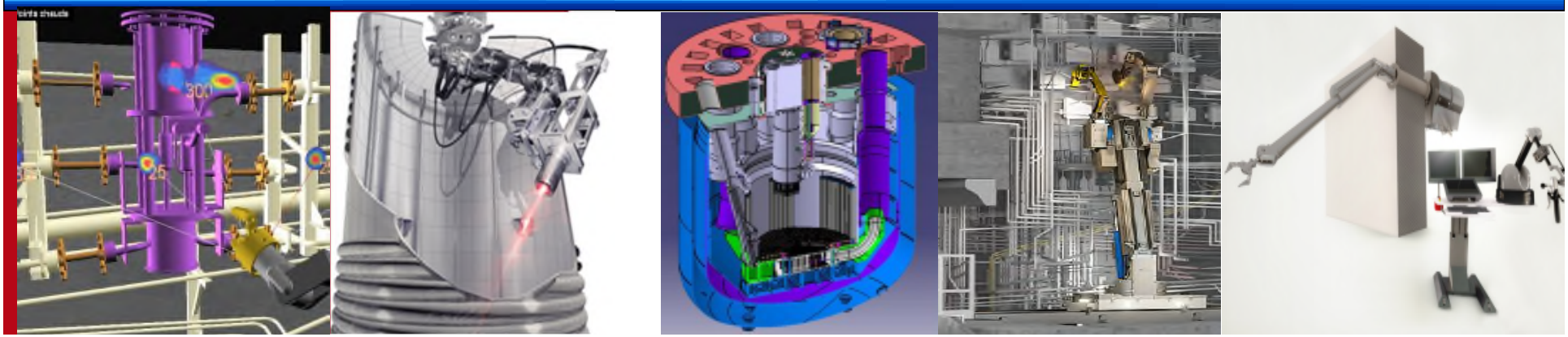
FROM RESEARCH TO INDUSTRY

nuclear expertise from France

FRENCH EXPERTISE ON REMOTE-CONTROLLED SYSTEMS FOR DECOMMISSIONING

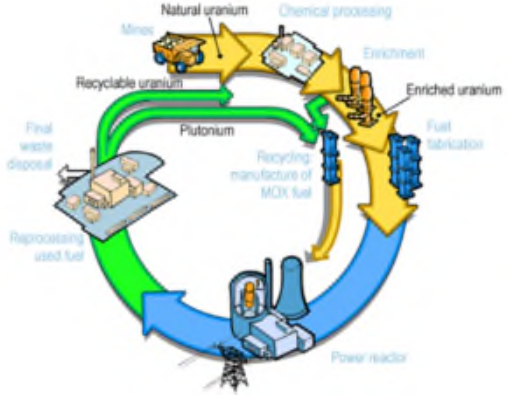
IWAKI, August 6th 2018

Christine GEORGES
CEA/DEN/DDCC
christine.georges@cea.fr



DECOMMISSIONING IN FRANCE: 3 OPERATORS WITH GREAT VARIETY OF FACILITIES

- ***~ 13,5 B€***
- D&D of Experimental reactors (Gas cooled/PWR/FBR) enrichment & fuel cycle facilities (UP1, APM, etc.)



- ***~ 7,5 B€***
- D&D of enrichment and Fuel-cycle facilities

- ***~ 24,4 B€***
- D&D of NPPs


Chinon A


St Laurent A


Bugey 1


Chooz A


Creys Malville


Brennilis

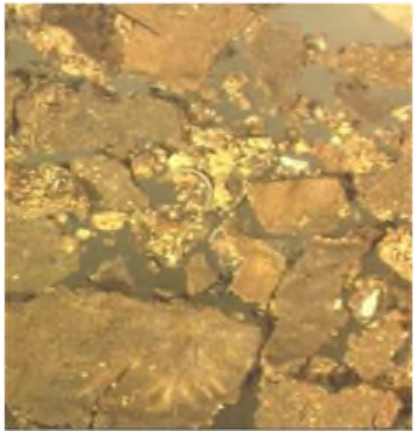
Challenges similar to 1F in CEA and ORANO **Fuel Cycle facilities** with joined experience on :

- unexpected situations
- diversity of waste
- high dose rate and contamination (U, Pu and fission products)

EXAMPLES OF VERY HIGH CONTAMINATION AND RADIOLOGICAL LEVELS – DECOMMISSIONING IN MARCOULE

Sludges in tanks up to 300 Gy/h with kilos of Plutonium mixed with Uranium and fission products

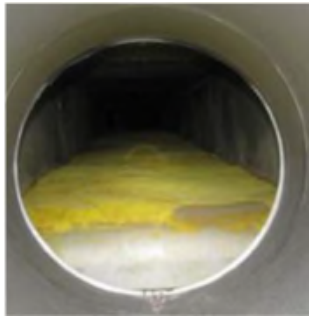
- **Unexpected after rinsings**
- **Difficulties to retrieve**
- **Waste management**

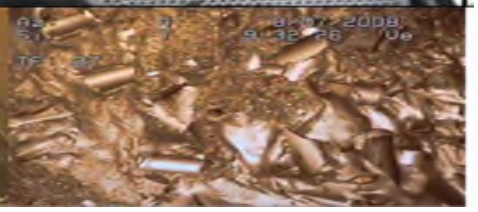


Example of legacy waste with fuel debris

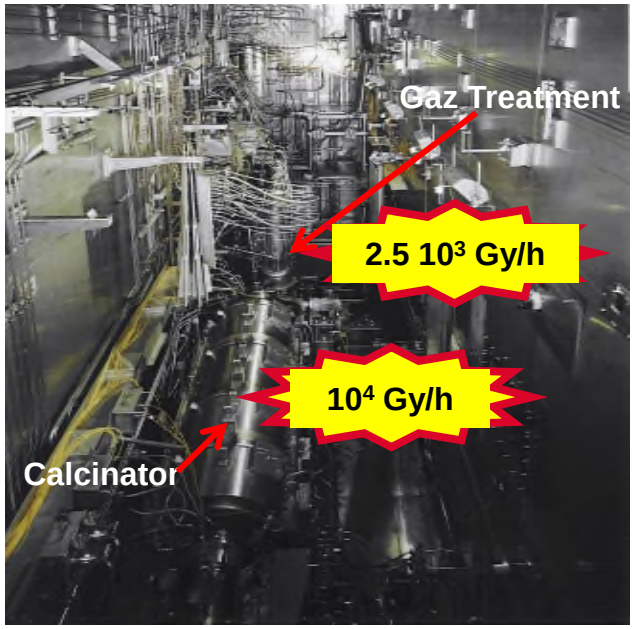
- **Very different chemical and radionuclide compositions; long-lived**

