Science and Technology Facilities Council

Engineering Frameworks

(an Engineering Approach to XLZD)

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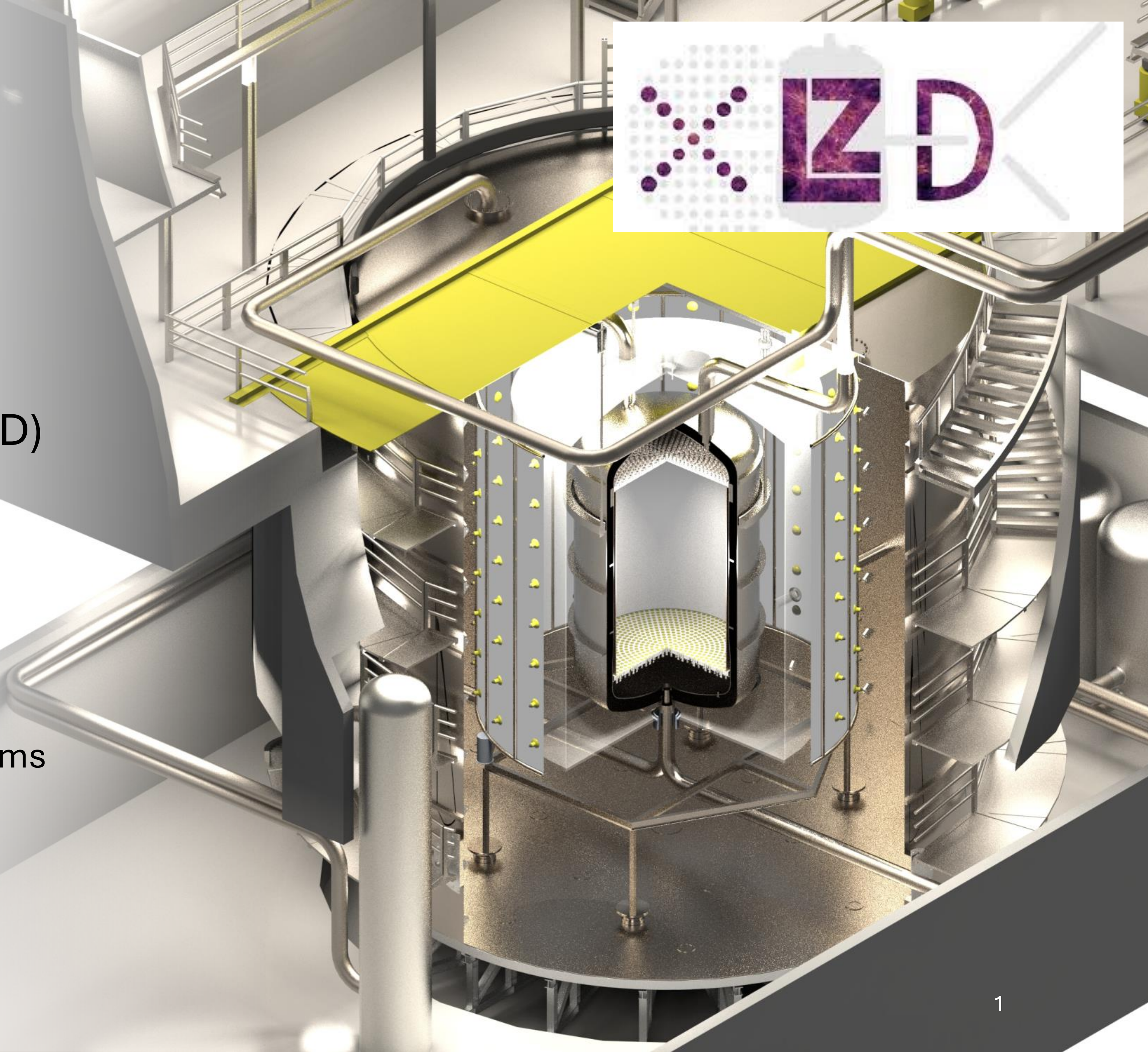
And XLZD UK and BDP Engineering teams

30 June 2025



Why Frameworks?

- XLZD is **significantly bigger** than any previous dark matter detectors
- We are combining many hardware contributions from different institutes across many different countries (much **wider collaboration** than previous collaborations)
- Large number of highly complex hardware deliverables **need to work**, be **delivered at the right time**, and have the **correct interfaces** to avoid **significant delays**

In order to succeed we need **Robust** engineering (and other) **frameworks** to ensure what is delivered meets its Science goals

- Frameworks are our friend! They should help us do a better job and make our lives easier
  - **Improve efficiency**
  - **Avoid duplication**
- **There needs to be the right amount of process; i.e. the process should be working for us, not us working for the process!**

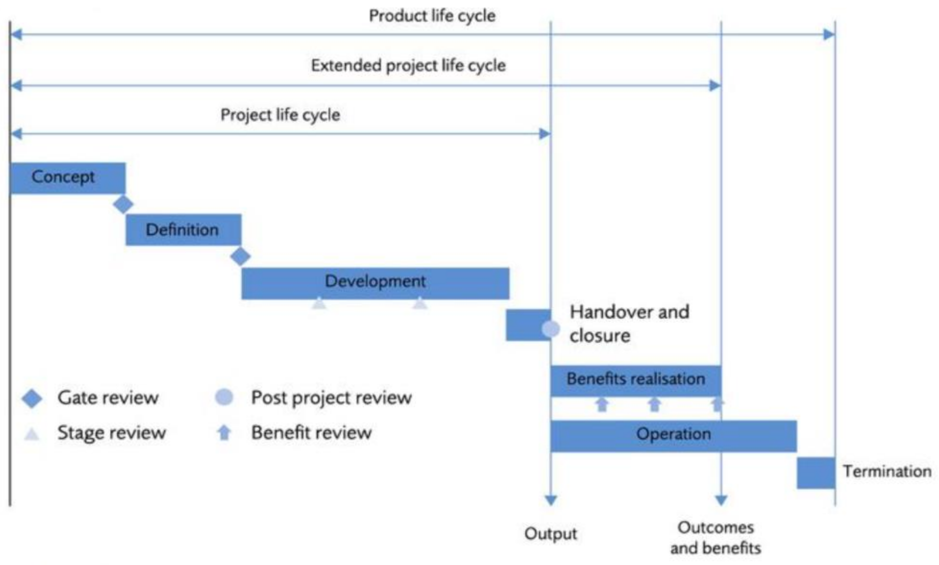
Note: An Engineering framework is a ***structured approach****, methodology, or set of principles that guide the* ***design, analysis, or development of mechanical systems and components****. It provides a systematic way to address engineering challenges, ensuring* ***consistency*** *and* ***efficiency.***

Robust engineering approach includes:

- Comprehensive set of **requirements**
- Robust **review process** (including expert reviewers)
- Clear engineering **specifications**
- Management of budgets for radioactivity, cleanliness, thermal
- Set of agreed working parameters for design and integration
- **Clear scope** and requirements for each sub-system
- Top-level integrated **CAD model coordination**, and agreed working framework
- Working envelopes and robust change control process
- Understanding of inter-relationships between sub-systems and **control of interfaces**
- **Frequent, open and constructive communication** across the project

Great level of investment = Great level of scrutiny!

- Large government investments come with a great deal of scrutiny, and **we are looking for a very large investment!**
- We are spending public money
- Scrutiny will manifest itself through additional reviews (demonstrate value for funding) of which there **could be many**
- The international nature of the project will require us to have an **international project structure and review framework** that **allows each institute to satisfy its funding requirements**
- We need **engineering frameworks that fit** into that structure
- We want to embed **good engineering process** into the project from the start, and **develop common tools and frameworks** that help all teams delivering for XLZD
- Let's **make it easy** to do the right thing.
- We are beginning to think about the processes....



Typical project lifecycle diagram with reviews

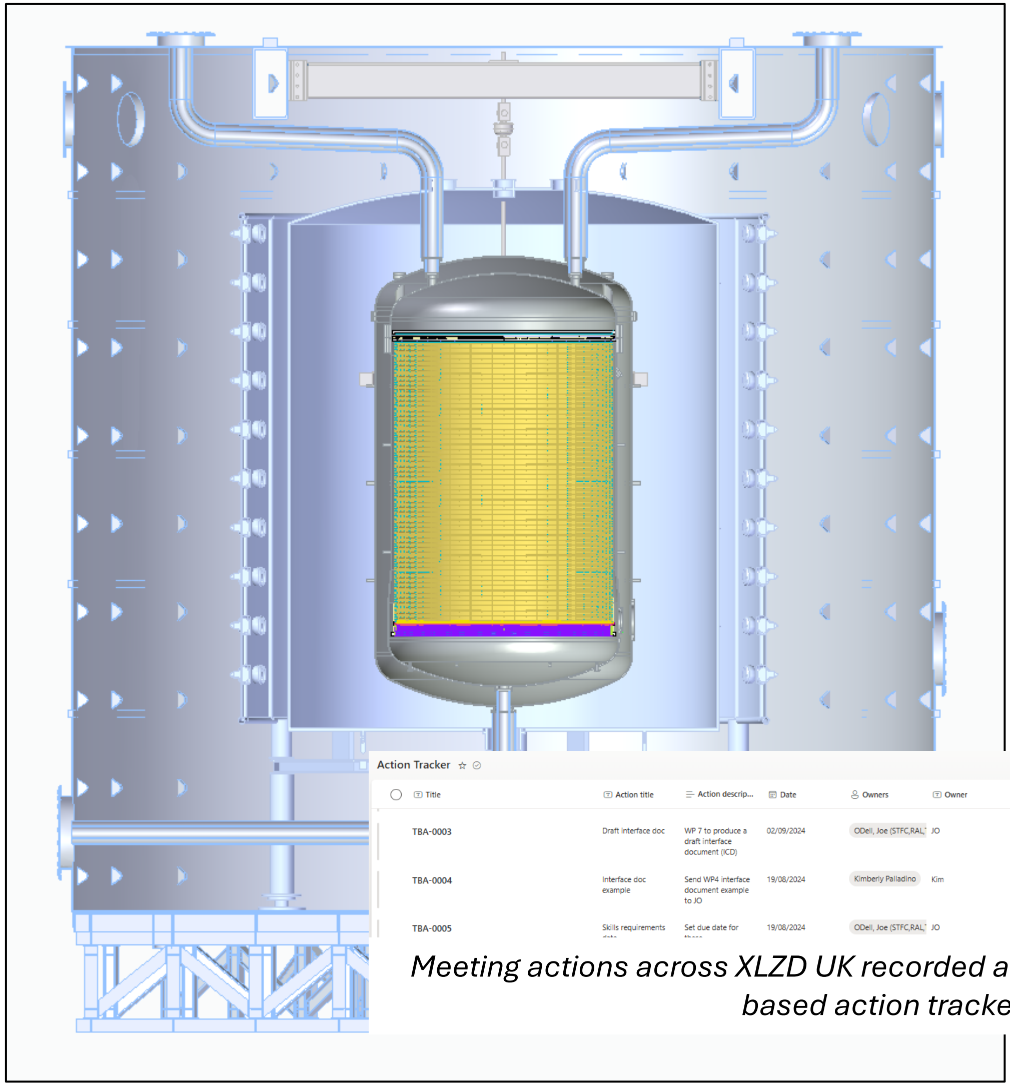
XLZD needs Significant Engineering resources throughout!

- Key specifications have been completed and have been reviewed by the appropriate Project Engineer for Conceptual Design readiness. All the specification terms have been identified, and the driving requirements are defined.
- Risk has been assessed on specifications that are to be resolved or to be determined, or with other issues.
- Traceability and validation-and-verification processes are included.
- Risk Registry is completed (including mitigation of technical and schedule risk) as appropriate.
- Conceptual design is at the system and hardware level that meets the requirements.
- New technologies are developed or there is an R&D plan and risk assessment.
- Development plans and progress, including rationale, are documented.
- Engineering analyses to support conceptual design are complete.
- Major system interface points are identified, both organizational and technical:
- Control system implementation plan is recommended.
- Interface agreements are drafted.
- Major design alternatives have been considered (Value Management).
- Consideration is being given for quality control and reliability.
- A baseline hazard list is completed and incorporated into the Preliminary Hazard Analysis report.
- Cost and schedule are estimated

CDR Input requirements from a typical DOE project

- For the CDR example here, most of the output require a **combination of Physics and engineering.**
- Those in red are likely to have **heavy engineering involvement**
- In order to achieve this, **significant engineering** is needed **throughout the project**, **embedded in each sub-system**
- Consideration is needed to how engineering **resource** in the project is **coordinated**

Engineering Coordination across the XLZD UK pre-construction project



More recent version of the CAD integration model

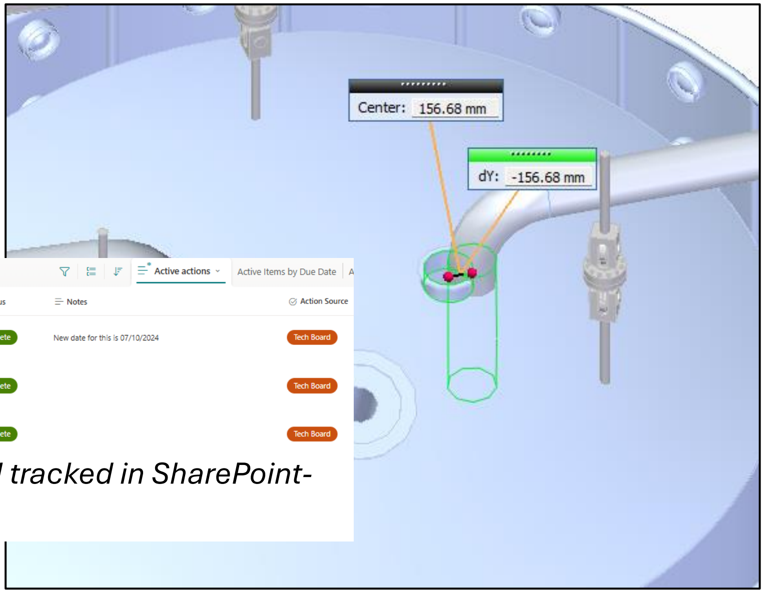
For the XLZD UK Preconstruction project

- 8 technical **WPs,** each responsible for a particular **sub-system**
- Within that WP, **Scientists & Engineering work together** to propose specific solutions
- There is an **Engineering POC in each WP**
- **POC Reports to LE** at Bi-weekly engineering meeting
- **CAD updates** from WPs are integrated and issues resolved
- Engineering topics are discussed, with input from scientists with oversight of system performance
- **Actions are tracked**

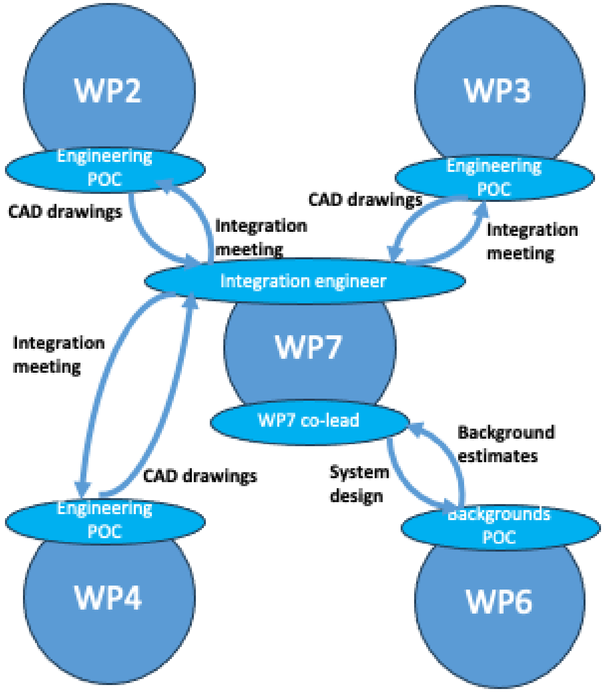
Action Tracker

Title	Action title	Action descrip...	Date	Owners	Owner	Status	Notes	Action Source
TBA-0003	Draft interface doc	WP 7 to produce a draft interface document (ICD)	02/09/2024	ODell, Joe (STFC,RAL,	JO	Complete	New date for this is 07/10/2024	Tech Board
TBA-0004	Interface doc example	Send WP4 interface document example to JO	19/08/2024	Kimberly Palladino	Kim	Complete		Tech Board
TBA-0005	Skills requirements	Set due date for	19/08/2024	ODell, Joe (STFC,RAL,	JO	Complete		Tech Board

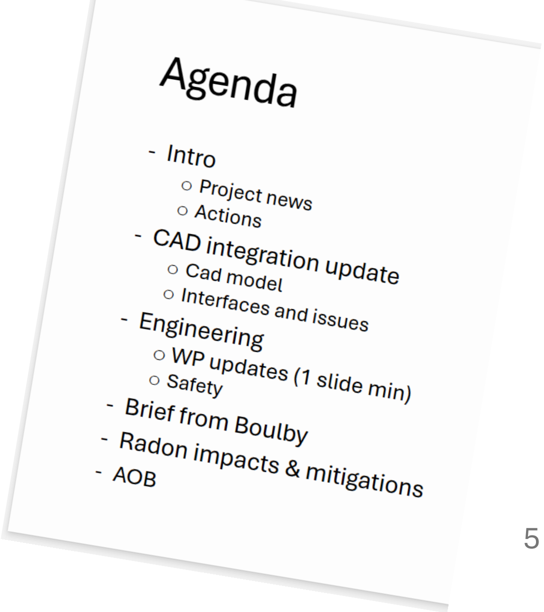
Meeting actions across XLZD UK recorded and tracked in SharePoint-based action tracker



Example misalignment discovered in CAD integration model



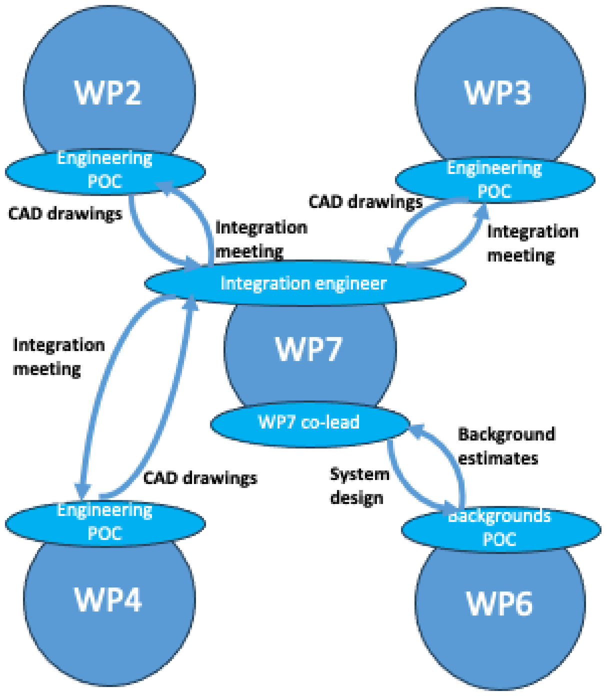
XLZD UK pre-construction Engineering coordination model



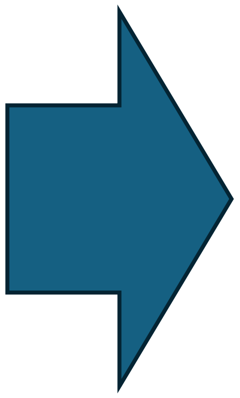
Example integration meeting agenda

Engineering Coordination for International project

- We would need an **equivalent structure** for the **international project**.
- Our approach could be **scaled up for the international** project **Engineering Coordination** with a POC for e.g. each LV2, reporting to central engineering function
- Within this structure, **lower-level structures** could be **WBS/institute specific**

