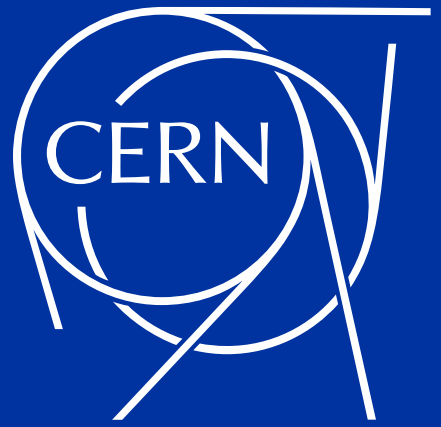
Controls
Electronics &
Mechatronics



BEAMS

14th HL-LHC Collaboration Meeting

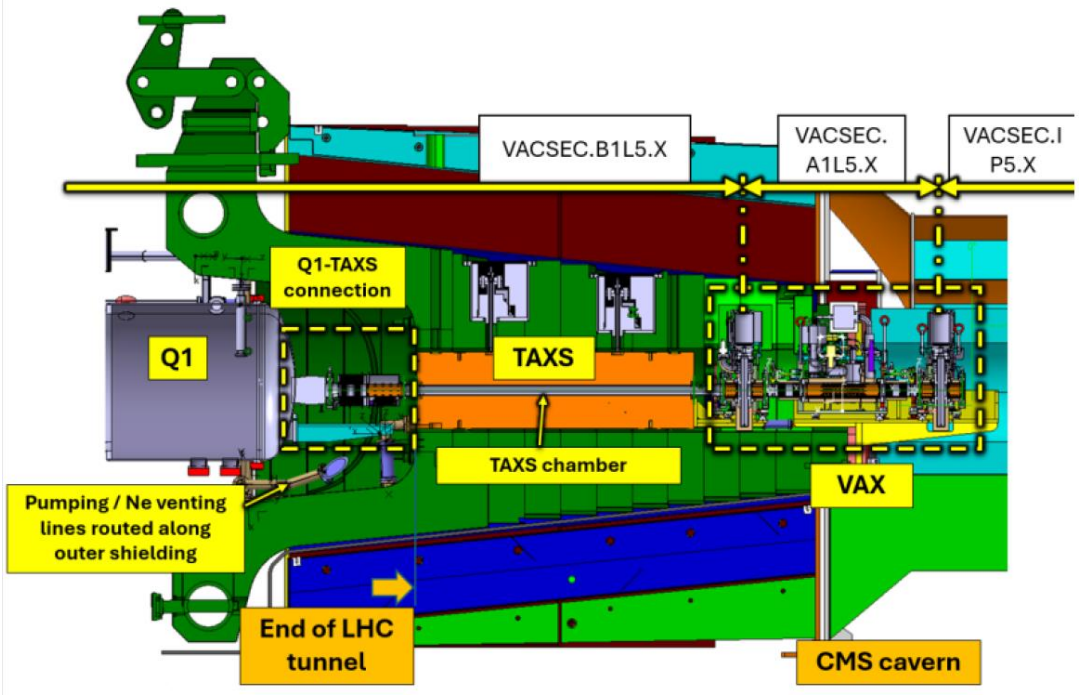
WP8 - Remote manipulation of VAX modules

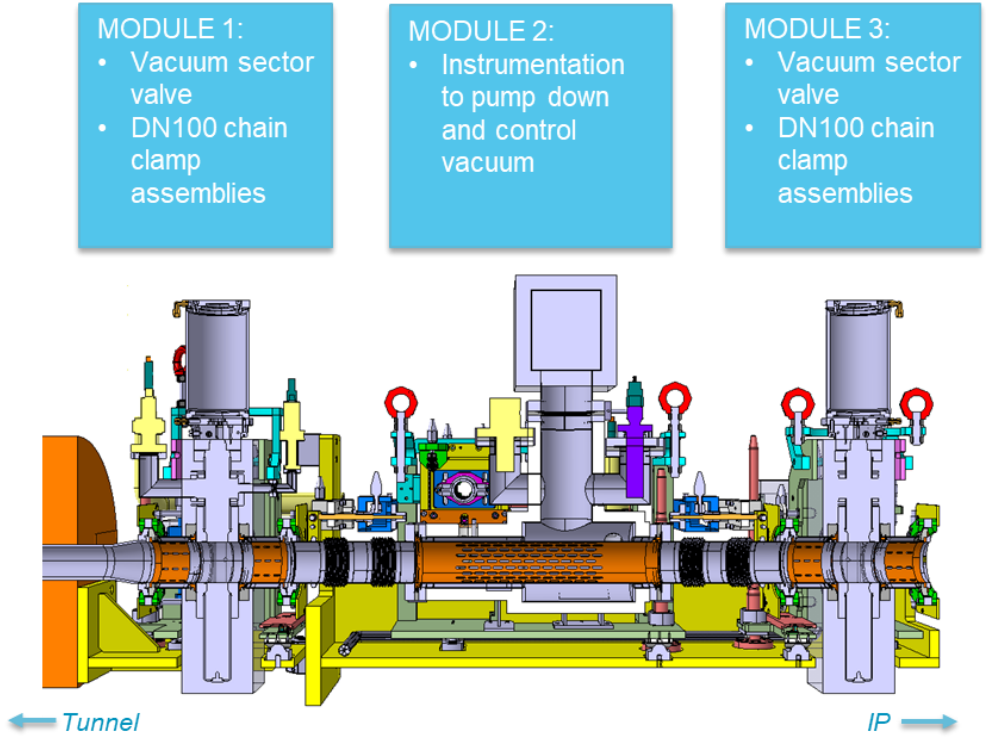
Sergio Di Giovannantonio (BE-CEM-MRO)

Introduction: VAX (Vacuum Assembly for eXperimental area)

- The VAX comprises compact set of vacuum and instrumentation components that will be hosted on the experimental side of ATLAS and CMS after the TAXS chambers to decouple the experiments and the machine vacuum

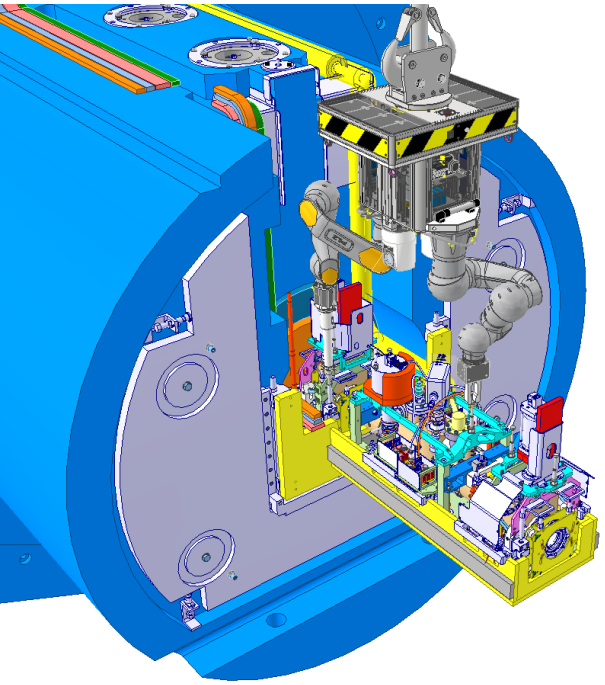
- The system is divided into 3 modules with 2 sector valves and 3 vacuum sectors with universal expansion joints for their interconnections

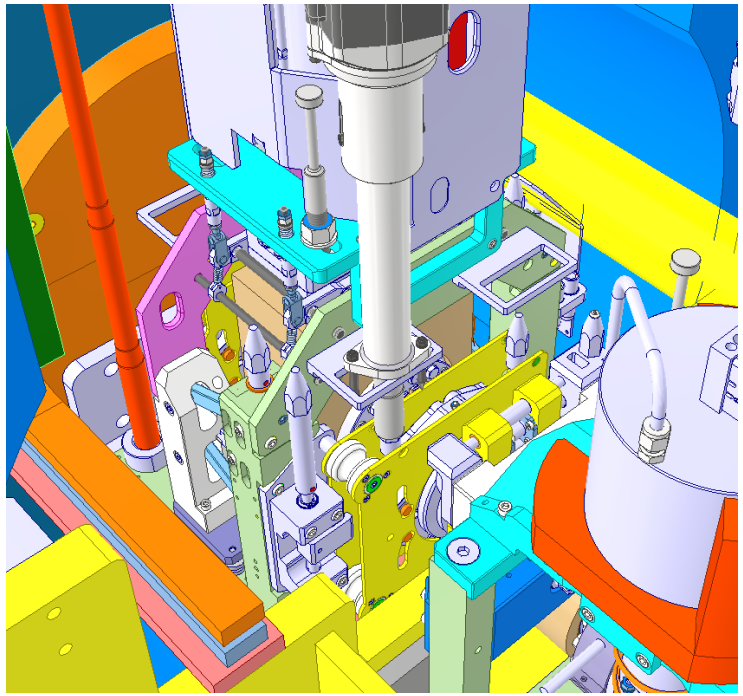


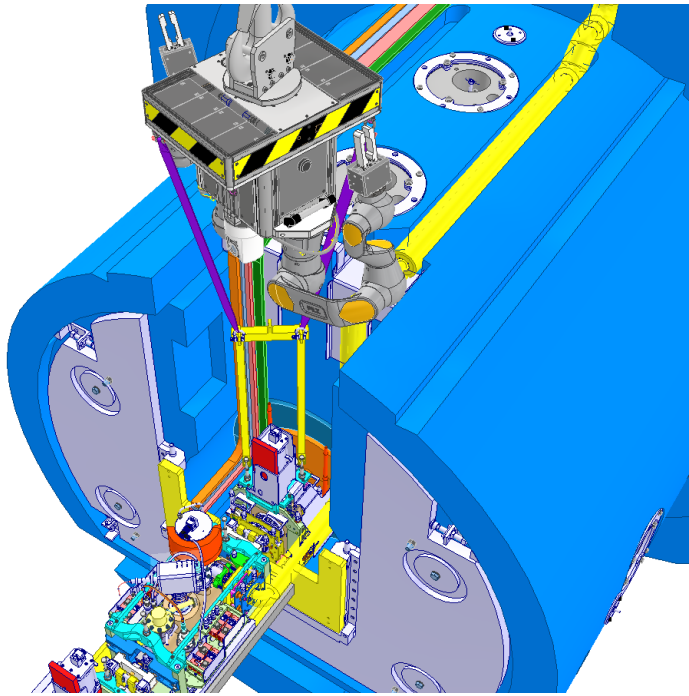


Introduction: VAX remote maintenance

- Residual dose rates expected in ATLAS and CMS during the HiLumi era will increase by a factor of 15 to 30 times the values measured during LS1
- High radiation levels and bad accessibility of the VAX area make the use of robots crucial for future maintenance of the VAX assembly
- Installation, removal, connection, and disconnection of each module will be carried out fully remotely and safely in line with the ALARA principle

