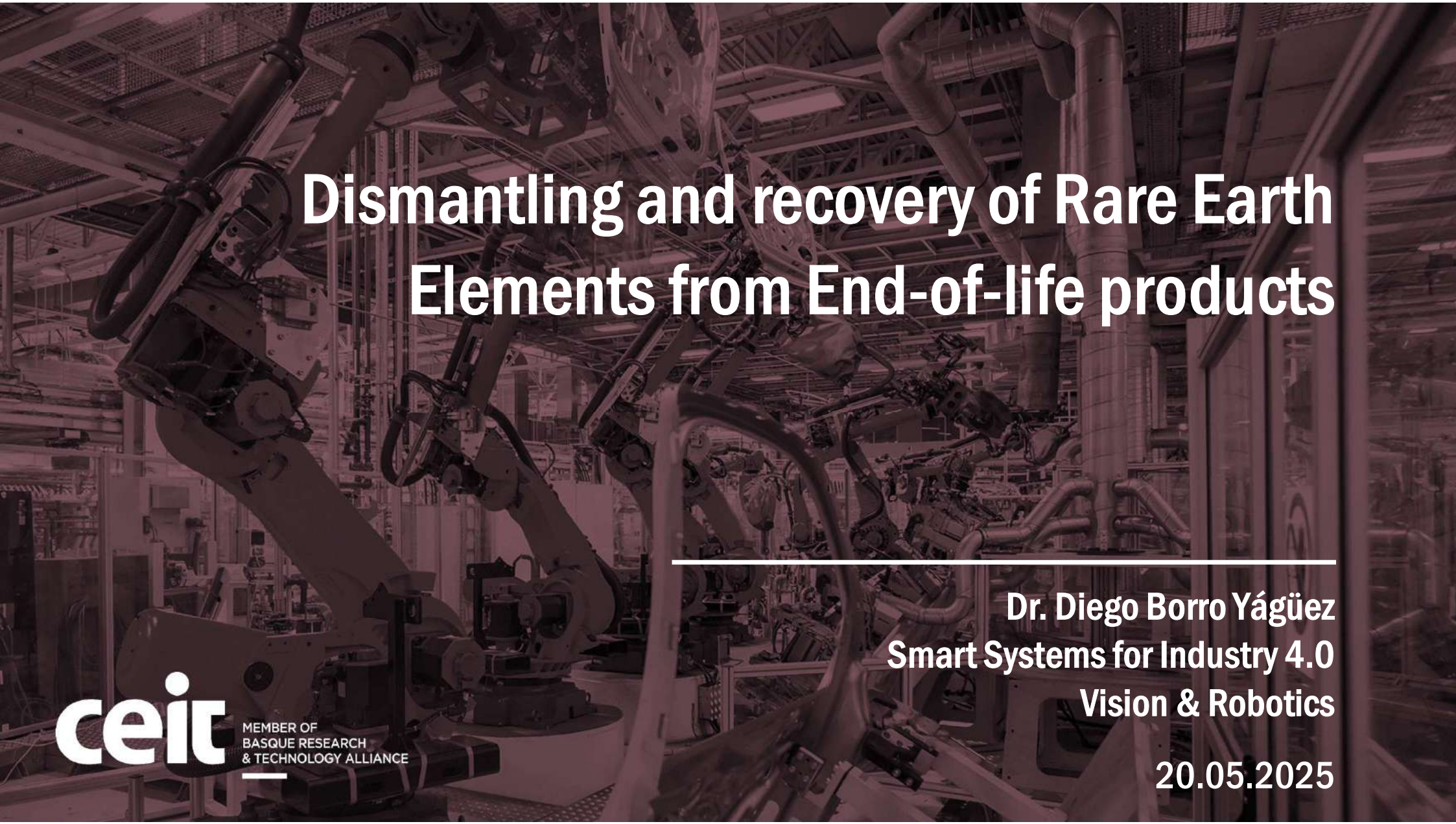


# Dismantling and recovery of Rare Earth Elements from End-of-life products

Dr. Diego Borro Yágüez
Smart Systems for Industry 4.0
Vision & Robotics

20.05.2025

ceit
MEMBER OF
BASQUE RESEARCH
& TECHNOLOGY ALLIANCE

# Institutional profile

History and mission

## Founded in 1982 by the School of Engineering of the University of Navarra

## Our mission is to serve society and industry by non-profit research(1)

- Developing research projects for industry (TRL4-TRL7)
- Training young researchers
- Dissemination of knowledge
- *(1) Profit is re-invested in research*

**Personnel**

Total: +280
Doctors: 100
PhD students: 30

**Scientific production**

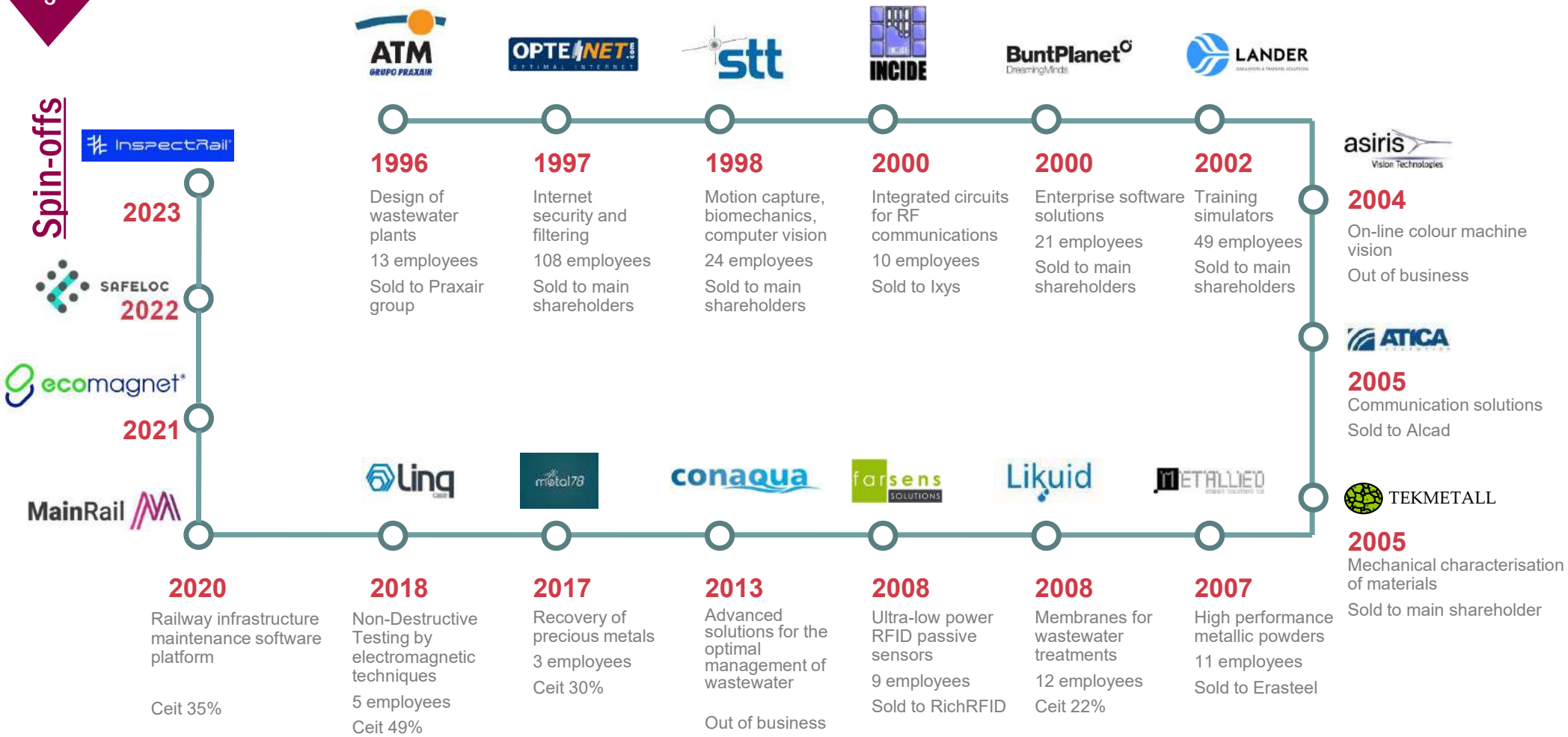
Journal papers: > 70
Conferences: > 80
PhD theses: >15

