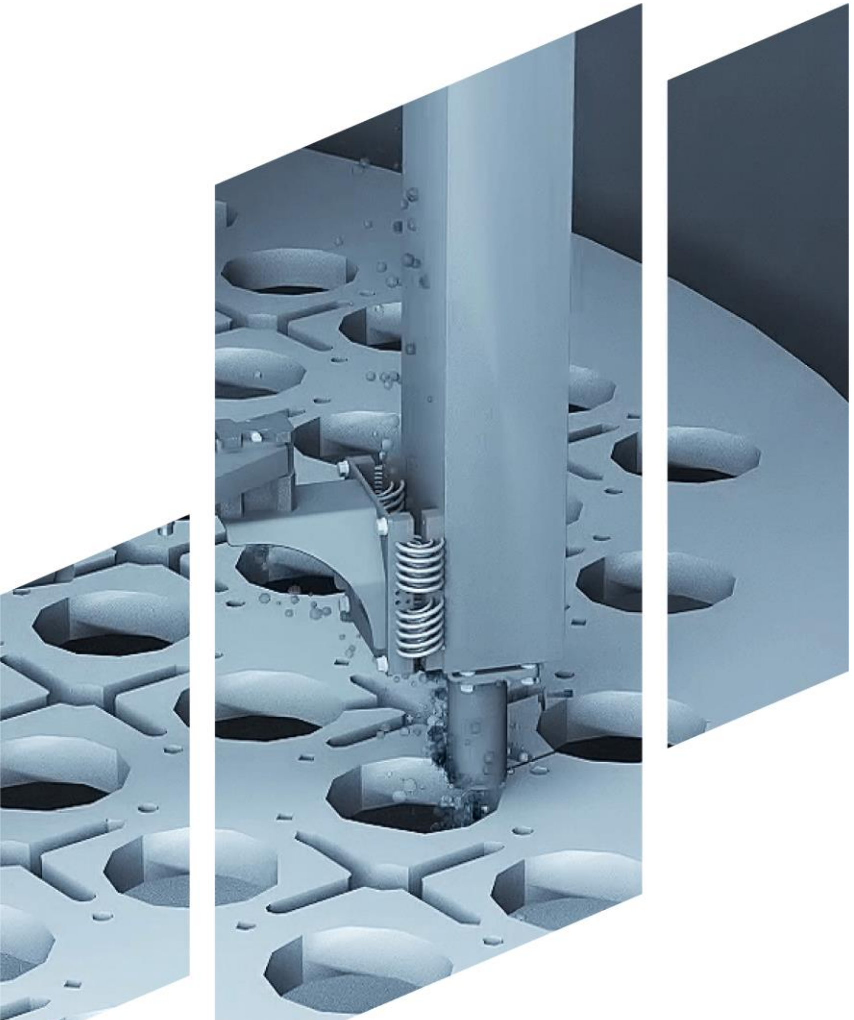
Laser Dismantling Environmental and Safety Assessment



LD-SAFE

Laser technology for PWR/BWR RVI segmentation

NEA Workshop
December 1, 2022

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This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 945255

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Summary

1. CONTEXT & CHALLENGES
2. LASER CUTTING TECHNOLOGY
3. LD-SAFE
4. MAIN TECHNICAL ACTIVITIES
5. PROGRESS
6. MAIN OUTCOMES & NEXT STEPS

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Context & challenges

Decommissioning of a power reactor

- Commonly scheduled to be completed over a **long period (over 20 years for PWR/BWR in general)**
- **New challenges** (acceleration of the decommissioning project schedules)
- Need to improve the **dismantling processes**
- **Limited effectiveness** of the conventional cutting techniques (i.e. Plasma Arc Cutting, Band Saw Cutting, Abrasive Water Jet Cutting).

➢ **Key operation to improve: cutting of Reactor Pressure Vessel and Internals**

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Context & challenges

Need

- Development of **innovative technologies**
- Improve **safety**, **radiation protection**, **waste management**, **time** and **cost** aspects
- Laser technology **widely used in the conventional industry** (25.000 applications, since 1970s, mostly used for cutting/welding; increasing market for all segments)

Why adapting laser cutting technology for RPV and RVI?

- **Key benefits** in comparison with conventional cutting techniques
- More than **10 years of R&D (laboratory trials)**
- Capabilities to cut **complex geometries: tubes, plates, multi thickness**
- **Various materials tested:** carbon & stainless steel, titanium, Zr alloy, fuel debris simulant, fused cast zirconia, inconel, etc.
- **Mature** and **operational technology** for dismantling activities (already used for fuel cycle / research facilities; i.e. Dissolvers of UP1 MAR200 fuel reprocessing facility at CEA in France)

