Flexible remanufacturing using AI and advanced robotics for circular value chains in EU industry

EFFRA Manufacturing Partnership Days

17/11/2026

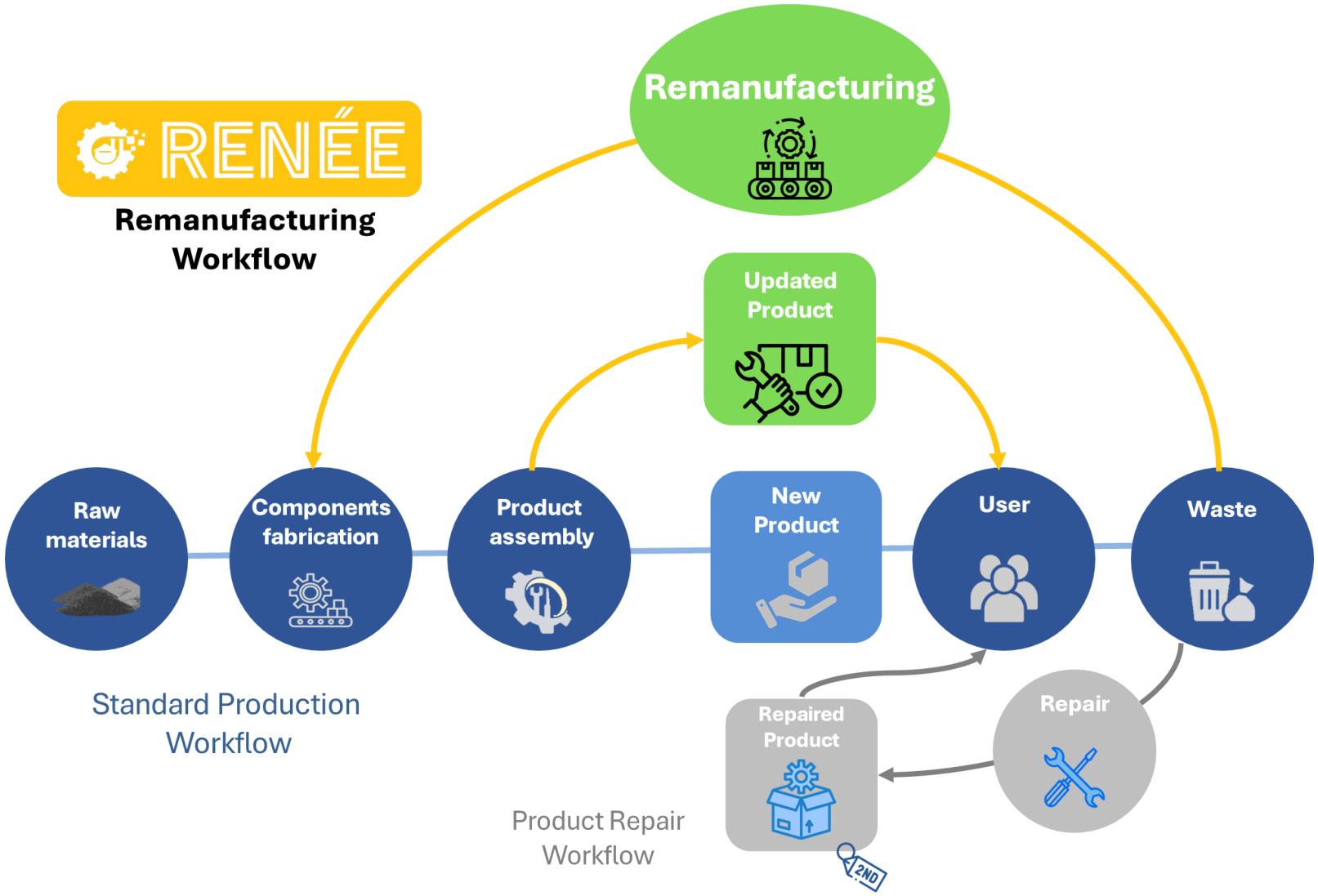
Christos Gkournelos

LMS
Laboratory for Manufacturing Systems & Automation

This project has received funding from the European Union's Horizon Europe Framework Programme under grant agreement nº 101138415.

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The Remanufacturing workflow



The case for remanufacturing

Why circular value chains are no longer optional

20%[1]

of global GHG emissions

Manufacturing alone is responsible for roughly one fifth of the EU's greenhouse-gas footprint.

