Evolution of assembly tooling and procedures for UK Crab Cavity Cryomodules

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Early Careers Showcase – CERN – 14th January 2025

DQW-LHC Cryomodules UK

- Build poster overview
- FPC tooling
- Space optimisation
- Vacuum tooling
- Bellows protection
- PIMs processing
- Portable Cleanroom
- Transport
- Procedure bottlenecks
  - BOM kitting & parts preparation

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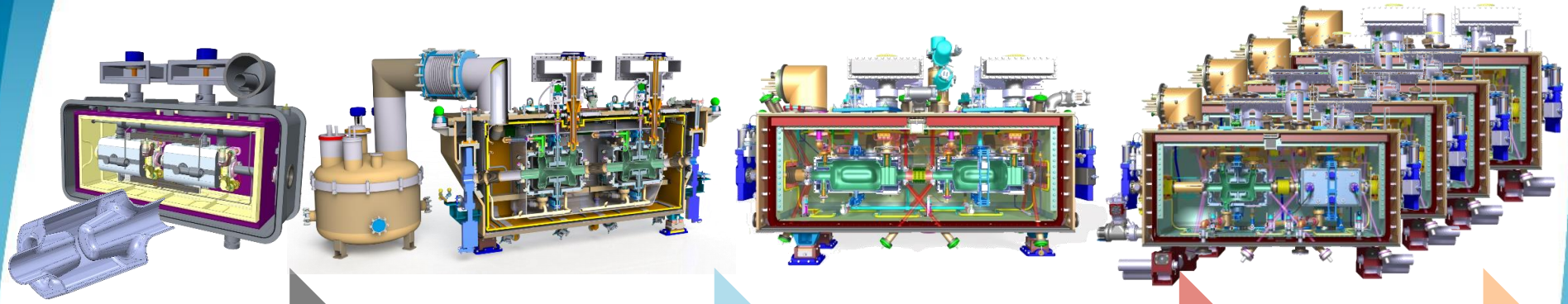
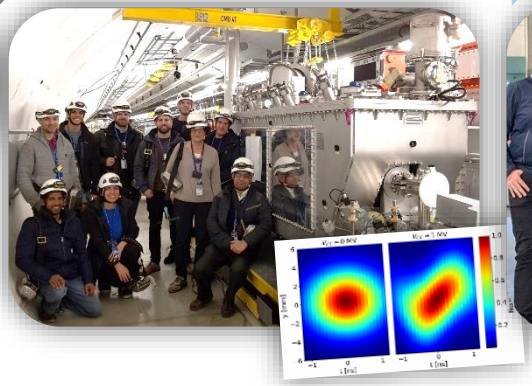
Hi Lumi Crab Cavities – UK Collaboration



2011 UK 4-Rod Crab Cavity → DQW-SPS CM → RFD-SPS CM → DQW-LHC CMs 2027



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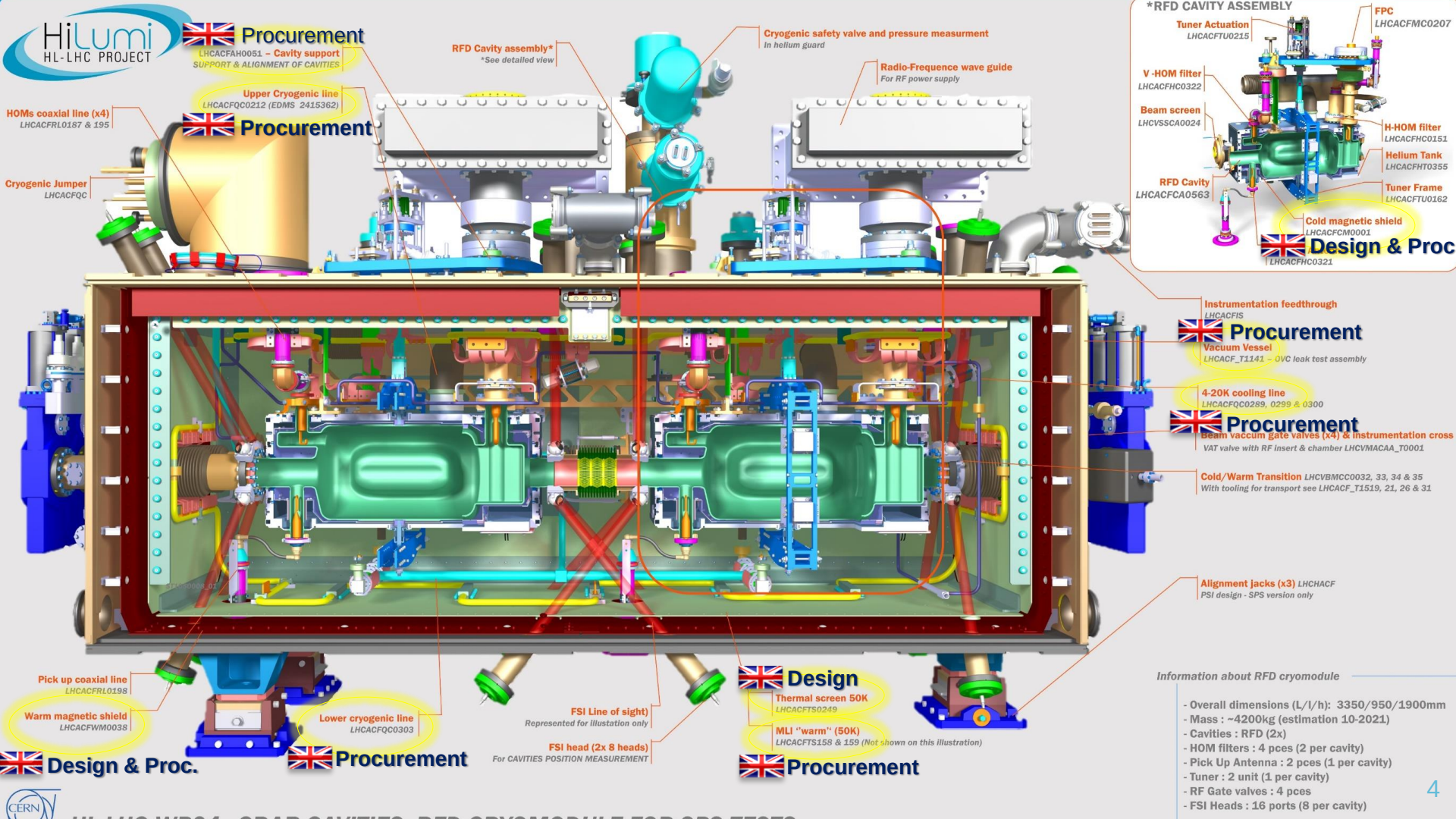
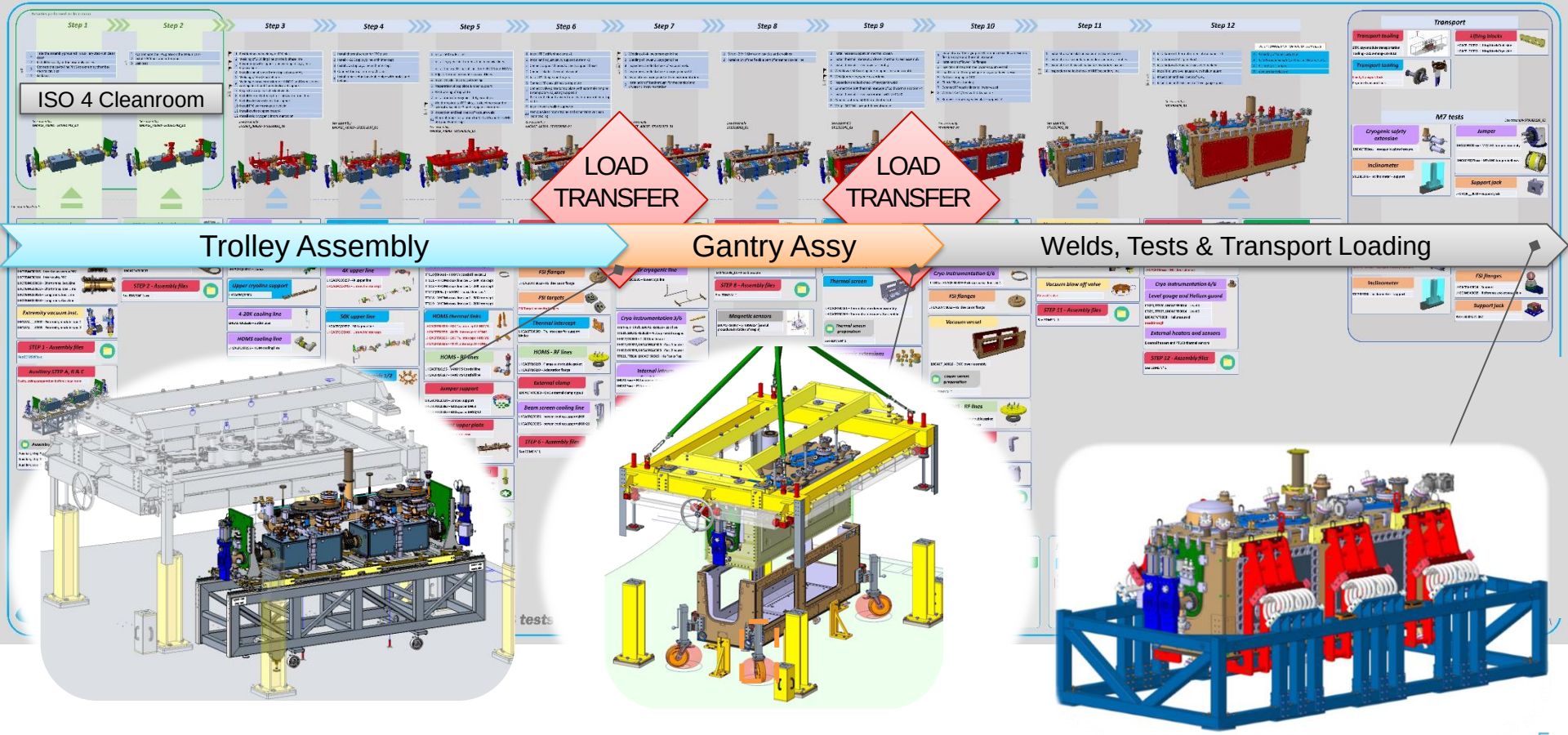