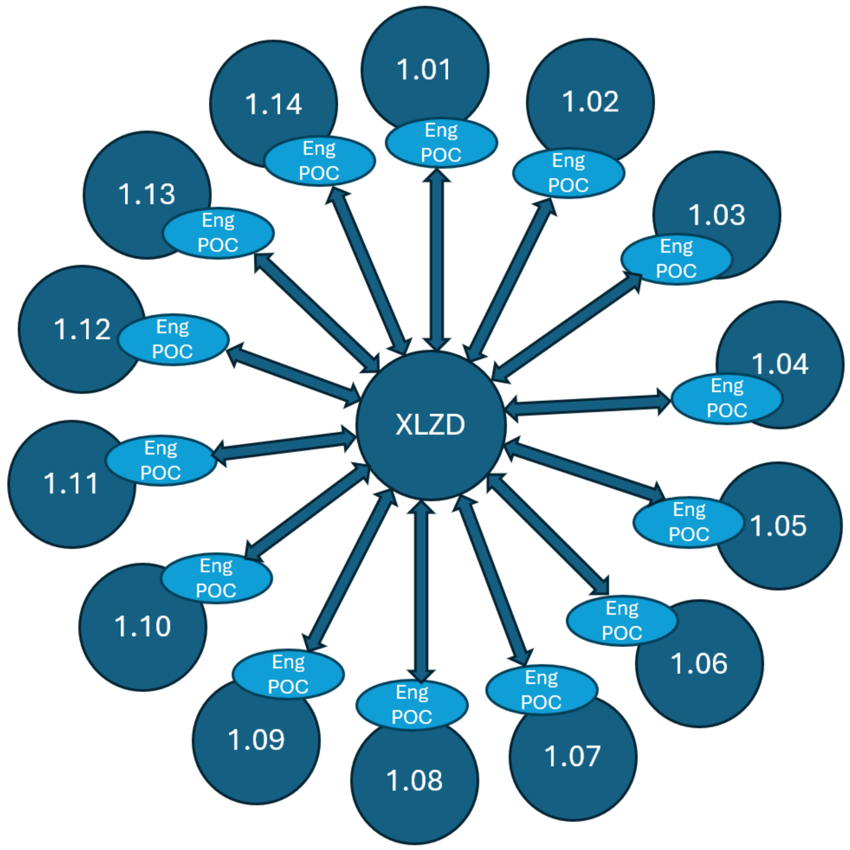


XLZD UK pre-construction Engineering coordination model



1.01	Project Management, Admin & Systems Engineering
1.02	Xe Acquisition
1.03	Xe Purification & Handling
1.04	Cryogenics
1.05	Cryostat
1.06	Xe Detector
1.07	Outer Detector System
1.08	Calibrations
1.09	Electronics, DAQ, and Online Computing
1.10	Controls
1.11	Computing & Software
1.12	Screening, cleanliness
1.13	Integration and Installation
1.14	Integrated Testing (early validation) (not yet developed)

Draft XLZD WBS lv2 - WIP



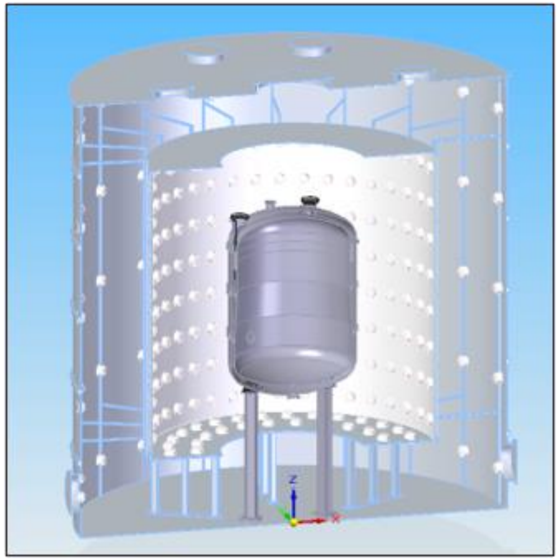
Notional (and simplistic) suggestion for scaled model for XLZD full project engineering coordination

Engineering coordination - CAD

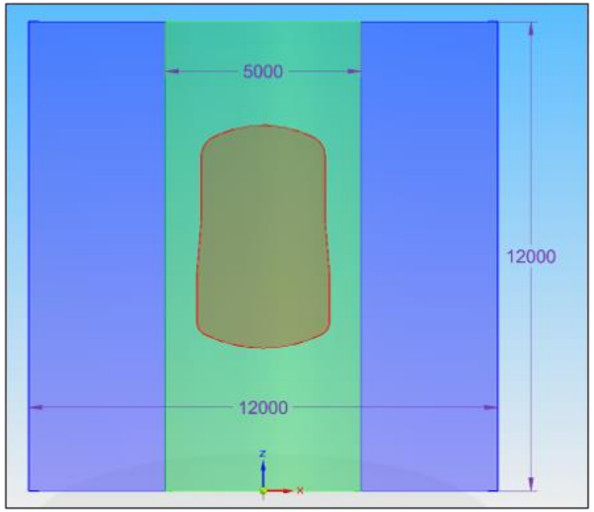
- A **Top level CAD model** is needed to integrate all the **sub-system-level CAD.**
- This is a significant about of work for a project with so many contributors

For XLZD UK pre-construction project:

- Each **WP** supplies Bi-weekly **CAD updates** in common (STP) format
- CAD integration engineer **combines** them in model using **common CAD coordinate system**.
- We plan to develop **working envelopes** for each sub-system, but we need input from the international project to do this effectively
- This is common model, is working well, **and could be scaled-up** to meet the needs of the **international project**



Early iteration of CAD integration model



Conceptual envelope for Cryostat

XLZD Coordinate System

Harry Byrne - STFC

Summary

This document defines the coordinate system currently used for: the XLZD detector

In future will be updated for: Boulby lab layout, survey reference for installation of the detector.

1. Engineering Coordinate System

X=0, Y=0 at the central axis of the Top flange of the water tank, labelled "Water tank lid".

Z=0 at the bottom of the water tank, the lowest wetted surface.

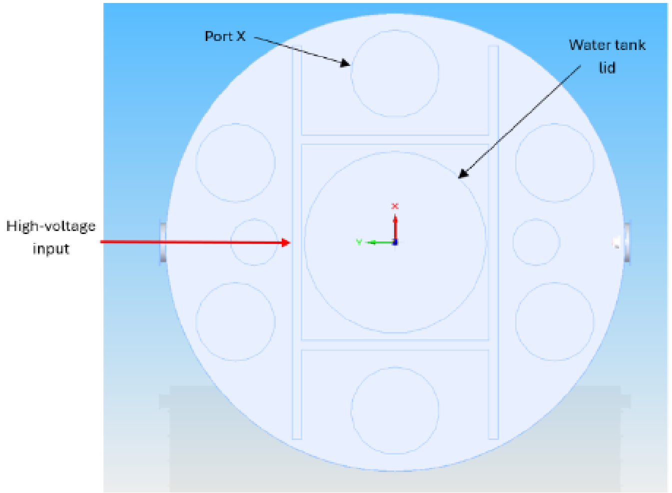
The **Z axis** will point vertically up as determined by gravity.

The **X axis** will point to the centre of the top water tank flange, labelled port 'X'.

The **Y axis** will point toward the high voltage input.

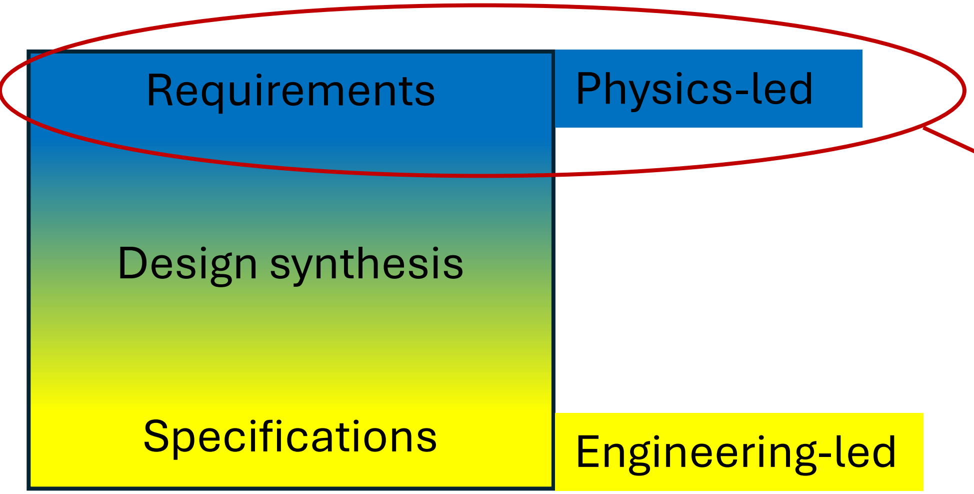
The high voltage connection enters the tank from the positive Y direction.

The **inside** dimensions of the water tank are Ø12 m x 12m, with the particle interaction point 6 m above the origin (X=0, Y=0, Z=9)



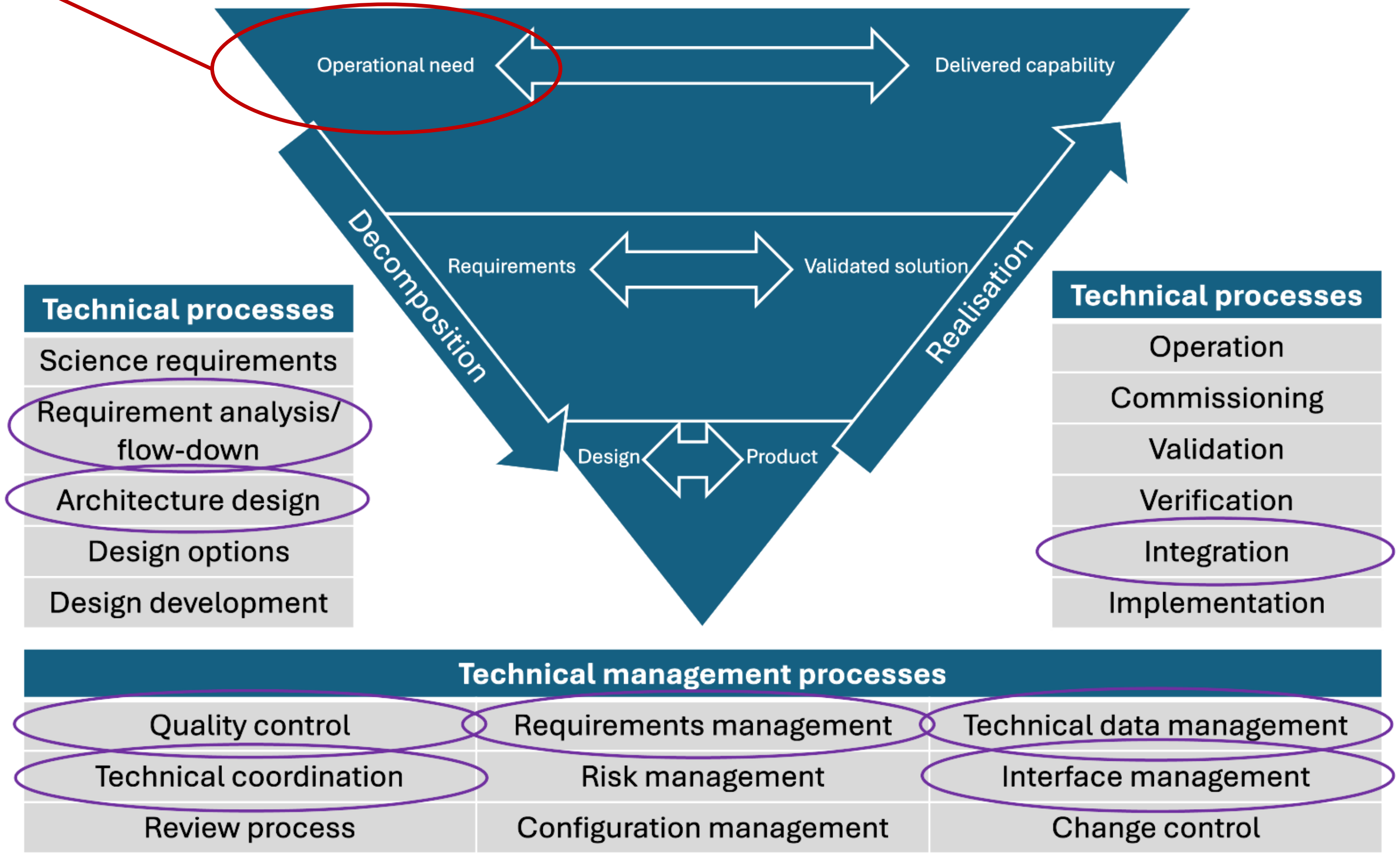
Right-handed cartesian coordinate system with Z pointing up, Z=0 at the bottom of the tank

A unified language



- **Physicists** understand what is needed for the **science**
- **Engineers** know how to **build systems** (but not necessarily the science).
- Systems are **designed, built and tested** by engineers to specifications, derived from the requirements
- Science needs to **sign off** on the engineering **specifications** as appropriate interpretations of the requirements
- **If the requirements are incorrect (vague, not verifiable, missing), the system will not perform the expected function**
- Once we have established requirements, we need a robust engineering approach to managing the design, production, and testing of the system to meet them
- **For XLZD, we need heavy emphasis on integration throughout the project**

* We have a head start - Utilise experience gained from LZ, XENONnT and other similar projects



The Systems Engineering approach

The majority of performance issues come from inadequate requirements, or else specifications that do not meet requirements, but nobody realised.

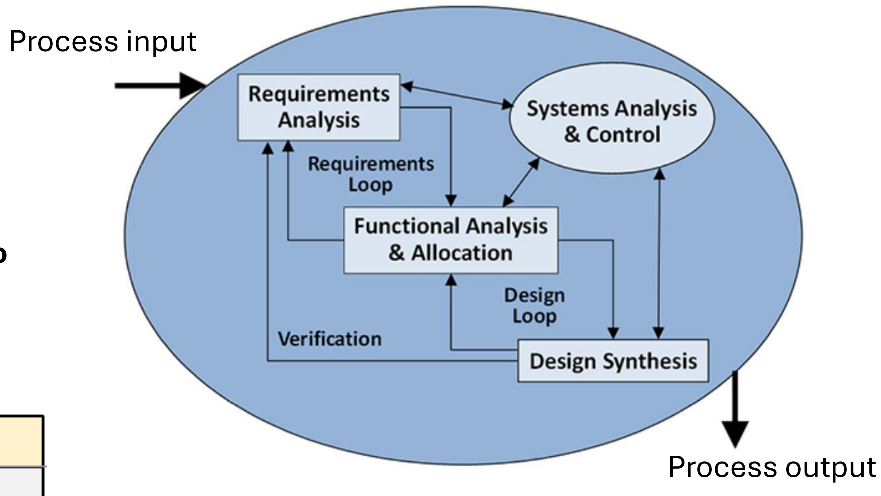
Science Requirements

The system will only be as good as the requirements!

For XLZD we do not yet have top level requirements, BUT thanks to experience in collaboration we can estimate some of the lower-level requirements enough to progress designs **to some extent.**

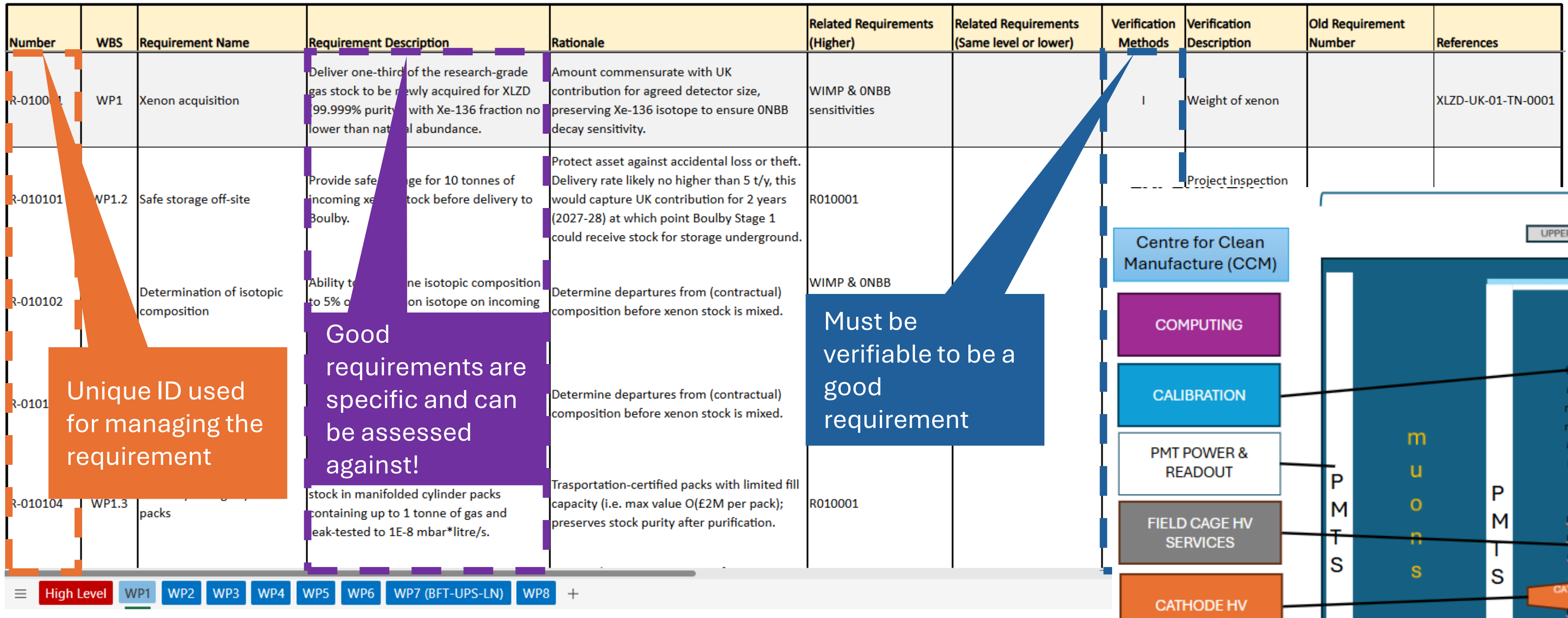
Requirements to be **clearly identified (unique ID) and managed**

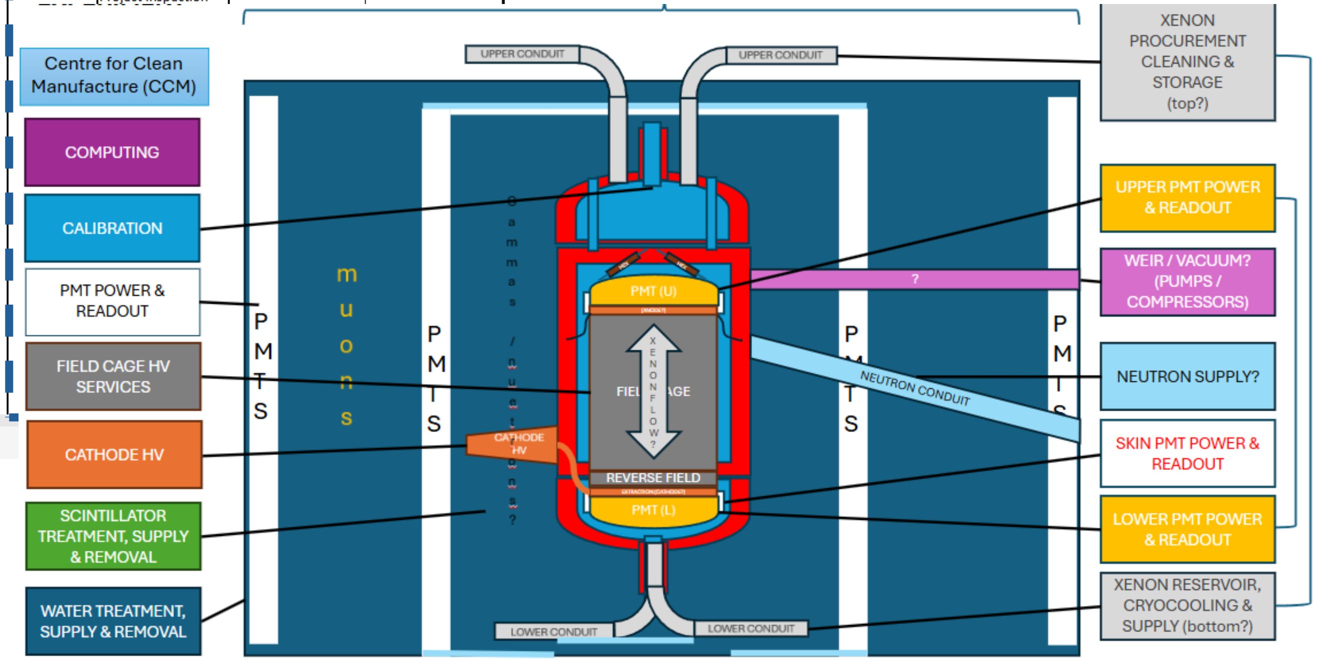
Think about how requirements are verified. Build system testing into your plans – sometimes they incur significant time and cost!



Circular nature of design requirement flow-down

XLZD Requirements Register (affecting UK scope)





Example of early XLZD schematic – building up a picture of the experiment

Note – requirements are at **provisional draft** stage. They are a set of assumptions that allow us to progress the design of the UK-scope and are subject to change as top-level requirements are finalised by an international working group.