## Creating knowledge and for more than 40 years

| | |
|---|---|
| Scientific production | + 1,300 publications and 2,000 contribution to international congresses |
| PhDs and researchers transferred to the industry | +350 PhDs and 400 researchers (+60% locally) |
| New jobs created in spin-offs | + 300 employees |
| Accumulated incomes of spin-offs | + 200 M€ |
| Number of EU projects | > 100 |

# Institutional profile

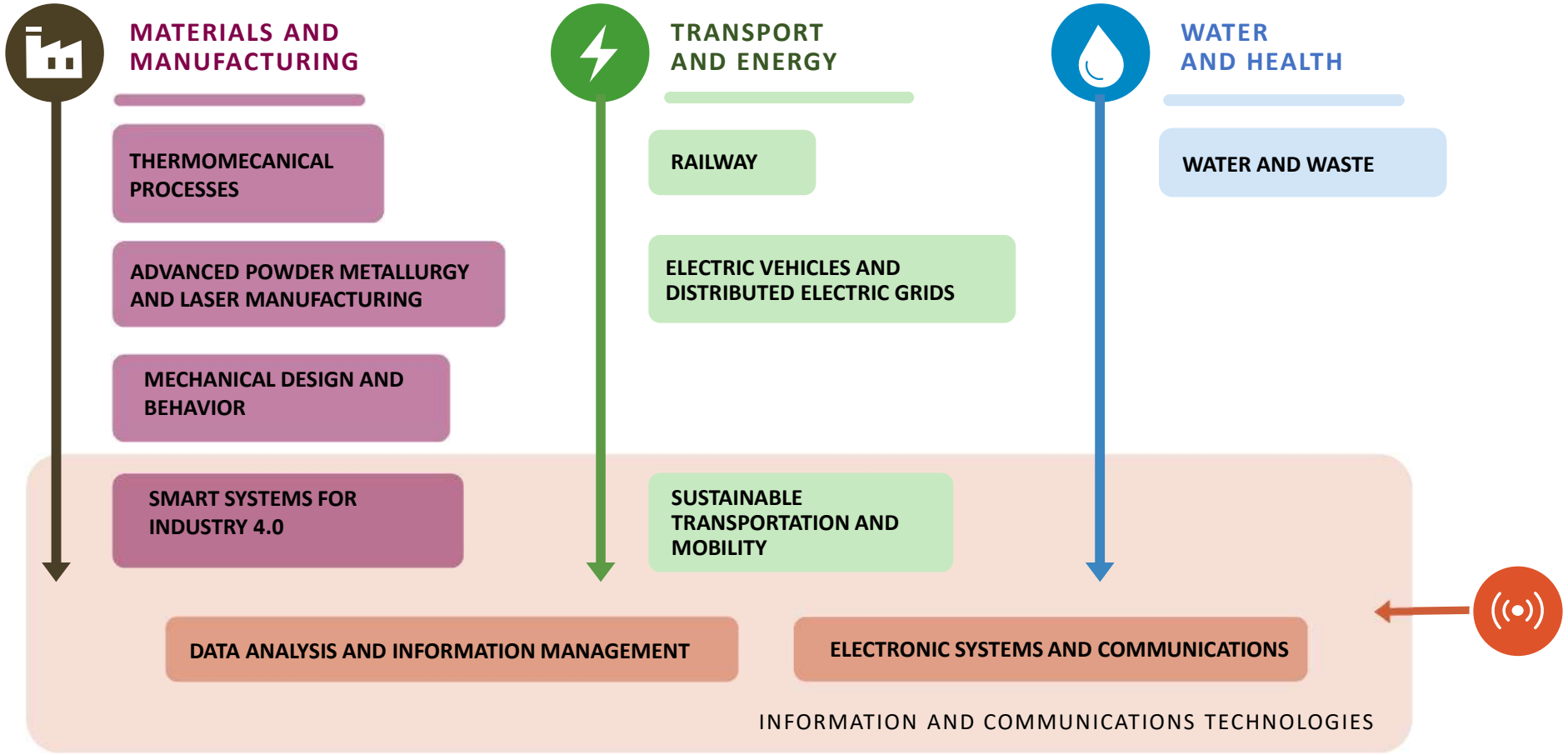




# Institutional profile

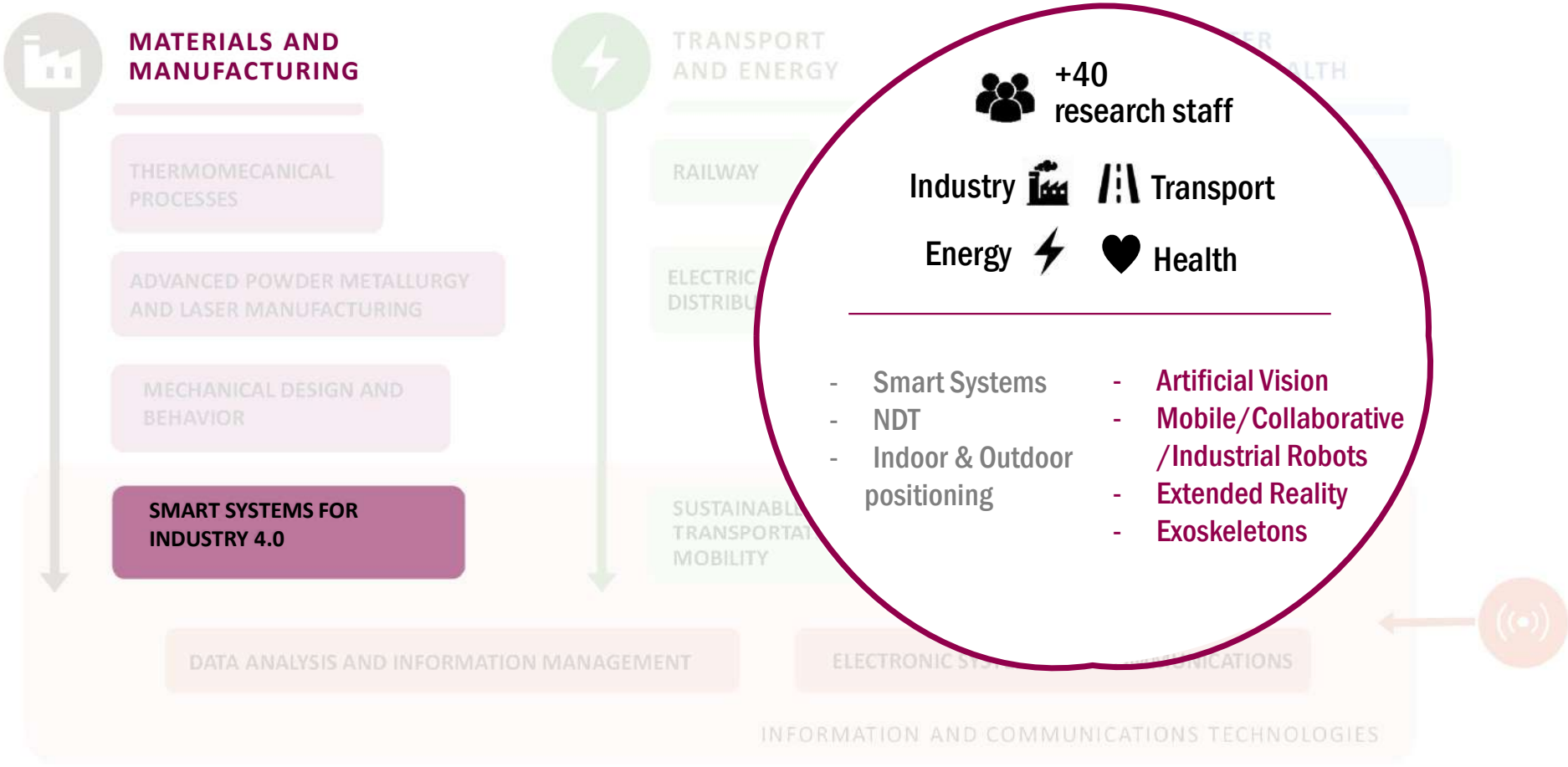
Organisation

## 4 Divisions and 11 Groups



# Institutional profile

Our Group



# Project context



The Permanent Magnets (PMs) sector is the most valuable end-user REEs

Nd-based PMs industry, represents ca. 68% of industrial REEs total demand by value

- Electric motors for convectional, hybrid and electric vehicles (ELVs).
- Industrial applications like wind turbines, pumps, rotors and magnetic separator.
- Household electronic equipment's.

