LD-SAFE

Laser Dismantling Environmental and Safety Assessment

STAKEHOLDERS WORKSHOP REPORT

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1. SUBJECT OF THE DOCUMENT

1.1. Subject of the document

This document corresponds to the 'Stakeholders Workshop Report' requested on the Work Package n°6 of the LD-SAFE project. This version represents the first delivery to the public.

1.2. Workshops objectives

As defined in the LD-SAFE Grant Agreement **[R1]**, two technical workshops are planned with the stakeholders of the project:

1- **At the beginning of the project:** to present the project to the stakeholders and sharing views with them about the use of laser cutting technology for reactor dismantling.

2- **And at the end of the project:** to disseminate the results of the project both to industry, academics and RTOs.

The main stakeholders of the project are:

- The European Commission,
- The LD-SAFE Consortium composed of: ONET TECHNOLOGIES, CEA, IRSN, EQUANS (previously named ENGIE), VYSUS GROUP (previously named Lloyd's Register) and TECNATOM.
- The Advisory Board (see chapter 4.2).

1.3. Versions

The first version of this deliverable only includes information about the first technical workshop performed at the beginning of the project. The second delivery (final version) will summarize the content of the second technical workshop which represents an important milestone of the project and will be a measure of its success.

2. REFERENCE DOCUMENTS

N°	Reference	Version	Description
R1	945255 (and amendment reference AMD-945255-2)	N/A	Grant Agreement – LD-SAFE

3. TERMINOLOGY

Acronym	Definition
CEA	Commissariat à l'Energie Atomique et aux énergies alternatives
EC	European Commission
EG	Expert Group
EQUANS	EQUANS
EUG	End User Group
IRSN	Institut de Radioprotection et de Sureté Nucléaire
LD-SAFE	Laser Dismantling environmental and SAFEty Assessment
MS	Milestone
OT	ONET TECHNOLOGIES
TE	TECNATOM
TW	Technical Workshop
VYSUS	Vysus Group

4. LD-SAFE SUMMARY

4.1. Project presentation

Introduction

The main conventional cutting techniques used up to now are limited effectiveness. To improve safety, radiation protection, waste management, cost and time aspects for the forthcoming power reactor decommissioning, the development of innovative cutting tools seams necessary and represents an immense challenge.

Laser Cutting Technology

Among innovative technologies which could be used, the laser cutting technology is one of the most promising in this context in comparison with conventional cutting techniques currently used.

LD-SAFE

That is why the LD-SAFE project, which is a R + D + i project financed within the Horizon 2020 program of the European Commission (Euratom), will assess the maturity of laser cutting technology for dismantling pressure vessels and internals of nuclear power reactors.

Objectives

The project aims to demonstrate that the laser cutting technique applied to dismantling allows meeting technical and safety challenges in a more efficient and economical way than conventional cutting techniques.

Organization

LD-SAFE is being carried out by a European consortium coordinated by ONET TECHNOLOGIES and composed of 5 members: CEA, IRSN, EQUANS, VYSUS GROUP and TECNATOM.

Main activities / Work Packages

To meet the goals and the requested impacts, the project is structured into 7 Work Packages covering a project time of 4 years.

WP1: production of analysis and specifications for the use of laser cutting technology in operational reactor environment.

WP2: laboratory tests/calculations to assess and mitigate the environmental and safety impacts. These trials are dedicated to the laser cutting technology applied to the dismantling of reactor components. It represents the characterization of the laser beam residual power, secondary emissions as aerosols and hydrogen generation (during underwater emerging laser cutting).

WP3: Technology Qualification of the laser system in relation with the protection of the workers and of the environment will be carried out, and a Technology Qualification Certificate (TQC) and guidelines for the industry for use of laser cutting technology in reactor dismantling environment will be delivered.

WP4: safety assessment for the implementation of the laser technology. Development of the risk analysis and the compilation in a safety analysis of the answers to the known safety concerns of the stakeholders. The final objective is to deliver a generic safety assessment supported by an independent review for laser cutting in reactor environment.

WP5: validation of the implantation and the use of the laser cutting technology in operational environment through a demonstrator (in air and underwater).

WP6: setup of an ambitious plan for dissemination and exploitation of the project outcomes which include public communication.

WP7: coordination of the project (project management).

Conclusion

This project proposes an innovation which could enhance the safety, economic and technical aspects of one of the most challenging task of power nuclear reactor dismantling.

This project has the opportunity to support European nuclear field in remaining a step ahead in the development of this technology by achieving a world first laser dismantling of a power nuclear reactor.

4.2. Advisory Board

An Advisory Board completes the LD-SAFE organization to provide an external point of view on the project. It plays the role of an ecosystem for providing inputs for running the project and for ensuring the match between project results and market, societal, and environmental needs. It is composed of 3 groups: Expert Group, End User Group and Support Group. These groups represent important participants of the Technical Workshop because they are able to provide inputs to the LD-SAFE Consortium to progress in their technical activities.

Expert Group: Experts on laser safety, conventional cutting techniques for dismantling of reactor pressure vessels and internals, nuclear safety, and dismantling project management. They will monitor and redirect when needed the scientific developments, project management and the strategy for the dissemination of results.

GRS — One nuclear safety expert

PYLA, ALPhA NOV — One laser safety expert

EDF — One expert of conventional cutting techniques used for RPV and RVI dismantling

Dounreay — One dismantling project management expert

Figure 1: Expert Group composition

End User Group: Dismantling Operators and Contractors, Research & Technology Organizations and Technical Safety Organizations interested in the results of the project. The EUG ensures project activities adequately address the conditions and restrictions of nuclear facilities during decommissioning, and to increase the visibility of the project. The EUG members participate to all Technical Workshops or specific events scheduled by the project.

Figure 2: End User Group composition

Support Group: Groups with activities whose inputs or outputs are connected to LD-SAFE objectives. The members act primarily as observers, although they can share their views and participate in technical workshops.

Figure 3: Support Group composition

5. FIRST TECHNICAL WORKSHOP

5.1. Objectives

This first technical workshop aims to present the main objectives of the LD-SAFE project, our organization and the main activities to the main stakeholders (the members of the Advisory Board) at the beginning of the project.

5.2. Sequence

Due to the Covid-19 pandemic, the first Technical Workshop has been done in two steps:

1- A technical workshop with the members of the Advisory Board already involved in the LD-SAFE project (End User Group, Expert Group and Support Group).

   This workshop has been done by videoconference (webinar) the 09th of December 2020.

2- An additional workshop to present LD-SAFE and the progress to the public.

   This public workshop has been performed physically at WNE 2021 (in Paris) the 1st of December 2021.

5.3. Technical Workshop with the Advisory Board (Webinar)

Presentation: this first technical workshop has been performed only with the stakeholders (already involved) of the project (not open to the public because confidential data was included in the presentations shared with the participants).

Participants:

- LD-SAFE Consortium: ONET TECHNOLOGIES, CEA, IRSN, EQUANS, TECNATOM and VYSUS GROUP.
- Expert Group: ALPHANOV / PYLA, DSRL, EDF (DP2D) and GRS.
- End User Group: Bel V, DSRL, EDF (DP2D), ENGIE, GRAPHITECH, IGNALINA NPP, JAEA, KTE, LEI, SCK CEN, SOGIN.
- Support Group: VTT.
- European Commission: the Project Officer.

Program/Sequencing:

1- Introduction

   a. Welcome to all participants

   b. Webinar introduction (program and interactions with the Consortium)

   c. Presentation of the LD-SAFE Project Coordinator (ONET TECHNOLOGIES) and the Project Officer (European Commission)

2- LD-SAFE project and objectives

   a. Introduction (context and LD-SAFE project)

   b. Objectives (focus and Global ambition)

   c. Organization (main information, stakeholders and Advisory Board)

   d. Main activities (overview, Work Packages and methodology)

   e. Next steps

3- Challenges of reactor components segmentation with conventional techniques

   a. Introduction of the Work Package 1

   b. Conventional cutting techniques (introduction and overview of common techniques)

   c. Reactor components (introduction, BWR and PWR, characteristics, difficulties/challenges)

   d. Conclusion

4- Introduction to laser technology

   a. Principle of laser cutting

   b. Tools development and cutting performances

   c. Technology implementation

   d. Decommissioning experience and feedback

   e. Application to reactor dismantling

5- Presentation of the main technical aspects of the Work Packages 3 and 4

6- Generic Safety Assessment and independent review

   a. Generic Safety Assessment Objectives (and timeline)
   b. Methodology
   c. Independent review

7- <u>Questionnaire</u>

   a. Introduction (reminder)
   b. Objectives (expectations)
   c. Structure (questionnaire)
   d. Information (instructions)

8- <u>Webinar closing</u>

   a. Greetings to all participants

   b. LD-SAFE communication

Duration: 2 hours.

Interactions during the webinar:

- Polls (with mulitple choices) launched during the webinar:

  - How many laser cutting applications are currently used in the industrial field?

    - 1 000
    - 10 000
    - 25 000
    - 50 000

    ⇨ *Answer: today, there are over 25,000 high-power laser cutting applications in the industry.*

  - Based on your experience (or your perception if you have no experience) what is the most widely used cutting technique for dismantling RPV/RVI?

    - Mechanical cutting
    - Thermal Cutting
    - Water jet Cutting

    ⇨ *Choice the most used from the participants: mechanical cutting.*

  - What are the key technical criteria for Safety Authorities to allow the use of any cutting technology in a given decommissioning project?

    - Ability to be remotely operate
    - Limitation of radiation exposure
    - Minimization of generated waste and discharges

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- Reliability and safe maintainability
- Compliance of generated waste with packaging, transport and storage

⇨ *Choices the most used from the participants:*

- Limitation of radiation exposure

- Minimization of generated waste and discharges

- Reliability and safe maintainability

- Main questions asked on the chat and answers (from the Consortium) provided during the webinar:
  - RVI and RPV segmentation contracts have already been awarded and some already completed. Did one of the project partners already proposed the laser technology for such operation, and if yes why it has never been implemented?
    - Up to now, from the few segmentation call for tender (for Power Nuclear Reactor), none was opening the possibility to use laser as a cutting technique. When discussion were made to see whether laser could be accepted, the answer was no. Because the technology has already been selected before the tender phase, and was included in the preliminary safety reports with difficulties to be changed afterwards. That's why the LD-SAFE project will prepare and deliver a generic safety assessment in order to allow the use of laser cutting technology in the forthcoming Power Reactor decommissioning programs.
  - What about saw dust / particles to recover, and secondary waste. Is that also looked at in assessing the different techniques?
    - During the analysis of all the conventional cutting techniques, identification of the benefits and the drawbacks regarding secondary waste has been done (for Band Saw Cutting, Plasma Arc Cutting and Abrasive Water Jet Cutting). The objective is to perform a quantitative comparison of these 3 cutting techniques (which will be useful to compare with laser cutting technology).
  - Are there any data on the resistance of the optical fiber laser and the laser head to radiation? Has the radiation hardness of the fiber optic transmitter been tested?
    - During past decommissioning activities (for instance: the dismantling of the dissolver A of UP1 at CEA Marcoule), no damages have been detected (regarding radiation) on the laser head and the optical fiber (included in an umbilical).
  - How will the end users be involved for the boundary conditions definition?
    - The generic safety assessment should be designed to be easily applicable to an existing nuclear facility. At this stage of the project (first steps), the End Users boundary conditions are not yet included in the generic safety assessment process (for the moment). However, the main boundary conditions from the End User Group will be taken into account in our studies (through questionnaires sent to the End User Group).

Replay:

This webinar has been recorded. The replay has been provided to the participants after this first Technical Workshop.

Key figures:

- Subscribers for the webinar (including speakers): 44
- Attendees (including speakers): 39
- Participation rate: 89%
- Number of rates: 16
- Average rate: 4.5/5

Questionnaire:

Following the first TW (webinar) performed in December 2020 with the stakeholders, LD-SAFE questionnaires have been sent to the EUG members.

The objective is to collect feedback about:

- Their experiences in implementing different remotely operated technologies for the cutting of highly radioactive material (especially regarding safety, radiation protection, waste, cost and time aspects)
- Their comparison of dismantling technologies (for instance about cutting, implementation of the technology, necessary resources, the collection of waste, etc.)