The system – defining parameters/top level specifications

XLZD-UK-MD-03-001 Revision A

1. Summary of Working Parameters and Major Dimensions

Table 1 – Provisional WP3 cryostat parameters

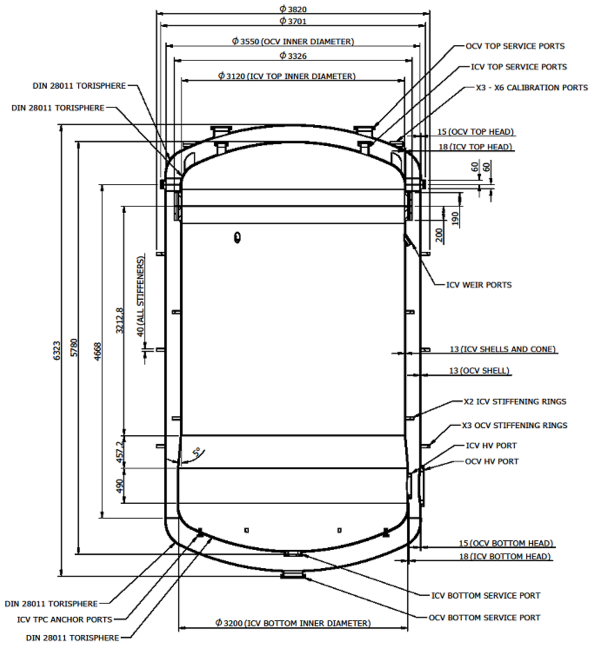
Outer Cryostat Vessel (OCV)	Value	Unit
Internal design pressure	1.00	barg
External design pressure	2.05	barg
Minimum design temperature	0	°C
Maximum design temperature	40	°C
Inner diameter of shell and heads	3550	mm
Number of stiffening rings	3	-
Shell wall thickness	13	mm
Top head thickness (torispherical/ elliptical)	15/ 15	mm
Bottom head thickness (torispherical/ elliptical)	15/ 15	mm
Top head height (torispherical/ elliptical)	750.9/ 952.5	mm
Shell height	4850	mm
Bottom head height (torispherical/ elliptical)	750.9/ 952.5	mm
Overall OCV height (assumes two torispherical heads)	6323	mm
Overall OCV mass* (assumes two torispherical heads)	6.1	tonnes
Flange thickness (top/ bottom)	60/ 60	mm
Outer diameter of flanges	3701	mm
Mass of water to fill OCV (liquid for hydraulic pressure test)	57	tonnes
Inner Cryostat Vessel (ICV)	**Value**	**Unit**
Internal design pressure	4.90	barg
External design pressure	2.05	barg
Minimum design temperature	-112	°C
Maximum design temperature	40	°C
Top shell and head inner diameter	3120	mm
Bottom shell and head inner diameter	3200	mm
Number of stiffening rings	2	-
Top shell wall thickness	13	mm
Bottom shell wall thickness	13	mm
Cone wall thickness	13	mm
Top head thickness (torispherical/ elliptical)	18/ 13	mm
Bottom head thickness (torispherical)	18	mm
Top head height (torispherical/ elliptical)	670.5/ 843	mm

3 of 12

Extract from XLZD UK Cryostat parameters

- As we progress the design options, we can start to develop the **top-level specifications**/parameters for each.
- Parameter examples: **Working pressures** and temperatures, headline **sizes** and **weights**
- Parameter documents are controlled – parameters are reviewed and have owners

- Overall size of components allows us to define working CAD envelopes
- Size and mass of components feeds into assembly/staging plans, and **facility requirements**



Parameters become inputs into parts of the detailed design & **facility requirements**

We are doing well at capturing these for UK PC WPs, but these need to be captured for full experiment scope

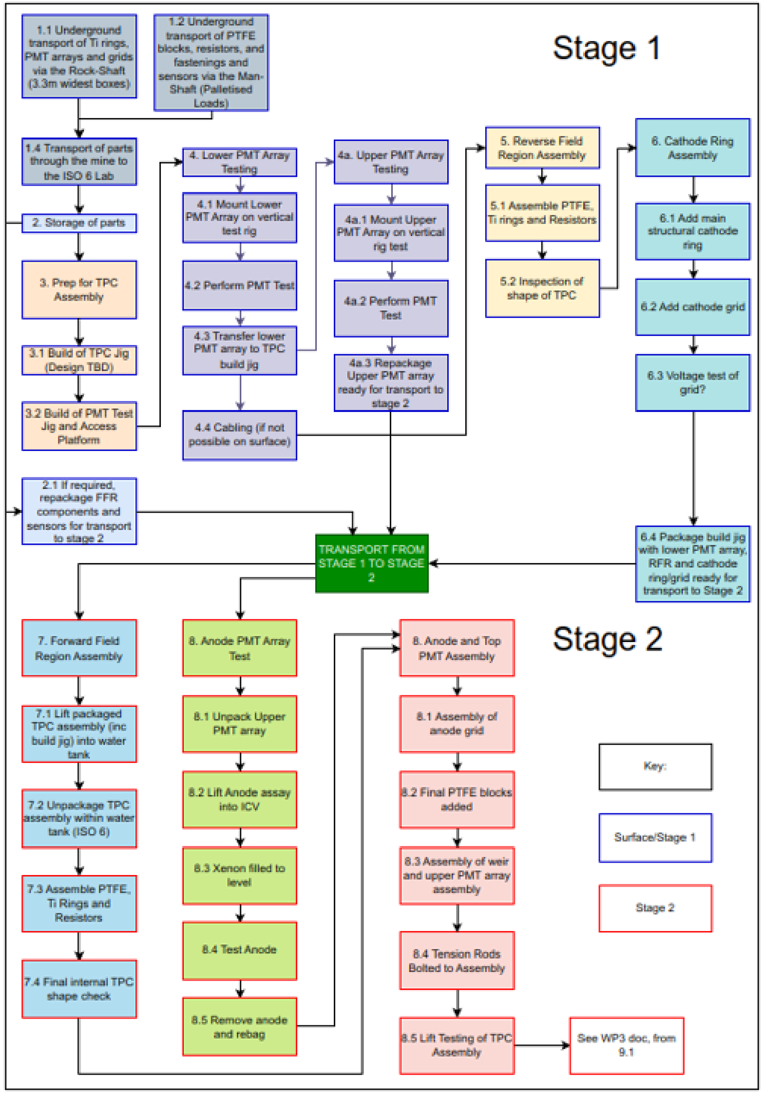
XLZD-UK-MD-02-001 Revision A

	15C for Gd+WbLS 15C for Gd+Water?	Dark rate changes from 1kHz to 0.5kHz when moving from 21C to 15C (which could be important for WbLS where the light yield is low) (https://iopscience.iop.org/article/10.1088/1748-0221/18/08/P08017/pdf) Expect higher light yield at lower temperatures in WbLS.
Water purity	15-18 MΩ-cm	LZ water is 15-17 MΩ-cm, LUX achieved 18 MΩ-cm
Muon Veto		
Displacement of PMTs from BFT Walls	0.5 – 1 m	Driven by reducing rate of Cherenkov in both water and PMT glass from cavern gammas
Number of PMTs	30-100	The number of PMTs depends on requirements for the muon veto part of the Outer Detector. For muon detection only few (~30) PMTs will be enough. External background characterisation and monitoring will require more PMTs to guarantee better light collection efficiency and some energy reconstruction (~100 PMTs). Neutrino detection will require much more sophisticated detector and much more PMTs.
Neutron Veto		
Height of inner neutron veto volume	Overall OCV height + 1m on the top and 1m on the bottom.	Aim to have 1m of scintillator between cryostat and acrylic walls for good gamma energy absorption. The overall OCV height in XLZD-UK-MD-03-001 is currently 6323 mm. The PMTs should be separated from the scintillator by ~1m which would add to the height of the inner neutron veto or other photosensors have to be used.
Radius of inner neutron veto volume	Outer radius of the OCV + 1m	Aim to have 1m of scintillator between cryostat and acrylic walls for good gamma energy absorption. The overall OCV diameter in XLZD-UK-MD-03-001 is currently 3701 mm. The PMTs should be separated from the scintillator by ~1m which would add to the radius of the inner neutron veto or other photosensors have to be used.
Number of PMTs	120-500	
Volume displacement by cryostat	57 m³	Mass of water to fill OCV in XLZD-UK-MD-03-001-RevA is 57 tonnes.
Medium density	0.85-0.86 g/cm³ (GdLS) 0.98-1 g/cm³ (WbLS)	
Mass of neutron veto volume	~116 T (GdLS) ~135 T (WbLS)	Mass of the liquid inside the neutron veto volume. GdLS is 86% the density of water.

3 of 9

Extract from XLZD UK Outer Detector Parameters

Developing Engineering facility requirements



Extract from Xenon detector provisional component journey diagram

From an understanding of our design parameters, we can start to develop facility requirements

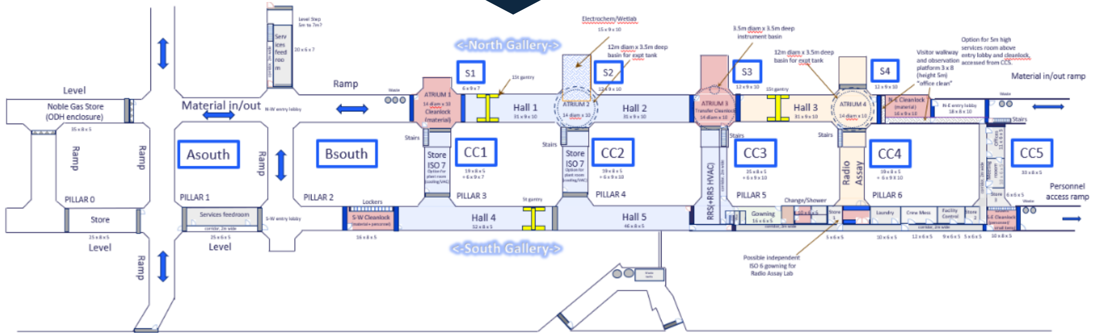
For Boulby

- Process diagrams for each system manufacture, metrology, testing, assembly, system testing
- Feeds into **Activity details** with location and requirements for each activity
- Feeds into **facility requirements** for each lab space
  - E.g. floor loading
  - Power
  - Air handling
  - Radon reduction

We need your help to develop facility requirements for other parts of the system

	Activity Title: Underground machining of flange sealing faces	Activity Owner: LC, PAM
	Info required [possible format if available]	**Information or Outstanding Questions**
Equipment	Delivery state (packaging sizes, package weights, special unpacking [e.g. protective packaging] or special handling requirements)	4 partially fabricated flanges (2 OCV, 2 ICV) Machinery/ equipment in boxes or crates
	Deliverable equipment, ancillaries & services etc (components or assemblies for the experiment, sizes & weights) [CAD]	TD-2803-0003/ TD-2803-0004/ TD-2803-0008/ TD-2803-0014 OCV flanges ~140kg each (~Ø3.8m OD), ICV flanges ~950kg each (~Ø3.4m OD)
	Handling (frames, points, restrictions etc)	Swivel hoist rings, slings, and spreader beam for handling flanges
	Tooling required	In-situ milling machine (Type XX), portable drilling machine (Type XX)
	Services (light, power, gas etc)	Power requirement (XX)
	Test / Inspection equipment	Flatness measurement tool (e.g Easy-Laser alignment Type XX), Surface roughness tester, metrology requirements tb
	Consumables / waste	Swarf/ debris
Location	Surface, Stage 1, Stage 2, Specific Lab etc	Stage 1
	Environmental requirements	Tent to capture machining particles/ debris
Activity	Risk Assessment & Method Statement [RAMS] / Tasks (hazards)	Fit machine to flange, drill holes, machine surface and seal grooves, inspect Trained personnel/ inspection of machines (noise, cutting tool)/ documented lift procedures (heavy load)/ safe minimum distance zone for other lab users/ PPE
	Estimate of space required to undertake operation	5m x 5m footprint
	Working @ height (height requirement)	~5m
	Other safety considerations?	Lasers (may be used for inspecting flatness)
	Estimate of time	~2 weeks
	Estimate of People (incl. specialists, external staff etc)	2 contractors, supervisor in lab, technician support (e.g. for lifts)
Operation	Emissions or surface conditions (temperature hot [kW] / cold [T], electrical emissions, vibration, noise, possible fluid leaks etc)	Machining noise
	Sensitivity (temperature [T], electrical emmisions, vibration, moisture humid or dry, light, pressure)	n/a
Post Activity	Packing requirement	n/a
	Handling (frames, points, restrictions)	Swivel hoist rings, slings, and spreader beam for handling flanges
	Storage requirement	ISO7 clean space, preferably store flanges flat (~Ø4m footprint)

*Extract from cryostat **activity details table** - Underground machining of flanges*



Note – for Boulby we need early engagement from manufacturing partners to ensure we have all the required fabrication infrastructure in place

Room/Hall	***XLZD activities performed here***	***Equipment needed***	***Services needed***
North Gallery			
North feedroom			~0.3kW power supply for ventilation air handling unit. ~0.3kW direct cooling for ventilation air handling unit.
Atrium 1/S1 protrusion/CC 1 north	Cleaning transport vehicle (esp. for heavy items). Outer bag debagging of incoming items.	Transport cleaning station. Debagging station. Basin cover.	Cleanroom ventilation? ~2.2kW power supply for ventilation air handling unit. ~2.2kW direct cooling for ventilation air handling unit.

Extract from Location-based lab requirements summary

What are the main infrastructure engineering requirements drivers?

We need to capture **driving requirements** for things like:

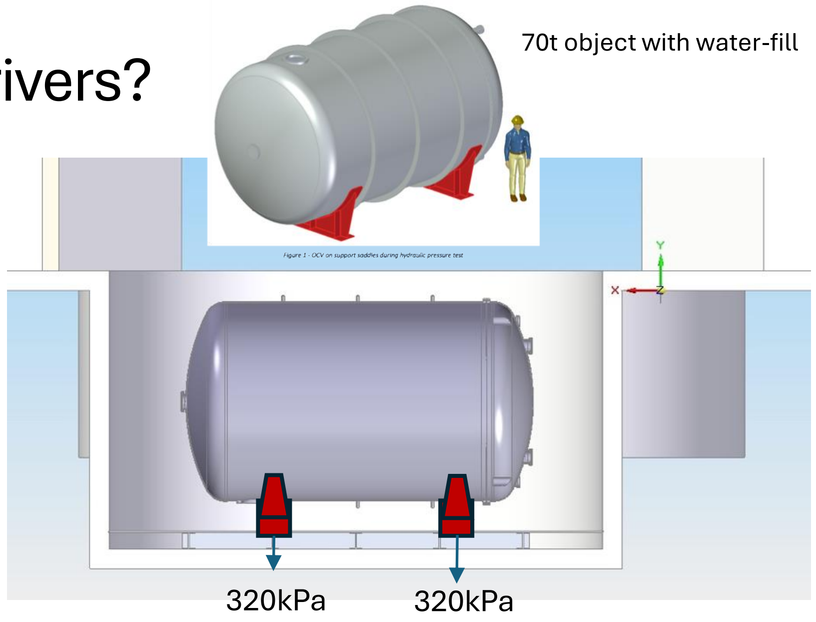
- Lab height
- Hazardous Chemical containment
- Floor loading

Avoid blanks specs – can we meet these requirements with localised specifications?

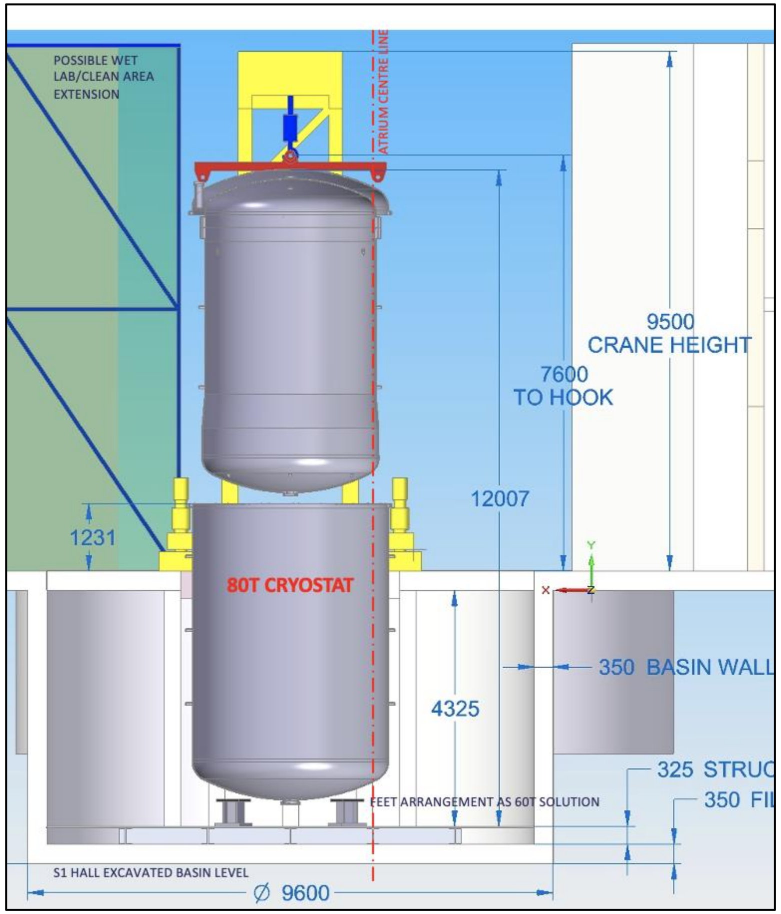
For Boulby stage1, we try to confine the most demanding requirements to local features called basins

This avoids blanket requirements that incur additional cost

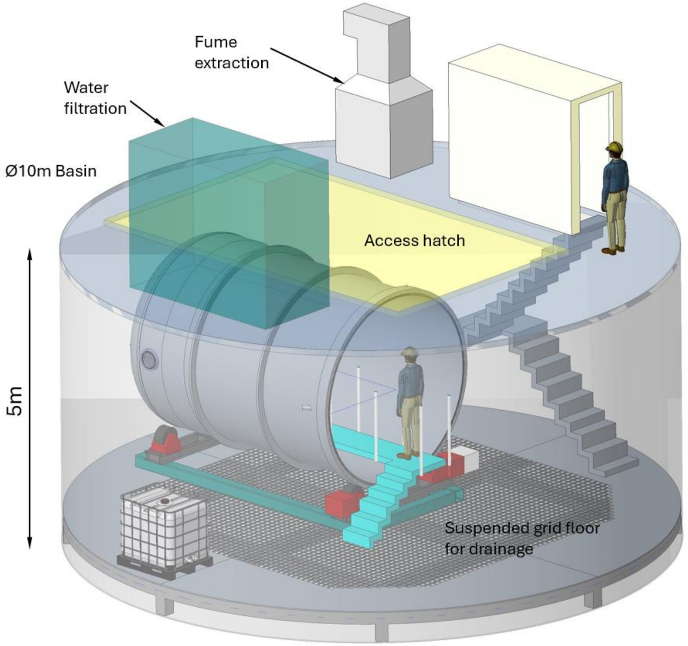
These are the main drivers we are aware of from the UK project. What are the drivers elsewhere?



