Universal Adjustment Platform (UAP) System reliability and radiation hardness / maintainability

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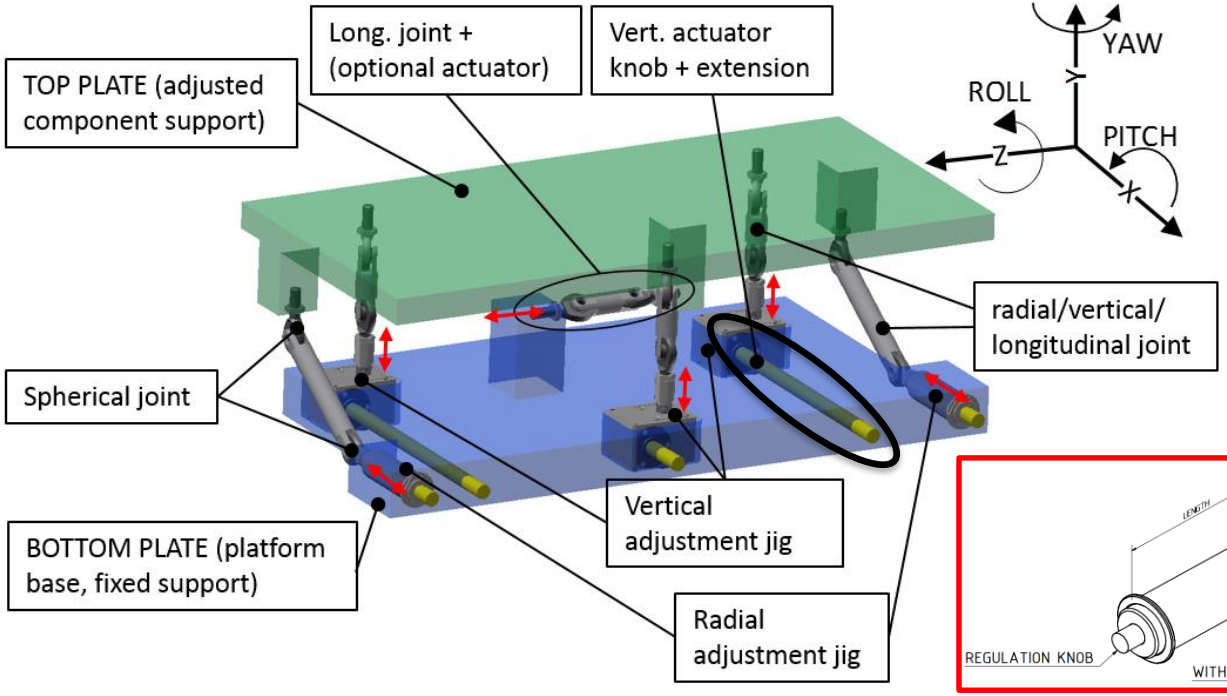
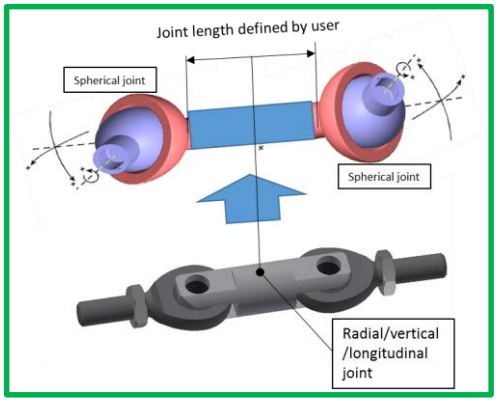
Review of HL-LHC Alignment and Internal Metrology (WP15.4)
CERN, 26-28 August 2019

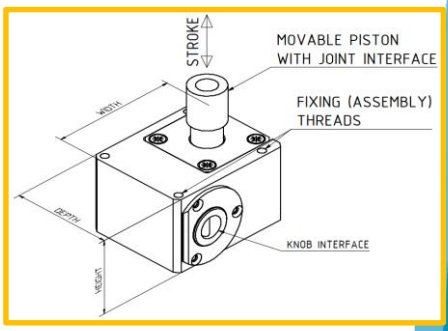
Outline

- UAP critical components identification
- UAP components lifetime and operation components assumptions
- Reliability driven design
- First radiation test results
- Failure Mode Effects Analysis for critical components failures
- Maintanability
- Conclusions

