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Deliverable

D2.1 – Requirements Data Collecting and Oil&Gas Demo Case Process Design

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Executive Summary

This deliverable outlines the requirements to implement the Oil&Gas demo case of the R3-Mydas project, focusing on the current state (**As-Is**) and the target objectives (**To-Be**). The **As-Is** scenario describes the existing processes, systems, and challenges, while the **To-Be** scenario defines the desired improvements and goals to optimize performance and efficiency.

Additionally, we summarize the key data involved, including sources, types, and their relevance to achieving the project objectives. This data will guide the execution of the use case and ensure alignment with project goals.

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Definitions, Acronyms and Abbreviations

Acronym/ Abbreviation	Title
AM	Advanced Mechatronics
CAD	Computer-aided design
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
LCI	Life Cycle Inventory
MAG	Metal Active Gas
MIG	Metal Inert Gas
ML	Machine learning
SSH	Social Sciences and Humanities
SbD	Sustainability by Design
s-LCA	Social Life Cycle Assessment
TAM	Technology Acceptance Model
TIG	Tungsten Inert Gas
UTAUT	Unified Theory of Acceptance and Use of Technology

1 Introduction

1.1 Project Information

Despite the multiple advantages of products remanufacturing, being widely recognised as an effective means for transitioning to a more circular economy, there is still need for improved research and experimental observations, to improve traceability and reliability of the final products from end-users' perspectives, as well as enhanced impacts monitoring.

The primary R3-Mydas objective is to develop a multi-actor framework, integrating innovative digital technologies (ML for process and quality control, marketplace, graph models for defects detection, digital twins), advanced mechatronics (AM, laser-cladding, automated disassembly/reassembly) and newly developed approaches from SSH (extended TAM/UTAUT models, ethics and legal framework), for functionally, environmentally and economically sustainable circular value chains for remanufacturing of energy goods at the factory level (Oil & Gas crankshafts – demo 1, E-vehicles batteries – demo 2, Wind turbines gearboxes – demo 3).

R3-Mydas will deliver unprecedented impacts throughout the targeted value chains, as follows:

- up to 60% time reduction in programming for remanufacturing; up to 20% increased product quality; up to 30% rework reduction [Demo 1];
- up to 30% improved detection of tiny deviations from normal behaviour; up to 50% faster anomaly localization; up to 30% increase the number of different modality data streams handled; up to 20% faster fusion process [Demo 2];
- up to 99% reusage rate; -90% prevention rate; -75% lead time; up to 85% raw material savings potential [Demo 3].
- R3-Mydas will deliver a marketplace associating to each remanufactured product or services/component for remanufacturing a Digital Passport-like set of information, ensuring full traceability. Finally, a dedicated training programme will be designed and delivered by EITM, targeting the R3-Mydas project remanufacturing value chains (100+ training hours and 100+ diverse stakeholders engaged during the Project).

R3-Mydas will deliver a marketplace for buying/selling the remanufactured products and components/services for remanufacturing, including advanced blockchain technologies. To ensure full traceability, each remanufactured product or service/component for remanufacturing will have a Digital Passport-like set of information.

Also, a dedicated training programme will be designed and delivered, targeting the R3-Mydas project remanufacturing value chains, to result in 100+ training hours and 100+ diverse stakeholders engaged during the project.

The partners in Table 1 are part of the R3-Mydas consortium.

Table 1: The R3-Mydas consortium.

Number[1]	**Name**	**Country**	**Short name**
1 (CO)	NETCOMPANY-INTRASOFT SA	Luxemburg	NCI
2	EUROPEAN FEDERATION FOR WELDING JOINING AND CUTTING	Belgium	EWF
3	EIT MANUFACTURING SOUTH SRL	Italy	EITM
4	FLENDER FINLAND OY	Finland	FLE-FI
4.1 (AE)	FLENDER GMBH	Germany	FLE
5	AVL LIST GMBH	Austria	AVL
6	TALLERES MECANICOS COMAS SLU	Spain	TMCOMAS
7	SPIN ROBOTICS IVS	Denmark	SPIN
8	ASOCIACION DE INVESTIGACION METALURGICA DEL NOROESTE	Spain	AIMEN
9	LAPPEENRANNAN-LAHDEN TEKNILLINEN YLIOPISTO LUT	Finland	LUT
10	INFORMATION TECHNOLOGY FOR MARKET LEADERSHIP	Greece	ITML
11	DEEP BLUE SRL	Italy	DBL
12	CHAROKOPEIO PANEPISTIMIO	Greece	HUA
13	IKERLAN S. COOP	Spain	Ikerlan
14	ZIKNES TECHNOLOGY SL	Spain	Ziknes
15 (AP)	CSEM CENTRE SUISSE D'ELECTRONIQUE ET DE MICROTECHNIQUE SA - RECHERCHE ET DEVELOPPEMENT	Switzerland	CSEM

1.2 Document Scope

The objective of this deliverable is to provide a detailed description of the Use Case in two scenarios: the current scenario (As-Is) and the target scenario (To-Be). This analysis will serve as foundation to understand the improvements that are planned to be implemented within the project and how they will impact the processes, technologies and workflows involved.

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[1] CO: Coordinator. AE: Affiliated Entity. AP: Associated Partner.

In the As-Is scenario, the current state will be described, highlighting the technologies, methodologies and limitations presented in the existing system. In contrasts, the To-Be scenario will outline the envisioned future state, emphasizing the expected enhancements and new capabilities.

