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Type		
R	Document, report (excluding the periodic and final reports)	x
DEM	Demonstrator, pilot, prototype, plan designs	
DEC	Websites, patents filling, press & media actions, videos, etc	
DATA	Data sets, microdata, etc	
DMP	Data management plan	
ETHICS	Deliverables related to ethics issues	
SECURITY	Deliverable related to security issues	
OTHER	Software, technical diagram, algorithms, models, etc	

Dissemination level		
PU	Public, fully open, e.g. project website	x
SEN	Sensitive, limited under the conditions of the Grant Agreement	
Classified R-UE/EU-R	EU RESTRICTED under the Commission Decision No2015/444	

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LIST OF ABBREVIATIONS

Abbreviation	**Meaning**
AI	Artificial Intelligence
DBS	Dynamic Beam Shaping
EC	European Commission
IIoT	Industrial Internet of Things
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
MaaS	Manufacturing-as-a-Service
MES	Manufacturing Execution System
OPC UA	Open Platform Communications – Unified Architecture
RAMI 4.0	Reference Architectural Model for Industry 4.0
SME	Small and Medium-sized Enterprise

1 Executive summary

1.1 Purpose of the document

This document presents the outcomes of Work Package 3 (WP3) of the project, focused on the design principles and enabling technologies for flexibility and reconfigurability in advanced laser welding systems. The purpose is to outline the conceptual foundations, methodologies, and system-level approaches developed to support adaptable, modular, and intelligent manufacturing environments. Special emphasis is placed on the integration of dynamic beam shaping, jigless design, and the design-x-MaaS paradigm, all of which contribute to the project's broader vision of transitioning from smart factories to smart value networks.

1.2 Scope and limitations

The deliverable covers work performed across the three tasks of WP3, including:

- Development of methodologies for digital servitisation of design/manufacturing processes (T3.1)
- Application of beam shaping and jigless principles to enhance flexibility (T3.2)
- Creation of modular design libraries and production schemes (T3.3).

As this is a public deliverable, proprietary or sensitive technical information, particularly related to internal developments, system parameters, and business strategies of project partners - has been intentionally excluded or generalized. The document focuses on high-level concepts and validated design principles suitable for public dissemination and cross-industry dialogue.

2 Introduction

2.1 Background and motivation

The manufacturing sector is undergoing a paradigm shift toward **on-demand, high-quality, and highly customizable production** enabled by digital technologies. This shift, commonly referred to as the **digital servitisation of manufacturing**, promises greater flexibility, shorter lead times, and more sustainable operations. Despite its potential, the transition faces a critical bottleneck: the absence of robust, scalable methodologies that can connect advanced manufacturing technologies with digital services in a cohesive, reconfigurable manner.

To address this gap, the **Lasers4MaaS project** aims to advance the integration of **laser-based manufacturing technologies** with **digital platforms and service models**. The project's broader vision is encapsulated in a six-point strategy: **reconfigure, connect, control, predict, improve, and comply**, key elements in operationalising the smart, decentralised, and sustainable factories of the future.

One of the project's technological cornerstones is **dynamic beam shaping (DBS)**, which allows real-time adaptation of the laser welding process. When combined with **modular production schemes** and **jigless design concepts**, this enables a step-change in the flexibility and responsiveness of production systems.

2.2 Objectives of WP3 - Methodologies for flexibility, reconfigurability and automation

WP3 contributes directly to the "reconfigure" pillar of the project's strategy by exploring new **design principles, tools, and system architectures** that enable modularity, scalability, and intelligence in laser-based manufacturing. The main objectives are:

- To develop **design methodologies** that support "design-x-MaaS" models, enabling digital servitisation of both product and process design.
- To implement **flexible system architectures** based on **dynamic beam shaping** and **jigless fixture principles**, reducing dependency on dedicated tooling and rigid production setups.
- To establish **modular design libraries** and reference architectures aligned with industry standards (e.g., RAMI 4.0), facilitating interoperability and system scalability.
- To support the integration of **IIoT** and **digital twin technologies** within reconfigurable laser welding environments.

By achieving these objectives, WP3 provides a foundational layer for flexible, service-oriented production systems that are adaptable to varying product demands and industrial domains.

3 Conceptual Foundations

3.1 Definitions: flexibility vs. reconfigurability

In the context of advanced manufacturing, **flexibility** refers to a system's ability to adapt to a range of product variants and process conditions with minimal disruption or reconfiguration time. It often involves the capacity to accommodate product diversity and variation in production volume without requiring extensive redesign or downtime.