54%[2]

of world's energy

Industrial production consumes more than half of all energy generated worldwide.

> €180bn[3]

annual disruption cost

Supply-chain shocks now cost the European economy hundreds of billions of euros every year.

Remanufacturing is now a strategic priority — tightening EU regulation, volatile raw-material supply and customer demand for circular products are converging into a clear industrial mandate.

[1] European Parliament [link]
[2] U.S. EIA Industrial Sector Energy Consumption Report [link]
[3] JS Held: Global Risk Report [link]

Challenges towards Flexible Remanufacturing Adoption

From open-world uncertainty to industrial-scale circularity

THE CHALLENGE

Used products are unpredictable

Variability in core condition, geometry and history makes traditional automation fail

OPERATIONAL GAPS

- High capex
- Variable cores
- Rigid automation
- Manual labour

THE FLEXIBLE REMANUFACTURING PARADIGM

AI — Open-World AI Reasoning

LLMs and AI perception generate flexible robotic skills and disassembly plans on the fly — identifying and unscrewing components without rigid programming.

DI — Digital Infrastructure

A circular value chain toolbox of intelligent tools and digital systems for decision support, data governance and smart workflow orchestration.

HC — Human-Centric Collaboration

Safe human-robot collaboration and intelligent interfaces that support and upskill operators through complex remanufacturing tasks.

Flexible remanufacturing paradigm

Circular value chains configuration toolbox

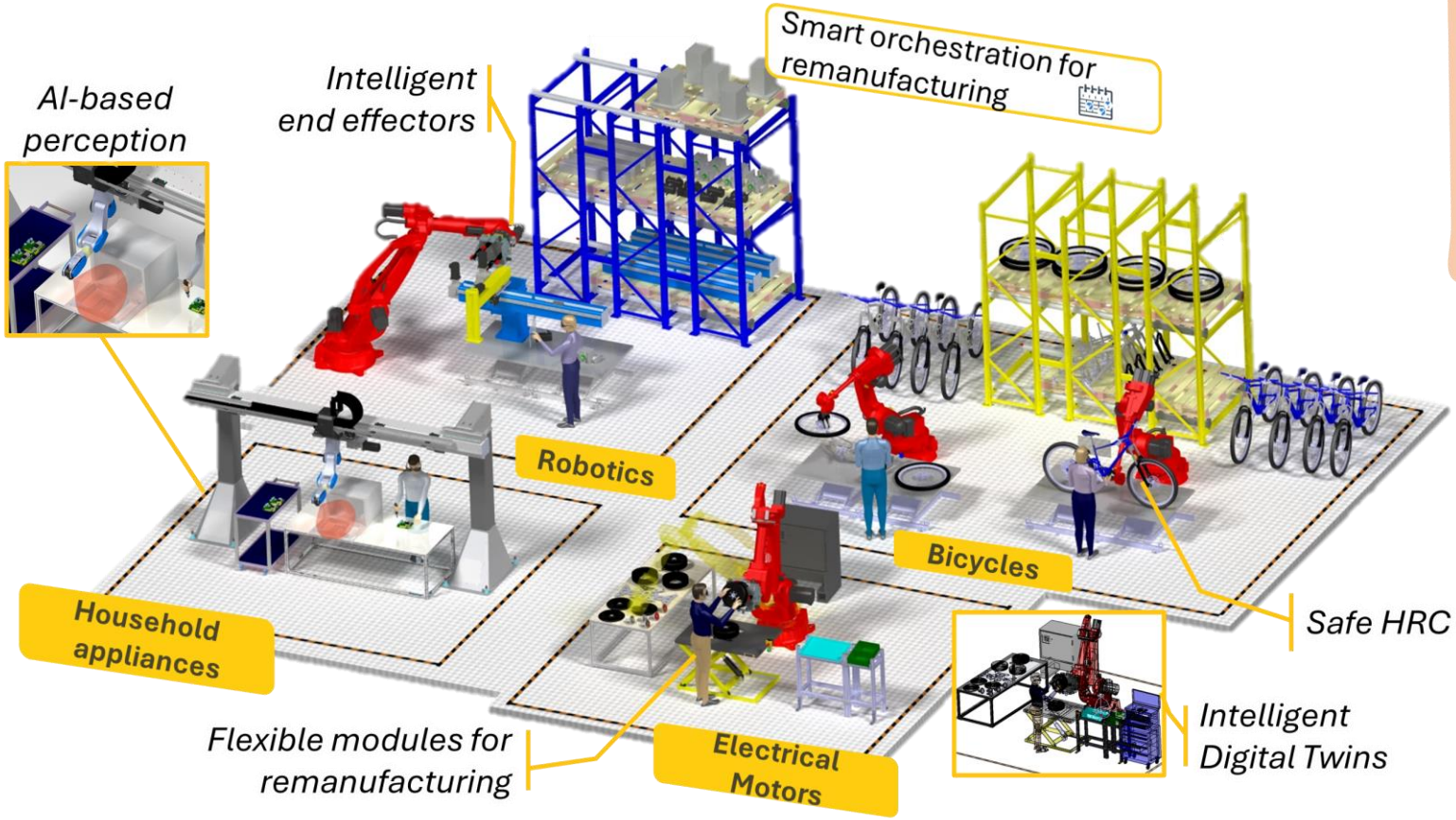
- Smart planning, disassembly,
- Product lifecycle tracking and DPP.