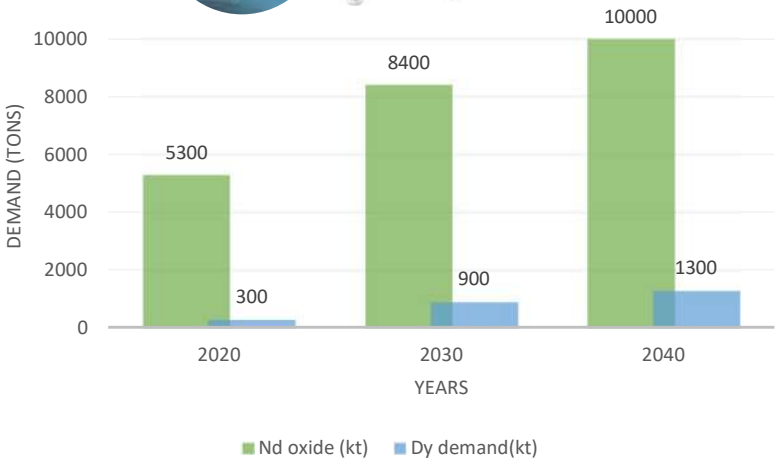
Due to the expansion of green technologies, global market size for PMs is expected to exhibit a robust 8% Compound annual growth rate (CAGR).

# Challenges in REEs supply





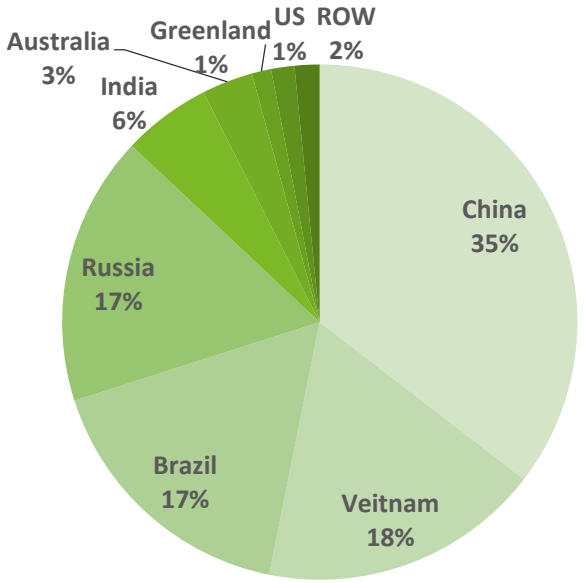
## INCREASING DEMAND WORLDWIDE AND IN EUROPE




Investment bank UBS, 2021(URL)

**The EU needs REEs to become climate-neutral continent by 2050**

## EU ~100% DEPENDENCY ON REES IMPORTS



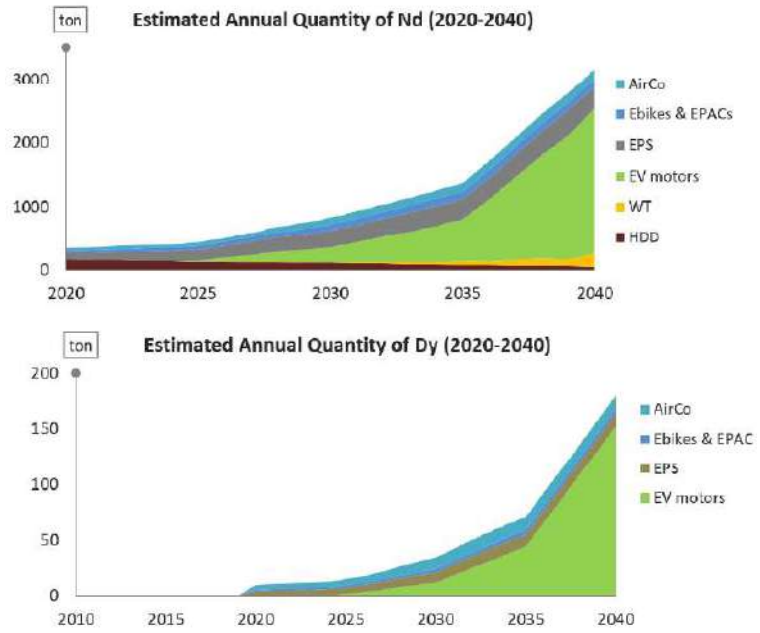

Worldwide reserves of rare earth (M. Garside 2022)

**EU imports ~98% REEs from China**

# Challenges in REEs supply



## Significant REEs quantities are available for recycling in Europe




Source: PNO market analysis REE4EU project (URL)

**Significant REEs quantities are available for recycling from different EoL products in EU**

## Lack of technologies for recycling

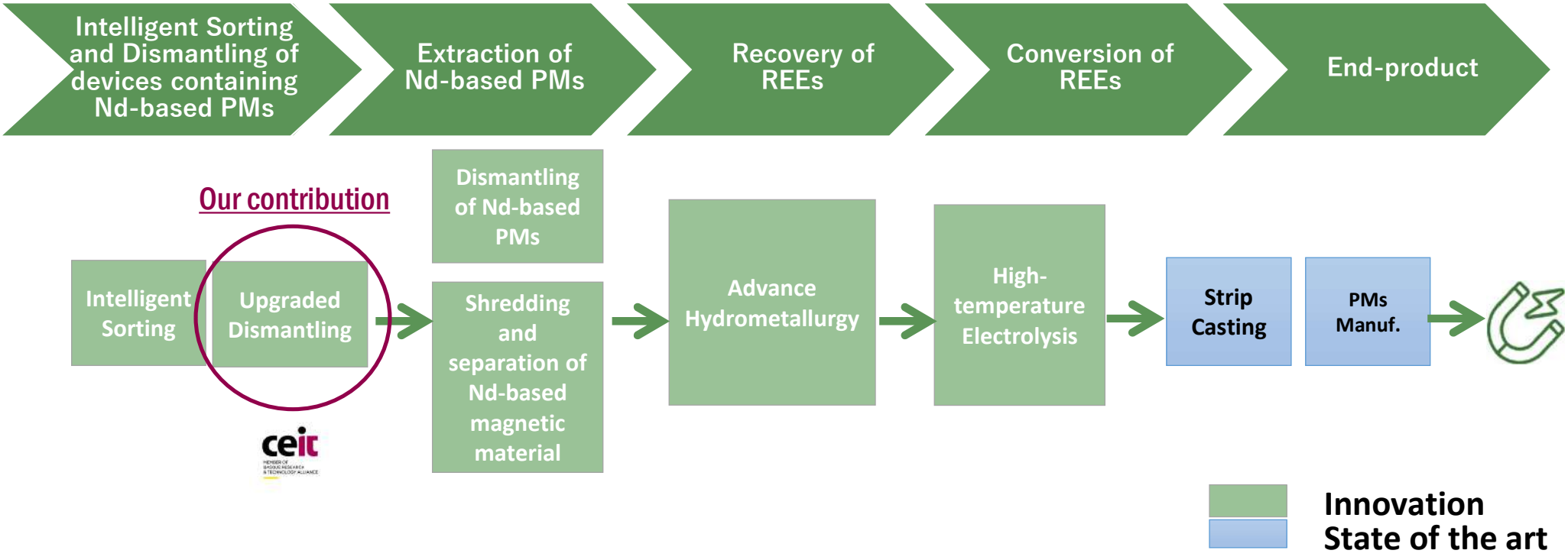
Source: E-scrap and complex raw material snapix (URL)

