualification and industrialization of complex customized measurement devices

CEA became specialized in the design and qualification of customized characterization devices to avoid destructive analysis, or to meet changes in regulatory requirements and special issues related to D&D and R (Fig.7. and Fig.8.). These systems could also be transposition of prototypes to industrial scale or adaptation of existing system.

Fig. 7. Passive neutronic measurement of Plutonium

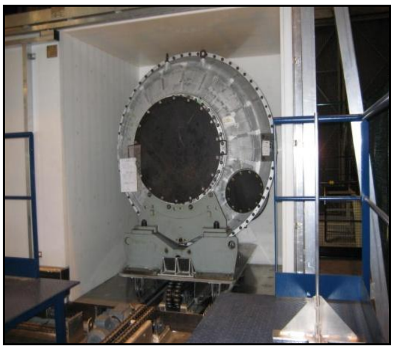


Fig. 8. Passive neutronic measurement of Uranium

CEA owns high performance modeling and simulation tools and ten industrial-type non-destructive characterization platforms, able to handle large-scale objects for calibrations and qualifications of all sorts of waste measurement.

SPECIFIC DEVICES AND SIMULATION FOR OPERATIONS IN HOSTILE ENVIRONMENT

CEA needed to develop tools for its own D&D projects when they didn't exist on the market: robots, tele-operated equipment, cutting process and software for validation and optimization of intervention scenarios.
For 20 years, project managers had the dream to get 3D cartographies from in situ investigations and to use them as entrance data to scenarios conception in an immersive room. All the elementary technological bricks are now available ready to be linked from collection to conception up to training of operators.

Fig .9. A complete model: characterization, tele-operation, simulation and costing

Design and nuclearization of remotely-handled equipment

CEA learnt how to choose devices suitable for workshops with specific physico-chemical and radiological conditions by nuclearization of off-the-shelf systems or complete design of fine-tuning innovative systems for computer-assisted tele-operation actions, as well as carriers. MAESTRO (Fig .10.) is an example of remote handling designed arm for high resistance radiations and for adaptation to all kind of carrier: on a crane, on a telescopic mast, on a remote controlled machine, etc.

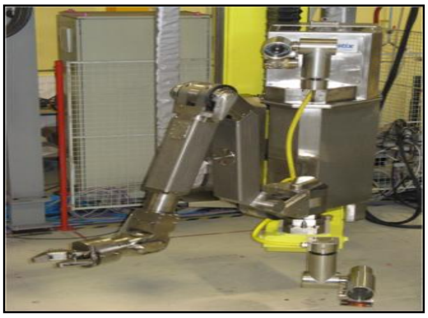
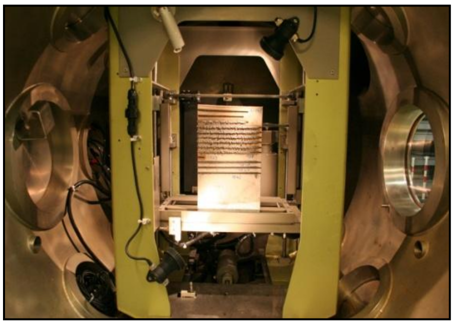


Fig .10. Remotely-handled arm



In order to improve cutting yields while limiting aerosols and waste generated, CEA had to develop powered Laser processes with safety demonstrations regarding dust treatment or risks of inappropriate cuttings. Specific laser heads had to be conceived: heads for cutting in air with air-cooling to prevent water leaking and heads for cutting under water (Fig .11.).

CEA also developed Control devices and devices to guarantee dynamic containment in case of fire.

Fig .11. Under-water cutting trials

Simulation for scenarios optimization and equipment qualification

CEA developed various platforms and tools for scenarios optimization and equipment qualification from feasibility studies to tests, demonstration and training:

- Test and demonstration platforms for cold qualification,
- 3D simulation software and virtual reality in Immersive room to compare alternative scenarios, qualify remotely-controlled equipment, or ensure that an equipment will be accepted by Safety Authorities:
- 3D simulation and doses calculation software, in immersive situation to choose the best way to operate with minimum dose integration,
- Pilot job sites for qualification under real conditions

