Lessons learnt and future vision on remote maintenance robots

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BE-CEM

FCC Week 2022, May 30th – June 3rd, Paris France

Technology Session

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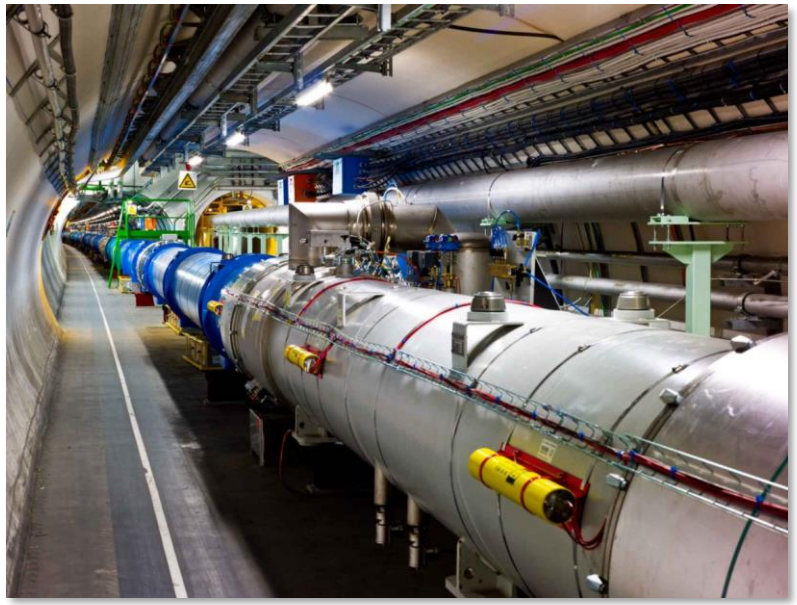
Main Needs for Robotics at CERN

- Inspection, operation and maintenance of radioactive particle accelerators devices towards maintainability and availability increase
  - ✓ Experimental areas and objects not built to be remote handled/inspected
    - ✓ Any intervention may lead to “surprises”
    - ✓ Risk of contamination



The LHC tunnel

North Area experimental zone

Radioactive sample handled by a robot

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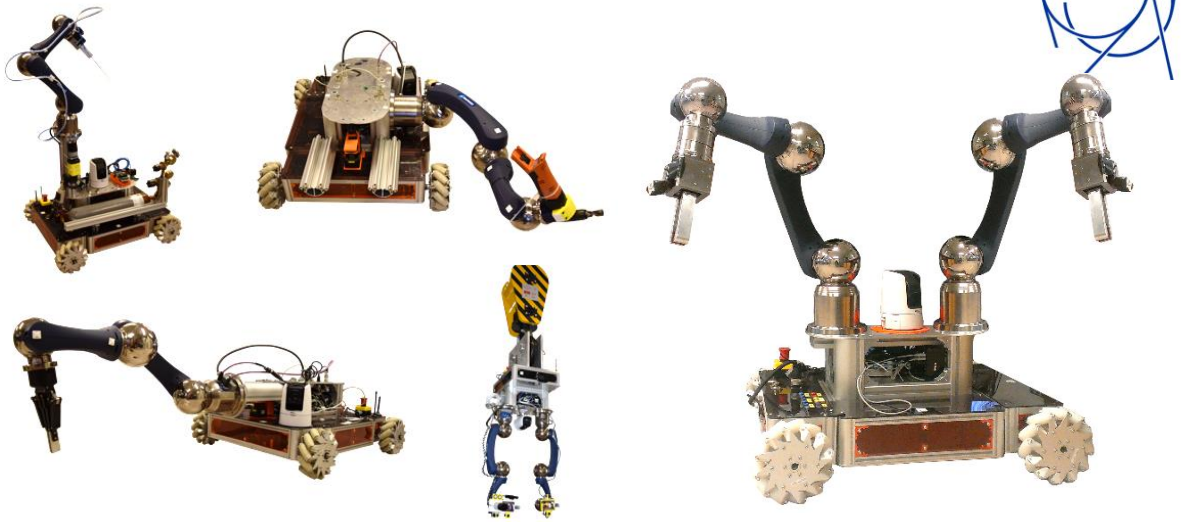
CERN's Robots [2]

Telemax robot

Teodor robot



CERNBot in different configurations(CERN made)

Train Inspection Monorail (CERN made)

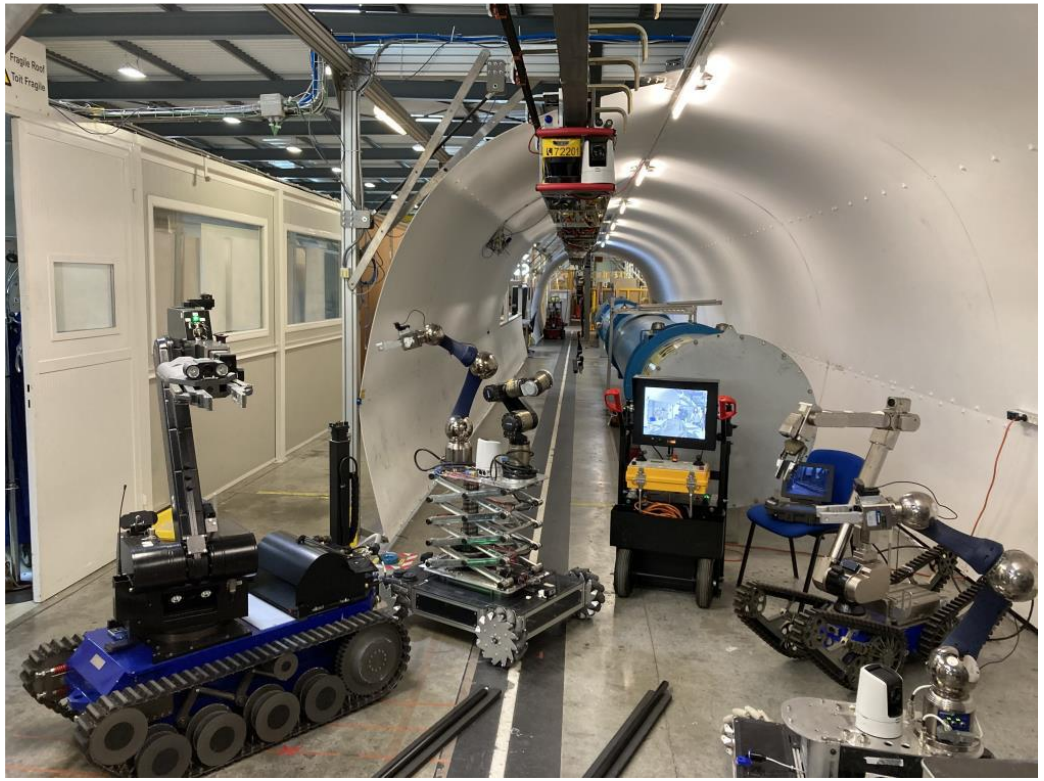
CERNBot (CERN made)

EXTRM Robot (CERN made)

Drones

Robots are mainly used at CERN for:

- Environmental measurements, maintenance and inspection in radioactive areas
- Human intervention procedures preparation
- Quality assurance
- Post-mortem analysis/inspection of radioactive devices
- Reconnaissance
- Search and rescue



CERN Robots in the Workshop Mockup Area

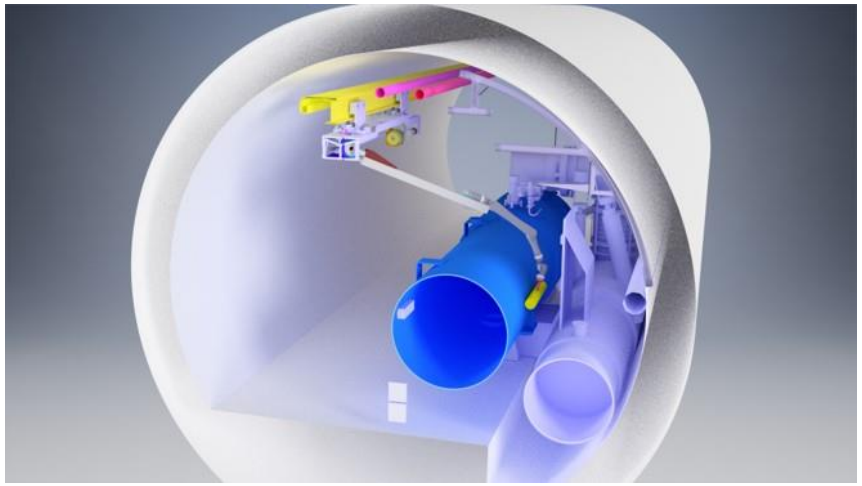
Main Motivations for Custom Robotic Development