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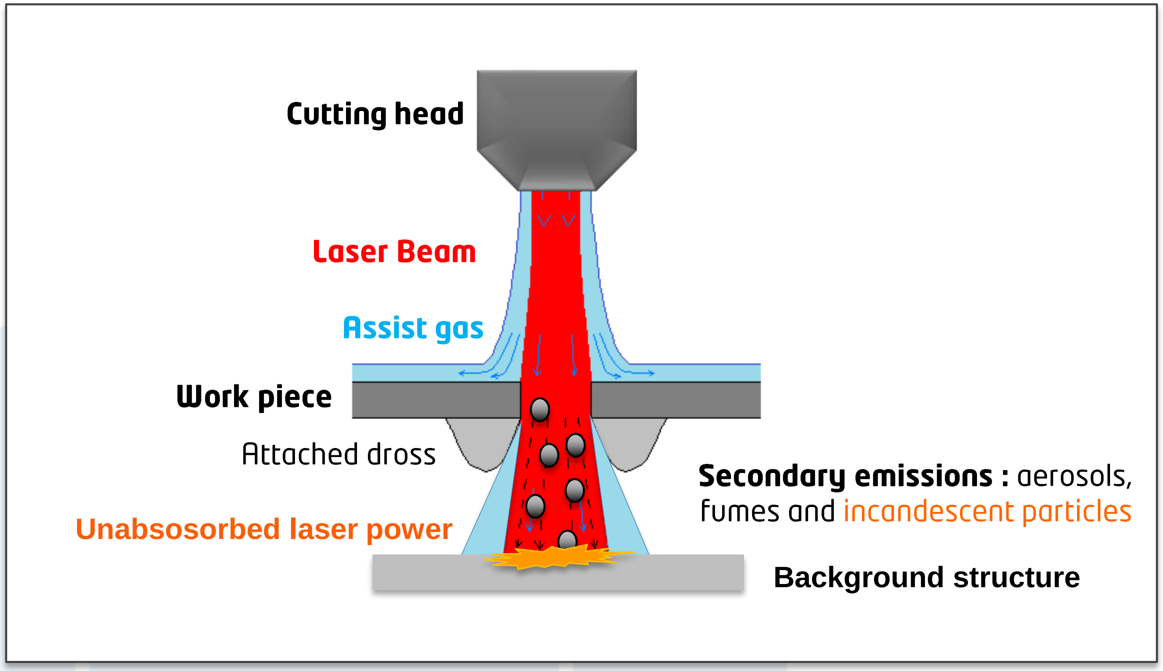
Laser cutting technology in air



- **High intensity laser beam** heats and melts locally the sample
- **Pressurized assist gas** ejects the molten material
- Laser beam or sample manipulation generates a narrow kerf