**No available technologies at industrial scale to sort, dismantle, extract and recover REEs from EoL products.**

# Aim and Objetives

"To set up for the first time a sustainable and complete **European REEs-recycling value chain** at industrial scale, able to produce REEs from EoL products at competitive cost and with environmentally friendly **technologies** for the **green strategic sectors**".

**A complete European REEs-recycling value chain, at industrial scale for the recovery of REEs in a most efficient, economical and sustainable way.**



# Dismantling precedence graph: hoverboard





- Arrows point towards those nodes that must be removed previously

- 15 tasks to undertake in an automatic way
  - Except 1 manual tasks: wires cut

- 35 elements to be dismantled

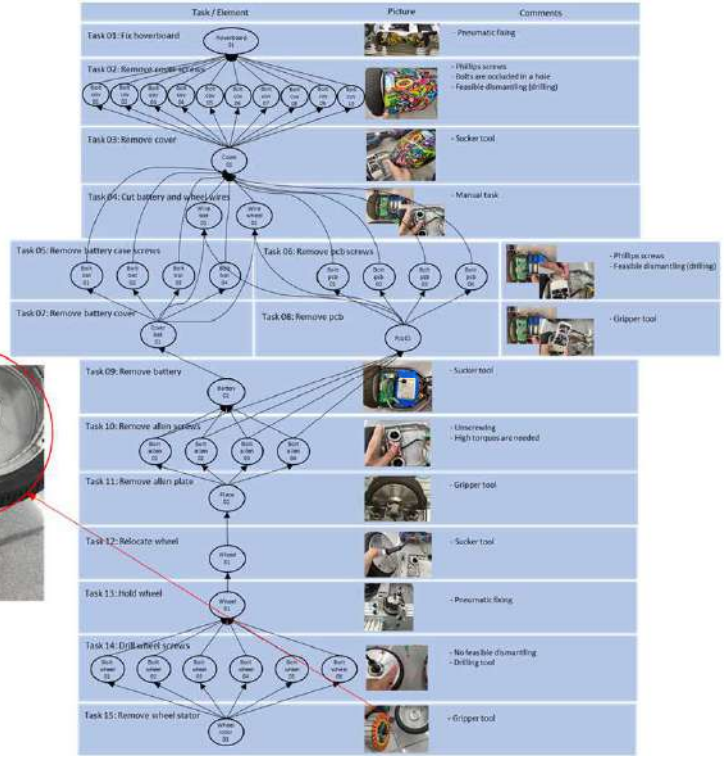
- 5 tools used:
  - Drill
  - 3-finger gripper
  - 2-finger gripper
  - Vacuum (own design)
  - Unscrewdriver (own design)

<u>Input</u>
RAEE product: hoverboard

<u>Output</u>
REE element: Nd magnets


1. Fix hoverboard
2. Remove case screws
3. Remove case
4. Cut battery and wheel wires
5. Remove battery case screws
6. Remove pcb screws
7. Remove battery case
8. Remove pcb
9. Remove battery
10. Remove allen screws
11. Remove allen plate
12. Relocate wheel
13. Fix wheel
14. Drill wheel screws
15. Remove wheel stator


Result for WP3



# Dismantling precedence graph: HDD

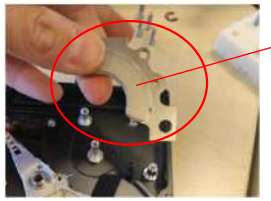




- Arrows point towards those nodes that must be removed previously
- 7 tasks to undertake in an automatic way
- 12 elements to be dismantled
- 3 tools used:
  - Drill
  - Vacuum (own design)
  - Magnetic picking tool (own design)

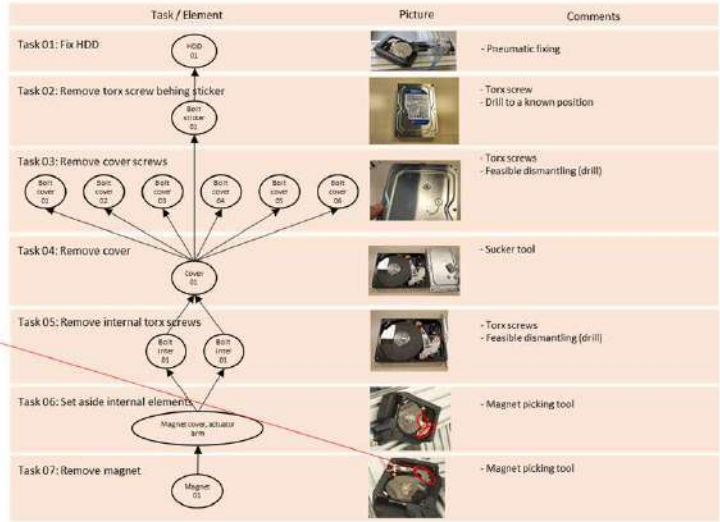
<u>Input</u>
RAEE product: HDD

<u>Output</u>
REE element: Nd magnets




1. Fix HDD
2. Remove torx screw behind sticker
3. Remove cover torx screws
4. Remove upper case
5. Remove internal torx screws
6. Set aside magnet cover and actuator arm
7. Remove magnet