Example of vent pipes and corridors contaminated by spent fuel solutions liquors

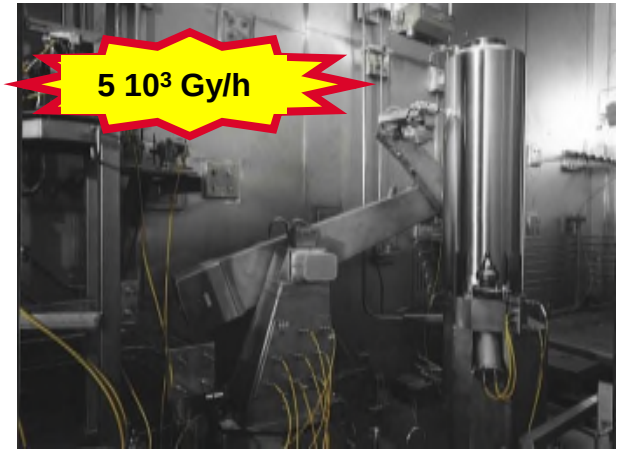




EXAMPLES OF VERY HIGH CONTAMINATION AND RADIOLOGICAL LEVELS - MAINTENANCE IN LA HAGUE



Vitrification Cell



Automatic Contamination Control

- Dispositions and tools ensuring confinement, easing maintenance operation, facilitating decontamination, avoiding contamination spreading, rad proof equipment
- Handling operations and clear vision in hot cells

Vitrification facility hot cells

Remote removable parts

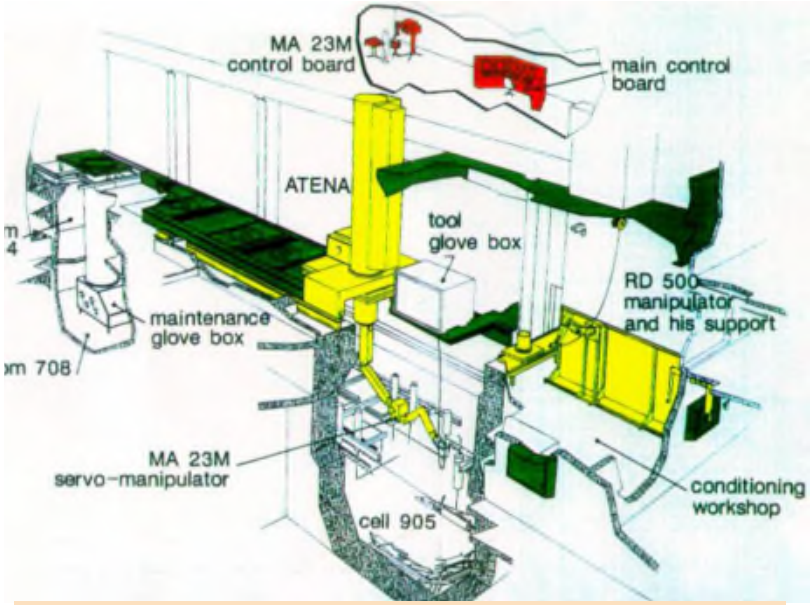
In-cell handling crane (LH ACC)

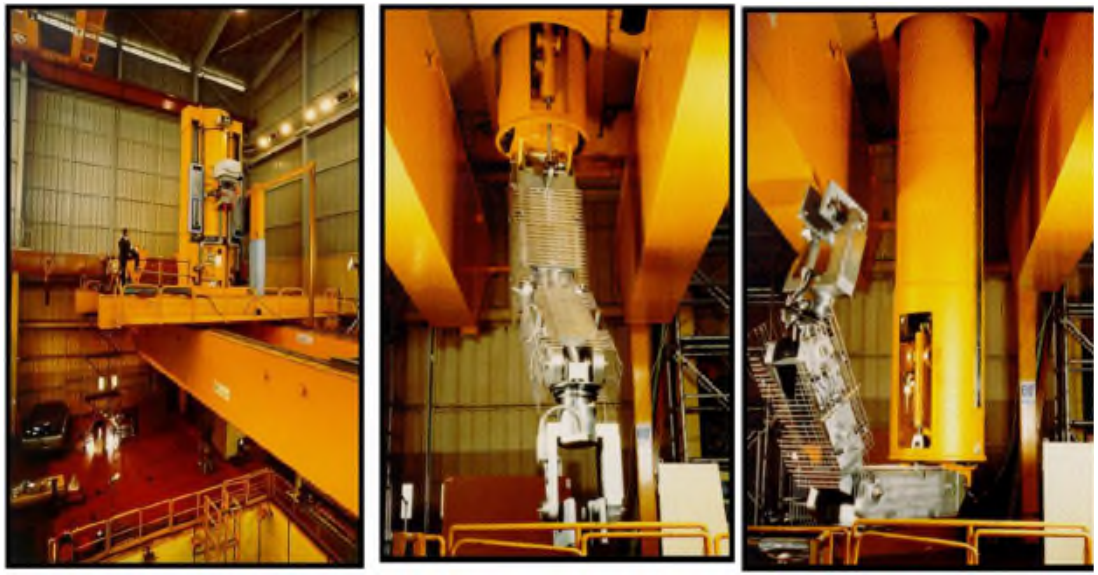
LESSONS LEARNED FROM THE 90s

ATENA = FIRST OPERATIONAL DEMONSTRATOR

AT1 reprocessing pilot plant – CEA La Hague

- AT1 shut down in 1979, 2,5 years decontamination
- 4 years from 1990 for dismantling of mechanical hot blind cells with ATENA



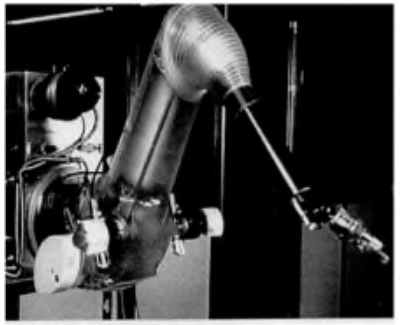


ATENA: multi-jointed holder, equipped with RD 500 type remote manipulator

- Good process for decontamination and cutting of equipment and concrete walls
- Very modern concept of telescopic arm
- First demonstration of modern TAO 2000 control command computerized with force feeback, cartesian mode and graphic supervision

But

- Heavy machines
- Lack of capacity for decommissioning (500N)
- Could reach equipments only 13 meters of the cell's entry point
- Poor reliability
- Problems with some tools
- Not reusable and very expansive