The deliverable will also provide detailed information regarding the types of data that will serve as input to the subsequent tasks and work packages (WP´s). These data sources, critical for achieving the project´s goals, will be identified and analysed. Additionally, a comparison between the current and target states will be presented, emphasizing the key differences and the expected improvements in performance, quality, and efficiency. This will ensure a clear understanding of how the transition from the current to the target scenario will support the overall objectives of the project.

1.3 Relation to other Tasks and Work Packages

WP2 focuses on the automation of the cladding process, which is instrumental for achieving the overall objectives of the project. Its activities are closely interconnected with WP5 and WP6, as detailed below.

Collaboration with WP5

WP2 provides critical data regarding the automated cladding process to WP5, enabling the evaluation of environmental and socio-economic impacts. Specifically, the data includes process parameters and metrics that contribute to assessing:

- Greenhouse gas emissions (GHG): Insights into how the automated cladding process reduces emissions compared to traditional methods.
- Reduction of harmful substances: Analysis of improvements in material usage and waste minimization.
- Cost efficiency: Evaluation of potential reductions in final product costs over the entire lifecycle, driven by automation and process optimization.

This information is essential for WP5 to quantify the benefits and support the development of sustainable remanufacturing technologies.

Collaboration with WP6

WP2 serves as a foundational source of data for WP6 to develop predictive quality control models. By systematically logging parameters and performance metrics from the automated cladding process, WP2 ensures the availability of reliable datasets. These datasets are used in WP6 to:

- Train a Machine Learning (ML) pipeline, which forms the basis for a constrained Reinforcement Learning (RL) algorithm.
- Improve process control and predict quality outcomes, ensuring that automation contributes to consistent and reliable remanufacturing results.

The synergy between WP2, WP5, and WP6 highlights the integrated approach of the project, ensuring technological advancements in automation are aligned with sustainability and quality control objectives.

1.4 Document Structure

This document is comprised of the following chapters:

Chapter 1 presents an introduction to the project, the document objectives and structure.

Chapter 2 describes the demo case, including as-is and to-be scenarios.

Chapter 3 covers the relevant data being collected.

Chapter 4 provides the process workflow for the demo case implementation.

Chapter 5 lists the relevant KPIs.

Chapter 6 provides concluding remarks.

2 Demo Case Description

2.1 Target Application Description

The target scenario aims to innovate beyond the current state-of-the-art in the remanufacturing of damaged crankshaft components by applying a digital-based procedure for laser-cladding process planning. The focus is to improve the restoration process of end-of-life crankshaft components by leveraging advanced technologies such as reverse engineering, 3D scanning, and CAD design, enabling more precise, cost-effective, and environmentally sustainable remanufacturing.

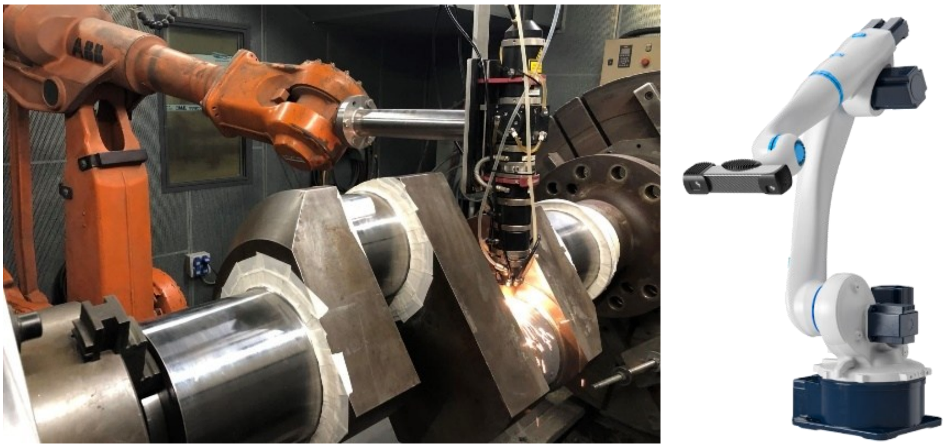


Figure 1: TMCOMAS Robot CELL and scanning robot example.

In the target application, the damaged or worn-out areas of the crankshaft will first be scanned, after a first surface modification, to create a detailed 3D model of the affected zone. This model will serve as the foundation for the design of the clad layer, which will be deposited precisely along the damaged areas using laser cladding. This digital workflow will optimize the process of remanufacturing, reducing time and cost by eliminating the need for extensive post-processing and minimizing the risk of deformation or metallurgical damage commonly associated with traditional methods like arc welding (TIG/MIG/MAG).

The CAD model generated from the 3D scan will allow for accurate path planning of the laser deposition, ensuring high spatial resolution and the precise application of the clad material. Using a developed software, data generated from the scanning stage will be used to generate a robot program with the deposition pattern. This robot movement file will include all the collision restrictions, cladding head tilting restrictions and, the number of layers to be cladded to achieve final dimensions. Thanks to the work done during the project, the limitations of the cladding head as regards the quality of the cladding layer will be input in the programming software too.

This digital-driven remanufacturing strategy not only enhances the quality and reliability of the refurbished crankshaft but also significantly reduces environmental impact by avoiding manufacture new crankshafts.

2.2 As-Is Scenario

The current setup for the repair process in the Oil & Gas industry use case consists of a standard cladding system, which includes a robot, a laser head, a powder feeder, and a laser source with its peripherals. The TMCOMAS lay-out are shown in Figure 2.