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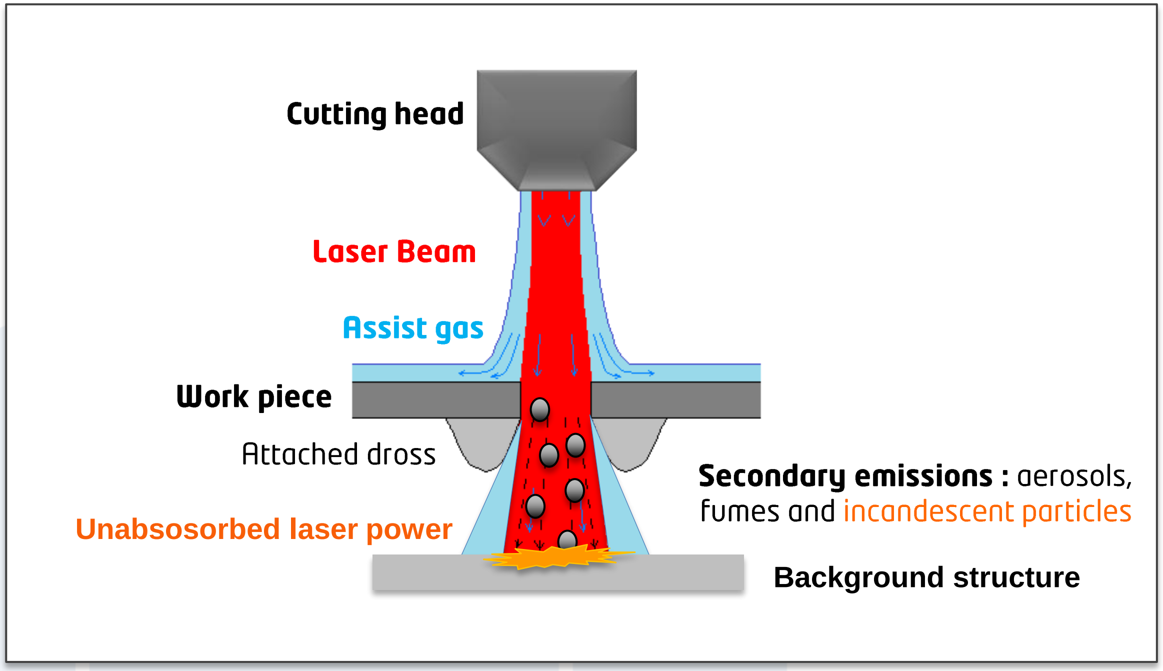
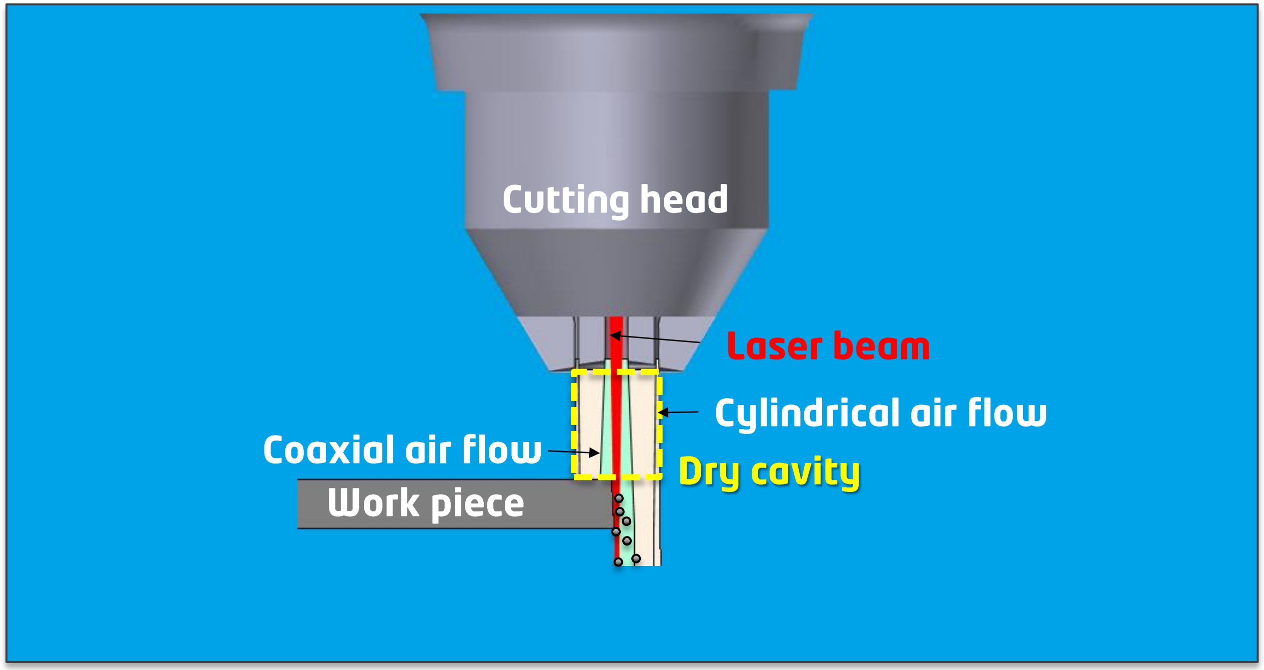
Laser cutting technology underwater





Based on **dry cavity concept**

→ **Laser beam propagates in air** between the laser head and the work piece and in the kerf

→ With no laser power loss due to the water absorption

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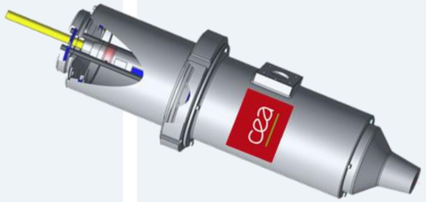
Laser cutting technology (performances)

Straight Head
up to 14 kW

90° Angle Head -
up to 8kW



Up to 16 kW

Configuration	Material	Thickness (mm)	Laser Power (kW) vs. Cutting Speed Limit (mm/min)			
			4	8	10	14
In-Air	Steel and Stainless Steel	20	175	350	500	700
		40	20	125	150	225
		60	-	40	55	120
		100	-	7.5	25	50
		120	-	-	8.5	32.5
		200	-	-	-	2.5
Underwater	Stainless Steel	40	Not tested	70	Not tested	Not tested

- **Specific laser heads for in-air and underwater operation** (developed by CEA and designed for nuclear dismantling facilities to work in severe conditions and harsh environment)
- **New underwater cutting tests to be performed underwater** (for thicknesses > 40mm)
- **Increased cutting speeds** are expected in the coming years due to the availability of higher-power laser sources