RD500 developped in the 80's by CEA with Cybernetix

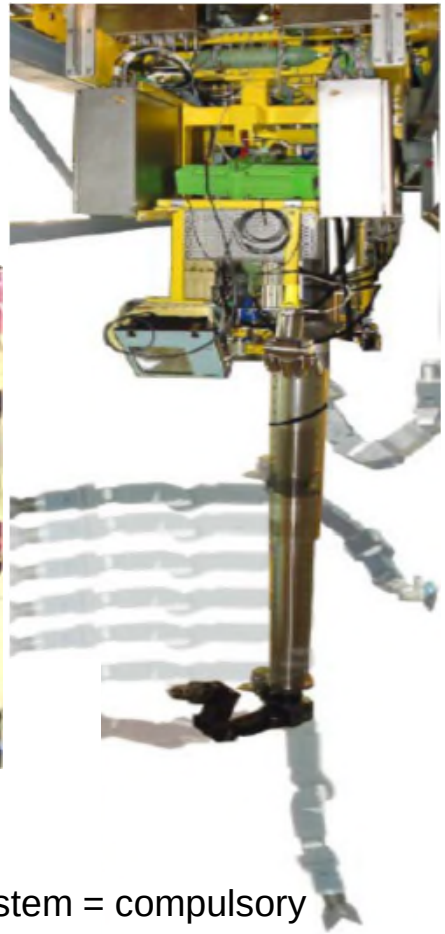
UP1 REPROCESSING PLANT – CEA MARCOULE
CHEMICAL VERSUS MECHANICAL CELLS

Ex: Decommissioning of Liquid/liquid extractions Unit (U/PU and fission products)

NO remote controlled operations after decontamination in 2 steps:
1°) through process lines with adequate reagents
2°) decontamination of mixer settlers with decontamination foams

≠

Ex: Decommissioning of spent fuel storage



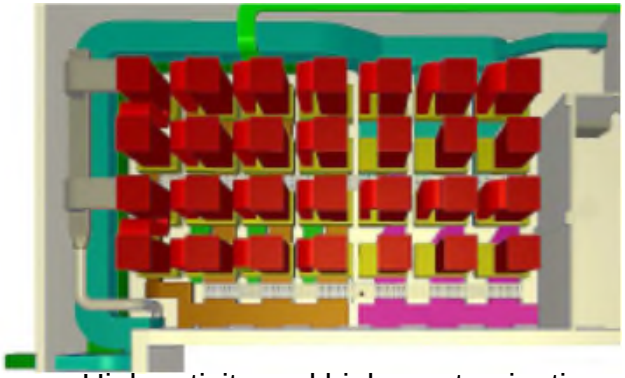
Here, remote controled system = compulsory

DECOMMISSIONING AFTER INCIDENTAL CONTAMINATION BY SPENT FUEL DISSOLUTION LIQUORS IN UP1 MAR200 BUILDING VENTILATION

Former strategy: To use as much as possible «on the shelves » systems and let sub-contractors responsible for the choice of remote controled systems

In 2000: complete project subcontracted at « cost to objective» to a consortium of the best companies of the moment in D&D, but:

- Lack of experience in remote operations
- Minimalist view on operation constraints
- Cutting cadence not well predicted Initial contract broken, time x 4, dosimetry x2

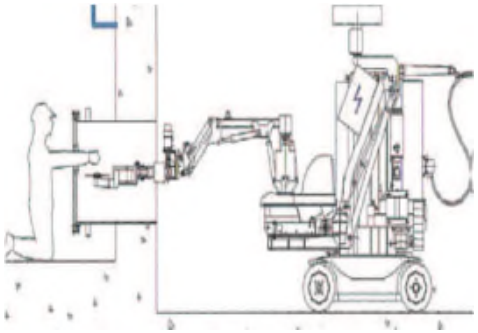


High activity and high contamination

For Bottom of filters

For top of filters

For transfer of cut pieces

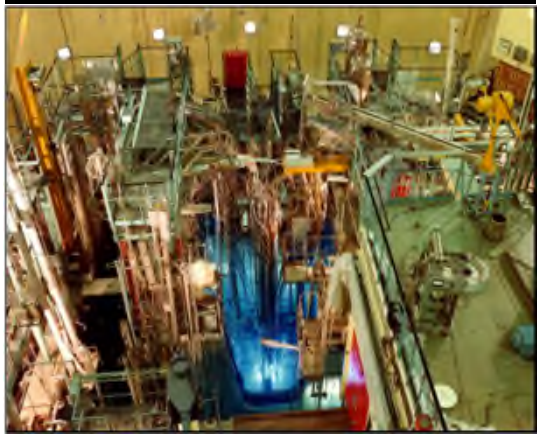


SEVERAL INCIDENTS AND ACTIVE DEPOSITS LEADING TO DIFFICULTIES FOR RETRIEVAL OF WASTE AND EQUIPMENTS

- Incidents happened in 1982 and 1985 in the spent fuel dissolution facility: 460 kg of dry sludge were found in 2011.
- Simple system but numerous inactive tests were necessary for qualification together with need for process equipments and storage for waste management.

DECOMMISSIONING OF SILOE RESEARCH REACTOR IN GRENOBLE

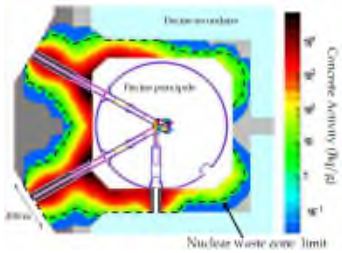
1997: Shut down



2005

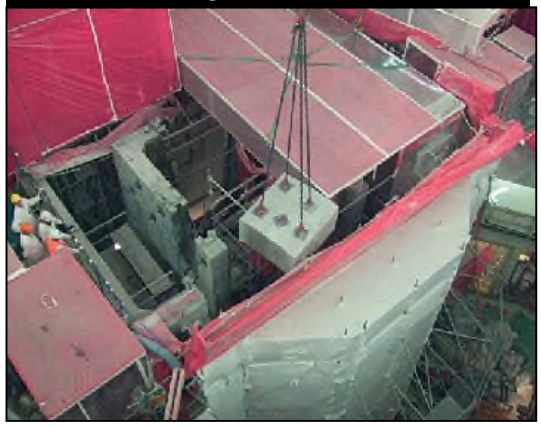
2007: Remote cutting

2008



After water draining, dose rate at the bottom of the main pool much higher than expected (activation) => remote-controlled operations