Universal Adjustment Platform

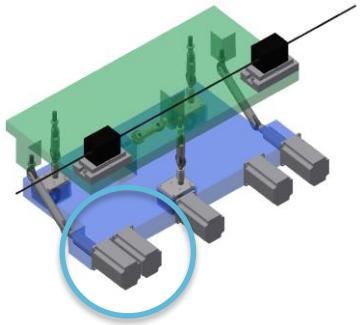






Critical components - failure source equipment

- **Joints**
- **Vertical adjustment jig**
- **Radial adjustment jig**
- **Motorized adapter unit**
- **Vertical jig knob extension**



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UAP components – livetime and operation conditions assumptions

- Platform lifetime: 10 years
- Assumed nominal scenario: 5 minutes of operation per week over 10 years
  - Static system, alignment mostly triggered by ground motions
  - Total operation time: 43.5 h
  - Big system shift expected only during initial alignment
  - Small shifts of platform during corrective realignments (< 100 µm), local wear expected
- Operation in ambient (tunnel) temperature
- Ultimate Total Ionizing Dose for UAP: 1MGy

UAP components design & relibility

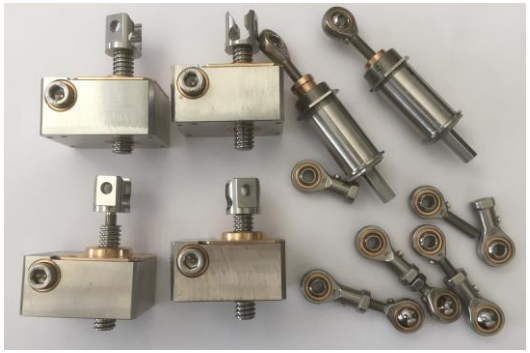
High radiation levels (see morning G. Lerner presentation) and difficult access forces surveyors to deploy possible-maintenance free platform