Information about RFD cryomodule

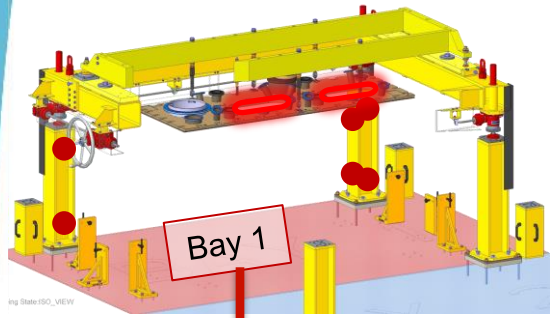
- Overall dimensions (L/l/h): 3350/950/1900mm
- Mass : ~4200kg (estimation 10-2021)
- Cavities : RFD (2x)
- HOM filters : 4 pces (2 per cavity)
- Pick Up Antenna : 2 pces (1 per cavity)
- Tuner : 2 unit (1 per cavity)
- RF Gate valves : 4 pces
- FSI Heads : 16 ports (8 per cavity)

RFD Build Poster – Teddy Capelli

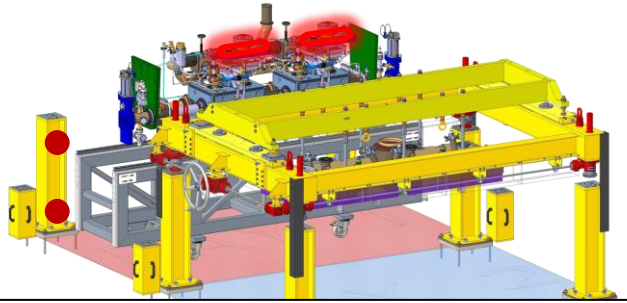


Improved alignment strategy for load transfer

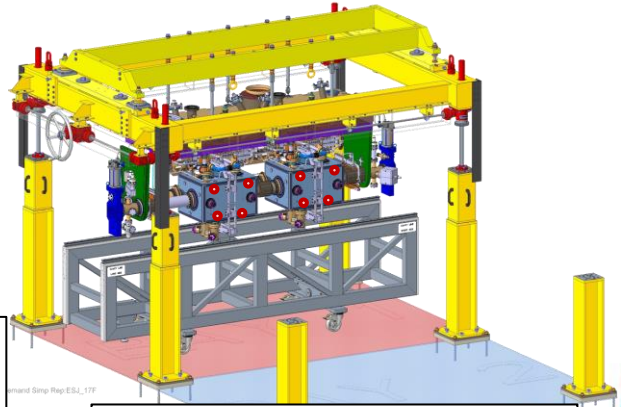
- Improved Survey and Alignment strategy for string & top plate integration
- Intermittent electrical continuity checks on FPC throughout build
- Strain gauges on Blades & FPC can help to identify movement during build