This feedback will be used to:

- Confirm the information gathered and assessed under WP1 and complete gaps in respect with input data
- Identify the End Users expectations about Laser Technology
- Respond to End Users issues as part of the project
- Ensure that:
    - The project starts with the right quality of input data to achieve the targets (and if necessary, by adjusting first deliverables)
    - The project is aligned with the market reality

As inputs, all questionnaires results will be used in the technical activities of the LD-SAFE project. The blank version of this questionnaire is available in annex.

5.4. Technical Workshop with the public (at WNE)

Presentation: shared during the public workshop (at WNE, in Paris) is available in annex.

Participants: around 40 people participated at this event (including the people who followed this presentation by videoconference).

Program/Sequencing:

1- Welcome & LD-SAFE presentation:
   a. LD-SAFE project
   b. Laser cutting technology
   c. Safety aspects of the project

2- Exchanges (Q/A) / Networking
   d. Discussions about the objectives of the project and our expectations, but also about the laser cutting techniques, our experience with the use of this technology and its advantages.
   e. Presentation of the laser heads (developed by CEA) and the various samples cut with this technology at CEA stand.

Duration: 1 hour.

Replay: this public presentation has been recorded and shared in our LD-SAFE dissemination materials:

- On the LD-SAFE project website: https://ldsafe.eu/
- On the Social Media:
  - LinkedIn Page: LD-SAFE Project
  - Twitter account: @ld_safe

6. SECOND TECHNICAL WORKSHOP

To be developed after the next Technical Workshop (planned at the end of the project, in 2024).

7. ANNEX

7.1. EUG questionnaire (blank version)

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QUESTIONNAIRE

End User Group

Number of Pages: 22

Distributed to: End User Group (Advisory Board)

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1. SUBJECT OF THE DOCUMENT

1.1. Introduction

This document corresponds to the LD-SAFE 'Questionnaire' to fill in by members of the End User Group (Advisory Board). The scope is Reactor Pressure Vessel and its internals.

1.2. Objectives

The objective is to collect feedback about:

- Their experiences in implementing different remotely operated technologies for the cutting of highly radioactive material (especially regarding safety, radiation protection, waste, cost and time aspects)
- Their comparison of dismantling technologies (for instance about cutting, implementation of the technology, necessary resources, the collect of waste, etc.)

This feedback will be used to:

- Confirm information we already have in our first WP1 deliverables and complete gaps in respect with input data
- Understand what End Users can expect about Laser Technology
- Respond to your issues as part of the project
- Make sure:
    - We start the project with the right quality of input data to achieve our target (by adjusting our first deliverables)
    - We are aligned with the market reality

1.3. Structure

This questionnaire is divided in 3 parts:

- Global questions including multiple choice questions with an area dedicated to comments
- A datasheet focused on complex reactor components. It includes specific criteria: physical and radiological characteristics, environment of the component, segmentation and waste management processes. You will mention the name of the component you consider as complex to cut and indicate your data, comments and expected improvement with the laser technology (if any).
- A technology comparative analysis focused on 3 conventional technologies (Mechanical Cutting which includes Band saw/disk grinder/Milling cutter, Abrasive Water Jet Cutting and Plasma Arc Cutting). In this part, you will indicate your experience/feedback for these conventional technologies regarding different aspects: Feasibility and suitability, Safety, Performances / Key

factors, and waste. You will also indicate your data which represents the state of the art for each cutting techniques (if any). Finally, you can have the possibility:

- To do an overall appraisal of each cutting technique by indicating the main advantages and drawbacks.
- To indicate your expectations regarding laser technology (the benefits but also the drawbacks).

1.4. Instructions

How to fill in the questionnaire?

- The questionnaire can be filled in digitally (in this Word version).
- Instructions will be specified for the 3 parts.
- Your experience depends on your own organization. **You will not be able to answer all the questions/criteria**. This is the complementarity of all questionnaires which will help us.
- If you have documents that can directly answer to some questions of the questionnaire, you can send them to us (if it is possible).

Confidentiality of data:

- The questionnaires filled in will not be shared between all End Users.
- All data you consider as confidential has to be indicated in red in the questionnaire.
- Signing a Non-Disclosure Agreement is required.

2. QUESTIONNAIRE

2.1. Global Questions

Instructions:

The following questions concern dismantling activities of nuclear power reactors internals (RVI) and pressure vessels (RPV).
If you consider a question not applicable to your organization or not relevant, please indicate N/A or N/R

	GLOBAL QUESTIONS
Q1	**Do you think dismantling RPV/RVI represents a cutting challenge in decommissioning programs?**
	☐ Yes ☐ No Comments (if any):
Q2	**Have you ever considered using laser technology for dismantling RPV/RVI?**
	☐ Yes ☐ No If not, why?
Q3	**Based on your experience and/or knowledge (or your perception if you have no experience) what is the most widely used cutting technique for dismantling RPV/RVI?**
	☐ Mechanical cutting ☐ Thermal Cutting ☐ Water jet Cutting According to the cutting technique chosen, which tool is the mostly used (**circle your answer**)? Mechanical cutting: Shearing - Sawing - Grinding - Blasting - Milling. Thermal cutting: Oxygen cutting - Plasma Arc Cutting - CAMX-Processes - Laser Beam Cutting. Water jet Cutting: Abrasive Water Injection Jet (AWIJ) - Abrasive Water Suspension Jet (AWSJ)
Q4	**What is your preferred cutting environment to dismantle RPV/RVI?**
	☐ In air ☐ Underwater ☐ Both In air and Underwater ☐ Not yet decided If not yet decided, why?
Q5	**How many cutting tools and handling systems do you use (or intend to use) for dismantling RPV/RVI (in average)?**
	Number of cutting tools (if you intend to use 2 different tools from a same technology, please count each of them): Number of handling systems (crane, manipulator, pole, bespoke mechanical systems, etc.): Number of back-up systems:

Q6	**According to your experience or knowledge, what are the key technical criteria for Safety Authorities to allow the use of any cutting technology in a given decommissioning project?**
	Key criteria for Safety Authorities (the choice can be multiple): ☐ Ability to be remotely operate ☐ Limitation of radiation exposure ☐ Minimization of generated waste and discharges ☐ Reliability and safe maintainability ☐ Compliance of generated waste with packaging, transport and storage Other:
Q7	**What are your main constraints / difficulties in your dismantling activities?**
	☐ Cutting environment (in air or underwater) ☐ Accessibility of tools and/or handling systems (for cutting) ☐ Control and monitoring of the operations (e.g. moving the system remotely, visualizing the operation, etc.) ☐ Space needed to implement the tools and their utilities in controlled area ☐ Maintenance and replacement of spare and wear parts ☐ Filtration / dust and fume collection ☐ Radioprotection and safety of the workers ☐ Coactivity Other:
Q8	**What are the most impactful steps about cost and time?**
	☐ Studies/Design/segmentation plan ☐ Manufacturing/Testing/Operators Training ☐ Installation/Commissioning ☐ Cutting operations ☐ Maintenance (preventive and corrective) ☐ Waste management ☐ Protection of workers / safety aspects Other:
Q9	**According to your experience or knowledge, what is the most complex component to cut (for PWR / BWR)?**
	Regarding its physical/radiological characteristics, environment, waste generation, cost and time operation (several components possible) To list (if possible): Can you provide us an example of datasheet? ☐ Yes ☐ No

Q10	**According to your experience or knowledge, which steps represent a challenge for reducing dismantling cost?** ☐ Cutting duration ☐ Operation and Maintenance costs (including consumables) ☐ Corrective maintenance costs (troubleshooting, repairs) ☐ Number of tools and handling systems ☐ Implementation of the cutting system (as a whole) / space available ☐ Drying (of the segmented components) ☐ Waste characterization and packaging ☐ Waste logistics (handling, interim storage, transport) ☐ Human resources Other:
Q11	**How do you carry out the secondary waste collection for each cutting technology used (in air and underwater)?** Provide some examples: Examples: - Cutting chips: underwater pumping or in-air vacuuming + filtration - Dust (in air): local collection by vacuum system + filtration / containment with general HVAC - Sludge (underwater): local collection by suction system + filtration / global water treatment system
Q12	**According to your experience or knowledge, what is the duration (ratio) of cutting operation compared to other operations (handling, cleaning and decontamination)?** Approximately:
Q13	**In addition to the radiological spectrum, total activity and dose rate, are you aware about other limitations for the transportation of nuclear waste coming from RVI/PRV decommissioning (Type B Packages for ILW waste)?** ☐ Absence of liquid (drying needed) ☐ No mobile piece/dust ☐ No filtering media (other than metal) ☐ Each single item must be characterized separately Other:

2.2. Datasheet – Reactor component (RPV/RVI)

Instructions:

The objective of this datasheet is to focus on the most complex component(s) to cut in the scope of Reactor vessel internals (RVI) and pressure vessels (RPV) following several criteria:

- ***Physical characteristics***
- ***Radiological characteristics***
- ***Environment of the component***
- ***Segmentation and waste management processes***

In order to fill in correctly this datasheet, please find below the instructions.

*1-In link with the **Question 9** of the Global Questions, please indicate the **name of the component** you consider the most complex to cut in the table.*

*2-If you have data to provide us, please complete the '**DATA**' and '**COMMENTS**' columns for each criterion. Also, we will have the possibility:*

- *To indicate your main comments regarding each criterion*
- *To propose additional criteria (if any) which you consider important and which should be taken into account in the LD-SAFE project (**available cells**)*
- *To provide us your own datasheet of this component*
- *To leave the cell empty if you don't have information regarding specific criteria*

*3-You can also mention if a specific challenge connected to these criteria could be solved by the laser technology or if an improvement is expected ('**EXPECTED IMPROVEMENT WITH THE LASER TECHNOLOGY**' column). In this column, you can also indicate expected benefits but also the drawbacks.*

*4-In each column, if the information is confidential, please indicates it in **red color**.*

5-if you consider doing the same exercise with other components, please do copy-paste the table below in this document (as often as necessary).

Datasheet - Reactor component (RPV/RVI)

Component name:

CRITERIA	IMPORTANCE	DATA	COMMENTS	EXPECTED IMPROVEMENT WITH THE LASER TECHNOLOGY
Physical Characteristics				
Global appraisal:				
Material / Combination of different materials if any	*Impact on cutting technology* *Impact on secondary waste (oxides, dusts, etc.)* *Presence of mix of material (e.g. sandwich) can be challenging*			
Thickness (min - max)	*Impact on cutting performances*			
Geometry description (external dimensions and shapes)	*Impact on cutting sequence*			
Volume description (e.g. hollow parts ?)	*Impact on cutting technology*			
Available cell (to add criteria if necessary)				

Datasheet - Reactor component (RPV/RVI)

Component name:

CRITERIA	IMPORTANCE	DATA	COMMENTS	EXPECTED IMPROVEMENT WITH THE LASER TECHNOLOGY
Radiological Characteristics				
Global appraisal:				
Specific Activity [Bq/kg]	*Some high-irradiated components are difficult to cut mechanically (radiation hardening) Activity of secondary waste (chips, swarf, dust, slag) Impact on Dismantling and Waste Management Strategy*			
Dose Rate (specifying the distance from the component and the environment, i.e. in air or underwater)	*Potential impact on tools Impact on Dismantling and Waste Management Strategy*			
Presence of surface contamination (loose or fixed and specifying whether the component was decontaminated, e.g. by Full System Decontamination)	*Resuspension in the environment*			
Available cell (to add criteria if necessary)				

Datasheet - Reactor component (RPV/RVI)

Component name:

CRITERIA	IMPORTANCE	DATA	COMMENTS	EXPECTED IMPROVEMENT WITH THE LASER TECHNOLOGY
Environment of the Component during segmentation				
Global appraisal:				
Accessibility (available area to access the cutting location)	*Impact on cutting tool and carrier*			
Environment (in air / underwater and depth)	*Impact on cutting technology*			
Environment description (around the component - nearby structures, equipment, components - building services such as HVAC, RP, water treatment systems, etc.)	*Impact on cutting technology and management of secondary waste (e.g. HVAC or RP constraints)*			
Available cell (to add criteria if necessary)				

Datasheet - Reactor component (RPV/RVI)

Component name:

CRITERIA	IMPORTANCE	DATA	COMMENTS	EXPECTED IMPROVEMENT WITH THE LASER TECHNOLOGY
Segmentation and Waste Management Processes				
Global appraisal:				
Dismantling step (when and why)	*To know what other components remain when this one is segmented and why this component is cut at that moment*			
Possibility to disassemble the component (e.g. bolted) or not (e.g. welded)	*Impact on dismantling sequence and cutting technology*			
Dismantling location (where: in situ, pool, etc. and why)	*To understand the drivers, e.g. for deciding to segment in pool or in situ (Due to space? Due to RP ?)*			
If not in situ, description of the environment (in air/UW - nearby structures, equipment, components - building services)				
Cutting technique(s) used (Mechanical, Abrasive Water Jet Cutting, Plasma Arc Cutting, etc...)	*To know the most common technique used, although this may change from a project to another.*			

Datasheet - Reactor component (RPV/RVI)

Component name:

CRITERIA	IMPORTANCE	DATA	COMMENTS	EXPECTED IMPROVEMENT WITH THE LASER TECHNOLOGY
Number of pieces of cutting equipment used to cut this component. Even if only one family of cutting technologies is used (e.g. mechanical), please count the pieces of cutting tools (e.g. different saws).	*To understand the versatility of the cutting tools used and the specificities of the components regarding different tools to address the segmentation.*			
Segmentation plan (Number of cuts, length of cuts, etc.)	*Impact on the cutting technology*			
Handling means needed (for disassembly, cutting, packaging / standard or bespoke)	*Handling means versus segmentation plan*			
Waste container used for the packaging (type / family)	*To understand the drivers to select the waste package in relation with the segmentation plan (e.g. interesting to cut smaller or not? importance of making precise shapes or not, etc.)*			
Waste routes for the primary and secondary waste	*Does the segmentation of this component generate any waste for which no waste route exist on the site (e.g. fines, filters, etc.)*			
Any specific challenge	*E.g. requirement to cut at a precise location (such as section of upper internals from the vessel head)*			
Available cell (to add criteria if necessary)				

2.3. Technologies comparative analysis

Instructions:

The objective of this spread sheet is to focus on 3 conventional technologies (Mechanical Cutting which includes Band saw/disk grinder/Milling cutter, Abrasive Water Jet Cutting and Plasma Arc Cutting).

In this part, you will indicate your experience/feedback for these conventional technologies regarding different aspects:

- ***Feasibility and suitability***
- ***Safety***
- ***Performances / Key factors***
- ***Waste***

In order to fill in correctly this sheet, please find below the instructions.

*1-At first, please indicate the **main specifications** of your tools for which you provide the data (e.g. size, power, etc.). Should you prefer to provide answers for another technology (e.g. Circular saw instead of Disk grinder), please do so and change the name of the tool.*

*2-If you have data to provide us, please complete the '**DATA**' and '**COMMENTS**' columns for each criterion and cutting techniques (some examples are indicated in the first lines). Also, we will have the possibility:*

- *To indicate your main comments regarding each criterion*
- *To propose additional criteria (if any) which you consider important and which should be taken into account in the LD-SAFE project (**available cells**)*
- *To provide us documents which will answer to some criteria*
- *To leave the cell empty if you don't have information regarding specific criteria*

3You can also:

- *Indicate your point of view regarding each criterion: Do you agree with our LD-SAFE project comment (Yes or No, Why)?*
- *Indicate your expectations regarding laser technology in the ('**EXPECTATIONS FOR LASER TECHNOLOGY**' column) if any.*
- *Do an overall appraisal of each cutting technique by indicating the main advantages and drawbacks at the end of the table.*

*4-In each column, if the information is confidential, please indicates it in **red color**.*

Technologies Comparative Analysis (for the Dismantling of RPV/RVI)									
CUTTING TECHNIQUES		State of the art					YOUR POINT OF VIEW	COMMENTS	EXPECTATIONS FOR LASER TECHNOLOGY
		Mechanical Cutting			Abrasive Water Jet Cutting (AWJC)	Plasma Arc Cutting (PAC)			
		Band saw	Disk grinder	Milling cutter					
SPECIFICATIONS		*Size:* *Power:* *Etc.*	*Size:* *Power:* *Etc.*	*Size:* *Power:* *Etc.*	*Size:* *Power:* *Etc.*	*Size:* *Power:* *Etc.*			
CRITERIA	ENVIRONM.	DATA							
Feasibility and Suitability for the Segmentation of RPV and RVI									
Global appraisal:									
Maturity [Qualitative Answer] *Could you please provide your perception of the maturity of the technology for dismantling RPV or RVI, making your choice in the list below:* *1.* **Fully mature** *(commonly used, since a long time)* *2.* **Proven** *(use demonstrated but improvements are still in progress)* *3.* **New** *(not yet actually used, still in development)* *If you have some ideas about the developments which are yet to be carried out to improve the technology, you can mention them in comments*	In Air	*e.g. Fully mature*	*e.g. Fully mature*	*e.g. Fully mature*	*e.g. Fully mature*	*e.g. Fully mature*	Do you agree with? (Yes / No)		
	Underwater	*e.g. Proven*	*e.g. Proven*	*e.g. Proven*	*e.g. Proven*	*e.g. Proven*			
Our point of view regarding this criterion: Cutting tools proven for the intended application, used in the same operational environment in the industry before.							*e.g. Yes*	**Why?** *Your comment*	
Versatility [Qualitative Answer] *Could you please provide your perception of the versatility of the technology for dismantling RPV or RVI, making your choice in the list below:* *1.* **High** *(can be used to address most of the segmentation scope)* *2.* **Medium** *(used on a rather large but targeted part of the scope)* *3.* **Low** *(used on a limited scope or for specific cutting tasks only)*	In Air						Do you agree with? (Yes / No)		
	Underwater								
Our point of view regarding this criterion: Cut with one tool components of various physical properties (different material or materials modified by radiations, containing hollow parts, etc.), thus reducing the number of tools / systems needed for the project.							*e.g. Yes*	**Why?** *Your comment*	

Efficiency [Qualitative Answer] *Could you please provide your perception of the efficiency of the technology when operating on its part of the segmentation scope, making your choice in the list below:* *1.* **High** *(efficiency gives flexibility to the segmentation plan, not constraining)* *2.* **Medium** *(balanced pros and cons, average compared to other technologies)* *3.* **Low** *(using the technique constraints the segmentation plan, constraining technique impeding efficiency)* *In comments, you could list the aspects which make the technique efficient or constraining.*	In Air						**Do you agree with? (Yes / No)**		
	Underwater								
Our point of view regarding this criterion: Do not constrain the segmentation plan due to technological limitations (allows performing less -or more- cuts, depending on what is preferred). Operates with few needs or constraints (reduced handling means, precise positioning, necessary instrumentation and controls, etc.).							*e.g. Yes*	**Why?** *Your comment*	
Technological Limitations [List of exceptions] *Could you please list the materials or components, if any, which according to your knowledge, cannot -or do not- cut with this technology during segmentation of RPV/RVI.* *Comment to briefly explain why.*	In Air						**Do you agree with? (Yes / No)**		
	Underwater								
Our point of view regarding this criterion: Avoid the need for bespoke solutions to address limited but specific parts of the scope.							*e.g. Yes*	**Why?** *Your comment*	
Maximal thickness of cut [Value in mm] *Could you please indicate the maximum thickness of stainless steel which, according to your knowledge, can be cut with the technology.*	In Air						**Do you agree with? (Yes / No)**		
	Underwater								
Our point of view regarding this criterion: Capable of cutting material in the range of the high thicknesses of RPV and RVI components.							*e.g. Yes*	**Why?** *Your comment*	
Available cell (to add criteria if necessary)									

Safety									
Global appraisal:									
Radiation Protection [Value - Proportion of works carried out remotely in %] *For the use of this technique, including operation and maintenance, could you please provide an assessment of the* ***works carried out remotely (%)*** *(i.e. workers operating the system from an area with no radiation exposure or contamination risk).* *In comments, you could specify which operations must be carried out hands-on, or remotely but still in the working area.*	In Air	*e.g. 30%*	*e.g. 30%*	*e.g. 30%*	*e.g. 60%*	*e.g. 60%*	**Do you agree with? (Yes / No)**		
	Underwater	*e.g. 50%*	*e.g. 50%*	*e.g. 50%*	*e.g. 90%*	*e.g. 90%*			
Our point of view regarding this criterion: Internal exposure of workers is the main risk for dismantling activities. Avoiding hands-on human activities, by increasing the proportion of works carried out remotely, is the most efficient way to reduce this risk.							*e.g. Yes*	**Why?** *Your comment*	
Failure of equipment in the work area [List of risks] *Could you please indicate the main risks of failure in the work area associated with the use of this technology (e.g. blockage of blade in the cut component).* *In comments, you could indicate if specific provisions to mitigate the risks and to allow the rescue of the equipment are necessary.*	In Air						**Do you agree with? (Yes / No)**		
	Underwater								
Our point of view regarding this criterion: Failure and rescue of equipment in the work area is a source of risk for the operators and must be reduced.							*e.g. Yes*	**Why?** *Your comment*	
Protection of Systems Structures or Components in the surroundings of the cutting area [Value - Unit of distance] *Could you please indicate whether SCCs in the surroundings of the cutting area must be protected against any impact of this cutting technique (e.g. projections, residual beam/jet behind the cut, etc.) and if yes indicate an estimate of the* ***shortest distances (m)*** *between the position of the cutting tool and the SCCs which must be protected. If not, please indicate N/A.* *In comments, you could describe a concrete example particularly relevant which you would like to be taken as an example for a demonstration.*	In Air						**Do you agree with? (Yes / No)**		
	Underwater								
Our point of view regarding this criterion: For safety reasons the absence of impact on SSCs located nearby the cutting area may have to be demonstrated.							*e.g. Yes*	**Why?** *Your comment*	
Generation of aerosols [List of Safety Requirements] *Please note that the question of the quantity and size of aerosols generated by the cutting techniques is asked below in the section Waste.* *According to your knowledge, could you please indicate what are your safety requirements in respect of aerosols generation when this cutting technique is used, such as composition (specific radionuclides, e.g. 60Co), limits (mass and/or sizes), collect and mitigation means (local or by building's systems), etc.*	In Air						**Do you agree with? (Yes / No)**		
	Underwater								
Our point of view regarding this criterion: Reduce generation of radioactive aerosols and contamination hazard (related not only to the quantity but also to the size of the aerosols generated).							*e.g. Yes*	**Why?** *Your comment*	

Generation of gas and bubbling [List of Safety Requirements] *For underwater cutting works, and according to your knowledge, do you have any concern and/or safety requirements regarding the release of compressed air (or inert gas) in the cutting environment in relation with topics such as bubbling or impact on the ventilation?* *In addition to the above topic, could you please indicate if you have any concerns and/or safety requirements regarding the generation of hazardous gases during the cutting, such as hydrogen.* *In comments, you could provide data associated with the safety requirements in this respect (e.g. flow rate, concentration, etc.).*	Underwater Only						**Do you agree with? (Yes / No)**		
Our point of view regarding this criterion: Techniques generating bubbles might concern operators, due to the potential transfer of contaminants to the surface. This is true for any technic using gas: Assist gas (for plasma or laser) but also pneumatic mechanical tools, etc.							*e.g. Yes*	**Why?** *Your comment*	
Water Contamination [Value - Unit of concentration] *Could you please indicate whether the cutting technique increases water contamination during use and, if available, provide the concentration reached and/or the limit as per safety requirements (e.g. mass of particles in a volume of water).* *In comments, you could indicate whether monitoring and purification systems are required.*	Underwater Only						**Do you agree with? (Yes / No)**		
Our point of view regarding this criterion: Keep better water clarity and better visibility during underwater cutting is an important safety aspect in addition to being required to allow the operations.							*e.g. Yes*	**Why?** *Your comment*	
Specific Safety Topics [List] *Could you please list any safety topics, other than the ones above, inherent to the use of this technology for RPV and RVI dismantling and which require a demonstration in the framework of the Safety Assessment.*	In Air						**N/A**		
	Underwater								
Available cell (to add criteria if necessary)									