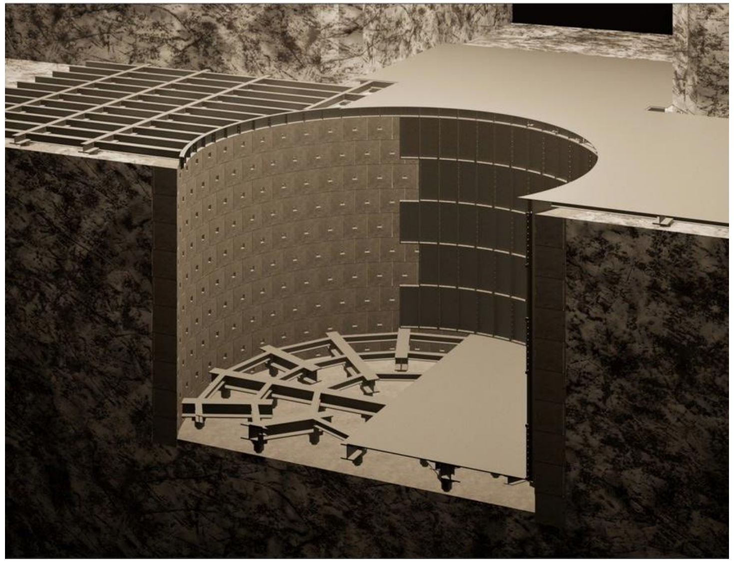
Floor loading driver – exceeds 120kPa assumed for AMCO design



Height driver – Insertion of ICV into OCV



Chemical containment driver – electro-plating, etching (concept)

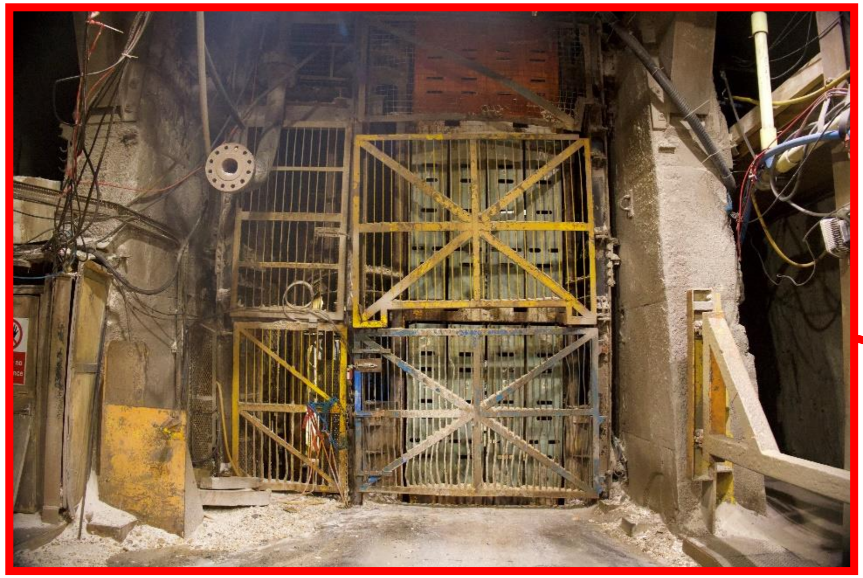


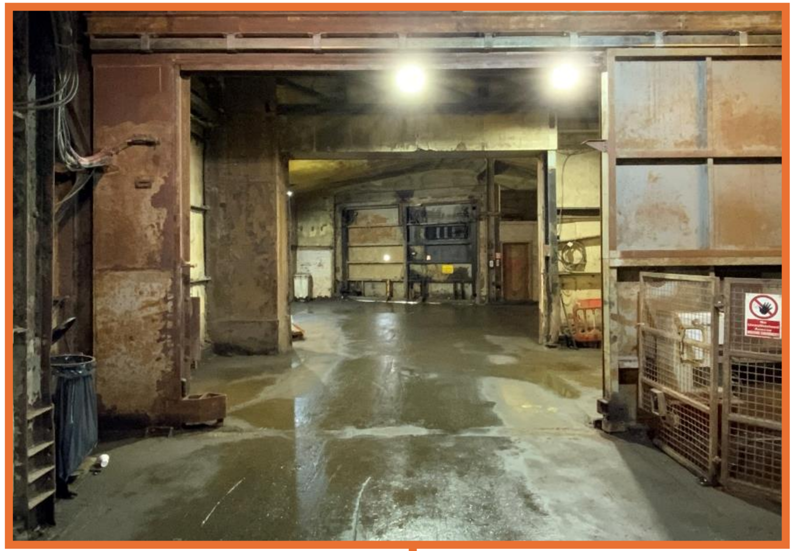
Boulby lab basin concept – where increased height/floor loading/chemical containment is required

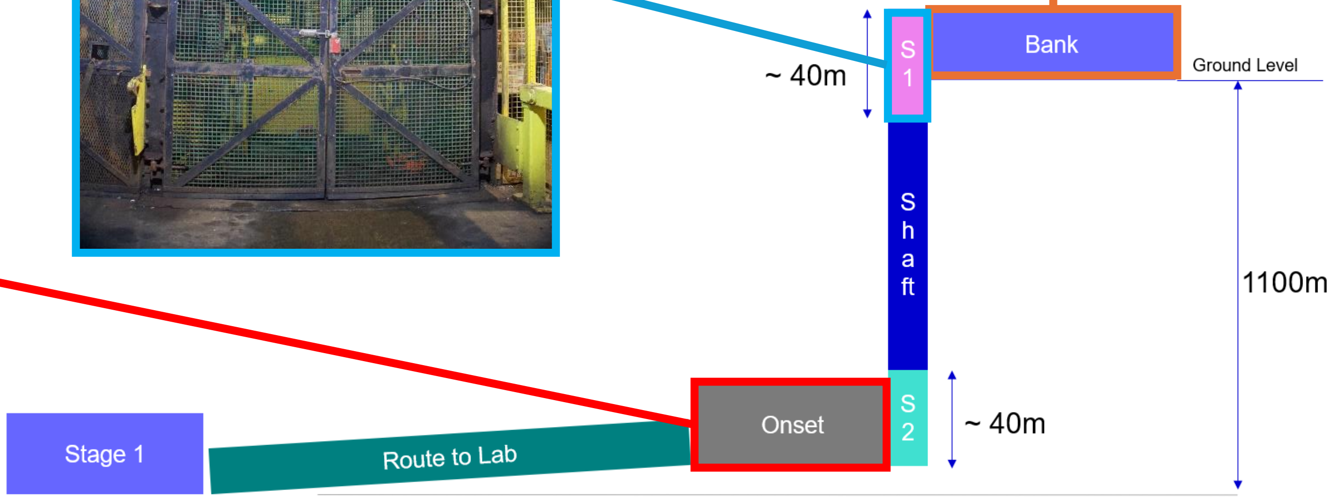
Work within facility constraints or modify?

We are considering whether to **work within existing constraints, or customise facility** (additional cost)

- **Cost/benefit analysis**: Additional cost (and risk) of underground manufacture vs cost of modifications to shaft infrastructure
- For Boulby, we are planning for work within the current shaft restriction, but also **considering options for improving access**
- **Survey** of onset, shaft and bank **planned** from which we will receive CAD model to aid our access improvement studies.
- For these studies, we need the details of **all large components across the whole project**







Cartoon Boulby shaft and surround layout

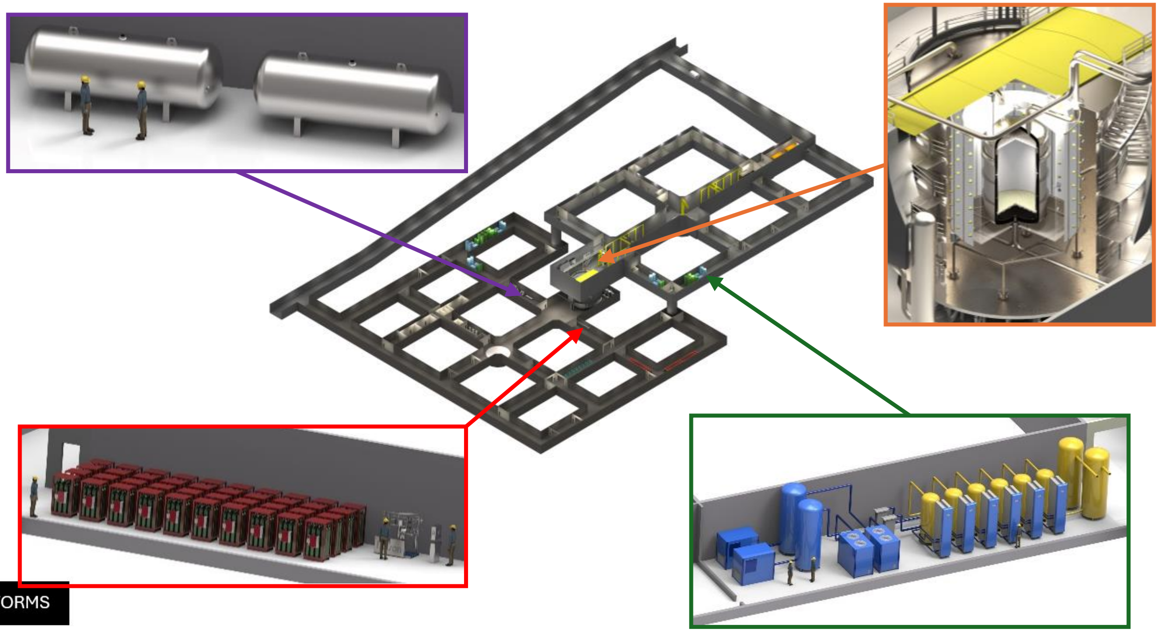
System architecture - layout

Consider high-level design relationships, and location of sub-systems relative to each other

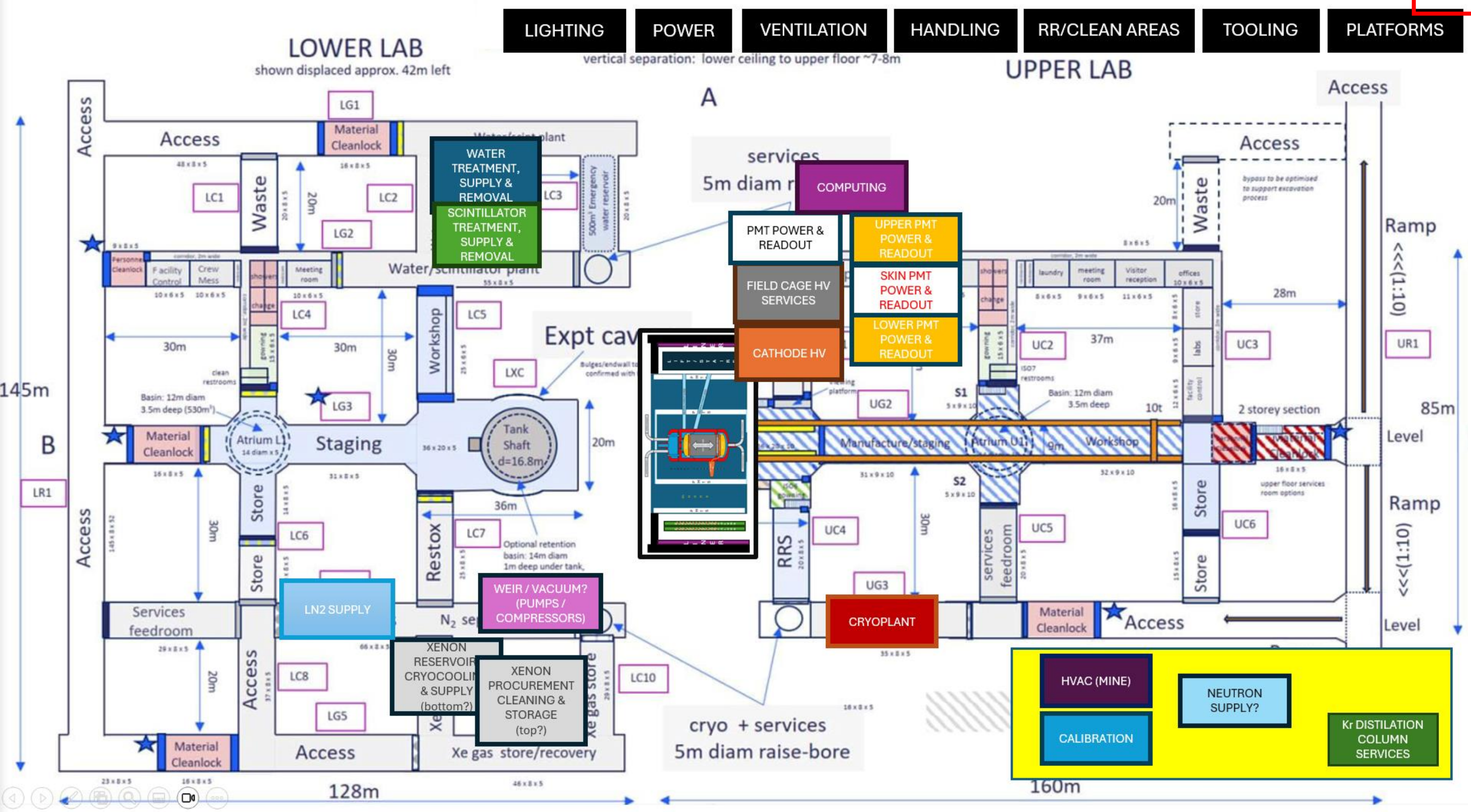
- E.g. gravity fed systems (cryogenics relative to cryostat)

Where are the pinch points:

- Sub-systems competing for space
- Services (e.g. through the facility tank)



Extracts from XLZD UK CAD model



Schematic layout of XLZD in Boulby stage 2 lab

We can also start to think about layout with respect to:

- Hazards **– grouping systems by hazard controls** (e.g. ODH controlled areas)
- How can we improve **system efficiency**?
    - E.g. **grouping systems with common infrastructure requirements**
    - **Minimising service runs**, cables/pipes, reducing pumping requirements
- When will sub-systems be delivered, and does that impact layout? (probably not in the case of Boulby due to “block” layout, and redundant spaces)
- Testing regimes – impact on layout?
- **How we consider this is quite different for a purpose-built facility vs fitting into an existing facility**

System architecture – Protecting the system

- We need to **consider what happens when things fail**, and how do we protect people and equipment
- Our approach is to capture the **sensitivities and criticality** of each system, and the effects of failure (Failure Mode and Effects Analysis - FMEA)

Note: Many of these considerations may be driven by safety

- **What are the risks?**
- Which systems are critical?
  - Could be critical because they are **safety critical**
  - Could be critical because they can become damaged (and this incurs **significant down-time and/or cost**)

- **How do we protect each system?**
- UPS to cover back-up power start-up
- How can we reduce local UPS requirements?
  - Thermosiphon
  - Liquid Nitrogen storage
  - Pneumatically controlled valves (with buffer tanks)

We need to know sensitivities of your systems!
We would also like feedback on this approach.

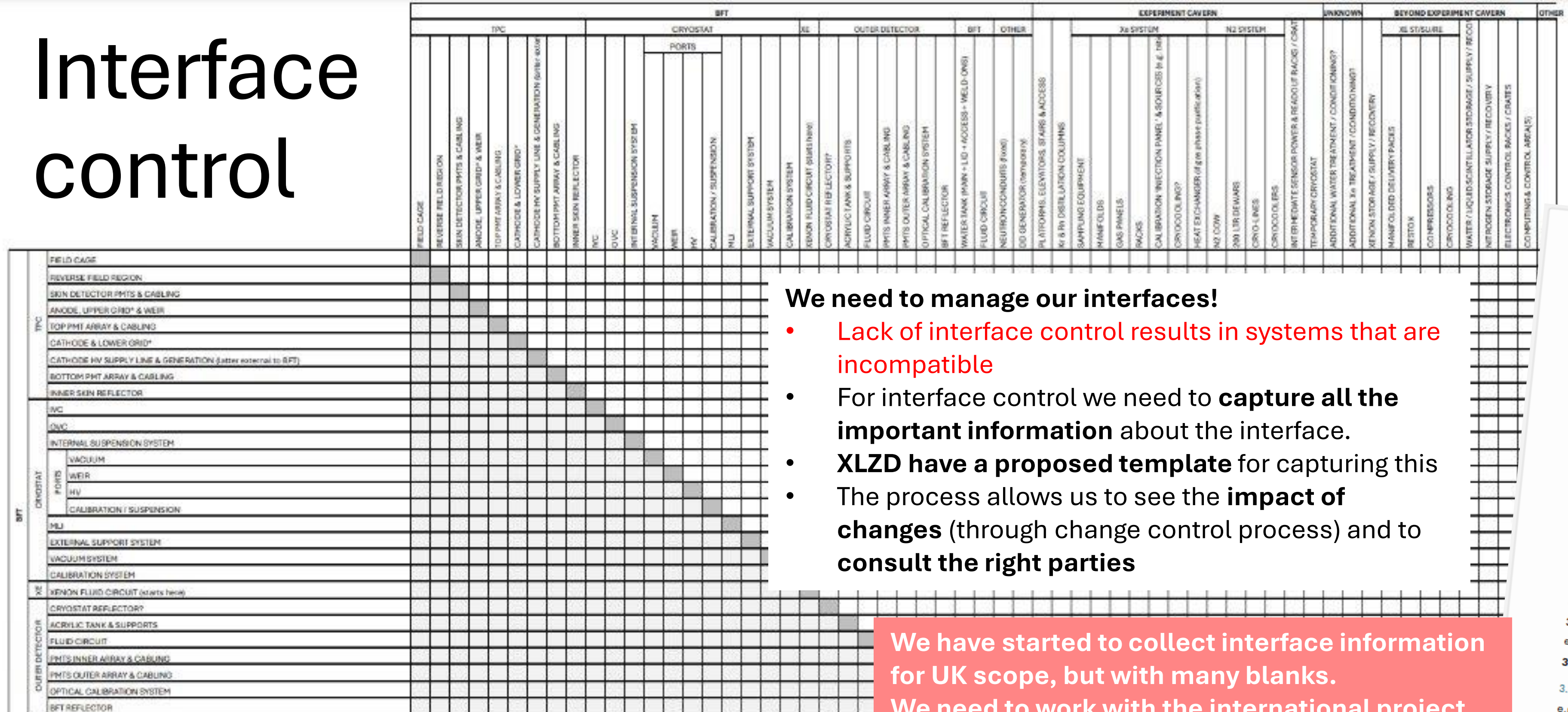
Notional – demonstrates our approach to considering this issue, but not our outcome

	Power Outage Imapct/Risk		
Module	**Glitch**	**Short (<5min)**	**Medium-Major (>5min)**
DAQ System	Hardware Damage	Interuption of Experiment	
Controls	Hardware Damage	Interuption of Experiment	
Detector	Hardware Damage	Interuption of Experiment	
Networking	Hardware Damage	Interuption of Experiment	
Experiment	Hardware Damage	Interuption of Experiment	
Grid Supply	Hardware Damage	Interuption of Experiment	
Vacuum System	Hardware Damage	Interuption of Experiment	Long Recovery
Equipment Cooling	Hardware Damage	Acceptable	Hardware Damage
Cryogenic	Hardware Damage	Acceptable	Long Recovery
LN generator	Hardware Damage	Acceptable	Long Recovery
Xenon Recovery	Hardware Damage	Acceptable	Long Recovery
Xenon Gas Purigication	Hardware Damage	Acceptable	Long Recovery
Xenon Liquid Purigication	Hardware Damage	Acceptable	Long Recovery
Safety systems	Hardware Damage	Compromise Safety	
Ventilation	Hardware Damage	Acceptable	Compromise Safety
Air Conditioning	Hardware Damage	Acceptable	Compromise Safety
Critical and Emergency lighting	Insensitive	Compromise Safety	
General lighting	Insensitive	Acceptable	Acceptable
Radon Deduction System	Hardware Damage	Acceptable	Long Recovery
Water Treatment Plants	Hardware Damage	Acceptable	Long Recovery
Chilled Water System	Hardware Damage	Acceptable	Long Recovery
Manufacturing Equipment	Insensitive	Acceptable	Acceptable
Cranes	Insensitive	Acceptable	Acceptable
Misc	Insensitive	Acceptable	Acceptable

Notional – demonstrates our approach to considering this issue, but not our outcome

	Supply Power Outage				
Module	**Glitch**	**Short (<5min)**	**Medium (5min-1hour)**	**Long (1hour-1day)**	**Major (>1day)**
DAQ System	Device/Local Protetion	Off			
Controls	Device/Local Protetion	Off			
Detector	Device/Local Protetion	Off			
Networking	Device/Local Protetion, some on UPS	Some on UPS	Surface Generator		
Experiment	Device/Local Protetion	Off	?	?	?
Grid Supply	Device/Local Protetion, some on UPS	Some on UPS	Surface Generator		
Vacuum System	Device/Local Protetion	Off	Surface Generator		
Equipment Cooling	Device/Local Protetion	Off	?	?	?
Cryogenic	Device/Local Protetion	Off			Surface Generator
LN generator	Device/Local Protetion	Off			Surface Generator
Xenon Recovery	Device/Local Protetion	Off?	Surface Generator?		
Xenon Gas Purigication	Device/Local Protetion	Off?			
Xenon Liquid Purigication	Device/Local Protetion	Off?			
Safety systems	UPS	UPS	Surface Generator		
Ventilation	Device/Local Protetion	Off	Surface Generator		
Air Conditioning	Device/Local Protetion	Off		Surface Generator	
Critical and Emergency lighting	UPS	UPS	Surface Generator		
General lighting	Special Protection not Necessary	Off			
Radon Deduction System	Device/Local Protetion	Off?	Surface Generator?		
Water Treatment Plants	Device/Local Protetion	Off	?	?	?
Chilled Water System	Device/Local Protetion	Off	?	?	?
Manufacturing Equipment	Special Protection not Necessary	Off			
Cranes	Special Protection not Necessary	Off			
Misc	Special Protection not Necessary	Off			

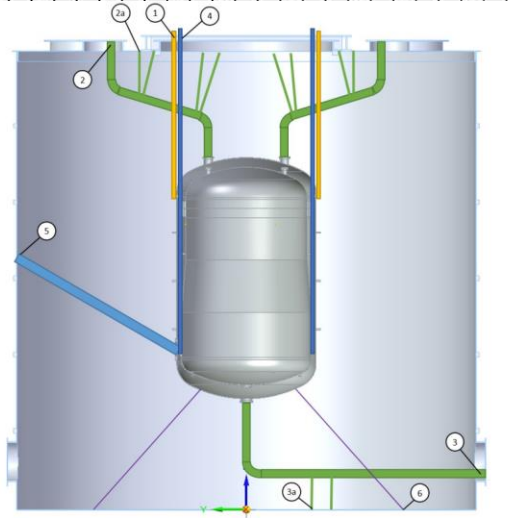
Interface control



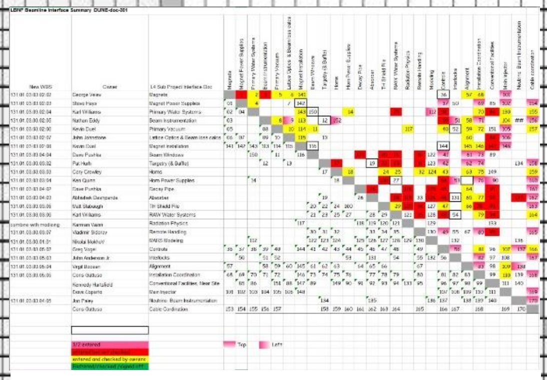
We need to manage our interfaces!