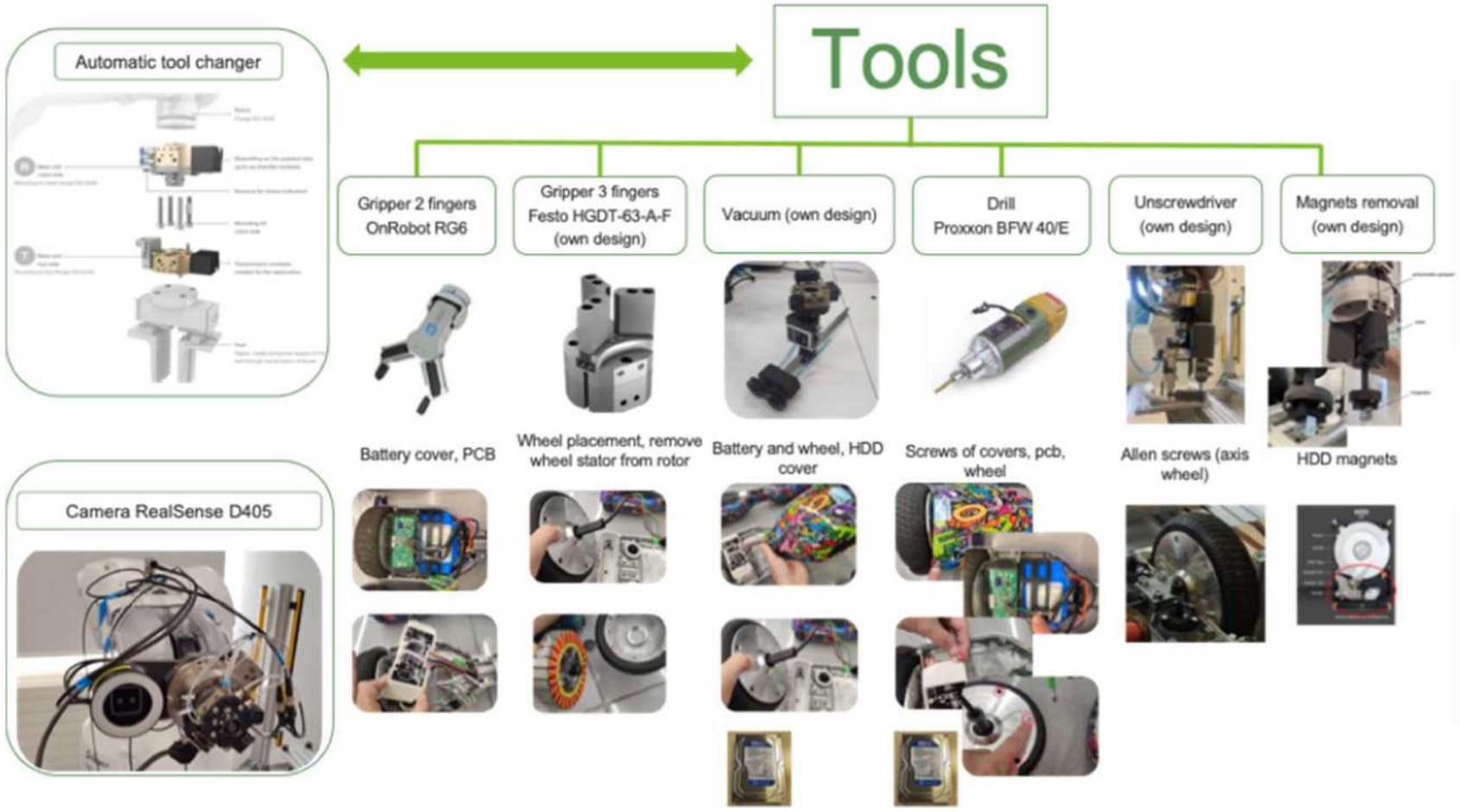
Result for WP3



# Our solution: tools used and tasks



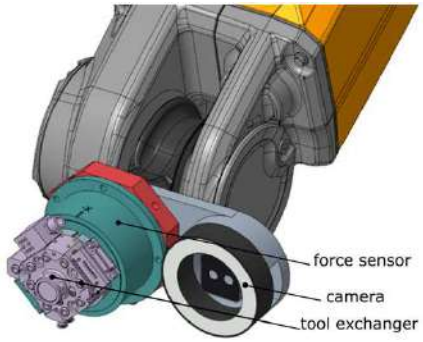


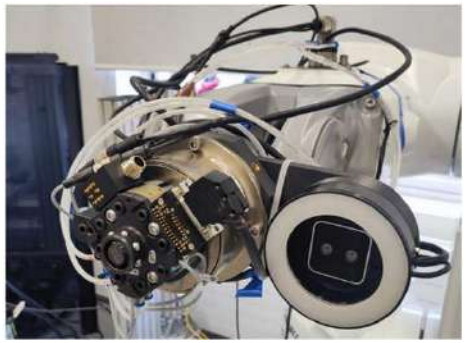


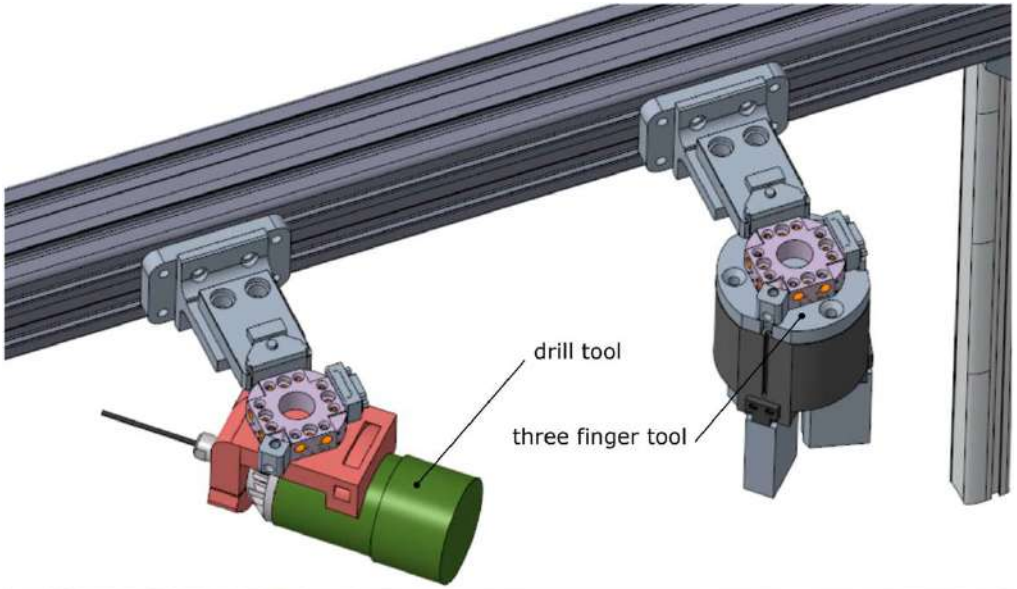
# Tools used summary





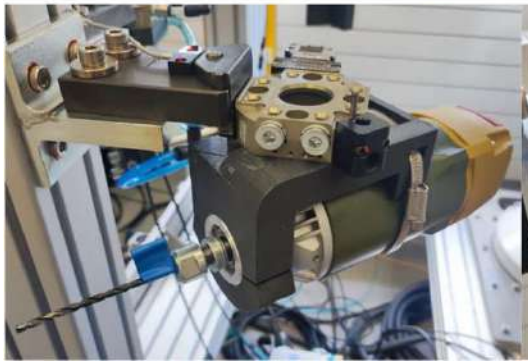


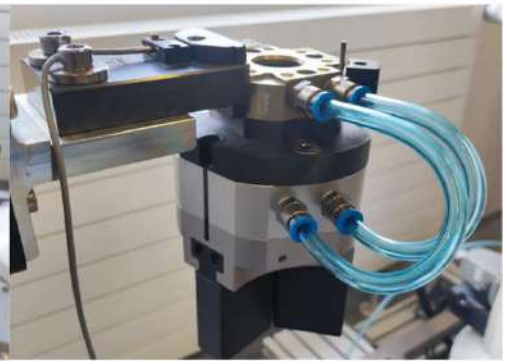






| Model | FOV (mm) | Z-Range (mm) | WD (mm) | Resolution (um) | | | Points | Wavelength (nm) | kHz | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | X | Y | Z | | | | |
| RealSense 405 | X: 84°<br>Y: 58° | 500 | 100 | | | 2% | 1280 X 720 (0,92 MP) | 850 | 0,03 | Focal length: 1,93mm |

| Model | Color | Wavelength (nm) | Power (W) | Type |
|---|---|---|---|---|
| DRL-E-W100 | White | 400-700 | 5,76 | Ring |