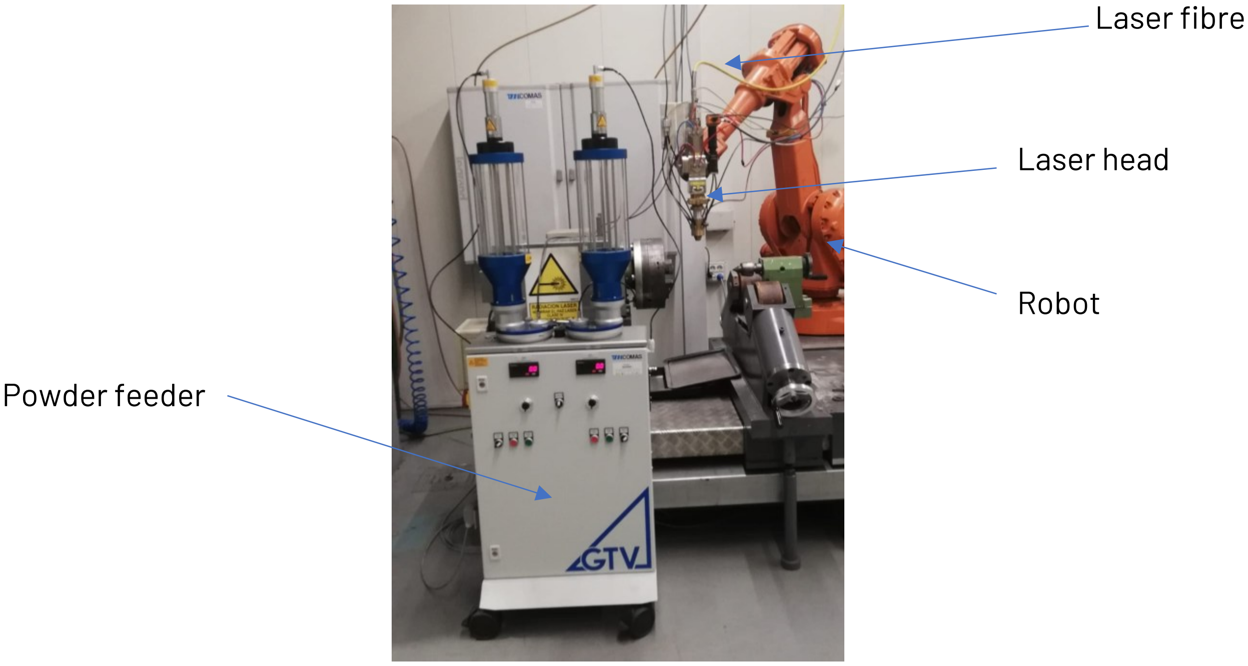


Figure 2: TMCOMAS Lay-out.

The robot is responsible for performing the repair of the component in an automated manner, requiring pre-programming to define the movements it needs to execute. To achieve this correctly, the robot operates in conjunction with an external single-axis positioner (turntable) that allows the laser head to work perpendicularly to the surface. Without this turntable, the repair process would not be possible.

The powder feeder is responsible for directing the powder from a hopper to the work point. It is important to note that the powder flow must be proportional to the other manufacturing parameters, and it is a key parameter to consider during cladding process optimization.

As for the laser equipment, we have the laser head, the laser source, and the optical fiber. The laser source generates the laser beam needed to melt both the substrate and the supplied material at the work point. The laser beam is transmitted to the laser head via the optical fiber, which influences the geometry of the laser beam. Finally, the laser head collimates and focuses the laser beam onto a specific point called the "spot." This head is responsible for positioning both the powder and the focused laser beam at the same spot for proper material melting and subsequent formation of the weld bead.

Due to the complexity of the parts that need repair in this sector (crankshafts), the operator uses two different laser heads (Figure 3), depending on the accessibility of the component. The first is a coaxial head with a multi-stream nozzle (6 streams). This nozzle is positioned approximately 20 mm away from the part to be repaired (Figure 3, left). For narrow geometries, a lateral feed head is used (Figure 3, right), with de same optical system but a different configuration, avoiding collision issues.