- Lack of interface control results in systems that are incompatible
- For interface control we need to **capture all the important information** about the interface.
- **XLZD have a proposed template** for capturing this
- The process allows us to see the **impact of changes** (through change control process) and to **consult the right parties**

We have started to collect interface information for UK scope, but with many blanks.
We need to work with the international project on this



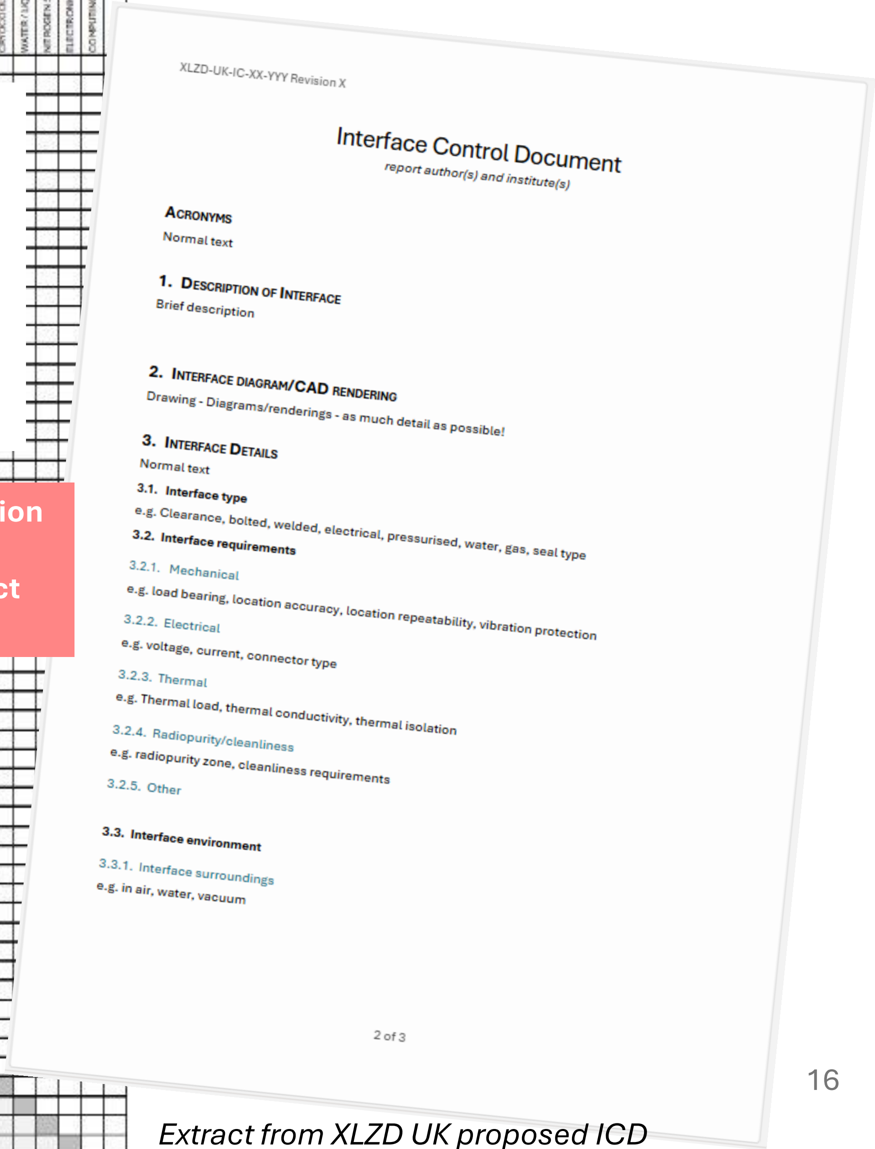
CAD model helps with interface identification



Calls out relevant ICDs

For XLZD UK we are developing:

- Interface matrix
- ICD template to prompt users for all information needed


XLZD-UK-IC-XX-YYY Revision X

Interface Control Document
report author(s) and institute(s)

ACRONYMS
Normal text

1. DESCRIPTION OF INTERFACE
Brief description

2. INTERFACE DIAGRAM/CAD RENDERING
Drawing - Diagrams/renderings - as much detail as possible!

3. INTERFACE DETAILS
Normal text

3.1. Interface type
e.g. Clearance, bolted, welded, electrical, pressurised, water, gas, seal type

3.2. Interface requirements

3.2.1. Mechanical
e.g. load bearing, location accuracy, location repeatability, vibration protection

3.2.2. Electrical
e.g. voltage, current, connector type

3.2.3. Thermal
e.g. Thermal load, thermal conductivity, thermal isolation

3.2.4. Radiopurity/cleanliness
e.g. radiopurity zone, cleanliness requirements

3.2.5. Other

3.3. Interface environment

3.3.1. Interface surroundings
e.g. in air, water, vacuum

2 of 3

Extract from XLZD UK proposed ICD template

Coordinating engineering resources

Consider how we make the most of engineering resources

- Utilising engineering resource – Make sure that the engineers **understand the system well enough to contribute effectively**

For UXLZD UK preconstruction:

- Senior engineers and physicists identified **"technical challenges"**
- These are identified and tracked, and help WP managers to **deploy their engineering effort in the right areas.**
- These have been very helpful for us in getting the engineers up-to-speed and I would recommend this approach!

Number	Challenge	Type	Description	Actions required	Who	Date entered	Date revised	Action Status
C030100	**Radiopurity**							
C030101	Finding radiopure material	Phys/Eng	Finding suitable material for the cryostat, welds, and ancillary elements (e.g. fasteners, MLI, seals)	Supplier engagement, procurement of samples, screening	WP3 (PM/ AG)	Oct-24	Feb-25	In progress, titanium, stainless steel and some ancillary (MLI, fasteners, tie-rod) samples have been ordered.
C030102	Preserving radiopurity	Eng	Preserving the radiopurity of the material through processing (e.g. forging, rolling, surface treatment)	Understand from suppliers the processes that the material is subject to	WP3 (PM)	Oct-24	Feb-25	In progress, communication is being established with TIMET.
C030200	**Transport of large components underground**							
C030201	Transport of flanges	Eng	Transporting the OCV and ICV flange underground, including the required packaging	Compare size of parts with the conveyancing data (i.e. shaft size, available space at the top and bottom of the shaft, and the drifts), design to minimise work required UG	WP3 (LC)	Oct-24		With input from WP7 conveyance studies (OJ).
C030202	Transport of heads	Eng	Transporting the OCV and ICV heads underground, including the required packaging	Compare size of parts with the conveyancing data (i.e. shaft size, available space at the top and bottom of the shaft, and the drifts), design to minimise work required UG	WP3 (LC)	Oct-24		With input from WP7 conveyance studies (OJ).
C030203	Transport of shell segments	Eng	Transporting the OCV and ICV shells underground, including the required packaging	Compare size of parts with the conveyancing data (i.e. shaft size, available space at the top and bottom of the shaft, and the drifts), design to minimise work required UG	WP3 (LC)	Oct-24		With input from WP7 conveyance studies (OJ).
C030204	Transport of containers/ protection	Eng	Choice of/ or design of transport containers. Note feedback from Button indicated that parts going down the Boulby shaft do not have an 'easy time' (electrical racks)	Consider protection of parts being transported, and ensure these are factored into conveyance considerations	WP3 (LC)	Oct-24		With input from WP7 conveyance studies (OJ).
C030300	**Welding**							
C030301	Welding technique	Phys/Eng	Choice of welding technique and preperation applicable for the cryostat fabrication above and underground	Include this in the WP3 consultancy contract	WP3 (PM/ LC)	Oct-24	Mar-25	Contract in place with the NAMRC, the scope covers the initial investigation of welding techniques.
C030302	Welding electrodes	Phys/Eng	Choice of welding electrodes for TIG, or applicable electrodeless techniques	Include this in the WP3 consultancy contract	WP3 (PM/ LC)	Oct-24	Mar-25	Contract in place with the NAMRC, the scope covers the initial investigation of welding electrodes.
C030303	Transport of welding equipment	Eng	Transport of the welding equipment underground, including the required packaging	Compare equipment size to conveyancing data	WP3 (LC)	Oct-24		With input from WP7 conveyance studies (OJ).
C030304	Minimising distortion	Eng	Minimising distortion through choice of welding process, segmentation of parts, welding fixtures, and heat treatment	Include this in WP3 consultancy contract	WP3 (PM/ LC)	Oct-24	Mar-25	Contract in place with the NAMRC, the scope covers the initial investigation of welding & joining techniques.
C030400	**Surface cleanliness and plating**							

WP1 WP2 WP3 WP4 WP6 WP7

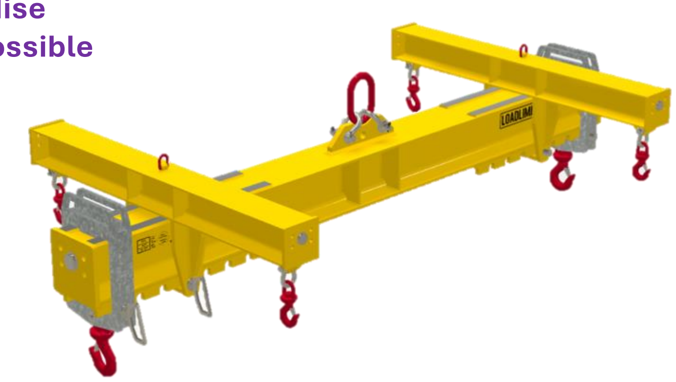
Extract from XLZD UK engineering challenge spreadsheet

For XLZD UK, engineering coordinated centrally through WP7 (lead and integration engineer)

This approach allows us to:

- Effectively share information
- reduce duplication of work
- **Coordinate/standardise processes**, use of components etc. E.g.
  - Reduce variations of:
    - **Fasteners**
    - **Tooling**
    - **Lifting fixtures**

We expect to develop a framework to collect information about designs and allow us to standardise where possible



Idea for a universal lifting beam

Quality Control frameworks

Part name	Part Serial #	Variation	Drawing number	Revision	Material	RFS	Quote	PO#	Order Date	Sales receipt	Vendor	Material Cert	Heat treatment	Vendor metrology report	RAL Metrology report	Metrology anaylysis and additional metrology	Welding report	Post weld metrology	Testing
Feature prototyping																			
Cross-flow flange		Cross-flow flange	TD-1268-211	B	Ti grade 2	OM35356	3090	4070269843	16-Feb-21		B-Tech Engineering Ltd				TD-1268-211-report package				
Short section		Grade 2 - Sample 1 - turned & drilled blank	TD-1268-599	A	Ti grade 2	Short section					R12	4356			Sample 1 grade 2 - post turn & drill	Short section met summary			
Short section		Grade 2 - Sample 1 - complete sample	TD-1268-599	A	Ti grade 2	Short section					R12	4356			Sample 1 grade 2 - post EDM	Short section met summary			
Short section		Grade 2 - Sample 2 - turned & drilled blank	TD-1268-599	A	Ti grade 2	Short section					R12	4356			Sample 2 grade 2 - post turn & drill	Short section met summary			
Short section		Grade 2 - Sample 2 - turned & drilled blank - post SR	TD-1268-599	A	Ti grade 2	Short section					In-House	4356	Same as 339		Sample 2 grade 2 - post SR	Short section met summary			
Short section		Grade 2 - Sample 2 - complete sample	TD-1268-599	A	Ti grade 2	Short section					R12	4356			Sample 2 grade 2 - post EDM	Short section met summary			
Short section		Grade 5 - sample 1 - turned & drilled blank	TD-1268-599	A	Ti grade 5	Short section					R12	3974			Sample 1 grade 5 - post turn & drill	Short section met summary			
Short section		Grade 5 - sample 1 - complete sample	TD-1268-599	A	Ti grade 5	Short section					R12	3974			Sample 1 grade 5 - post EDM	Short section met summary			
Short section		Grade 5 - sample 2 - turned & drilled blank	TD-1268-599	A	Ti grade 5	Short section						3974			Sample 2 grade 5 - post turn & drill	Short section met summary			
Short section		Grade 5 - sample 2 - turned & drilled blank - post SR	TD-1268-599	A	Ti grade 5	Short section						3974	Same as 339		Sample 2 grade 5 - post SR	Short section met summary			
Short section		Grade 5 - sample 2 - complete sample	TD-1268-599	A	Ti grade 5	Short section						3974			Sample 2 grade 5 - post EDM	Short section met summary			
Full length section		Gun drilled blank - Grade 2	TD-1268-419	B	Ti grade 2		400582					4356			TD-1268-419-grade 2&5 pre SR				
Full length section		Gun drilled blank - Grade 2 - post heat treat	TD-1268-419	B	Ti grade 2							4356	339		TD-1268-419-grade 2&5 post SR				
Full length section		Grade 2 in jig	TD-1268-413	A	Ti grade 2		4737					4356		A&M met grade 2	Grade 2 IN JIG report	grade 2 / grade 5 compar			
Full length section		Grade 2 - post removal from jig	TD-1268-413	A	Ti grade 2		4737					4356			Grade 2 NO JIG (folder)	Grade 2 wall thickness report			
Full length section		Gun drilled blank - Grade 2 spare - post heat treat	TD-1268-419	B	Ti grade 2		400601					4356	343		TD-1268-419-grade2-spare				
Full length section		Gun drilled blank - Grade 5	TD-1268-419	B	Ti grade 5		400582					3974			TD-1268-419-grade 2&5 pre SR				
Full length section		Gun drilled blank - Grade 5 - post heat treat	TD-1268-419	B	Ti grade 5							3974	339		TD-1268-419-grade 2&5 post SR				
Full length section		Grade 5 (in jig)	TD-1268-413	A	Ti grade 5		4737					3974		A&M met grade 5	Grade 5 IN JIG report	grade 2 / grade 5 compar			
Full length section		Grade 5 - post removal from jig	TD-1268-413	A	Ti grade 5		4737					3974			Grade 5 NO JIG (folder)	Grade 5 wall thickness report			
Full length core			TD-1268-679				1385												
Full length core			TD-1268-679																
Weld straigtness		Sample 1 end 1	TD-1268-589	B	Ti grade 2	OM35632	Q1345					20191024			TD-1268-589 - S1 - remake				
Weld straigtness		Sample 1 end 2	TD-1268-590	B	Ti grade 2	OM35632	Q1345					20191024			TD-1268-590 - S1 - remake				
Weld straigtness		Sample 1 assembly	TD-1268-591	B			E738								TD-1268-591-pre-weld	TD-1268-591-visuals	65941	TD-1268-591-post-weld	
Weld straigtness		Sample 2 end 1	TD-1268-589	B	Ti grade 2	OM35632	Q13458	4070282057	24-Jan-21		FraserNash	20191024			TD-1268-589 - S2 - remake				
Weld straigtness		Sample 2 end 2	TD-1268-590	B	Ti grade 2	OM35632	Q13458	4070282057	24-Jan-21		FraserNash	20191024			TD-1268-590 - S2 - remake				
Weld straigtness		Sample 2 assembly	TD-1268-591	B			E7388	4070282574	28-Jan-21	49496	EBP				TD-1268-591-pre-weld	TD-1268-591-visuals	65941	TD-1268-591-post-weld	
Weld straigtness		Weld straightness sample 3 end 1	TD-1268-589	B	Ti grade 2	OM35632	Q13458	4070282057	24-Jan-21		FraserNash	20191024			TD-1268-589 - S3 - remake				
Weld straigtness		Weld straightness sample 3 end 2	TD-1268-590	B	Ti grade 2	OM35632	Q13458	4070282057	24-Jan-21		FraserNash	20191024			TD-1268-590 - S3 - remake				
Weld straigtness		Weld straighness assembly 3	TD-1268-591	B			E7388	4070282574	28-Jan-21	49496	EBP				TD-1268-591-pre-weld	TD-1268-591-visuals	65941	TD-1268-591-post-weld	

We need to do this from the start.

We cannot get this information back once it is lost.

- Components need to be **traceable** back through various processing steps, to the **original material billet/certificate.**
- To include information like; material certificate, batch, heat treatment, processing, metrology reports, order number, receipt, surface treatment, radioassay data.
- **This tracking spreadsheet example was developed for another project**
- **We will need something like this for XLZD**, probably more complex, with the **cleanliness/radioactivity considerations**

- We need to recognise that different sub-systems may have different focusses.
- There may not be a single solution that fits all!

We also need Frameworks/high-level guidance on things like:

- Inspection of components
  - E.g. requirements for component interfaces that can't be tested prior to shipping
  - Thread gauging....
- Testing
- Spares count

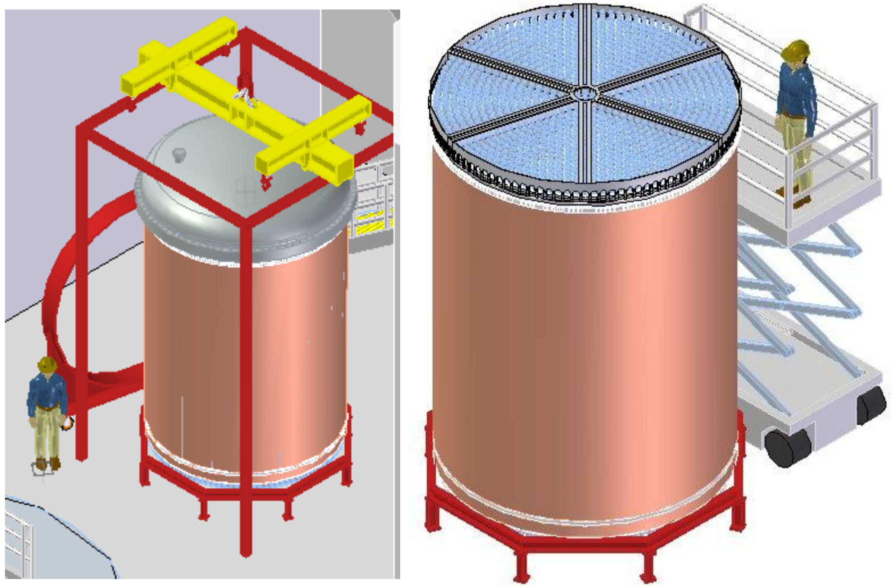
Design for Integration

We need to incorporate the following considerations into our design:

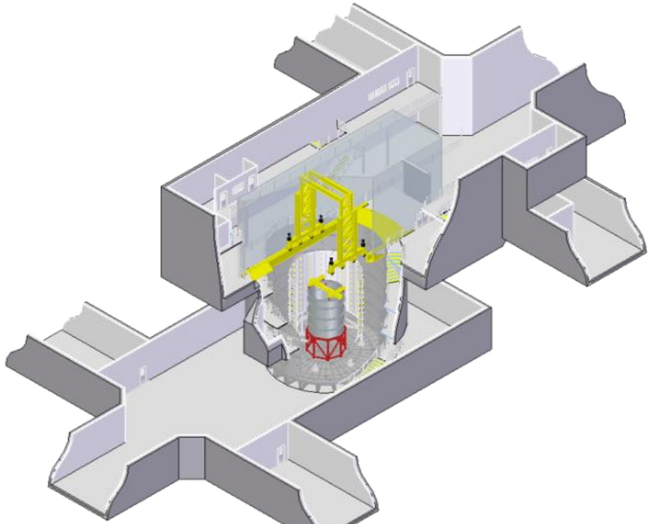
- How components are handled
- How they are transported (including international transit)
- What access is required?
- What tooling/equipment is required
- Where it is tested
- How it is tested
- Etc…
- **These are all potential candidates for frameworks**

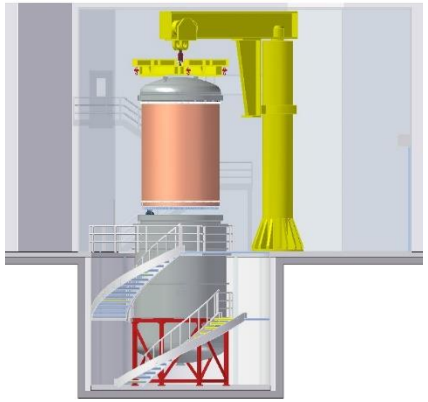
Design reviews should check these things have been considered

Notional lifting bar and lifting points



XD assembly tooling placeholder





For example, a component like a large vessel will need:

- Lifting points
- Pumping attachments for leak/pressure tests
- Blanking flanges
- Crane/transport cart
- Assembly areas
- Clean areas
- Design for test rig/diagnostics
- Crate/transport diagnostics (accelerometers?)