Reconfigurability, on the other hand, is the system's inherent capability to undergo structural changes, such as adding, removing, or rearranging functional modules—to adapt to new tasks or production goals. A reconfigurable system is modular, scalable, and can be rapidly adjusted to meet evolving manufacturing requirements.

While flexibility is often realized through process-level adaptability (e.g. control settings, sequencing), reconfigurability emphasizes physical and architectural transformation of the system components. Together, these capabilities are critical for enabling **on-demand, customised manufacturing** in high-mix, low-volume and low-mix, high-volume scenarios.

3.2 Key principles of reconfigurable manufacturing systems

The design of reconfigurable systems is governed by six core principles, each contributing to the system's adaptability and long-term sustainability:

- **Scalability** – The ability to adjust production capacity in response to changes in demand.
- **Convertibility** – The ease with which equipment and processes can be changed to manufacture different products.
- **Diagnosability** – The system's capability to detect and isolate faults quickly and accurately.
- **Customisation** – The ability to tailor both product and process to specific customer requirements.
- **Modularity** – Design of system components as interchangeable modules for easy replacement or upgrade.
- **Integrability** – Seamless integration of new components or technologies into existing systems.

These principles underpin the development of **modular production schemes** and **jigless fixture approaches** explored in WP3, enabling manufacturers to quickly repurpose equipment and reduce the dependency on dedicated tooling.

3.3 Overview of Design-x-MaaS approach

The **Design-x-MaaS** approach introduced in Lasers4MaaS extends the concept of Manufacturing-as-a-Service (MaaS) to the design phase. It promotes a paradigm where **design itself becomes a service**, supported by digital tools, cloud-based collaboration, and modular design libraries. This approach is aligned with the goals of digital servitisation and leverages:

- **Digital design templates** for rapid configuration of laser welding stations (robots, lasers, fixtures),
- **Virtual simulations** for validation of design before implementation,
- **Service-oriented frameworks** that link product design to manufacturing workflows via interoperable platforms.

Design-x-MaaS supports **reconfigurability by design**, where production systems can be dynamically adjusted to match changing product requirements without extensive manual intervention or downtime. This model also allows for cost-efficient customisation, remote collaboration, and accelerated time-to-production.

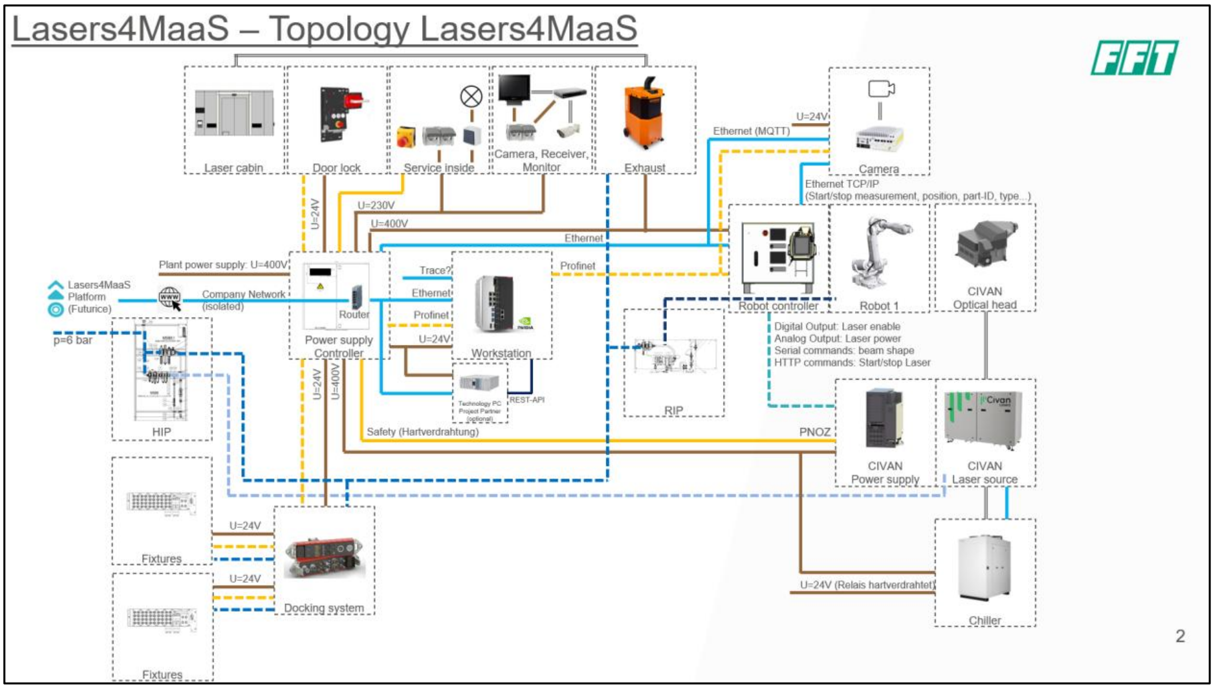

Figure 1: Lasers4MaaS welding system topology concept

By embedding Design-x-MaaS into reconfigurable architectures, Lasers4MaaS aims to create a new standard for **responsive and intelligent laser-based manufacturing systems** that are modular, interoperable, and future-ready.