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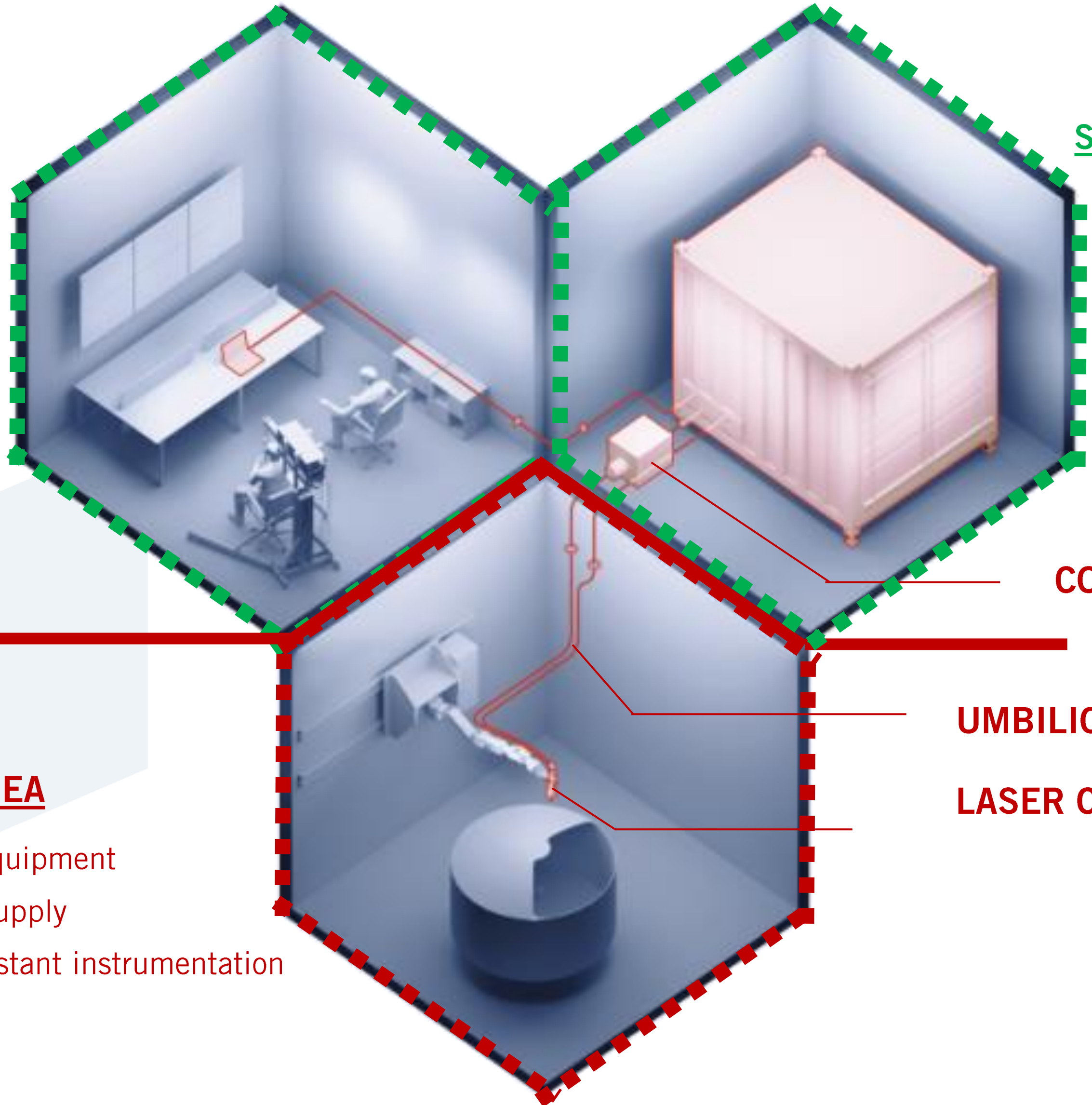
Laser cutting technology – on-site implementation



Control ROOM

Control software

SHELTER ROOM

- LASER Source
- Utilities
- Electrical Control & Instrumentation

Contaminated zone boundary

COUPLER

UMBILICAL

LASER CUTTING TOOL

DISMANTLING AREA

- Dismantled equipment
- AIR/WATER supply
- Radiation resistant instrumentation

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Management of aerosols generated during cutting

Depending on the cutting configuration, two possibilities:

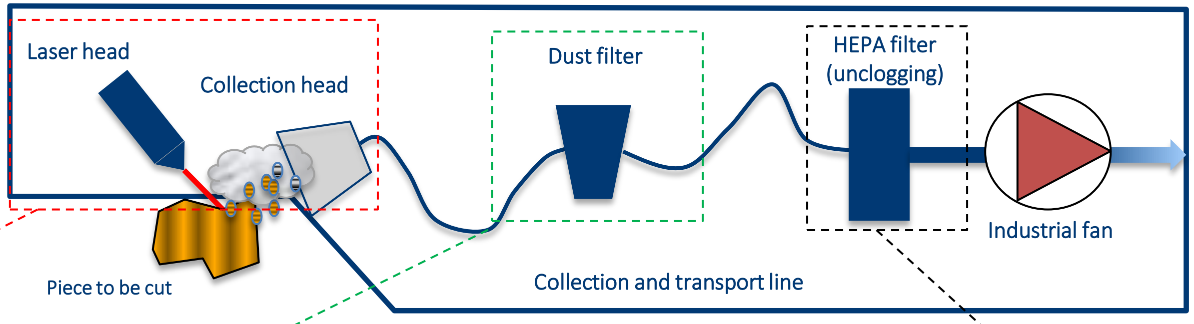
Cutting in a confined enclosure with overall filtration of the room

- Decontamination of the space to be provided at the end of construction (particle deposit)
- Increased labile contamination over time