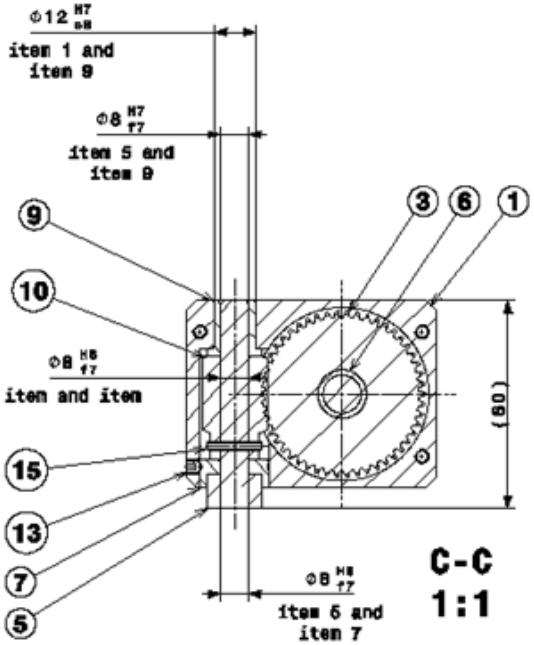
Simple and robust mechanical design

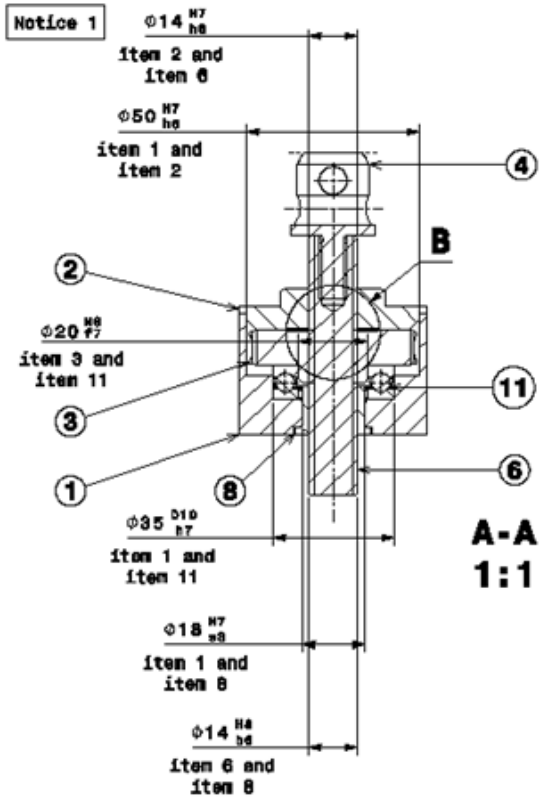
- Minimum amount of rotating / moving parts
  - Transmissions designed with low load ratio
- Materials selected according to best tribological performance and radiation hard
- Lubrication using *Molykote BR2 plus*
- Self lubricating (sintered bronze) sliding bearings and spherical joint

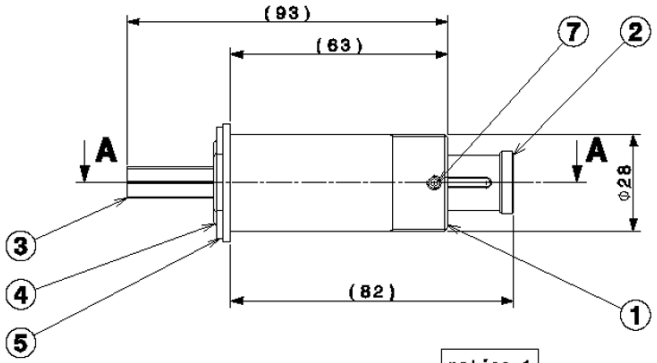
Small UAP jigs, joints prototypes design

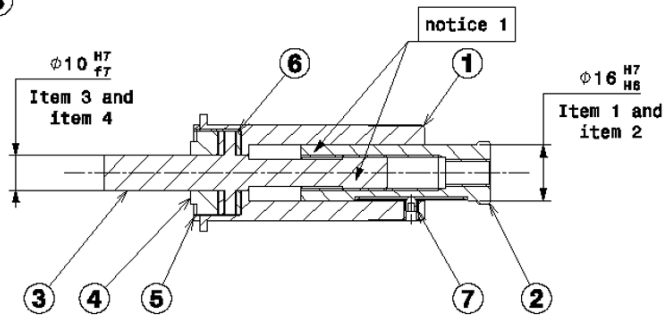
- Jigs (vertical, radial) first batch assembled in 9.2019
- LHCGUPS_0001 (radial), LHCGUPS_0007 (vertical)