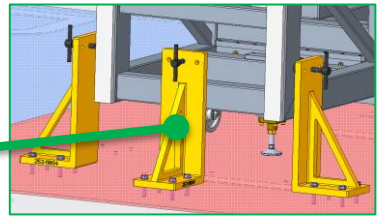
Measure position of FPC interface on top plate in Bay 1



Position string FPC interface accurately to measured position in Bay 1



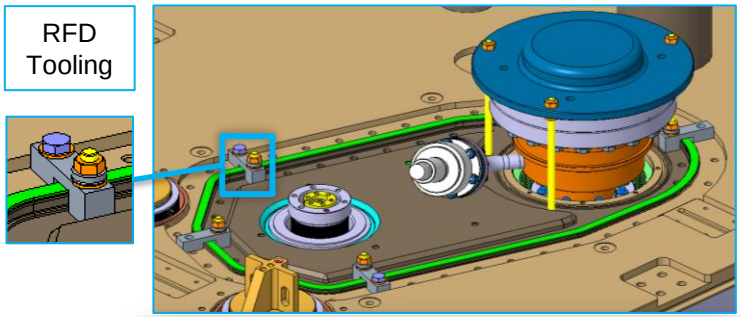
Perform integration of string



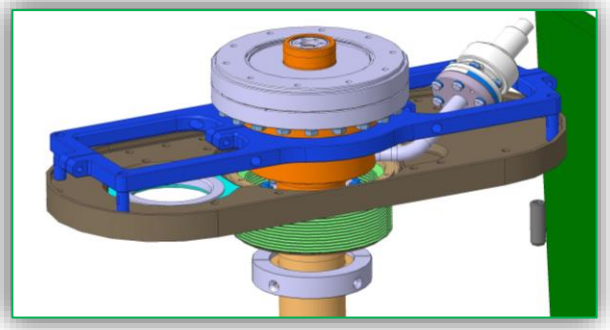
Trolley Positioning Tool

Improvements FPC plate tooling

RFD Tooling

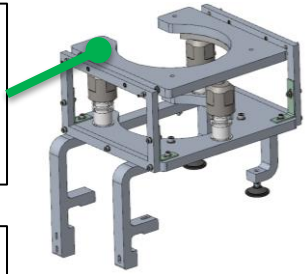


DQW Tooling

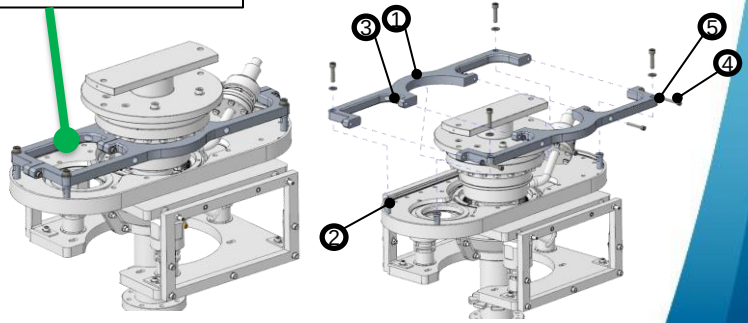


- Improved alignment tooling for welding plate to FPC bellows
- Improved support tooling for FPC plate (mimic interfaces used on Cryomodule)

Alignment support for plate welding, designed for orientation w.r.t centre axis



Fixture to support FPC plate during assembly designed to replicate CM interfaces



Challenges:

- Needs to pass through OVC top plate
- Support cantilever load
- Height and level adjustment for welding

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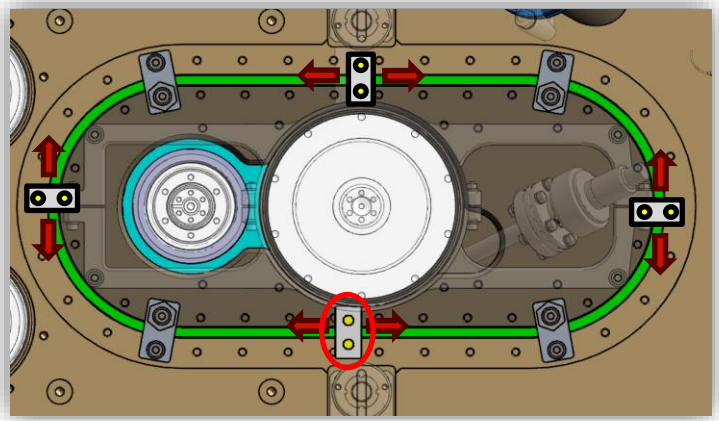
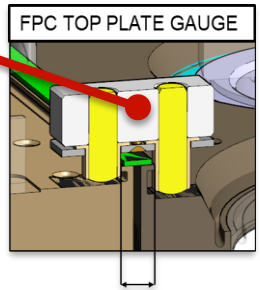
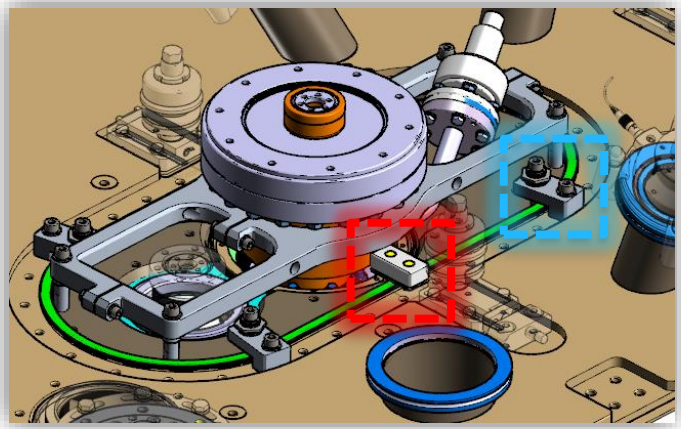
FPC plate welding and installation

- Extra tools designed to check and align FPC plate to OVC
- Load path removed between FPC and plate