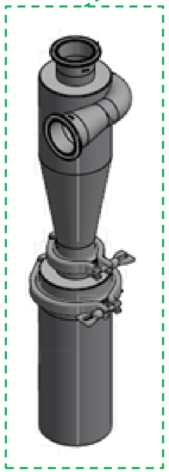
Cutting with local collection (efficiency < 100%)

- Capture particles generated by cutting as close as possible to the cutting point
- Effectively contain collected materials
- In-situ filtration possible to recover dust directly in hot zone

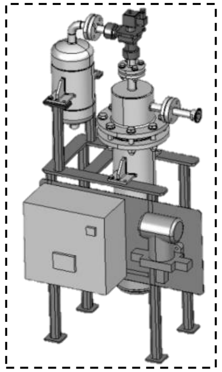
Local collection principle (tested for Fukushima projects)



Collection head mounted on the laser head: to collect dust and aerosols generated by laser cutting



1st level of filtration (cyclone filter) to recover dust and « large » particles in a collection pot.
Constant load losses, no clogging.



HEPA filter cartridge (unclogging in stainless steel) with collection pot (qualification tests on-going)

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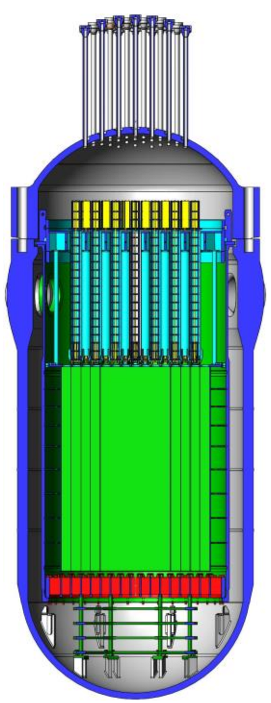
LD–SAFE H2020 project

LD-SAFE (H2020 program)

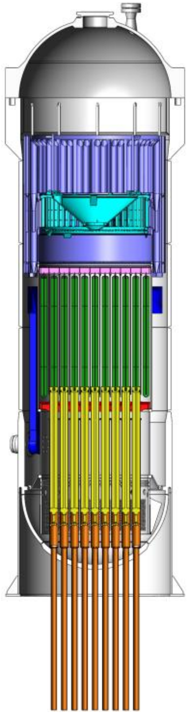
- To demonstrate in-air and underwater laser capabilities, safety, economic advantages and suitability for power nuclear reactor dismantling activities

Most challenging task

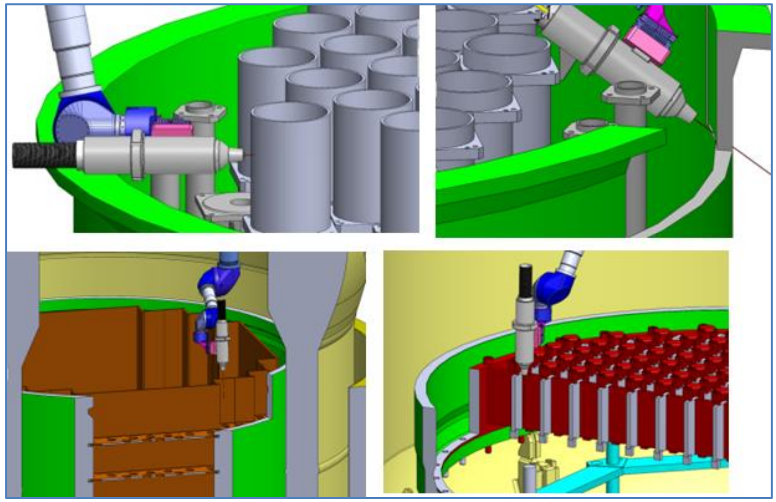
- Dismantling Reactor Pressure Vessels and Internals (**RPV and RVI**) of Power Nuclear Reactor

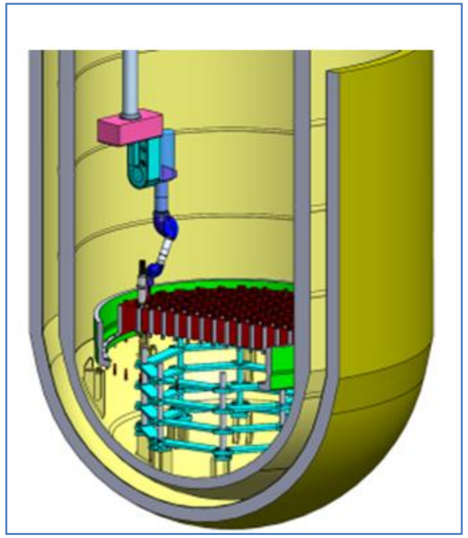


PWR



BWR





3D modelling of general cutting scenario for a PWR

Organization

H2020 program

- **R + D + i project**
- Funding by **EC (Euratom)**
- **4 years** (July 2020 to June 2024)