Extract from staging CAD. Features moving cranes to help step through assembly steps in CAD

Summary

Key messages from this talk:

Robust engineering processes are needed for large complex projects

Science has to define what is required

Engineering has to define how to deliver it

Make sure those two things are in step, and make sure the engineering specifications are aligned with the science requirements

Consider what are your Engineering facility requirements drivers are, and the best way to meet them

Develop frameworks to help ensure that hardware meets all levels of requirements, as efficiently as possible

For big construction projects, **Plan, plan, plan!**

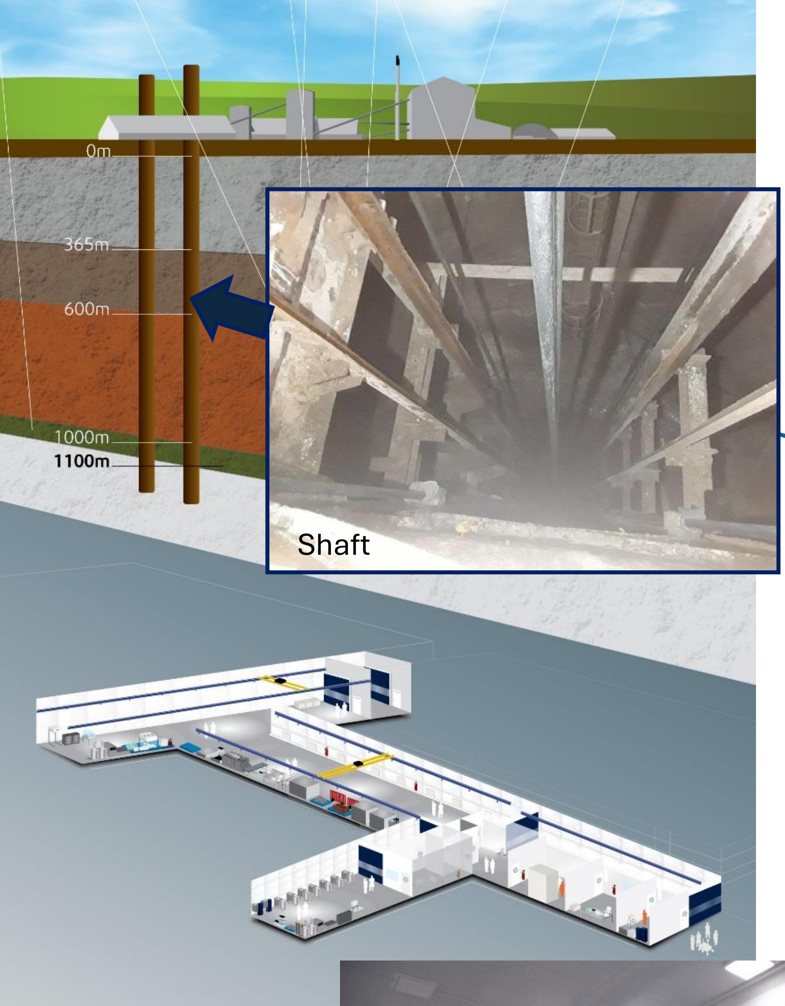
And there is far more to this than what I have discussed. I have not talked about:

- PM frameworks (including review structure)
- Safety
- Cost/schedule/risk
- Options analysis
- Configuration control
- Change control
- Code implications for different sites
- Testing/verification
- Procurement frameworks
- Manufacturing frameworks
- Skills
- Document management
- Inventory system, travellers

Questions?

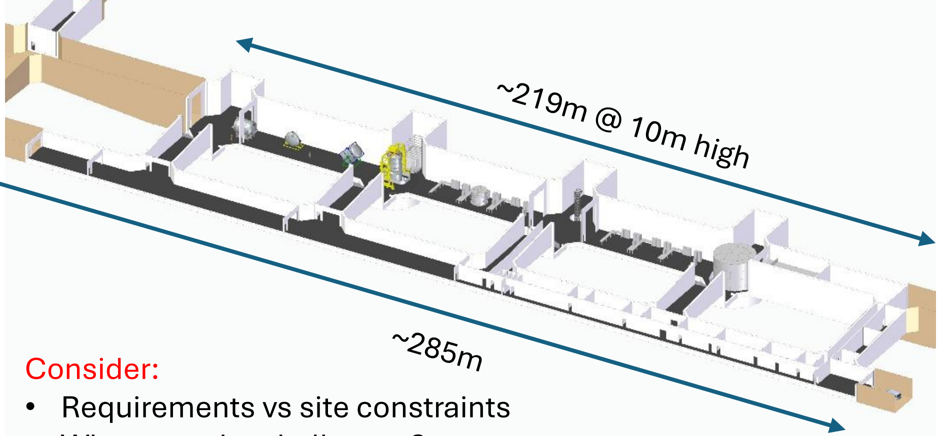
Back-up slides

Infrastructure requirements vs constraints



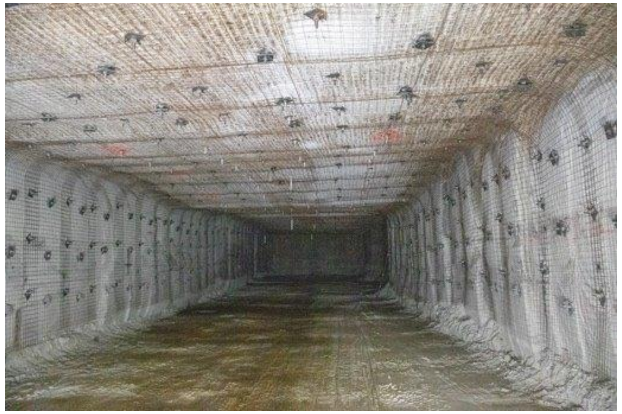
Current lab – 6000m^3

Stage 1 lab (manufacturing facility) ~ 45,000m^3



Consider:

- Requirements vs site constraints
- Where are the challenges?



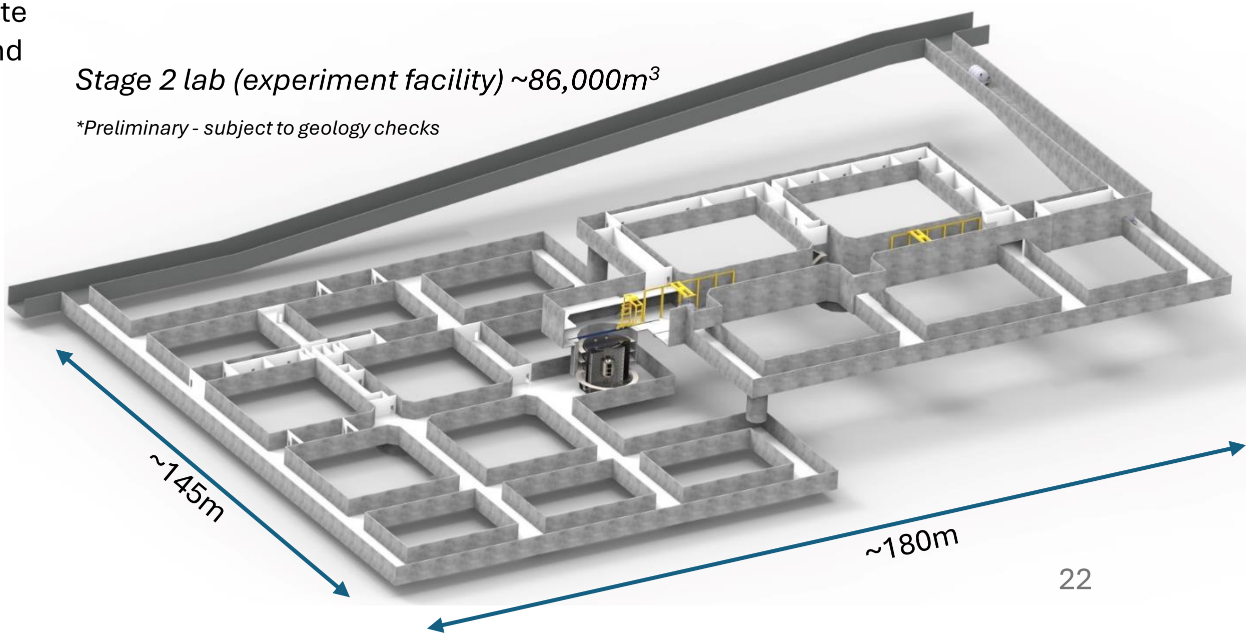
Stage 1 excavation – 8m wide by 5m high

E.g. for Boulby, current shaft restriction drives the need to fabricate some large components underground

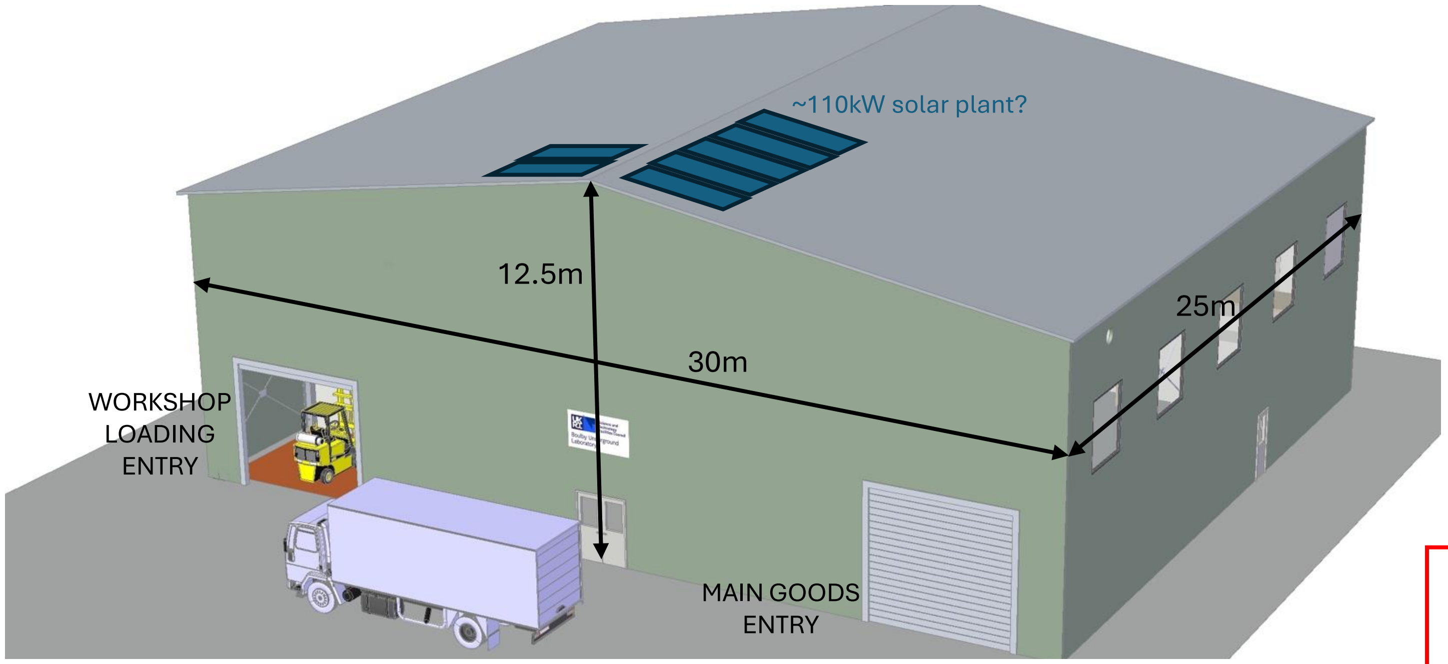
Current lab photo – 6000m^3

Stage 2 lab (experiment facility) ~86,000m^3

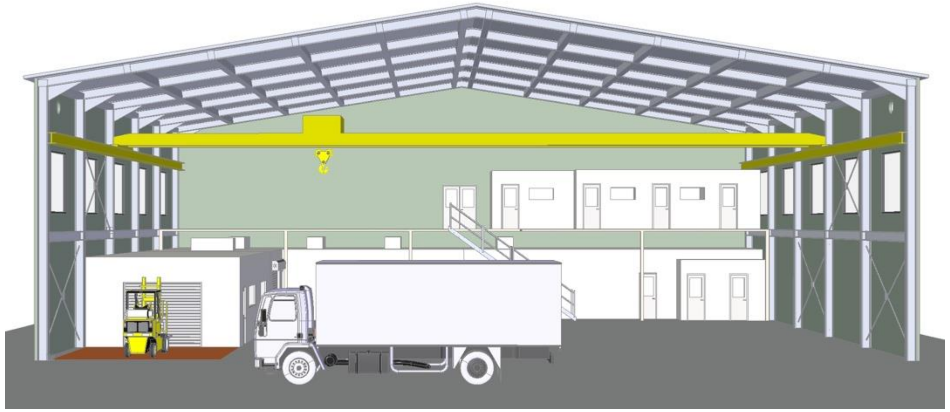
**Preliminary - subject to geology checks*

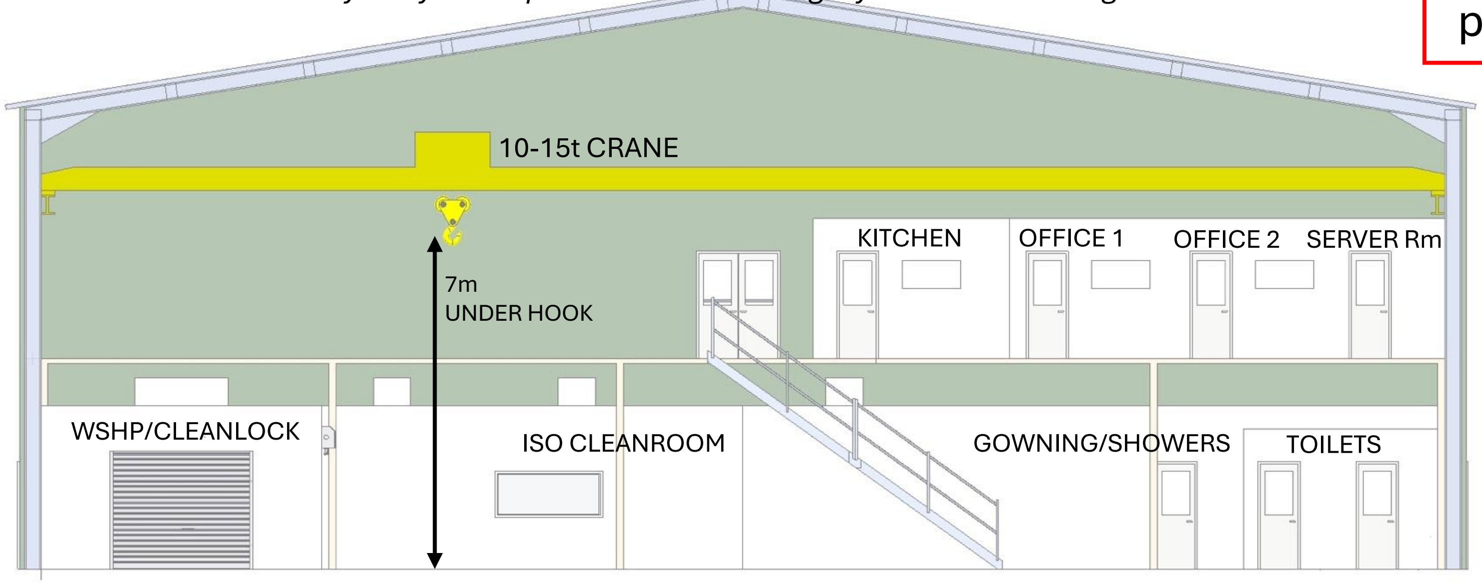


The environment (facility) – Marshalling equipment as it arrives



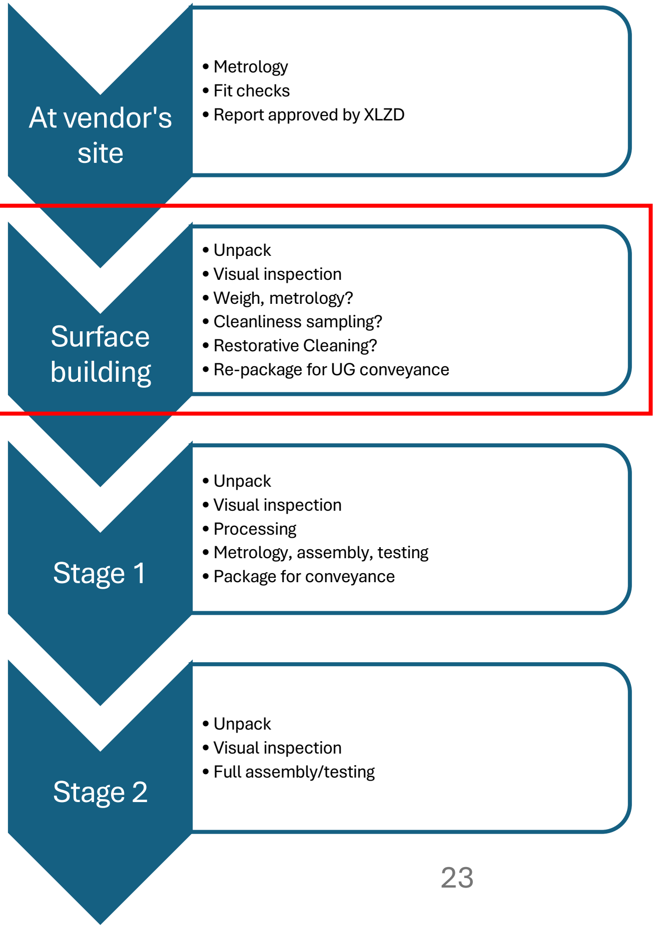
Boulby early conceptual surface building layout – Work In Progress





Consider what happens when parts arrive on site

Travellers to track components through their lifetime, including its journey through site

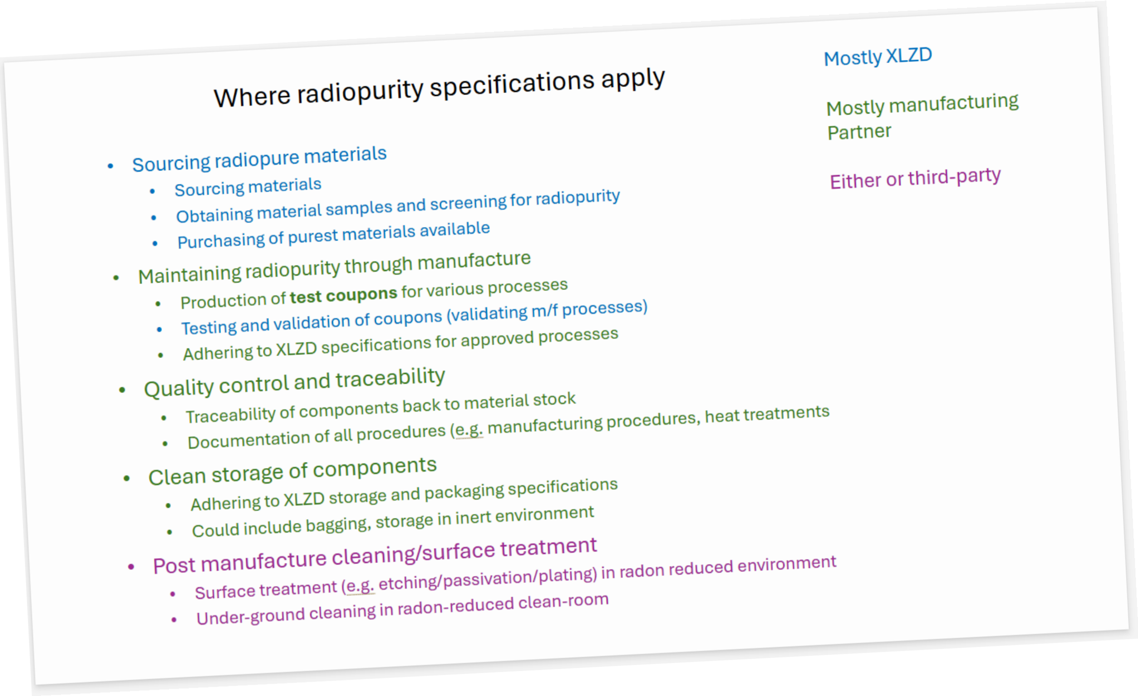


Developing requirements into specifications

- Specifications define how a requirement can be achieved
- These can apply to individual components or parts of a system

E.g. for radiopurity requirements

- Flow down requirements to derive specifications at least at the WBS lv3 level.
- Avoid Blanket specifications that raise cost!
- Consider how specifications relate to all parts of the process, and who they affect.



