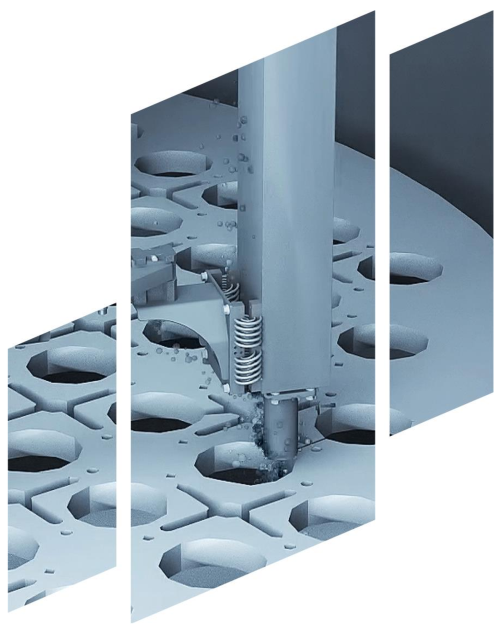

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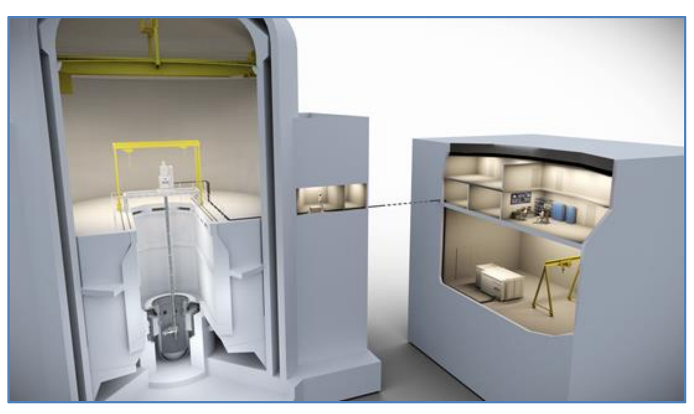
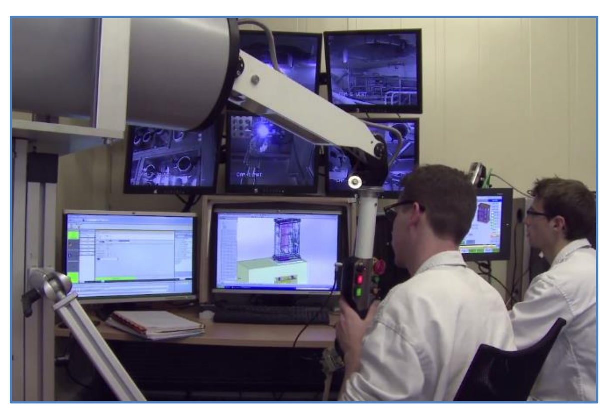
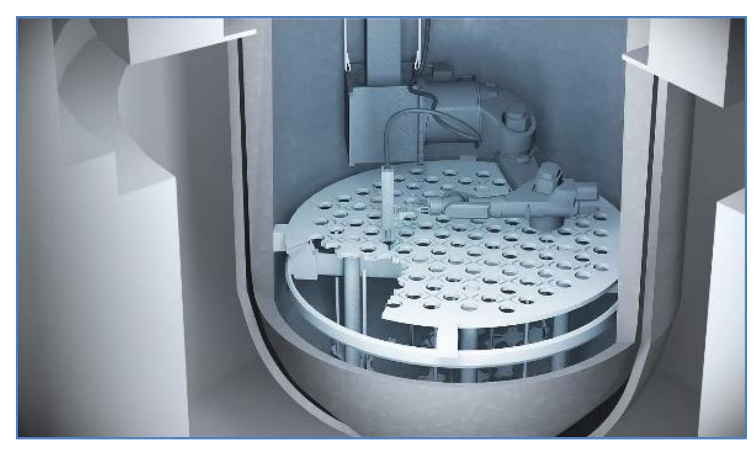
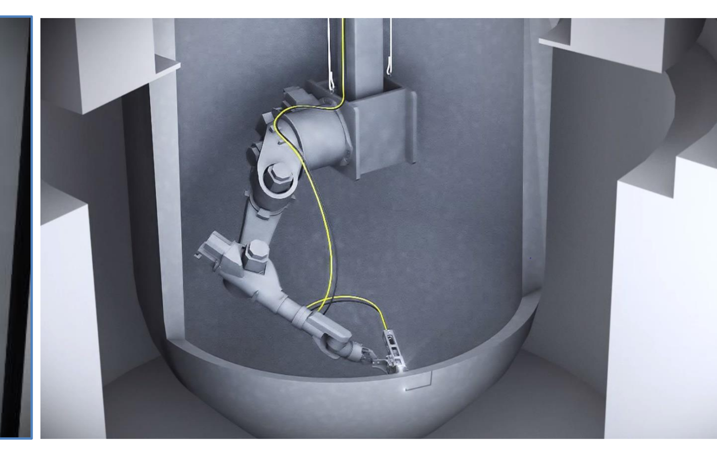



LD-SAFE

Four-year European research and innovation project focused on the use of laser cutting technology for the dismantling of nuclear power plants (NPPs). It will demonstrate that laser cutting capabilities meet key technical challenges in dismantling, assessing its environmental and safety impacts, and proving the economic advantages of its use.





Challenges

It is essential to decommission NPPs safely, and time/cost effective. In this regard, dismantling of the reactor pressure vessel (RVI) and internals (RVI) is known to be the most challenging part:

- Technically: complex shapes and access, some components to be dismantled underwater due to radiation protection requirements
- Mechanically: radiation hardening of the metal and combinations of materials
- In terms of safety: highly radioactive, activated, components located closer to the surface.

This task requires long periods of planning and at least a year to execute (often on the critical path).

Main objectives

Focus on removing the last technical, financial and psychological barriers to propose the laser cutting technology as an alternative to conventional cutting techniques used for RPV and RVI dismantling.

