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Design of a High-Speed Disc Chopper Test Rig

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Overview

- Background
- Scope & Requirements
- Initial Concepts
- Project Plan
- Design Considerations
- Analysis
- Final Design

The ISIS Facility

- Oxfordshire, UK
- 1985 Facility Opened
- 2008 TS2 opened
- Pulsed Spallation Source
- Target Stations
  - TS1 160kW 40Hz
  - TS2 40kW 10Hz

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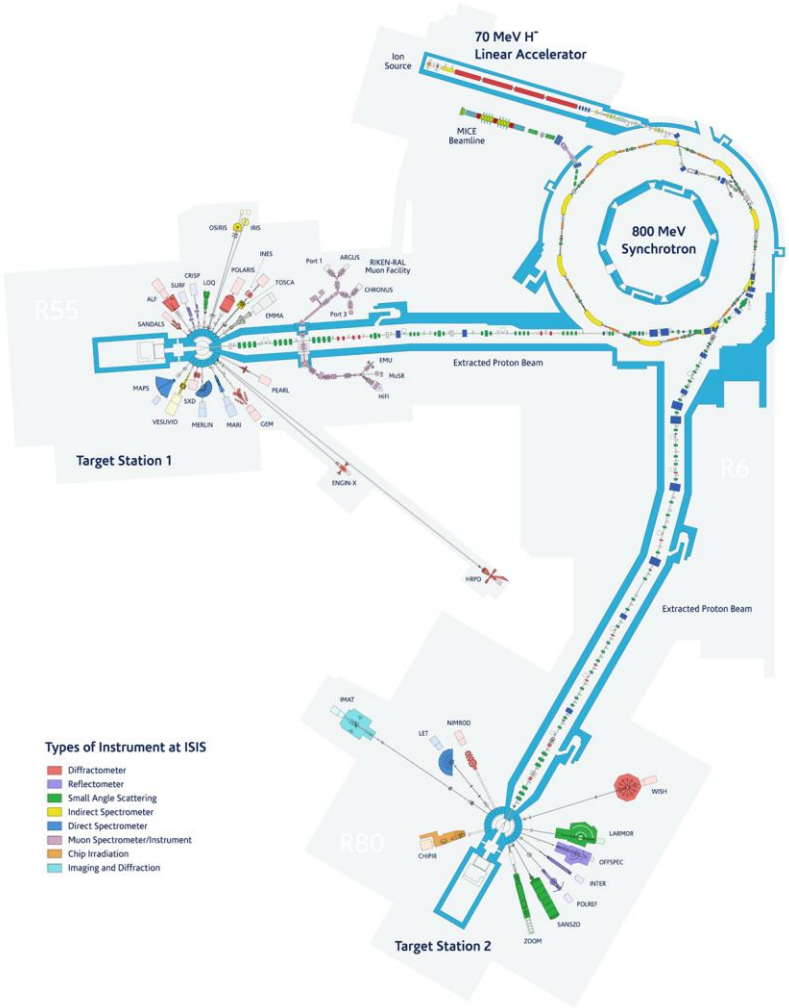
The ISIS Facility

- 30 Operational Beamlines
- 350 staff members
  - 24 Instrument Design Engineers



Types of Instrument at ISIS

- Diffractometer
- Reflectometer
- Small Angle Scattering
- Indirect Spectrometer
- Direct Spectrometer
- Muon Spectrometer/Instrument
- Chip Irradiation
- Imaging and Diffraction

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Background

- New FREIA instrument
- ESS require larger disc choppers than any at ISIS
- Currently no facility for over-speed testing of disc choppers (balancers, acoustic chambers)
- Use analysis and past experience

EUROPEAN SPALLATION SOURCE

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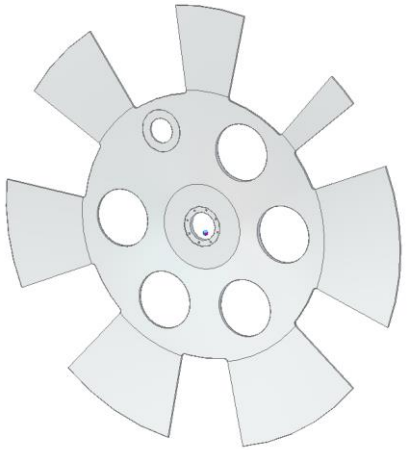
Disc Chopper

- Disc choppers allow the flow of selected neutrons, and absorb all others.
- Aluminium alloy disc potted with an area of neutron absorbing B_4C resin.
- Rotating at up to 50hz – 3000rpm.
- Synchronised to the beam pulses.



