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JET Decommissioning - Transition from Operations to Decommissioning

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Discharge the UK's liability for JET decommissioning in a **cost-effective** manner, using **innovative** cost saving methods, and reducing nuclear hazard. **Minimize waste** streams and **maximize tritium recovery**.

Develop, implement and prove **new technologies** to position the UK for future **international markets**.

Repurpose JET facilities for UK science and innovation where there is a clear case to do so. Enable the growth of the **fusion cluster** by regenerating land released from JET.

Retain and build on key UK **skills base** gained through hosting and operating JET, including within the supply chain.

UKAEA Mission & Goals

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Mission

To lead the delivery of sustainable fusion energy and maximise the scientific and economic benefit.

Goals

- **Solve** challenges of sustainable fusion energy - from design through to decommissioning - with world-leading science and engineering.
- **Enable** partners to design, deliver, and operate commercial fusion power plants.
- **Drive** UK economic growth and a thriving industry that exports fusion technology around the world.
- **Create** clusters that accelerate innovation in fusion and related technologies.
- **Develop** the talented, diverse people needed to deliver fusion energy.

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Strategic and political context

Programme Stages Completed to Date

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Stage/Dates	Activities completed in each preliminary stage
Identification Phase **2004 - 2021**	• 2004-2008 – Creation, baselining and archiving of initial Culham Lifetime Plan (LTP) • 2018/19 – Unpacking plans from archive – annual updates to Nuclear Decommissioning Authority (NDA) on current JET decommissioning liability • 2019-2021 – Programme requirements identified based on archived LTP • 2021 – UKAEA asks JDR to create an Alternative Decommissioning Strategy • 2021 – Decommissioning Management Agent (DMA) status transferred from NDA to UKAEA
Definition Phase **2021-2023**	• 2022 – Strategic optioneering and identification of critical success factors for the JET Decommissioning and Repurposing Programme (JDR) • March 2022 - Strategic Outline Business Case (SOBC) • Recruitment and mobilization of initial JDR team focused on Outline Business Case (OBC) • April/May 2023 – Outline Business Case reviews and move to Tranche approach • June 2023 – Parliamentary Investment Committiee

Outline Business Case for Tranche 1

Fusion Regulation Proposals - 2021

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Department for Business, Energy & Industrial Strategy

Towards Fusion Energy

The UK Government's proposals for a regulatory framework for fusion energy

- 2021 – UKAEA declared as the decommissioning management agent (DMA) for JET. Responsibility for JET decommissioning moved to UKAEA from the Nuclear Decommissioning Agency (NDA) which is the DMA for fission.
- JET decommissioning to be regulated by the Environment Agency (EA) and Health and Safety Executive (HSE).
- UK government department BEIS was devolved to become the Department for Energy Security and Net Zero (DESNZ). This body funds JET decomm.

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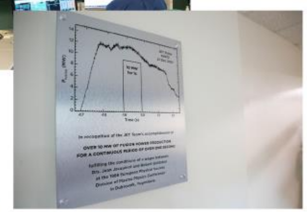
JET'S LIFE CYCLE

1973

DESIGN, PLANNING AND BUILDING

1983

PLASMA SCIENCE OPERATIONS AND UPGRADES



2024

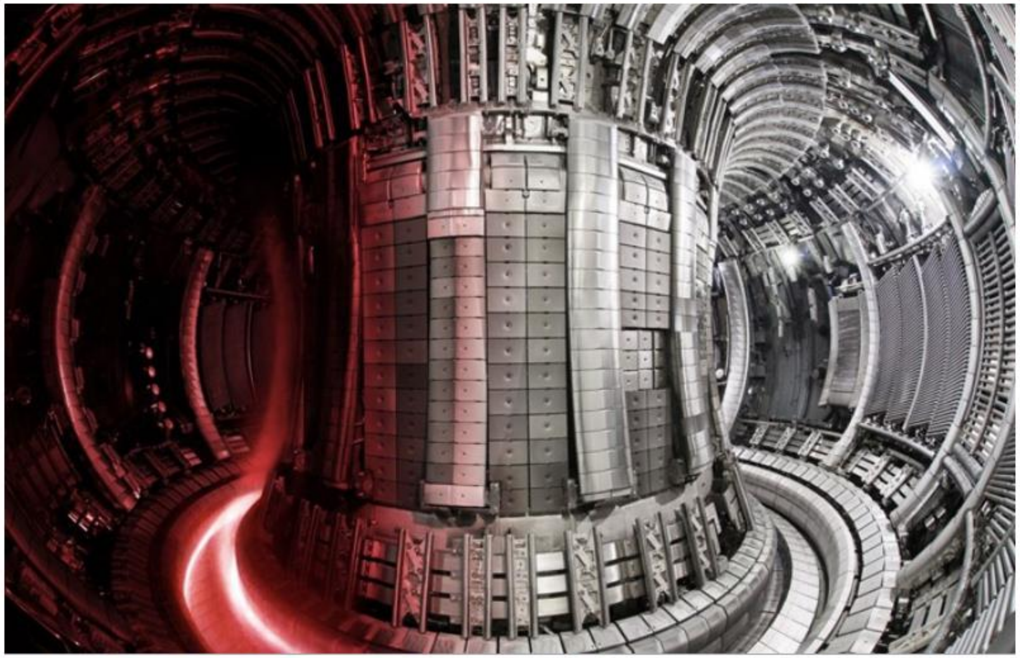
DECOMMISSIONING AND REPURPOSING

Why shut JET?