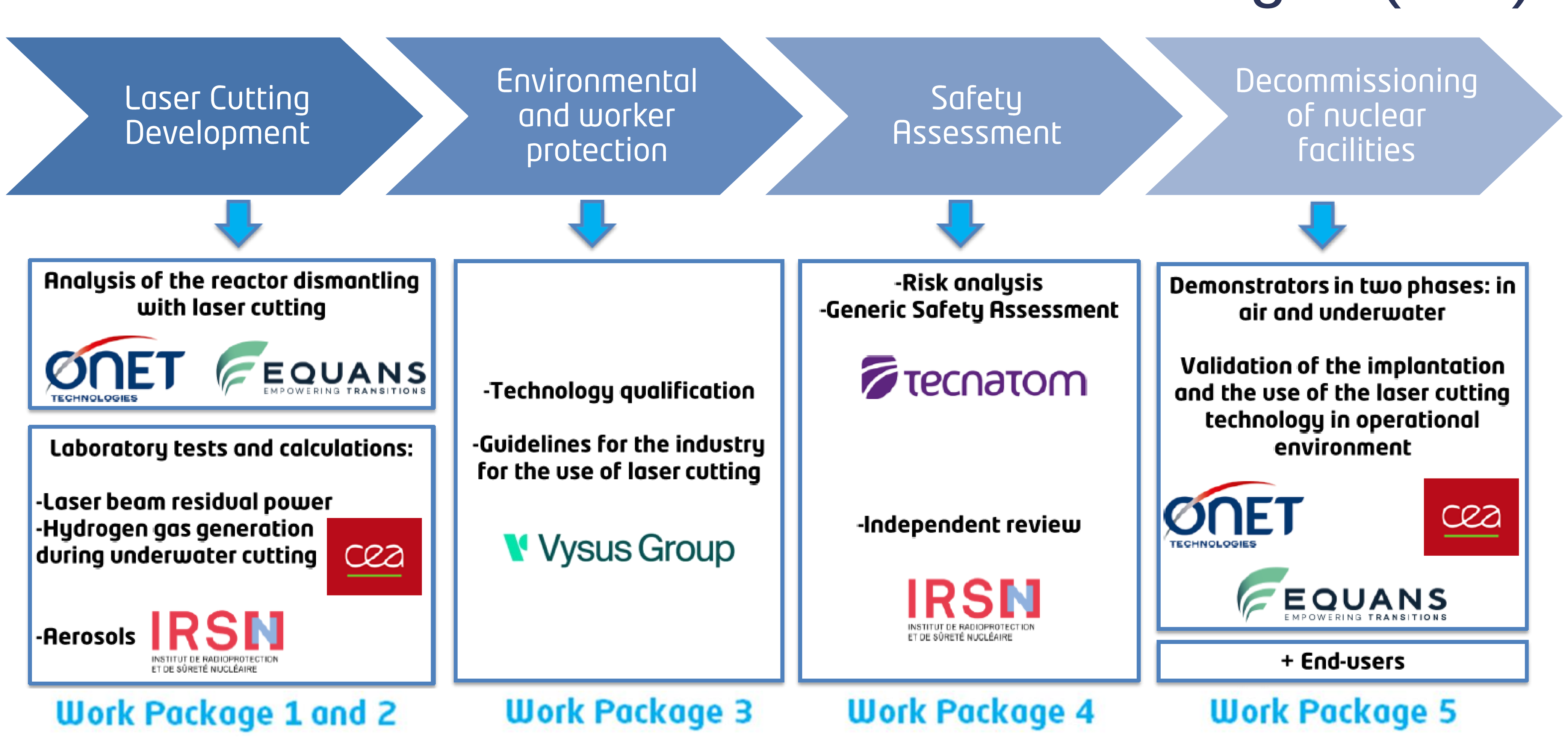
Objective 1: Demonstration of the capabilities of a versatile laser cutting solution to address key technical challenges in large NPPs decommissioning.

Objective 2: Environmental and safety assessment of the implementation of laser cutting for nuclear reactor decommissioning.

Objective 3: Technical validation of the laser cutting prototype in operational environment.

Objective 4: Demonstration of the economic advantage of using laser cutting technology for the forthcoming reactor decommissioning market.

Main technical activities and Work Packages (WP)



- **WP1:** Analysis of the reactor dismantling with laser cutting
- **WP2:** Laboratory tests and calculations
- **WP3:** Protection of workers and environment
- **WP4:** Safety assessment
- **WP5:** Case studies and demonstrator
- **WP6**: Dissemination and exploitation activities
- **WP7**: Project management

Upcoming events

- **Spanish Nuclear Society** (Oct. 4-6, 2021) - Granada, Spain
- **ICOND conference** - ICOND 2021 (Oct. 19-21, 2021) - Aachen, Germany
- **BASE symposium** - SafeND (Nov. 10-12, 2021) - Berlin, Germany & Virtual
- **WNE 2021** - LD-SAFE workshop public session (Dec. 1, 2021) - Paris, France

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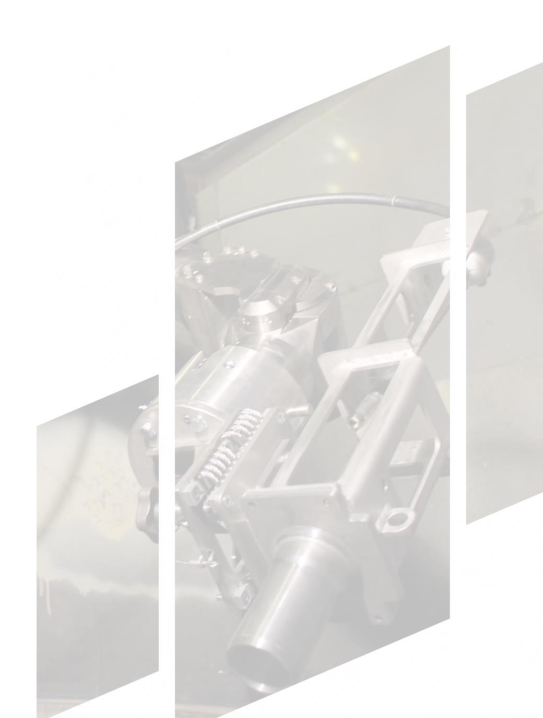

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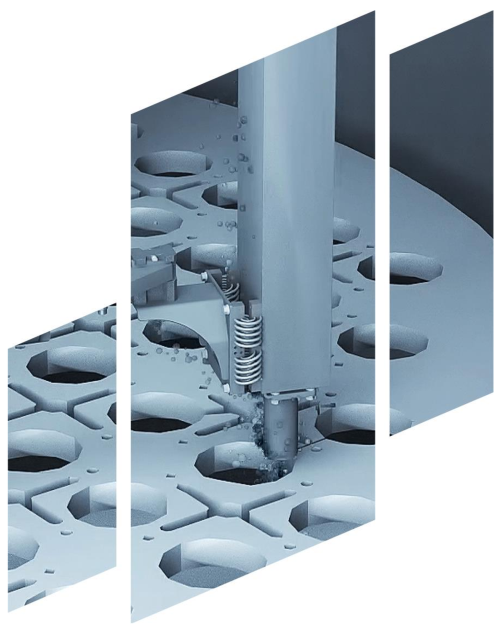