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Requirements

Requirement	Essential	Desired
Capable of testing chopper discs of varying size	Up to 1.3 metre diameter	Up to 1.5 metre diameter
Fits within space allocated for rig	AxBxC m of room	Possible to change motors/discs/fittings with ease of movement in space
Parts of rig needing moving capable of being lifted by crane	Proposed new crane limit 2 ton	--------
Mechanism for opening rig to change chopper discs and motor	-------	Can be performed with minimal crane assistance
Double disc testing	-------	
Service life	-------	10 years
Vacuum	10^{-3} mbar	
Door	Contain any catastrophic failure	Double hinge or craned in. Operable by 1 person
Mechanism to put disc in place – crane	Capable of placing 1.3-1.5 meter (20-50 kg) chopper disc on chamber end easily	-------
Rig secured to floor	Bolted directly to ground to negate dynamics/vibration effects	-------
Adaptor to connect motor bearing system	SKF G5 adaptor	Other adaptors to be manufactured to accommodate a variety of motors
Modular design	Rig can be disassembled and rebuilt in new location.	-------
Ports for monitoring of discs	Power feedthroughs for thermocouples and speed monitors	Possibility of adding a viewport

Location

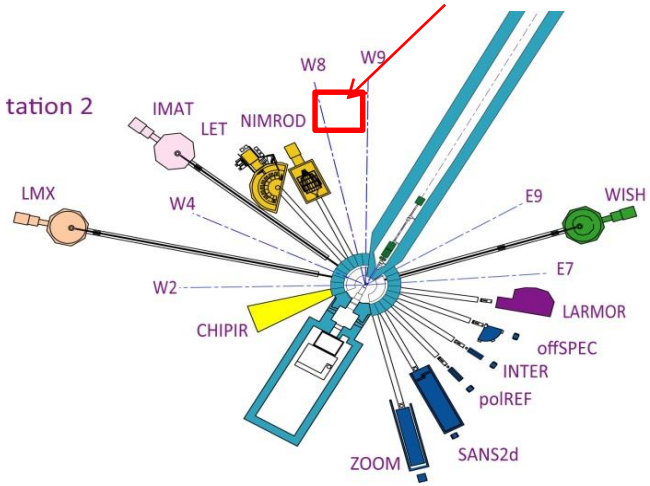

Figure 1: Proposed location of test rig.

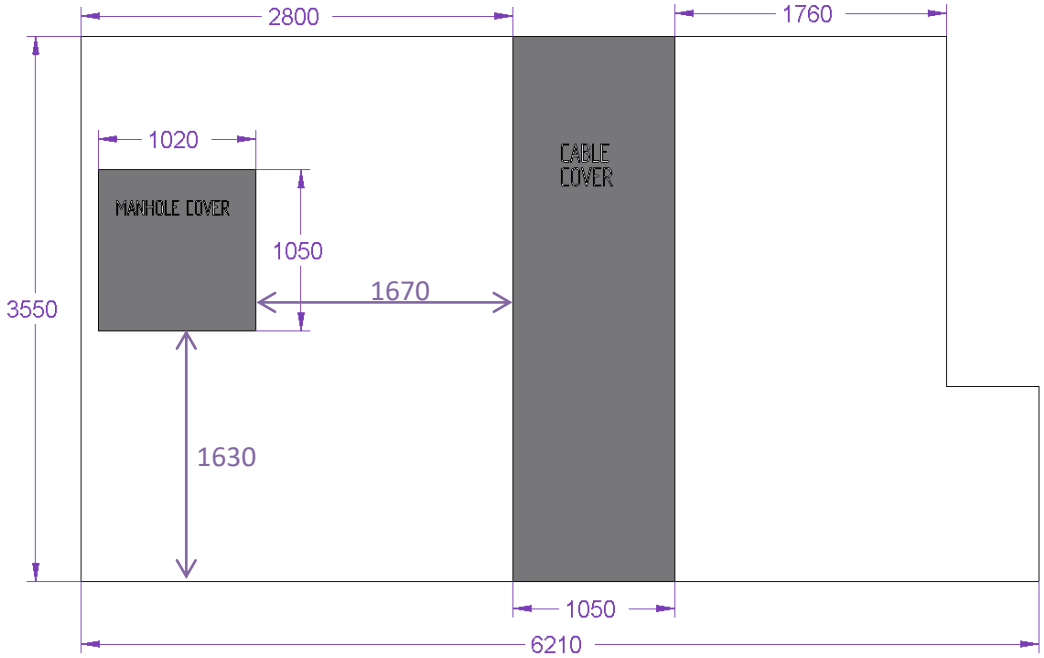

Figure 2: Floor dimensions of bunker, in mm, to house the rig (manhole cover and cable trench cover shown)