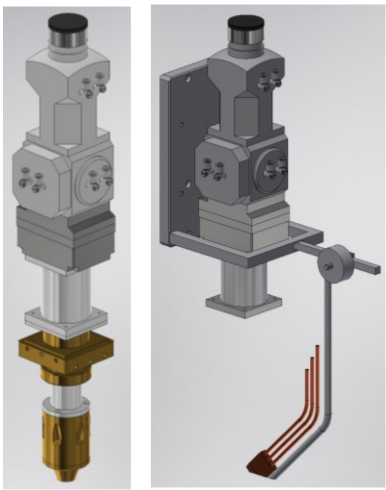
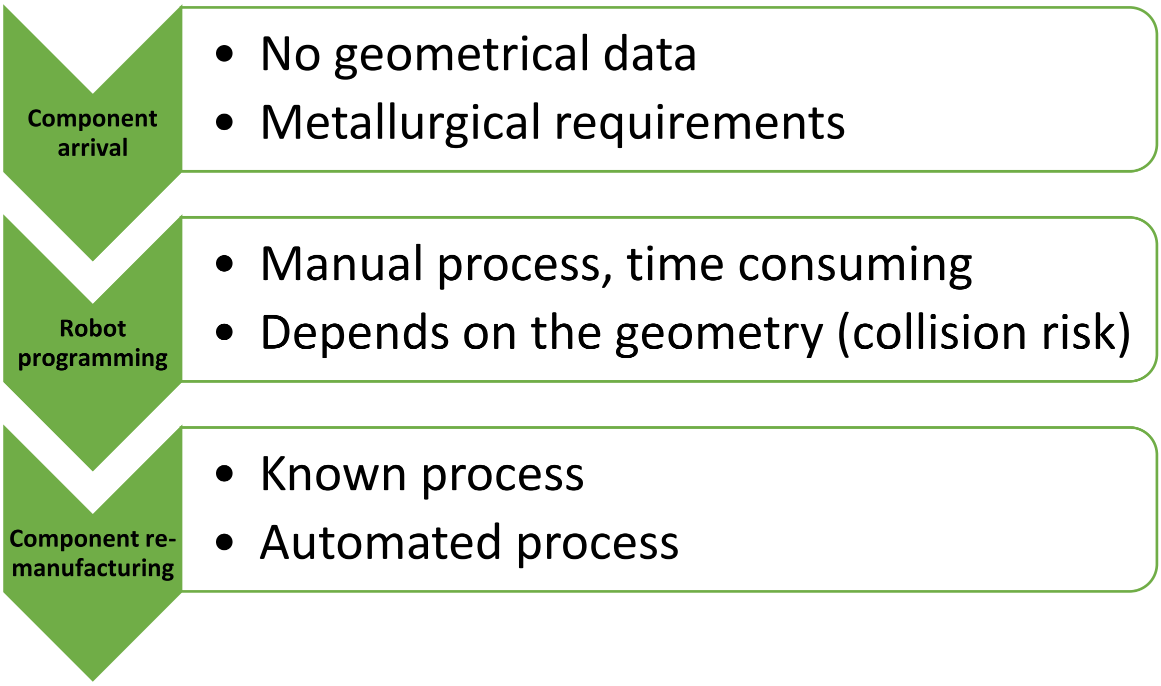


Figure 3. TMCOMAS laser heads.

Having described the necessary equipment for component repair via laser cladding in the Oil & Gas sector, the next step is to outline the workflow for carrying out the repair.



Component arrival

- No geometrical data
- Metallurgical requirements

Robot programming

- Manual process, time consuming
- Depends on the geometry (collision risk)

Component re-manufacturing

- Known process
- Automated process

In the first stage, the component arrives along with the specifications required for the repaired piece, that are the final dimension needed, material specification and delivery time needed.

In the second stage, the robot is programmed manually to prepare for the repair using laser cladding. The challenge here is that the repair process for these components is unique every time as TMCOMAS business is focused on repair not serial production. Thus, each repair requires new programming. Additionally, the fact that the components often lack a common axis of revolution or consistent dimensions makes the programming process long and tedious. Finally, in the third stage, the cladding process is executed. This process is well-known to the end user, and the materials typically used are familiar but at the same time, particular geometry and cladding head position are critical to avoid defects in the repaired part. This stage does not present as many challenges as the previous one, but it can be considered as the most important one.

The challenges faced in the current scenario stem from the lack of automation, primarily due to the absence of advanced digital tools in the process. As previously mentioned, the repair of these components is highly individualized, requiring a highly customizable approach that must adapt to varying geometries. This results in time-consuming and labour-intensive programming efforts, as each repair must be uniquely tailored. The lack of digital integration not only hampers efficiency but also increases the likelihood of errors, making it difficult to achieve the precision and repeatability needed for high-quality repairs.

2.3 To-Be scenario

The envisioned scenario aims to overcome the challenges of the current state by automating the robot programming process through the integration of optical sensors directly into the robotic system. This technological advancement will streamline the repair process, significantly reducing the manual labour and time required for programming and improving overall precision and efficiency.

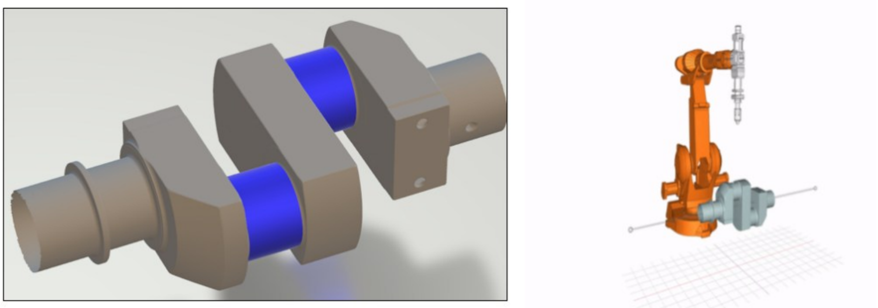


Figure 4: Cladding surfaces and virtual cell respectively.

The main innovation involves the use of onboard sensors attached to the robot, specifically a Photoneo snapshot camera or a 3D scanner. These sensors will enable the robot to autonomously generate scan paths based on basic operator inputs. The system will automatically scan the worn component to create a detailed digital model of the damaged area. This digital model will serve as the foundation for the subsequent repair strategy.