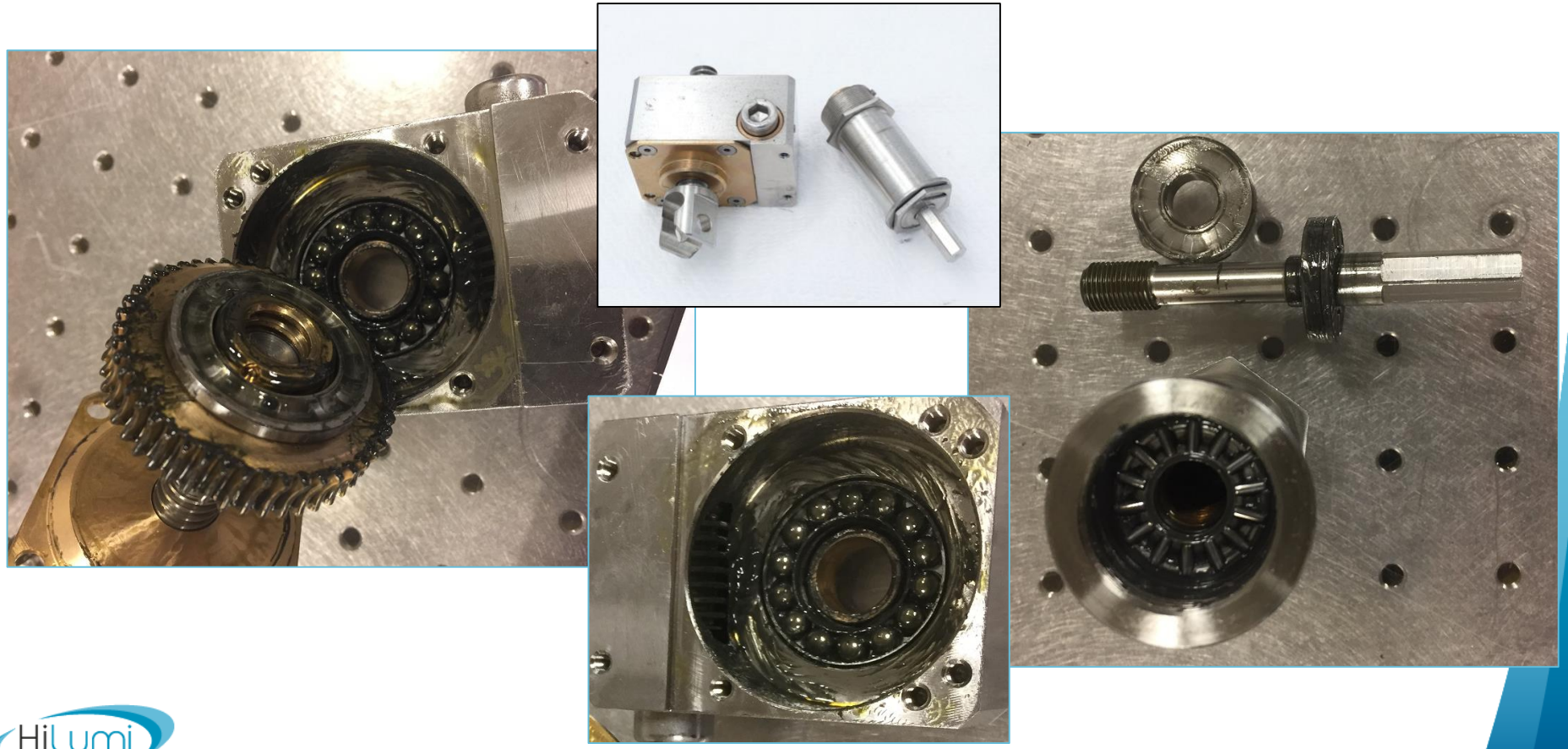






Small UAP jigs radiation tests

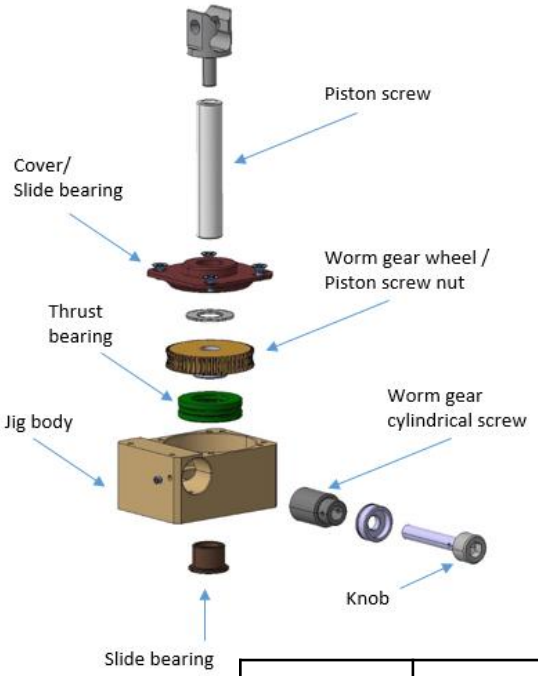
- Preliminary 3MGy radiation tests in Fraunhofer Institute 8-10.2018
- Report: EDMS 2138404
- No operational issues observed, no grease problems (Molykote BR2 plus)