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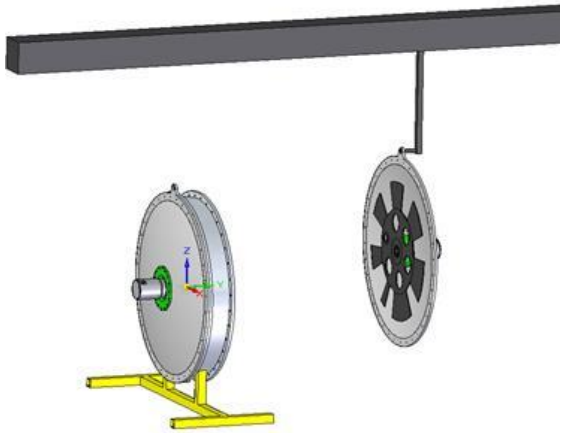
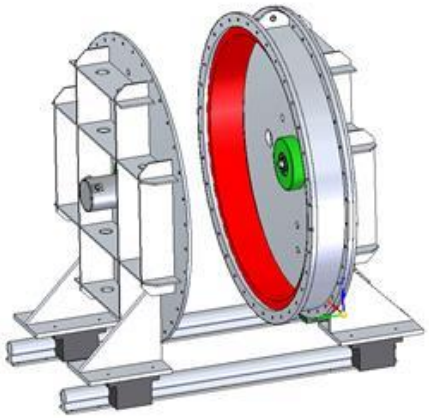
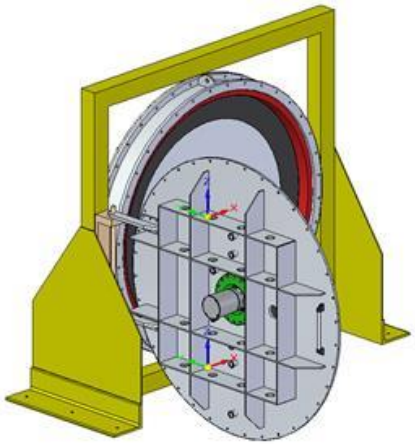
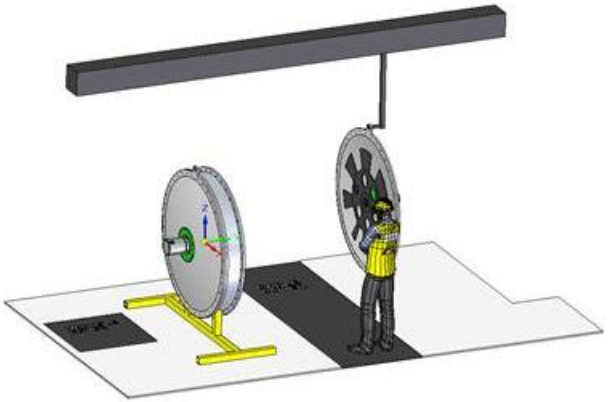
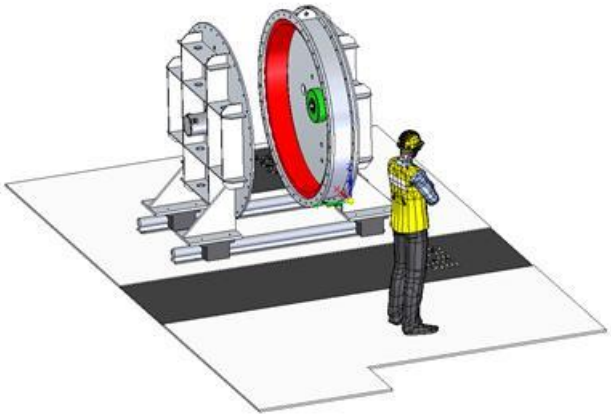
Initial Concepts

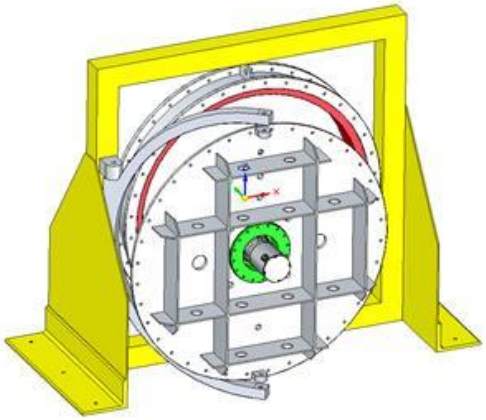












Stand-alone concept

Rails concept

Door concept

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Project Plan

- March 2017 – Scope & Stakeholders established
- Concept designs
- PDR – End of April
- Develop design based on PDR
- CDR – Start of July
- Create drawings *Largest deviation from plan*
- October 2017 – FDR held and Progress document written