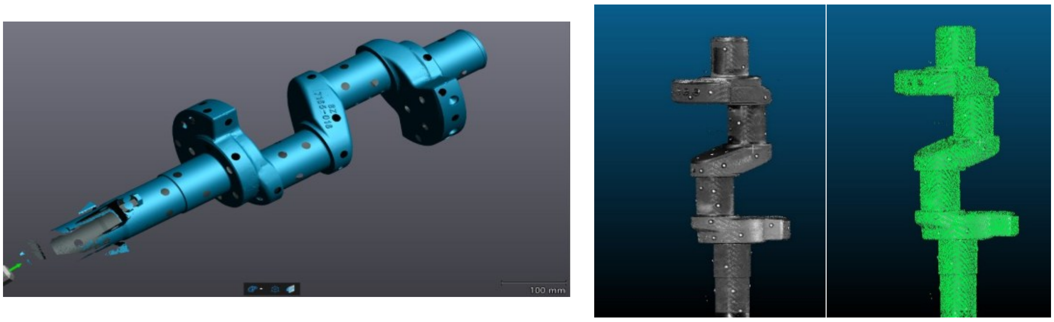


Figure 5: Scanned crankshaft using different methods.

Once the 3D model is generated, specialized robot simulation software will be used to design the repair strategies. This software will consider the geometry of the component and the accessibility of the laser heads to ensure precise cladding deposition. It will allow for accurate path planning and ensure that the selected repair approach is tailored to the specific component geometry, while avoiding potential collisions or accessibility issues that might arise with complex shapes.

By automating the programming of the robot and integrating real-time digital modelling into the workflow, this scenario ensures a faster, more reliable, and highly customizable repair process. This not only improves the overall quality and repeatability of the repairs but also enhances the sustainability and efficiency of the process by minimizing the need for manual interventions.

To study better the TO-BE scenario and have a clearer picture of it, a series of user research activities have been performed. With specific online meetings and one on-field visit (on 2nd of July 2024), data was collected by DBL: interviews with TMCOMAS representatives and operators and observations were conducted. This activity focused on clarifying the overall future task that will be implemented, the roles involved, the main points of interaction between users and the technologies under development, and the gap within the current AS-IS scenario and the TO-BE scenario.

Through the analysis of the data collected has been created a description of the TO-BE scenario using the User Task Matrix tool (see Appendix A). The User Task Matrix is a visual tool, often implemented as a Microsoft Excel table, mapping different use roles (e.g., Laser operator, Grinder, Inspector, Technician) considering the various tasks they would perform within the envisioned scenario. This tool provides a deeper understanding of the way users interact with other actors during the tasks, both technological (e.g., IT system, AI, robots) but also organisational (e.g., procedures). It describes the actors by identifying who performs each task (operator, robot, etc.), the communication between them, the frequency of the task, possible criticality, and working conditions (specific environmental factors and need for personal protective equipment).

The User Task Matrix highlighted the main differences between the AS-IS and TO-BE scenario, making possible to identify some main points of attention. The first one is related to the new task that will be performed by the robot, together with the operator: the 3D scanning of the crankshaft. The software that will be developed must consider the usability for the laser operator, who is not skilled in 3D scanning procedures. The system and the interface should be designed to support the operator work and make it possible for him to perform and supervise the 3D scanning in the most efficient and reliable way. Considering the complexity of 3D scanning, and of understanding the results from 3D scan operations, it would be necessary to have a software able to automate most of it, giving to the operator the ability to supervise the procedure and intervene if some kind of error happen.

Another important change will be about the programming of the robot for the laser cladding operation, now the procedure is performed almost manually, what will happen in the TO-BE scenario will be the use of the 3D scan for programming the robot. Also in this case, the operator should use a software which allows him to perform his task in a simple way. The automation of this task will support a decrease of the time spent by the operator programming the robot, making possible to optimize the procedure and reduce the time of the overall cladding task. The software for the robot programming should guide the operator, giving feedback about the different steps, and support him in giving the needed input for completing the setup of the robot.

In this scenario, it will be needed to consider the possible troubleshooting procedures in case of errors and problems with the software and the robot. The operator should receive specific training and information about how to intervene in case of errors.

3 Data Collecting

In the To-Be scenario, data collection is a critical component to ensure quality, traceability, and process optimization. For this reason, data was collected to provide high quality information of As-Is scenario. The next step will be to analyse the effect of R3-MYDAS solution in this data. The collected data can be categorized into three main types: physical data, digital data and sustainable data.

3.1 Physical Data

Physical data include mainly information regarding the physical lay-out and all information related to the equipment and the process. In the As-Is scenario, a robot is used with two external axes, one workpiece positioner and one-track positioner. In the following Table 2 we consider all the peripheral devices and software needed to perform the cladding process.

Table 2: Layout and process data.

Parameters	Description	Data
Robot cell	This includes the robot information.	**Robot**: ABB IRB 2600 **Gear Unit**: ABB MTD 750 **Encoder**: HM10 Devicenet, driver PLC fagor **Signals**: Set hopper, Set laser preparation, Set laser, Set lathe chuck, external axes (gear unit and track synchronism control).
Laser	Information related to laser machine	**IPG fiber YLS-6400-S4** **Max power** 6 kW **Wavelength**: 1070 nm **Fiber**: 1000 µm
Powder feeder	Powder delivery device	**Feed rate**: 10-150 g/min Two hoopers
Pre-heating	Yes/No	Temperature
Laser Head	Information about different laser head´s	**Coaxial cladding head**: 6 powder jets, working distance 25mm, coaxial feeding. **Lateral cladding head**: 1 single powder jet: working distance 255mm
Process parameters	Laser cladding process parameters window	Power, Speed, Laser spot, Beam shape, Powder flow and gas flow
Materials	Base material and powder	Steel F114 (C45 according to UNE-EN ISO 683-2:2019)/ Stellite 21

3.2 Digital Data

In this project, digital data plays a central role in achieving the digitalization and automation of the crankshaft repair process. The approach integrates advanced thermal sensing and data processing techniques to ensure precision and efficiency.