4 Methodologies and design approaches

This lays the methodological foundation for flexible and reconfigurable laser-based manufacturing systems within Lasers4MaaS. It focuses on creating service-oriented design methods ("design-x-MaaS") that integrate dynamic beam shaping, advanced robotics and jigless fixture concepts into a unified digital workflow. The outcome is a set of principles, templates and reference models that allow partners and future adopters to configure laser welding stations quickly, reuse modules across product variants and scale capacity with minimal disruption.

4.1 Digital servitisation in product and process design

The "design-x-MaaS" approach extends Manufacturing-as-a-Service into the design phase by treating product and process design themselves as digital services. Within T3.1 this is realised through:

- Cloud-based design templates for robots, lasers and fixtures, enabling rapid configuration of welding cells without starting from scratch.
- Virtual commissioning and simulation to validate process parameters, including dynamic beam shapes, before physical implementation, reducing trial-and-error on the shop floor.
- Service-oriented workflows linking CAD/CAM, process modelling and shop-floor control systems, so that updates in design automatically propagate to production modules.
- Knowledge capture and reuse: best-practice weld recipes, beam-shape settings and fixture strategies are stored as reusable digital assets for different product families.

This digital servitisation approach decouples manufacturing know-how from fixed hardware, making it possible to deliver cost-efficient customisation, faster changeovers and improved access to confined welding areas.

4.2 Application of reconfigurability principles

This embeds the six recognised principles of reconfigurable manufacturing systems scalability, convertibility, diagnosability, customisation, modularity and integrability into the design process:

- Scalability: parameterised cell layouts and modular hardware specifications allow production capacity to be scaled up or down by adding or removing robot-laser-fixture modules.
- Convertibility: dynamic beam shaping settings and modular fixtures enable rapid switching between micro-, macro- and mixed-material welds without re-engineering the cell.
- Diagnosability: sensors and IIoT devices at module level feed condition and process data to digital twins, supporting real-time fault detection and isolation.
- Customisation: jigless, robot-based positioning uses part features to locate and constrain components, enabling product-specific welding paths without dedicated jigs.
- Modularity: robots, lasers, optics and fixtures are treated as interchangeable building blocks with standardised mechanical and digital interfaces.
- Integrability: adherence to open standards (e.g. RAMI 4.0, OPA UA) ensures new modules and digital services can be added seamlessly to existing stations.

By embedding these principles in the design workflow, reconfigurability is achieved by design rather than as an after-thought, reducing redesign loops and downtime.

4.3 Functional role of system components (robots, lasers, fixtures)

Within the modular welding station architecture each component plays a distinct yet interoperable role:

- Robots: provide flexible, multi-axis manipulation of parts or optics. They replace or complement traditional jigs by using in-process sensing to align to part features, thus supporting jigless welding. Robots also serve as carriers for modular end-effectors, such as adaptive clamping devices or process monitoring sensors.
- Lasers with dynamic beam shaping: act as the "all-in-one" welding tool, capable of real-time adjustment of spot size, energy distribution and temporal modulation. This allows one laser source to address thin-section micro-welding, thick-section macro-welding, mixed-material joints and aesthetic seams without hardware changes.
- Fixtures and auxiliary modules: evolve from fixed, product-specific jigs to reconfigurable, often robotised supports or modular clamping systems. Their intelligence shifts from hard tooling to software and sensor-based alignment routines, increasing reusability across product variants.

All components are linked through open-standard automation and a unified digital twin environment, ensuring that design changes, whether a new beam shape, a modified robot path or a different clamping strategy, propagate consistently across the physical and virtual system. This integrated approach underpins the Lasers4MaaS vision of responsive and intelligent laser-based manufacturing systems.