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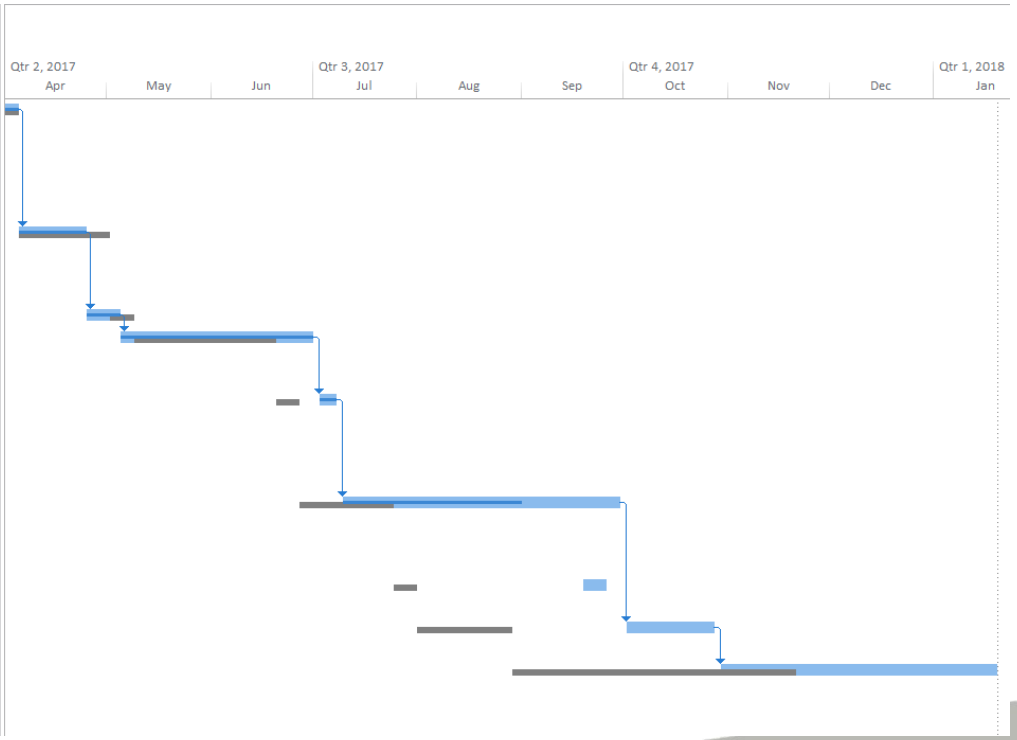
	Task Name	Start	Durati	Finish	Baseline Start	Baseline Finish	% Com	Start Var.	Finish Var.	Add
1	Identify stakeholders and capture requirements for the ISIS chopper test rig – create a plan	Wed 29/03/17	5 days	Tue 04/04/17	Wed 29/03/17	Tue 04/04/17	100%	0 days	0 days	
2	Develop 2 to 3 concepts and hold a PDR of the ISIS chopper test rig	Wed 05/04/17	8 days	Mon 24/04/17	Wed 05/04/17	Mon 01/05/17	100%	0 days	-2 days	
3	PDR	Tue 25/04/17	5 days	Thu 04/05/17	ıe 02/05/17	lon 08/05/17	100%	-2 days	-2 days	
4	Develop chopper test rig design based on PDR feedback	Fri 05/05/17	41 days	Fri 30/06/17	Tue 09/05/17	Mon 19/06/17	100%	-2 days	9 days	
5	Hold a CDR for developed chopper test rig design, including plan and cost estimates	Mon 03/07/17	5 days	Fri 07/07/17	Tue 20/06/17	Mon 26/06/17	100%	9 days	9 days	
6	Produce detail drawings of chopper test rig following CDR	Mon 10/07/17	60 days	Fri 29/09/17	Tue 27/06/17	Mon 24/07/17	65%	9 days	49 days	
7	Hold a FDR of the chopper test rig	Tue 19/09/17	5 days	Mon 25/09/17	Tue 25/07/17	Mon 31/07/17	0%	40 days	40 days	
8	Place orders for chopper test rig	Mon 02/10/17	20 days	Fri 27/10/17	Tue 01/08/17	Mon 28/08/17	0%	44 days	44 days	
9	Manage delivery of chopper test rig components	Mon 30/10/17	60 days	Fri 19/01/18	Tue 29/08/17	Mon 20/11/17	0%	44 days	44 days	



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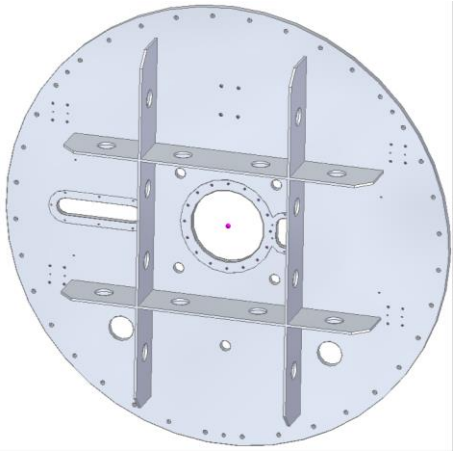
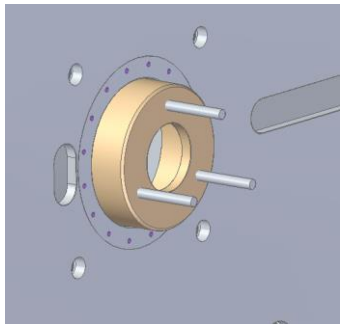
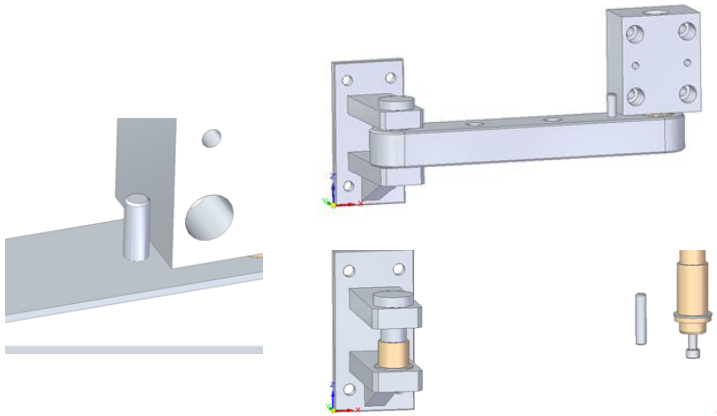
Design Considerations