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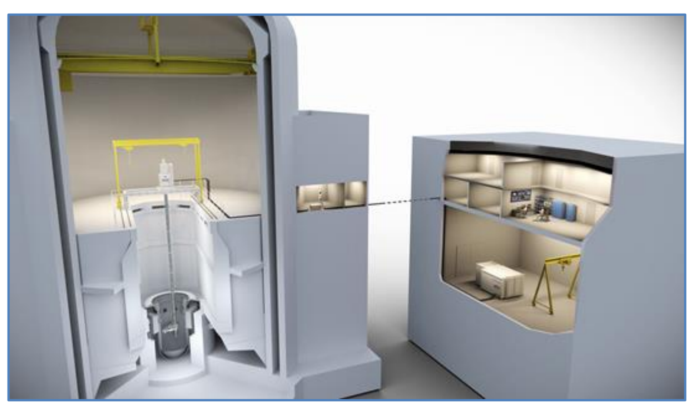
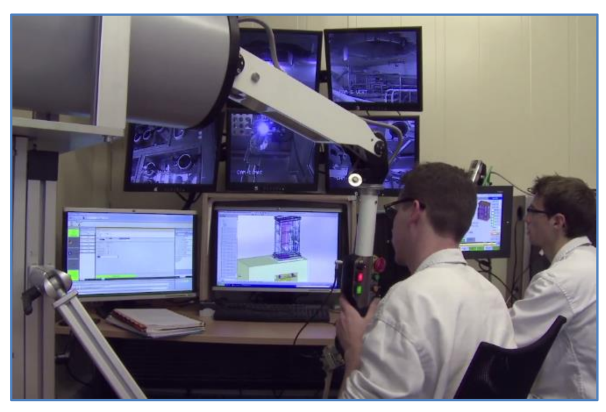


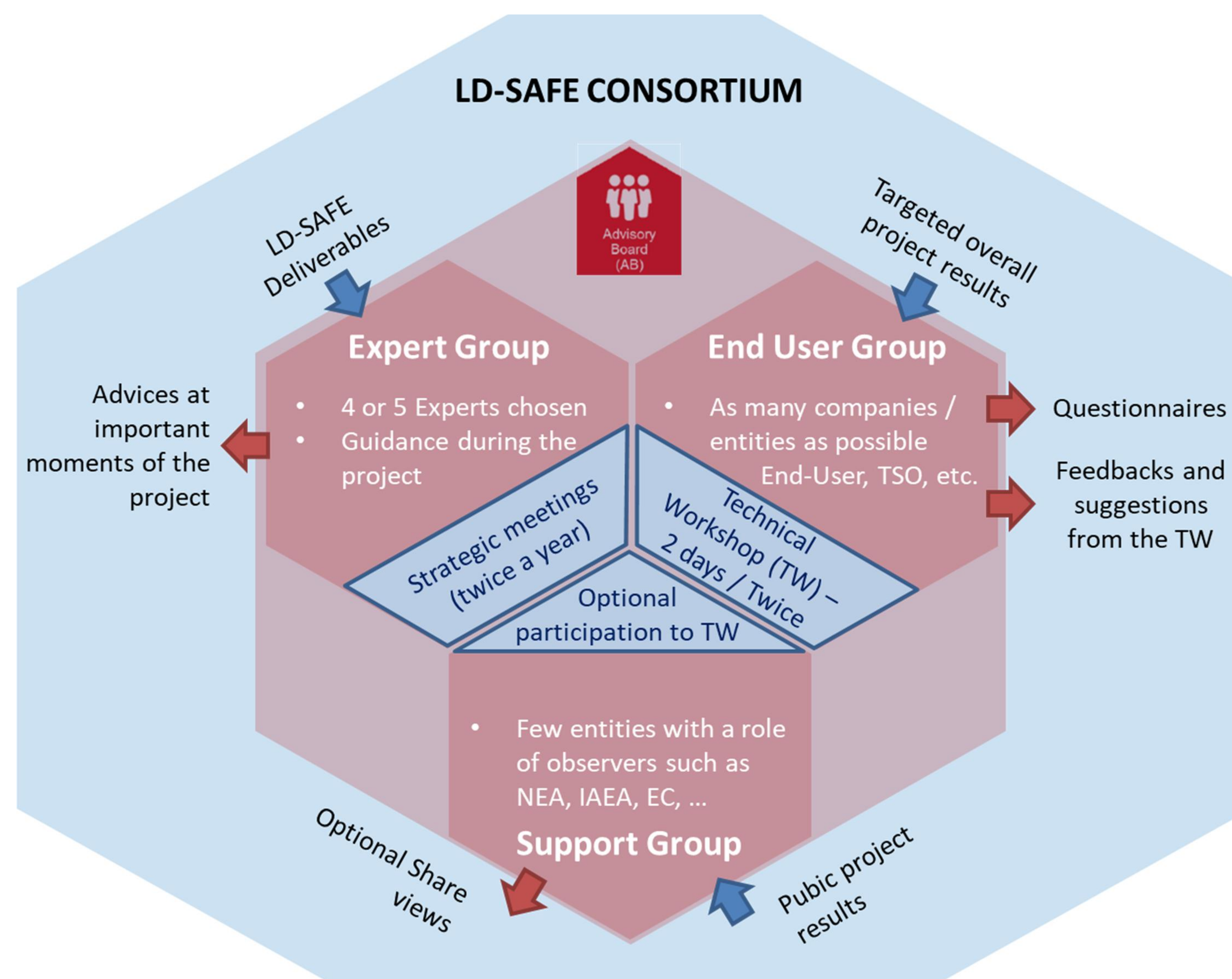


Organization

Consortium

Strong partnership of leading industrial companies and European research centers with extensive track-records in nuclear dismantling, protection of people and the environment, safety assessment, and associated domains.

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



Advisory Board

The Advisory Board is divided in 3 groups (Expert Group, End User Group and Support Group).

It creates an ecosystem for providing inputs for running the project and for ensuring the match between project results and market, societal, and environmental needs.

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.

EUG answers to the questionnaire of the Technical Workshop are synthetized in page 5.

Expert Group

The EG 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 – ALPhANOV — One laser safety expert

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

Dounreay — One dismantling project management expert

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.