Performances / Key factors									
Global appraisal:									
Cutting speed (feed rate) [Value in unit of length by unit of time] *Could you please give us some data about acknowledged* **feed rate (e.g. mm/min)** *with this technology. If possible, complement this data with the parameters of the cut, such as the* **cutting tool specifications**, *the* **material cut** *and the* **thickness cut.** *Should you have more relevant data (other material or thickness), it will be welcome. Please feel free to add lines to these criteria or attach other answers to your questionnaire at your convenience.* *If you lack data for some of the technologies, you may provide a qualitative answer instead:* *Fast (increasing the cutting speed would not be so beneficial, as it is not a limiting factor)* *Medium (increasing the cutting speed would be beneficial)* *Slow (the cutting speed is a real limiting factor, impacting other aspects such as the segmentation plan)*	In Air	*e.g. 50mm/min*	*e.g. 60mm/min*	*e.g. 75mm/min*	*e.g. 80mm/min*	*e.g. 90mm/min*	**Do you agree with? (Yes / No)**		
	Underwater	*e.g. 25mm/min*	*e.g. 30mm/min*	*e.g. 35mm/min*	*e.g. 40mm/min*	*e.g. 40mm/min*			
Our point of view regarding this criterion: Improvement of the cutting speed to reduce the duration of the step of segmentation of the RPV and RVI.							*e.g. Yes*	**Why?** *Your comment*	
Footprint [Value in unit of surface area] *Could you please provide the total* **footprint (surface area occupied, e.g. in m2)** *of the system for this cutting technology in the work area (e.g. reactor building, cover floor over the pool).* *In comments, you could indicate whether the space occupied is an issue (e.g. high proportion of available space) and whether part of the system is installed in remote areas where the available space is not an issue.*	In Air						**Do you agree with? (Yes / No)**		
	Underwater								
Our point of view regarding this criterion: Space available in the reactor building and pool cover floor is limited. The footprint of the system in the dismantling area is key because of the lack of space.							*e.g. Yes*	**Why?** *Your comment*	
Robustness and Reliability [Value in Availability Rate %] *Could you please provide the* **Availability Rate (%)** *of this technology during RPV and RVI segmentation, i.e. the percentage of time during which the technology is operational (thus deducting the stops for failures, maintenances, etc.).* *If you are lacking data you may provide an estimate or a qualitative answer instead (High, Medium, Low).* *In comments, you could give details such as the percentage of time dedicated to maintenance or wear parts replacement. Provide brief descriptions of the main reasons of failures, if any.*	In Air						**Do you agree with? (Yes / No)**		
	Underwater								
Our point of view regarding this criterion: Improve the reliability and availability rate of the cutting system, considering maintenance and wear parts replacement. Improved robustness and reliability is beneficial to the safety of the workers.							*e.g. Yes*	**Why?** *Your comment*	

Resistance to Radiations [Value in Sv/hr and/or Gy] *Could you please indicate if the tool or part of the cutting system is required to be qualified to resist to radiations. Please provide the* ***qualification dose rate and/or total absorbed dose*** *(as relevant) or indicate "none" if there is no qualification required.* *In comments, you could indicate whether shielding is used instead or if the tool or part of the cutting system needs actual radiation hardening.*	In Air						**Do you agree with? (Yes / No)**		
	Underwater								
Our point of view regarding this criterion: Resistance to radiations is a key factor for the availability of the technology							*e.g. Yes*	**Why?** *Your comment*	
Cost for the segmentation of RPV and RVI [Value in EUR] *Could you please provide the* ***overall cost (or budget, assessment; order of magnitude)*** *for the use of this technology for the segmentation of RPV and RVI, including CAPEX and OPEX (i.e. not only the cost of the cutting system, but also its operation including maintenance, consumable, workforce, etc.).* *Please specify the scope which you considered in your assessment, such as RVI only, one or more reactor units, etc.* *If several types of technologies are used for the same scope (e.g. mechanical and AWJC), could you please add an estimate ration of the works carried out with this technology.* *In comments, you could add any detail which you agree to share, such as CAPEX and OPEX separately, cost of maintenance, or any other relevant cost breakdown.*	In Air						**Do you agree with? (Yes / No)**		
	Underwater								
Our point of view regarding this criterion: Reduce the cost for the dismantling of a power nuclear reactor, segmentation of RPV and RVI being often one of the most costly steps and subject to uncertainties.							*e.g. Yes*	**Why?** *Your comment*	
Time for the segmentation of RPV and RVI [Value in Months] *Could you please provide the overall* ***time (actual or planned)*** *needed for the segmentation of RPV and RVI, including design, procurement, deployment and operation of the system until completion of the works.* *Please specify the relevant parameters used for you assessment, such as scope considered (same as above for costs), work in single or several shifts and number of resources.* *If several types of technologies are used for the same scope (e.g. mechanical and AWJC), please add an estimate ration of the works carried out with this technology.* *In comments, you could add any detail which you agree to share, such as the duration of the main phases.*	In Air						**Do you agree with? (Yes / No)**		
	Underwater								
Our point of view regarding this criterion: Reduce the time for the dismantling of a power nuclear reactor, segmentation of RPV and RVI being often on the critical path of the project.							*e.g. Yes*	**Why?** *Your comment*	
Available cell (to add criteria if necessary)									

Waste

Global appraisal:

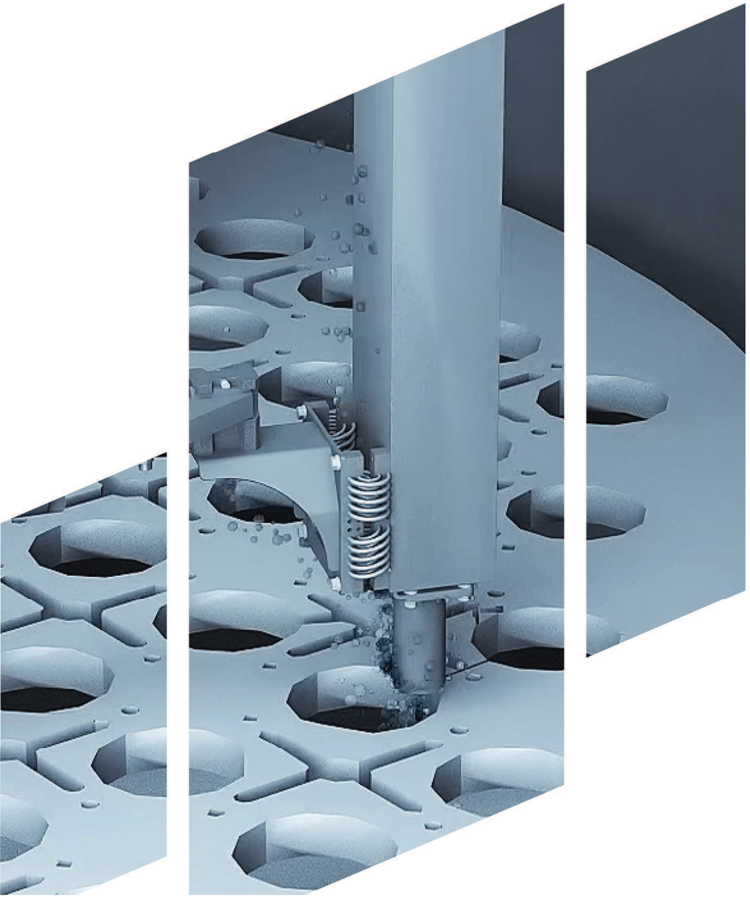
Primary waste handling [Qualitative Answer] *Could you please indicate if you see any advantages -or drawbacks- inherent to the use of this technology in respect of handling of the primary waste, making your choice in the list below:* *1.* **Advantages** *(using this technique limits the need for handling means, allows standard handling means)* *2.* **Neutral** *(balanced pros and cons, average compared to other technologies)* *3.* **Drawbacks** *(requires several, bespoke, handling means)* *In comments, you could provide the type of handling means which have to be used when cutting with this technique.*	In Air	*e.g. Advantages*	*e.g. Neutral*	*e.g. Neutral*	*e.g. Neutral*	*e.g. Neutral*	**Do you agree with? (Yes / No)**		
	Underwater	*e.g. Neutral*	*e.g. Drawbacks*	*e.g. Advantages*	*e.g. Advantages*	*e.g. Advantages*			
Our point of view regarding this criterion: Avoid the need for bespoke mechanical systems to handle the cut component and segmented pieces (primary waste), such as need to transport, lift, rotate, fix, etc.							*e.g. Yes*	**Why?** *Your comment*	
Primary waste packaging [Qualitative Answer] *Could you please provide your perception of the advantages -or drawbacks- of the technology in respect of facilitating the packaging of the segmented RPV or RVI components, making your choice in the list below:* *1.* **Advantages** *(enables optimized packaging, eases compliance)* *2.* **Neutral** *(balanced pros and cons, average compared to other technologies)* *3.* **Drawbacks** *(does not allow optimized packaging, introduces risk of non-compliance)* *In comments, you could provide the reasons of your rating, the average percentage of packages' filling achieved with this technology, the necessary control means inherent to this technology required to guarantee the packages' compliance, etc.*	In Air						**Do you agree with? (Yes / No)**		
	Underwater								
Our point of view regarding this criterion: Reduce the quantity of waste packages (by optimizing the filling). *Guarantee the compliance of the waste package with the regulatory criteria (e.g. controlled filling of the waste package to avoid introduction of forbidden material or uncharacterized pieces, such as fines, loose slag, etc.).*							*e.g. Yes*	**Why?** *Your comment*	

Secondary waste generated during the cut [Values in unit of mass or unit of mass per surface of cut and Characterization] *During the cutting, the mass removed from the component and added by the cutting tool, will contribute to the generation of secondary waste, which can be described as per the following families:* *- Gases and aerosols* *- Particles (fines, sludges)* *- Solids (coarser chips, swarfs, slags)* *For the relevant types of secondary waste, could you please provide:* *- The* ***mass generated*** *with the reference for your value, i.e. total mass for one reactor unit or for one specific component, or mass by unit of surface cut (surface being the length x thickness).* *- The* ***characterization*** *including description, main modes of the size distribution and waste classification as per your regulation.* *If you lack data to provide the above values, please describe quantitatively the secondary waste generated (none, low, medium, high).*	In Air						**Do you agree with? (Yes / No)**		
	Underwater								
Our point of view regarding this criterion: Reduce the quantity of secondary waste generated by the cutting operations, which is often considered as key criteria to select cutting technologies due to the technical difficulty and cost for managing this waste.							*e.g. Yes*	**Why?** *Your comment*	
Collection of the secondary waste generated during the cut [description of method / equipment] *Could you please describe how you collect the secondary waste generated by the cutting technique (e.g. local or building collection system) and how you manage the waste (processing and packaging).* *Please indicate if this is a particularly challenging and/or has a high cost and time impact.* *In comments, If the collection system itself generates significant amount of secondary waste (e.g. filtering media), could you please describe the type of waste and quantities.*	In Air						**Do you agree with? (Yes / No)**		
	Underwater								
Our point of view regarding this criterion: Reduce the quantity of secondary waste generated by the cutting operations, which is often considered as key criteria to select cutting technologies due to the technical difficulty and cost for managing this waste.							*e.g. Yes*	**Why?** *Your comment*	
Secondary Waste generated during dismantling of the segmentation system [Value in unit of mass and waste classification] *Upon completion of the segmentation of the RPV / RVI, the cutting system itself, along with spare or wear parts and consumable, may have to be disposed as radioactive waste.* *Could you please provide an average - or estimate - of the total mass of waste generated, along with its classification as per your regulation.* *In comments, you could add a description and specify, for instance, whether parts of the cutting system can be reused, on the same site (other unit) or a different site (other NPP).*	In Air						**Do you agree with? (Yes / No)**		
	Underwater								
Our point of view regarding this criterion: Although this is not ILW, disposal of the cutting system after its dismantling generates additional waste management costs which could be reduced.							*e.g. Yes*	**Why?** *Your comment*	
Available cell (to add criteria if necessary)									

Overall Apraisal of the Technology						
In case of using this technology for the dismantling of RPV/RVI, could you please describe your overall experience (e.g. which projects)?						Short responses are expected for each technology
Describe your overall feedback throughout the process (design, safety analysis and licensing, installation and commissioning, operation, etc.)						
Whether you use this technology or not, could you please indicate its main advantages according to your knowledge?						
Main drawbacks according to you						

7.2. Public presentation (at WNE 2021)

Laser Dismantling Environmental and Safety Assessment



LD-SAFE

WNE 2021 – Workshop 2
Project presentation

Author: LD-SAFE Consortium

Date: Dec. 01, 2021

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

European Commission | Horizon 2020 European Union funding for Research & Innovation