3.2.1 3D Scanning and Point Cloud Generation

The crankshaft will be scanned using a high-resolution 3D camera/ scanner to generate a point cloud. Here AIMEN is developing their own software to reconstruct a full point cloud matching snapshots from different points. This point cloud serves as the digital representation of the component's geometry and condition that until now they had no way to do that. The data will then be processed to:

- Optimize the geometry by removing noise and refining the cloud. In that stage, after the captures, some algorithms of filtering, remeshing and smoothing will be carried out to obtain a good point cloud.
- Generate a mesh that accurately represents the crankshaft's structure, providing a foundation for downstream processes such as automated path planning for the cladding operation, decreasing notably the programming time.

3.2.2 Thermal Data Acquisition

To monitor and control the repair process, thermal data will be captured using thermal cameras and thermocouples. These sensors will provide real-time temperature measurements during the cladding process. This data will be essential for:

- Feeding simulation models to predict thermal behaviour and material response.
- Enhancing Machine Learning models, which will leverage thermal data to optimize process parameters and improve quality control through predictive analytics.
- The combination of geometric and thermal data ensures a comprehensive digital framework, enabling the automation and optimization of the crankshaft repair process while supporting advanced simulation and machine learning applications.

3.3 Sustainable Data

During R3-MYDAS is important to ensure lasting impact to perform a Sustainability by Design (SbD) assessment (Task T5.2) on the new circular value chains. The SbD assessment includes:

- Environmental dimension: It will consist of a Life Cycle Assessment (LCA) of the proposed remanufacturing process for the three demo cases, including the Carbon Footprint as one of the environmental impact outcomes. The ISO 14040 series of guidelines for LCA are followed.

- Socio-economic dimensions: This consist of a Life Cycle Cost (LCC) assessment to ensure that new remanufacturing processes are economically viable, but also a Social Life Cycle Assessment (s-LCA) to identify potential social issues of the new circular value chains.

Figure 6 shows the new circular value chain for the oil-gas sector. Rather than relying on a traditional linear value chain (in black), where when a component fails, such as a crankshaft from an industrial pump or blower, the only option is disposal, R3-MYDAS will allow the component to be repaired at the end-of-life of the equipment, but also during maintenance operations during the use phase. This remanufacturing process will reintroduce the component into the value chain during the assembly or manufacturing phase of pump/blower. In this way, it is possible to achieve a more circular scheme (in green).

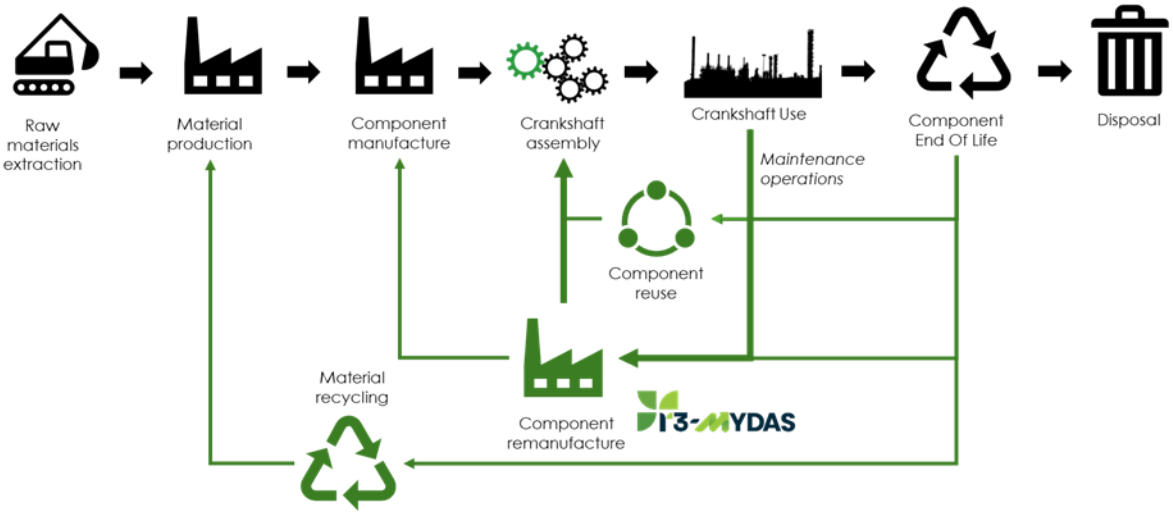


Figure 6: Circular value chain for Oil-gas component.

The ISO 14040[2] series of guidelines for LCA will be followed (Figure 7). This methodology consists in different steps, one of the main important are the Life Cycle Inventory (LCI), where data from system to assessment are gathered.

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[2] ISO 14040:2006. Environmental management — Life cycle assessment — Principles and framework.

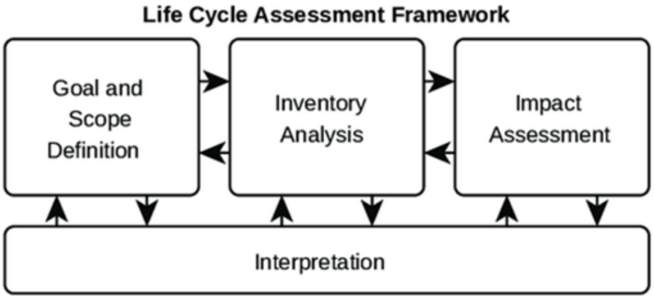

Figure 7: ISO14040 scheme for LCA.