Digital Twin & Traceability:

- Orchestration
- Digital vault
- Digital twin
- Supply management





Flexible Robotics

- Cognitive robots
- Intelligent end effectors
- AI-sensing
- Robot skills



Workforce upskilling

- Human-centric design
- Interfaces
- Educational platform
- Training services



Remanufactured products

EV Motors				**Green Mobility Support** More affordable and sustainable electric mobility options by reusing components
Household appliances				**CO_2 Emissions Avoided** Every remanufactured unit saves approx. 280 kg of CO_2e. **~14,000 tons CO_2e savings/year.**
Industrial Robots				**Local Industrial Impact** Strengthening European service networks and reducing reliance on importing new robots
Bicycles				**Affordable Mobility** Provide low-cost, reliable bicycles for customers, promoting sustainable mobility

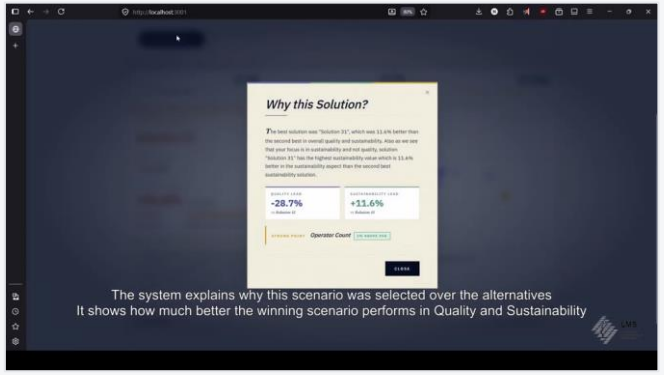
Flexible remanufacturing in action

Three steps, one multi-agent system – each shown in a demo

DI STEP 1

Design & evaluate the cell

Multi-agent evaluation framework

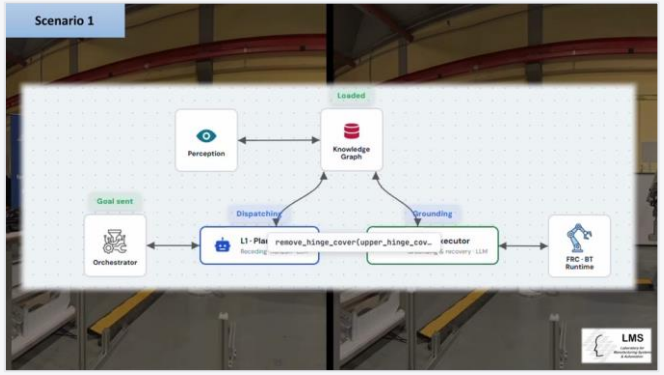


Gap: High capex

AI STEP 2