2009: cutting of activated walls



2010: Internal structures out

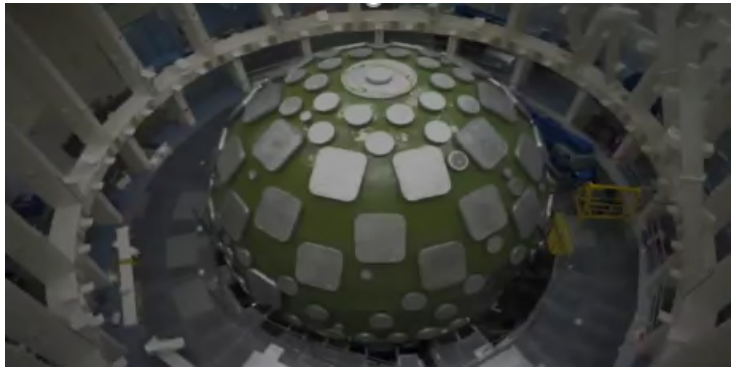
LONG REACH MANIPULATORS FOR MAINTENANCE OF PLASMA / FUSION RESEARCH FACILITIES

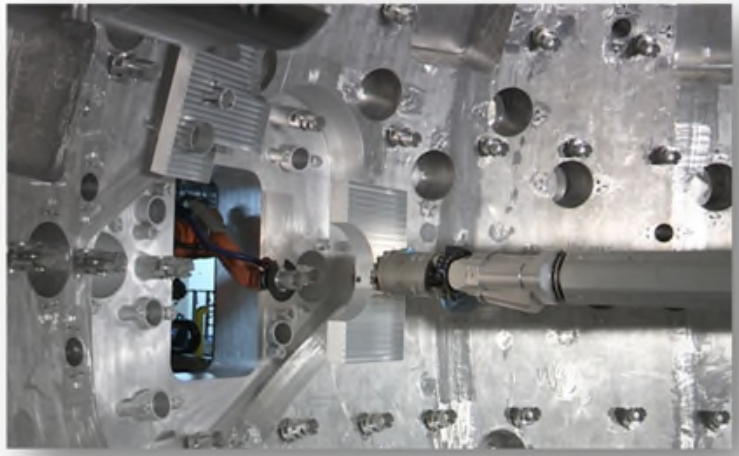
Long reach articulated arm Cea List design & development (2004-2008) , Industrialization by CYBERNETIX in collaboration with CEA List:

⇒**1st introduction in TORE SUPRA** tokamak in 2008 (200°C, 10^{-5} Pa)

⇒ **Operational since 2012 at CEA DAM LMJ (Laser Maga Joule) :** automatic replacement of protective panels (250 panels /50kg) with 2cm accuracy

- System with 8 degrees of freedom over 17m and a 100kg payload; 12m horizontal extension, folds back in a 6m mobile casing
- Tie-in diameter 630mm for complete internal room surface radial access





SYNTHESIS / LESSONS LEARNED
1. ABOUT METHOD

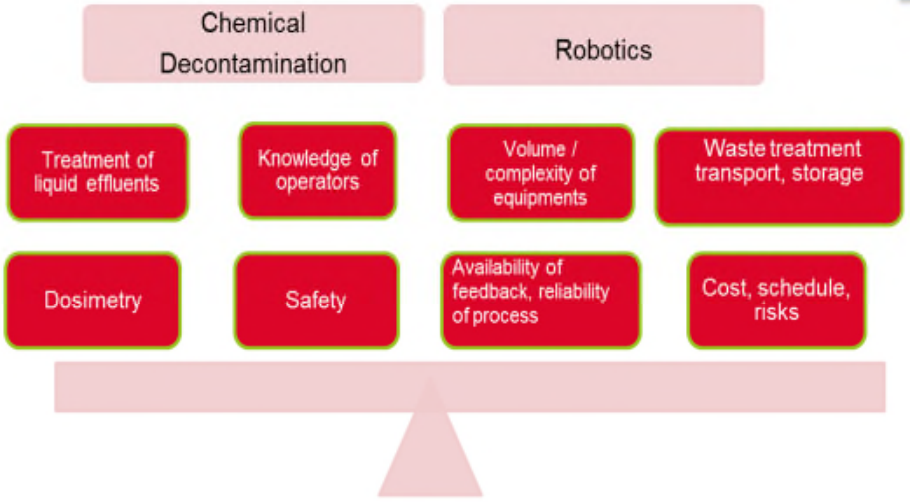
- Knowledge/ initial state and Definition of final state (radiological but also physical and chemical / waste management)
- Remote systems = Long process often on critical path for D&D operations

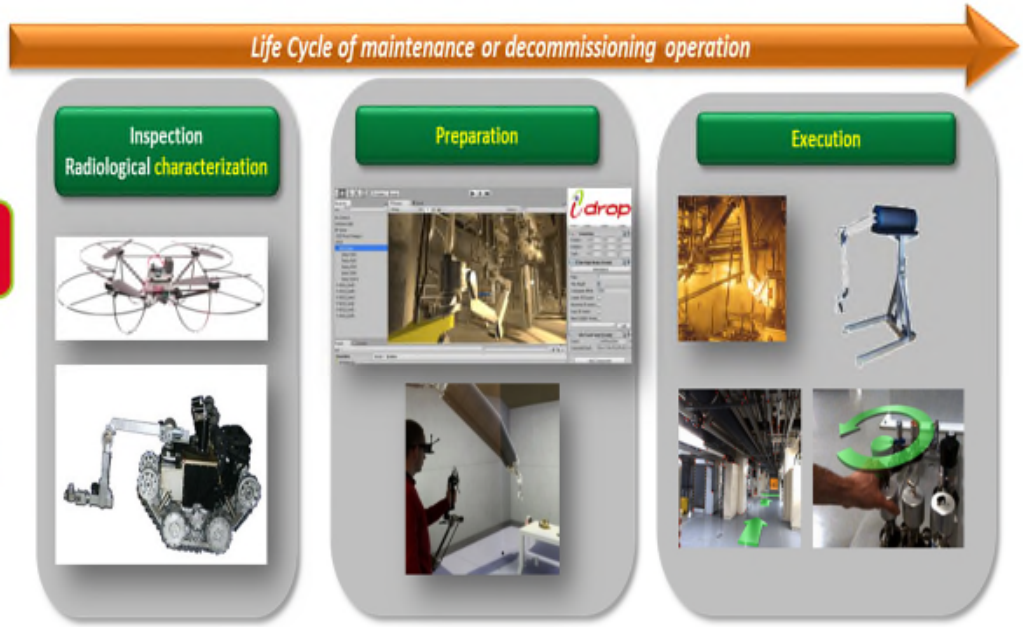
→ Specific tools for Investigation campaigns

→ Comparison of scenarios with multiple criteria on global process from investigations to waste routes

- Need for full scale mockups to qualify process and method

→ «Product lifecycle management » with simulation tools and hazard analysis to validate process and mitigate risks