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Summary

CONTENT

Horizon 2020
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Introduction

Decommissioning of a power reactor

- Commonly scheduled to be completed over a **long period (over 20 years for PWR/BWR in general)**
- Change in strategy (**immediate dismantling** after permanent shutdown)
- **New challenges** (acceleration of the decommissioning project schedules)
- Need to improve the **dismantling processes** and **existing techniques**

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

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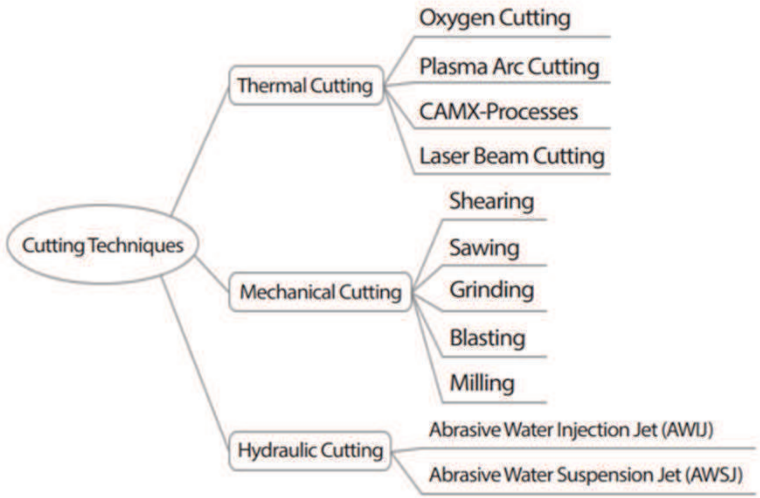
Cutting techniques

Main categories / Main tools used

- Thermal cutting (Plasma Arc Cutting)
- Mechanical cutting (Band Saw Cutting)
- Hydraulic cutting (Abrasive Water Jet Cutting)



Classification of remote handling technologies

Comparison / Limitations

	Plasma Arc cutting	Band Saw cutting	Abrasive Water Jet cutting
Advantages	Large dimensions Fast Less maintenance on site	Cut large thicknesses All materials Limited contamination	Complicated shape All materials Few air pollution
Drawbacks	**High degree of filtration** Slower underwater Electrically conductive material	**Slow (cutting speed)** Maintenance Wear part replacement	**Water treatment** High cost Required space

For cutting RPV/RVI in-air and underwater

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Cutting techniques

Need

- Development of **innovative technologies**
- Improve **safety**, **radiation protection**, **waste management**, **time** and **cost** aspects

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 testing)**
- **Mature** and **operational technology** for dismantling activities (already used for fuel cycle / research facilities)

Examples of operational experience

- *Dissolvers of **UP1 MAR200** fuel reprocessing facility at CEA in France*
- *Piping at Creys-Malville NPP (**SUPERPHENIX** prototype fast reactor)*
- *Radioactive waste evaporator at **La Hague** site*

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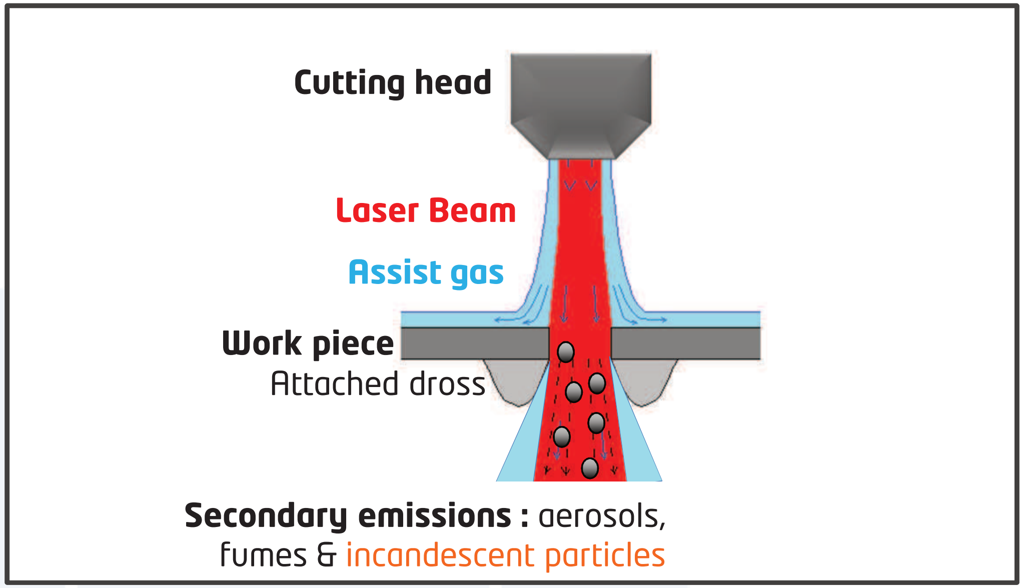
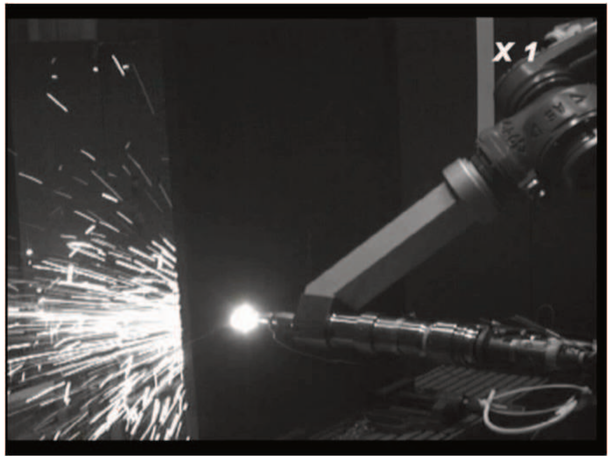
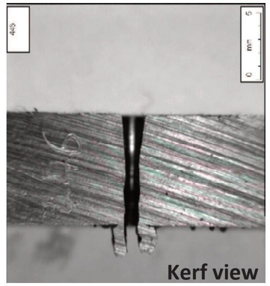
LASER CUTTING IN AIR







- **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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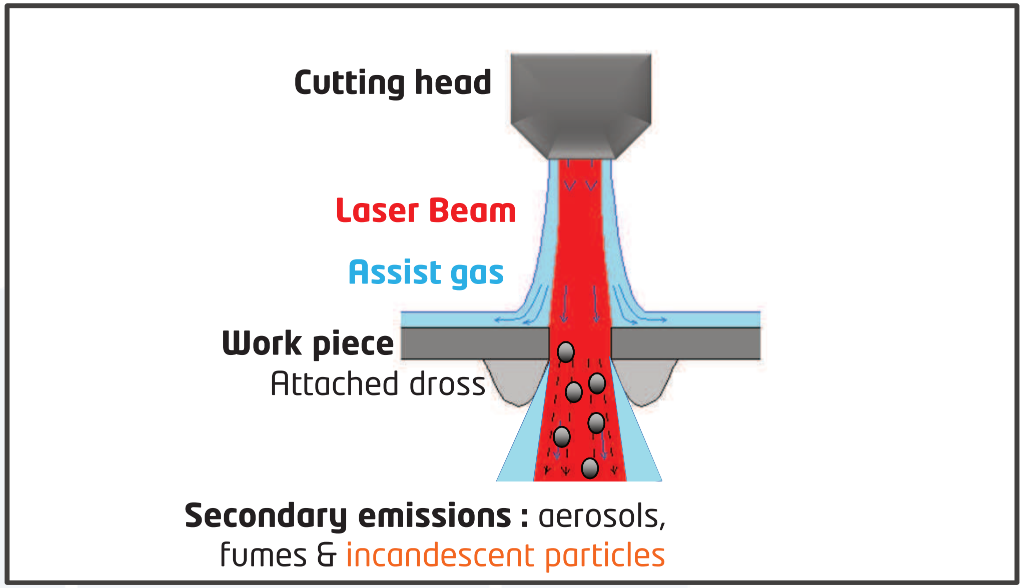
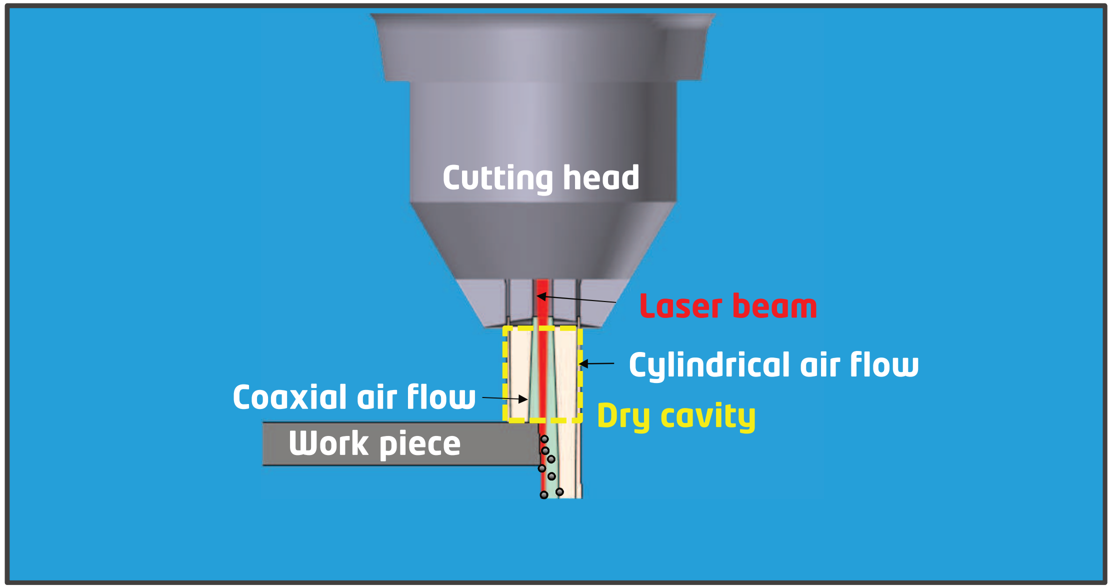
LASER CUTTING UNDERWATER



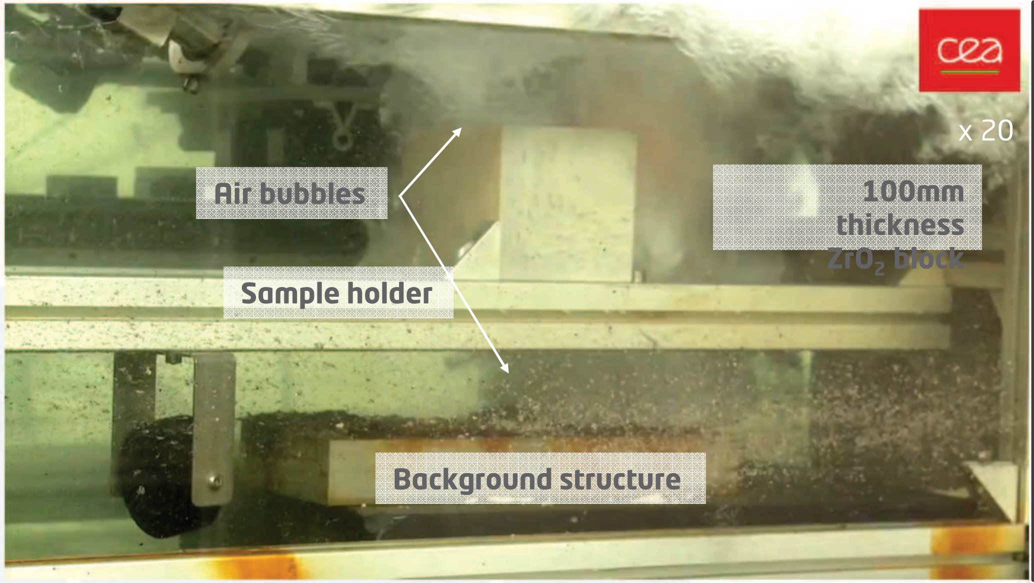


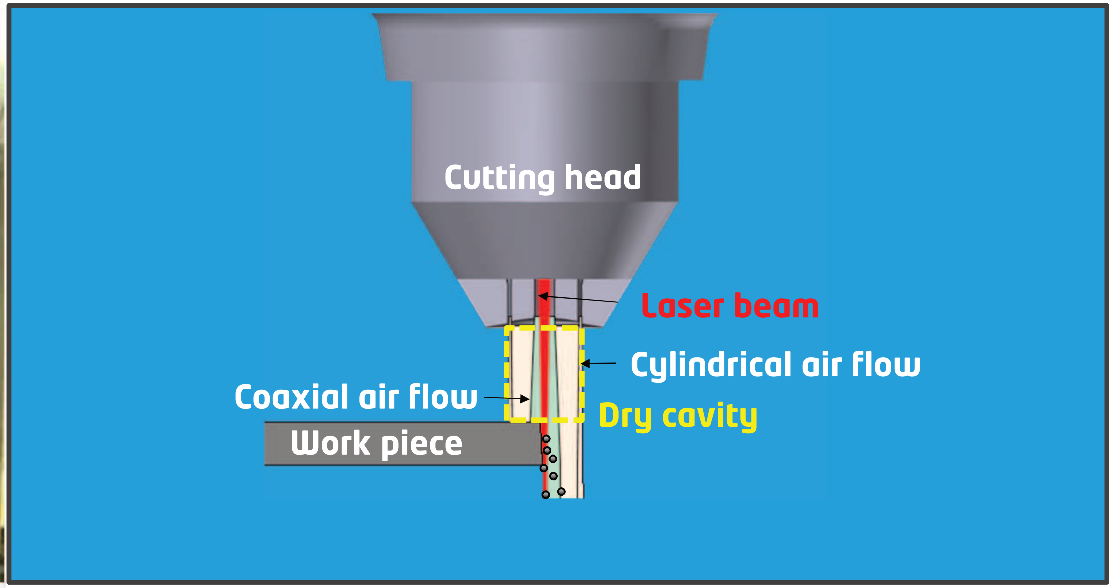
Based on **dry cavity concept** → **Laser beam propagates in air** between the laser head & work piece & in the kerf
→ With no laser power loss due to the water absorption