Reason & adapt robot skills

Open-world perception + LLM agents

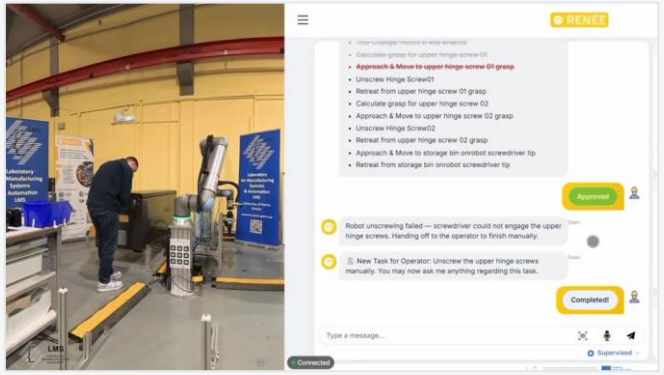


Gap: Variable cores · Rigid automation

HC STEP 3

Keep the operator in the loop

Multi-agent operator support



Gap: Manual labour

Multi-agent orchestration on an AAS-based digital infrastructure – product, resource and task data shared across every step

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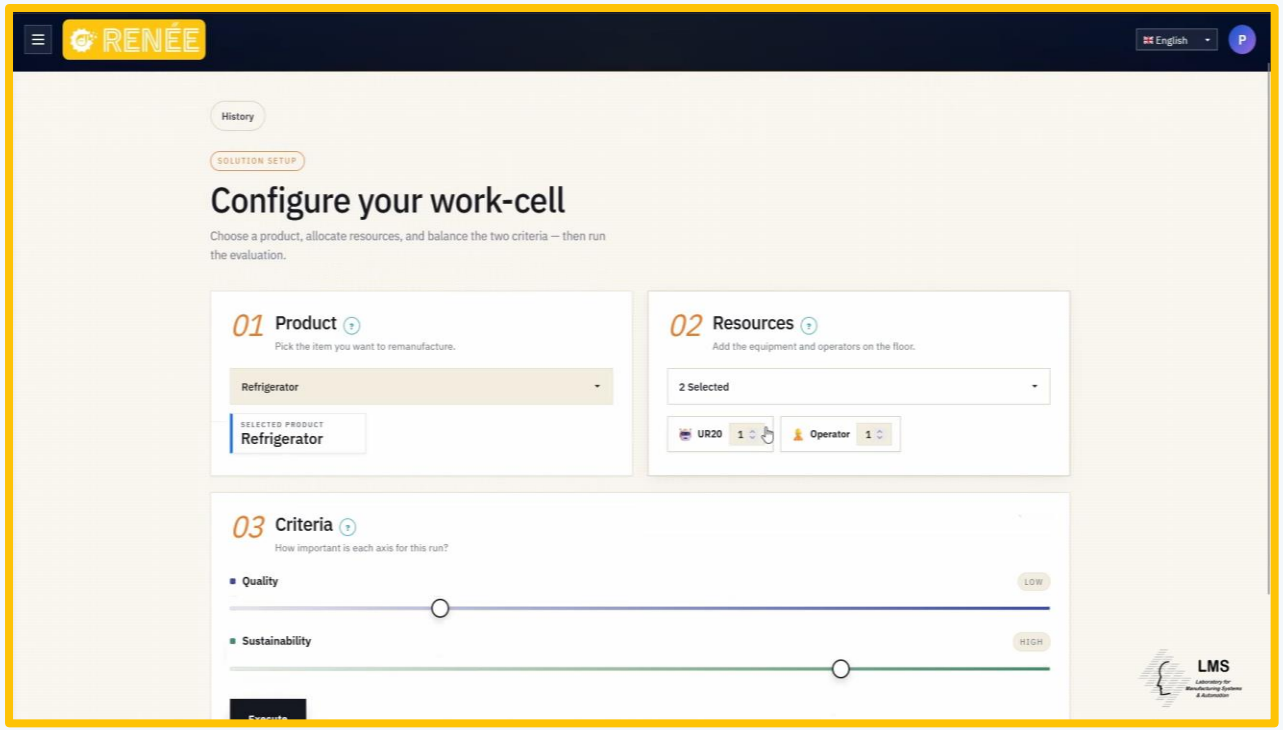
Flexible remanufacturing in action

DI

STEP 1 · DIGITAL INFRASTRUCTURE

Design & evaluate the cell

Multi-agent evaluation framework



Generate
an optimiser proposes workstation layout scenarios

Evaluate
agents score each one on quality & sustainability

Explain
an LLM justifies the best option; multilingual chatbot for the engineer

Gap addressed:
High capex

AI

STEP 2

Reason & adapt robot skills

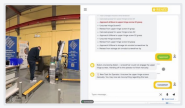


Variable cores · Rigid automation

HC

STEP 3

Keep the operator in the loop



Manual labour

Multi-agent orchestration on an AAS-based digital infrastructure – product, resource and task data shared across every step