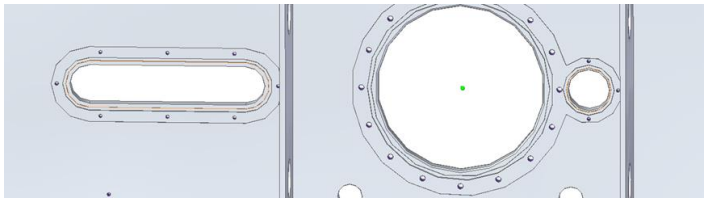
Ribs



Guide Rods



Hinge System



Access Holes

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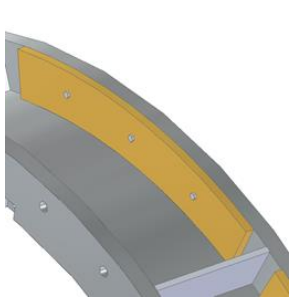
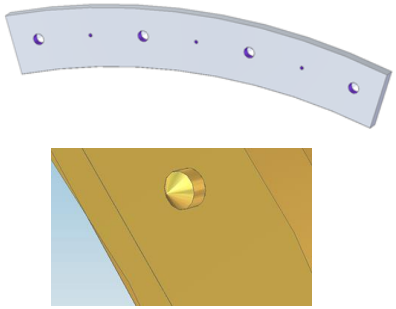
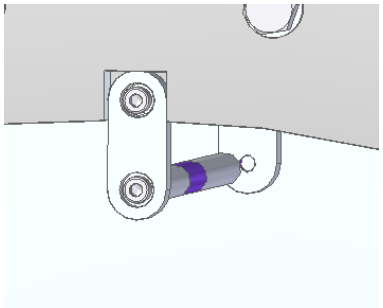
Design Considerations

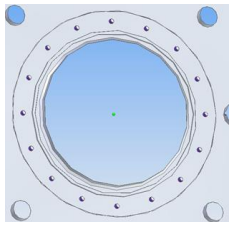


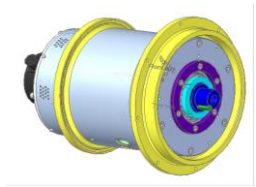


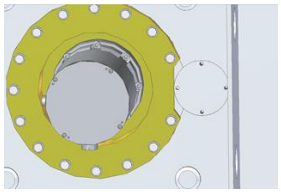
Screw Plates



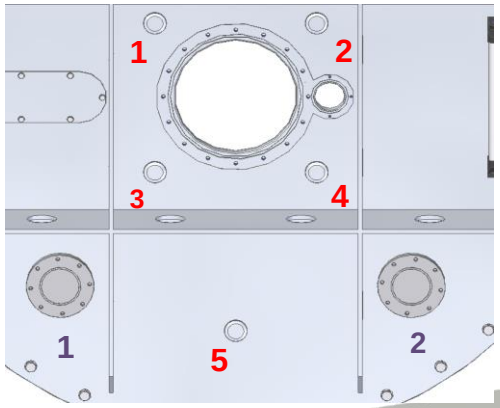
Baffle Plate connection







Adaptor Hole



KF40

ISO-F 100

Vacuum Ports

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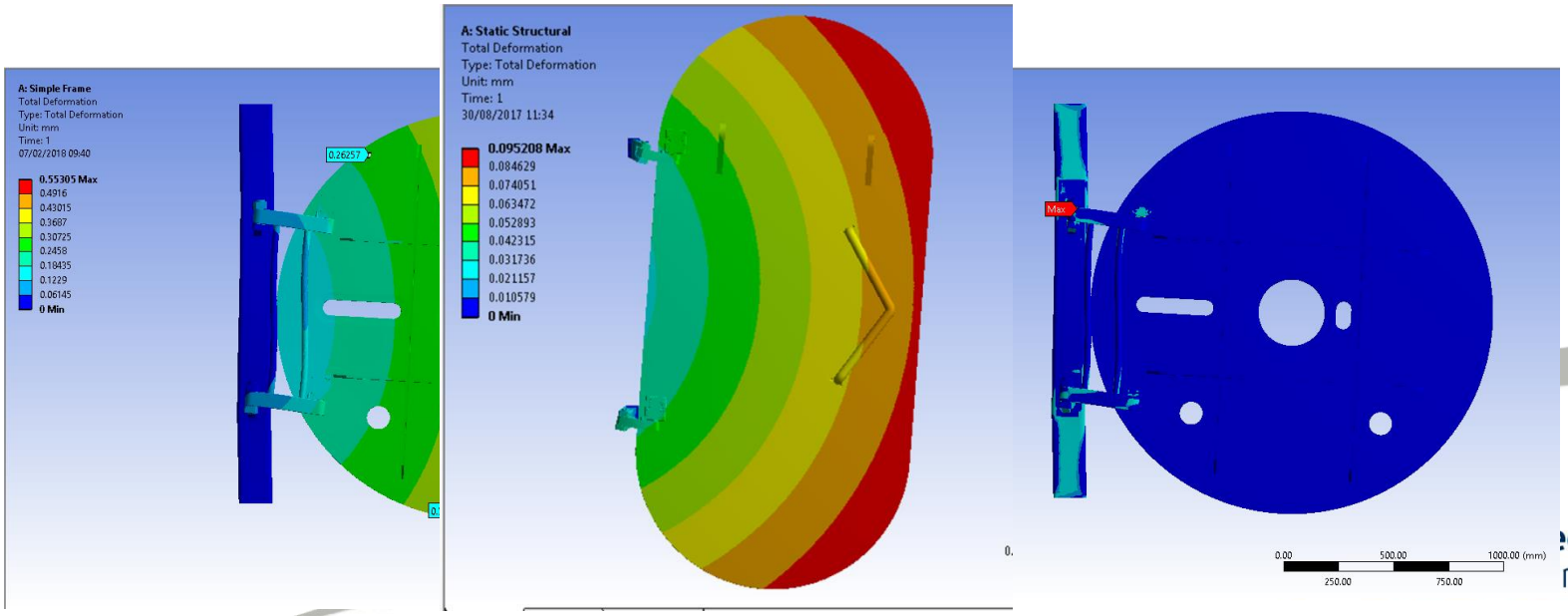
Analysis