Fig. 12. Under-water cutting trials

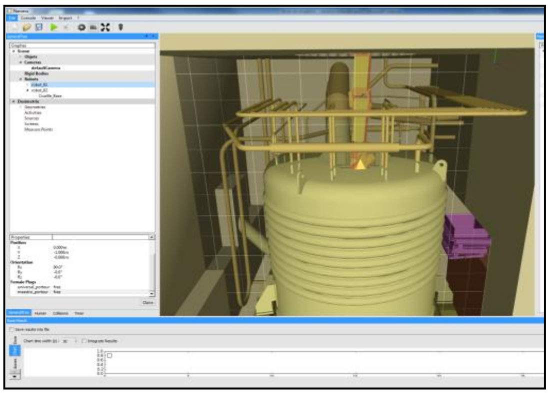


Fig. 13. Dosimetry 3D simulation software

DECONTAMINATION OF SOLIDS, SOILS AND STRUCTURES

CEA developed technologies for decontamination of solids adaptable to many geometrical configurations, and to a wide range of materials and natures of contamination: self-drying coating gels, laser ablation, viscous foams or active solutions, float foams or supercritical fluid

Several chemical medium formulations were studied with associated physic-chemical characterizations and suitable techniques, to help for implementation on pilot or industrial site in order to decrease radiological and chemical releases

Fig.12. AspiLaser ® technology

Fig.13. Decontamination foams

Fig.14. Pilot / Supercritical CO2

Other processes were also developed for decontamination of facilities by various rinsing reagents:

Ex: Before dismantling, all the process units of APM were cleaned up by a 4-step process:intensive rinsing (nitric acid) to remove the maximum of uranium and plutonium, degreasing (sodium hydroxide + surfactants) to eliminate organic matter, alkaline oxidation
(sodium hydroxide + ozone) to eliminate hot spots,pickling (nitric acid + cerium + ozone) to eliminate encrusted contamination to a depth of 2–10 µm.This process limited the long-lived intermediate-level waste to only 11 metric tons instead of an initially estimated 200 tons, significantly diminishing the residual radioactivity for dismantling.

Ex : For Concentrated fission product storage tanks D&D, the decision was also taken in 2005 to rinse the tanks of AVM with “specific” reagents. The objective was to decontaminate them while minimizing the effluent volume generated, and to ensure that during the dismantling phase a maximum of intermediate-level long-lived waste could be reclassified as low- and intermediate-level long-lived waste. These operations required the construction of a new evaporator. Rinsing operations allowed decategorization of 5% of ILW LL waste in LILW LL.

WASTE TREATMENT AND CONDITIONING

For its own facilities and D&D workshops, CEA had to develop efficient treatments for complex radioactive waste to enhance the efficiency of decontamination, to minimize the volumes of secondary waste, to protect the operators and to minimize the overall costs.

Now, CEA possesses a longstanding experience in both solid and liquid waste treatment, from the initial waste to the final disposal form. Innovative solutions have being and continue to be developed with processes involving chemical, electrochemical, hydrometallurgical, pyro chemical as well as thermal techniques.

Decontamination of effluents

CEA developed and implemented decontamination processes for radioactive radioactive effluents through physico-chemical techniques to reduce downtime and improve effluent treatment facilities, e.g. decrease radiological and chemical releases.

CEA specialized in design and development of optimized equipment and customized synthesis of reagents (Fig . 15.). It owns cutting-edge experimental means enabling inactive and active investigations and testing at laboratory and pilot scales, as well as experimental studies and modeling for extrapolation and associated technological development.

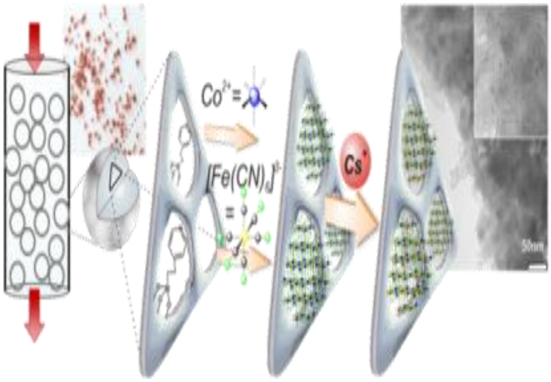


Fig .12. Innovative nanostructured adsorbents

Treatment of Sodium Waste

An example of CEA R&D application to D&D workshops is the treatment by carbonatation of the sodium removed from Phenix and Rapsodie fast breeders, one of the major tasks prior to the dismantling of these reactors. The process designed in CEA Cadarache laboratories will be implemented in a facility under construction in Marcoule, close to Phenix reactor (Fig .13.). It has already been implemented by EDF for SuperPhenix D&D.