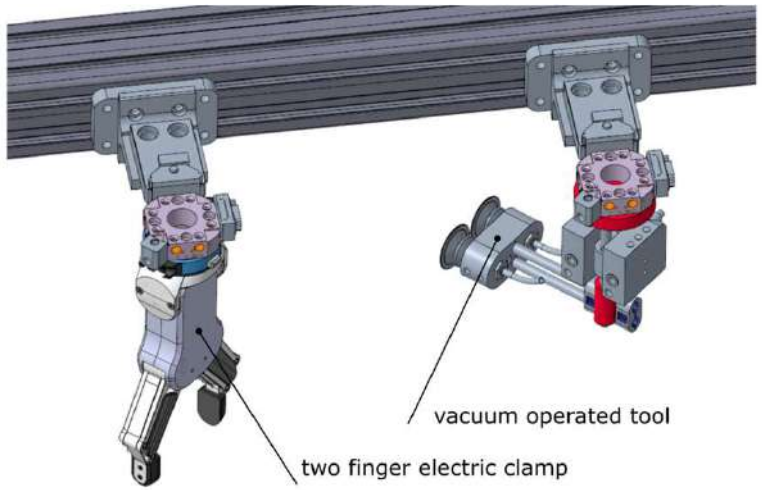


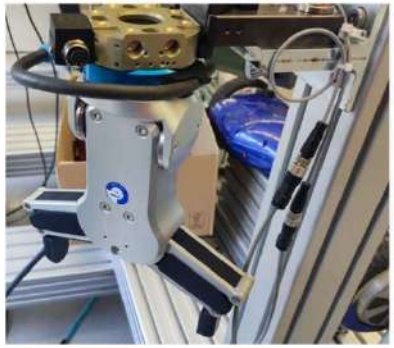


# Tools used summary







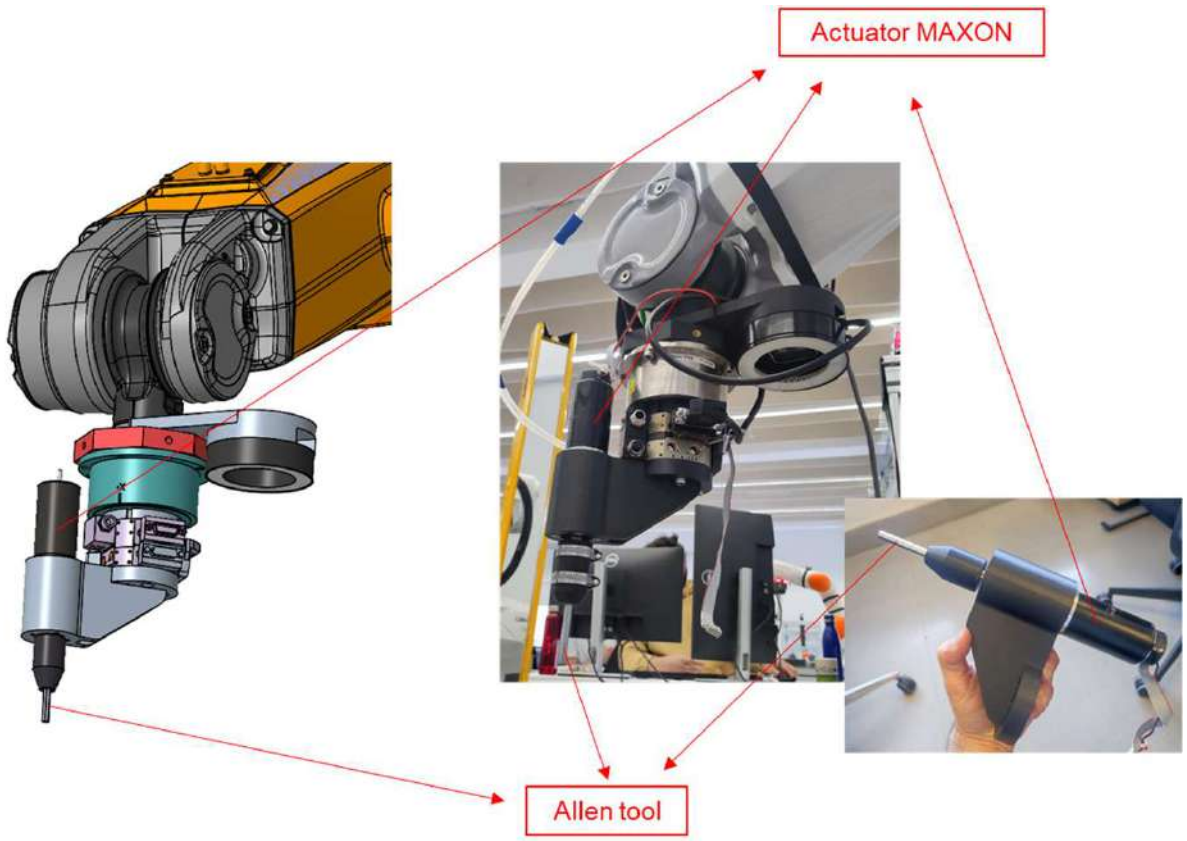



# Hoverboard: allen screws





- New tool designed (unscrewdriver)



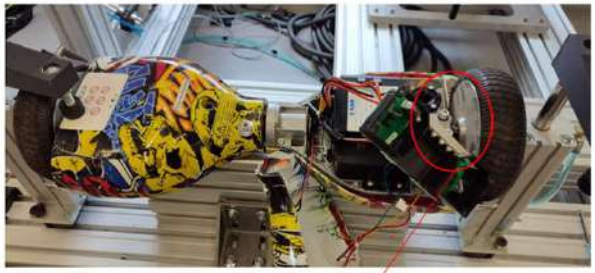



Figure 1: Hoverboard used

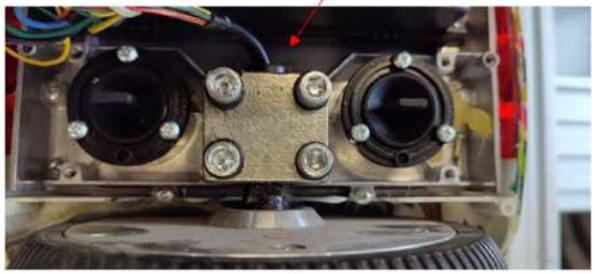
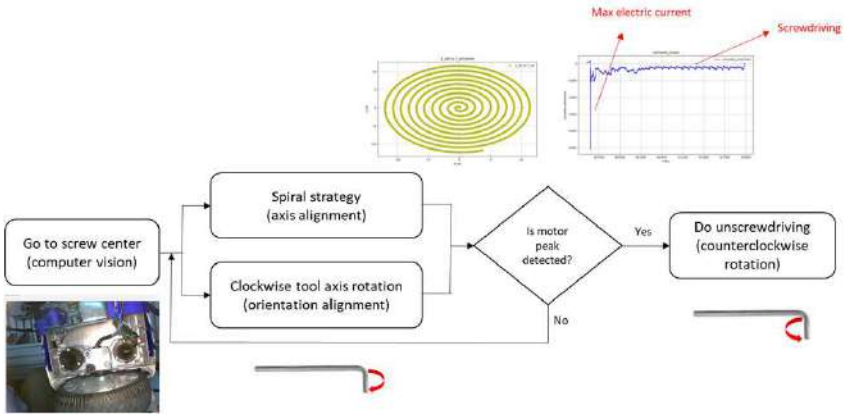