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Flexible remanufacturing in action

DI

STEP 1

Design & evaluate the cell



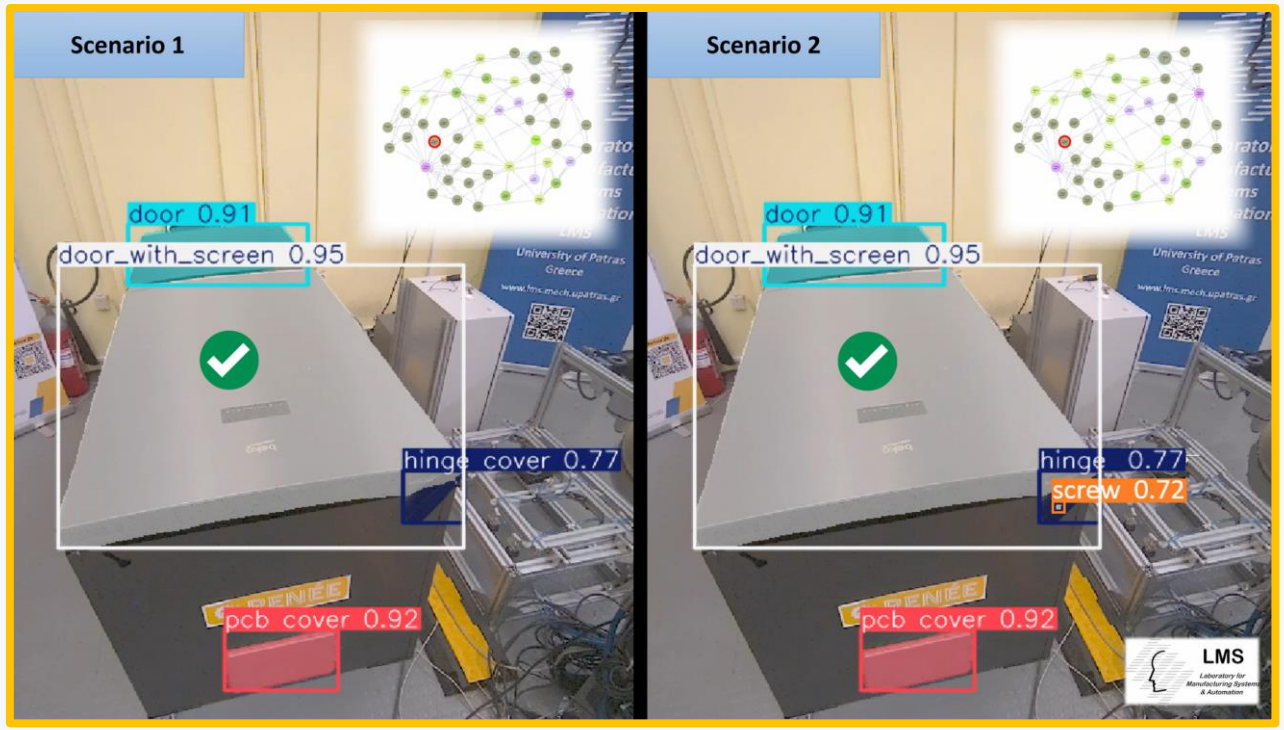
High capex

AI

STEP 2 · OPEN-WORLD AI REASONING

Reason & adapt robot skills

Open-world perception + LLM agents



Perceive
RGB-D, YOLOv8 and SAM2 build a live scene graph of the product

Reason
LLM agents generate the executable behaviour tree

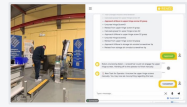
Adapt
a missing part is detected and the plan changes on the fly

Gap addressed:
Variable cores · Rigid automation

HC

STEP 3

Keep the operator in the loop



Manual labour

Multi-agent orchestration on an AAS-based digital infrastructure – product, resource and task data shared across every step

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Flexible remanufacturing in action