When dose rates allow to hesitate between remote controled or manual operations, remote operations need to be reliable to offer a valuable gain

SYNTHESIS / LESSONS LEARNED
2. ABOUT REMOTE OPERATED SYSTEMS

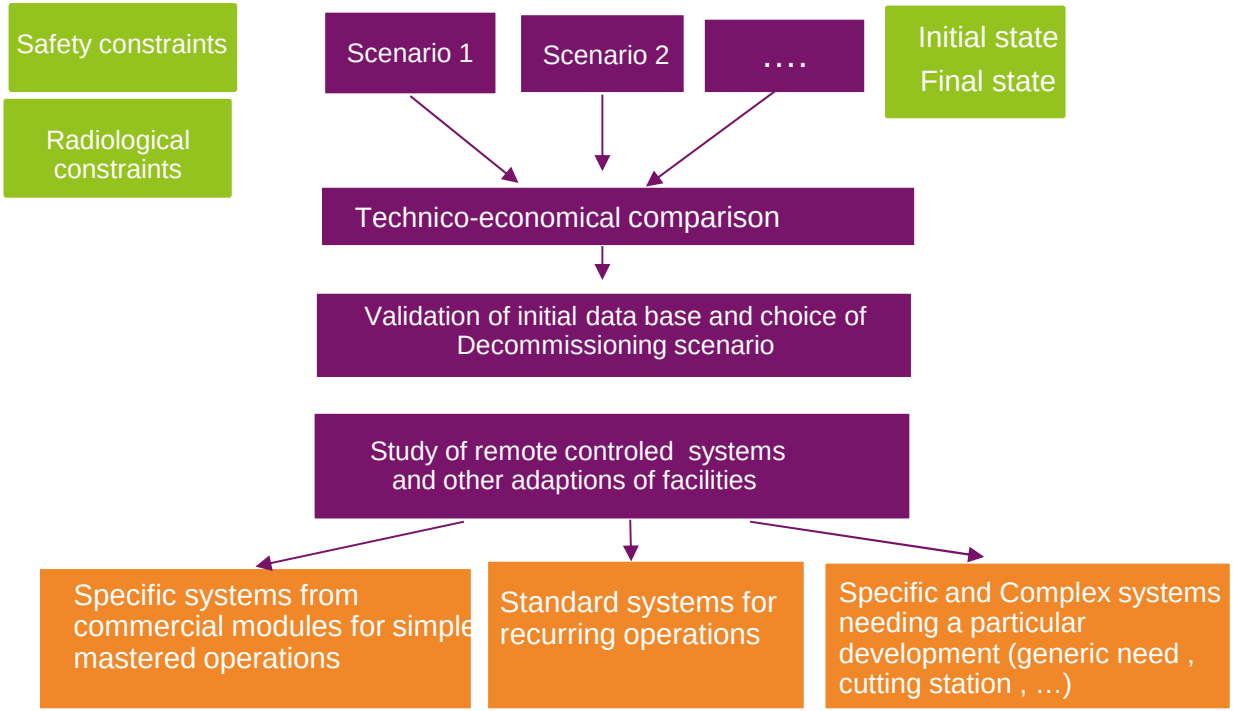
- Need to develop industrial systems with higher productivity and improved safety:
  - Lighter, cheaper and more versatile Carriers
  - Manipulator arms with higher payload capacities, more reliability and maintainability, including under agressive decontamination

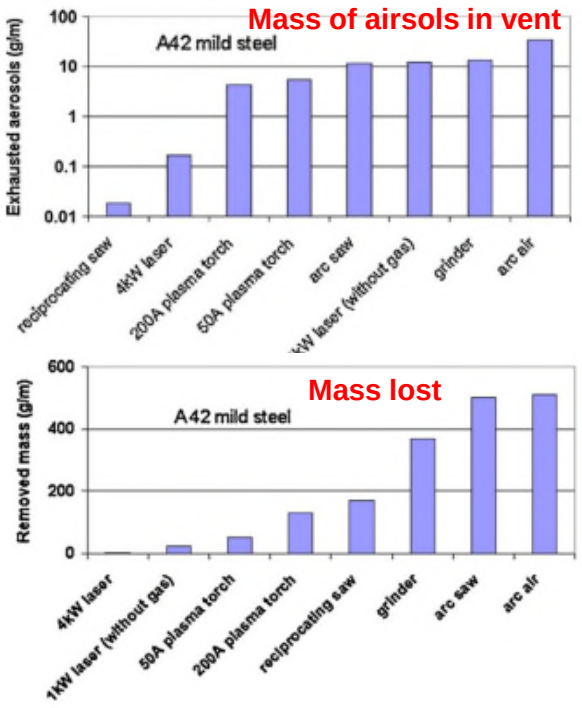
→ Prototypes only for highly recurring operations; for others, use of proven technologies / bricks + nuclearization

→ Multi-functional robotic platforms compatible with multiple configurations with easily changed tooling, both for investigation, decontamination, segmentation and retrieval of waste

- Need to improve tools for segmentation(speed and waste) + changing of tools + umbilical and cables management

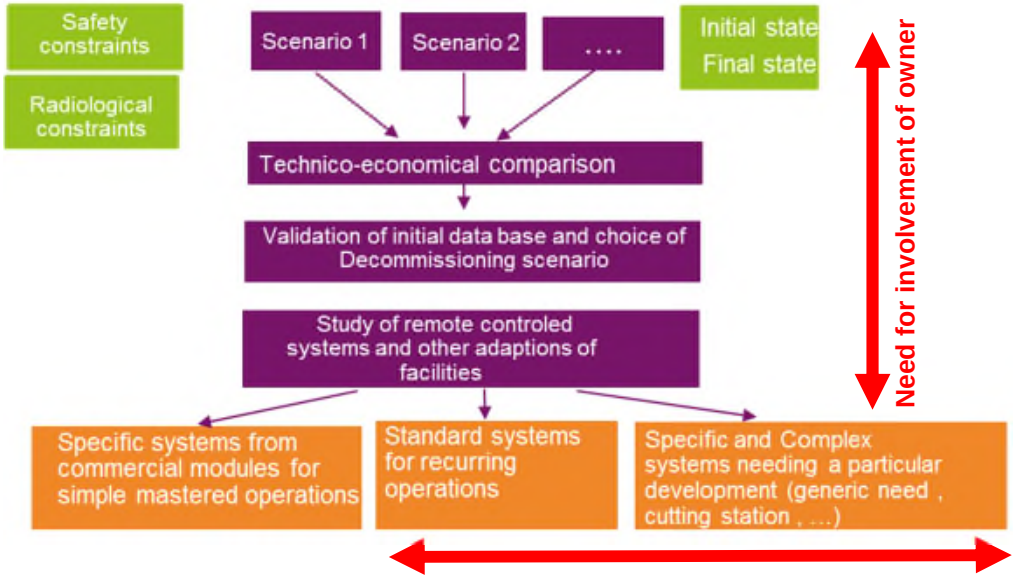
→ Tool box to be ready to face unexpected situations / development of laser cutting