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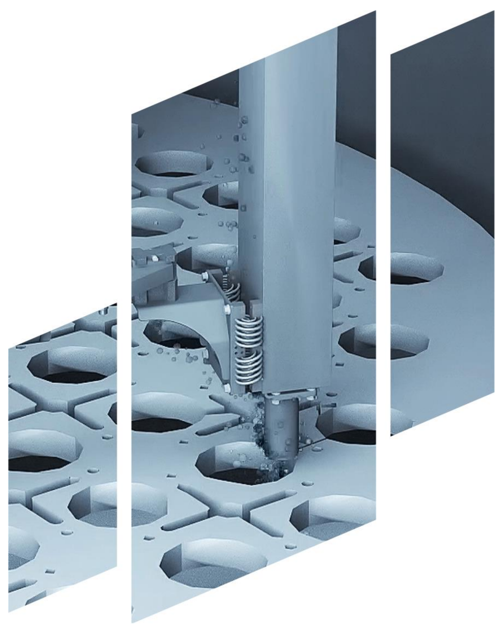

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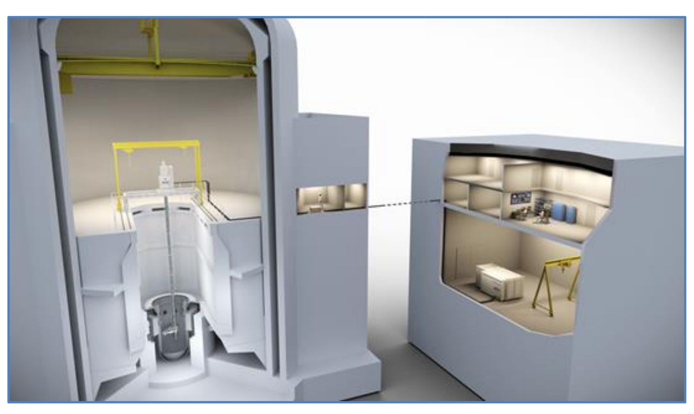
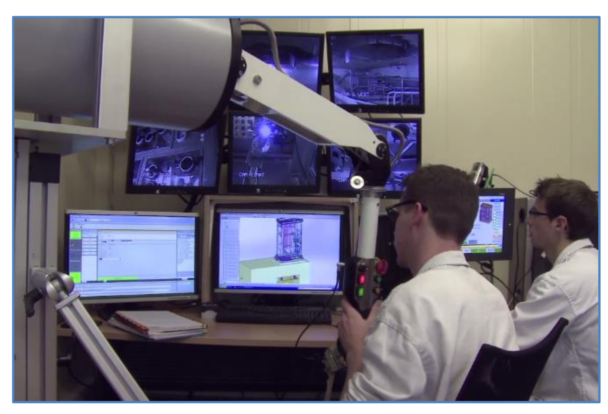




WP Progress

- WP1 - Milestone completed.
- WP2 - Laboratory tests definition.

Deliverables submitted

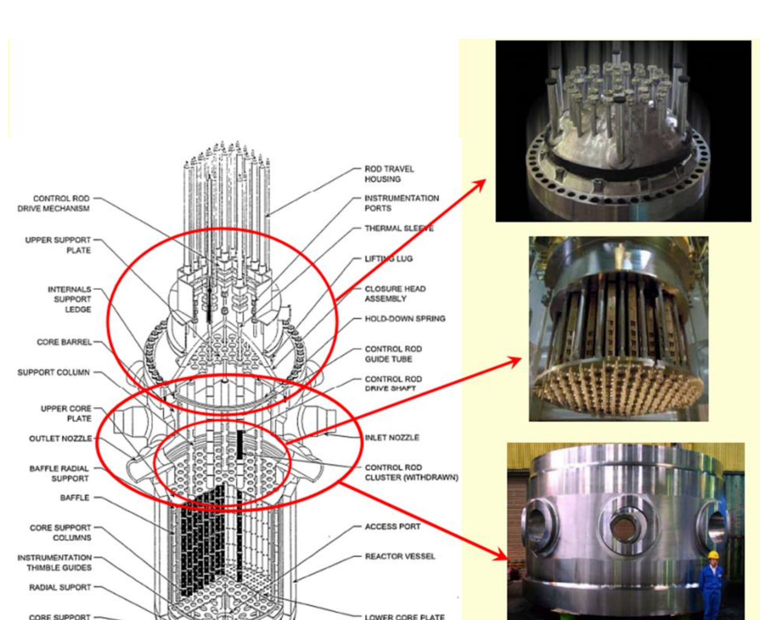
ID	Deliverable Title	Lead	Dissemination Level
D1.1	Analysis of the different reactor components in combination with the selection of conventional cutting techniques	ENGIE	Public
D1.2	Specifications for the laser cutting system	ENGIE	Confidential

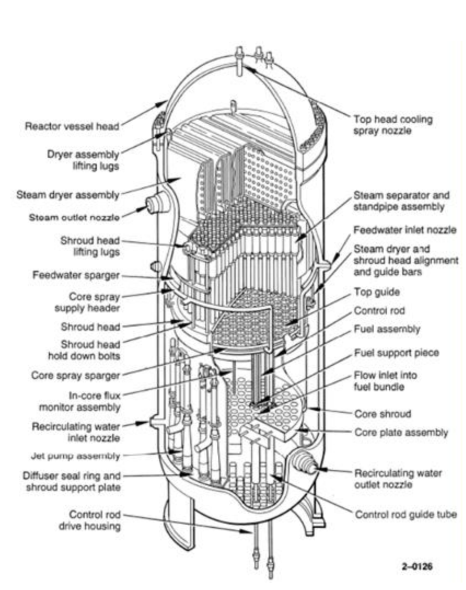
WP1 Progress (leader: EQUANS)

D1.1 - Analysis of the different reactor components in combination with the selection of conventional cutting techniques:

- Advantages and drawbacks of main conventional cutting techniques (thermal, mechanical and hydraulic) in regards of safety, secondary waste minimization, reliability and maintainability, and cutting performances.
- RPV/RVI structure of metal assemblies, which vary considerably based on the type, size and design of reactors (i.e., BWR vs. PWR).

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





D1.2 - Specifications for the laser cutting system:

Laser technology description, highlighting the cutting performance criteria. Preliminary safety rules and principles to be considered.

D1.3 - Specifications for the safety tests of WP2:

- Summary of safety related challenges raised by laser in a matrix of safety requirements to ensure that are covered by WP3 and WP4.
- Details of tests to be implemented in WP2, to support the safety demonstration.

D1.4 - Specifications for the demonstrator, including a conventional technique for comparison:

Identifying the most challenging piece to be cut into the reactor and describing the specifications for the mock-up in relation with the conventional technique band saw.

WP2 Progress (leader: CEA)

Task 2.1 (CEA) - Laser beam residual power (for in air cutting):

- Design of an experimental set-up and implementation in CELENA facility of specific instrumentation to characterize laser beam residual power.
- Purchase of specific instrumentation (thermal cameras and pyrometer) and qualification using background materials like graphite and stainless steel without cutting operation.