Overall organization

1 Project officer	6 partners	3 groups
European Commission	Consortium	Advisory Board EG/EUG/SG

Expert Group (EG)
End User Group (EUG)
Support Group (SG)

Consortium

ONET TECHNOLOGIES - France	
EQUANS (ENGIE) - Belgium	
CEA - France	
VYSUS GROUP - Sweden	
IRSN - France	
TECNATOM - Spain	

End User Group

Support Group

Main technical activities

Laser Cutting Development

Environmental and worker protection

Safety Assessment

Decommissioning of nuclear facilities

Analysis of the reactor dismantling with laser cutting

WP1

Laboratory tests and calculations:

-Laser beam residual power
-Hydrogen gas generation during underwater cutting

-Aerosols

WP2

-Technology qualification

-Guidelines for the industry for the use of laser cutting

WP3

-Risk analysis
-Generic Safety Assessment

-Independent review

WP4

Demonstrators in two phases: in air (from Mid 2023) and underwater (from beg. 2024)

Validation of the implantation and the use of the laser cutting technology in operational environment

WP5

+ Advisory Board

4 years (July 2020 to June 2024)

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Added value for reactor segmentation

Cost reduction

- Less cutting tools: only 2 cutting tools needed for dismantling activities (for in-air and underwater cutting) with one robotic arm
- No wear part replacement for the cutting tool
- Cutting duration improved and no maintenance during dismantling operations
- Optimization of waste packages filling level (laser can do complex geometries)
- Reduction of the number of waste packages

Safe for the workers and the environment

- Reduction of human operated works:
  - ➢ Laser heads used remotely (with a robotic arm)
  - ➢ No maintenance and no wear part replacement in the working area
- Reduction of secondary waste generated (aerosols) during cutting in comparison with PAC

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Added value for reactor segmentation

Reduction of risks

- Laser system versatile (only one laser system for all segmentation operation)
- No risk of blockage of the tools (effortless)
- Ease of access to the cutting position
- Reliable: availability rate expected with the laser system > 95%
- Limitation of radiation exposure for the workers

Planning optimization

- Easy implementation and use (fast to deploy and manoeuvre).
- Reusability and transportability of the laser utilities (located outside the controlled area)
- Optimization of the dismantling time (operating and maintenance)

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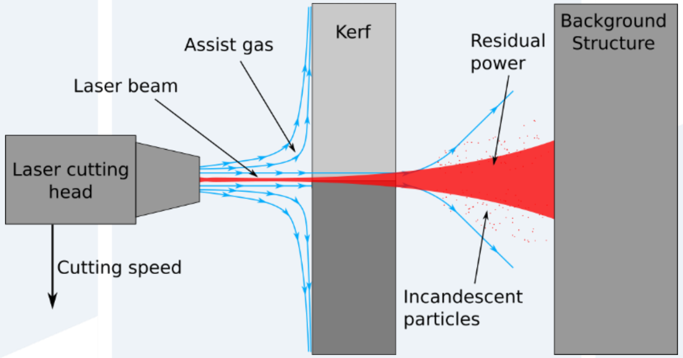
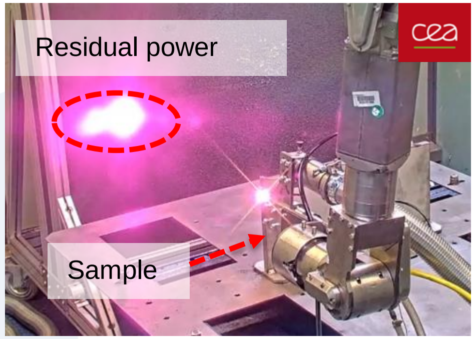
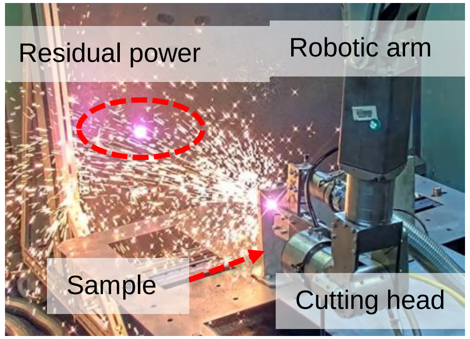
Main risks (WP2) - Progress