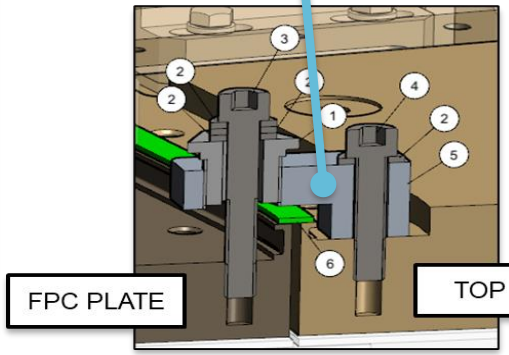


Gauge to align weld features between FPC plate and OVC

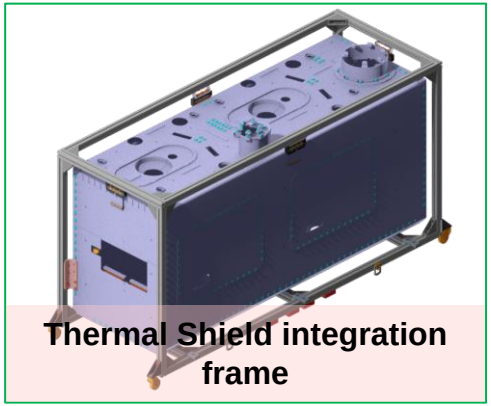




Setting tool to control height of Plate locally

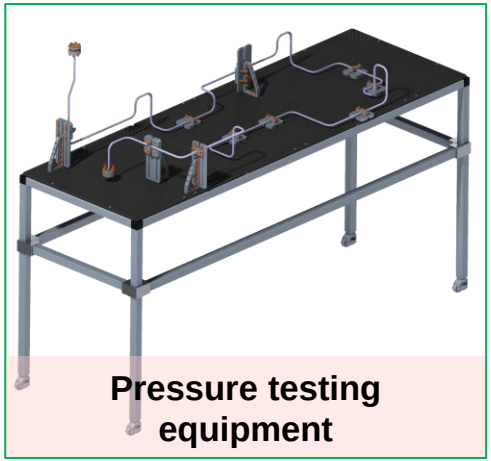


Space saving & design optimisation

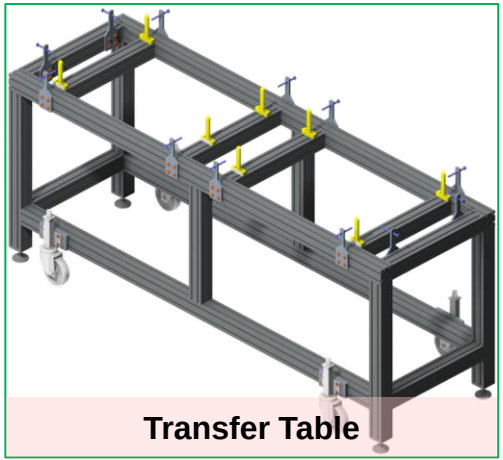


Thermal Shield integration frame

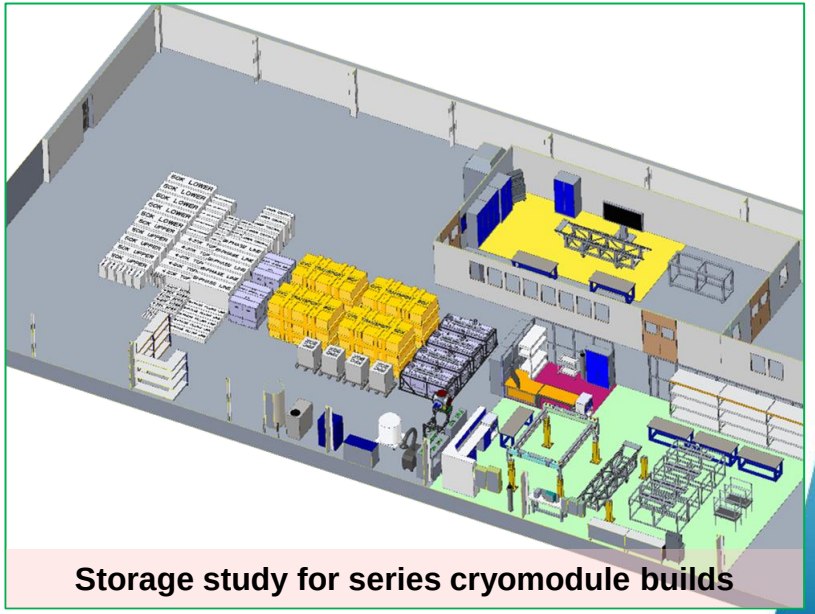
- Improved Cryogenic pressure testing table – includes breadboard for adjusting clamp positions
- Low profile thermal screen integration frame
- Bulky transfer table replaced and dismantled