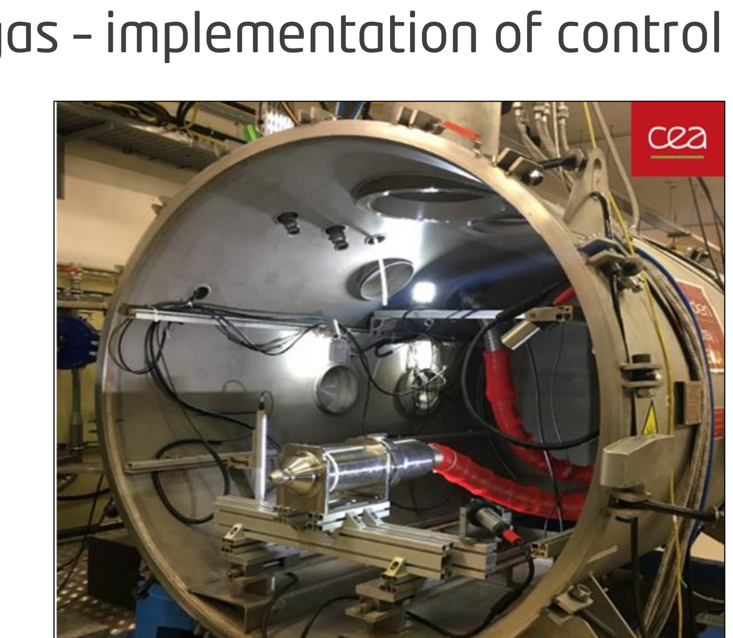
Task 2.2 (IRSN) - Secondary emissions: aerosols (for in air and underwater cutting):

- Definition of measurement needs and identification of aerosol metrology.
- Feasibility of implementation of aerosol sampling close to particle generation (particle size distribution, concentration and sampling for TEM analysis).
- First feedback on aerosol generation during laser cutting using nitrogen vs. compressed air assist gas.

CEA, DELIA Facility, aerosol sampling line

Task 2.3 (CEA) - Hydrogen gas generation during underwater emerging laser cutting:

- Qualification and implementation in DELIA facility of specific instrumentation for real time hydrogen and oxygen gas monitoring.
- Modification of DELIA facility for laser cutting operation using nitrogen assist gas – implementation of control safety measures.



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

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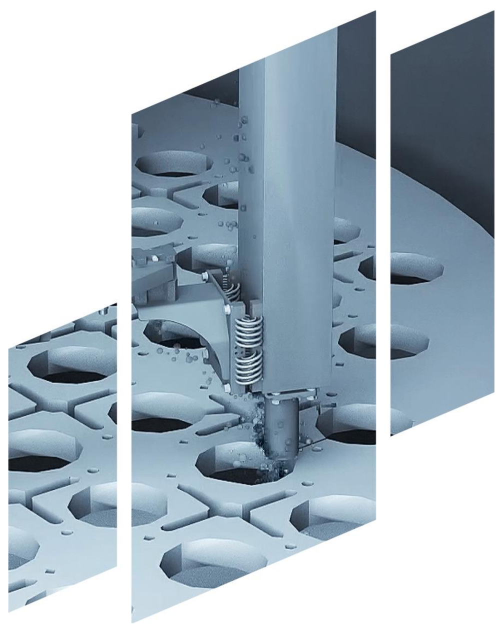

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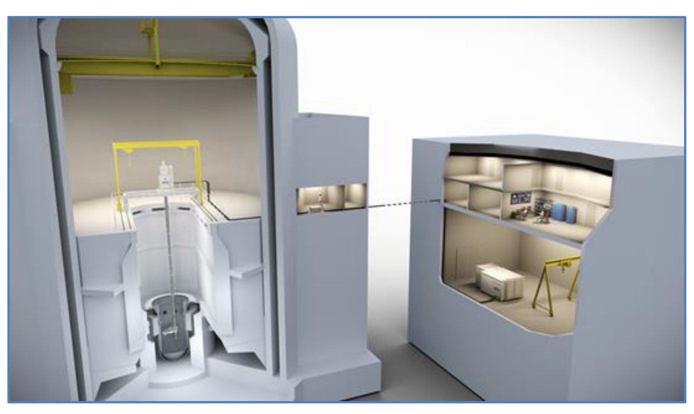
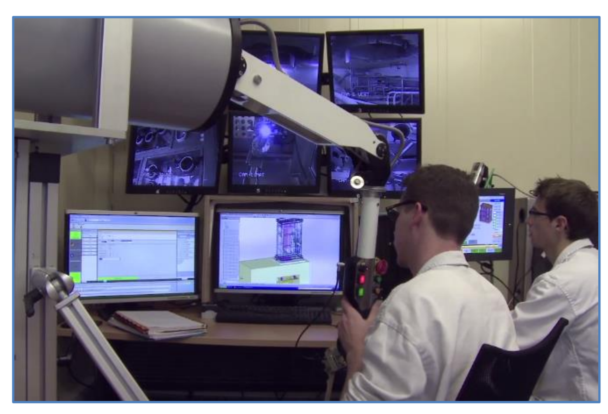




WP Progress

- WP3 – Appraisal of laser cutting technology and definition of qualification activities.
- WP4 – Preliminary risk analysis completion.

Deliverables submitted

ID	Deliverable Title	Lead	Dissemination Level
D3.1	Technology Appraisal Report	VYSUS GROUP	Confidential
D4.1	Risk analysis (summary: main aspects and results)	TECNATOM	Confidential