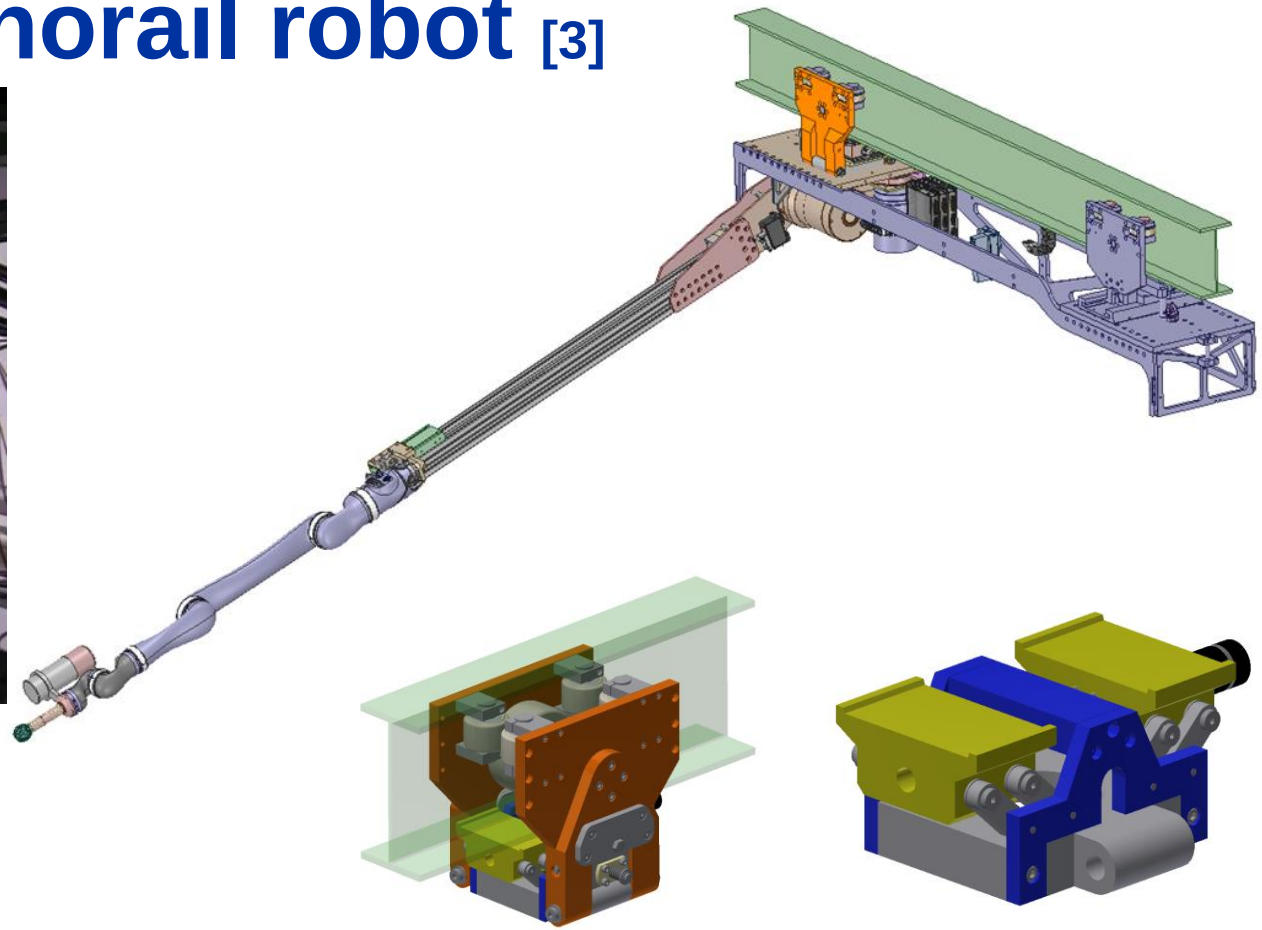
- Industrial solutions do not cover all of CERN needs for remote maintenance and quality control, and have **complicated user interfaces** requiring extensive training
  - ✓ Often use radio links for communications
  - ✓ Not built to reduce contamination risks
  - ✓ Hard to integrate with other systems

- Strong need to develop **a modular and adaptable robotic framework/system for** unstructured and harsh environments

- Necessity of having the human, the machine and the interface working together adopting **user friendly interfaces**
  - ✓ Increase of proprioception reducing operator's stress

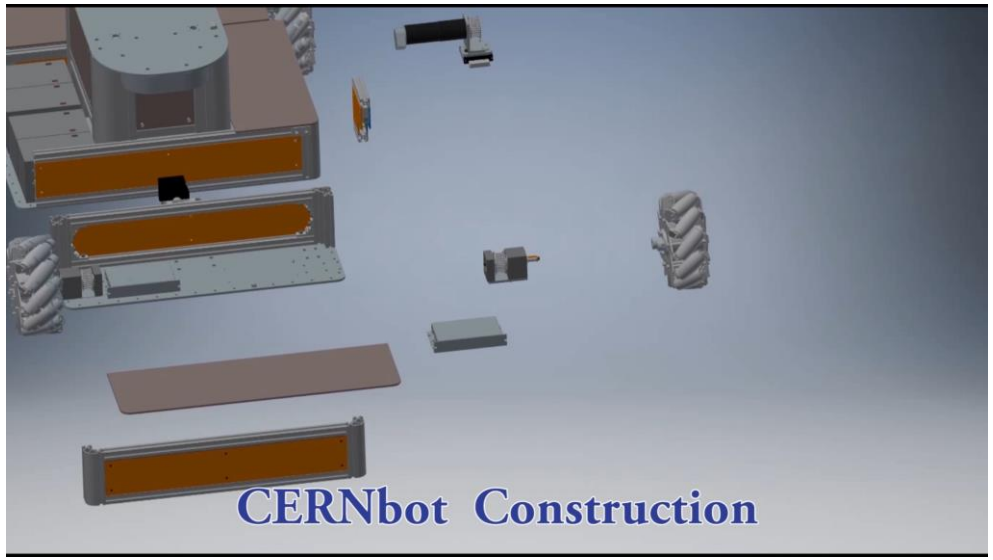
TIM: Train Inspection Monorail robot [3]



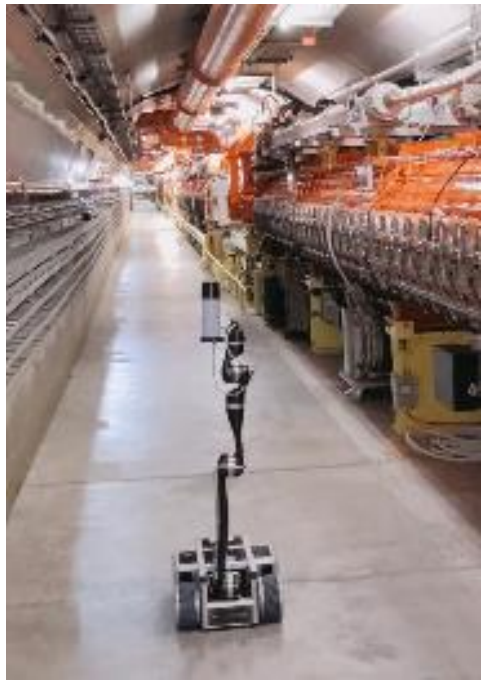


- Monorail mounted robot with different wagons – motors, batteries, sensors, arms
- Different wagons for specific missions

CERNbot robot [4]



- CERNBot is a custom ground robotic platform normally equipped with two robotic 6DOF arms and grippers for bimanual operation