Pressure testing equipment



Transfer Table

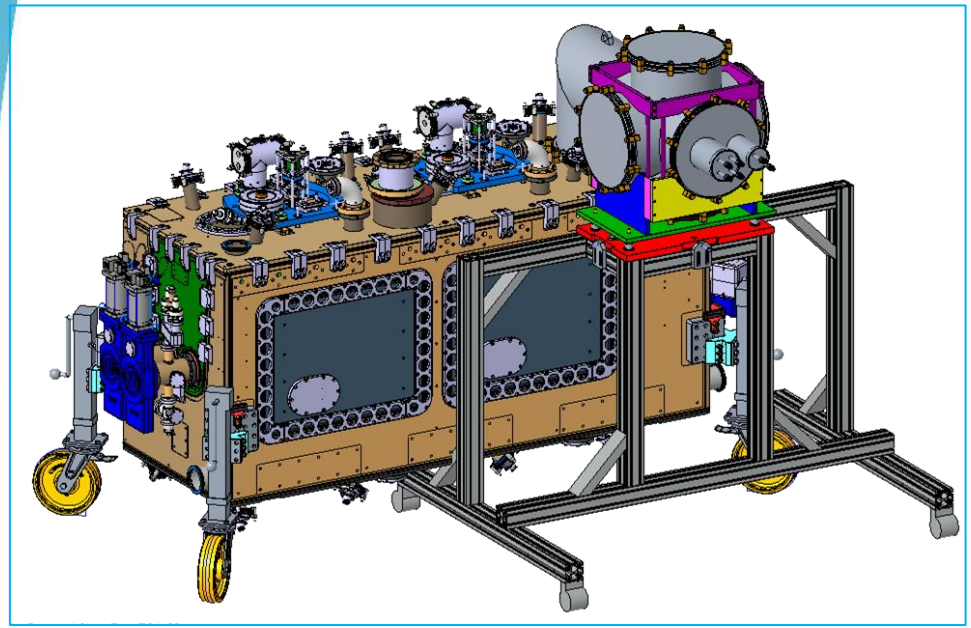


Storage study for series cryomodule builds

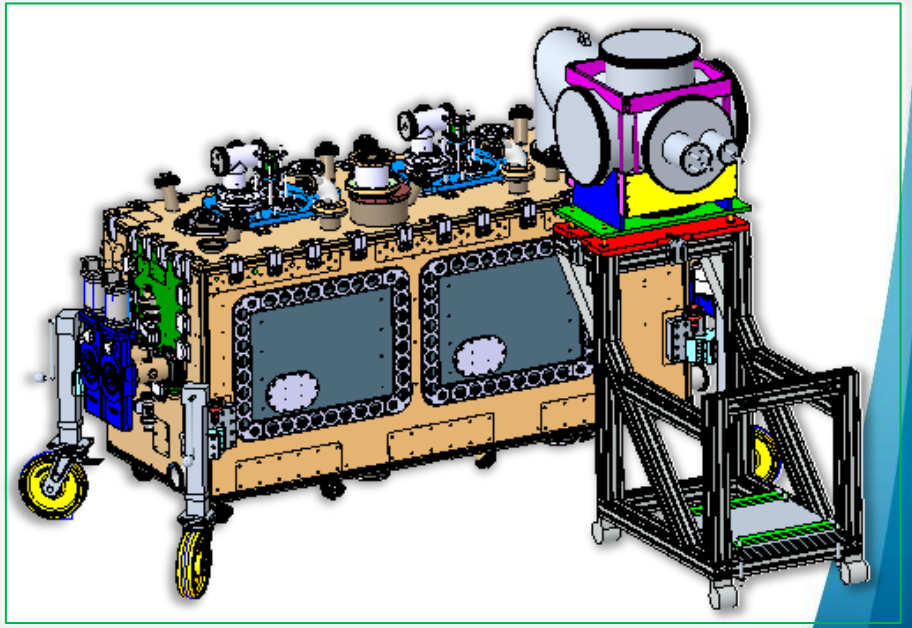
Space saving & design optimisation

- Cold test trolley for outgoing acceptance testing
- New Cantilever frame reduces footprint
- Easier to work around

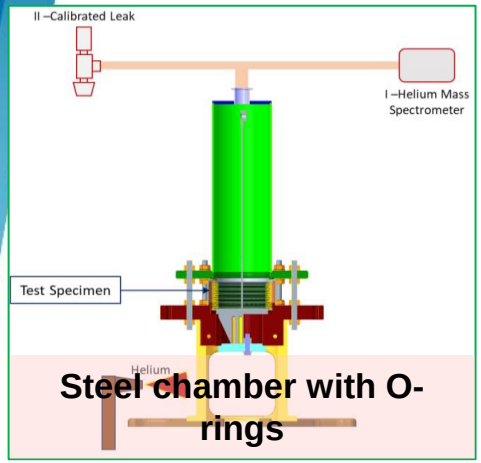
RFD



DQW



Evolution of weld leak test tooling



Steel chamber with O-rings

Bag & Tape

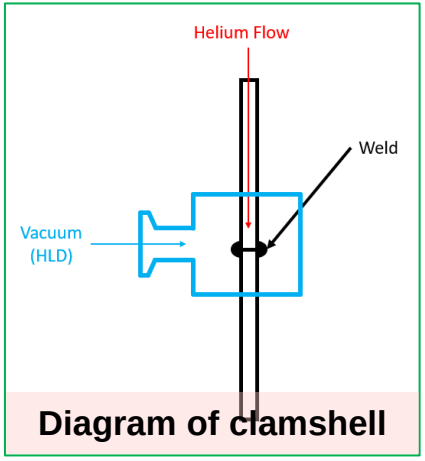
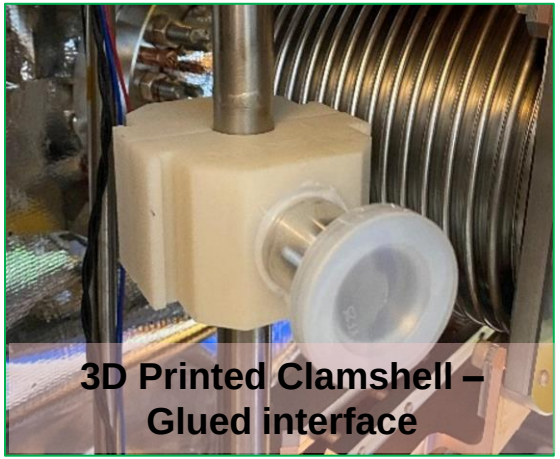
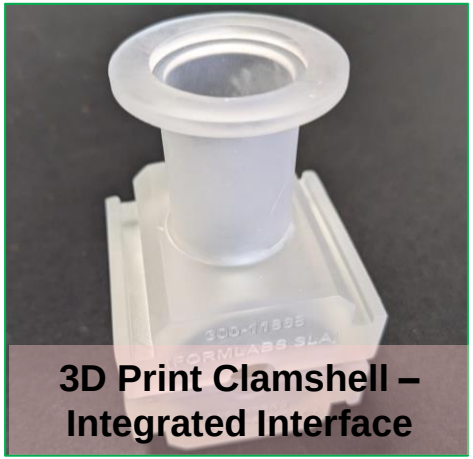


Diagram of clamshell

Stainless Steel Clamshell



3D Printed Clamshell – Glued interface



3D Print Clamshell – Integrated Interface

SLA 3D Printed Clamshell

- Cost saving
- Low lead time
- No welding
- Next : No glueing

Credit: Oliver Poynton (STFC)
Luke Farley
Ali Seller et al (CERN)

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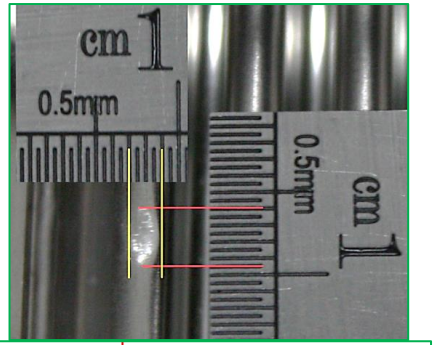
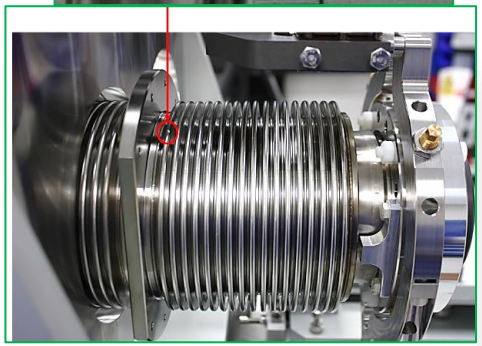
Bellows protection