SYNTHESIS / LESSONS LEARNED
3. ABOUT ORGANISATION

- **Economy on the material is nothing compared to years of delay with staffing costs** → Involvement of Owner since engineering studies
- Concurrency between companies → Hard to deploy feedback and mutualize for optimization → Adapted Contracts and interoperability through standards
- New skill: Both decommissioning and constructing , adapting technique to operational constraints of the facility → Integrated teams with operators, project managers, remote controlled specialists and R&D teams



Reluctance to use innovative technologies and search for approved technologies to minimize risks

Need to "Keep it simple" but also to encourage contractors to use more effective/ efficient techniques

SOLUTIONS DEVELOPPED

STANDARD REMOTE HANDLING MASTER-SLAVE / «TAO » WITH FORCE FEEBACK CARTESIAN POSITION

1970's

1990's computer assisted remote handling

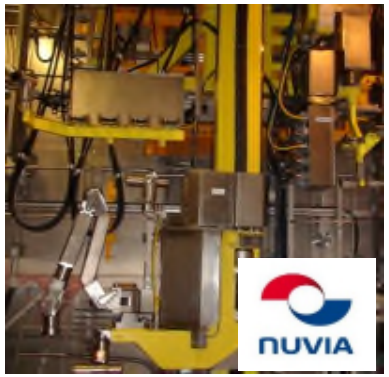
2000's Industrial transfer

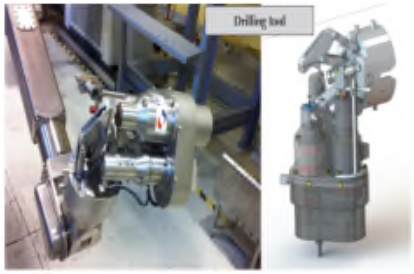
- Force feedback master/slave control: **improves productivity**
- Robotics trajectory control, Virtual Mechanisms
- Cartesian/joint position control: **enhances control effectiveness**
- Position/force homothetic setting, Gripper pursuit with camera
- 3D graphical supervisor

MT200 TAO and TERMAN TAO

REMOTE DISMANTLING
FROM R&D … TO IMPLEMENTATION AT CEA WORKSHOPS

- 4 worshops
- 3 D&D major companies
- 4 configurations (mast, Brokk, crane, rail)



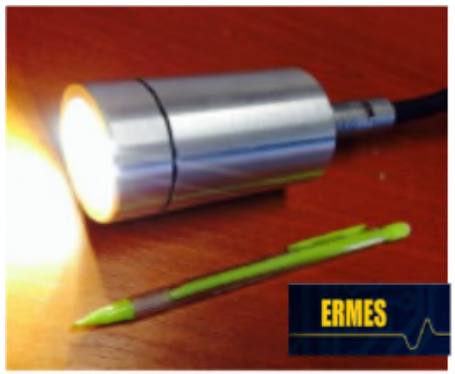


SOME TOOLS FOR INVESTIGATIONS IN SEVERE ENVIRONMENT

For visual inspection or sampling

In concrete structures

In decladding pools

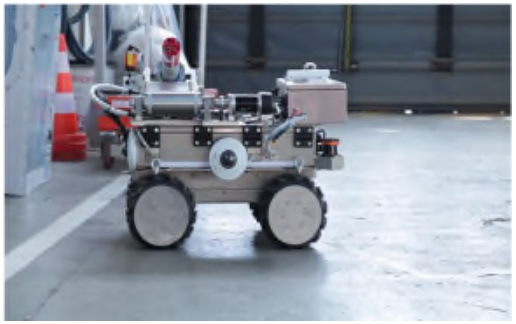


High Rad resistance CMOS

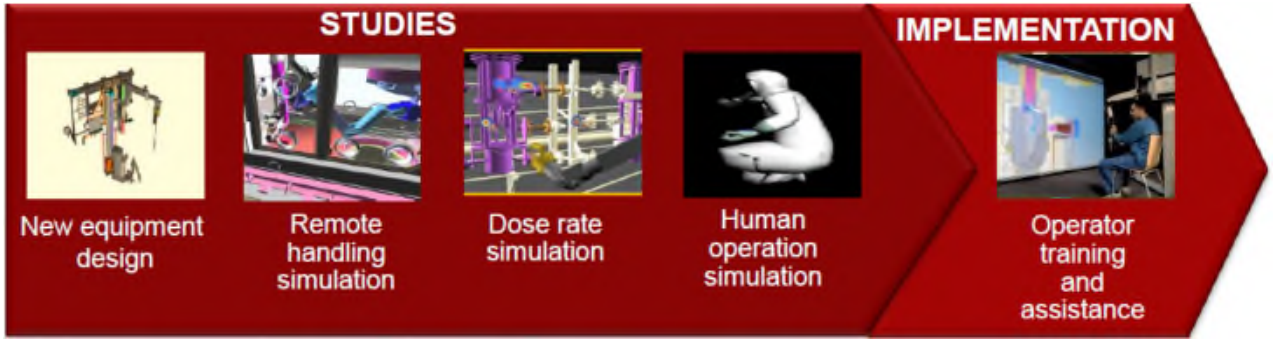
For sampling

For Radiological inspection

NANOPIX Currently smallest camma camera:
268g, 80x51x43mm



INTERACTIVE SIMULATION TOOL (15 years CEA R&D)



unity

idrop

Advanced *interactive simulation modules*

Dynamics simulation

- **Multibody** multicontact
- Accurate **collision detection**
- **Cable** (soft parts)
- **Robots and tools** library
- **Human** simulation

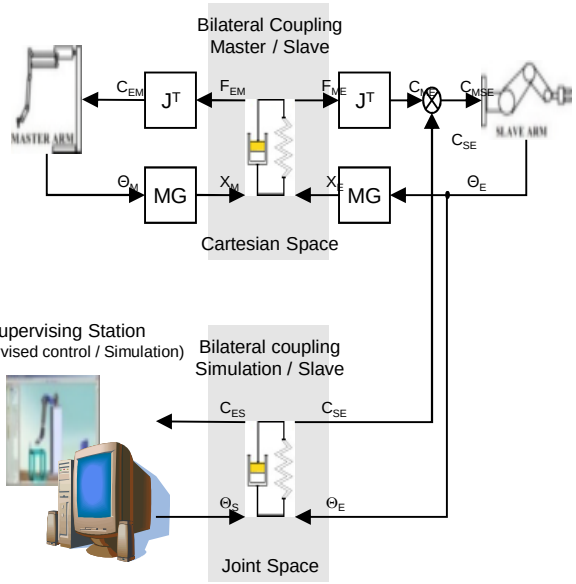
Dose rate simulation

- **Interactive** dose rate calculation with Build-Up
- **MERCURE 6.3** kernel optimized for real-time
- **ALARA** studies