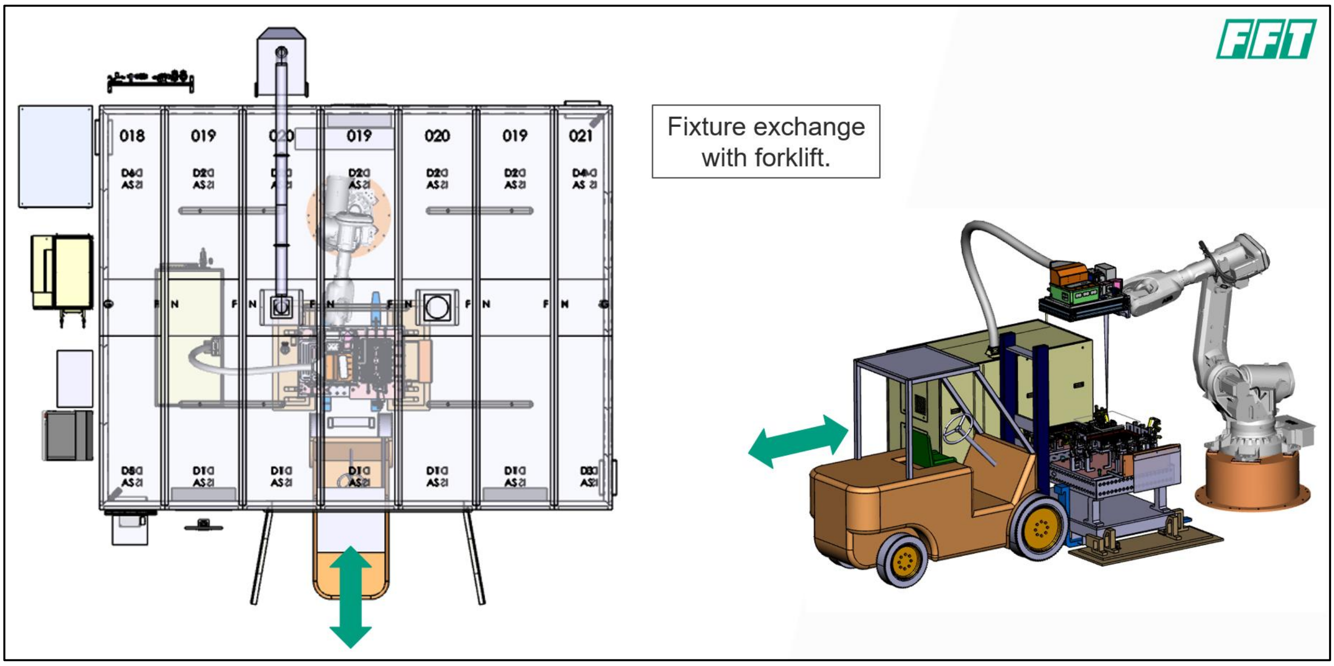

Figure 2: Lasers4MaaS welding cell concept

5 Enabling technologies and system design

This builds on the methodologies of "design-x-MaaS" by focusing on the concrete technologies and design concepts that enable flexibility and reconfigurability at station level. This includes the deployment of dynamic beam shaping lasers as "all-in-one" welding tools, the development of jigless welding strategies, and the integration of modular fixtures and robotic systems into a unified, standards-based architecture.

5.1 Dynamic beam shaping for adaptive welding

DBS is a cornerstone of the Lasers4MaaS concept. Using a digitally controllable optical element, the energy distribution of the laser beam can be modified in real time, changing spot size, shape, intensity profile and temporal modulation without interrupting production.