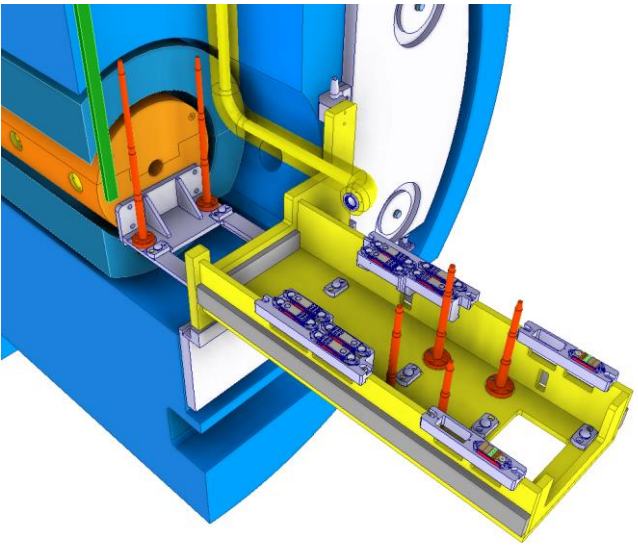




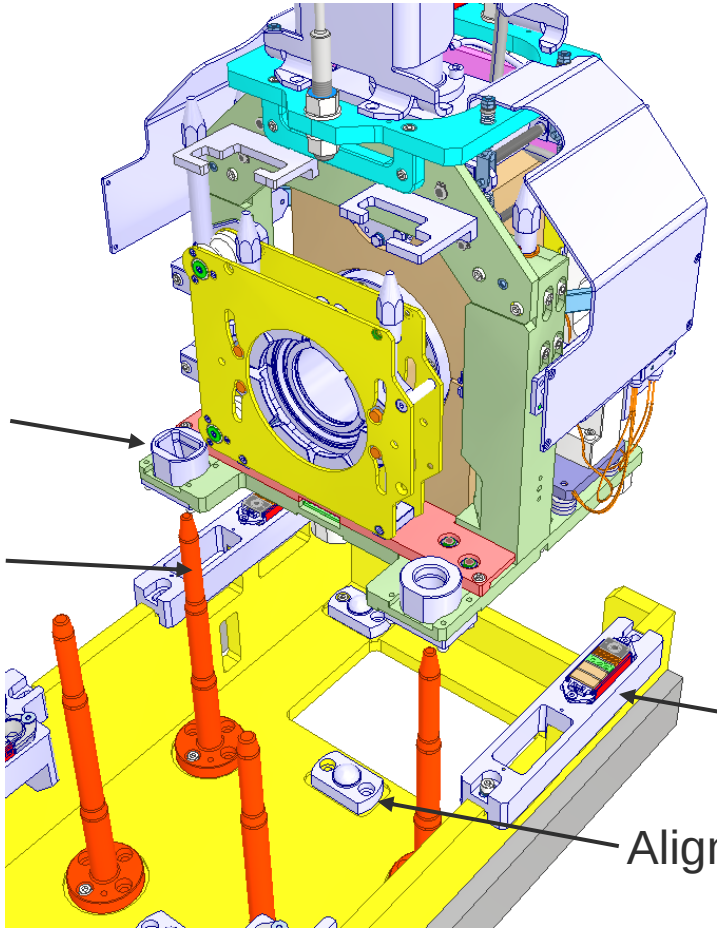


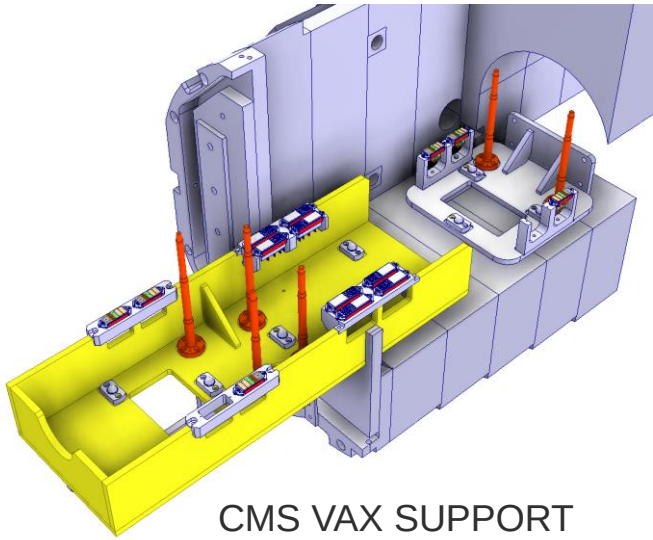
VAX modules installation in the VAX supports

- VAX supports are equipped with 3 sets of 2 guiding pins and 3 alignment spheres for the installation of the modules



ATLAS VAX SUPPORT

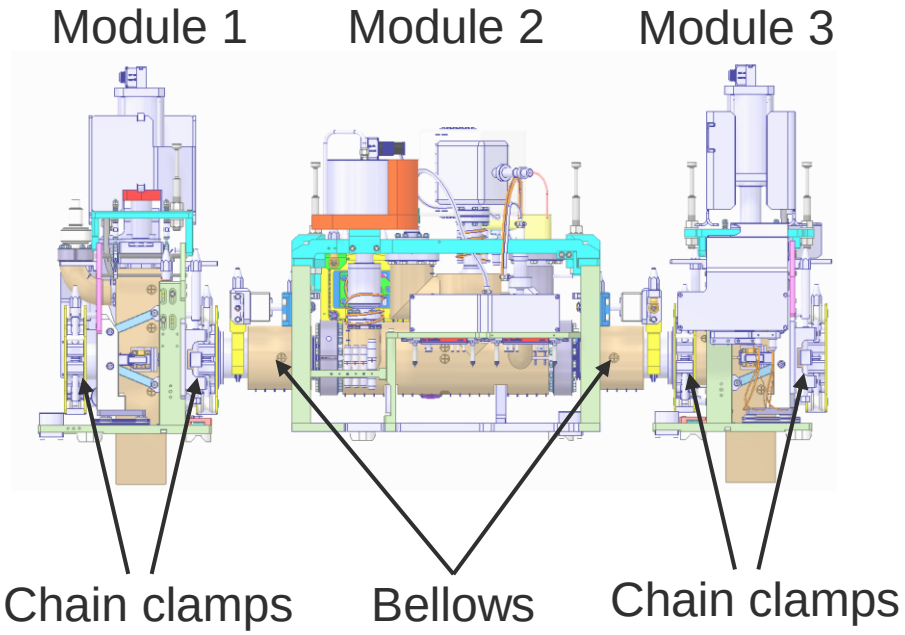


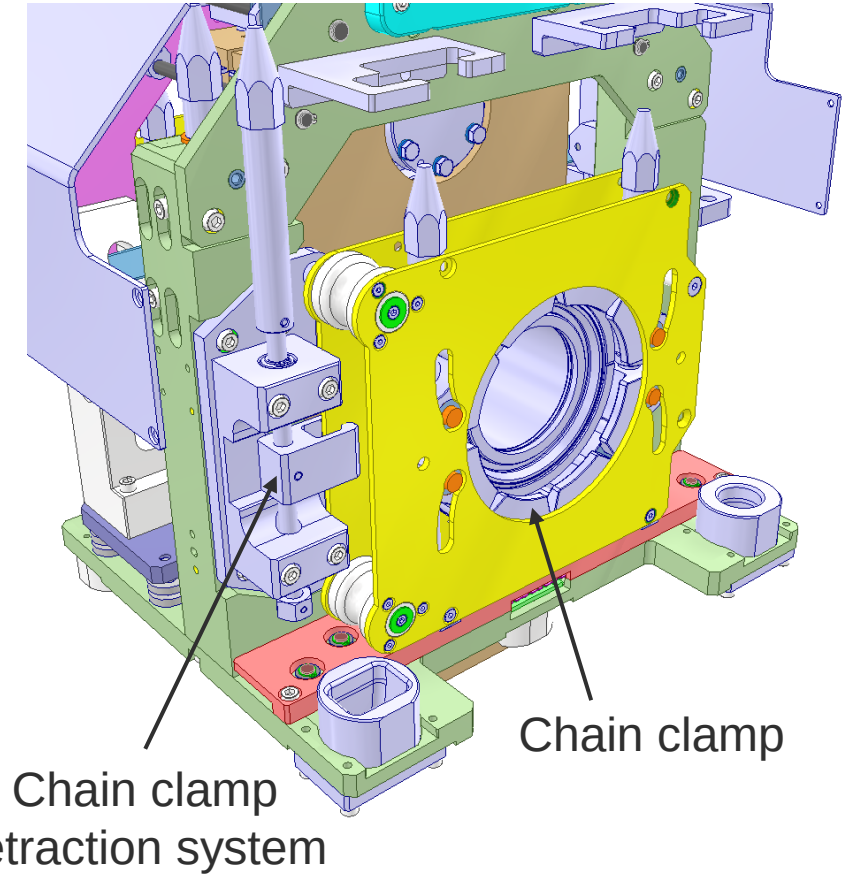


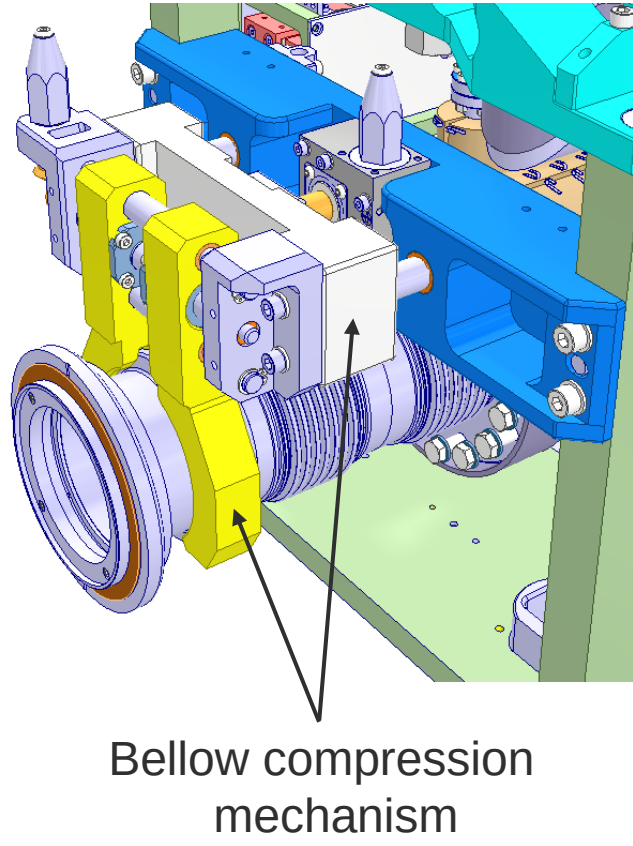
CMS VAX SUPPORT

VAX modules connection

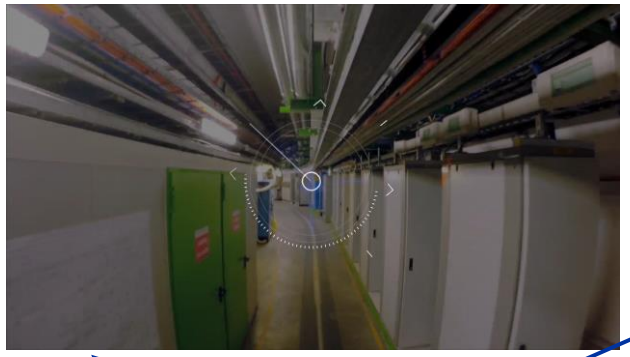
- A series of mechanisms allow to retract/extend the bellows and the connection flanges
- 4 sets of chain clamps allow the modules connections