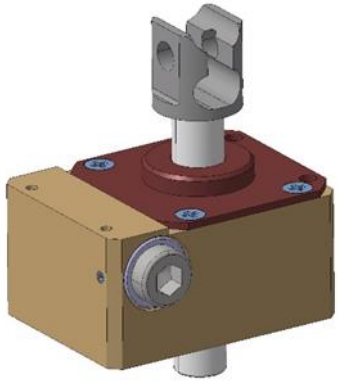


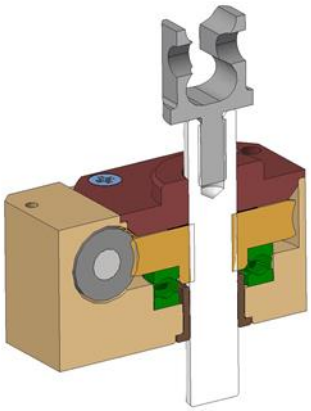
Failure Mode Effects Analysis (FMEA)

- Involves reviewing as many components, assemblies, and subsystems as possible to identify failures, and their causes and effects
  - Only basic analysis considered for the jigs and joints
- Results (Risk Priority Number) dependent on assembly quality and machining tolerances

FMEA Vertical jig

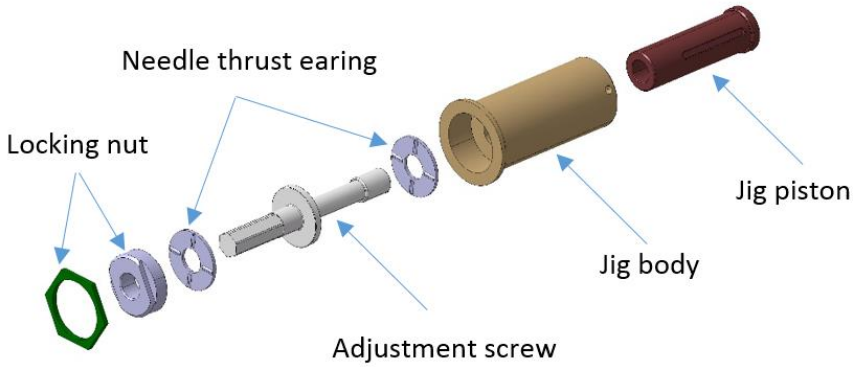


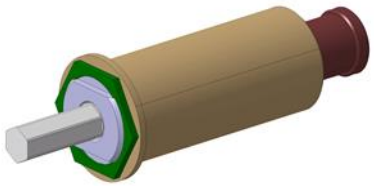


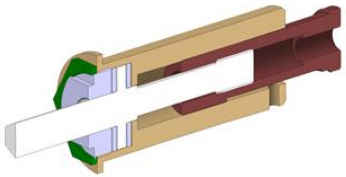


Group	Part	Potential Failure Type	Potential Failure No.	Failure Consequence	Possible Cause of Failure	Failure Recognition	Measures Recommended for Removing Failure	SEVER.	OCCUR.	DETEC.	RPN
Vertical jig	Worm gear / trapezoidal screw	Blocked - seizure	1	Vertical axis of UAP blocked, **platform misaligned**	Seizure	No movement, bad platform position measured	Increase torque	10	1	1	10
		Blocked - radiation caused or ageing	2	Vertical axis of UAP blocked, **platform misaligned**	Cold welding of components caused by radiation or ageing	No movement, bad platform position measured	Increase torque	10	2	1	20
		Bigger backlash	3	No specific consequences / Backlash on output piston	Wear of components	Bigger rotation of adjustment knob to start turn the gear	No needed / Platform pre-loaded in vertical direction	1 / 2	5 / 5	3 / 3	15 / 30