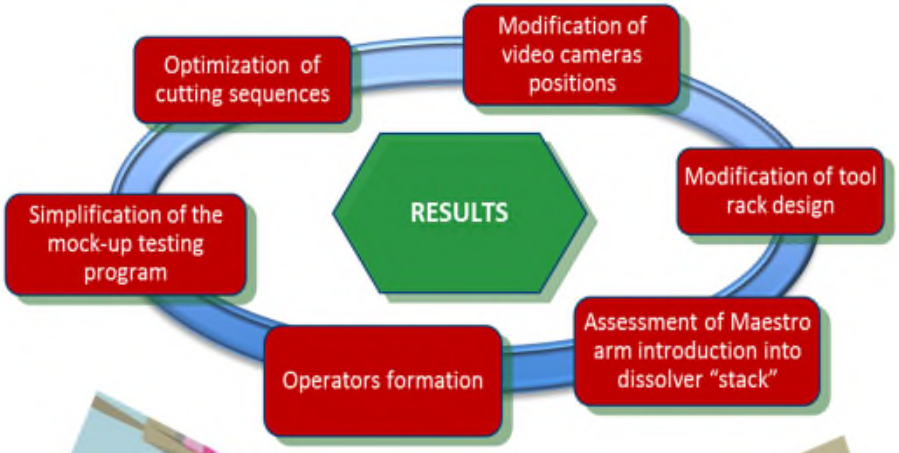
...

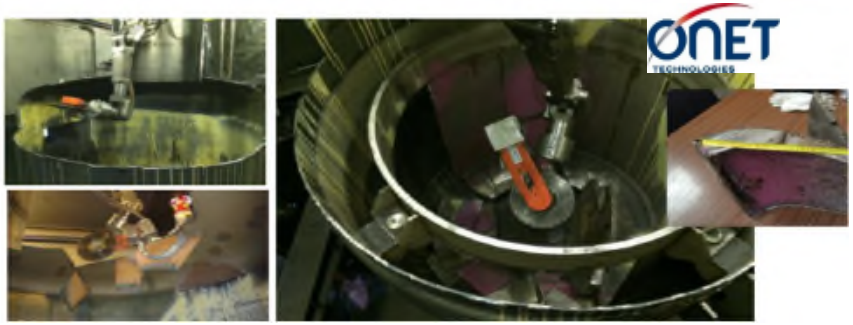
Immersive device coupling: haptics, MoCap, 3D systems ...

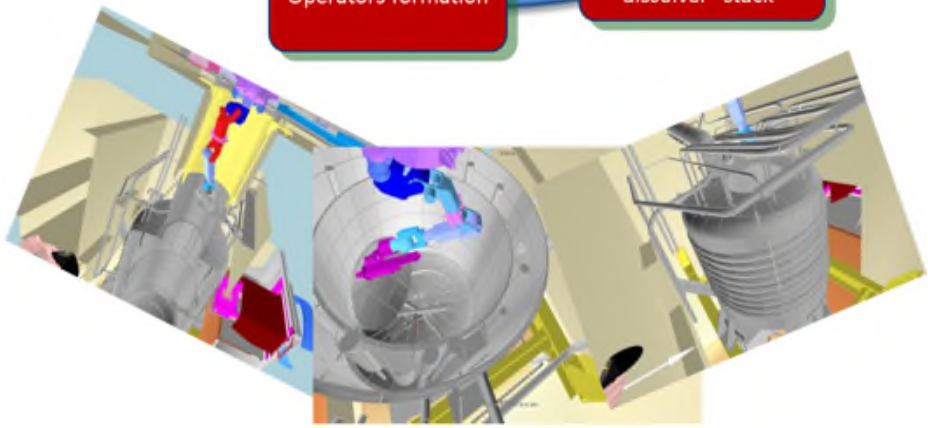
Coupling Scheme Principle

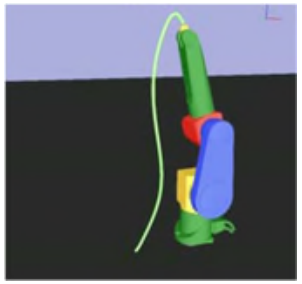


COMPLEMENTARITY OF VIRTUAL AND PHYSICAL MOCKUPS TO SECURE PROJECTS
Example of UP1 dissolver workshop









MORE FUTURISTIC …SOME ROBOTICS CURRENT TRENDS

Robotic manipulation for nuclear sorting & segregation

Dexterous master hand

Visual SLAM + constraints : Assistance to operators

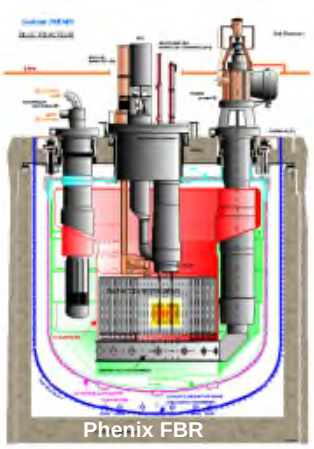
Wireless network

- 4G
- Multi-band WiFi Mesh

CONCLUSION

- **Lot of similarities** with challenges of decommissioning after severe accident : relevance of Fuel cycle Facility operations and D&D experience for Fukushima
- Study of scenarios based on multiples criteria (doses, waste, cost, schedule, etc.) taking into account each step of the process **from initial characterization to waste disposal.**
- Synergy between operators, project managers, remote controlled specialists and R&D teams
- Progresses in Robotics/ Cobotic in the last 15 years, but still needs for adaptations to increase resistance to radiations and need for qualification for more reliability, flexibility, performance and waste minimization ; **opportunities for collaboration within the nuclear community:**
  - To learn from successes and failures and avoid re-inventing existing proven technologies
  - To share R&I, studies for safety reports, standards for interoperability, pilot operations, etc.