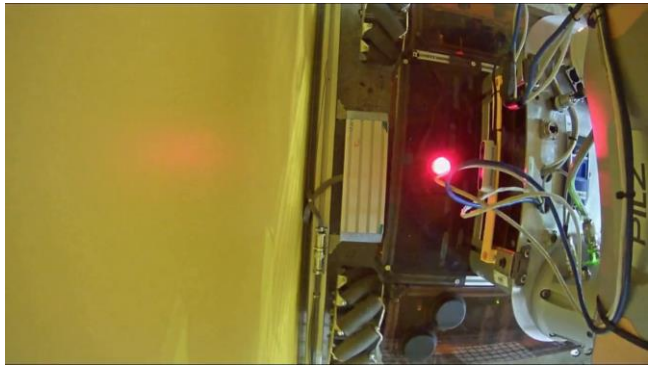




Robotic Service at CERN

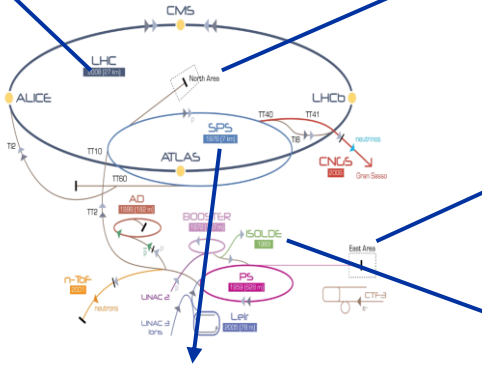


4x TIM operated by TI

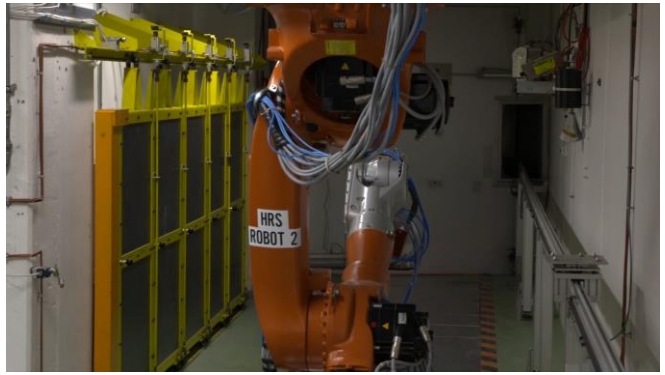


NA80 Robot (Intervention time reduced from 4 h to 5 min!)

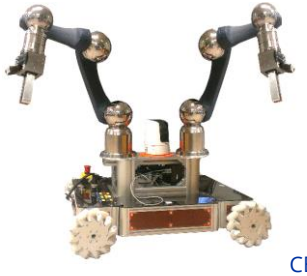
CHARM robot



2x SPS robot



3x Kuka Robots in ISOLDE-Medicis

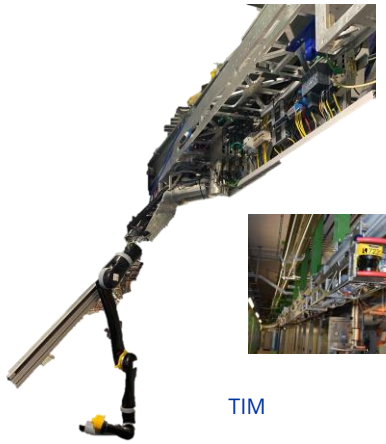


CERNBot1

Telemax

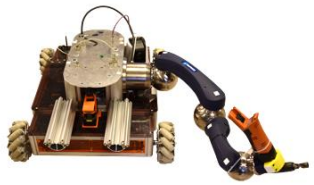
Teodor

CERNBotCrane



TIM

Drones



CERNBot1

Quadrupeds

CERNBotSPS

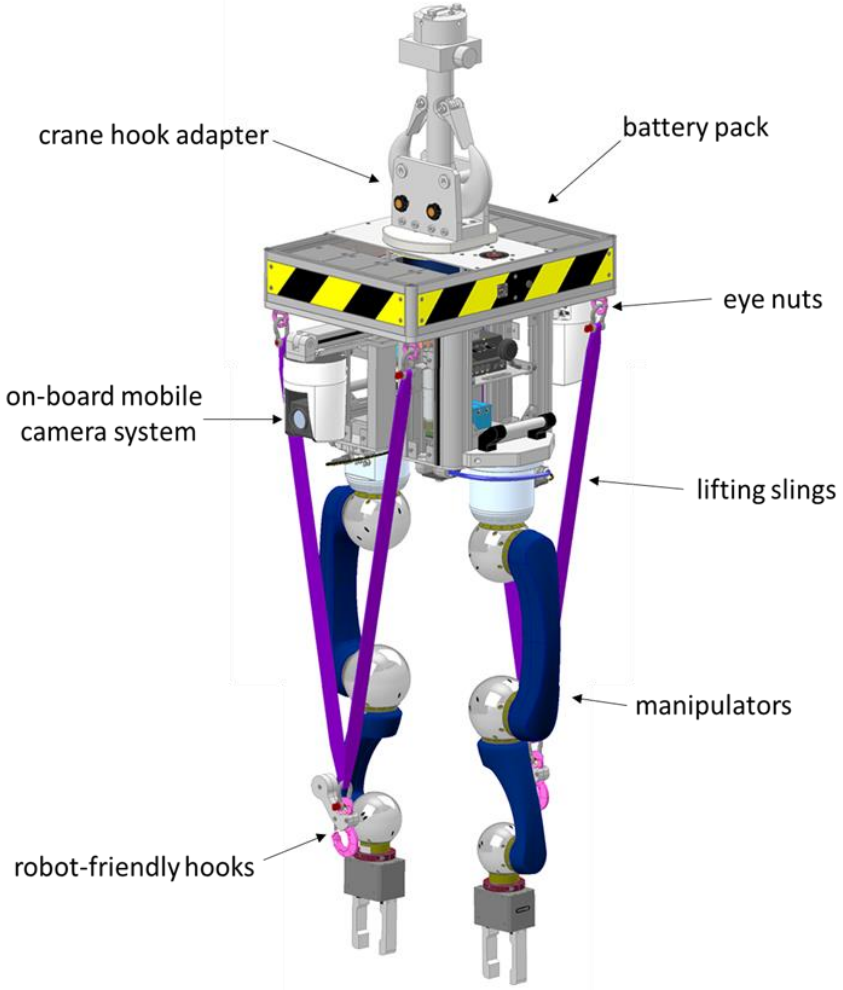
CERNBot2

Additional information on the service: https://indico.cern.ch/event/1055745/

CRANEbot: teleoperated crane-suspended robotic system

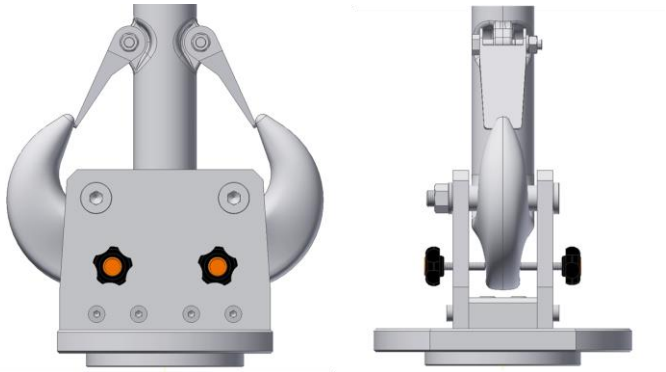
- To carry out the VAX maintenance operations a new robotic platform has been designed and developed by BE/CEM/MRO in collaboration with EN/HE

Technical data	
WLL	300 kg
Autonomy	8 h
Arms payload	6 kg
Compatible hooks	DIN 15402

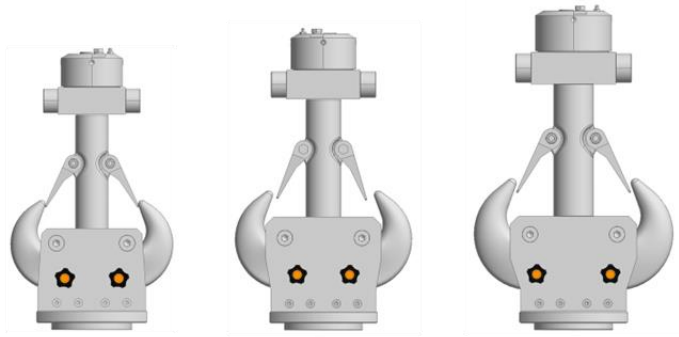


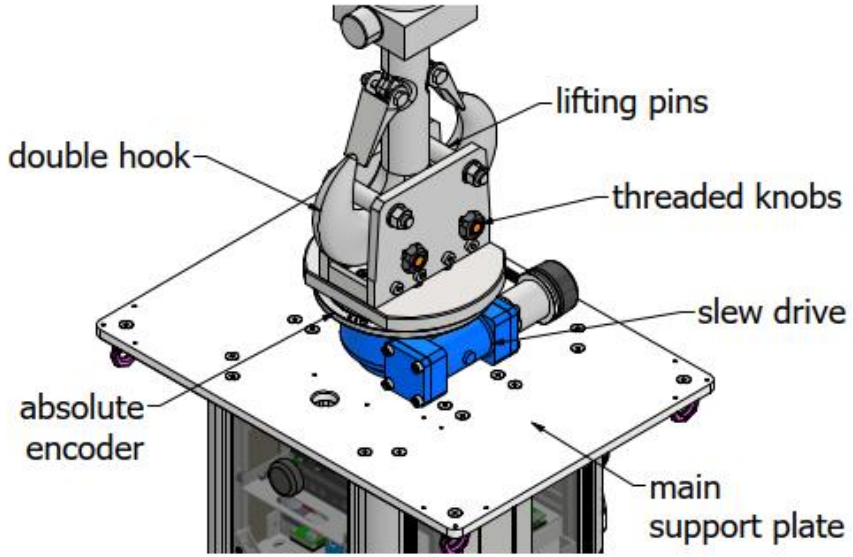
CRANEbot: hook adapter and platform rotation