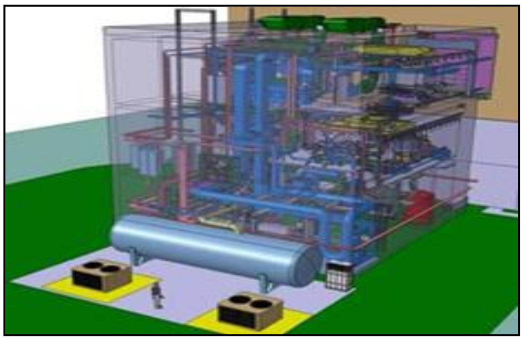


Fig .13. Sodium treatment facility

Treatment of organic liquids

CEA developed several processes for the treatment of solid or liquid organic radioactive waste: incineration, mineralization of organic liquids by hydrothermal oxidation or by plasma incineration.
A new process for incineration of radioactive solvents containing chlorine or Fluor by plasma under water is under way of industrialization (Fig .14.). The use of plasma under water should simplify dust treatment and prevent corrosion of the facilities.

Fig .14. Pilot / Plasma under water

Waste conditioning

CEA R&D capabilities and skills cover all fields related to waste conditioning:

- Formulation and qualification of conditioning matrices,
- Conditioning process development
- Validation for all steps through to industrial scale and qualification information for waste packages during their storage and disposal

Historically, two major fields of development are cementation and vitrification, finding applications in D&D &R: cementation with mineral geopolymers for encapsulation of Magnesium (Fig .15.), and vitrification "in can melting" for high level waste, for example for UP1 reprocessing plant powdered waste (Fig .16.).

Fig .15. Geopolymer matrix for UP1 Magnesium

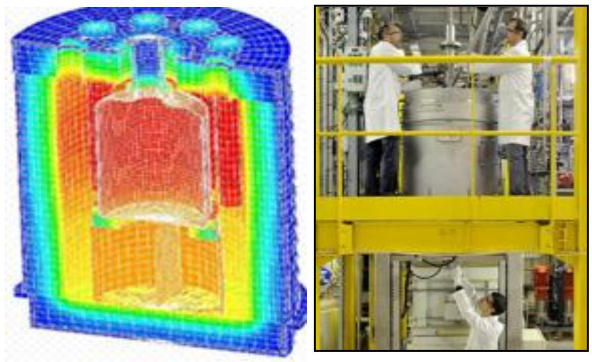


Fig .16. "In-Can Melting" Vitrification

METHODS AND INFORMATION TECHNOLOGY (IT) TOOLS FOR PROJECT AND WASTE MANAGEMENT

This field has to deal with our expertize as operator of big D&D &R projects on several sites CEA has set up a network of interconnected operational IT tools for all the steps involved in nuclear facility decommissioning and dismantling procedures, from cost estimation to waste and transportation management so that we can ensure traceability and harmonize the data provided.

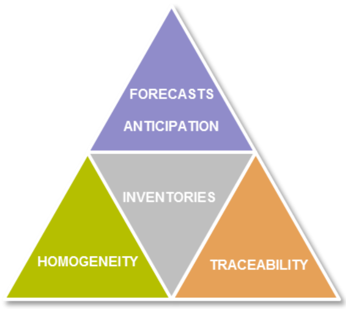
Key figures:

- 3000 technico-economic costing ratios,
- +50 product headings,
- 225 000 packages
- +300 users.

Estimation, methods and tools

CEA developed certified tools and methods to evaluate dismantling forecasts.
These tools are also available to know the probable future dismantling costs for a facility before its construction or to compare dismantling scenarios in order to optimize factors such as costs, scheduling, integrated doses, and amounts of waste generated.

Inventories, transportation and waste management



Even more than during operation information systems and data management are key to ensure the quality of adequate radiological and physico-chemical data concerning the facility and its equipment and of information collected during operating and dismantling phases is a key strategic element for well-run operations, efficiently-oriented scenarios and improved procedures.