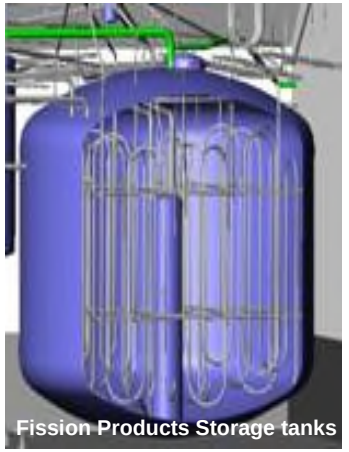
Underwater laser cutting / deep gouging



Phenix FBR

Rapsodie FBR

Fission products evaporators



Fission Products Storage tanks

Vitrification cells

Example = More than 20 «High activity projects» at CEA in the next 20 years

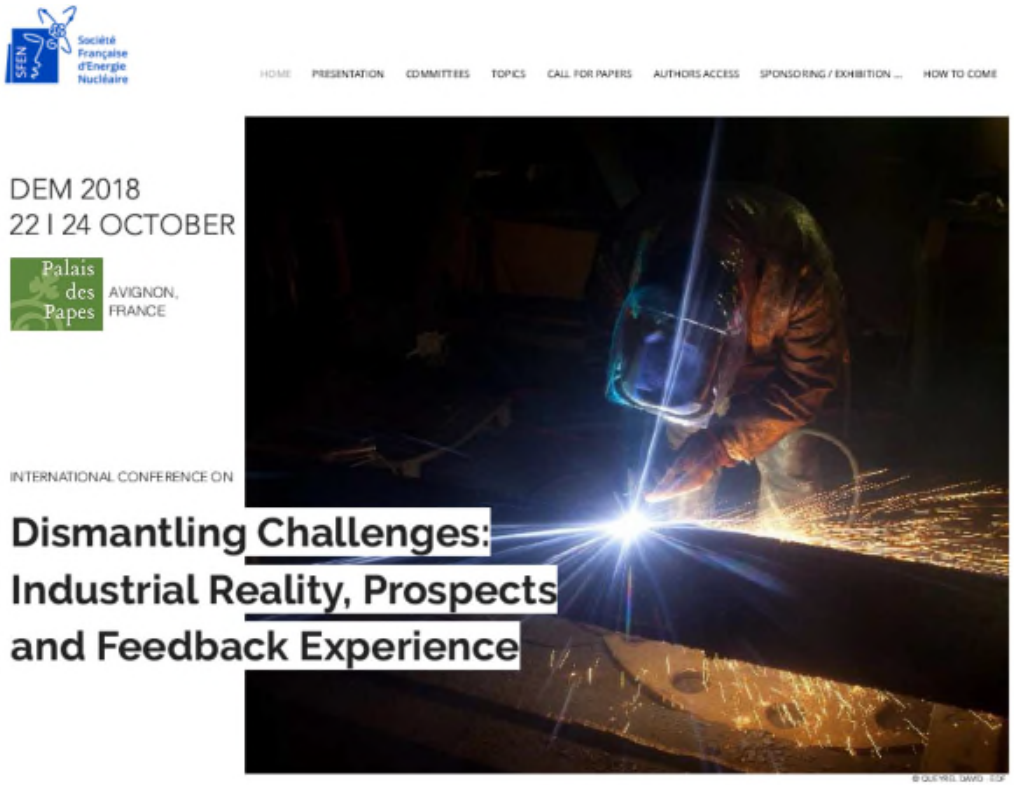
NEA WORKSHOP ON THE APPLICATION OF REMOTE AND ROBOTIC SYSTEMS IN DECOMMISSIONING AND WASTE MANAGEMENT

30-31 January 2019, Marcoule, France

Exchanges between R&D organisations, waste management and decommissioning operators, national decision makers, regulatory bodies and other interested parties on existing national experience/opinions:

- How to address the main requests of final users
- Determining factors that affect development and implementation: strategic decisions to support the implementation
- Dialogue at the international level to support and facilitate further implementation and to foster harmonized understanding, terminology and approaches through

DEM2018 – AVIGNON OCTOBER 22/24th
INTERNATIONAL CONFERENCE FOCUSED ON D&ER



- **5 previous editions :**
  1992, 1998, 2003, 2008, 2013
- **In 2013: 115 oral papers, 355 participants from 22 countries**
- **209 papers registered for DEM2018**

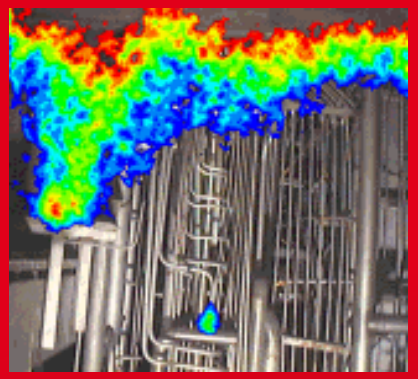
- **Dismantling Strategy and Program Development**
- **Regulation Evolution**
- **Initial Radiological State Characterization**
- **Project Feedback Experience**
- **Buildings and Sites Rehabilitation**
- **Material and Radioactive Waste Management**
- **Economic and Financial Aspects**
- **Stakeholders Involvements and Public Acceptance**
- **Development of New D&Ds' Technologies**
- **Digital Contribution to Dismantling Operations**
- **Fukushima: feedback and operation in progress**

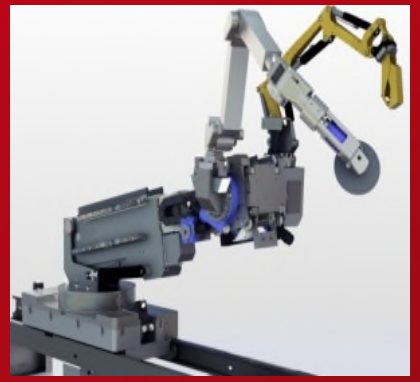
KEY DATES / DEADLINES / MILESTONES

FEB. 2017	JUNE 2017	15 JAN. 2018	FEB. 2018	MAR. 2018	15 JUNE 2018	15 JUL. 2018	8-15 OCT. 2018	22-24 OCT. 2018
Call for papers and intention to submit	Extended abstracts submission starts	Extended abstracts submission ends	Authors notification [oral & poster selections]	Conference registration opening	Full papers submission starts [oral & poster selections]	Full papers submission ends [oral & poster selections]	Presentations submission [oral selections]	DEM Conference

Thank you
for your attention

Hope to see you
in Avignon
next October





French Alternative Energies and Atomic Energy Commission
Centre of Saclay | 91191 Gif-sur-Yvette Cedex

Public industrial and commercial institution | R.C.S Paris B 775 685 019

ANNEX

INTERVENTION AFTER AN ACCIDENT: GIE INTRA

- Created in 1988 by CEA, EDF and ORANO
- CONSTITUTE, OPERATE and MAINTAIN a fleet of remotely controlled equipment for interventions in environment radiologically hostile for man.

Creation of an International normalisation commission for remote controled in nuclear in 2016