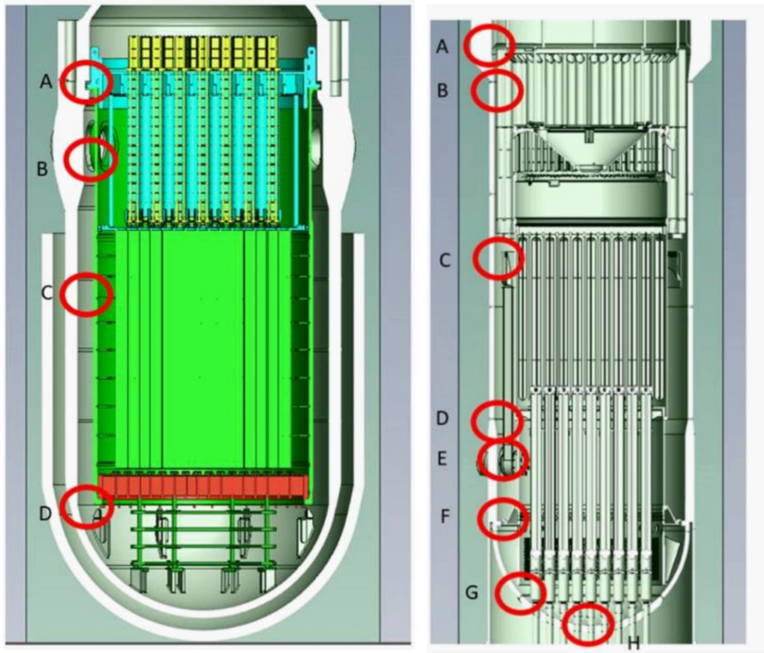
Laser beam residual power

- Evaluation of the influence of laser parameters (background distance, RVI thickness and cutting speed): **specific segmentation plan needed** to avoid risks (mechanical integrity of components to be dismantled and the loss of containment)
- **No risks for underwater cutting** (due to water absorption)









Most restrictive configurations for RVI cutting within the RPV (for PWR & BWR) - EQUANS source

Hydrogen gas generation during underwater cutting

- Underwater cutting generates oxides, which tend to clutter the kerf, and dangerous gases: $\mathbf{H_2}$
- Experimental evaluation of hydrogen generation risk for various cutting speeds and thicknesses: 1st laboratory tests showed **very low hydrogen concentrations** (to be analyzed in the next steps of the project)

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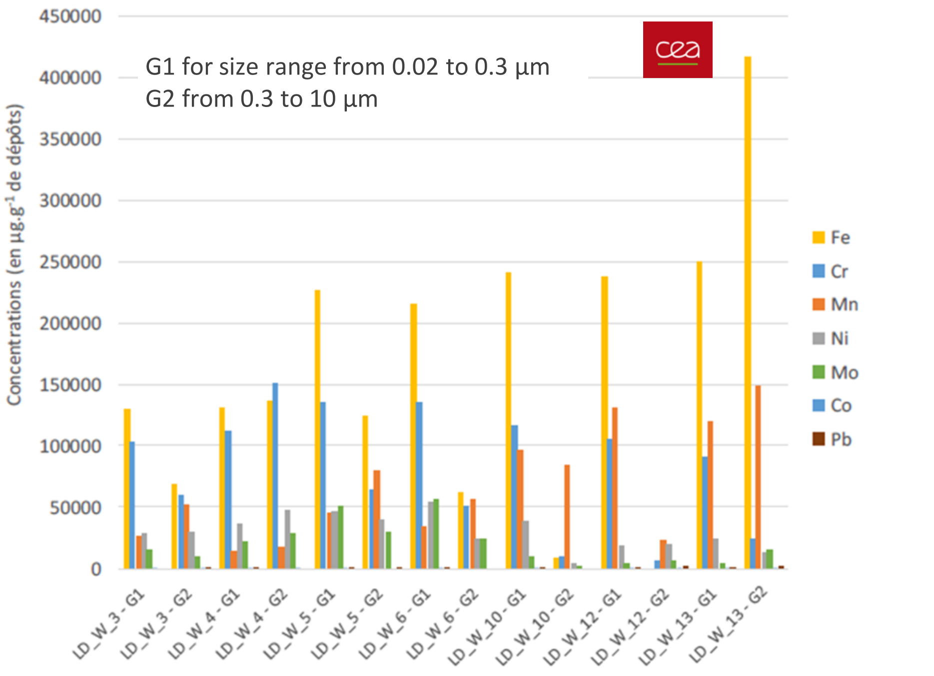
Main risks (WP2) - Progress

Aerosols characterization

- Characterization of particles size distribution for safety assessment to accurately evaluate doses for workers and to optimize filtration systems
- Tests performed in-air and underwater (2 water depths) using assist gas air and nitrogen
- Aerosols mitigation for underwater cutting due to pool scrubbing phenomena

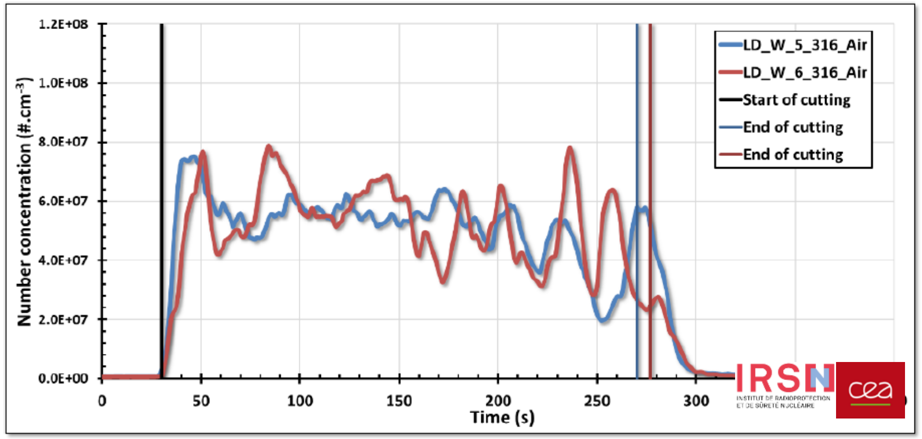
=>The prediction of Airborne Release Fraction is the key input data for safety assessment regarding containment function.