CEA developed a network of interconnected operational IT tool (Fig .17.) to ensure traceability and harmonization of the data provided by decommissioning and dismantling job sites in a centralized record base and be able to optimize waste management scenarios (storage, shipment, waste packages route, etc.).

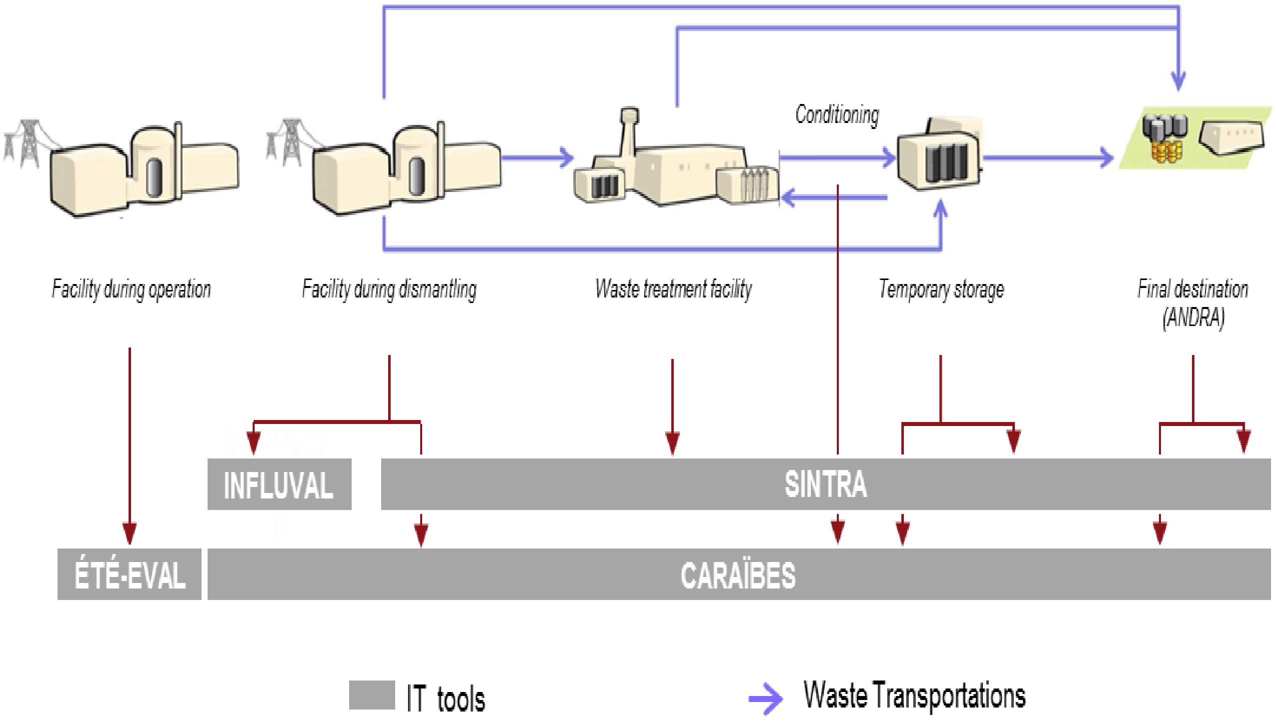


Fig .17. Network of interconnected operational IT tools

CONCLUSIONS

The position of CEA is quite unique:

- on one side the operator of a great number of facilities under decommissioning, with and a wide diversity from laboratory scale to industrial plants and contamination levels sometimes very high,
- on the other side a research organization with a nice range of experimental setups: integrated test benches for work with real wastes, means to analyze and characterize in inactive and active conditions, calculation and modeling tools, methodological tools, technological platforms, irradiators, etc.

This position allows CEA to implement technologies and processes from laboratory scale through to industrial application, with very concrete objectives coming from projects.

CEA leads R&D actions and develops expertise in the 6 main axes of D&D to afford adequate technologies and processes to solve remaining technical problems and to help decrease costs, schedules and amounts of waste or improve the safety of D&D &R workshops.

CEA is willing to work in partnership with other international contracting authorities and industrialists sharing the same challenges in order to share costs of R&D developments and best practices and to implement the results of this R&D on CEA D&D workshops and on the French and international market.