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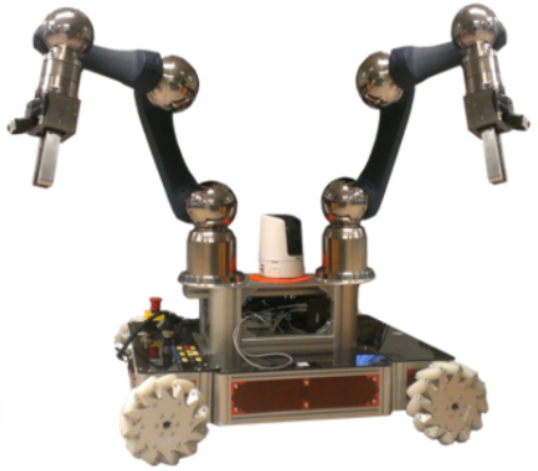
CERN Software: CERNTAURO Framework [5]



ROBOT WITH INSTALLED EQUIPMENT AND ITS ON-BOARD COMPUTER

CERN ROBOTIC FRAMEWORK (C++ framework)

Communication with devices

Processing the information from sensors

Real-time control

Communication points

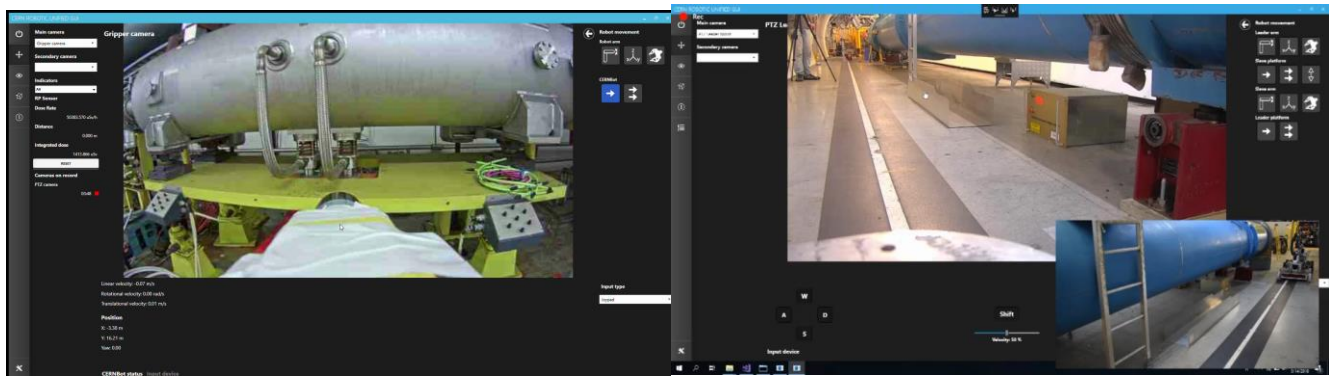
Communication over mobile 4G network, WiFi or CERN internal network

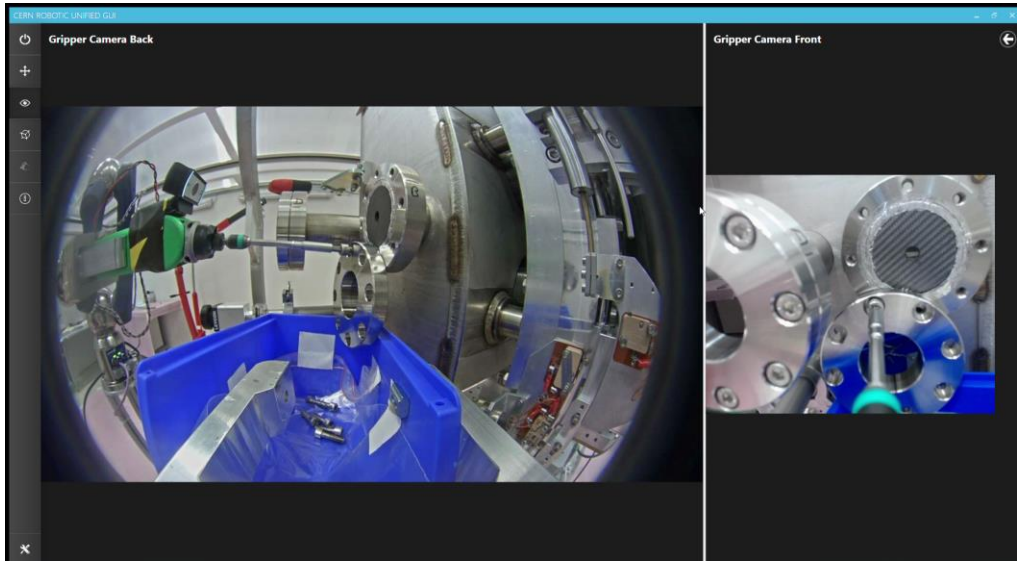
2D GUI (Windows Presentation Foundation, C#)

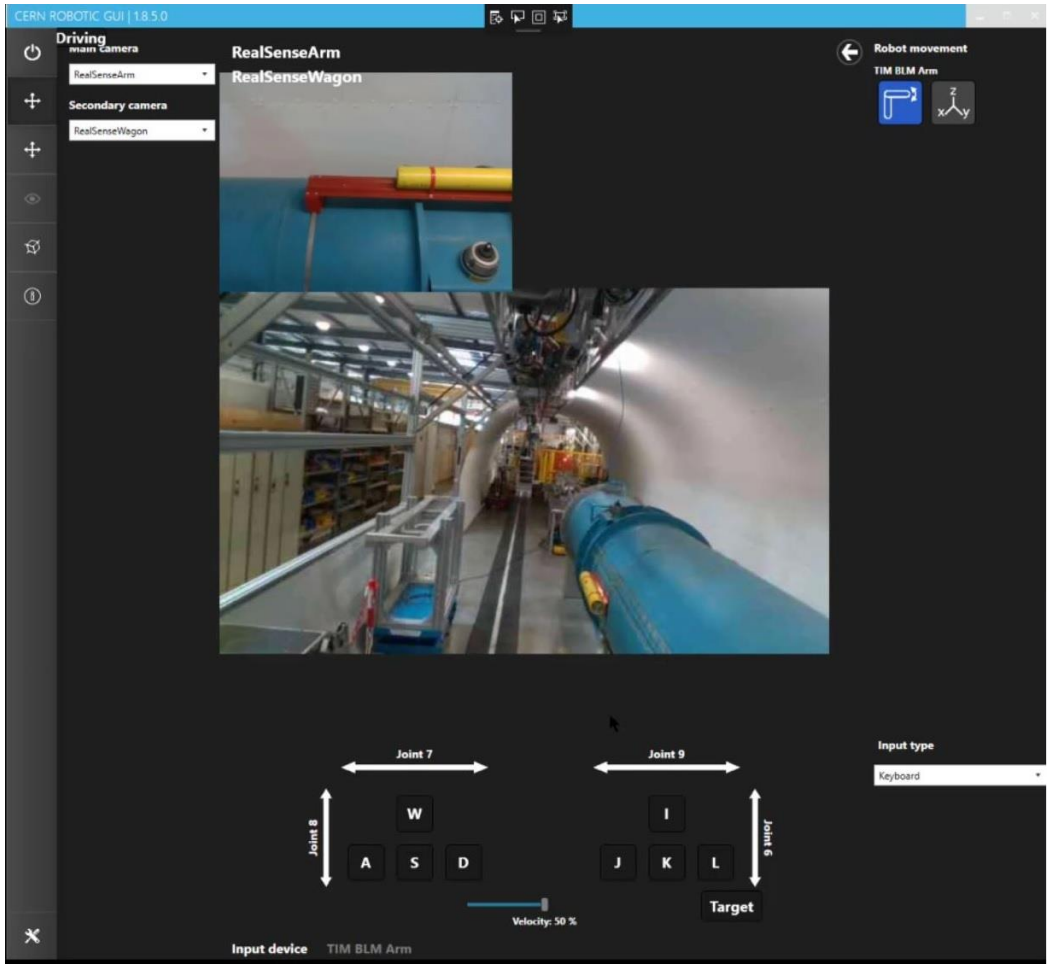
3D (Mixed Reality) GUI (Unity, C#)