For Demo-case 1, a "one crankshaft to be repair" was defined as Functional unit. Therefore, data was collected considering this reference. A summary of the sustainability assessment data (LCI) from AS-IS Scenario is show in the next tables below and includes, input materials, energy, waste generated, operational time, equipment description and cost.

Table 3: Input materials.

Phase description	***Material name***	***Amount required in the process phase (Kg)***	***Component cost (€/kg)***
Pre-GRINDING	F114 Steel	160.2	0.9
CLADDING	Stellite 21	3	50
Protective Gas	Argon	240	0.11

Table 4: Waste generated.

Waste Name	***Description***	***Waste yield in the process [kg]***	***Waste treatment /disposal cost [€/kg]***
Powder	Stellite 21	0.6	0.15
Metal shavings	F114 + Stellite 21	0.14	0.15

Table 5: Equipment description data.

Equipment	***Brand, model***	***Operation time [h/kg]***	***Energy consumption [kWh/kg]***	***Equipment cost [€]***	***Equipment Lifetime (years)***
Powder feeder	GTV-PF-2/2LC	0.74	0.4	22,000 €	9
Laser	IPG YLS-6000-S4	0.74	13.5	73,000 €	5
Grinding machine	ROBBI REX 2200-L	-	10.0	35,000 €	5
Anthropomorphic robot	ABB IRB-2400	0.74	2.2	23,000 €	5

Improvements in operational time, energy and material efficiency are expected over the course of the project, and these data will be reviewed for further analysis as the project progresses.

4 Process Design

The process workflow for the automated crankshaft repair (DEMO CASE 1) is illustrated in the provided diagram (Figure 8) and consists of the following stages:

4.1 Input Requirements and Component Scanning

- Inputs: The workflow begins with defining the client's dimensional, tolerance and materials requirements for the crankshaft.
- Sensor Integration: A 3D camera or ·3D scanner integrated with the robot scans the crankshaft, generating a point cloud that digitally represents the component.

4.2 Point Cloud Processing

Data from sensors undergoes transformation and alignment to ensure accuracy.

The reconstructed point cloud is further processed to improve its quality and prepare it for subsequent steps. This includes the application of advanced algorithms for:

- Refinement**:** Enhancing the resolution and detail of the point cloud to better capture geometric features.
- Filtering**:** Removing noise and outliers from the data to ensure reliability.
- Smoothing**:** Applying smoothing techniques to create a more uniform and accurate representation of the crankshaft's surface.

Once processed, the final point cloud is used as input for generating a CAD model, which serves as the basis for the remanufacturing strategy. The needed areas are identified as surfaces to use them as base for cladding process.

The CAD file supports the development of the remanufacturing protocol, detailing repair strategies for the robot in an automated manner, avoiding spending time on manual robot programming.

4.3 Process Development and Virtual Cell

The process development stage focus on optimizing the cladding process. This is achieved through a combination of simulation-based trials and physical mock-ups. Simulation allows for the evaluation of different process parameters and their impact on the thermal stresses and distortion.

Meanwhile, mock-ups provide practical insights into the process, allowing a deep understanding of process parameters in the final cladded material. The goals of this stage are: 1) to minimize the environmental impact of the repair process (e.g., reducing energy consumption and waste) and 2) ensure repaired crankshaft achieves the required mechanical and geometrical properties.

Parallel to process development a virtual cell is created to act as a digital twin of the physical repair environment. This virtual cell replicates all components and interactions within the real system, providing a powerful tool for validating and optimizing the process. One key advantage of the virtual cell is its ability to conduct collision simulations, where the robot movements and tool paths are tested digitally. This significantly reduces the time and effort required compared to traditional physical testing.

4.4 Integration, Testing, and Validation

After process development, the workflow advances to integration and testing of the automated solution. The final step is the validation of the repair process on a full-size crankshaft component, ensuring compliance with all technical and operational requirements.