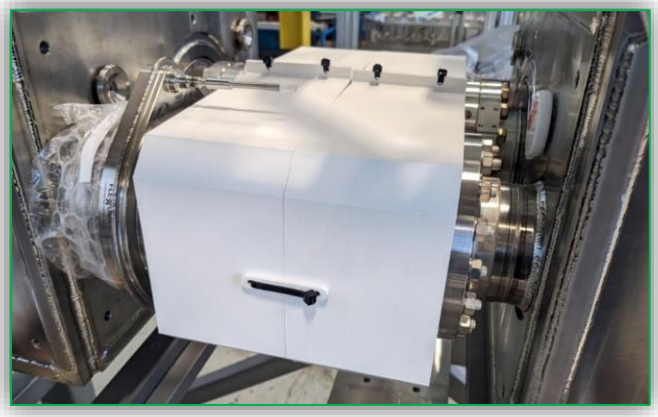


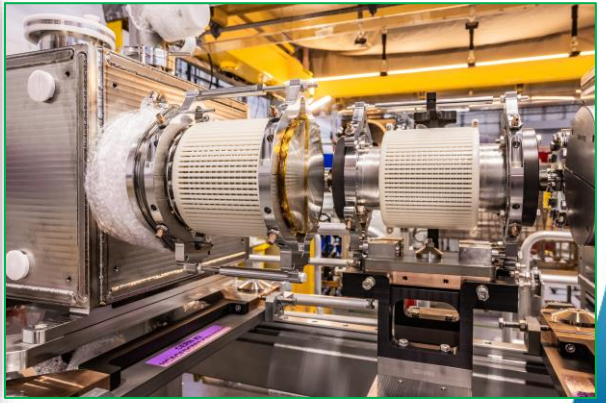


- Handling errors experienced during RFD SPS build
- Some imperfections are the result of not following procedure correctly, some from suppliers, others unknown.
- Difficult to categorically conclude when damages occurred as travellers were quite lightweight

Improvement

- Bespoke covers design for DQW build for various processing and assembly steps with bellow components





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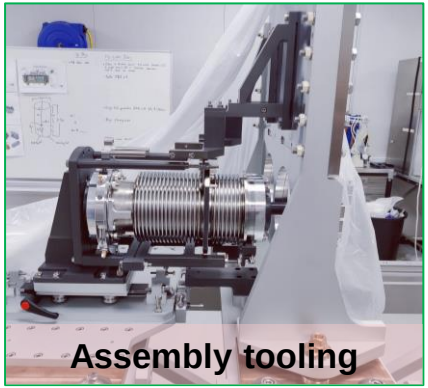
Plug-In-Module Ultra-High Vacuum Processing

Assembly and test tooling for;

- Ultra pure water rinse, Isopropanol bath, and N_2 dry in ISO4
- + RGA & helium leak test, and particle count qualification

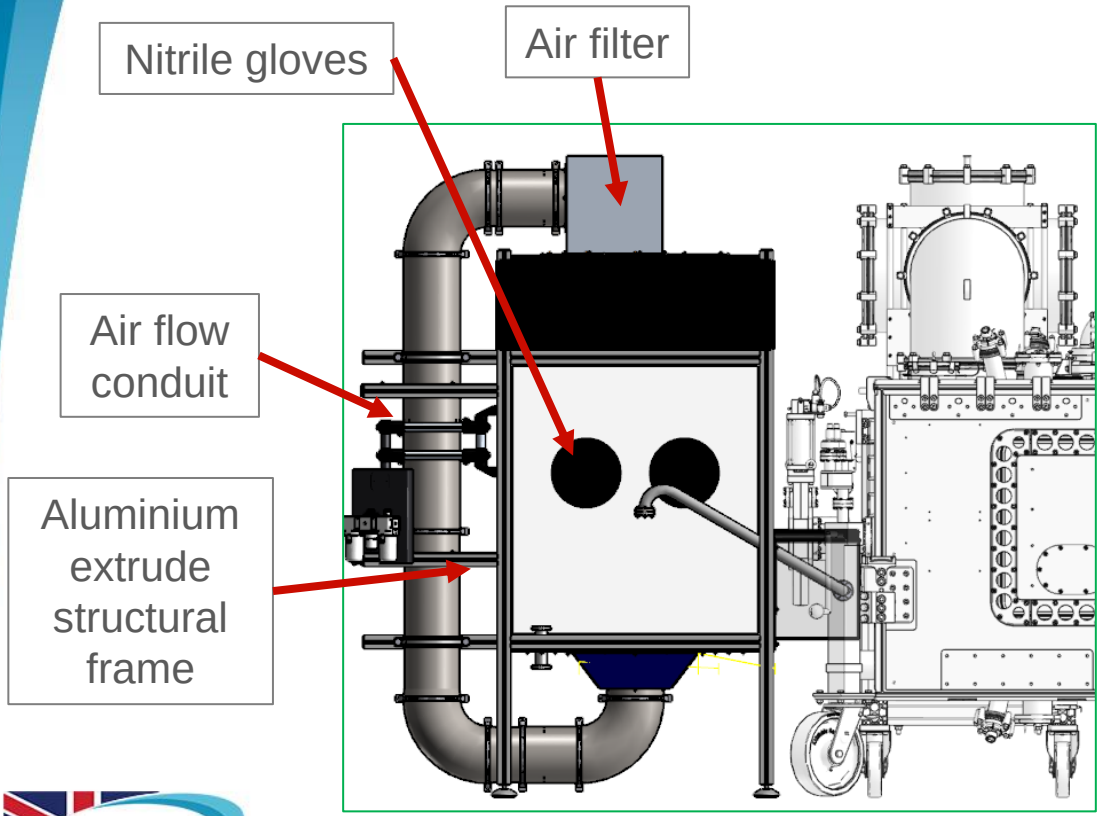

Particle Count Test


Assembly tooling


RGA & leak testing


Beamscreen cleaning at Daresbury

Portable cleanroom for beamline vacuum testing outside of the cleanroom



- Allows for temporary access to critical beamlines
- Final leak and RGA test on beamline outside of cleanroom
- Maintains ISO-4 connections of the beamline throughout the build at Daresbury
- Nitrogen > Vacuum > Nitrogen conversion