TELEOPERATOR CONTROLLING THE ROBOT VIA A PC OR USING HEAD-MOUNTED DEVICES

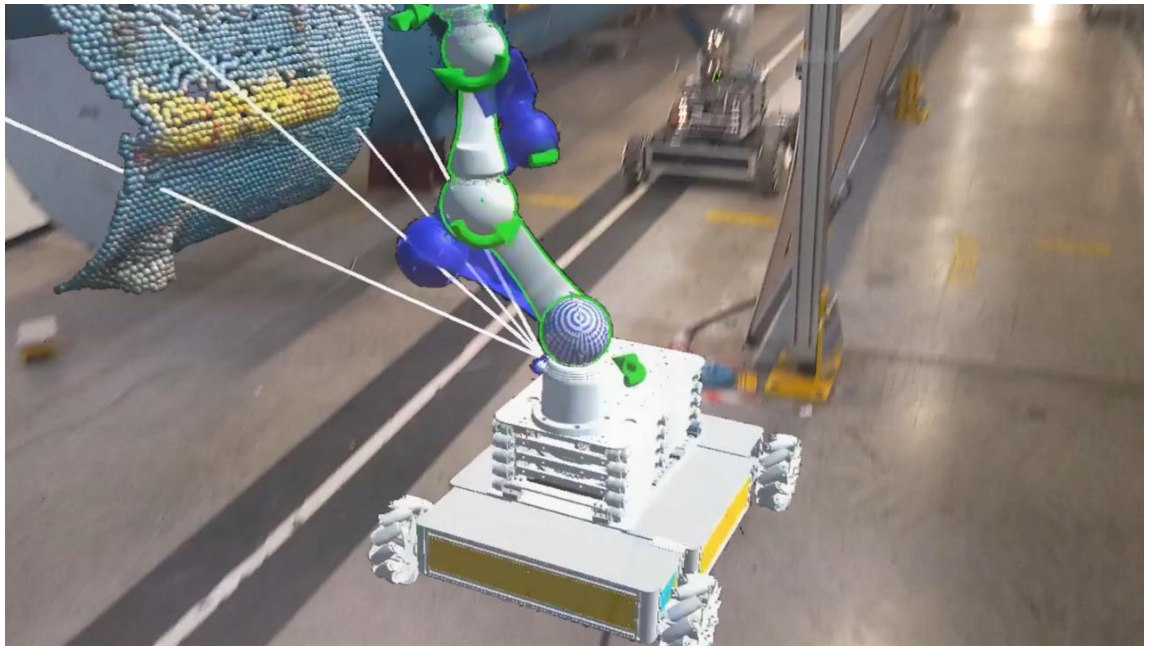
CERN Software: 2D GUI [6]