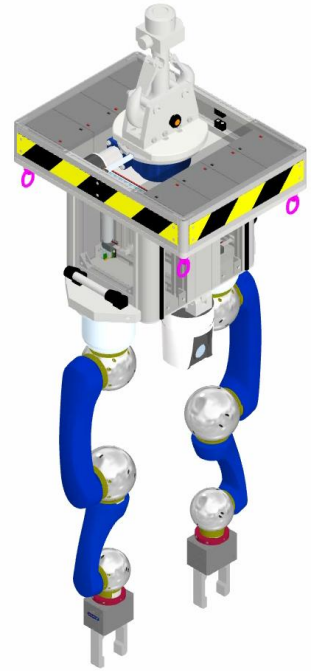
- Adaptable to different crane double-hook sizes: size 8 (CMS overhead crane), size 20 (ATLAS overhead cranes)
- The slewing drive can rotate the platform + module of 360º and facilitate the engagement of the guiding pins

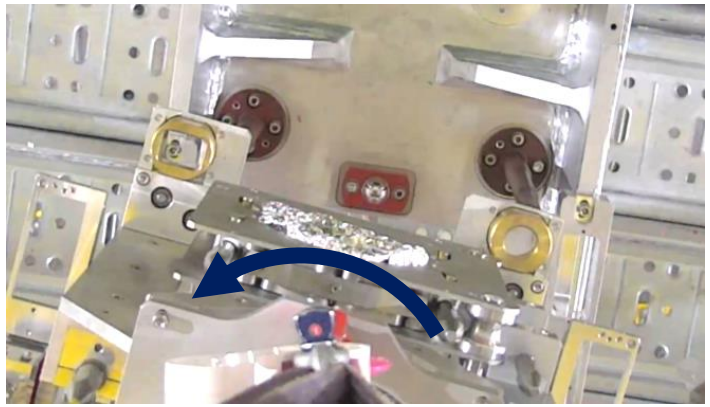


DIN15402 hook sizes:



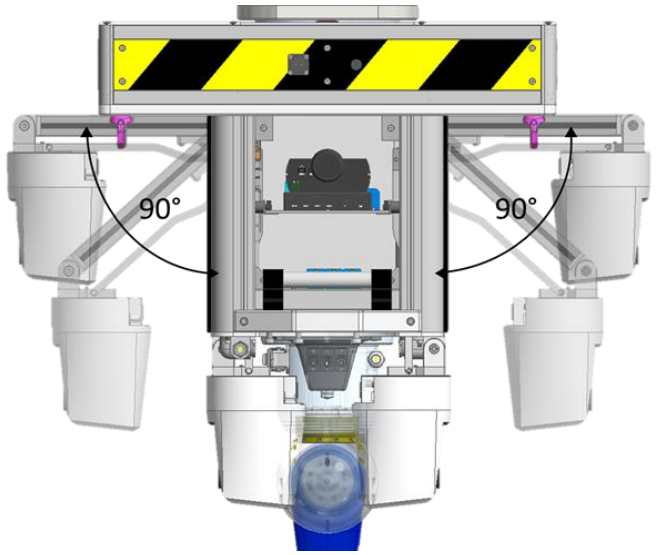


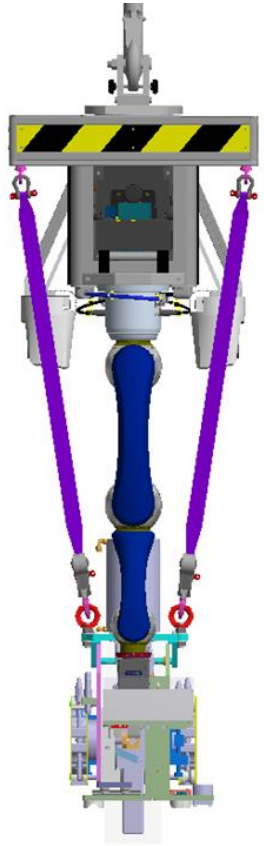


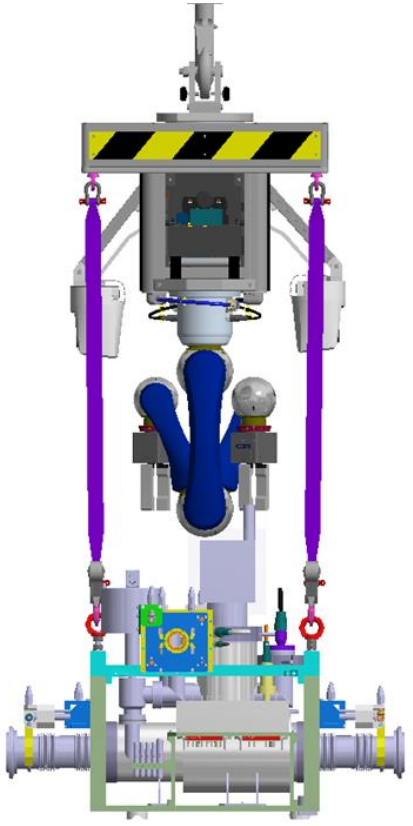


CRANEbot: onboard camera system with adaptable POV

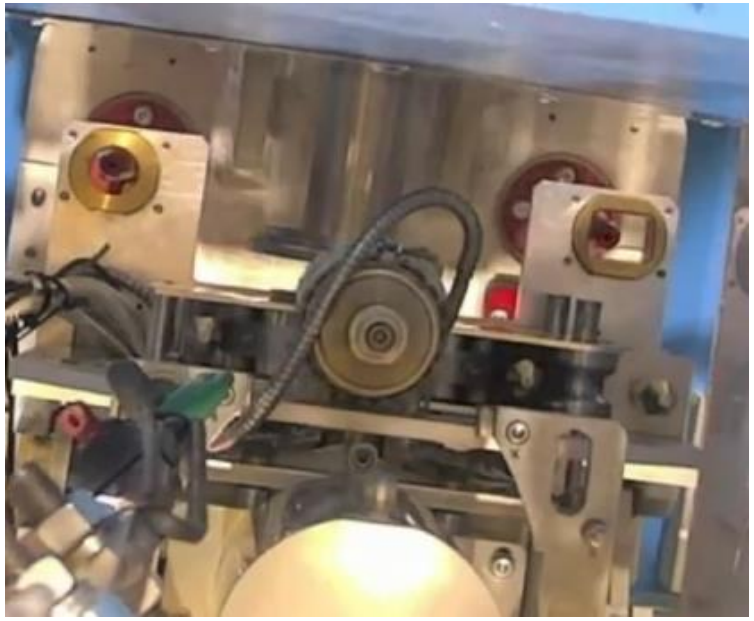
- A seagull wings system allows the operator to independently move the PTZ cameras on the sides of the platform, improving the view of the locating bushings of the different modules





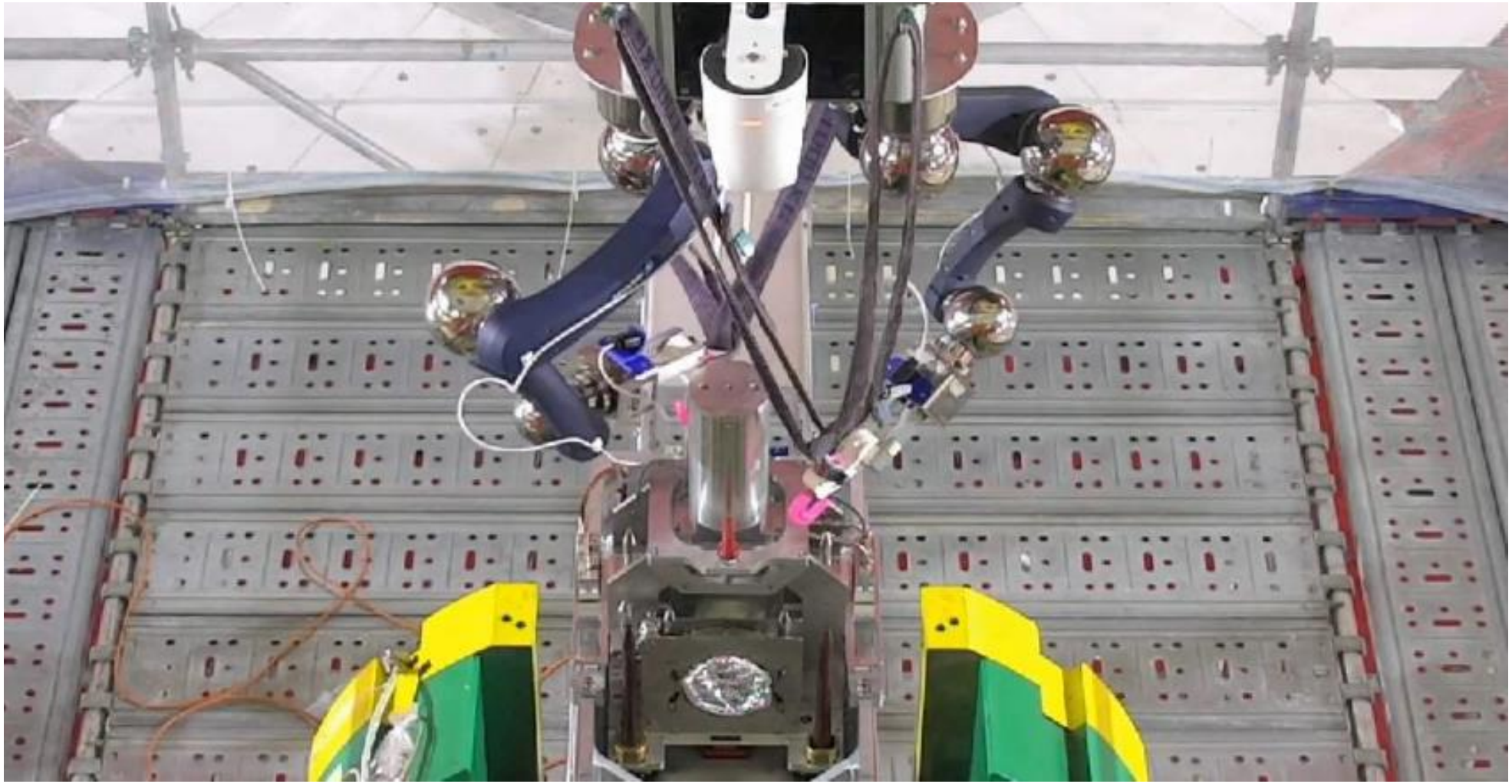


Module 1 and 3 Module 2



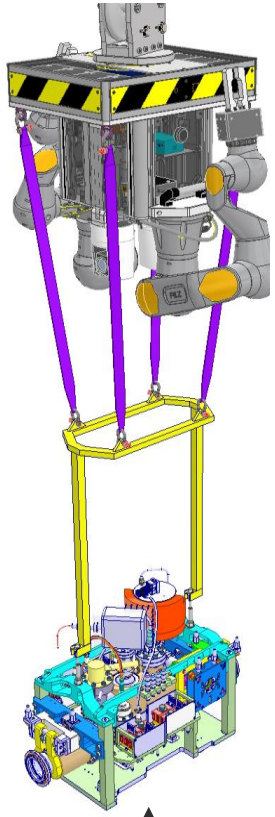
First remote positioning tests of Module 3 in CMS cavern using CRANEbot