FMEA Radial jig

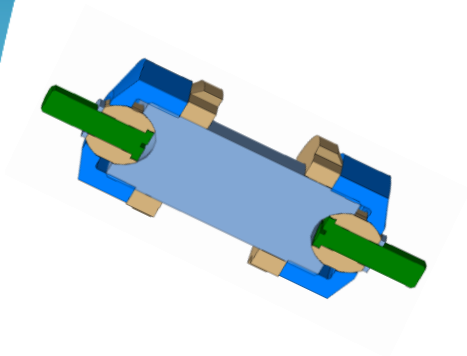


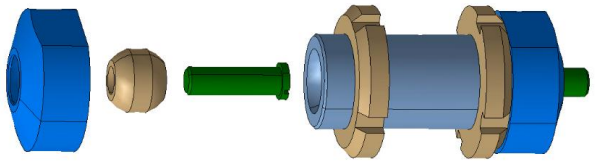




Group	Part	Potential Failure Type	Potential Failure No.	Failure Consequence	Possible Cause of Failure	Failure Recognition	Measures Recommended for Removing Failure	SEVER.	OCCUR.	DETEC.	RPN
Radial jig	Adjustment screw	Blocked - seizure	1	Radial axis of UAP blocked, **platform misaligned**	Seizure	No movement, bad platform position measured	Increase torque	10	1	1	10
		Blocked - radiation caused or ageing	2	Radial axis of UAP blocked, **platform misaligned**	Cold welding of components caused by radiation or ageing	No movement, bad platform position measured	Increase torque	10	2	1	20
		Bigger backlash	3	Backlash on output piston	Wear of components	Bigger rotation of adjustment knob to start move the piston	Platform pre-loaded in radial direction	2	5	3	30

FMEA Joints





Group	Part	Potential Failure Type	Potential Failure No.	Failure Consequence	Possible Cause of Failure	Failure Recognition	Measures Recommended for Removing Failure	SEVER.	OCCUR.	DETEC.	RPN
Spherical joint	Joint ball bearing	Blocked - seizure	1	Radial/vert. axis of UAP blocked, **platform misaligned**	Seizure	No movement, bad platform position measured	Increase torque	8	1	3	24
		Blocked - radiation caused or ageing	2	Radial/vert. axis of UAP blocked, **platform misaligned**	Cold welding of components caused by radiation or ageing	No movement, bad platform position measured	Increase torque	8	2	3	48
		Bigger backlash	3	Backlash on spherical joint	Wear of components	Bigger rotation of adjustment knob to start move the piston	Platform pre-loaded in radial/vertical direction	3	4	3	36

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FMEA initial analysis conclusions and further tests

- Risk Priority Number low, neverthless assumptions should be verified
  - Jigs and joints lifetime not yet tested with full operation time
  - Cycling tests planned in October 2019 after modification of Small UAP jigs and manufacturing of prototype series of Big UAP jigs
- Cycling tests (operation time), including small displacements impact check
  - Verification of assumed lifetime of components
  - Check wear of mechanical components (backlash increase)
- Radiation tests
  - Final prototypes

Impact of UAP failures on accelerator reliability

- Risks scenarios of the misaligned UAP supported components, to be analysed
- Risk evaluation using i.e. RIRE

Reliability Requirements and Initial Risk Evaluation – RIRE ☺

1. Risk matrix	2. Adapted FMEA
Accelerator reliability targets	System failure behaviour

3. System reliability requirements
4. Risk Evaluation: necessary reliability calculations

Successfully applied to

- ✓ Definition of reliability requirements for DYPQ
- ✓ Identification of DYPQ trigger link as critical part: reliability calculation, modification of system design on hardware level
- ✓ Definition of 11T reliability requirements (D. Sollich*) ongoing

*Reliability requirements for the 11T quench protection system, 17.10.2018, Session Wednesday PM - WP5/WP7/WP9/WP11

UAP maintainability

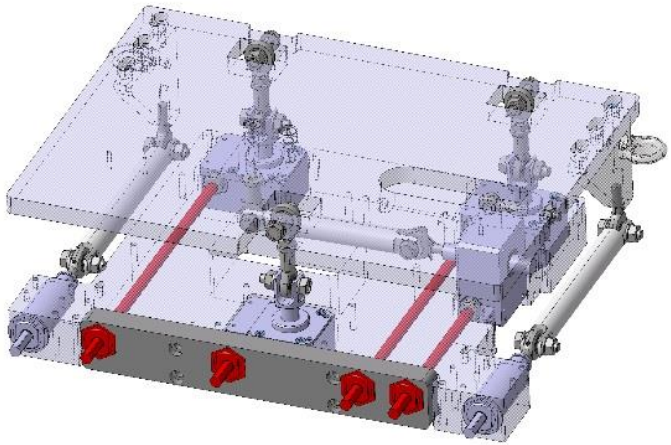
Maintainability assessment attributes:

Attribute	Assesment
Simplicity	The use of a minimal amount of components and assembliesin the devices will be checked, even those components that are redundant.
Identification	The identification of elements to be maintained and the locations for testing will be checked. It will be also observed that connectors are identified as well as danger areas, places where technicians have to position themselves for working, etc.
Modularity	It will be checked if there are different functional assemblyunits in the device, which allow to minimize the parts of the device to be touched in case of maintenance operations.
Tribology	Appropriate choice of device materials that are subjected to friction, lubrication and wear will be checked, with the aim of maximizing their life.
Ergonomics	It will be checked how easy it is the development of maintenance tasks, analyzing the weight, size and shape of components to be handled. Those areas allocated for the task completion will be also reviewed, etc.etc.checking their suitability interms of lighting, volume, etc.
Standardization	It will be checked the components compatibility to be replaced with others found in the market. It will result in a minimum storage of components, and minimum amount of adjustment sespecially in elements to replace at low maintenance levels.
Failure watch	The existence of failures indicators on the device will bechecked, as well as the possibility of monitoring parameters useful for maintenance.

Curtesy P. Moreu de Leon, „A practical method for the maintability assesment ...”

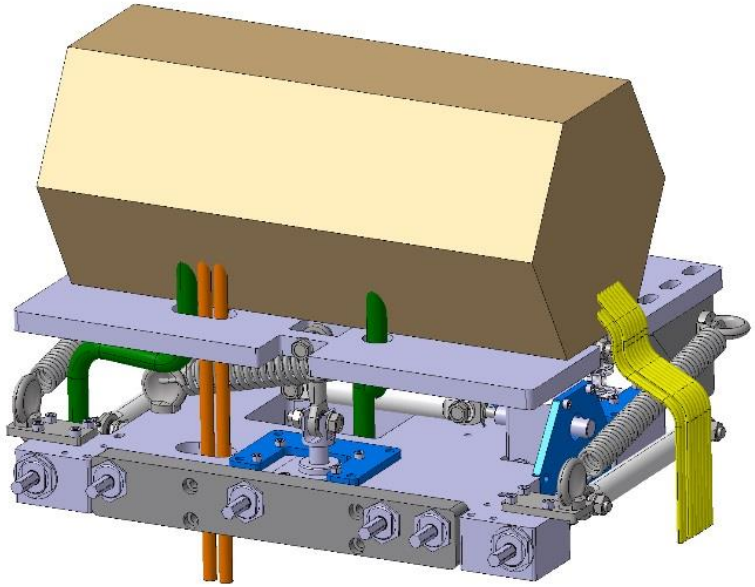
UAP maintainability

- Simplicity
  - **Main UAP assumption is to use minimum amount of components**
- Identification
  - **UAP components well identified as locations defined by UAP specification**. Additional components (connectors, sensors) are defined by final UAP user
- Modularity
  - **UAP modular approach**
- Tribology
  - Rate will be known after final cycles tests



UAP maintainability

- Ergonomics
  - Final ergonomics will depend on integration of all additional equipment by UAP user. **Considering only UAP with jigs and joints – guidelines assumes design in way to allow simplified assembly/ disassembly of jigs and joints. Neverthless access to space between TOP and BOTTOM plate is not so trivial. Also ergonomics will be different for Big and Small UAP**
- Standardization
  - **UAP standardized jigs and joints approach**
- Failure watch
  - Dependent on UAP version (manual / motorized-adapter/ fully motorized)



Conclusions

- UAP concept assumes high reliability and maintainability of platform
- Reliability of the UAP sub-components will be known after components cycle-testing and final tests of Small and Big UAP prototypes
- Impact of UAP failures on accelerator reliability to be analyzed

Thank you for your attention