☺ **Radiological protection**
Aerosols trapping by water (75 gain at 0.5 m water depth and 400 at 4 m)

😐 Reduced process tolerance
No possibility of multi thickness cut

LASER CUTTING UNDERWATER





Based on **dry cavity concept** → **Laser beam propagates in air** between the laser head & work piece & in the kerf
→ With no laser power loss due to the water absorption

☺ **Radiological protection**
Aerosols trapping by water (75 gain at 0.5 m water depth and 400 at 4 m)

😐 Reduced process tolerance
No possibility of double thickness cut

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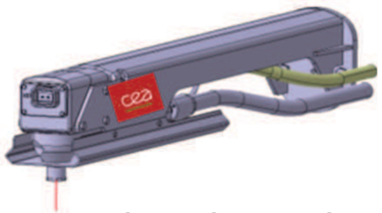
LASER CUTTING TOOLS DEVELOPED BY CEA

IN AIR LASER CUTTING TOOL

- Air-cooled head
- Successfully used for UP1 dissolver dismantling
- High tolerance cutting process
- Industrial head : 41.7 x 7.6 x7.2 cm, 6.3 kg w/o

Straight Head up to 14 kW



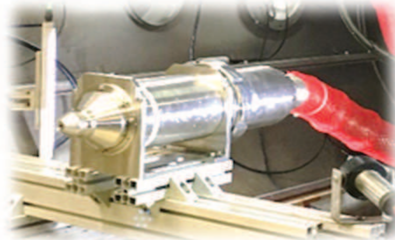
90° Angle Head - up to 8kW

UNDERWATER LASER CUTTING TOOL

- Operation under water - up to 5.6 m proved
- Robust and efficient shutter (stop bubbles for video observation)
- Easy umbilical cable connection
- No electronic components integrated
- Safety functions integrated
- Operational prototype - watertight :

60 cm long, 15 cm diameter, 20kg w/o

- **2 specific laser heads**: for in air operation & for underwater operation
- Designed for nuclear dismantling facilities to work in severe conditions and harsh environment
- High laser power capability: up to 16 kW
- Compact tools => work in cramped area
- Good robustness & high positioning tolerance, in particular for the in air cutting head



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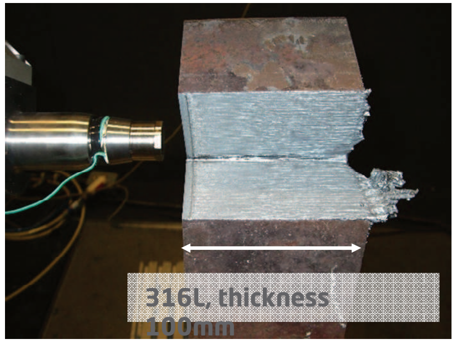
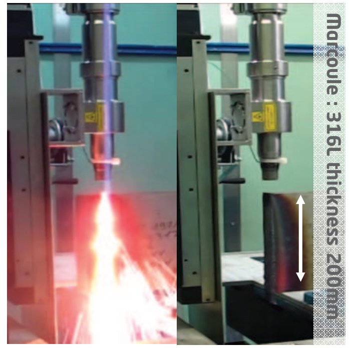
LASER CUTTING CAPABILITIES: STEEL

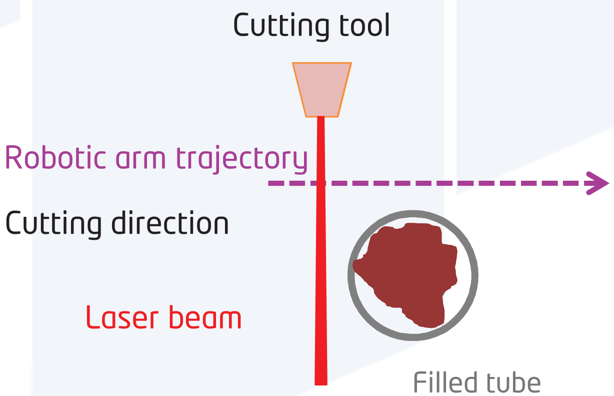
- **8kW + pressurized air → 100mm thick 316L**
  ~ 1 cm/kW when starting at the edge
- **14 kW → 200 mm thick 316L (CEA Marcoule)**

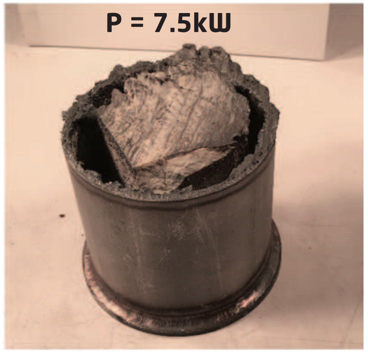




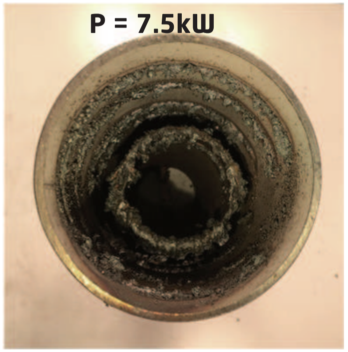
- **COMPLEX GEOMETRIES & MULTI THICKNESS CUT**

Straight trajectory of the robotic arm – does not follow the surface shape

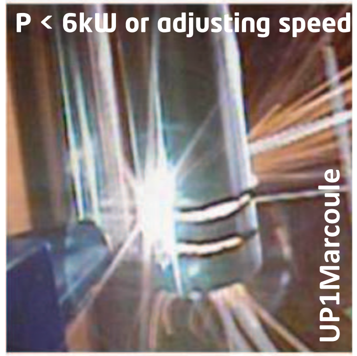




316L Ø 80mm,
3mm thickness + ZrO_2 block



316L Ø 80mm & Ø 40mm
thickness 3mm



316L Ø 80mm
thickness 7mm

316L Ø 80mm
thickness 3mm

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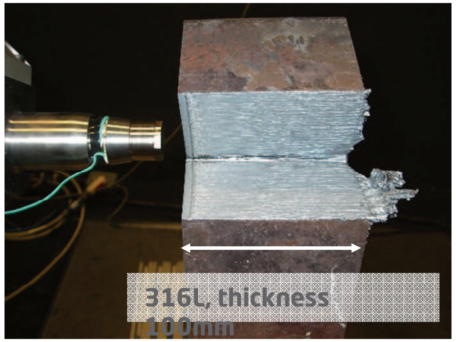
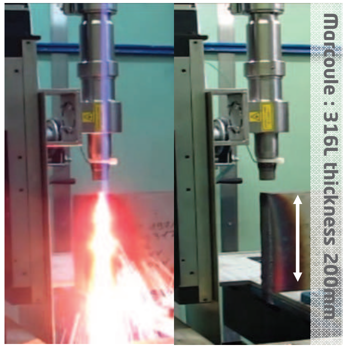
LASER CUTTING CAPABILITIES: STEEL

- 8kW + pressurized air → 100mm thick 316L

  ~ 1 cm/kW when starting at the edge

- 14 kW → 200 mm thick 316L (CEA Marcoule)

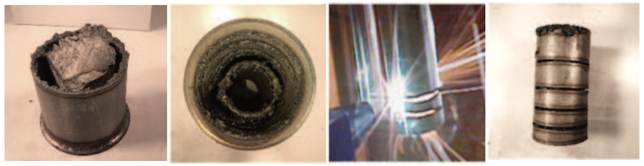


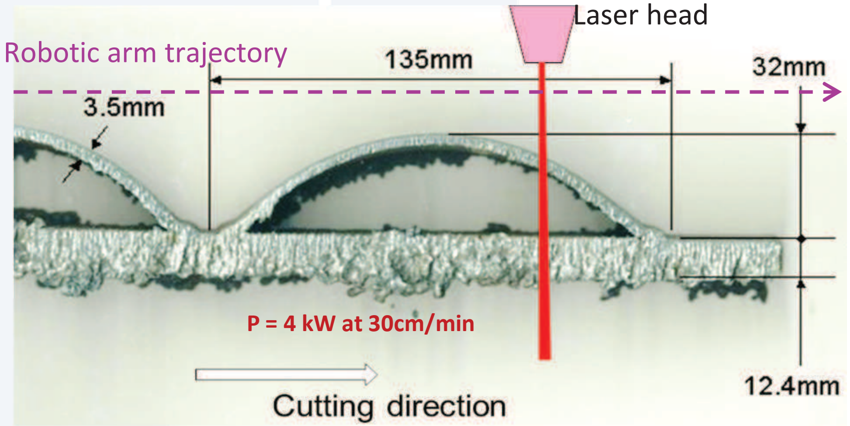


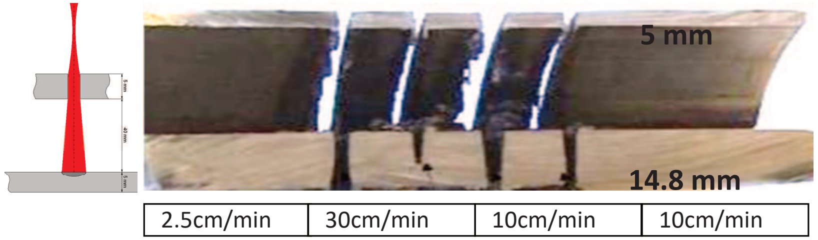
- **COMPLEX GEOMETRIES & MULTI THICKNESS CUT**

  Straight trajectory of the robotic arm – does not follow the surface shape

  Capability to cut simultaneously more than just one plate







Uranus 65 steel

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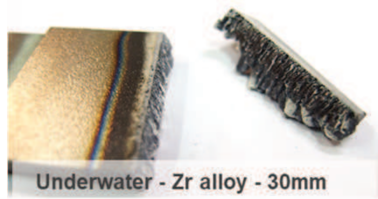
LASER CUTTING PERFORMANCES

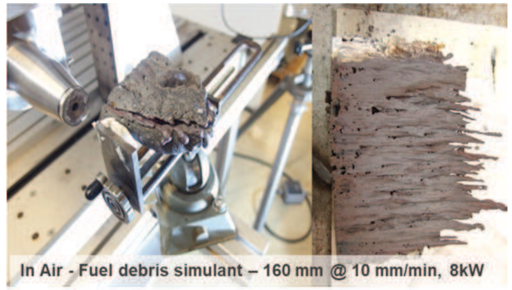
Laser cutting performances tested up to now

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	100

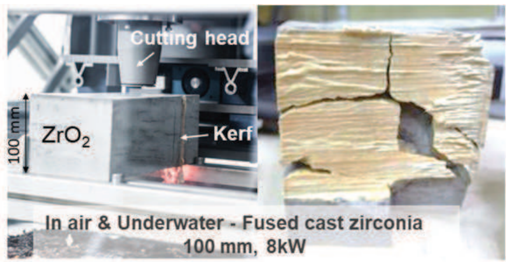
➢ **Increased cutting speeds are expected in the coming years due to the availability of higher power laser sources**