- Hooking the eyebolts using the manipulators was complex and time-consuming

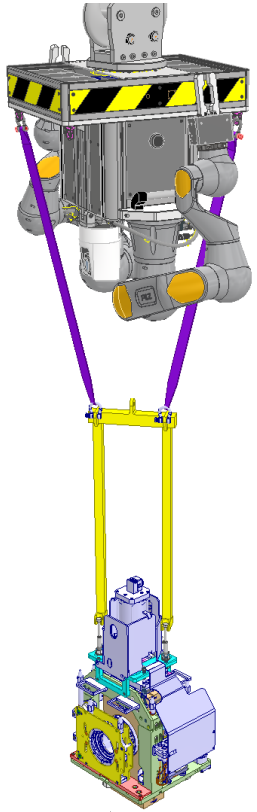


New lifting points and beams design in collaboration with EN-HE

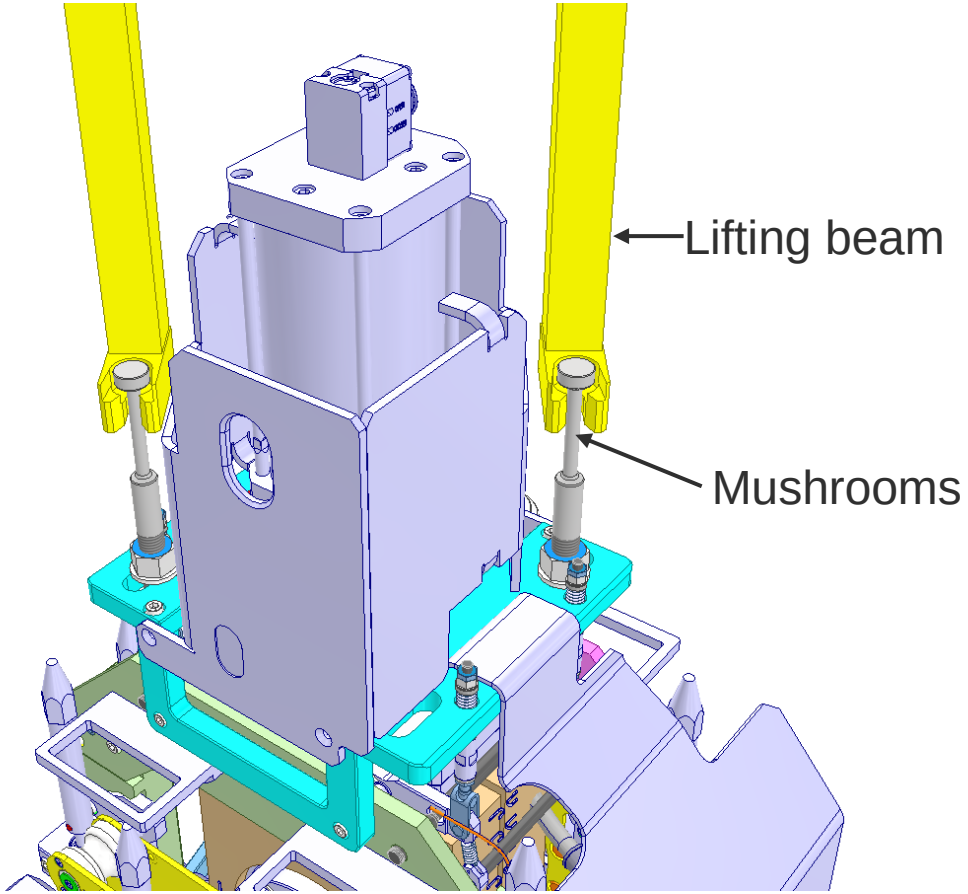
- New mushroom-shaped lifting points have been installed in place of the eye-nuts and a set of 2 lifting beams has been designed to enhance the remote hooking and release of the modules