- Analysis and stress calculations were performed on aspects of the test rig
  - Deformation of door
  - Deformation of chamber
- Led to changes in design
  - Castor added to bottom of door so it can close
  - Hinge system redesigned to be more rigid

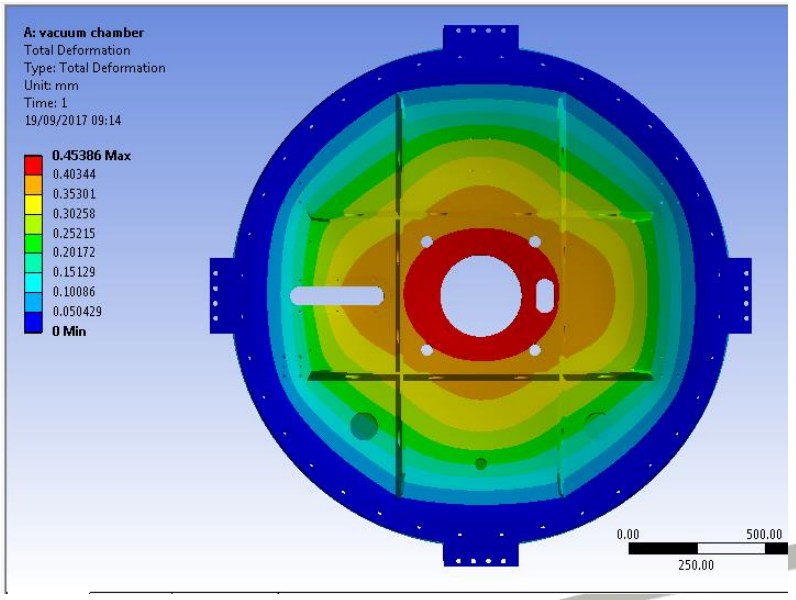
Hinge System Analysis

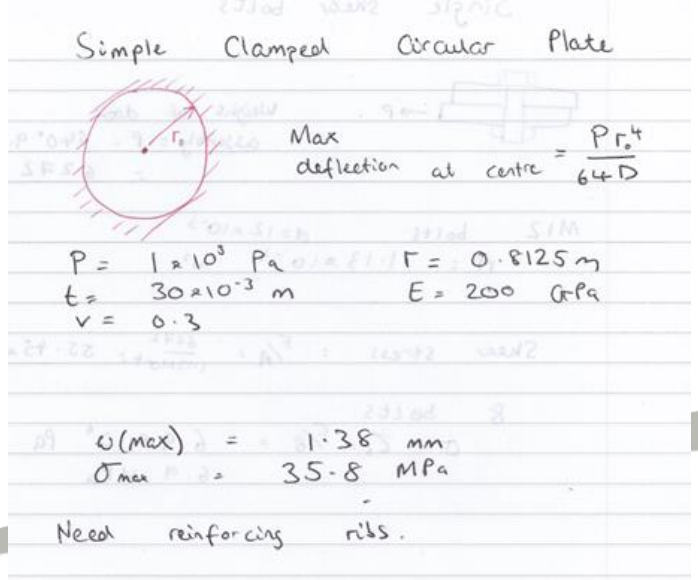
- Ideally deformation less than ~0.1 mm so door can close easily
- After analysis and changing of parameters decided to add a jacking castor
- Reduced deformation and easier operation of door



Pressure Vessel

- Deformation of fixed plate under pressure
- Hand calculations completed
- Deformation of ~0.45 mm
- Regular shape of deformation important





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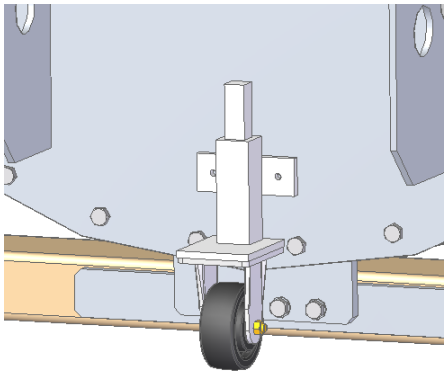
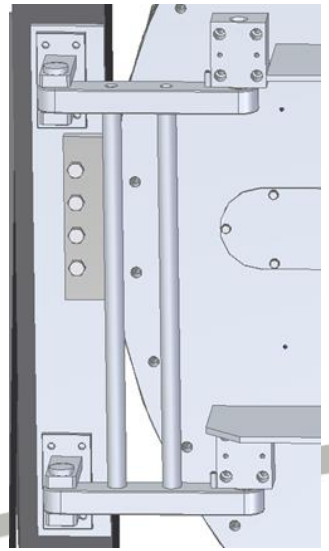
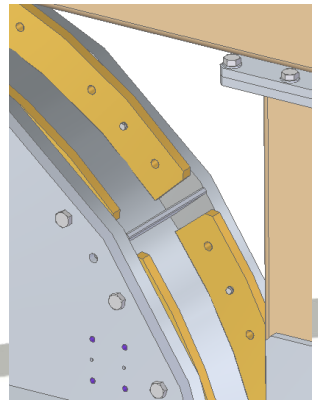
Further calculations