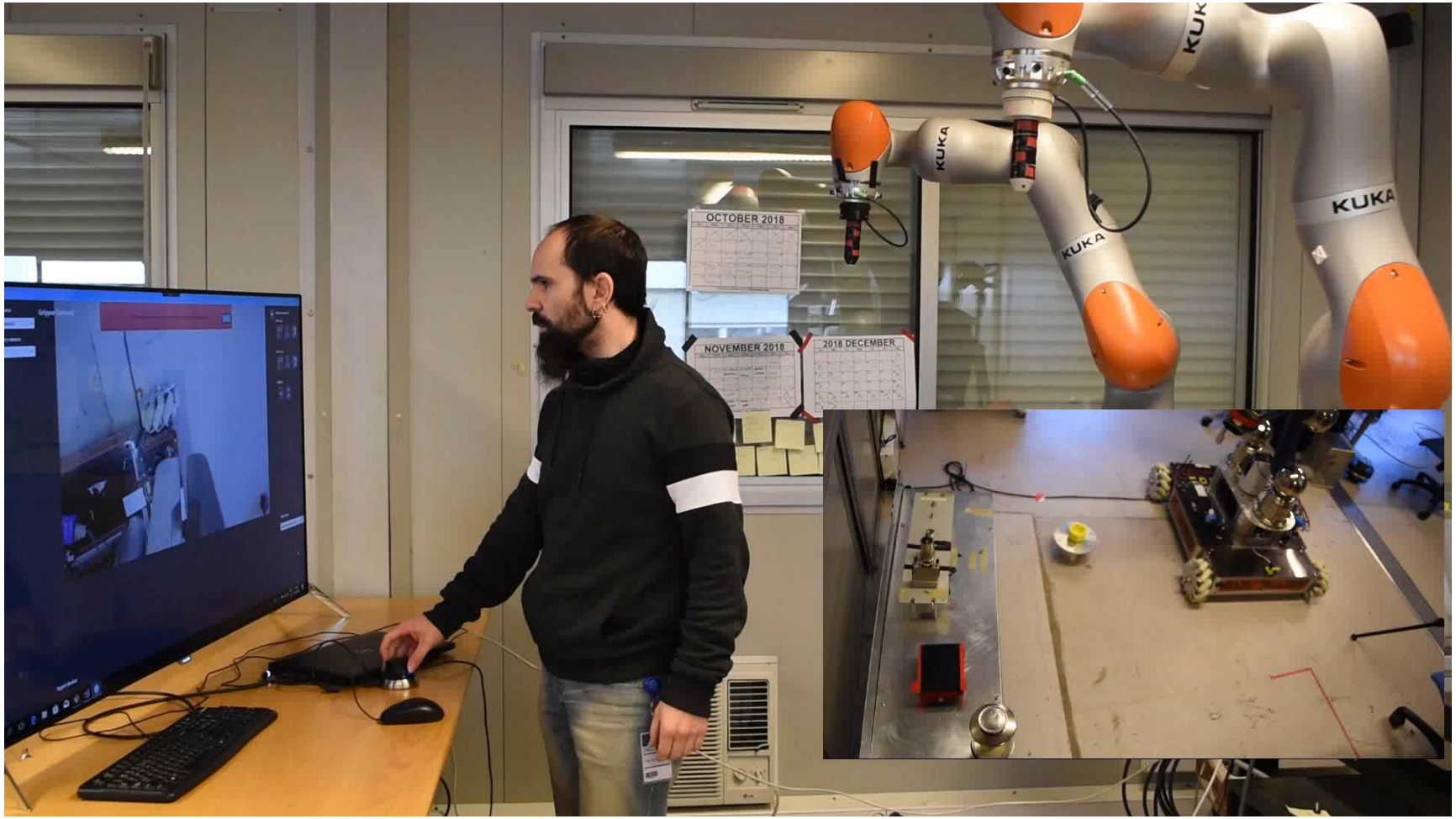
CERN Software: 3D GUI



Mockup test with the CERNBot

Tunnel test with TIM

CERN Software: Haptic Feedback



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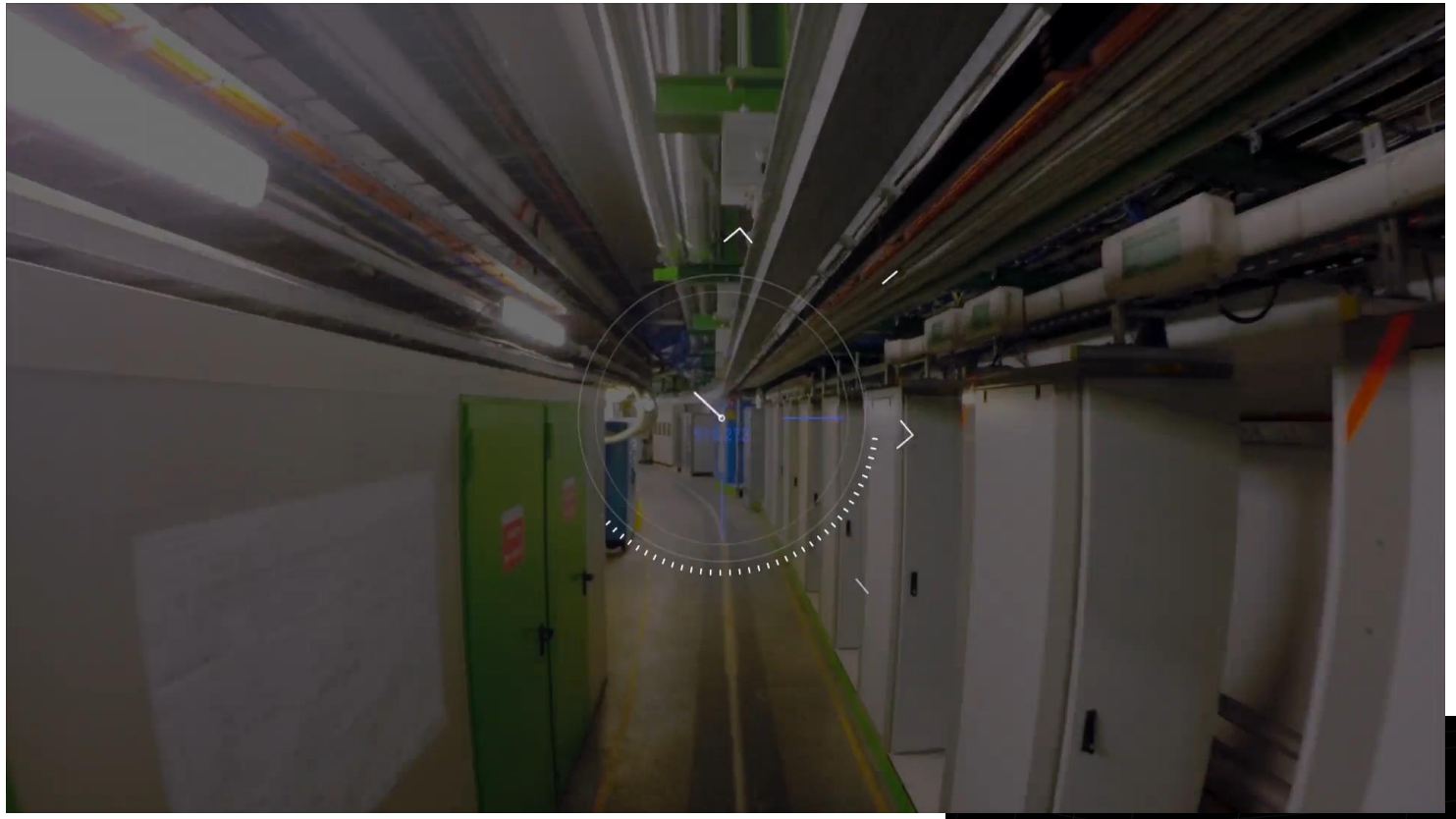
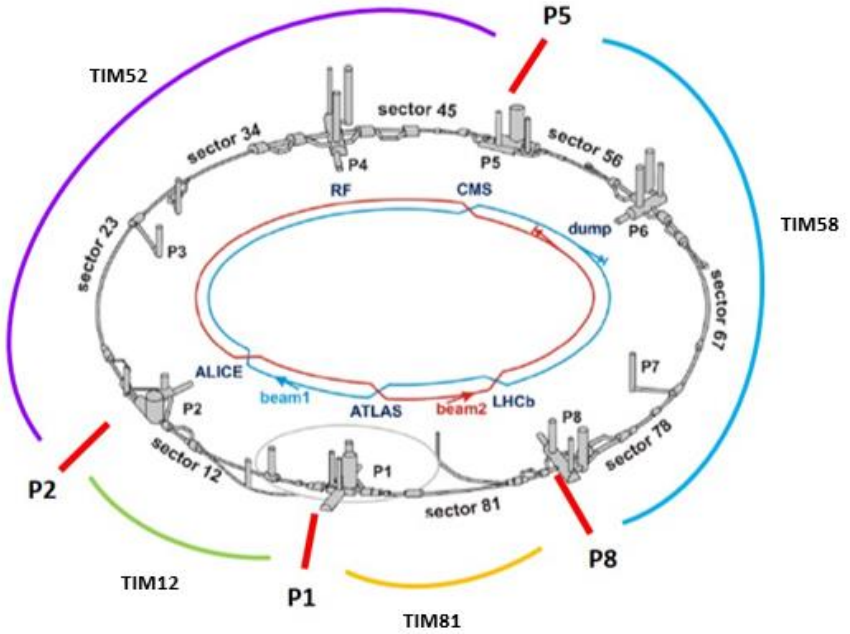
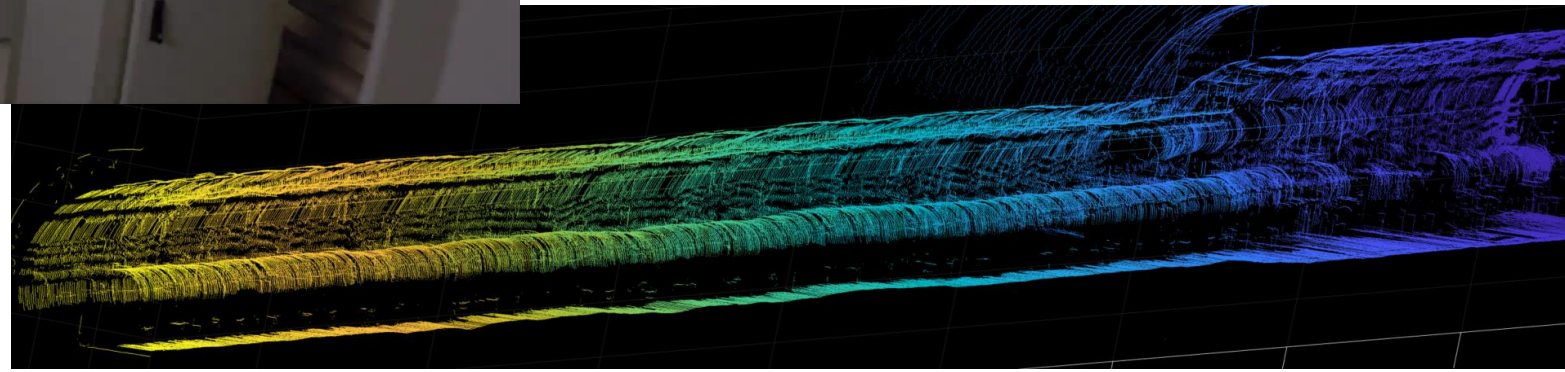
LHC TIM Robot for RP surveys