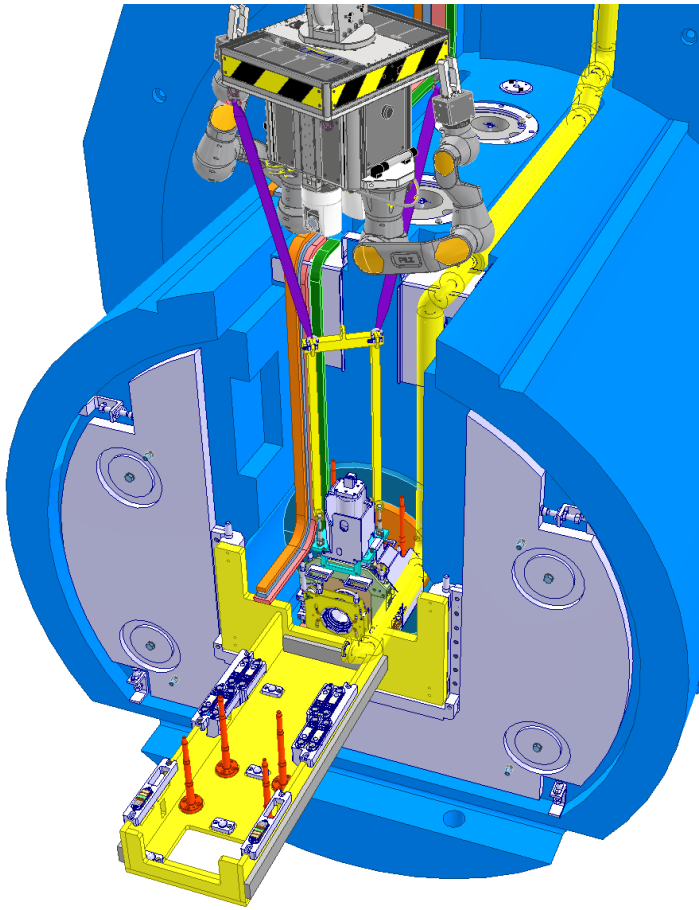


Module 2

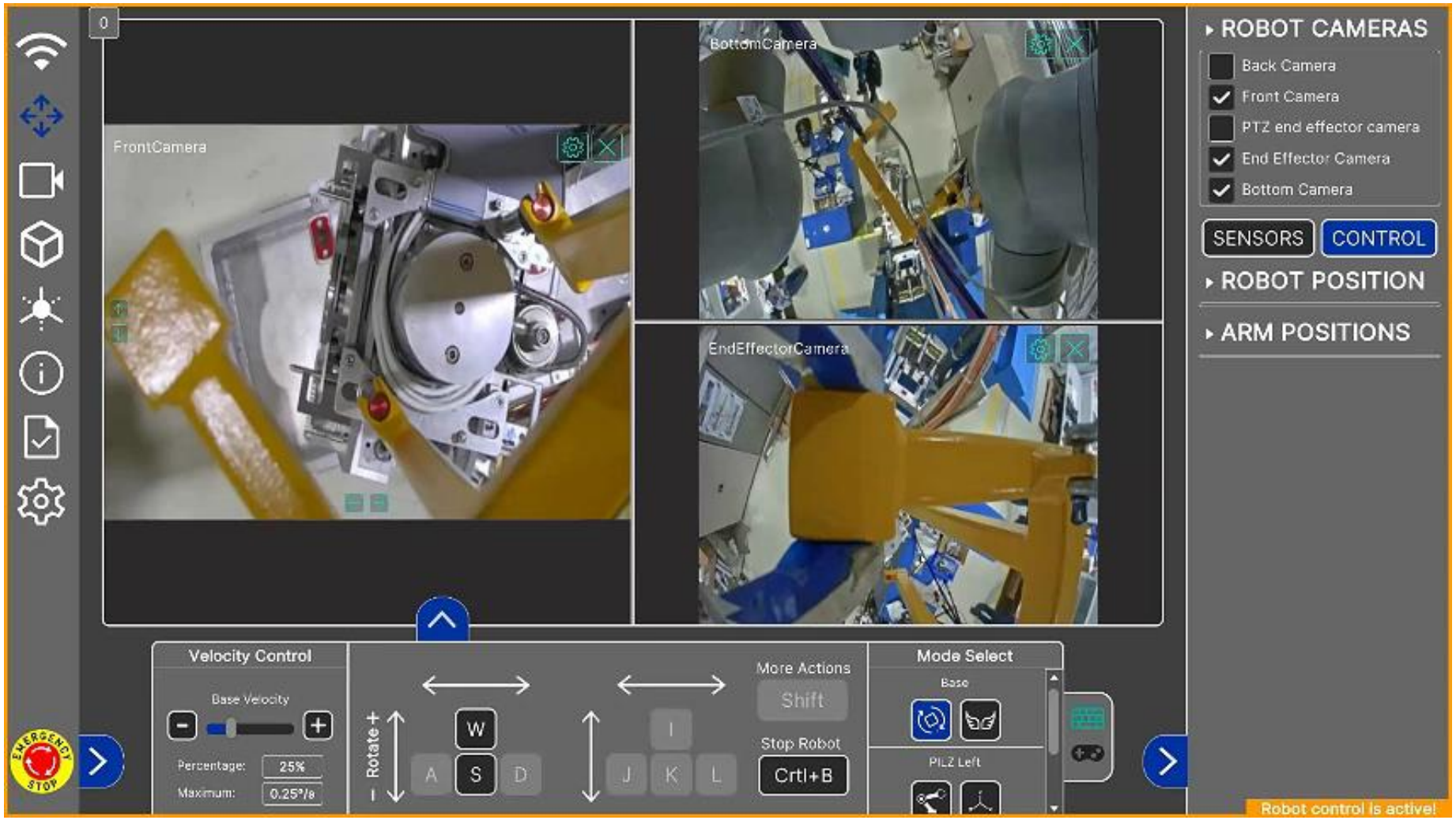


Module 1 and 3



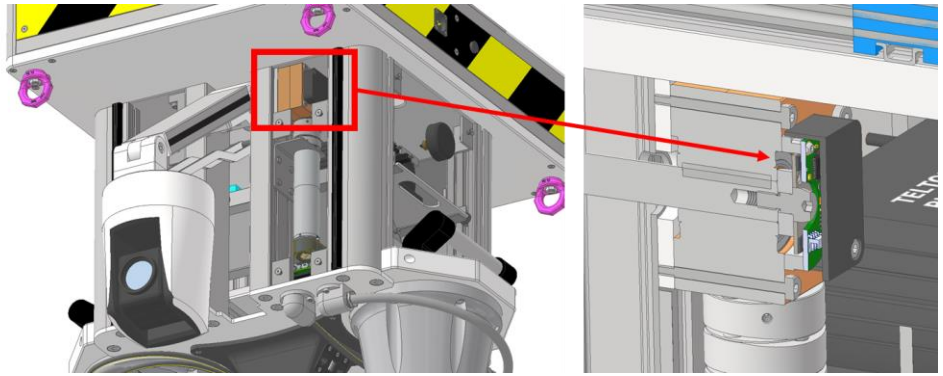


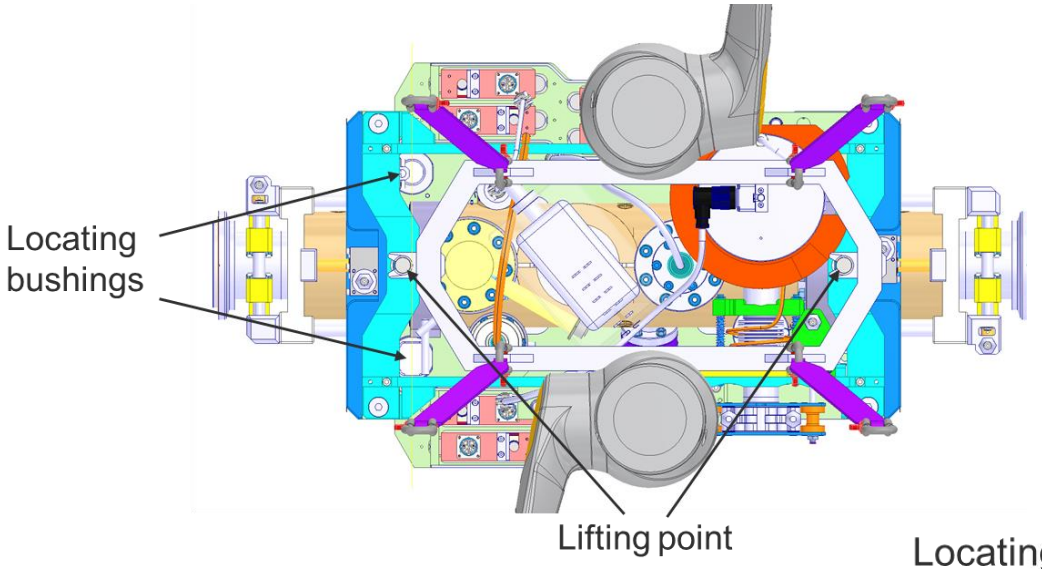
Installation/removal test of Module 1 in Building 867 (CERN Prevessin Site)

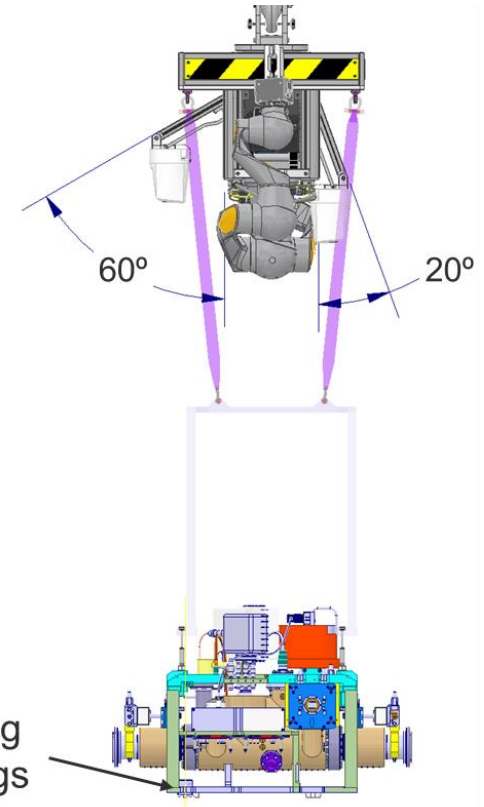


Test results and possible improvements

- The ability of the robot to rotate around the vertical axis facilitate the engagement of the mushrooms the insertion of the guiding pins
- The use of the lifting beam makes hooking and releasing the module 5 times faster
- Absolute encoders will be added to the robot's wings to pre-set the camera position for each module, reducing the operation time needed to align the cameras with the module bushings and enhance the visibility of the lifting mushrooms (in progress)





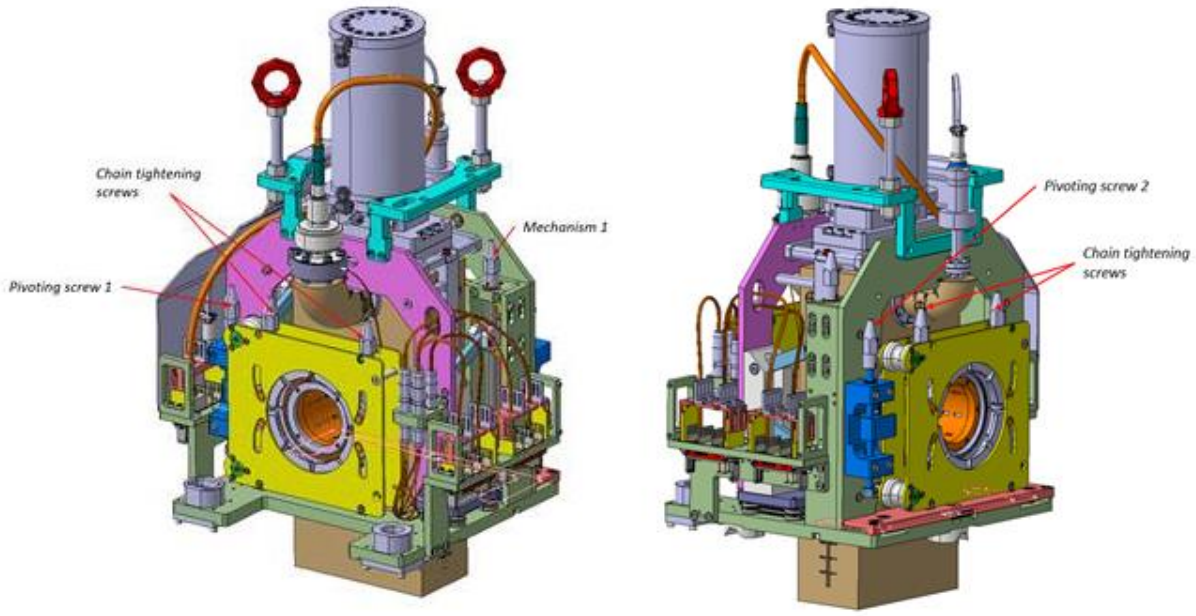


Modules connection

- The actuation of the mechanisms and chain clamps tightening is defined by steps, number of turns and max torque to apply on each hex head (TE/VSC)

Connection TAXS – M1:

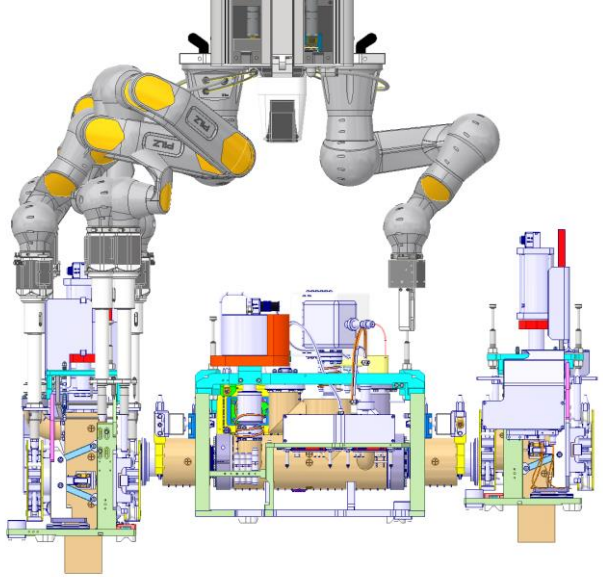
- Displacement of sector valve to the installation position by actuation of mechanism 1.
- Pivoting of chain clamp assembly actuating on "Pivoting screw 1".
- Closing the chain clamp:
  - Actuation of tightening screw 1 by 18 turns.
  - Actuation of tightening screw 2 by 21 1/2 turns.
  - Additional actuation of tightening screw 1 by 3 1/2 turns.