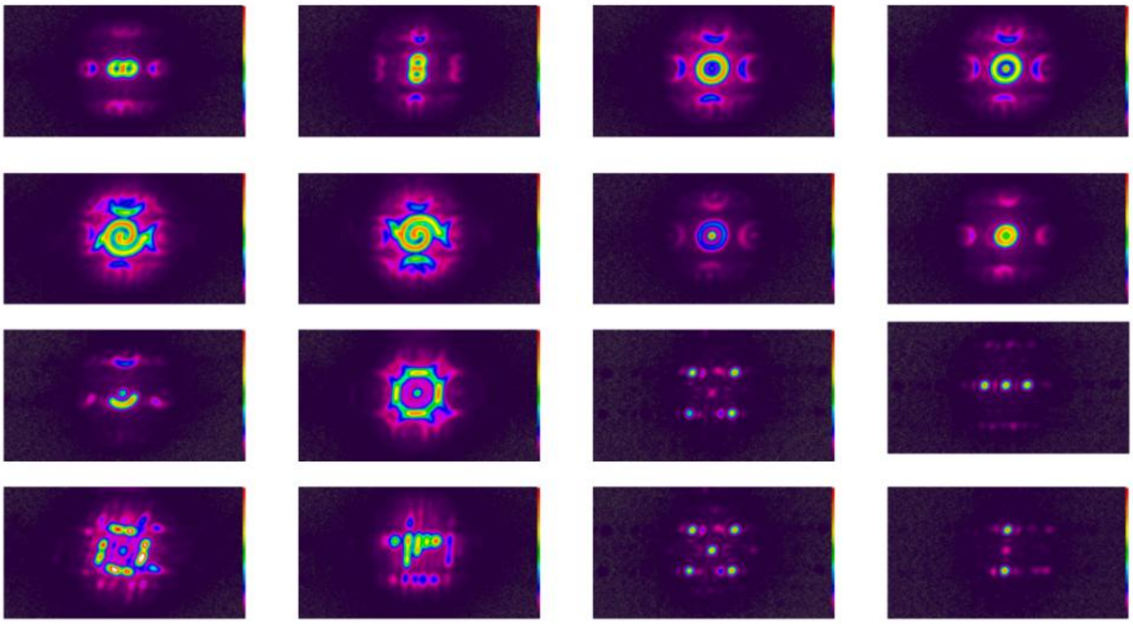

Figure 3: Dynamic beam shapes examples

DBS enables:

- **Single-source versatility:** one laser can switch seamlessly between micro-welding of thin sections, macro-welding of thick plates, mixed-material joints and cosmetic seams.
- **Process optimisation on the fly:** beam parameters can be tuned adaptively to compensate for variations in material thickness, joint geometry or heat input, reducing defects and improving weld quality.
- **Reduced hardware complexity:** fewer optics and no manual lens changes lower setup time and cost.
- **Integration with digital twins:** DBS settings become a parameter set in the virtual model of the cell, allowing rapid offline validation and automated upload to the real system.

To enable flexible, reconfigurable, and interoperable system architectures, the demonstrator framework relies on a combination of industrial communication interfaces for control and data exchange. The primary communication between robot, PLC, and associated technology controllers is usually established by using ProfiNET, e.g. to send job requests/releases, production part IDs, etc. for motion control and process coordination. Safety-critical signals, such as emergency stop, door interlocks, and protective device feedback are transmitted via ProfiSAFE, ensuring compliance with industrial safety standards. For data collection, system monitoring, and information exchange, MQTT and OPC UA could be incorporated. These interfaces create a robust communication framework that supports modularity, system reconfiguration, and efficient integration of new process and sensor equipment. This adaptive capability transforms the laser from a fixed-function tool into a flexible, service-oriented process module aligned with the “design-x-MaaS” paradigm.

The laser can be controlled for:

- Laser Ready
  - Over Ethernet (HTTP) / Manual by the provided GUI
- Power modulation
  - Analog signal [0-10V]
  - Digital signal - PWM [0-24V]
- Pre-determinate Dynamic beam shape command
  - delta x, delta y, delta z, sequence ID, angle of the shape
  - Transmission speed available
    - RS-422 115200bps / 2Mbps / 10Mbps
    - S/PDIF 20Mpbs

Beam Shape Control

UART Over RS-422, standard 8-bit data, minimum baud rate of 115,200 bps.

Packet of 6 Bytes:

Offset	Name	Simplified	Address Scope
0X00	Preamble		0XFF
0X01	X Offset	Beam offset	0Xnn
0X02	Y Offset		0Xnn
0X03	Z Offset		0Xnn
0X04	Sequence ID		0Xnn
0X05	Rotation angle	$\frac{Value}{256} \cdot 360_{\circ}$	0Xnn

5.2 Jigless design principles and implementation concepts

Traditional welding relies on dedicated jigs or fixtures to hold parts in position. In Lasers4MaaS, intelligence is shifted from the jig to the product features and robotic system:

- Robot-based referencing: multi-axis robots use vision, tactile or laser sensors to identify part features and dynamically adjust paths, eliminating the need for hard tooling.
- Modular clamping and support systems: standardised, reconfigurable fixtures or end-effectors can be quickly adapted to new part geometries.
- Adaptive alignment algorithms: software routines adjust welding trajectories in real time based on feedback from sensors, ensuring high positional accuracy even with part variability.
- Reduced design loops: reusing jigless strategies across product variants cuts lead times and the cost of designing and manufacturing new jigs.

These concepts support the transition from rigid, product-specific setups to agile systems capable of high-mix, low-volume production without sacrificing quality or cycle time.