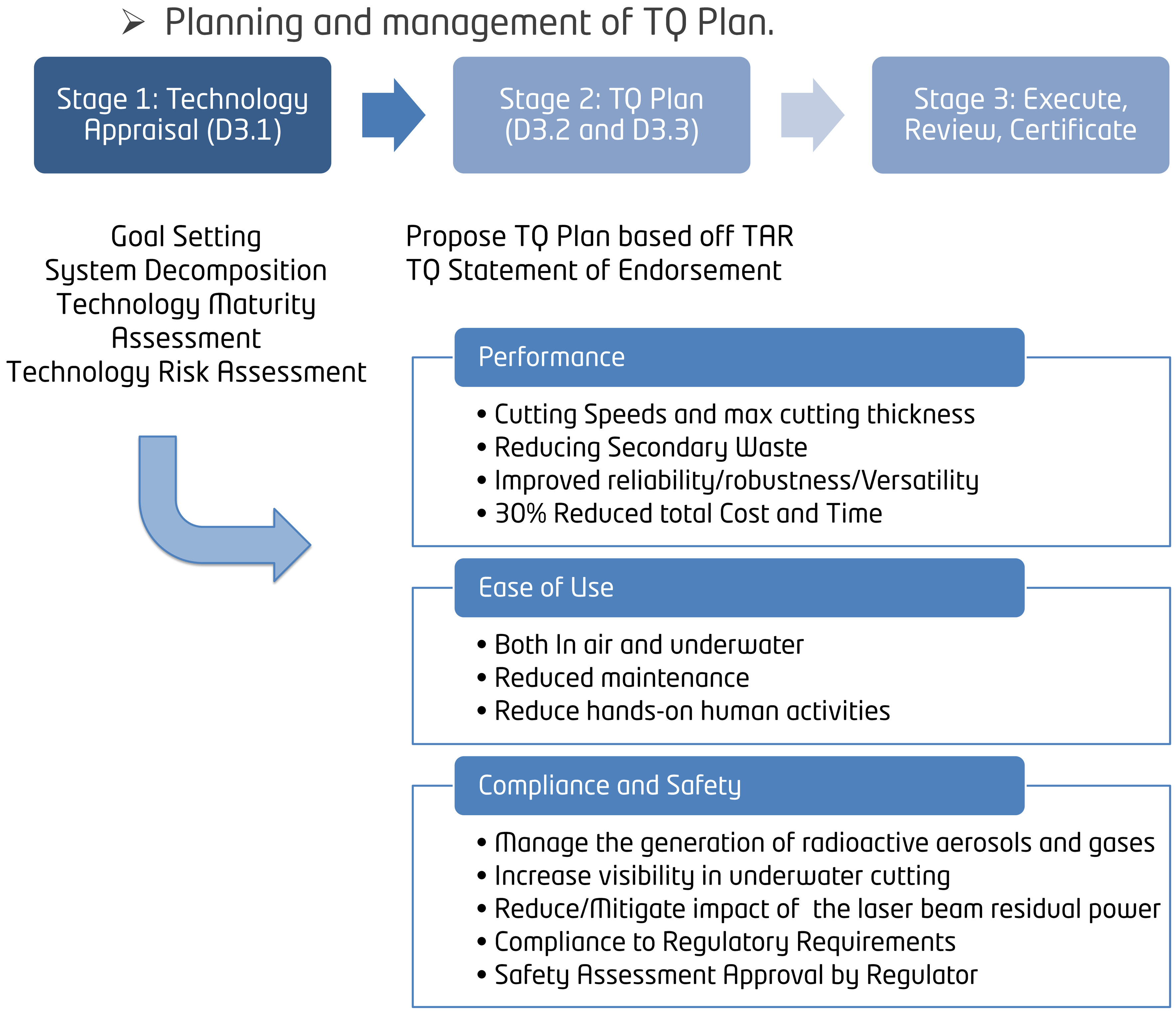
WP3 Progress (leader: VYSUS GROUP)

T3.1 – Technology appraisal:

- Establish the Goals for the Technology to which the Technology Qualification will be assessed against.
- Complete a Technology Qualification Workshop with all partners.
- Redaction of the Technology Appraisal Report 'TAR' (D3.1) which defines:
  - Full system decomposition (main components/subcomponents).
  - Their TML (Technology Maturity Levels) and IML (Integration Maturity Levels).
  - Components experience in Nuclear Decommissioning Environment.
  - Risk Matrix to be used for TQ Plan.

T3.2 – Technology Qualification Plan:

- Defines the tasks to be completed to reduce the technology uncertainties identified in the Technology Appraisal Report.
- Assist in developing the Technology Qualification Plan (D3.2).
- Redaction of the Technology Qualification Plan (D3.2) which:
  - ➢ Summary of technology appraisal stage (Stage 1 of TQ process).
  - ➢ Qualification activities.
  - ➢ Planning and management of TQ Plan.



WP4 Progress (leader: TECNATOM)

T4.1 – Risk analysis with regards to safety:

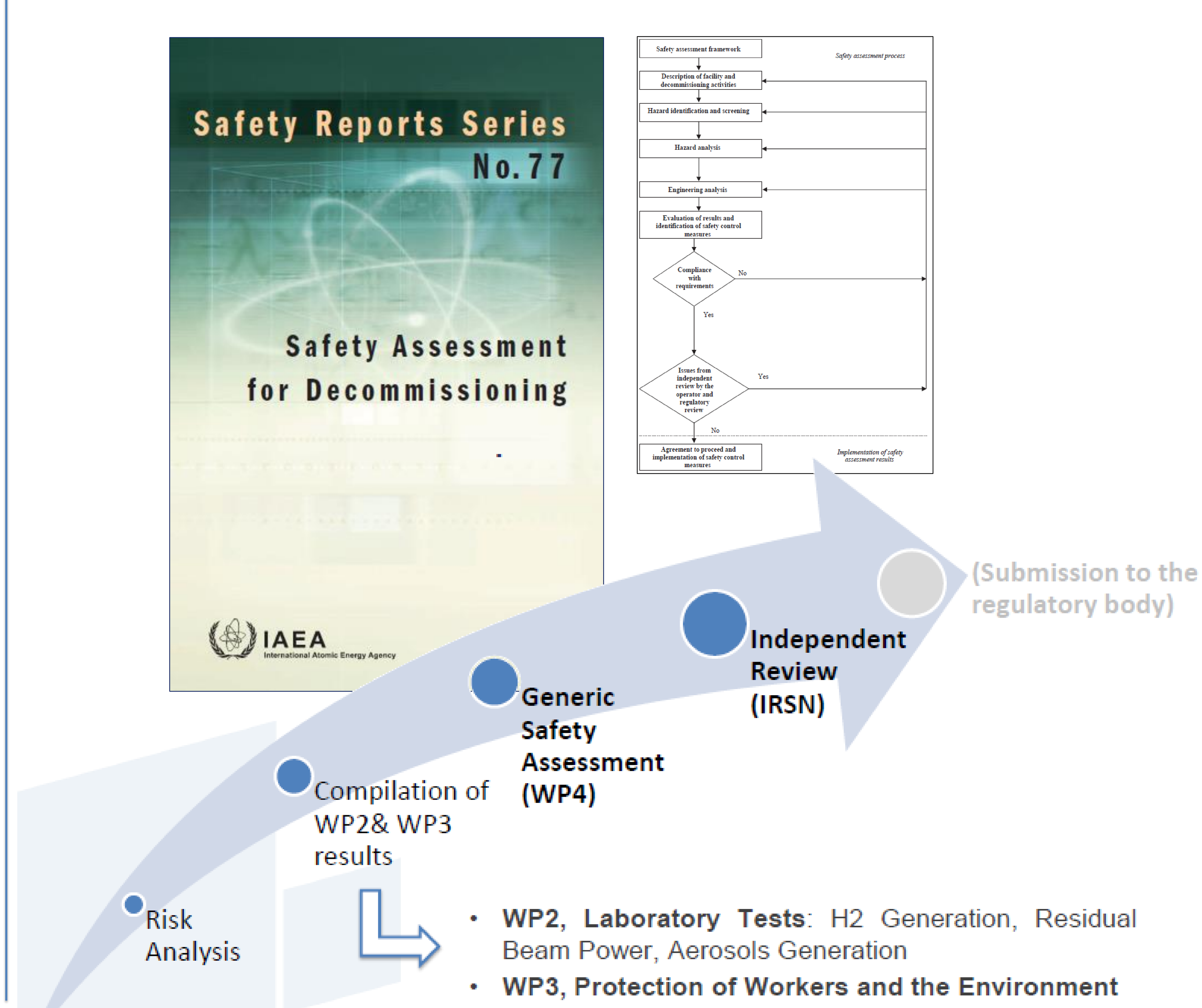
- Benchmarking of risks identified for other RPV/RVI dismantling projects.
- Boundary conditions definition based on WP1 deliverables and international references.
- Submittal of D4.1, Risk Analysis:
  - Identification of risks using IAEA checklists and HAZOP study.
  - Consequences evaluated in a deterministic manner, qualitatively and quantitatively (predefined radiological inventory).
  - Recommendation of design options (for normal conditions) and safety measures (for abnormal/accidental conditions).
  - Risk Matrix.