Where radiopurity specifications apply

Mostly XLZD

Mostly manufacturing Partner

Either or third-party

- Sourcing radiopure materials
  - Sourcing materials
  - Obtaining material samples and screening for radiopurity
  - Purchasing of purest materials available
- Maintaining radiopurity through manufacture
  - Production of **test coupons** for various processes
  - Testing and validation of coupons (validating m/f processes)
  - Adhering to XLZD specifications for approved processes
- Quality control and traceability
  - Traceability of components back to material stock
  - Documentation of all procedures (e.g. manufacturing procedures, heat treatments
- Clean storage of components
  - Adhering to XLZD storage and packaging specifications
  - Could include bagging, storage in inert environment
- Post manufacture cleaning/surface treatment
  - Surface treatment (e.g. etching/passivation/plating) in radon reduced environment
  - Under-ground cleaning in radon-reduced clean-room

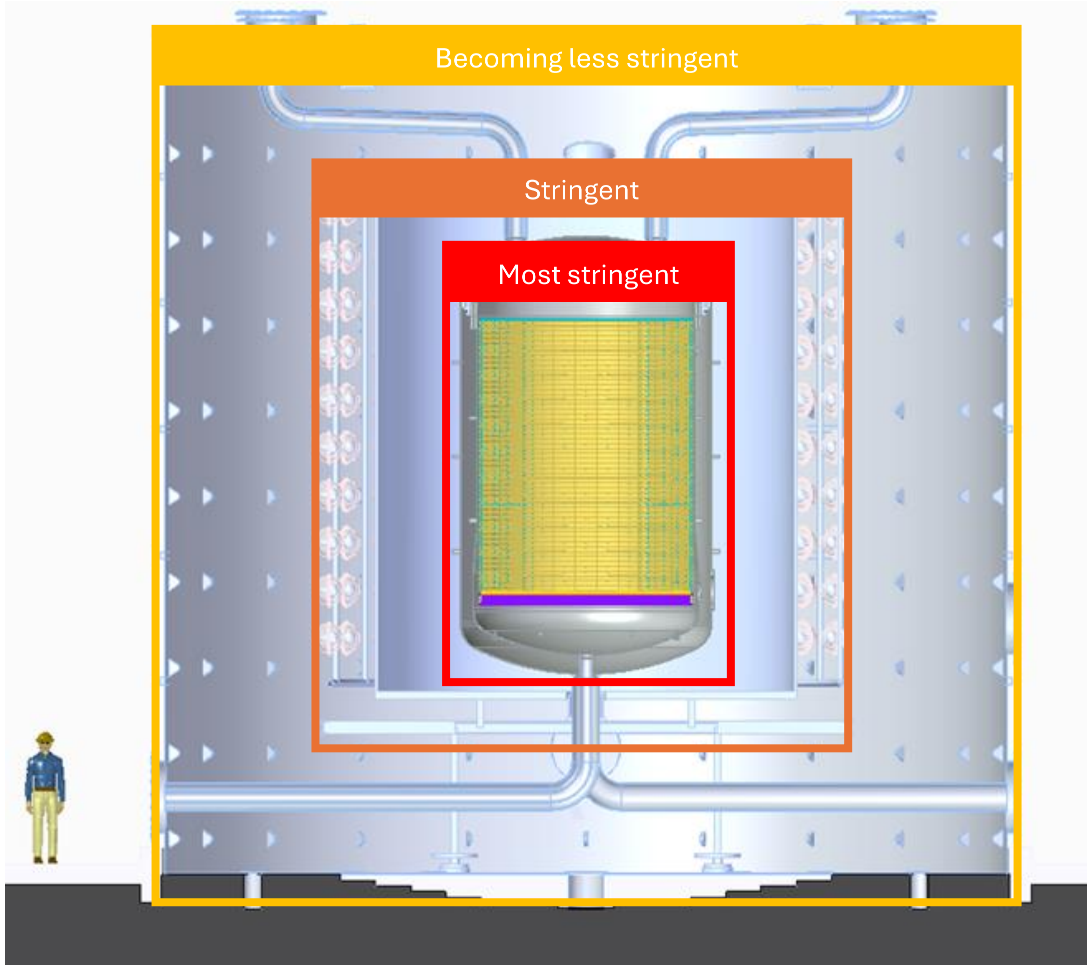


Illustration of how radiopurity requirements might flow down to different parts of the system – Indicative only.

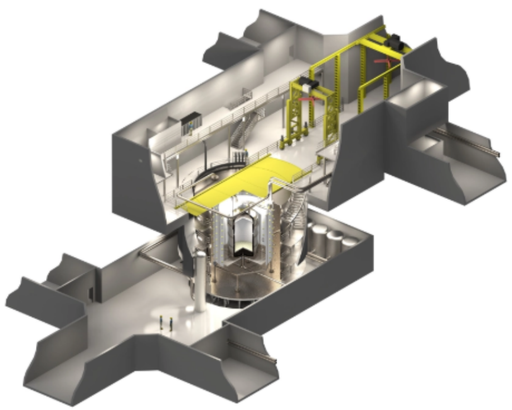
Document control system

XLZD-UK

XLZD-pre-construction

Home
WP0 - Management
WP1 - Xenon
WP4 - Xenon Detector C...
WP5 - Computing
WP6 - Clean Manufacture
WP7 - Engineering & Skills
Action Tracker
Controlled Documents
Documents
Notebook
Pages
Conversations
Site contents
Recycle bin
Edit

+ New · Page details · Preview · Analytics



Document Index - useful links

See Quick Links, Work package folders and document templates on the right.

For access to this sharepoint, please get in touch with jens.dopke@stfc.ac.uk. Please also note which work package you want new people to be added to.

Documents to be updated by WP managers weekly

Gantt chart and Milestones - XLZD GANTT export for progress tracking.xlsx
Action tracking is now in Sharepoint
Update slide (1 slide progress summary) - Tech board slide links

To be completed per timescale scheduled (and by CDR)

Requirements, parameters, challenges

Requirements - XLZD Requirements (UK).xlsx
Parameters - XLZD Parameters.xlsx
Technical challenges - Technical challenges-REV B - WIP.xlsx
List of major procurements - XLZDConstructionProcurements.xlsx
Milestone & deliverable reports - Milestone & Delivery reports

Costs

Cost BOEs - BoEs

People

List of project personnel
List of technical skills for construction phase

Comms & Outreach

XLZD model renderings - CAD Renderings - Harry Byrne

Activity · See all

Quick links

XLZD on STFC Indico
XLZD-UK Common File Store
XLZD-UK Document Register
Learn how to add a page

Controlled Documents

WP0 · WP1 · WP2 · WP3 · WP4 · WP5 · WP6 · WP7 · WP8 · WPX

Work Package Sandbox

Exec · WP0 (restricted) · WP1 · WP2 · WP3 · WP4 · WP5 · WP6 · WP7 · WP8

Document Templates below are read only - please make a copy before editing!

Document Templates

Interface Control... · Milestone Delivery... · Technical Note

Must have:

Access control
Data protection/security/robust backup system
Document sign-off/revision control
Different doc types, templates
Reserve unique document numbers
External links (SLACK, IDICO, GITLAB, Calendar, etc.)
Ability to share access across multiple organisations

Ideally have:

Top level "site" from which the system can be navigated (TWIKI style)
Assigned activities log and email prompts
Live documents
Drag & drop functionality (advanced searches)
Ability to share (full access) documents across multiple organisations worldwide
Associated template system

We have a SharePoint system that addresses all of the "must have" and most of the "ideally have".

Not perfect, but it is sufficient for XLZD-UK-pre-construction

Options for full project:

Upgraded SharePoint?
EDMS?
Doc DB?
TWIKI
....

DOCUMENT NUMBER	PURPOSE	APPROVALS?
XLZD-UK-TN-XX-YYY	Generic technical note or report	N
XLZD-UK-CD-XX-YYY	Generic controlled document	Y
XLZD-UK-MD-XX-YYY	Milestone or deliverable report	Y
XLZD-UK-IC-XX-YYY	Interface control document	Y
XLZD-UK-QA-XX-YYY	Quality assurance document	Y
XLZD-UK-PD-XX-YYY	Procurement document	Y
XLZD-UK-SD-XX-YYY	Safety document	Y
XLZD-UK-ED-XX-YYY	Engineering document	N
XLZD-UK-FT-XX-YYY	Forms and templates	Y
XLZD-UK-PT-XX-YYY	Presentations/Talks	N
XLZD-UK-LM-XX-YYY	Letters/Memos	N
XLZD-UK-MP-XX-YYY	Management or Policy	Y
XLZD-UK-PU-XX-YYY	Publications	Y
XLZD-UK-CR-XX-YYY	Change requests	Y
XLZD-UK-PM-XX-YYY	Project management document	Y
XLZD-UK-IR-XX-YYY	Incident reports	Y

XX: work package number with trailing zero, e.g. XX=06 for WP6.

YYY: 3-digit number, sequential from document repository.

Integration

The system (the inputs)

- What does it do (requirements)
- What are the components
- How are they connected
- What are the services and how are they connected
- What are the interfaces

The Environment (facility)

- Where is it built, and what are the constraints (space, access)
- What are the requirements of the experiment on the Facility
- What are the limitations of the facility
- What are the interfaces to the facility
- What are the applicable local standards/codes

System architecture (defining XLZD)

- What are the important relationships in the system
- Hardware-software interface
- Level of control/system autonomy
- Instrumentation
- Interlocks and automated control loops

Design for manufacture/assembly

- Specify lifting/ handling points
- Standardisation of lifting/transport rigs and assembly tooling
- Standardisation of components and fasteners
- Standardisation for reduced tooling and accessories

Engineering coordination

- Controlled documents, and sign-off
- CAD Product Lifecycle Management System
- CAD integration model/manager
- Component tracking documents

Assembly & Testing

- Assembly and resourcing plans
- Assembly tooling (off-the shelf)
- Assembly tooling (bespoke)
- Access platforms
- Assembly and Test plans (and acceptance criteria)

Where do the Engineering challenges lie

- Outstanding R&D. Possible late design changes?
- Cleanliness/radiopurity
- Manufacturing/ tolerances
- Pinch-points for access and services
- Testing that can't be done early (High risk)

holistic approach – system efficiency

- What are the inter-dependencies within the system
- How do we meet distributed requirements (flow-down/budgets)
- Where can we make efficiency savings (wholistic approach)

Protection – People, the environment, the experiment

- What are the critical systems for safety, Xenon retention, and protection of experiment and infrastructure, and how are they protected?
- What are the appropriate design/safety codes, and how do we ensure compliance throughout?

Developing facility requirements

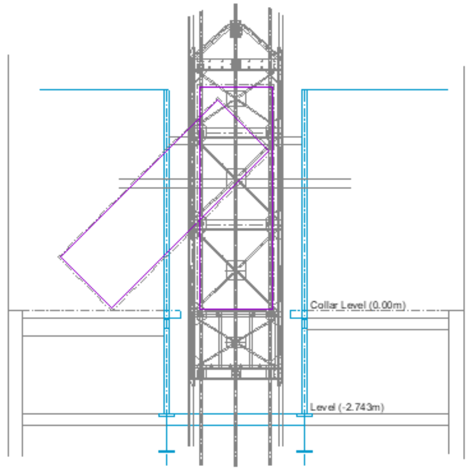
- **Access**
- Geological constraints on lab layout
- Cooling/ventilation capacity
- Impact of assembly infrastructure on fire control
- Floor loading requirements
- Power requirements
- Radon reduction constraints

Consider:

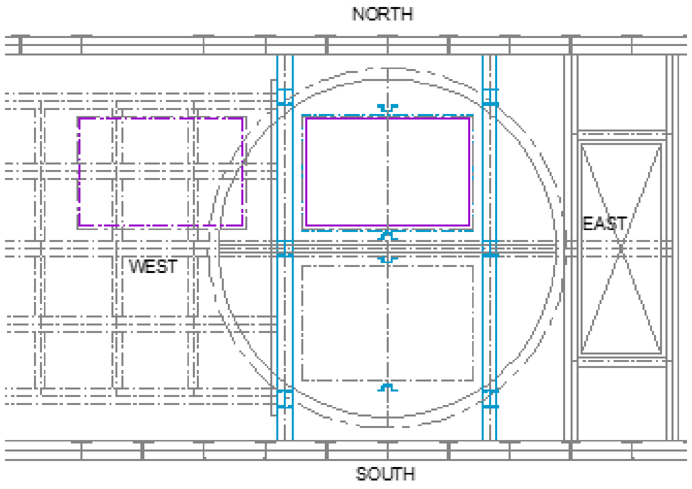
- What are our largest components, and what access do they need?
- Are there any restrictions that we cannot control?
- What is the impact of these on manufacturing/assembly of the experiment?

For Boulby: T

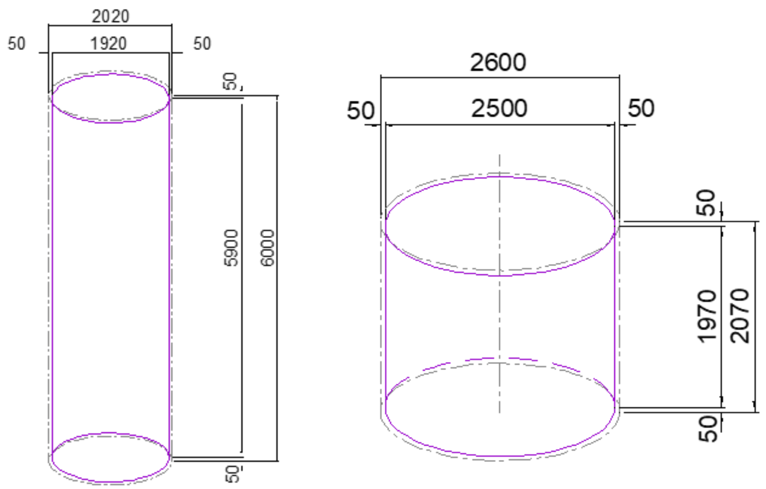
- The current shaft restriction would require some fabrication to take place underground

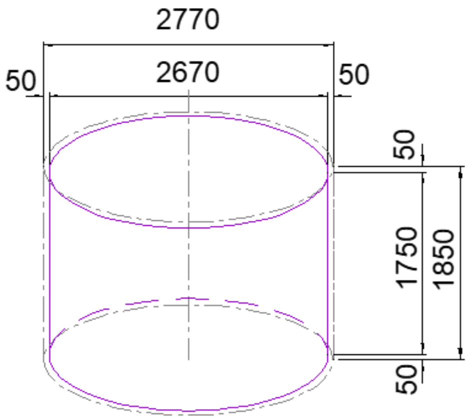


Routine slinging – man shaft



Routine slinging – rock shaft





Size constraints for different slinging configurations in the man shaft and the rock shaft

Working within the constraints of the facility

- Access
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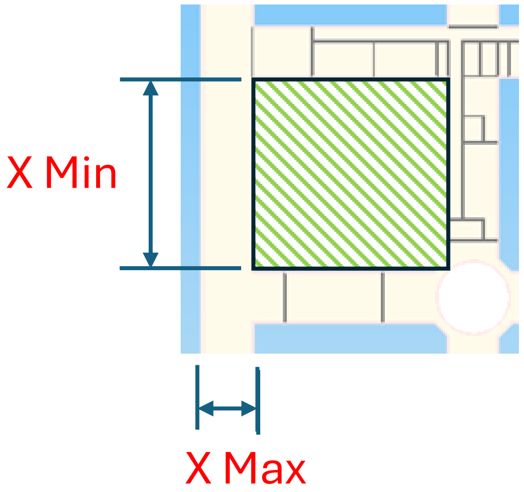
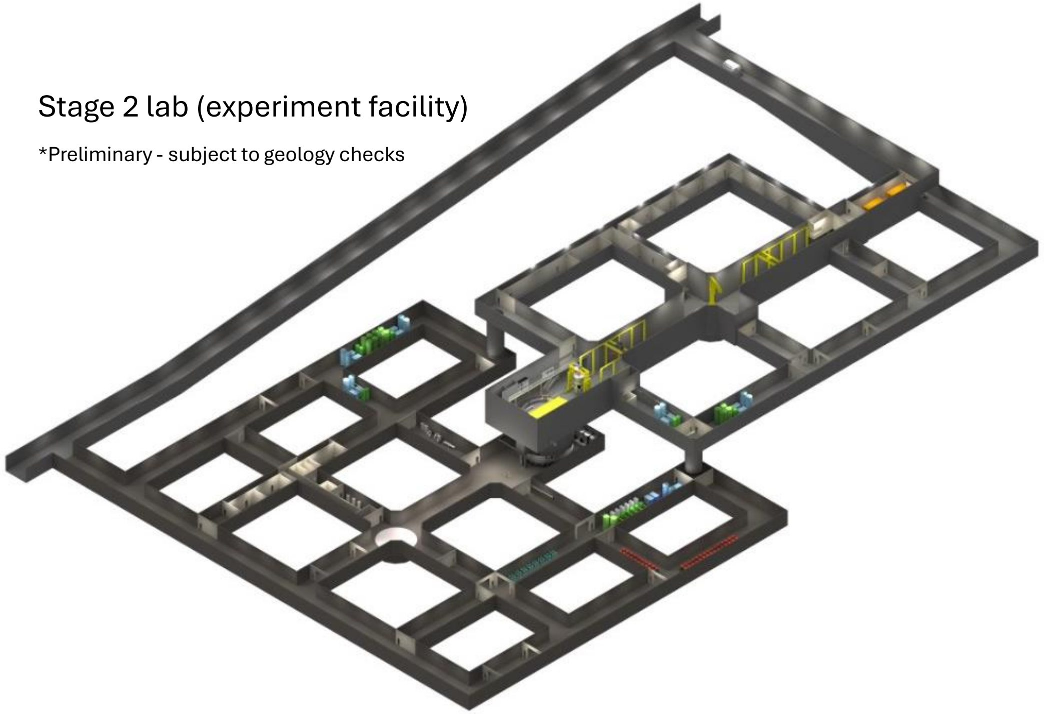


Stage 2 lab (experiment facility)

*Preliminary - subject to geology checks



Bigger halls need bigger support pillars

There is flexibility around this (e.g. experiment shaft, which is a civil project), but this would require iteration with the mine

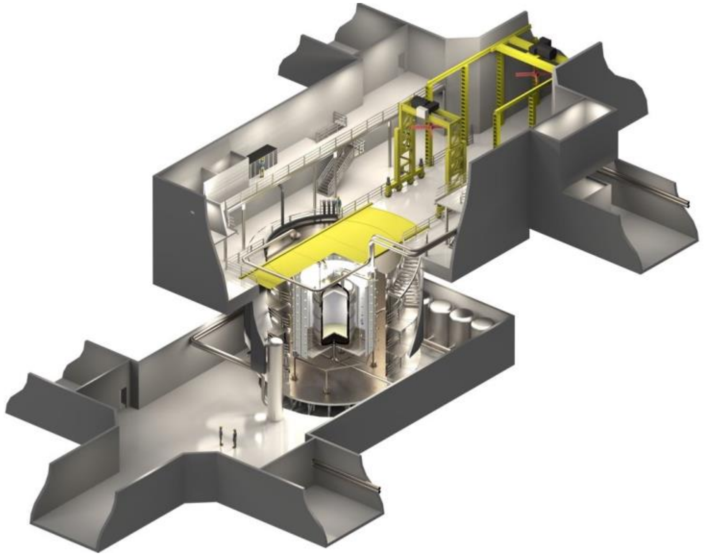
Need to understand the geology better, and studies are in progress

Lab layout driven by XLZD requirements and mining costs

In this design, mining cost is minimised using basic mining techniques (minimal civil engineering)

Mostly sticking to tried and tested lab widths (8m) and support cross sections (30m). Support requirement places minimum lab length limit

Layout is dependent on geological constraints.
Upper lab may be rotated relative to lower lab to fit different shape of polyhalite