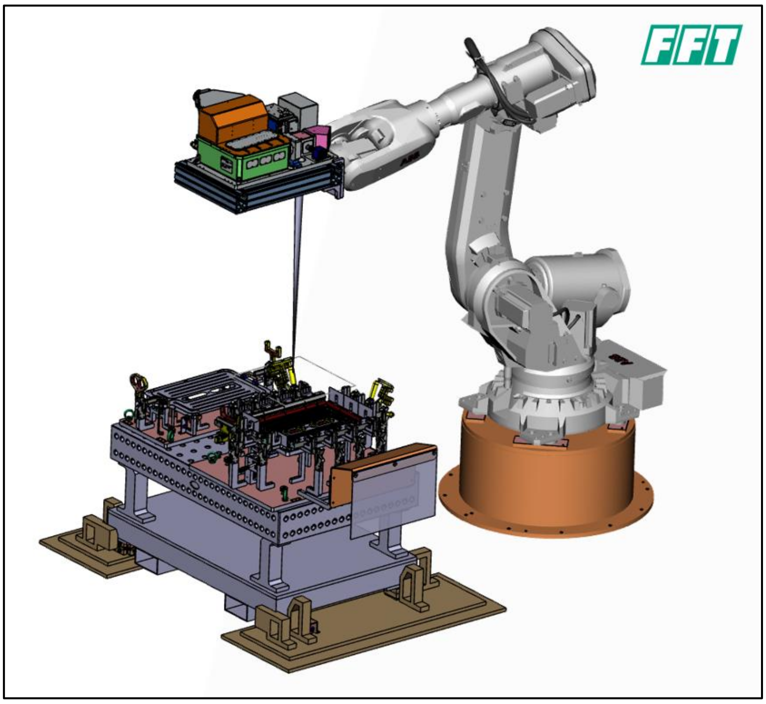

Figure 4: Robot-based laser welding, modular clamping and support systems

5.3 Integration of modular fixtures and robotic systems

To fully realise flexibility, DBS and jigless principles must be embedded in a modular station architecture:

- **Standardised interfaces:** mechanical, electrical and data connections between robots, fixtures and laser modules follow different standards, enabling plug-and-play integration.
- **Interoperable control systems:** robots, clamps and laser modules share a common control layer and synchronised data exchange, simplifying programming and changeovers.
- **Scalable station design:** modules can be added, removed or rearranged to increase capacity, change product mix or integrate new processes with minimal disruption.
- **Digital twin compatibility:** each module has a corresponding virtual representation, enabling off-line programming, predictive maintenance and quick reconfiguration planning.

This modular integration creates a production platform where dynamic beam shaping, robotic manipulation and reconfigurable fixtures act as coordinated services rather than isolated components, laying the groundwork for the demonstrators in WP4 and for the broader shift from smart factories to smart value networks.

6 Modular architectures and design libraries

This focuses on translating the methodologies and technologies of WP3 into practical, reusable assets. This involves creating a modular station architecture and digital design libraries underpinned by open automation reference frameworks. The outcome is a set of standardised building blocks, both physical and digital, that allow rapid configuration, interoperability and scaling of laser welding systems.

6.1 Use of automation reference architectures

Lasers4MaaS adopts established reference architectures such as RAMI 4.0 to ensure that modular laser welding stations are compatible with emerging Industry 4.0 standards:

- **Layered model alignment:** each station module (robot, laser, fixture, control) is mapped to the appropriate RAMI 4.0 layers (asset, integration, communication, information, functional, business).
- **Standardised communication:** OPC UA and other open protocols are used to exchange data across modules and with higher-level systems, enabling plug-and-play integration.

By grounding the architecture in RAMI 4.0, the project ensures long-term compatibility, easier certification and smoother integration with other digital manufacturing platforms.

6.2 Interoperability and standardization strategies

A key deliverable of T3.3 is the definition of interoperability rules for both hardware and software:

- **Mechanical and electrical interfaces:** unified connection standards for fixtures, end-effectors and sensors allow quick replacement or upgrading without custom engineering.
- **Data semantics and models:** common data dictionaries and information models (aligned with IEC/ISO standards) ensure that robots, lasers and digital twins “speak the same language.”
- **Automation workflows:** modular control blocks and programming templates reduce integration time and risk when combining modules from different vendors.
- **Cross-domain transferability:** strategies are developed to apply the same modular assets to different product families, welding processes or even other joining technologies.

This approach underpins the vision of a manufacturing ecosystem where modules from multiple suppliers can be combined dynamically to form customised production cells.