DI

STEP 1

Design & evaluate the cell



High capex

AI

STEP 2

Reason & adapt robot skills



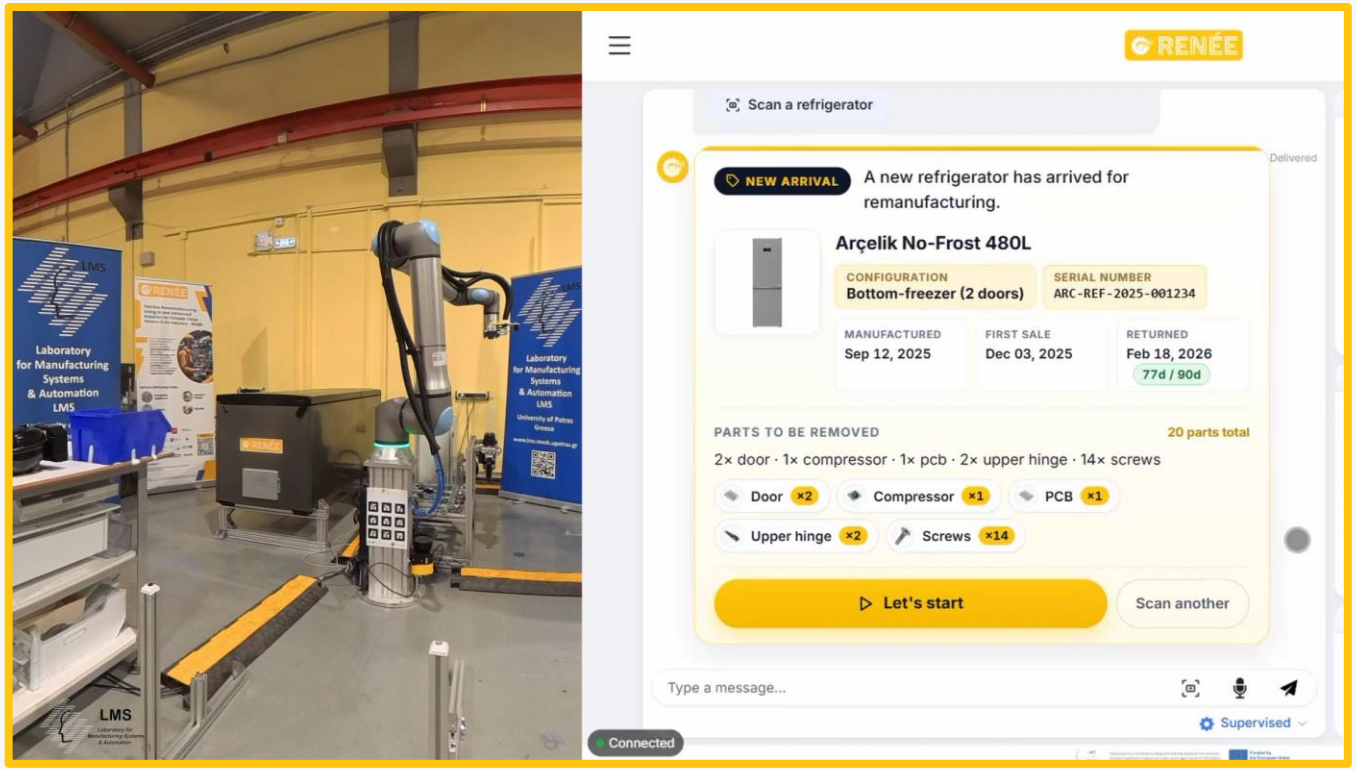
Variable cores · Rigid automation

HC

STEP 3 · HUMAN-CENTRIC COLLABORATION

Keep the operator in the loop

Multi-agent operator support



Approve
the operator validates each robot task plan

Hand over
a failed robot step is passed to the operator automatically

Guide
a chatbot leads step-by-step inspection

Gap addressed:
Manual labour

Multi-agent orchestration on an AAS-based digital infrastructure – product, resource and task data shared across every step

Meet the Project

Flexible **Re**manufacturing using AI and adva**n**ced robotics for circular valu**e** chains in **E**U industry

RENÉE: *French name, meaning born again or reborn*

Funded under **Horizon Europe** work programme:

Call: *HORIZON-CL4-2023-TWIN-TRANSITION-01-04 — Factory-level and value chain approaches for remanufacturing (Made in Europe Partnership) (IA)*

GA: 101138415



Follow our work:

Thank you for your attention!

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