T4.2 – Compilation of results from WP2 and WP3:

- Start of compilation of information from WP2/WP3 to develop D4.2, Summary of risks identified during WP2 and WP3.

T4.3 – Generic Safety Assessment:

- Development of Generic Safety Assessment Structure, as per IAEA SRS 77, Safety Assessment for Decommissioning.



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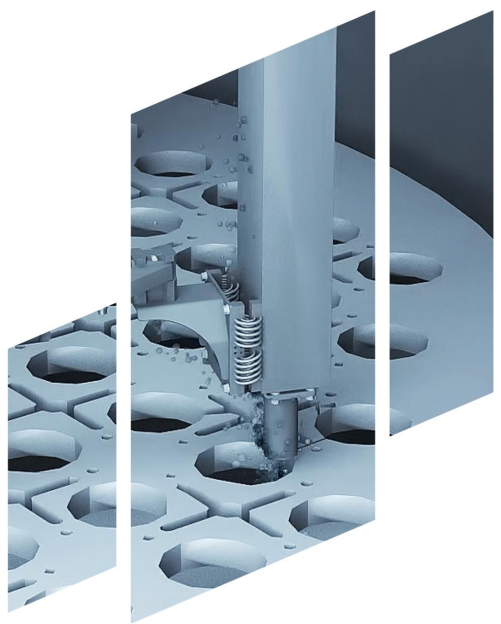

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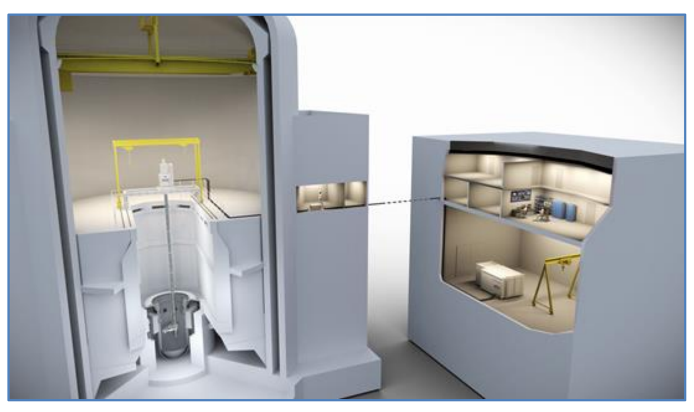

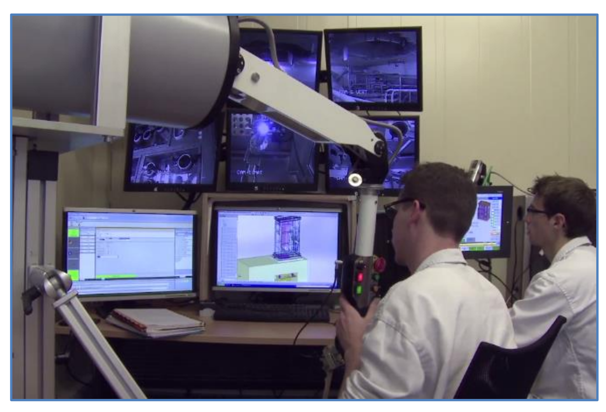

Questionnaires synthesis

- Synthesis of the LD-SAFE questionnaires filled in by the members of the End User Group (Advisory Board) on the basis off Global Questions.

Information

- Questionnaires analyzed: 13.
- Global questions: 13.
- Scope: Reactor Pressure Vessel and its Internals.
- Results indicated: from most to least replied.

Results

Q1: Do you think dismantling RPV/RVI represents a cutting challenge in decommissioning programs?

- Yes: every response indicated that the RPV and RVI represent a cutting challenge during the decommissioning phase.

Q2: Have you ever considered using laser technology for dismantling RPV/RVI?

- Yes and No (evenly split: 50%): responses are split evenly in the consideration of laser technology for dismantling. Analysis of the comments shows that even though there are considerations, there is no actual use of the technology. Problems noted are the problematic use on thick plates and the fact that the technology is still not commercially available.

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?

- 1. Mechanical Cutting
- 2. Thermal Cutting
- 3. Water Jet Cutting

The majority of responses indicate that Mechanical Cutting is the most commonly used technology in the industry followed by Thermal Cutting. Analysis of the comments shows that Sawing, Plasma Arc Cutting and Abrasive Water Injection Jet are the most widely used techniques.

Q4: What is your preferred cutting environment to dismantle RPV/RVI?

- 1. In Air
- 2. Both in Air and Underwater
- 3. Underwater
- 4. Not yet Decided

Responses are mixed showing that the industry dismantles the equipment both in air and underwater and therefore both environments need to be considered. Analysis of the comments shows additional consideration for worker dose rate can be a driving factor in this decision.

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): responses ranged from 2 tools up to a maximum of 10 cutting tools to be used. The common tools listed were band saws, disc saws and drilling tools. No distinction of tools used for RVI and RPV is clearly defined.
- Number of handling systems (crane, manipulator, pole, bespoke mechanical systems, etc.): responses ranged from 1-6 handling systems being used with the most common systems being the polar crane or conventional lifting platforms (various poles and cranes). Bespoke lifting platforms can be used: waste elevator or other mechanical systems including manipulators or robots.
- Number of back-up systems: back-up systems were not foreseen in the majority of responses. However, there are some responses indicating the use of either one or two 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?

- 1. Limitation of radiation exposure
- 2. Minimization of generated waste and discharges
- 3. Reliability and safe maintainability
- 4. Ability to be remotely operated
- 5. Compliance of generated waste with packaging, transport and storage

The majority of responses indicated that the predominant criteria for safety authorities are the considerations for radiation exposure and generation of wastes and discharges. This is further emphasized in the additional comments which indicated that Contamination Control and Risk to Workers are also important criteria.

Q7: What are your main constraints / difficulties in your dismantling activities?

- 1. Radioprotection and safety of the workers
- 2. Accessibility of tools (available area to access the cutting location) and/or handling systems (for cutting)
- 3. Space needed to implement the tools and their utilities in controlled area
- 4. Maintenance and replacement of spare and wear parts
- 5. Filtration of particles / dust and fume collection
- 6. Cutting environment (in air or underwater)
- 7. Control and monitoring of the operations (e.g. moving the system remotely, visualizing the operation, etc.)