6.3 Linking physical and digital models (digital twin compatibility)

Each physical module in the modular architecture is mirrored by a digital representation, creating a scalable digital twin environment:

- **Parametric models:** geometric, kinematic and process parameters of robots, lasers and fixtures are stored in a central library for reuse and simulation.
- **Virtual commissioning:** new cell configurations can be validated off-line, including dynamic beam shapes and robot paths, before deployment, reducing downtime.
- **Lifecycle data integration:** operational data from sensors and IIoT devices feeds back into the digital twin, enabling predictive maintenance and continuous improvement.
- **Interoperability of digital twins:** adherence to open standards (e.g. Asset Administration Shell, OPC UA information models) allows twins from different partners or platforms to interconnect seamlessly.

By tightly linking physical and digital models, Lasers4MaaS turns modular stations into living, data-driven systems that can be rapidly configured, monitored and optimised across their lifecycle, paving the way for the demonstrators in WP4 and, ultimately, for decentralised, service-oriented manufacturing networks.

7 Contribution to project goals and broader impact

Work Package 3 directly supports Objective 1 of Lasers4MaaS – "RECONFIGURE" – by delivering the methodologies, enabling technologies and modular architectures needed to create responsive, intelligent and service-oriented laser-welding systems. The outcomes of WP3 underpin not only the demonstrators in WP4 but also the project's wider ambition to make Manufacturing-as-a-Service a practical reality for European industry, including SMEs.

7.1 Alignment with RECONFIGURE strategy

WP3 embodies the "reconfigure" pillar of the project's six-point strategy (reconfigure, connect, control, predict, improve, comply):

- **Dynamic beam shaping as an all-in-one welding tool** enables rapid switching between different joint types, materials and thicknesses, removing the need for multiple dedicated lasers.
- **Jigless fixture and robot-based alignment** shifts intelligence from hard tooling to software and part features, reducing re-design loops and shortening changeovers.
- **Modular station architecture and design libraries** allow production cells to be scaled, rearranged or repurposed with minimal downtime, in line with the MaaS paradigm.
- **Open-standard automation and digital twins** ensure that each module can be integrated into cross-company workflows, supporting trusted and secure data exchange.

Together, these elements operationalise the RECONFIGURE strategy by turning fixed manufacturing assets into agile, servitised resources that can be orchestrated on demand.

7.2 Expected benefits for flexible manufacturing

The methods and technologies developed in WP3 directly address the expected outcomes set by the European Commission:

- **Lower entry barriers for SMEs:** ready-to-use design templates, modular fixtures and reconfigurable beam settings reduce upfront investment and speed up deployment of advanced laser welding.
- **Fast reconfiguration and upgrade:** dynamic beam shaping and jigless principles enable real-time adaptation to new products, while modular stations can be upgraded without disrupting production.

- **Trusted, interoperable data exchange:** adoption of RAMI 4.0 layers, OPC UA and Asset Administration Shell supports secure life-cycle data sharing across company boundaries, in line with initiatives such as the Digital Product Passport and Manufacturing Data Spaces.
- **Circularity and sustainability:** by reusing modules and reducing the need for new jigs and dedicated optics, the environmental footprint of production is lowered; life-cycle data can be leveraged for remanufacturing or recycling of assets, components and materials.
- **Improved value-chain integration:** digital twins and workflow templates connect product design, process planning and shop-floor execution across distributed facilities, enabling true production on demand.

These benefits contribute to competitiveness, shorter lead times and higher responsiveness across European manufacturing ecosystems.

7.3 Transferability and scalability potential

The WP3 outcomes are designed from the outset for cross-domain applicability:

- **Transferability:** the same dynamic beam shaping, jigless strategies and modular station templates can be applied to other joining processes (e.g. laser cutting, additive manufacturing) or to different sectors such as automotive, aerospace or medical devices.
- **Scalability:** modules and digital libraries can be scaled from single-cell installations in SMEs to multi-cell networks spanning several plants or service providers.
- **Cross-company orchestration:** by adhering to open standards and interoperable digital-twin models, different suppliers and service providers can plug into a common MaaS platform, exploiting unused capacity and enabling decentralised production.
- **Foundation for future business models:** the “design-x-MaaS” paradigm and the associated reference architectures create a basis for new service offerings (design-as-a-service, process-as-a-service) and for integrating real-time AI decision support, next-generation MES and life-cycle assessment tools.

By demonstrating these capabilities in at least two realistic use cases in WP4, Lasers4MaaS will show measurable improvements in flexibility, sustainability and competitiveness, thereby contributing to the objectives of the “Made in Europe” partnership and the wider European strategy for smart, decentralised and circular manufacturing.