Figure 2: Allen screws

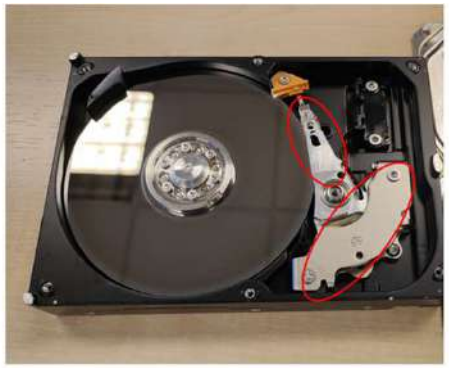


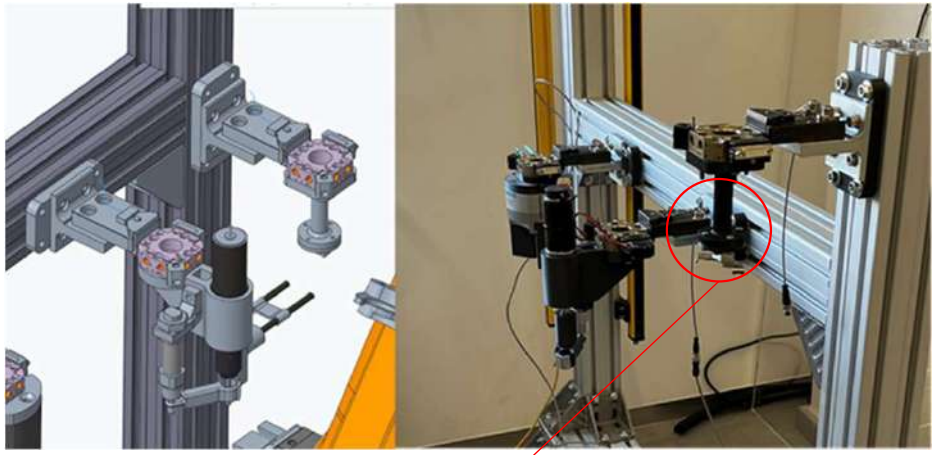
# HDD: small magnetic elements





- Complex problem:
  - Small elements: actuator arm, magnet cover, magnet itself
  - Magnetics
  - Bus cable attached to the actuator arm
  - …
- Grippers, pry tools, etc., doesn't work
- New magnetic picking tool designed →

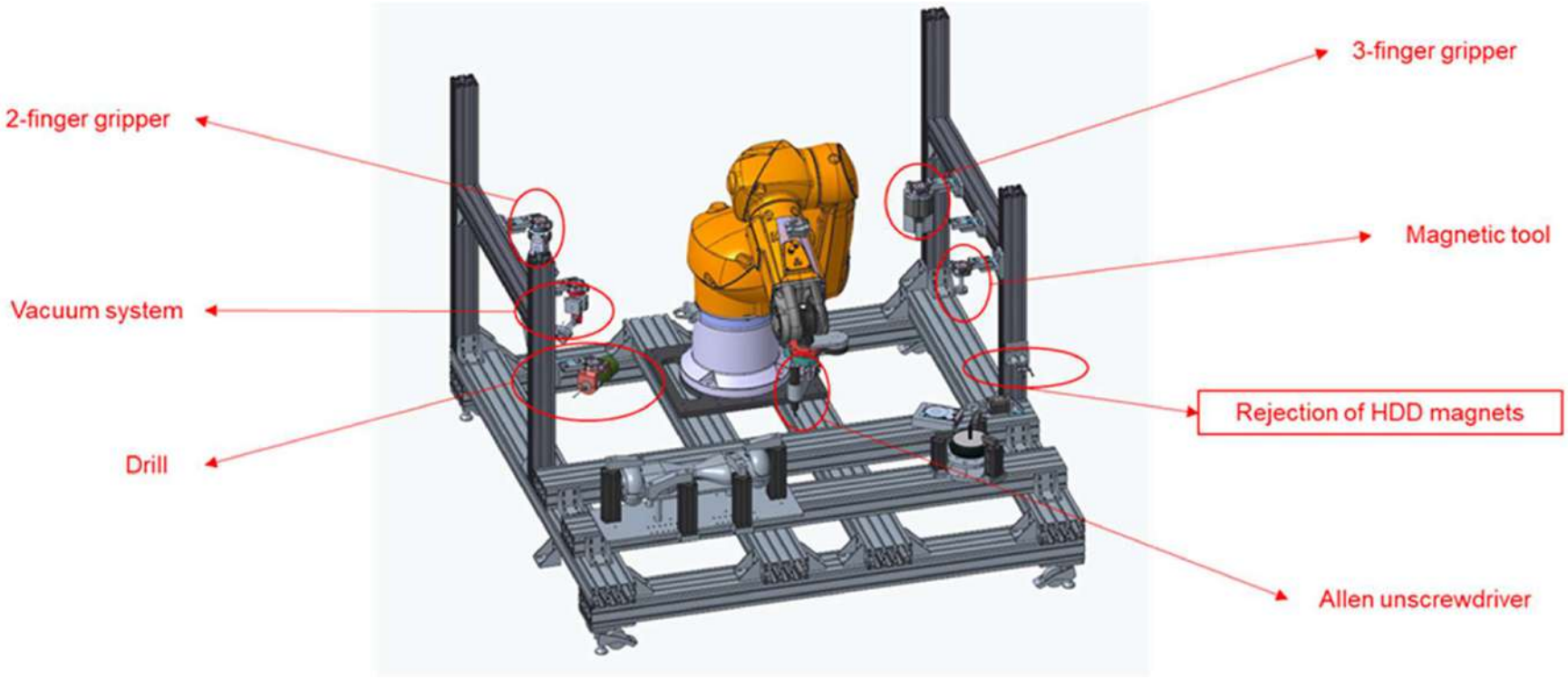




# Robotic 3D cell layout







# Robotic cell layout





# Databases for Computer Vision tasks





- AI models for classification, detection/localization and recognition of elements
- Requiring complex AI techniques to dare with:
  - High and different number of tasks, elements,…
  - Waste condition
  - Device variability

- Total database: 2.385 + 404 images for training AI models (labelling)

Hoverboard

| Stage | Images |
|---|---|
| Exterior | 1.000 |
| Interior | 345 |
| Allen | 423 |
| Wheel | 617 |

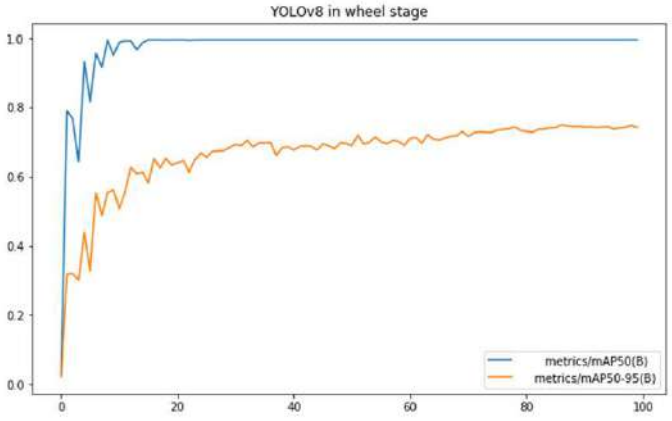
HDD

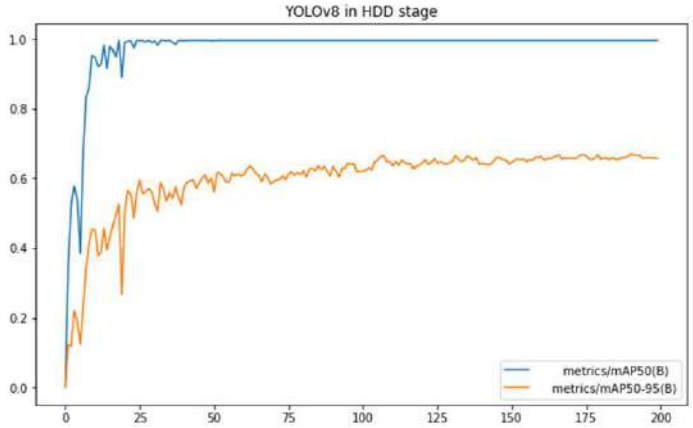
| Stage | Images |
|---|---|
| Exterior | 252 |
| Interior | 152 |