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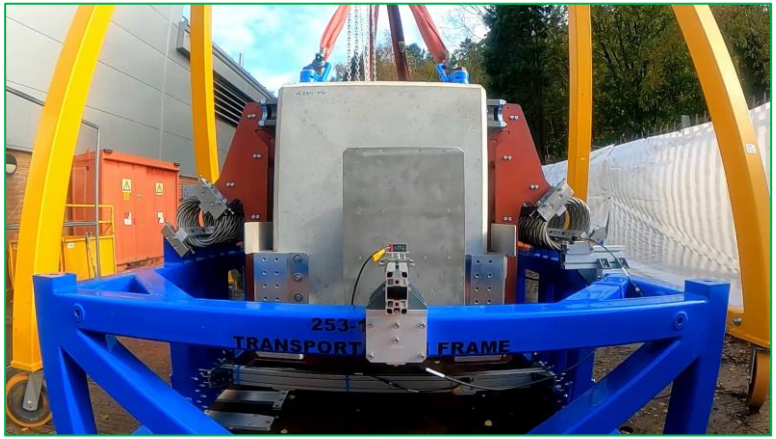
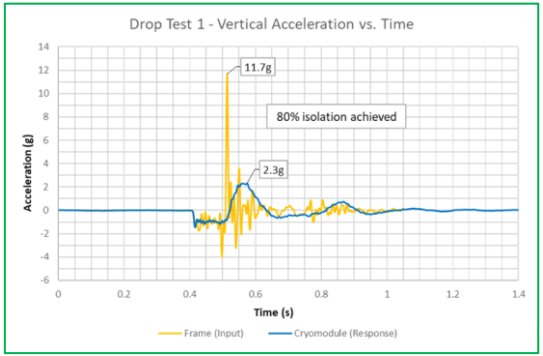
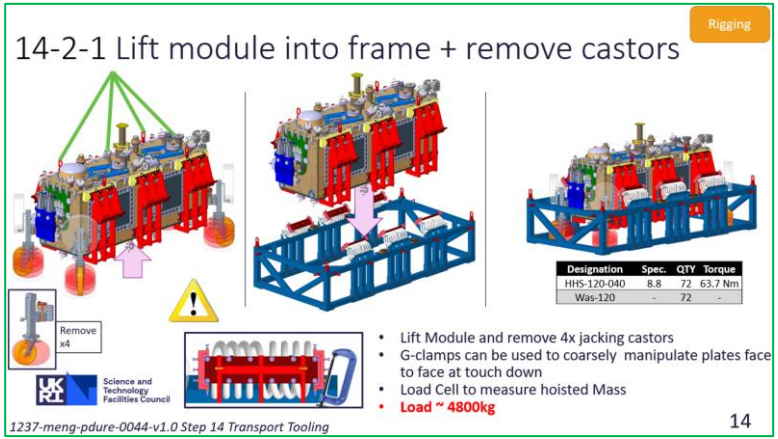
Anti-shock Transport frame & tooling

- STFC design & procurement
- MIL-STD-810H spec.
- 80% isolation

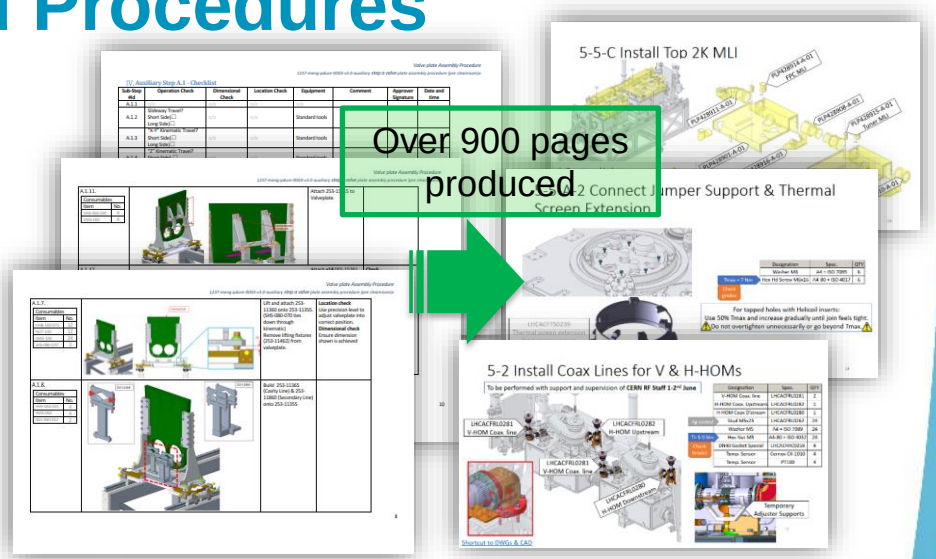


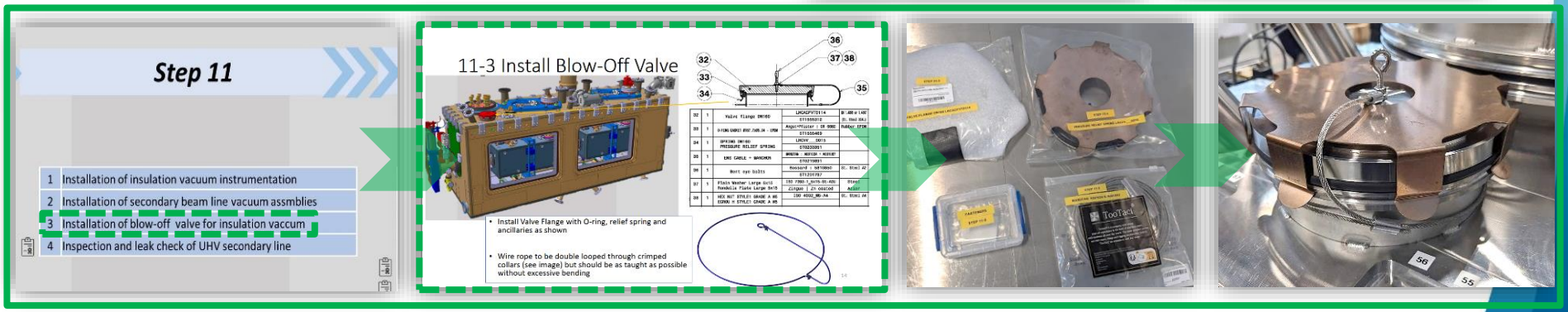




Detailed Build Procedures

- Poster logic + tooling & infrastructure
- Part of Traveller (QA)
- Troubleshoots & de-risk build
- Captures critical requirements, torques & sign-off
- ‘BOM kits’ pre-prepared by sub-step