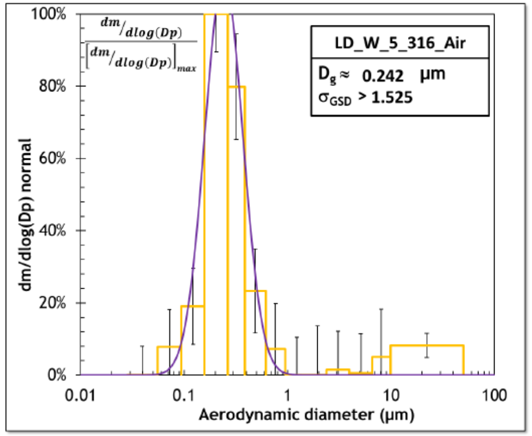


The results highlight:

- total mass release rate
- particles size distributions
- physico-chemical analysis of sampled aerosols

=> for radioactivity assessment of aerosols





CEA and IRSN sources

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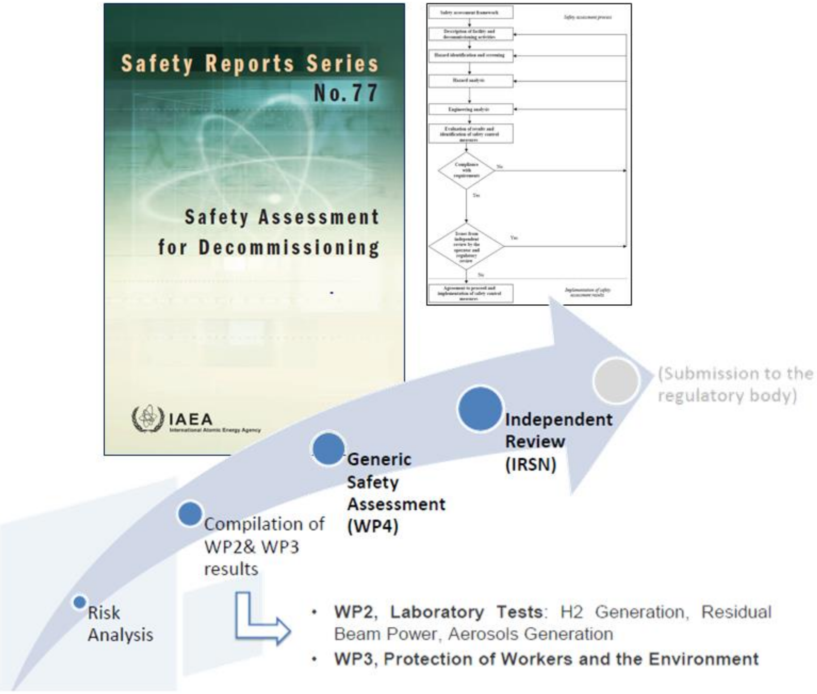
Development of a Generic Safety Assessment

- Generic safety assessment (following IAEA SRS 77) for laser cutting in reactor environment (to make it available to the European market)
- NUREG/CR-0130/5884 (PWR) and NUREG/CR-0672/6174 (BWR) were used as references (RPV/RVI structural and radiological information)
- Implementation of the 1st conclusions of the laboratory tests already performed (laser beam residual power, aerosols generation, H2 generation)
- Independent review by IRSN (on-going)
- Usual cutting configurations are considered: RVI segmentation underwater after removing it from the RPV & RPV segmentation in air
- In-air and underwater risks are considered separately, so it would be more a matter of adjusting the segmentation plan and radiological inventory rather than an RVI/RPV or cutting location issue

➢ **End users will have to adjust the generic safety assessment to their specific conditions.**

➢ **Demonstrating that laser cutting of RPV and RVI is at least as safe as the best techniques currently used.**



TECNATOM source

Main outcomes/ Next steps

Laser Cutting Development

Environmental and worker protection

Safety Assessment

Decommissioning of nuclear facilities

Analysis of RVI / RPV cutting techniques

Laboratory tests and calculations

Guideline – use of laser cutting in reactor dismantling environment

Generic Safety Assessment

Demonstrator in-air and underwater with representative mock-ups

Demonstration of the full laser system in cold conditions but with representative conditions in air (2023) and underwater (2024) as a conclusion of the project

✓ Ready to operate in real life

Dissemination

Project website and Social Networks

Education and training report & Online course on cutting technologies

Thank you for your attention!

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Laser Dismantling Environmental and Safety Assessment

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