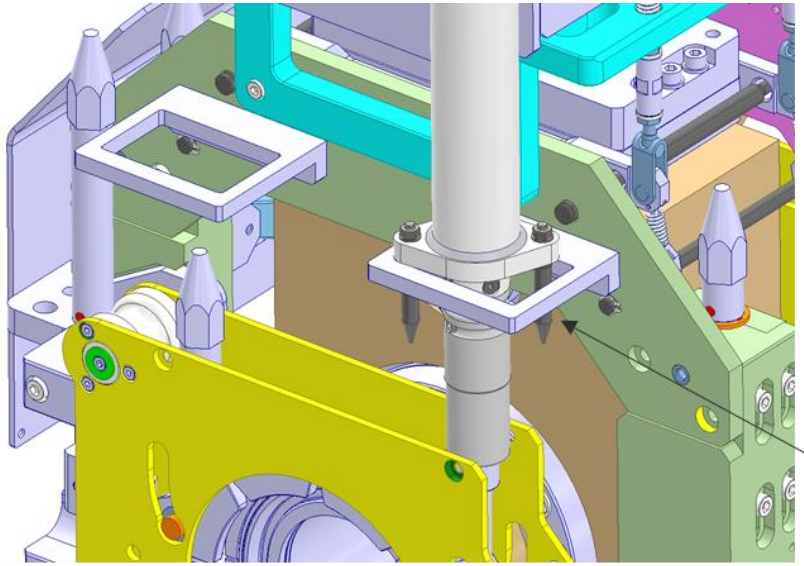


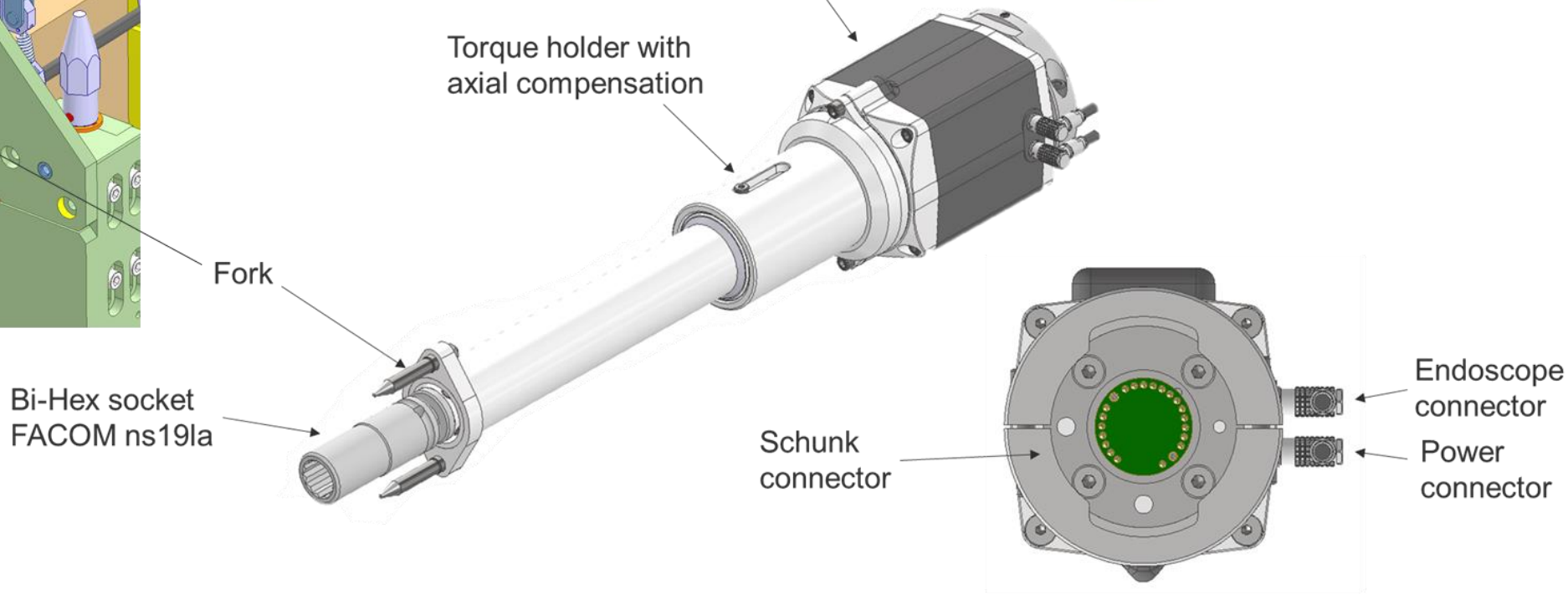
Steps	Direction of rotation	Number of turns	Torque
Mechanism 1 – Displacement of M1 to operation position	Clockwise	Until stop (~8)	7 Nm
Pivoting screw 1	Clockwise	1/6	5 Nm
Tightening screw 1	Clockwise	18	7 Nm
Tightening screw 2	Clockwise	18	7 Nm
Engage fork tightening screw 2	Clockwise	3 1/2	Up to 35Nm
Engage fork tightening screw 1	Clockwise	3 1/2	Up to 35Nm

New robotic screwdriver design

- Mechanical interface to counterbalance the tightening torque preventing the robot's wrist overload (torque holder)
- Optimized length to reach every hex head without colliding the valves

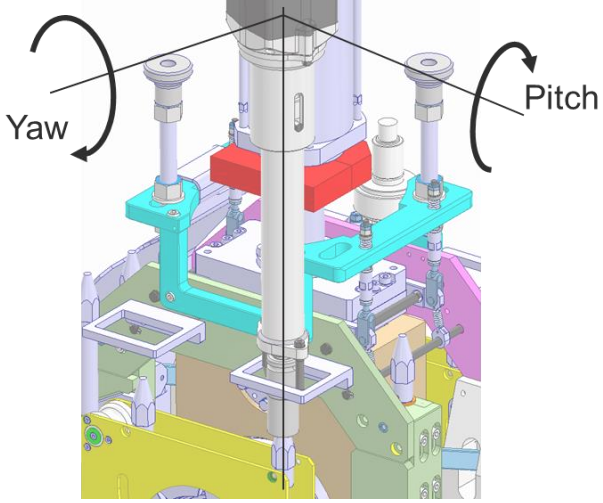




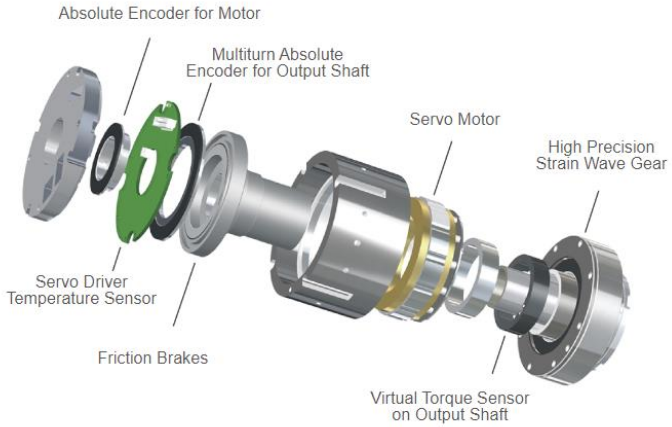


New robotic screwdriver design

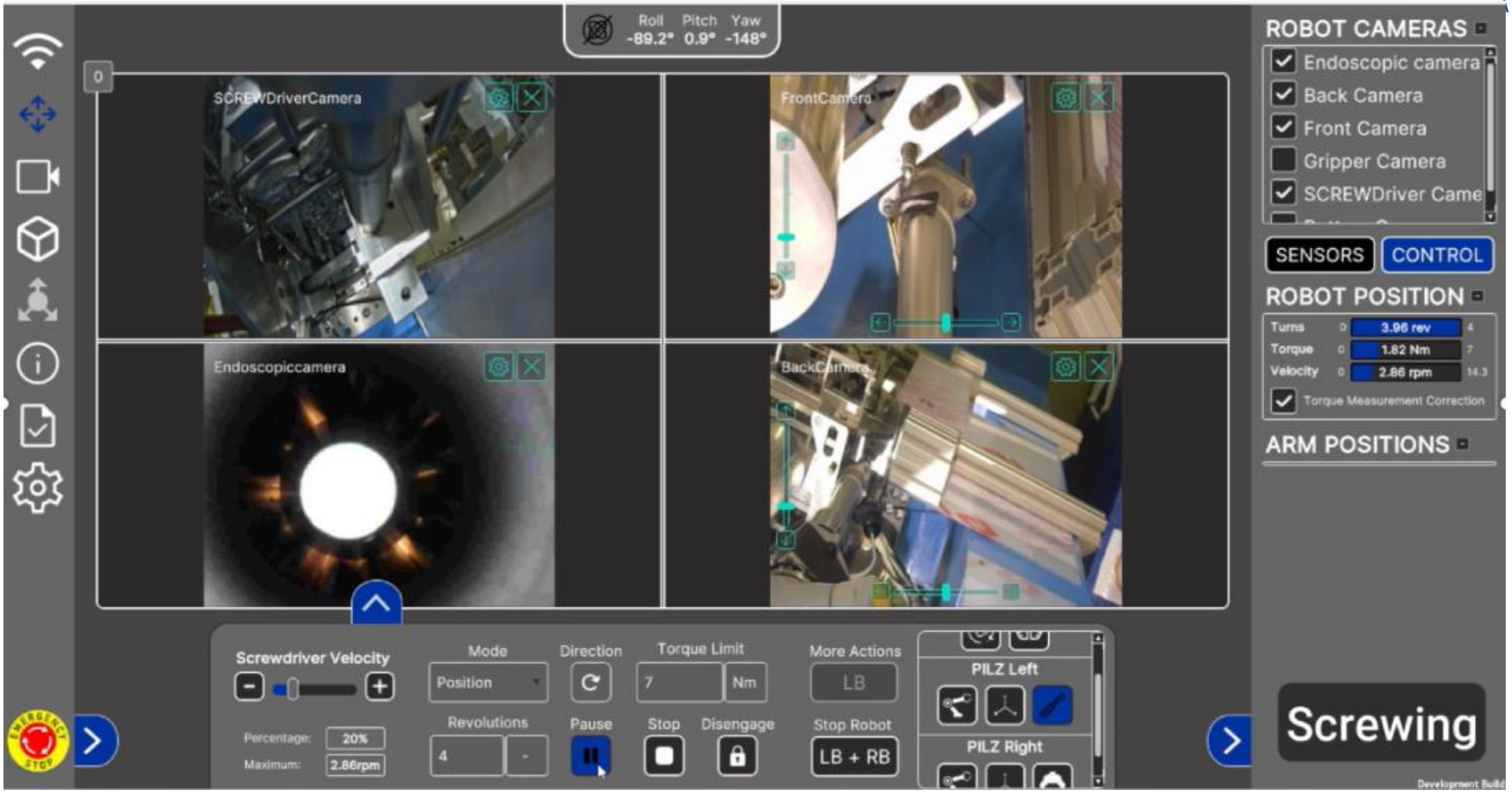
- Endoscopic camera to easily engage the hex heads
- IMU to minimize angular misalignment with the hex head axis
- High-precision motor with multiturn absolute encoder and strain wave gear