Underwater - Zr alloy - 30mm



In Air - Fuel debris simulant – 160 mm @ 10 mm/min, 8kW



In air & Underwater - Fused cast zirconia 100 mm, 8kW

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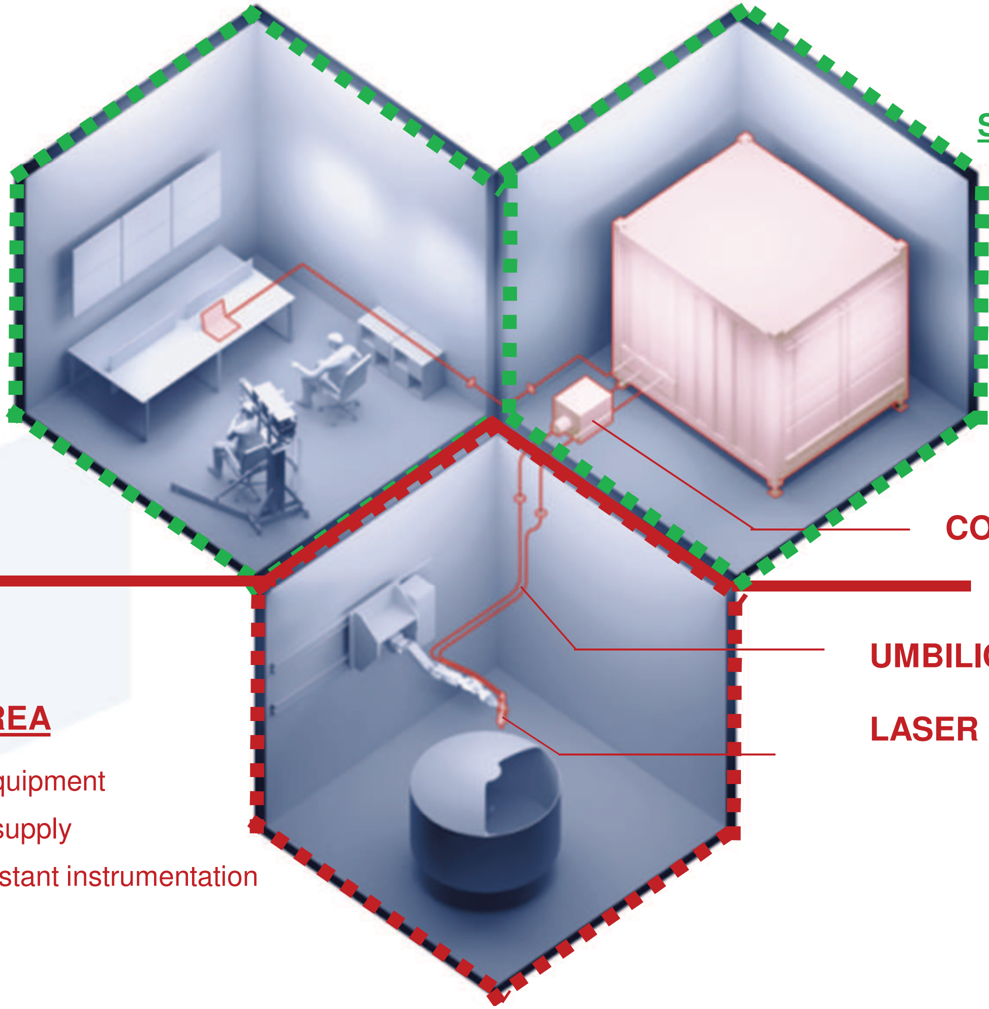
ON-SITE IMPLEMENTATION FOR DISMANTLING ACTIVITIES

Control ROOM

Control software

SHELTER ROOM

- LASER Source
- Utilities
- Electrical Control & Instrumentation



COUPLER

Contaminated zone boundary

UMBILICAL

LASER CUTTING TOOL

DISMANTLING AREA

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

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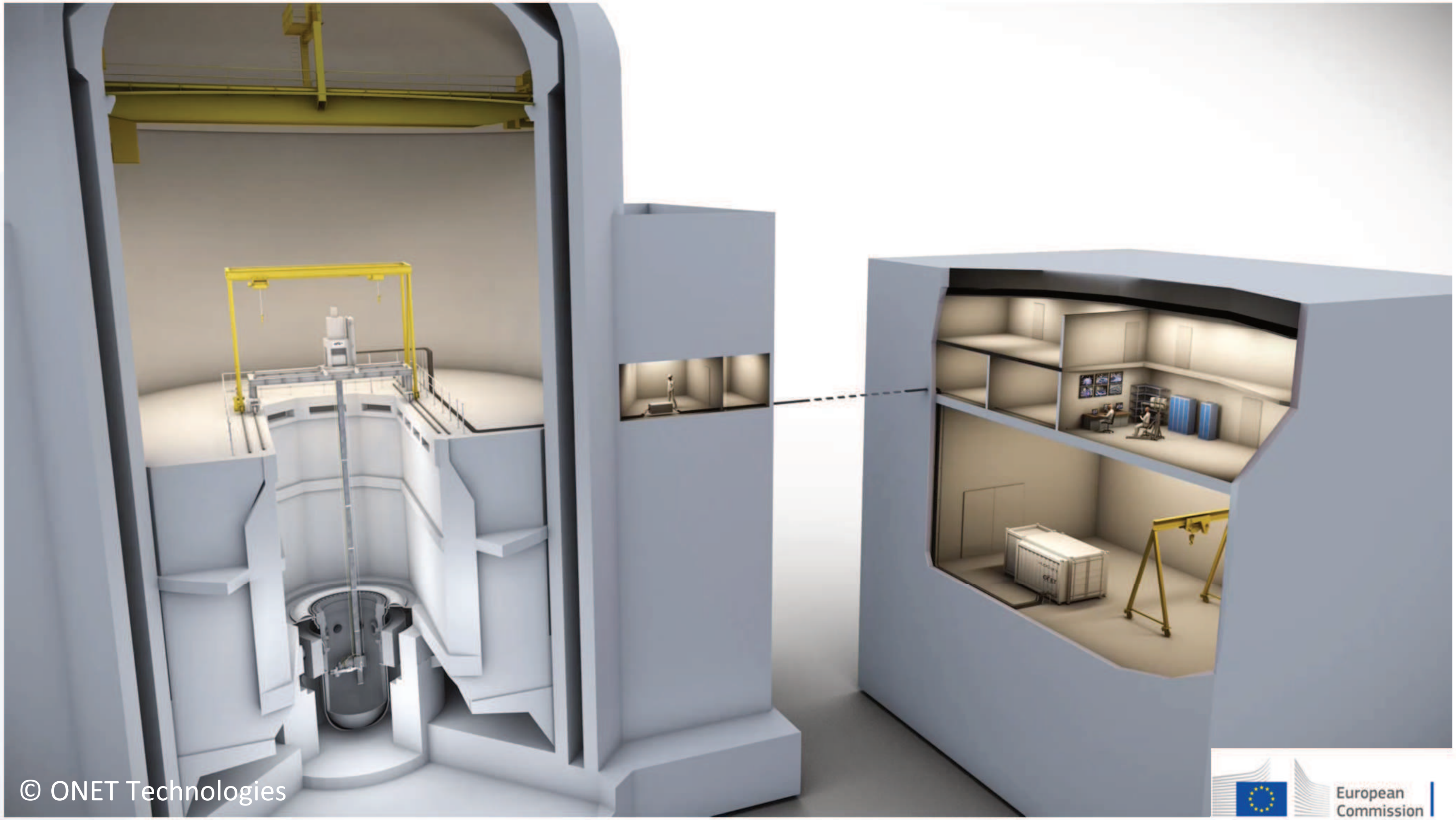
ON-SITE IMPLEMENTATION FOR DISMANTLING ACTIVITIES



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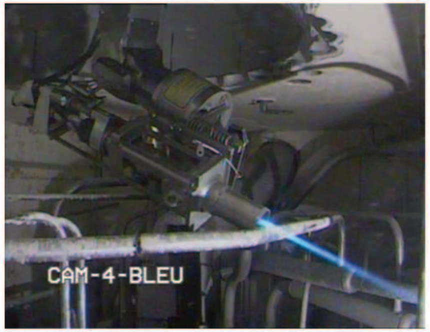
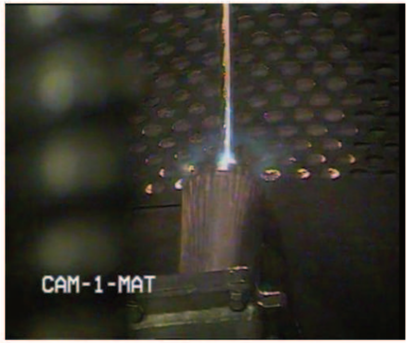
LASER CUTTING KEY BENEFITS FOR DISMANTLING

- **Safe** for the workers (remote operations)
- **Time** reduction and **cost** efficiency in operation
- **Effortless** cutting with high performance
- Ability to cut **complex geometries**
- **Contactless** which eliminates the risk of tool blockage
- **Minimization of the secondary waste** (aerosols and mass removed)
- **Cleaner** than most of other thermal techniques (especially for dust & fumes)
- **Robustness** and **reliability**, **no maintenance** or wear parts replacement in controlled area



Up to **200mm in thickness** in air (14kW laser power)



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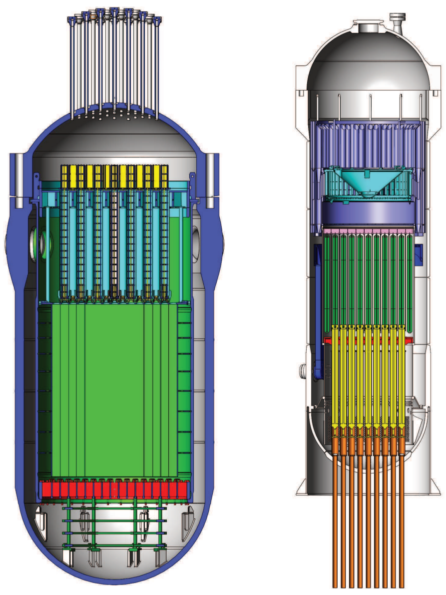
H2020 program

Not yet widely used in the nuclear decommissioning industry?

- Laser considered as new technology (**never used** for power nuclear reactor dismantling)
- Compliance with **safety requirements** need **to be checked**

Most challenging task

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



LD-SAFE (H2020 program)

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

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Organization

H2020 program
- **R + D + i project**
- Funding by **EC (Euratom)**
- **4 years** (July 2020 to June 2024)

Consortium

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

Overall organization

1 Project officer

European Commission

6 partners

Consortium

3 groups

Advisory Board

EG/EUG/SG

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

End User Group

Support Group

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Concept

LD-SAFE project

Laser cutting to replace conventional cutting techniques for the dismantling of commercial reactor components

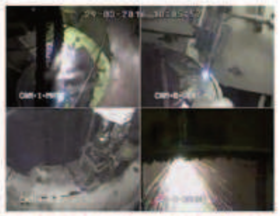
Advantages of cutting laser technology

- Effortless cutting and excellent cutting performances
- Minimization of the secondary waste produced
- Easily automatized with a manipulator in remote operation
- Safe for the operation and maintenance workers
- Modular system
- Easily installed in existing facilities

2017 — 2019 — 2020 — LD-SAFE Project — 2023

Fuel cycle facilities
TRL8 validated in Air

Dismantling of UP1 MAR 200 Dissolver (French fuel reprocessing plant stopped in 1997)



Cutting works in actual environment
FOAK commercial contract

Damaged reactors
TRL6 validated Underwater

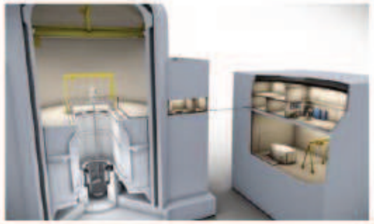
Prototype developed to rise to Fukushima Daiichi decommissioning challenges (corium), validated in technical underwater conditions