XLZD at Boulby - Concept

Working within the constraints of the facility

- Access
- Geological constraints on lab layout
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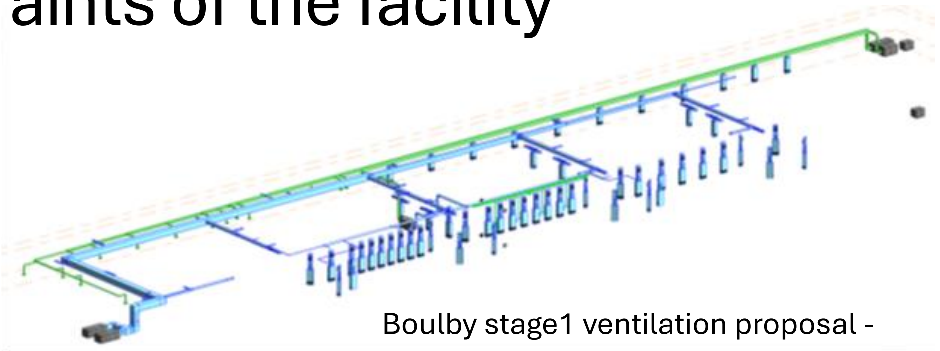
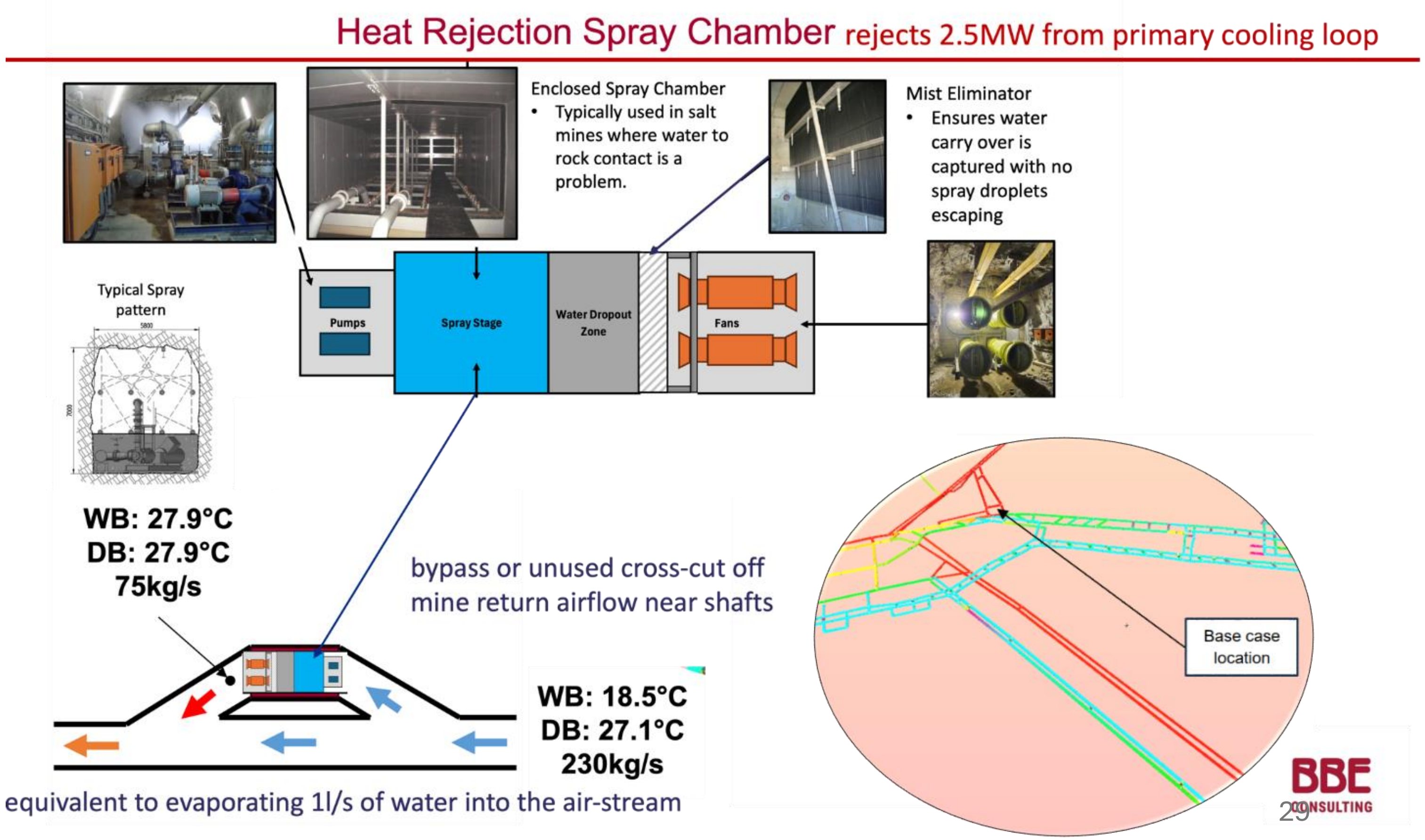


Boulby stage1 ventilation proposal - Provisional

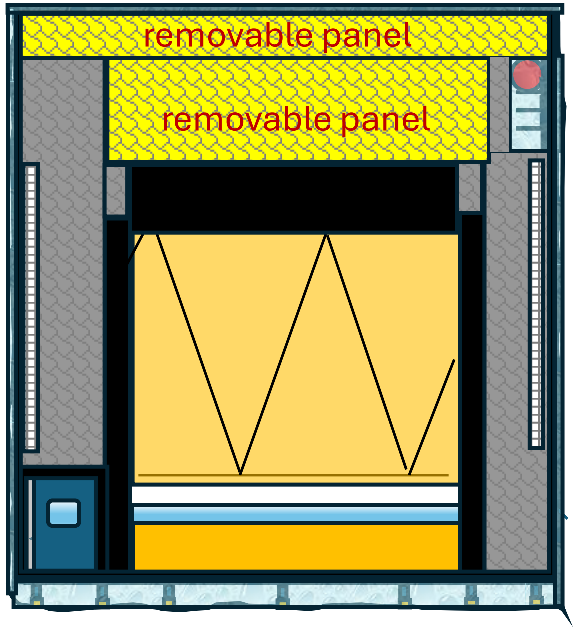
How will heat generated in the experiment be removed? Is there a Limit?

Enclosed spray chamber proposed for Boulby

Increased mine humidity, and heat removal by this method is not unlimited (probably up to 4-5MW) due to mine's wet-bult temperature limit



Working within the constraints of the facility

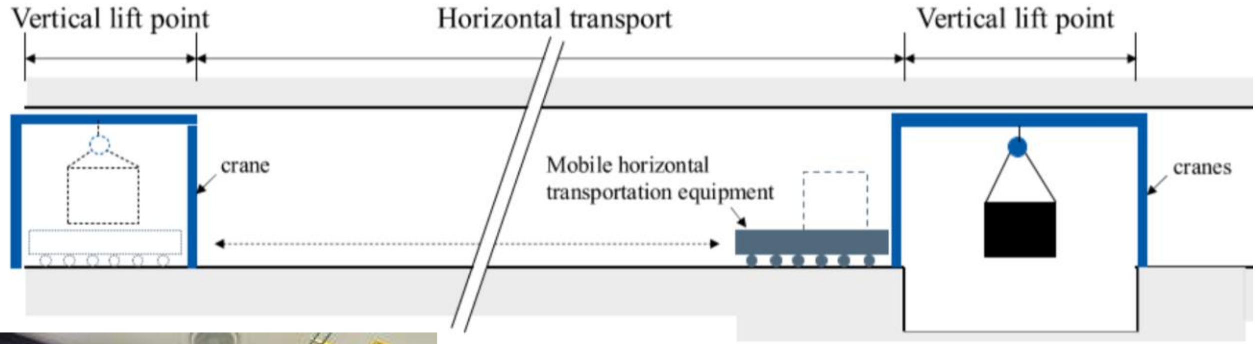


- Access
- Geological constraints on lab layout
- Cooling/ventilation capacity
- **Impact of assembly infrastructure on fire control**
- Floor loading requirements
- Power requirements
- Radon reduction constraints

Overhead cranes can increase the complexity of bulk-heads due too fire regulations.

Recommendation from lifting specialist to avoid complete crane coverage in favour of local lifting points with cart transfers in between

Helps avoid issue where crane overhead crane coverage impacts on fire control requirements



Developing facility requirements

- Access
- Geological constraints on lab layout
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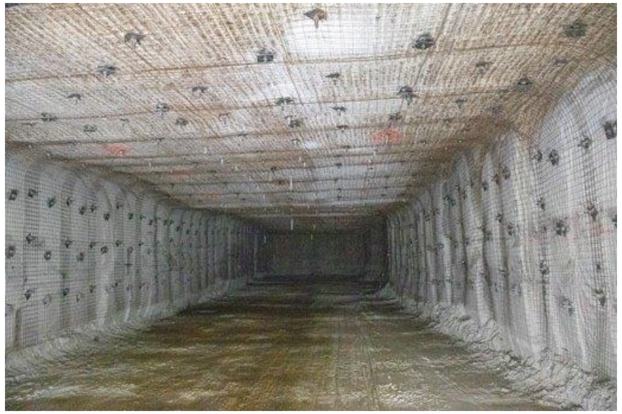
- **Floor loading requirements**
- Power requirements
- Radon reduction constraints

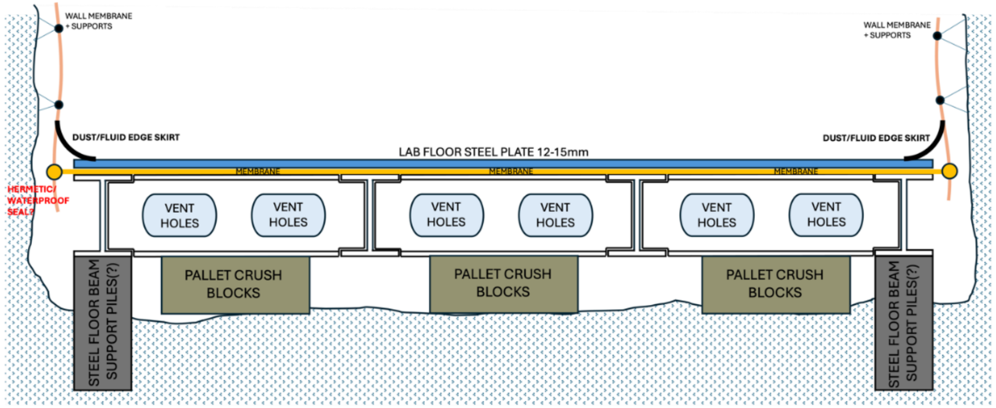
For Boulby

- Floor reinforcement = additional cost/complexity.
- Avoid blanket specs – work out the floor loading requirements in specific areas, and reinforce as appropriate.

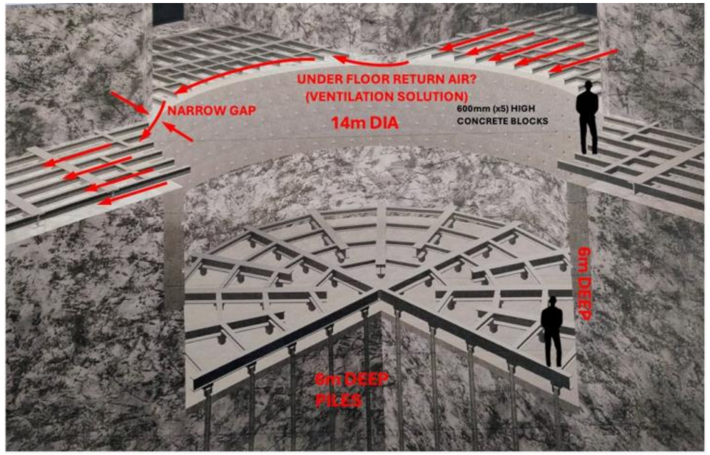
Consider:

- What are the floor load loading requirements
  - Generally
  - For specific aspect of the experiment
- For existing labs, are there floor loading limits that might affect how we handle components?


Stage 1 current status (as excavated)



Conceptual Boulby lab floor detail



Provisional - Pile reinforcement concept for a basin to meet floor loading spec

Scenario	Description	Loads	Support equipment (currently assumed)	Locations
General ICV handling	General handling of the ICV (whilst empty). See latest vessel drawings for sizes.	ICV (<10T) + additional handling frames and equipment (<~2T) = **<12T total**	Vessel mounted horizontally on a trolley. Load transferred to floor likely through four wheels or corner skid plates. Possibly sat on support saddles (see Figures 1 & 2) during slack periods.	Stage 1 Hall 1 &2, Atrium 1&2 (including basins), possibly Atrium 3 (shallow) basin. Stage 2 main hallway/ workshop.
General OCV handling	General handling of the OCV (whilst empty). See latest vessel drawings for sizes.	OCV (<10T) + additional handling frames and equipment (<~2T) = **<12T total**	Vessel mounted horizontally on a trolley. Load transferred to floor likely through four wheels or corner skid plates. Possibly sat on support saddles (see Figures 1 & 2) during slack periods.	Stage 1 Hall 1 &2, Atrium 1&2 (including basins), possibly Atrium 3 (shallow) basin. Stage 2 main hallway/ workshop.
ICV pressure test	Hydraulic pressure testing of the ICV.	ICV (<10 T) + test water (41 T) + support saddles (1 T) = **52 T**	Vessel mounted horizontally on support saddles (see Figures 1 & 2).	>9m diameter Stage 1 deep basin (for leak and burst protection).
OCV pressure test	Hydraulic pressure testing of the OCV.	OCV (<10 T) + test water (57 T) + support saddles (1.2 T) = **68.2 T**	Vessel mounted horizontally on support saddles (see Figures 1 & 2).	>9m diameter Stage 1 deep basin (for leak and burst protection).
ICV etching	Etching of the inner surface of the ICV. Assuming an etching arrangement similar to	ICV (<10T) + support frames permitting rotation (<2T) + HF paste (negligible) + suspended	Vessel mounted horizontally on roller frame and suspended floor. Load transfer to the basin will depend on	>10m diameter, 5m deep Stage 1 basin (for leak and fume containment). Possibly a smaller diameter basin usable.

Part of an XLZD floor loading estimate

Developing facility requirements

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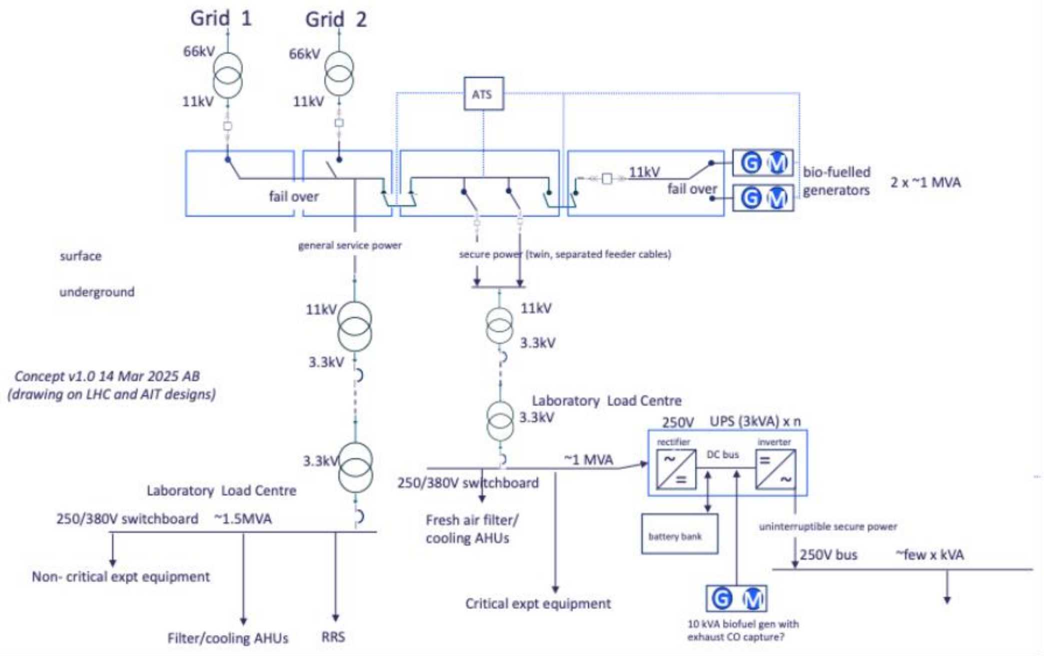
- **Power requirements**
- Radon reduction constraints



Provisional design for Boulby lab electrical upgrade to meet anticipated XLZD requirements – work in progress

In the case of Boulby:

- The limiting factor is not the power availability; it's the ability to remove the heat generated
- Boulby anticipate adding a water evaporation system to remove up to 5MW of heat generated
- There is a 3kVA limit per under-ground UPS
- Boulby are working on a design for an electrical upgrade that includes dual supplies, and back-up power to meet anticipated XLZD requirements

Consider:

- What are the site limitations on power
- Overall consumption
- Reliability of power
- Possible restrictions on battery UPS in under-ground labs?
- Transmission losses from a surface UPS systems

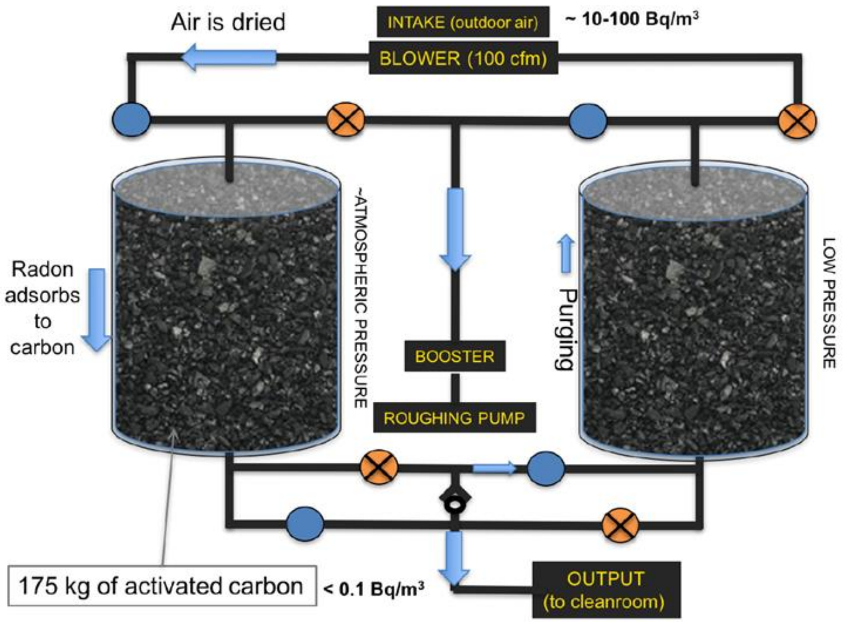
Developing facility requirements

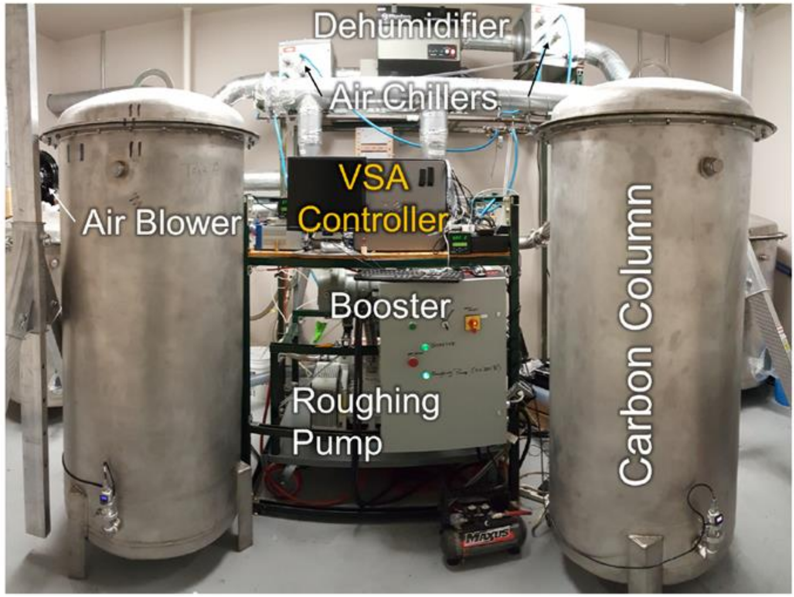
- Access
- Geological constraints on lab layout
- Cooling/ventilation capacity
- Impact of assembly infrastructure on fire control
- Floor loading requirements
- Power requirements
- **Radon reduction constraints**

Consider:
How do we achieve the required radon reduction level for assembly activities away from host lab, where we are dealing with higher ambient backgrounds?

Could they be centralised?

- Current Rn targets – 0.05Bq/m^3, in a volume of 2000-3000m^3.
- Conventional (continuous flow) radon reduction would require megawatts of cooling- impractical to achieve underground.





- Vacuum swing system prototyped by SD Mines/SNOLAB has achieved a >1000x reduction from ~80Bq/m^3 to 0.067Bq/m^3 for a much reduced power consumption, but only in a 50m^3 cleanroom volume.
- **BUL has ambient radon concentrations of ~3Bq/m^3, a good starting point for reduction at scale.**