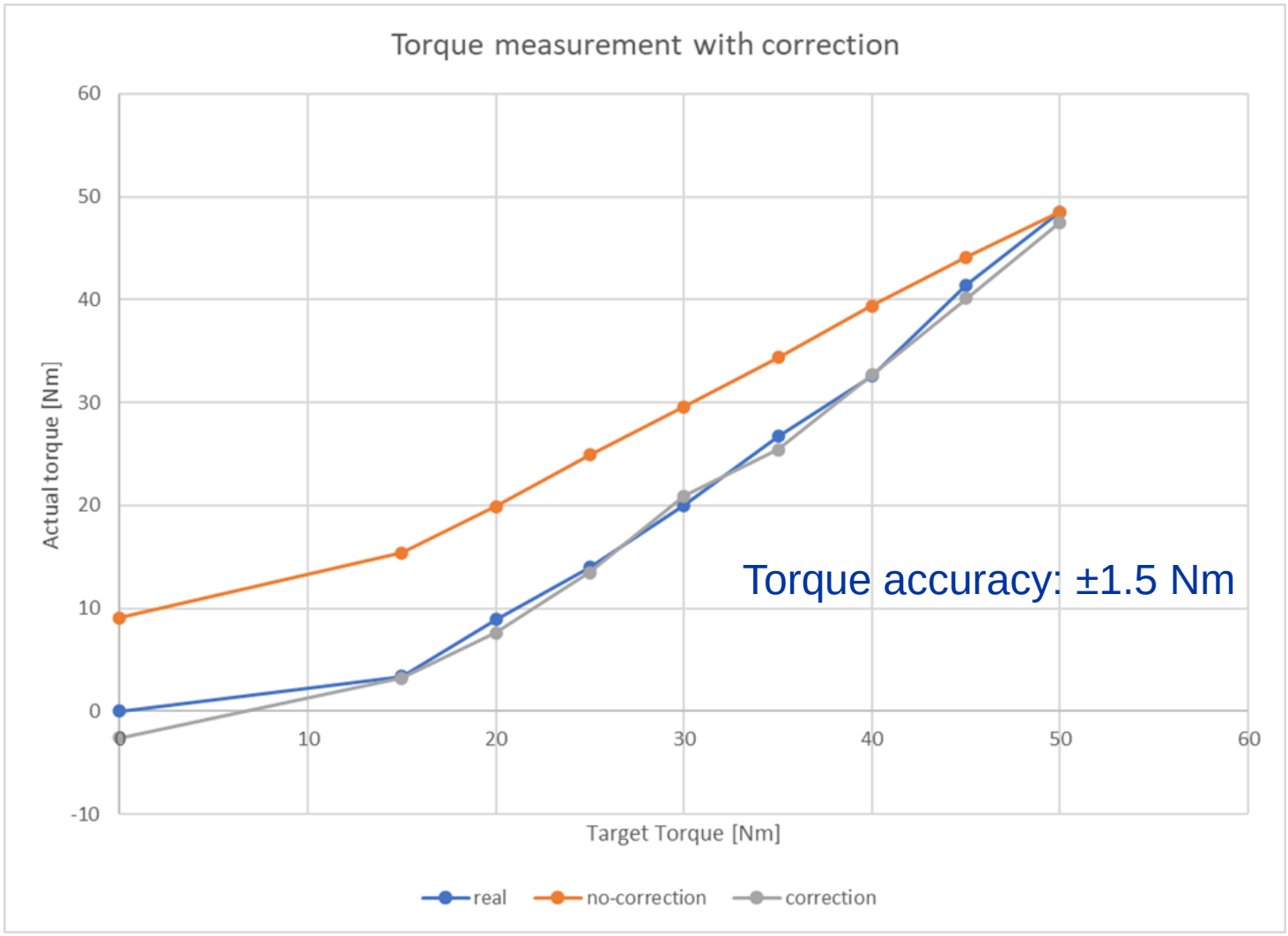
Motor technical data	
Max torque	51 Nm
Angular accuracy	±0.007 deg



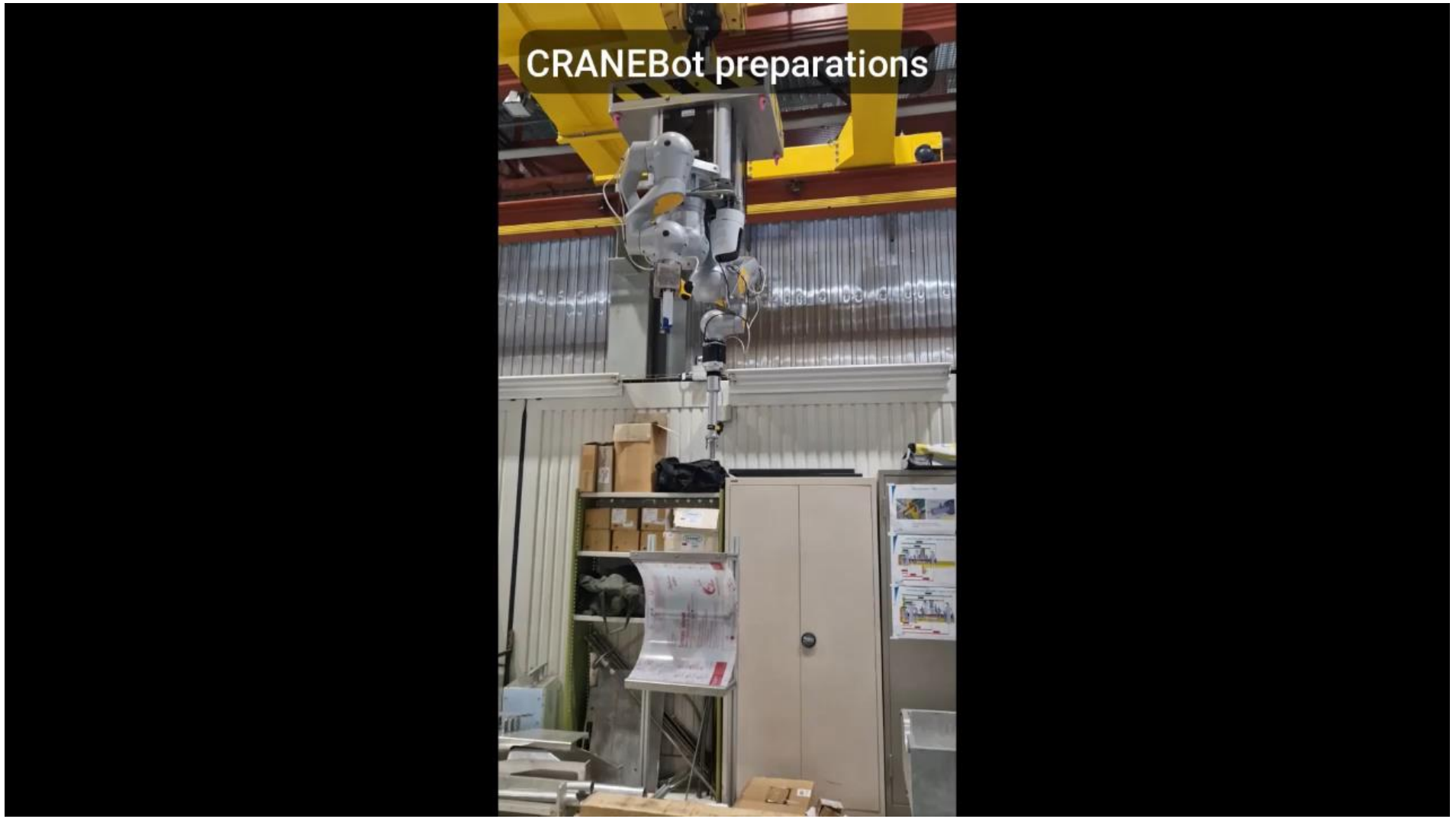
Screwdriver GUI overview



Screwdriver motor calibration

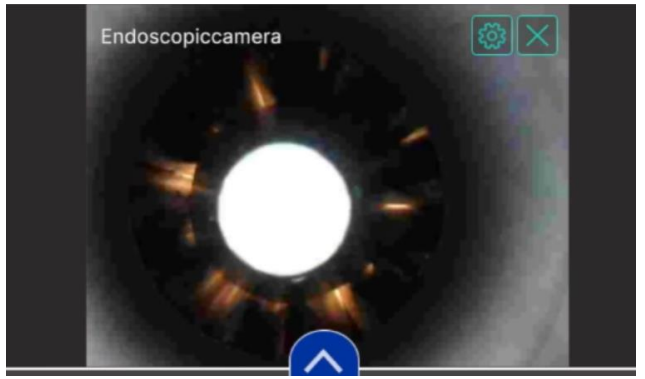


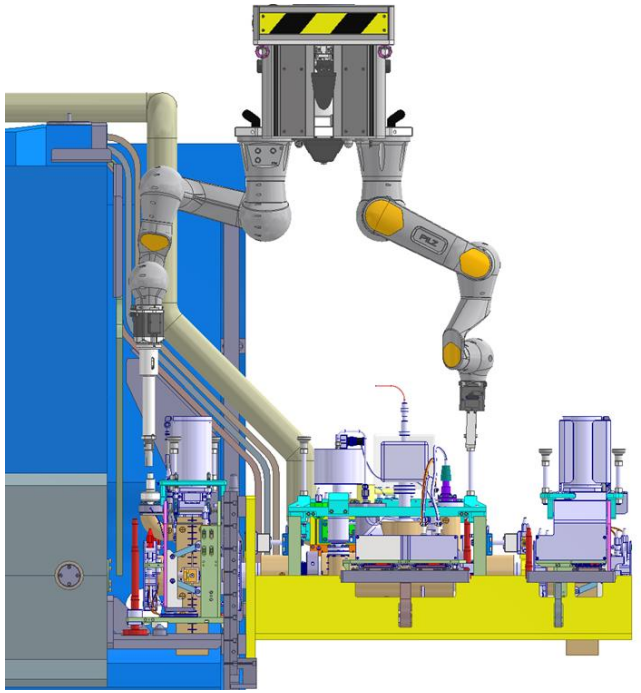
Screwdriver test in Building 867 (CERN Prevessin Site)



Test results and possible improvements

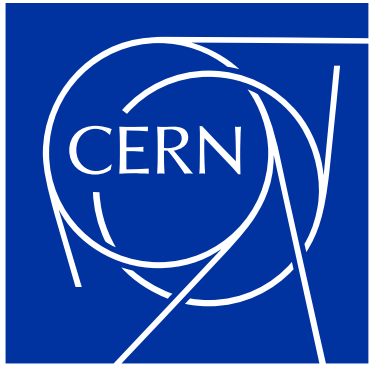
- Torque holders allow the chain clamps to be fully tightened preventing the robot's wrist overload
- The endoscopic camera and IMU allow easy engagement of the socket wrench preventing angular misalignments of the screwdriver
- The hex heads will be painted to avoid the reflection of the endoscope light and to improve their visibility from above
- Design new gripper fingers to grasp the mushrooms or add grasping points to the modules
- Pre-set poses of the manipulators will be defined to facilitate the positioning of the robot on the modules with the overhead crane before starting the tightening procedure





Conclusions and future steps

- A new robot and a new screwdriver have been developed and successfully tested in a full-scale mock-up of the VAX support (Building 867) using VAX module prototypes
- The installation/de-installation of M1 has been tested in the ATLAS shielding mock-up (Building 867) using the new lifting beam
- TAXS-M1 and M1-M2 connections sequence has been successfully tested with the new screwdriver
- Finalize the design of the lifting beam for M2 (with EN/HE) (by the end of 2024)
- Test the M2 positioning in B.867 (by mid 2025)
- Test the screwdriver on M2-M3 connections (by the end of 2024)
- Define and test the installation/removal procedure for each Module in ATLAS and CMS (to be defined)



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