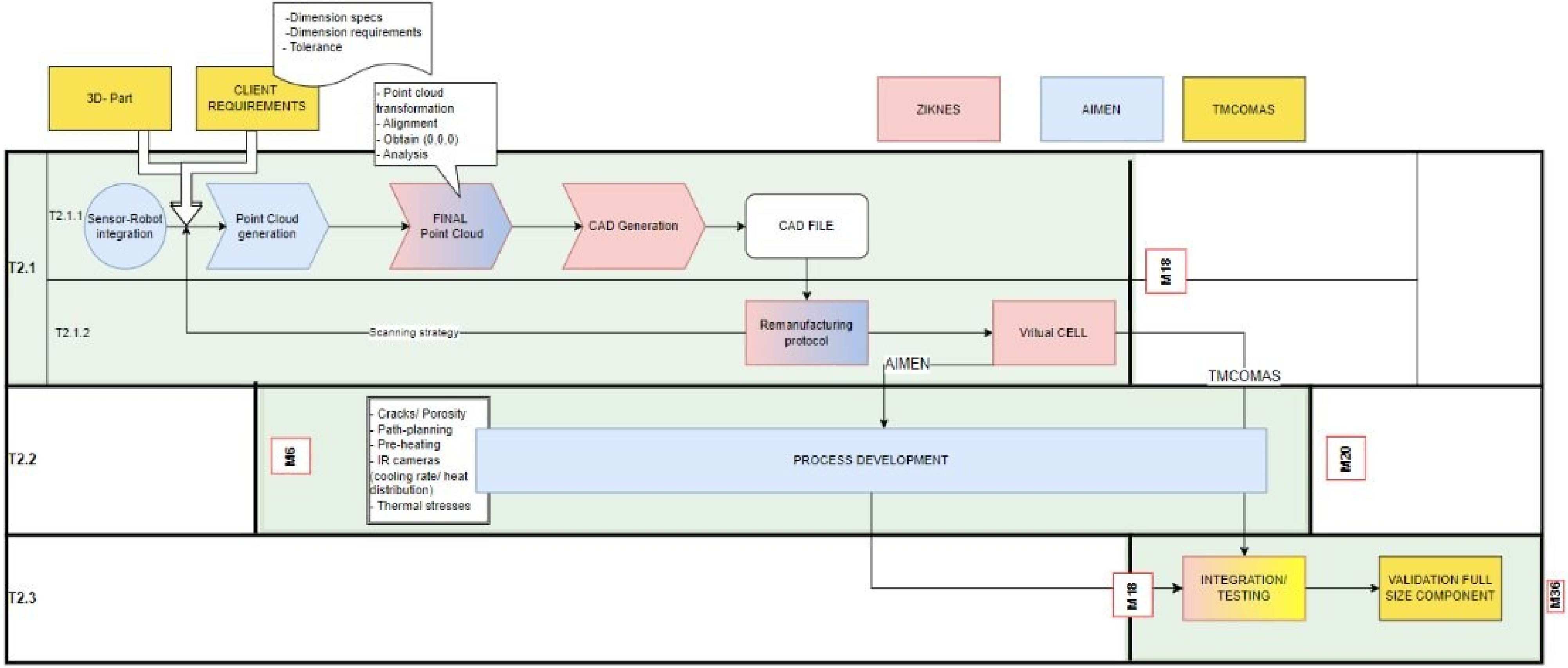

Figure 8: Workflow diagram.

5 Key Performance Indicators

To ensure the project´s success and objectively evaluate the impact of our technological solution, we already have defined a set of key performance indicators (KPIs) in the proposal. These indicators will enable us to measure progress in critical aspects of the process and verify compliance with the goals outlined in the target scenario. Furthermore, the selected KPIs are directly aligned with the areas where our technology adds the most value, ensuring a focus on continuous improvement and maximizing outcomes.

Table 6: Description of KPIs.

ID	Description	MYDAS solution
KPI-R1-1	Worktime spent in laser cladding programming for remanufacturing of crankshaft due to automated path-planning	Will improve the programming time by 60% due to process automation.
KPI-R1-2	Number of cracks, porosity and lack of fusion during laser-cladding	Process parameters will be optimised in order to reduce defects and avoid reprocesses.
KPI-R1-3	Rework time	Scanning and automation will improve machining and cladding times.
KPI-R1-4	Cost of repair over market price for remanufacturing	Reduction in programming time and reduction of material losses.

6 Conclusions

The project is built on a solid foundation, with clear definitions of both the current and target scenarios, helping us understand the challenges and goals. The workflow is well-organized, making it easier to execute tasks efficiently. We've also clearly identified the available data and future data needs, which will help us make data-driven decisions. Lastly, the defined KPIs will allow us to consistently track the project's goals and ensure we're achieving the expected results.

Appendix A User Task Matrix

Sequence of tasks																				Communications		Working conditions									Other Important Notes
Actors	Tasks	Duration (30 min)																		From the user to other actors	From other actors to the user	Workspace				Operator					
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18			Noisy space	Dusty space	Restricted space	Other	Glasses	Gloves	Ear protection	Safety helmet	Other	
Operator	*Moving the crankshaft through the workshop*	🟧																													
Laser operator	*Read component info on the info sheets and tablet*		🟩																		Providing information to operator about procedure to be done: technical information about the crankshaft, and the										
Laser operator	*Stacking the crankshaft on the Robot (with scanner as end-effector)*		🟩																	Start the scanning procedure using the software developed by Aimen							x				How does the robot is programmed for the scanning? The program is performed by software developed by Aimen and Ziknes.
Robot	*Scanning*			🟥	🟥	🟥															To the user: feedback on working phase (e.g., heatmap or similar) and about the final result										
Laser operator	*Prepare the laser cladding machine for welding (e.g., staking, centring, prepare cooper protections, change the nozzle, change the powder...)*			🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩																				This step depends on the size of the material. Includes staking, centring, prepare cooper protections, change the nozzle.
Laser operator	*Programming the movements of the robot*										🟩	🟩								To the robot: specific for the cladding. The operator should provide main parameters as input for the programming, together with the 3D scan of crankshaft											
Laser operator	*Preheating*												🟩												High temperature	x	x	x			Due to high carbon content, the preheating is mandatory. The time depends on the size of the material.
Robot	*Laser Cladding process*													🟦	🟦	🟦	🟦					x			Smell + High temperature	x					
Laser operator	*Laser Cladding quality check*																	🟩							Smell		x				
Laser operator	*Unstack the crankshaft*																		🟩						Smell		x				
Laser operator	*Compleate "info sheets" and page on the tablet*																		🟩						Smell						