Cutting trials in laboratory
R&D agreement

Nuclear power reactors
TRL6 in Air & TRL5 Underwater

LD-SAFE project demonstration on mock-up

Nuclear power reactors
TRL7 validated in Air & Underwater



- ✓ Addresses the key technical requirements for reactor dismantling
- ✓ Is safe and can be proposed in the safety cases of dismantling projects
- ✓ Is field tested in a representative environment
- ✓ Reduces the cost of reactor components dismantling

KPIs:

1. Improve feed rate: 50 mm/min for a thickness of 100 mm of steel with a 14kW laser source corresponding to a power consumption of 40 kW
2. Minimization of generated secondary waste: less than 800 g/m
3. Improve the versatility of cutting tool: 2 cutting tools need only
4. Improve the reliability of the cutting tool: Availability rate > 95%
5. Reduce hands-on human activities: 100% of works carried out in remote operations
6. Environmental and safety impact: Size distribution of aerosols between 0.1µm and 0.4µm / Particle mass in suspension in water between 0.3 to 1 g/m of kerf
7. TRL 7 validated in air and underwater
8. Cost reduction of -30% (1 unit), -50% (2 units) and time reduction of -30%

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Main technical activities

Laser Cutting Development	Environmental and worker protection	Safety Assessment	Decommissioning of nuclear facilities
Analysis of the reactor dismantling with laser cutting (ONET Technologies, EQUANS) **Laboratory tests and calculations:** -Laser beam residual power -Hydrogen gas generation during underwater cutting (cea) -Aerosols (IRSN)	-Technology qualification -Guidelines for the industry for the use of laser cutting (Vysus Group)	-Risk analysis -Generic Safety Assessment (tecnatom) -Independent review (IRSN)	**Demonstrator in two phases: in air and underwater** **Validation of the implantation and the use of the laser cutting technology in operational environment** (ONET Technologies, cea, EQUANS) **+ End-users**

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Progress

Laser Cutting Development

Environmental and worker protection

Safety Assessment

Decommissioning of nuclear facilities

Milestone completed:
Specifications for the dismantling of reactor components agreed (inputs for the other activities).

100%

Laboratory tests:
-Design of experimental setups
-Implementation & qualification of specific instrumentation
-Purchase of representative samples
-Preliminary experientations/analysis

25%

Milestone completed:
Qualification activities in the Technology Qualification Plan are defined and scheduled

Qualification activities:
-Appraisal of laser system maturity
-Technology Qualification Plan
-Monitoring qualification activities progress (on-going).

40%

Safety assessment:
-Risk analysis with regards to safety
-Compilation of inputs from previous activities (on-going).

25%

Demonstrators:
-First studies for the definition of the complete laser system for the 2 phases of the demonstrator (on-going)

15%

+ End-users

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Public outputs

Laser Cutting Development

Environmental and worker protection

Safety Assessment

Decommissioning of nuclear facilities

Analysis of the different reactor components in combination with the selection of conventional cutting techniques (available)

Laboratory tests and calculations

Confidential deliverables

Guideline - use of laser cutting in reactor dismantling environment (31/12/2023)

Generic Safety Assessment (31/08/2023)

Technical validation report (30/06/2024)

Stakeholders workshop report (31/05/2024)

Advisory Board

Dissemination

Project website and Social Networks (available)

Education and training report & Online course on cutting technologies (30/06/2024)

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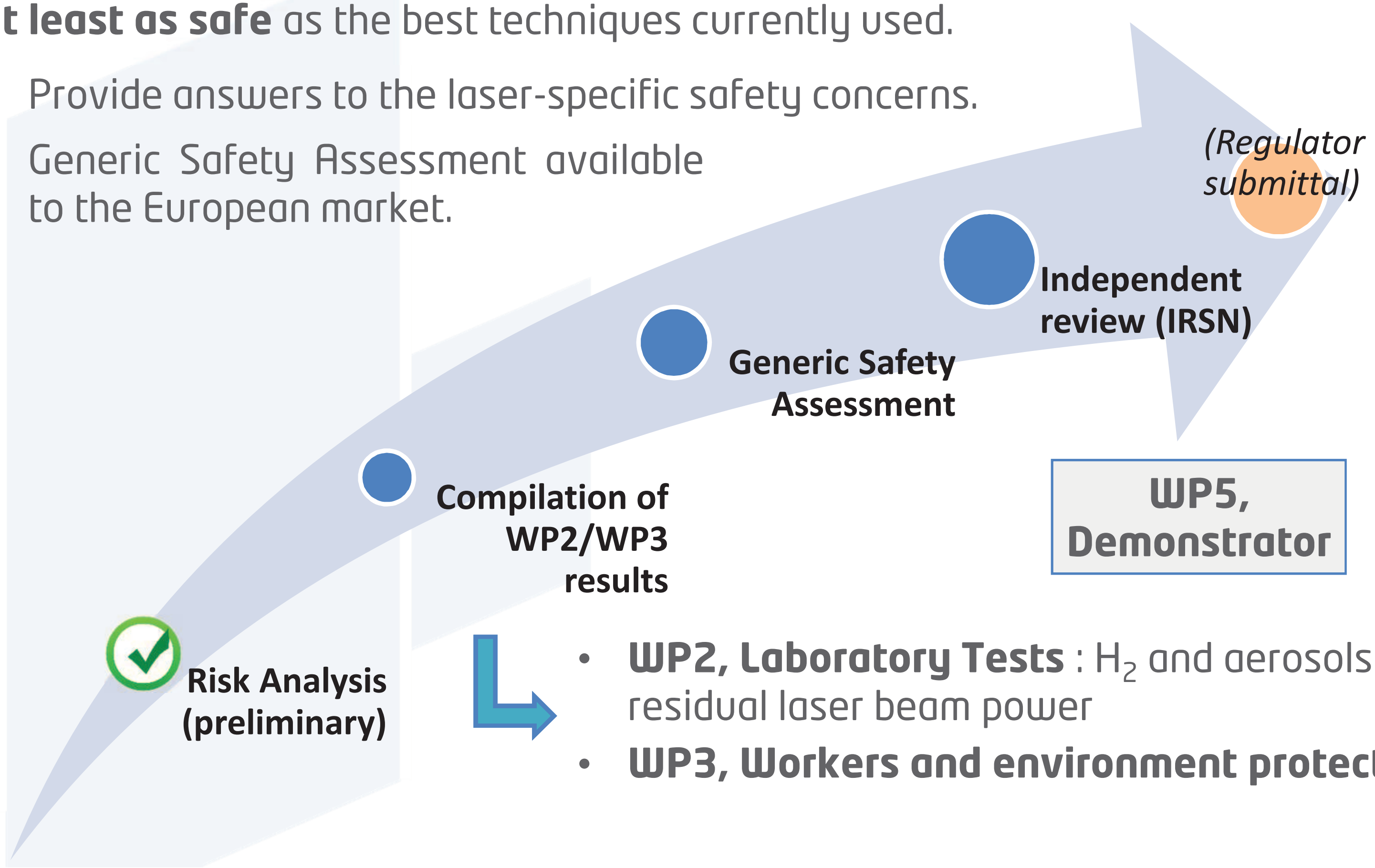
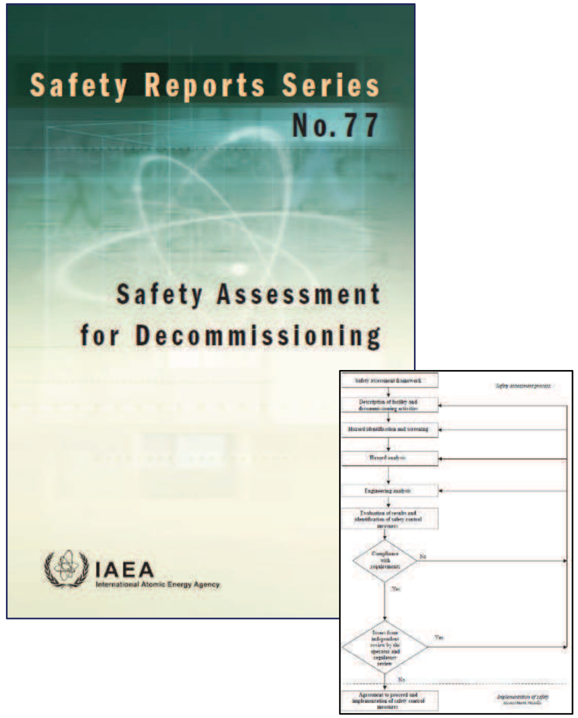
Safety aspects

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

- Provide answers to the laser-specific safety concerns.
- Generic Safety Assessment available to the European market.



- **WP2, Laboratory Tests** : H_2 and aerosols generation, and residual laser beam power
- **WP3, Workers and environment protection**



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Safety aspects

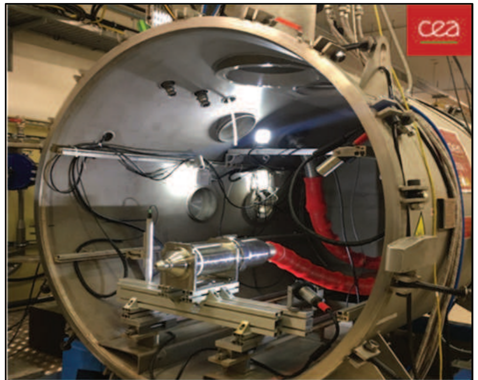
Preliminary risk analysis performed

- Identifying and evaluating radiological and conventional risks,
- Identifying safety systems, measures and controls,
- Identifying uncertainties.

Summarized in **Risk Matrixes** for Normal and Accident Conditions

Results should be understood as a **preliminary indication of the level of safety** that can be achieved.
For demonstrating its safety implementation, further information should be gathered:

- **WP2.** Tests and calculations of hydrogen and aerosols generation, and of residual laser beam power (performed in DELIA Facility at CEA Saclay).
- **WP3.** System maturity and integration analysis.
- **WP5.** Demonstration of laser cutting technology safety and efficiency in mock-up (reactor components and conditions simulation).



CEA, DELIA facility (1.38 m diameter & 2 m long vessel)
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Safety aspects

Risk Matrixes for Normal and Accident Conditions - "Safety Envelope"

Normal segmentation conditions

			Unoptimized Conditions				Safety Measures and Controls
Situation	Associated Activities	Potential Causes	Probability (1)	Dose to Workers	Dose to Public	Environment	Design options
External Exposure Normal conditions	All activities	Activities in radiation and contaminated areas.	All along the process	Very high if no measures are taken due to highly activated materials	Low	N/A	Remote Operation, robust design, easy installation & decontamination. Shielding, dosimeters, and other Radiation Protection (RP) procedures and controls. Area Radiation Monitoring. Water Level Monitoring. Building off-gas system monitoring and filtration. Training.
Internal Exposure Normal conditions	Segmentation activities	Airborne releases during RPV/RVI cutting. Sublimation of ruthenium to gaseous form (in-air cutting).	All along the process	Very low		N/A	Remote Operation. Dust/aerosols collection system. Contamination Control Confinement (Airlock). Area Radiation Monitoring. Building off-gas system monitoring and filtration.
Effluents and secondary waste Normal conditions	Segmentation activities	Airborne releases, dross generation, and water contamination during RPV/RVI cutting.	All along the process	N/A	N/A	Very Low	Protection of cavity floor. Effluents Monitoring. Auxiliary water filtration systems.
Waste management Normal conditions	Radioactive waste handling and fluxes	Cutting pattern choice	All along the process	Very low	N/A	N/A	Minimize waste generation. Shielding. Online removal of waste. Optimization of waste location considering personnel walking paths.
Hazardous materials exposure Normal conditions	Segmentation activities	Potential generation of hazardous chemical compounds during cutting operations, such as ozone, carbon oxides, nickel carbonyl, nitrogen oxide and toluene. Hexavalent chromium generation during stainless steel cutting.	All along the process	N/A	N/A	Toxicity	Dust/aerosols collection system. Contamination Control Confinement (Airlock). Area Radiation Monitoring.
Maintenance operation Normal conditions	Maintenance (nozzle replacement, support equipment - platform-...)	Maintenance activities, repairs, and replacements.	All along the process	Low	N/A	N/A	Robust design, easy and scarce maintenance. RP procedures and controls. Protective personal equipment.

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Conclusion

Expected impact

- ❑ To support the **European industry** by enhancing the decommissioning sector based on EU safety culture and know-how.

- ❑ To propose an **innovation** (in terms of safety, economic and technical aspects)

➢ **Achieving a world first laser dismantling of a power nuclear reactor!**

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Thank you for your attention!

Q&A

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