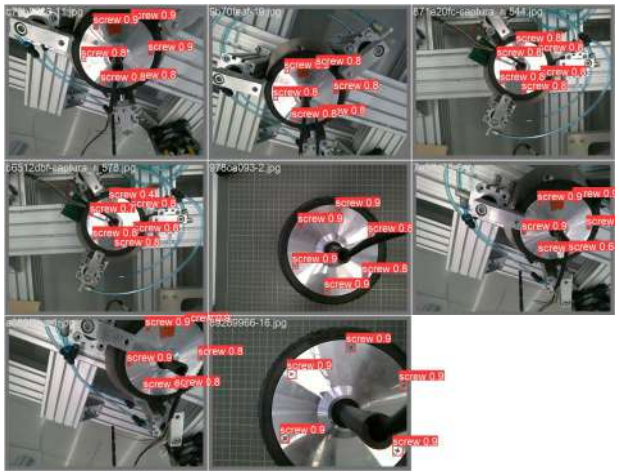
# Training of Deep Learning models



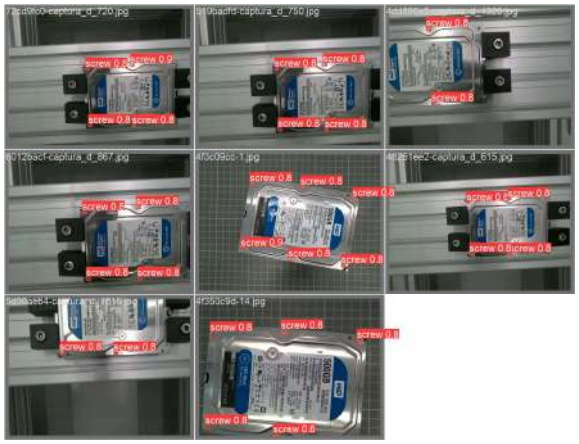




| Stage | Images | Inference Time (ms) v8-X | DETR-X | v11-X | mAP val v8-X | DETR-X | v11-X |
|---|---|---|---|---|---|---|---|
| Exterior | 1.000 | 12.3 | 13.5 | **10.3** | **0.822** | 0.808 | 0.813 |
| Interior | 345 | 15.2 | 18.1 | **13.6** | 0.890 | 0.878 | **0.892** |
| Allen | 423 | 15.5 | 17.6 | **12.2** | **0.987** | 0.982 | 0.984 |
| Wheel | 617 | 16.6 | 17.7 | **14.8** | 0.789 | 0.695 | **0.794** |



| Stage | Images | Inference Time (ms) v8-X | DETR-X | v11-X | mAP val v8-X | DETR-X | v11-X |
|---|---|---|---|---|---|---|---|
| Exterior | 252 | 18.6 | 19.7 | **16.8** | 0.782 | 0.780 | **0.791** |
| Interior | 152 | 19.8 | 21.3 | **17.9** | 0.845 | 0.850 | **0.857** |

# Video



REEPROCYCE

## Robotic intelligent dismantling for Nd magnets recycling

Use case: hoverboard

# Expected benefits





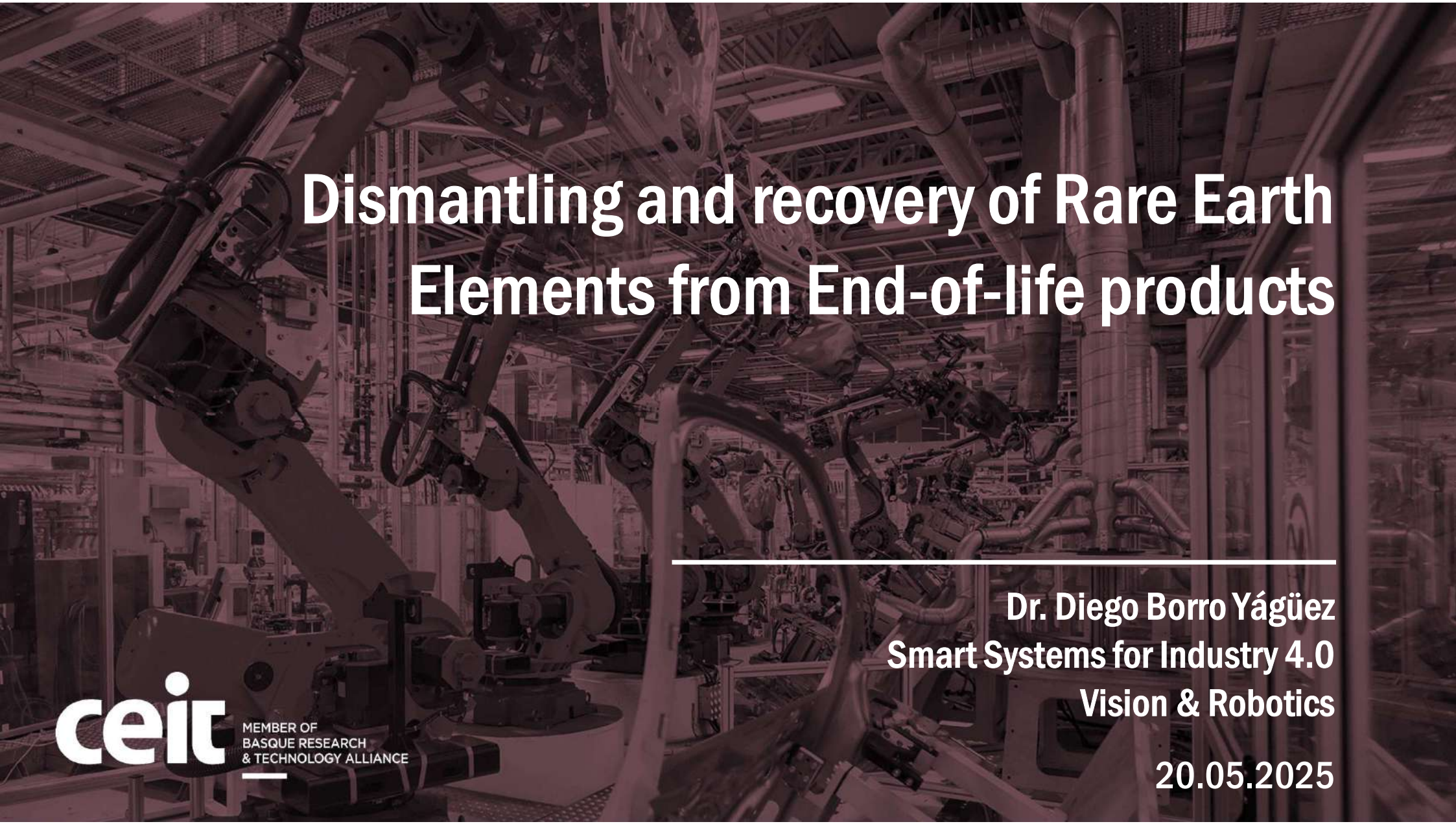
The manual dismantling of the magnets in the wheels is not carried out since currently, it is not economically viable. This results in the loss of critical materials during the recycling process. However, using automatic dismantling allows for the recovery of the magnets, making their recycling possible and increasing thus the recovery ratio of critical raw materials

No dismantling machines in the market. Our technology can be exploited by companies in a new and emergent market. The dismantling automation will be mandatory in the near future


The robotic system can work 24/7 and does not get tired

It does not have any subjectivity that can vary from person to person

It has no physical safety problems for the operators



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