8 Summary and conclusions

This deliverable has presented the design principles, methodologies and enabling technologies developed in Work Package 3 of Lasers4MaaS. Building on the project’s “RECONFIGURE” pillar, WP3 has established the conceptual and practical foundations for flexible, reconfigurable and service-oriented laser-based manufacturing systems.

Key outcomes include:

- **Methodologies for digital servitisation (“design-x-MaaS”)** that treat both product and process design as reusable, cloud-based services, enabling rapid configuration and virtual validation of laser welding stations.
- **Application of reconfigurability principles** across robots, lasers and fixtures, embedding scalability, convertibility, diagnosability, customisation, modularity and integrability by design rather than as add-ons.
- **Deployment of enabling technologies** such as dynamic beam shaping, jigless fixture concepts and modular station architectures that together transform the laser into an “all-in-one” welding tool.
- **Creation of design libraries and reference architectures** aligned with RAMI 4.0 and open standards to support interoperability, digital twin compatibility and secure cross-company data exchange.

These advances directly address the European Commission's expected outcomes for easy access to decentralised, flexible and sustainable manufacturing capacities, especially for SMEs, by lowering entry barriers, reducing setup time, improving value-chain integration and supporting circularity and re-use of assets.

The deliverable provides the foundation for WP4, where the concepts will be validated through realistic demonstrators across different supply chains and industry sectors. This will show how dynamic beam shaping, jigless principles and modular production schemes can be combined in practice to enable manufacturing on demand, using distributed facilities and exploiting unused capacity.

In summary, WP3 has turned the vision of "design-x-MaaS" into a practical framework for responsive and intelligent laser-based manufacturing systems. It sets the stage for scalable, interoperable and sustainable Manufacturing-as-a-Service platforms that strengthen Europe's competitiveness and accelerate the transition from smart factories to smart value networks.

9 References

#	Reference Title & Description	Source/Download Link
1	European Commission. "Horizon Europe - Made in Europe Partnership" (Work Programme 2023â€“2024). This covers the EU's coordinated R&D agenda for manufacturing innovation.	https://research-and-innovation.ec.europa.eu/document/download/26755d13-3e91-4e86-a05c-771cd89f1b07_en
2	Platform Industrie 4.0. "Reference Architectural Model Industrie 4.0 (RAMI 4.0)". The official standard model for Industry 4.0 architectures.	https://ec.europa.eu/futurium/en/system/files/ged/a2-schweichhart-reference_architectural_model_industrie_4.0_rami_4.0.pdf
3	OPC Foundation. "OPC UA Specification". Official specifications for OPC Unified Architecture (UA), a leading data-exchange standard.	https://opcfoundation.org/developer-tools/specifications-unified-architecture
4	ISO/IEC 62264 - Enterprise-Control System Integration (ISA-95). Standard for integrating enterprise and control systems.	https://www.iso.org/standard/67480.html
5	Digital Product Passport Initiative - European Commission (2023). EU plan for digital traceability and sustainability documentation.	https://data.europa.eu/en/news-events/news/eus-digital-product-passport-advancing-transparency-and-sustainability

Relevant scientific papers on Dynamic Beam Shaping in high-power laser processing (open-access examples):

Research Focus/Institute	**Title & Authors**	**Source/Download Link**	**Notes**
Civan Lasers & IFSW	"Basic Properties of High-Dynamic High-Power Coherent Laser Beam Combining for Materials Processing" (includes Civan's DBL, likely IFSW contributors)	SSRN Preprint PDF (2024)	Civan's DBL 6–14 kW laser used as case study for dynamic beam shaping and coherent beam combining, possible IFSW co-authorship
Eyal Shekel	"Dynamic beam shaping with coherent beam combining" by Eyal Shekel (2024)	Wiley Online Abstract	Open-access abstract, details CBC approach, Civan Lasers context likely
Eyal Shekel, Yaniv Vidne, et al.	"Basic properties of high-dynamic beam shaping with coherent combining of high-power laser beams for materials processing"	Stuttgart University Repository	Includes Eyal Shekel as author, technical insights relevant for Civan/IFSW users
IFSW (Univ. Stuttgart)	"Highly dynamic beam shaping with Civan's OPA6 laser at IFSW"	Institute of Photonic Technologies Stuttgart News	Application research with Civan lasers, includes experiment details and figures
IFSW/ICALEO	"High-speed x-ray imaging of pore and spatter formation during welding of hair pins" – Eveline Reinheimer (IFSW, using dynamic beam laser, ICALEO '23)	Civan Lasers Case Study	Award-winning student research on dynamic beam laser application to welding