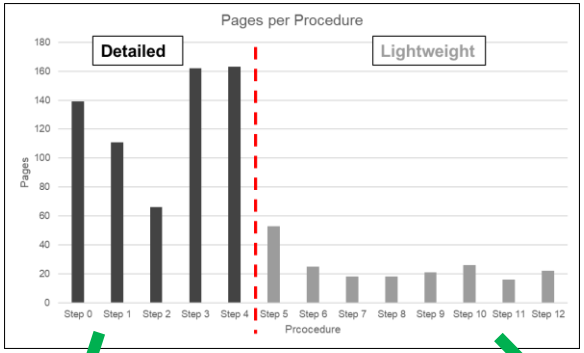




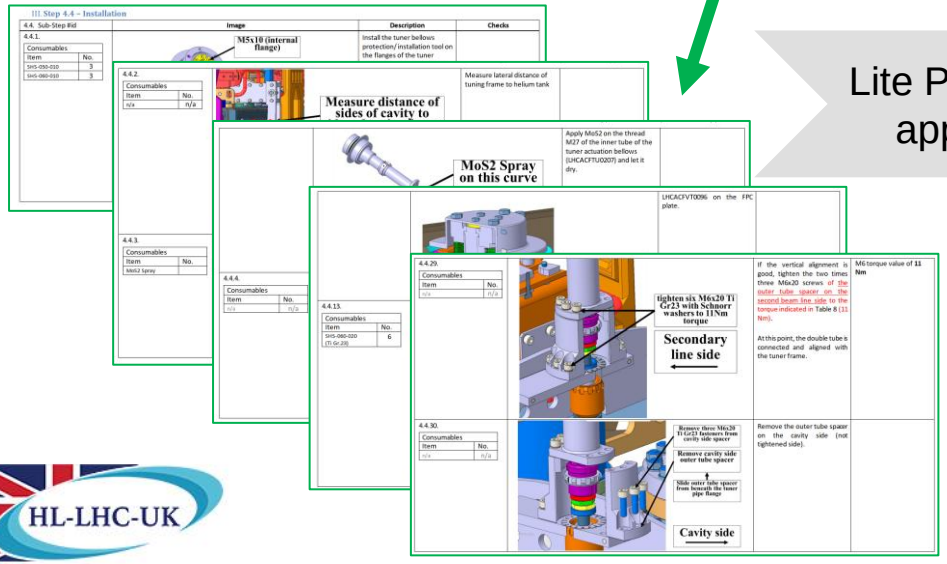
RFD Procedure Bottleneck

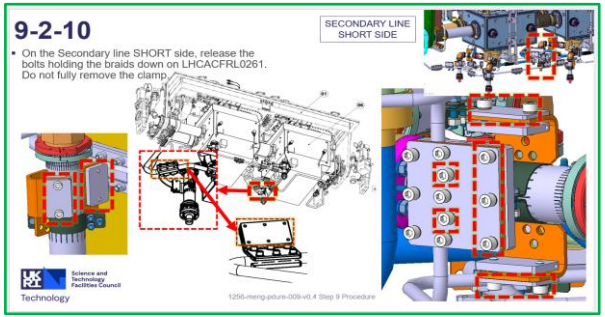
Mitigation

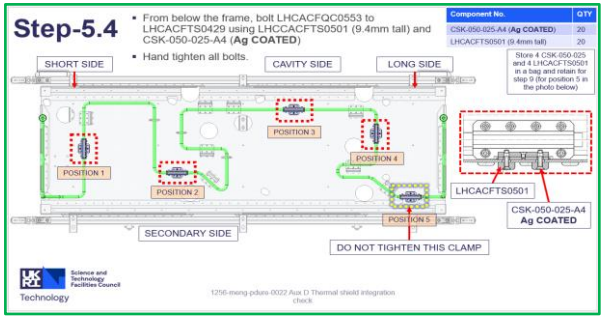
- DQW procedure development progressing well. Need to maintain buffer between publication & execution to allow information digestion beforehand

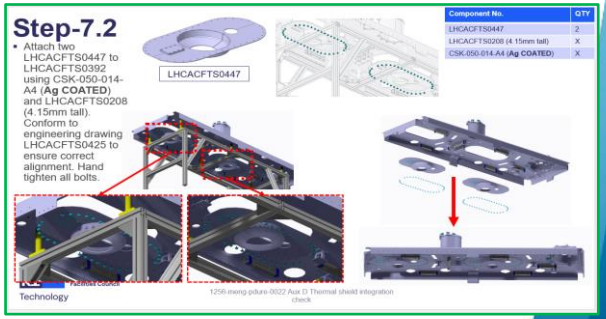


Lite Procedure approach



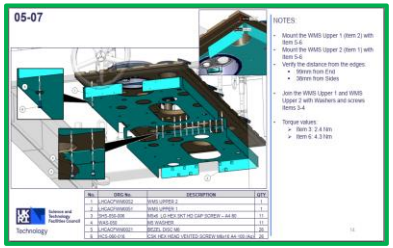


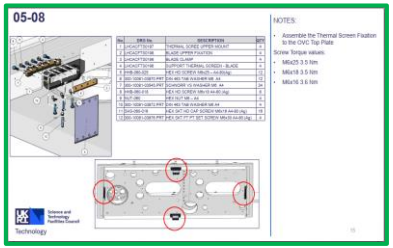


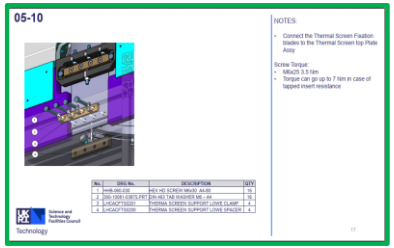


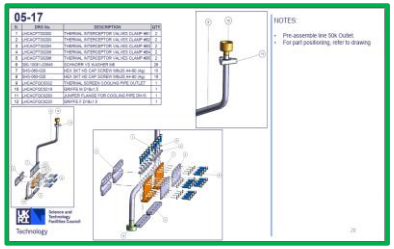
Where to next?

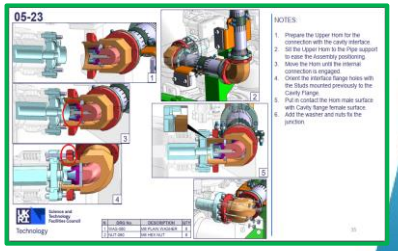
- 5 years of procedure progression so far
- Effort should match risk and reward
- VR/AR considered for future cryomodules
- Current procedures are viable for Hi-Lumi

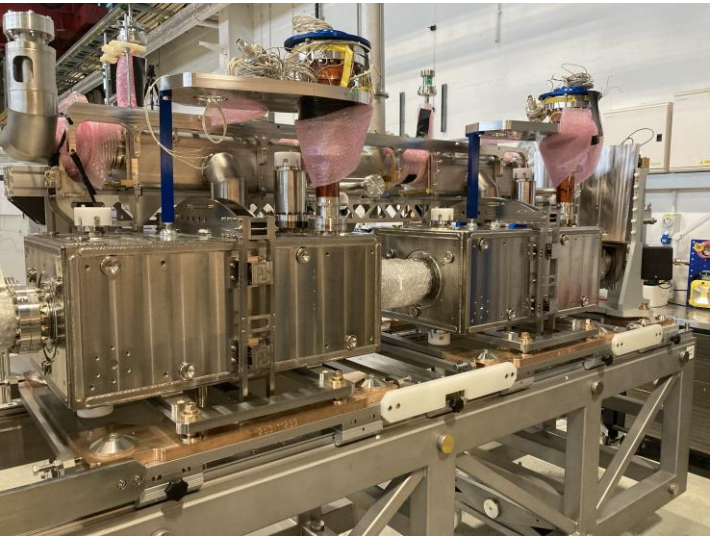












Questions?