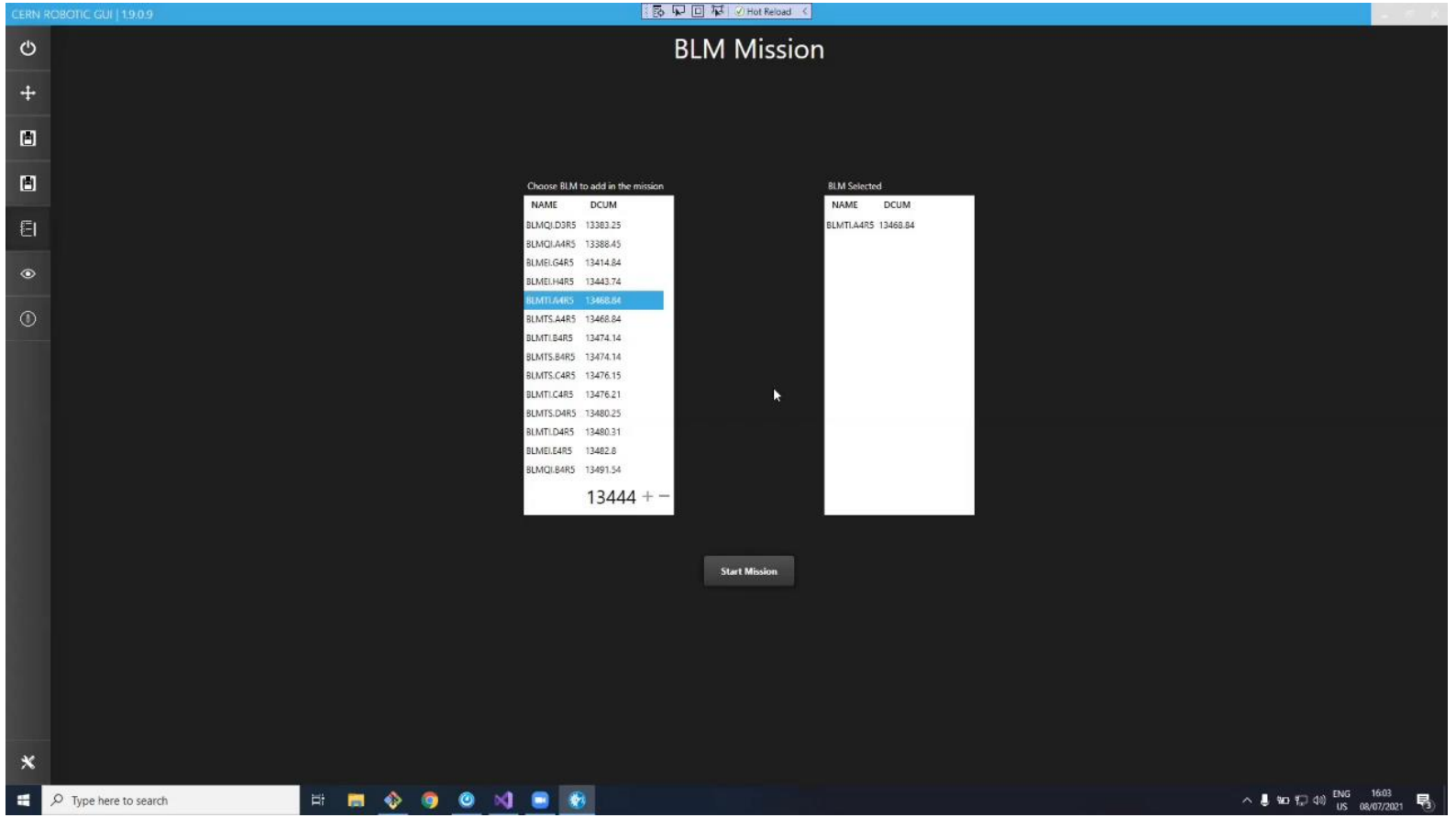


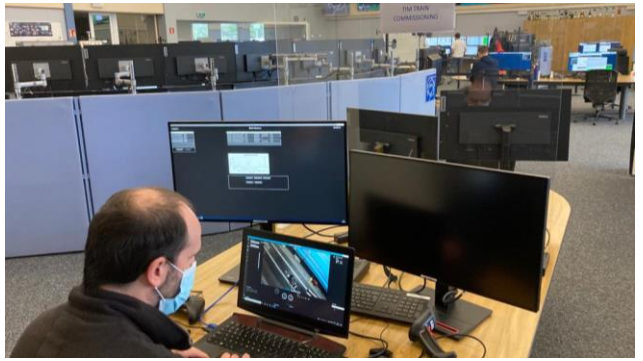




LHC TIM Robot for BLM Validation

- BLM Validation campaign in 2021



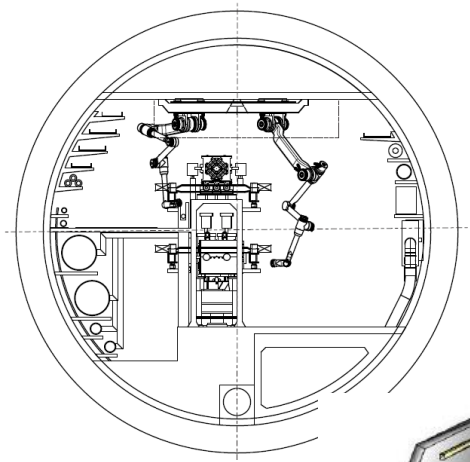


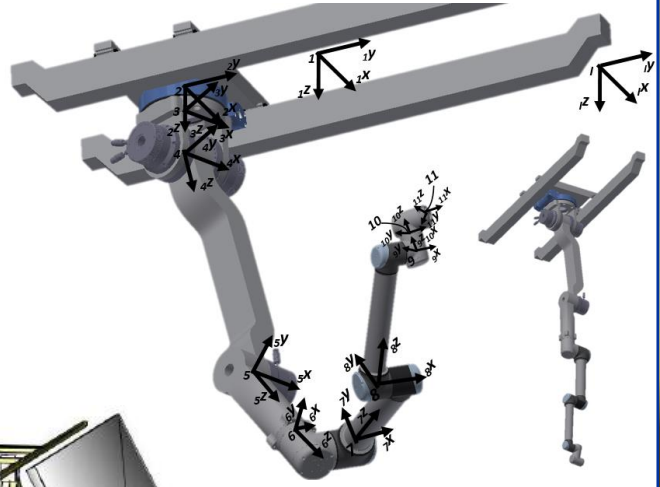
SPS Robot

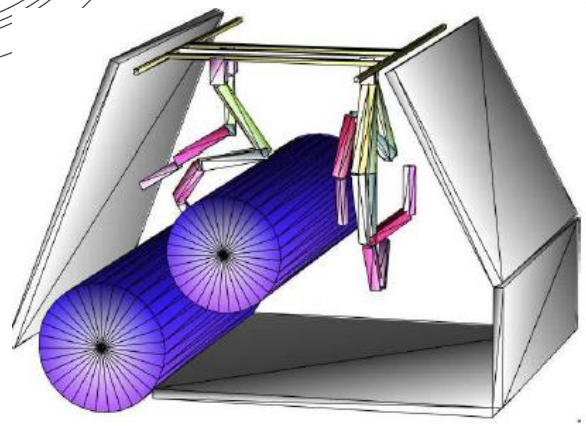
- Permanently installed robot with charging system in 2021
- Main function to perform RP surveys and other inspection tasks
- Equipped with 6DOF arm
- Autonomous sector door detection, recognition and passage – heavily relies on vision

Robotics for the FCC [1]

- Novel robotics platforms and controls for remote maintenance and intervention in case of accident.
- Ability to reach 100km of ring within 10 minutes