The responses showed that there is a large set of constraints to be considered at the same time. The only constraint/difficulty not considered in the answers is the co-activity of workers (considered as low issue during RPV/RVI cutting operations). The most replied answer is that of Radioprotection and Safety of the workers. This feedback further supports the previous information relating to the safety considerations in Q6. Therefore, all of these options selected in Q7 will need to be considered in the future aspects of this project.

Q8: What are the most impactful steps about cost and time?

- 1. Waste management
- 2. Manufacturing/Testing/Operators Training
- 3. Studies/Design/segmentation plan
- 4. Installation/Commissioning
- 5. Maintenance (preventive and corrective)
- 6. Protection of workers / safety aspects

Responses concentrated on Waste Management and the Manufacturing/Testing/Operators Training. The results indicate a spread of costs across all of the listed activities. Analysis of the additional comments shows that the link with stakeholders, especially regulators, is another impactful cost (and time) not previously considered in the questionnaire.

Q9: According to your experience or knowledge, what is the most complex component to cut (for PWR / BWR)?

The responses to this question were extremely diverse with no repetition in the complex components. This shows that there are many different scenarios which will need to be explored in the future stages of the project. A more detailed study of this question will be required to find commonalities in the various cutting tasks.

Unfortunately almost all responses indicated that there are no example data sheets available.

Results:

- Upper reactor internals (generally due to complexity: thick plates, several different tubes, accessibility)
- Guide tubes / Control rods
- Thermal shield
- Barrel
- Lower core plate and plenum
- Lower Core Support Assembly (LCSA)
- Vessel wall

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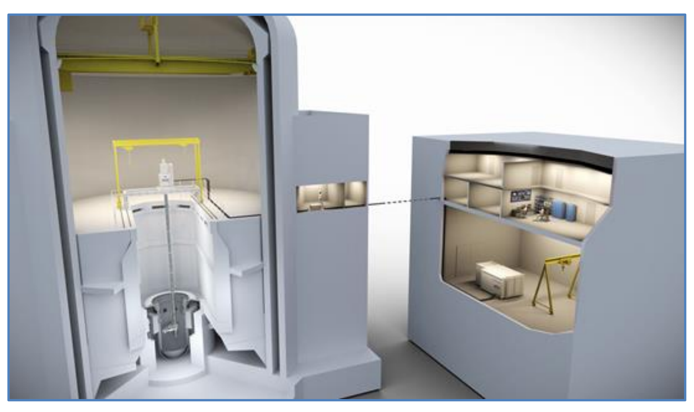

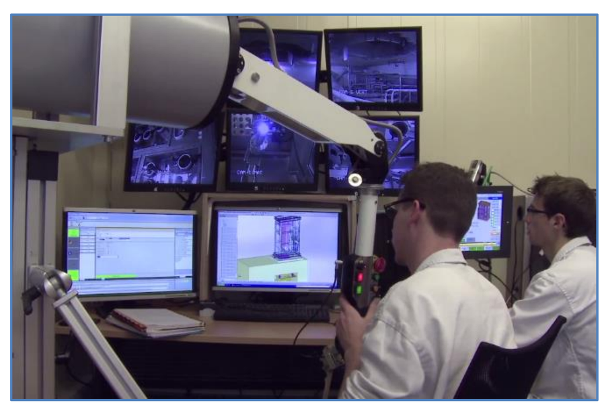

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Results

Q10: According to your experience or knowledge, which steps represent a challenge for reducing dismantling cost?

- 1. Waste characterization and packaging
- 2. Waste logistics (handling, interim storage, transport)
- 3. Operation and Maintenance costs (including consumables)
- 4. Cutting duration
- 5. Corrective maintenance costs (troubleshooting, repairs)
- 6. Implementation of the cutting system (as a whole) / space available
- 7. Human resources
- 8. Drying (of the segmented components)

The most problematic area for reducing the cost of decommissioning activities is the management of waste in its various stages. This further highlights the previous responses to Q8 in which it is stated that waste management is the most impactful cost. The combined result presents an opportunity for laser cutting if it is able to reduce the amount of waste produced and therefore reduce the overall cost of these tasks.

Q11: How do you carry out the secondary waste collection for each cutting technology used (in air and underwater)?

Responses to this question focused on the use of vacuuming for larger waste elements, followed by both air and water filtration systems for the finer pieces of debris.

Results:

- Scraps, Chips/Swarfs, Slags:
  - Underwater pumping + filtration (and shovel-like tool if needed),
  - In-air vacuuming + filtration (and shovel-like tool if needed),
  - The remaining metal swarf is collected by vacuum cleaner and remote handled brush. During cutting local collection is realized by mobile vacuum system,
  - A secondary vacuum system could be considered to remove beforehand (if large particles).
- Aerosols (dust and fumes 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)?

There is a large range in the replies to this question with an outlier of 1:20 ratio of cutting activities to other activities. There are however a group of responses which indicate that this value could be nearer to a 1:1 or 1:3 ratio. A possible reason for the large spread in results could be due to the lack of definition of "Other Activities" and what this actually includes. A more detailed study on this question may be required to find a more complete dataset.

Results (approximately):

- When using band saw:
  a. 10% of the time went to the preparation and clean-up of the yard,
  b. 90% of the time was spent to the cutting operations.
- 1:20 where decontamination, characterization, confirmation and final packaging is taken in to account.
- 40:60.
- Around 50%.
- The cutting phase has an average duration equal or lower than the handling and ILW packages management (characterization, drying, storage, etc.).

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/RPV decommissioning (Type B Packages for ILW waste)?

- 1. Absence of liquid (drying needed)
- 2. No mobile piece/dust
- 3. Each single item must be characterized separately
- 4. No filtering media (other than metal)

The vast majority of the answers show that the requirements for drying are the most common additional limitation which needs to be considered.

Expected improvement with Laser Technology

According to the answers provided to the questionnaire, the following issues are pointed out concerning the expectations of the EUG regarding the use of the Laser Technology:

- Versatility and efficiency of the technology:
  - Different thicknesses easier to cut,
  - Fastening the cutting process / Cutting performances improved.
- Maintenance:
  - No issues with consumables breaking during cuts,
- Flexibility:
  - Only one tool to perform every cut,
- Working environment:
  - Less space required (available area sufficient to access the cutting location).

Difficulties for using laser cutting technology

According to the answers provided to the questionnaire, the following issues are pointed out concerning the difficulties of the EUG regarding the use of the Laser Technology:

- Deployment and management of laser cutting at distances of up to 30m below the equipment location, management of the fiber and air, electrical requirements to the head through a number of mechanical systems.
- Licensing process: innovative technology will make it challenging to get permission from safety authorities. A reference case with the use of laser cutting technology or a former experience will help safety authorities in giving permission.

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

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