- Stress in bolts
- Lifting points
- Chamber flanges
- Impact analysis – operations highlighted the importance of safety







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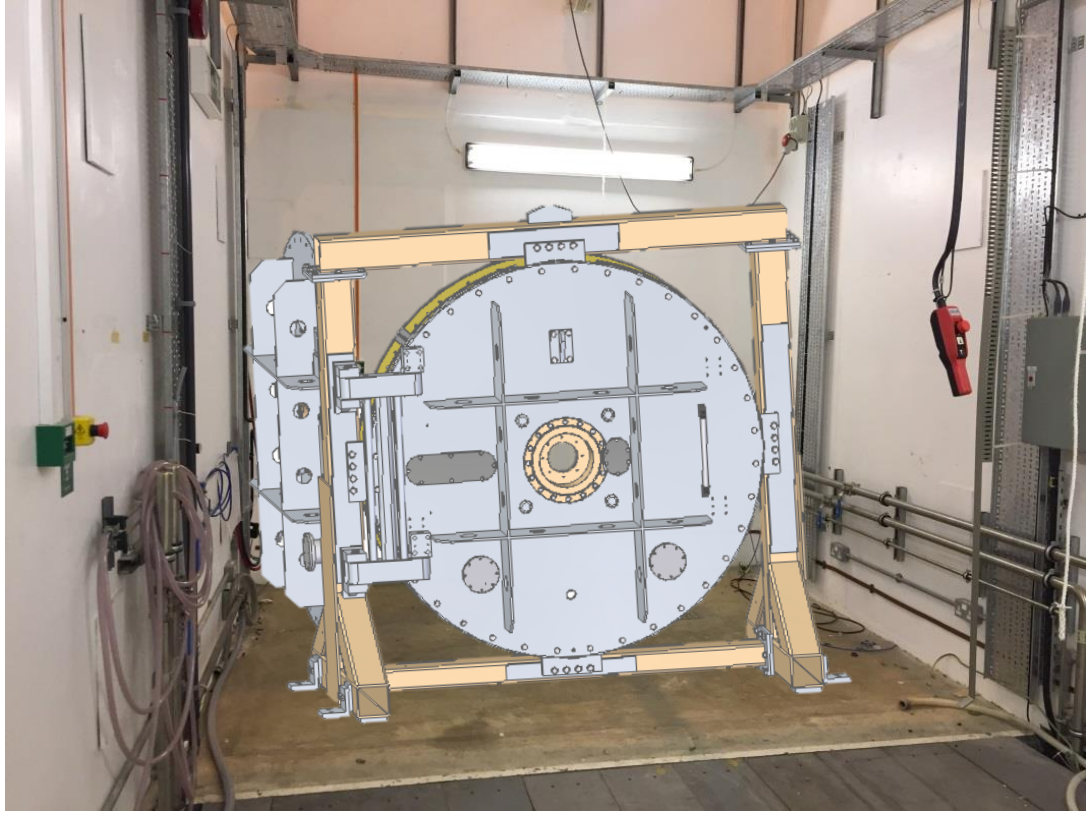
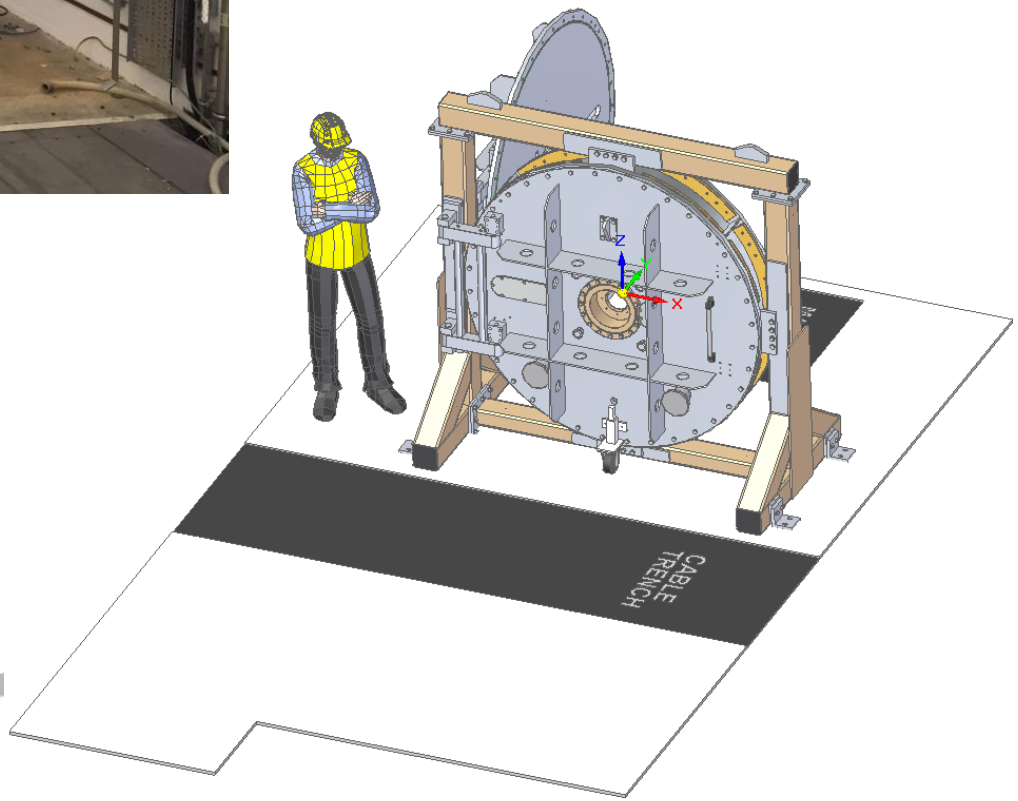
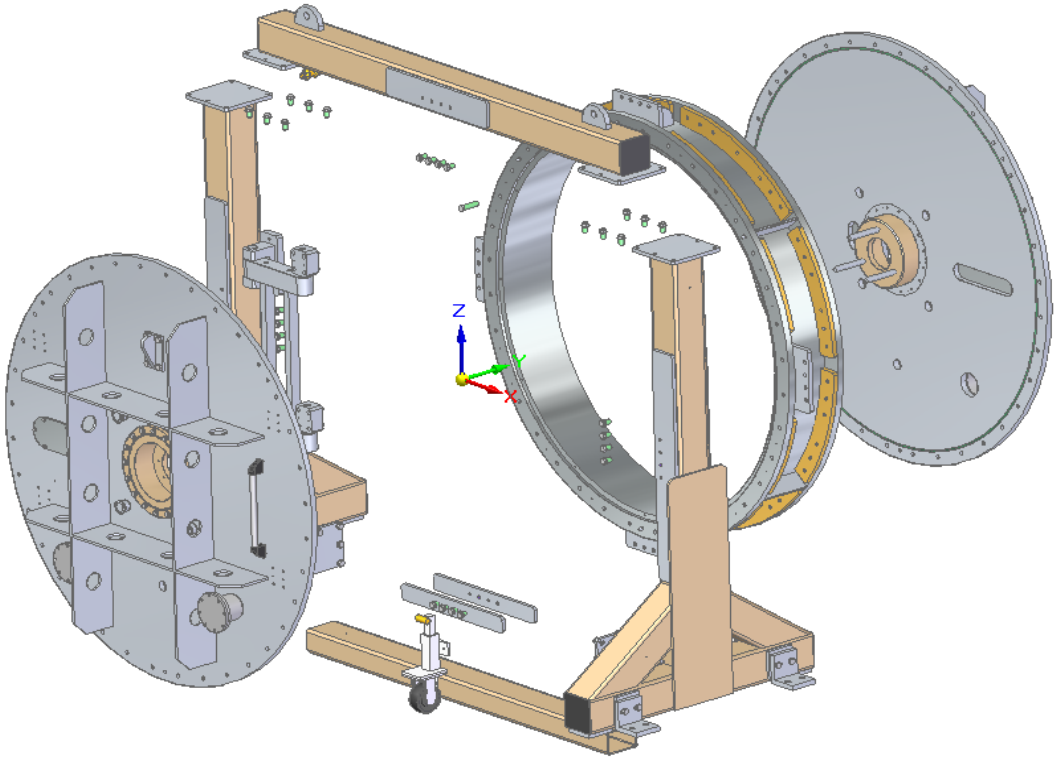
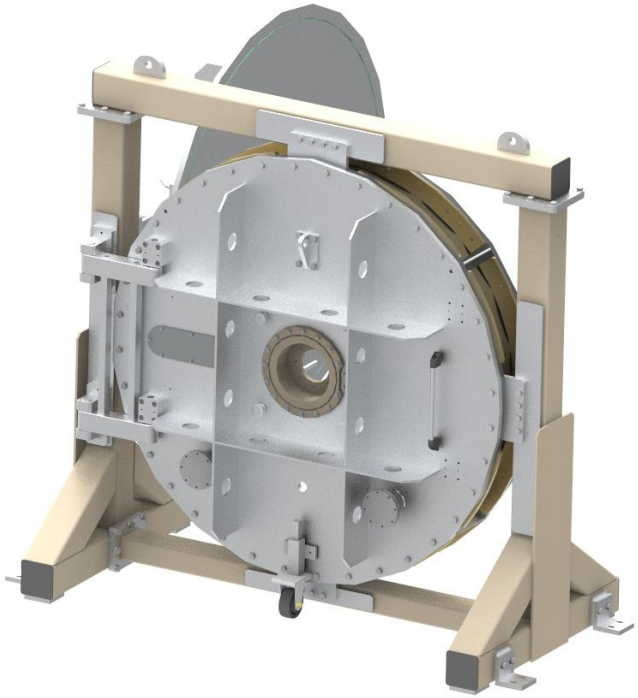



Z
Y
X
CABLE TRENCH

Modular Final Design





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Next Steps

- Drawings have begun and completed those for the frame
- Still need for disc test rig for in-house testing
- Ballistic modelling of failure

Any Questions?

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