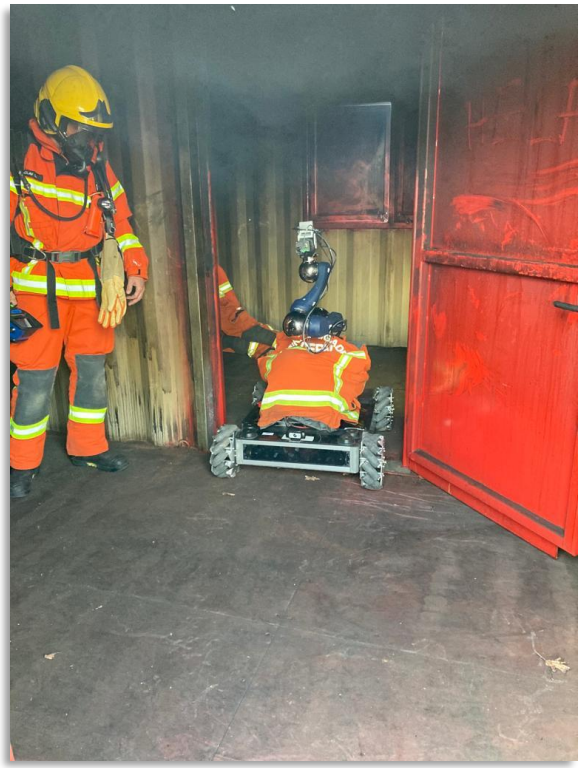


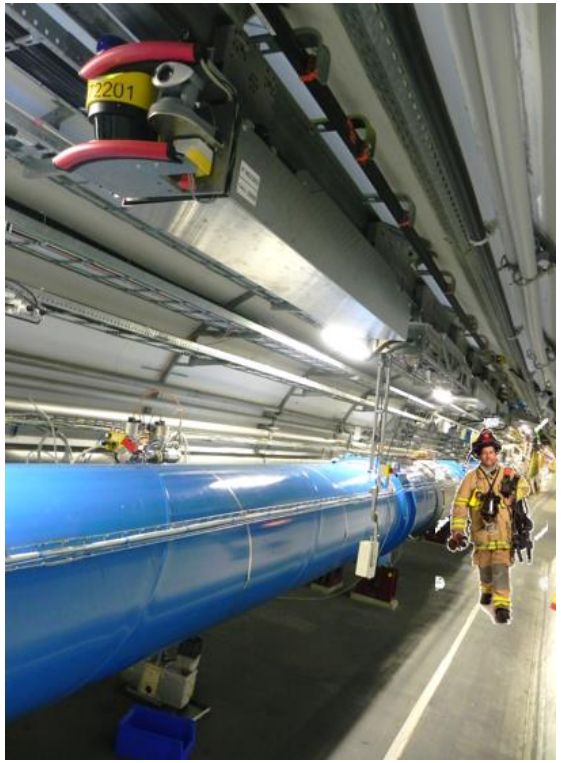


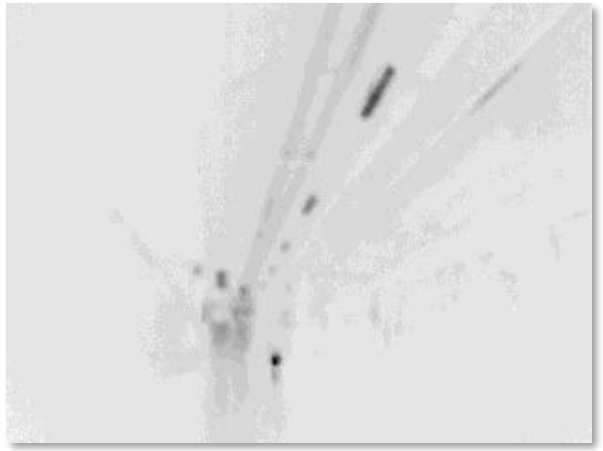


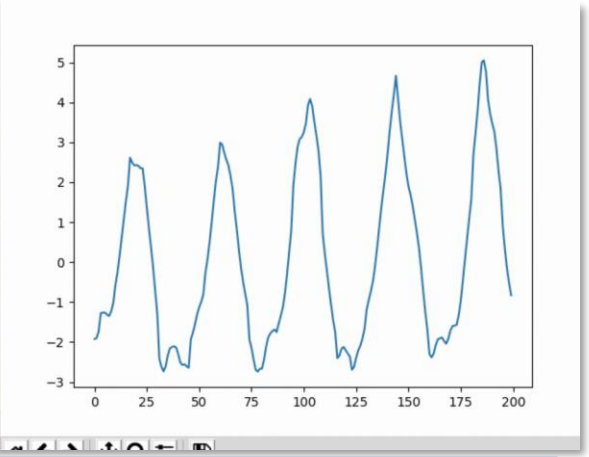
Robots for Search and Rescue

- More Info: Oriel Rios @ Thursday 2nd 14.00 – 15.30: Technical Infrastructures
  - ✓ Follow and ‘drone’ firefighters
  - ✓ Precise personnel location in smoke
  - ✓ Remote health monitoring





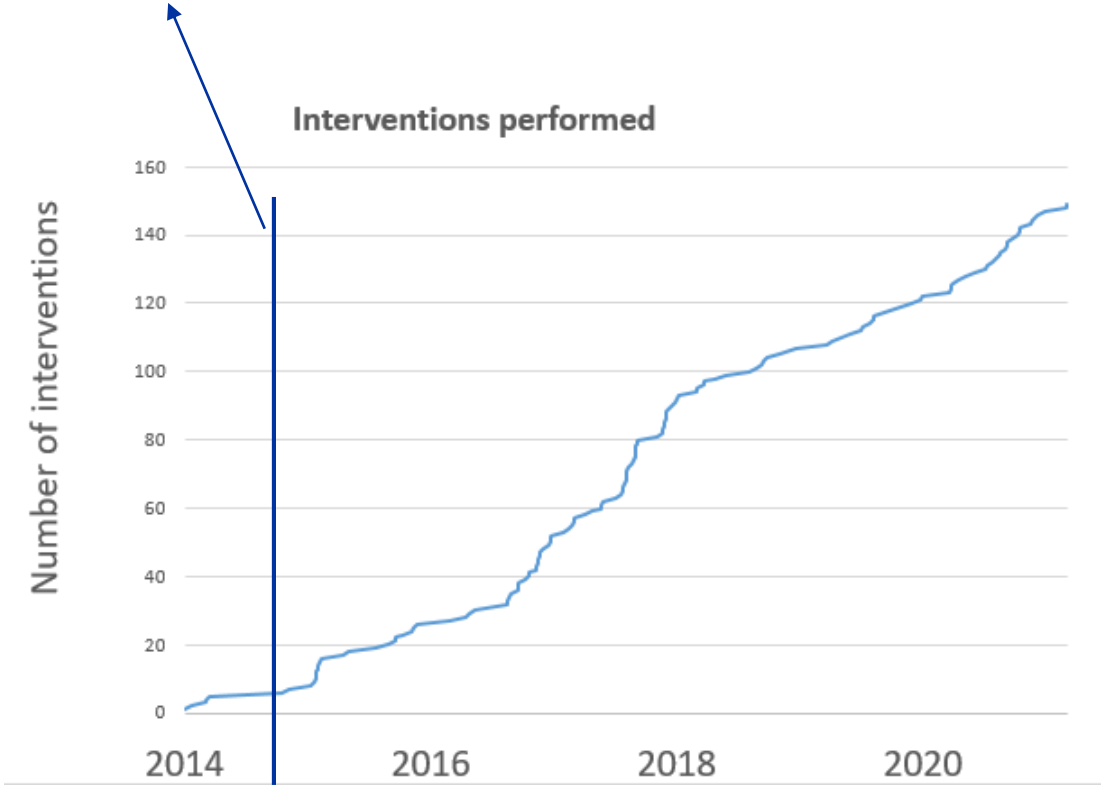


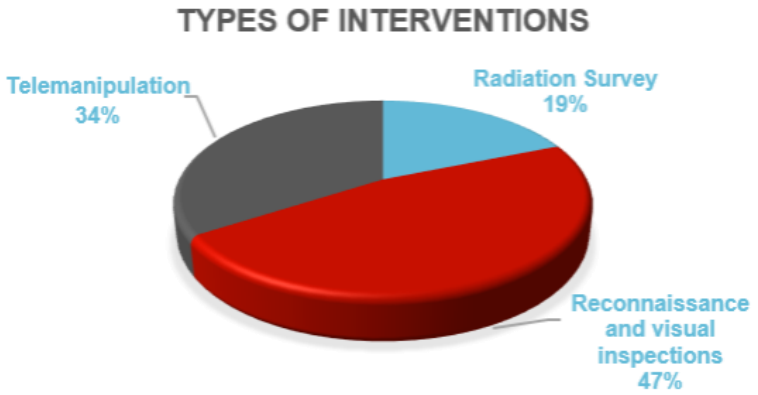


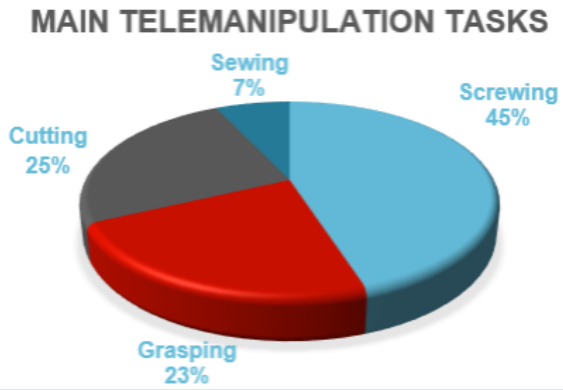
Our Impact

CERN custom made robotic solutions.

Nr. of Interventions since 2014	Nr. of tasks performed	Robot operation time in harsh environment [h]
150	~500	~ 500







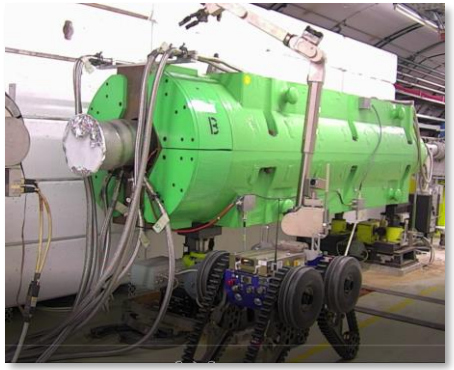
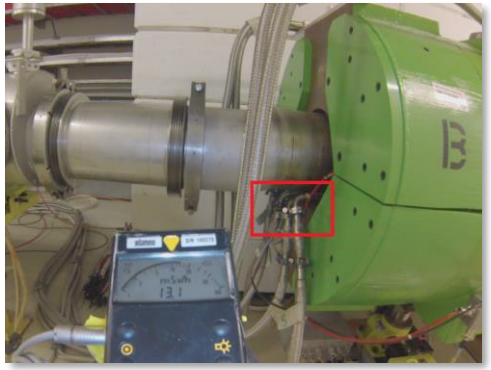
Contents

Procedures and Tools

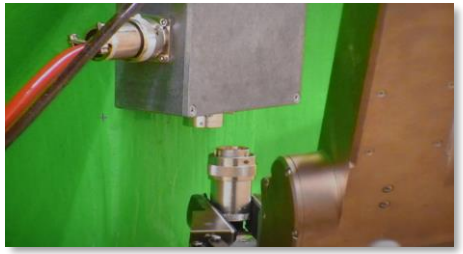
- Several time consuming and costly tools, procedures and mockups prepared for intervention on non-robotic friendly interfaces
- Intervention procedures, recovery scenarios, tools and mock-ups are as important as the robot
- Standardization of interfaces and procedures → reduces costs and intervention time

Importance of the Design Phase

- Designing machines that can be maintained by robots using appropriate and easily accessible interfaces will increase maintainability and decrease human exposure to hazards

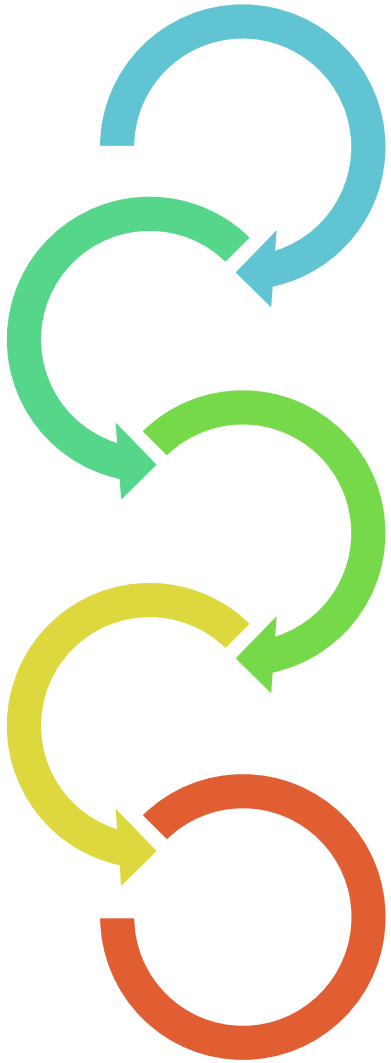






Easier remote or hands-on manipulation than chain-type connection

Guidelines for Robot Code of Practice



Modularity	Maintenance Time Labelling & guides Spare Parts
Accessibility	Space Access Visual
Simplicity	Components Procedures Natural Laws Aid
Standardization	COTS Sizes Cost reduction
Radiation & Decontamination	Surfaces Coverings Lifetimes & Shielding

EDMS: #2263542

Guidelines for Robot Code of Practice

Connectors

- Push/Pull
- 90º vs straight

Fasteners

- Bolt Heads & Lead-in
- Threaded vs Nuts
- Captive Bolts

Fluid Coupling

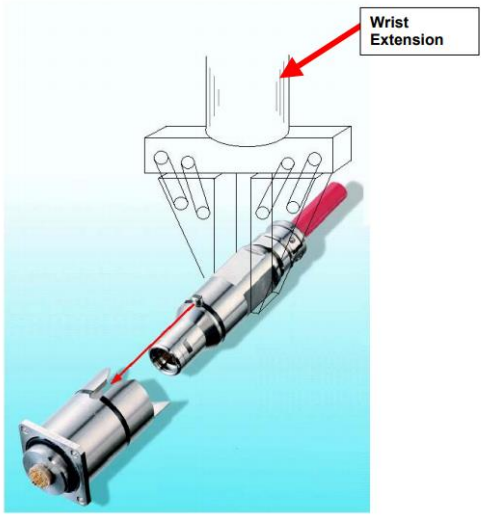
- Quick release
- Flexible hose
- Force for handling

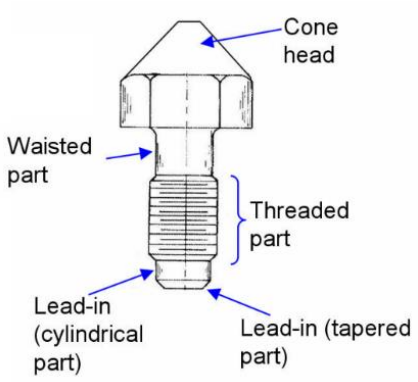
Pipes & flanges

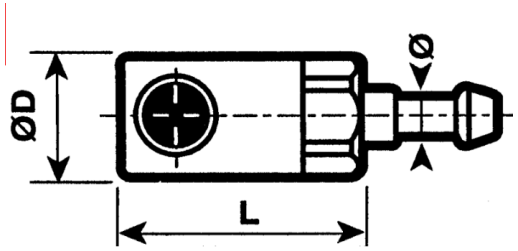
- Quick Disconnect System
- Consider seals
- Pipe dimensions

Patch Panels

- Element space
- Custom design
- Non-blocking position







Future of Robotics for FCC – food for thought

CERN design

Spot from Boston Dynamics

Locomotion

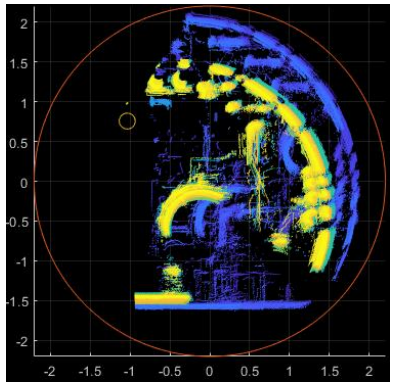
Eelume & NTNU

NASA & MIT

- Climb stairs
- Change gait and/or speed
- Reach hard to see places
- Manipulate on human friendly designs

Future of Robotics for FCC – food for thought

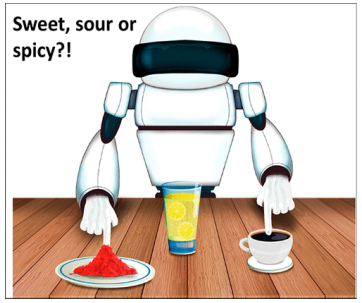
Robotiq



LHC cross section point cloud

Perception

KnowHow



American Chemical Society

- Better manipulation
- Knowledge outside visual
- AI for scene understanding
- Real-time environment mapping
- Digital Twins

Future of Robotics for FCC – food for thought

SupplyChain Review

KUKA Robotics

Cognition & Control

IGUS

Georgia Institute of Technology

- Human-Robot Collaboration
- User friendly interfaces
- Big tasks with little hands
- Connected system
- Autonomy

Conclusions

- CERN has a fleet of robots well suited to the types of interventions we face now
- New developments are ongoing – both for robot hardware, software and interfaces
- Maintenance and dismantling tasks must be considered using robots
- FCC design for ease of robotic interventions is extremely important from the beginning...improves personnel safety and machine availability
- We have almost decade of experience using robots at CERN to build on for FCC, and can take inspiration from other research groups and industries

References

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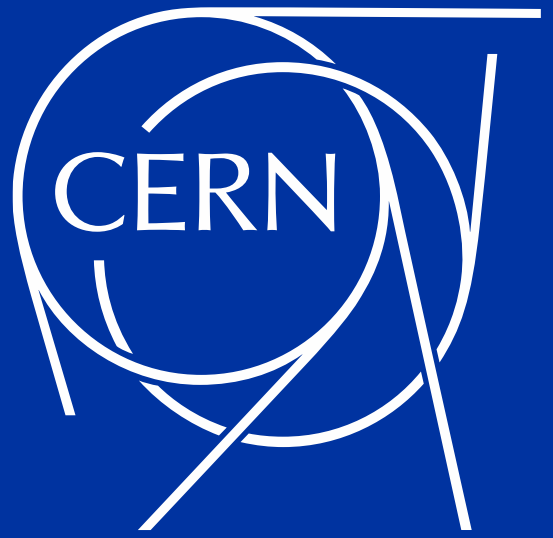
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