Fusion world

JET MAKES HISTORY, AGAIN

The JET tokamak has achieved a first-ever sustained, high-confinement plasma using the same wall materials and fuel mix that ITER will use. The results aligned with prediction ... and this predictability is very good news for the ITER research program and for fusion in general.



The record shot was achieved by the EUROfusion team on 21 December 2021 at 14:30 CET—a spectacular "star" on the longest night of the year. Pulse #99971 achieved total fusion energy of 59 MJ—more than doubling JET's 1997 record. Photo: UKAEA

JET has met its aims – and has done so incredibly well.

The business case for decommissioning JET to learn even more is compelling.

The next question to be answered in the fusion journey is "can we engineer clean decommissioning for fusion?"

Why shut JET?

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- There is more that can be learned from JET but this would be extremely expensive. No funding is available from any source to continue this work.
- Beyond the physics challenges that fusions presents, the question of waste disposal is just as valid. Without viable ways of treating waste and clear decommissioning plans, fusion reactors may not be given permission to operate.
- UKAEA are uniquely placed to research these problems and develop new technologies from the decommissioning of JET.
- UKAEA are also well placed to take part in the development of new fusion regulations which would govern the operating and decommissioning of fusion site.
- In terms of new fusion science, STEP will pave the way for the UK. Decommissioning will do much to inform the design of STEP.

How does decommissioning JET help us overcome these challenges?

- Can we reduce waste volumes by removing the tritium from components by a process called detritiation?
- Can we use robotics to decrease exposure of personnel to radiation, reduce secondary waste and speed up work?
- Can we use radionuclide fingerprinting of items from JET to help us analyse fusion reactor waste better? Can we design better materials using these results?
- Disposing of waste is very expensive, are we able to repurpose or refurbish any areas of the JET plant?
- Can we clear areas of the campus to give way to development land for investors and private companies who want to develop further in the fusion sector?

Decommissioning informs UK Fusion

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UKAEA are well placed to take part in the development of new fusion regulations which would govern the operating and decommissioning of fusion sites.

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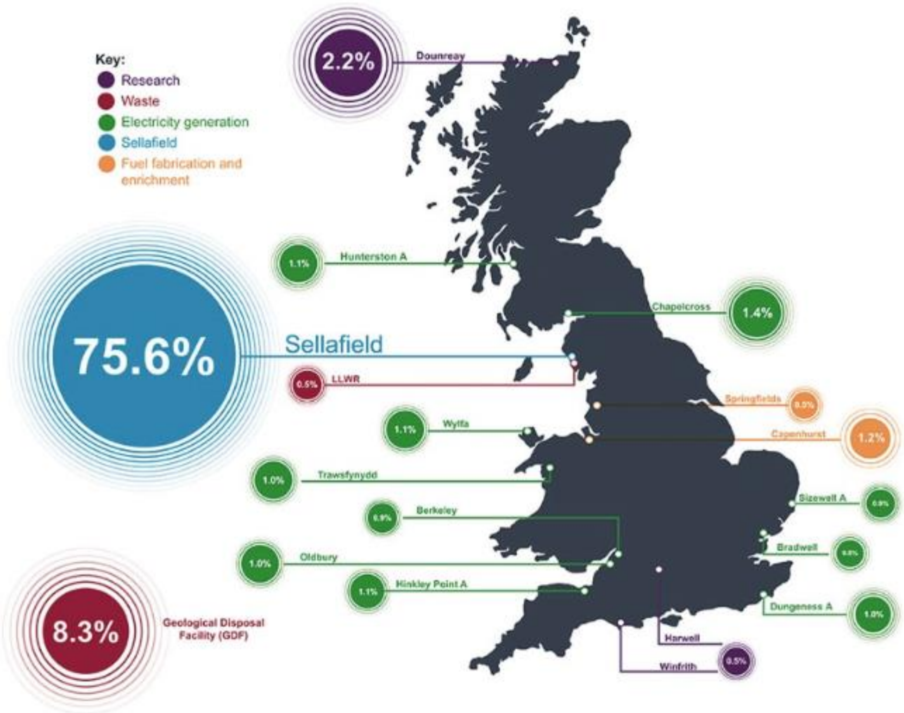
Why task UKAEA with innovation through JET decommissioning?



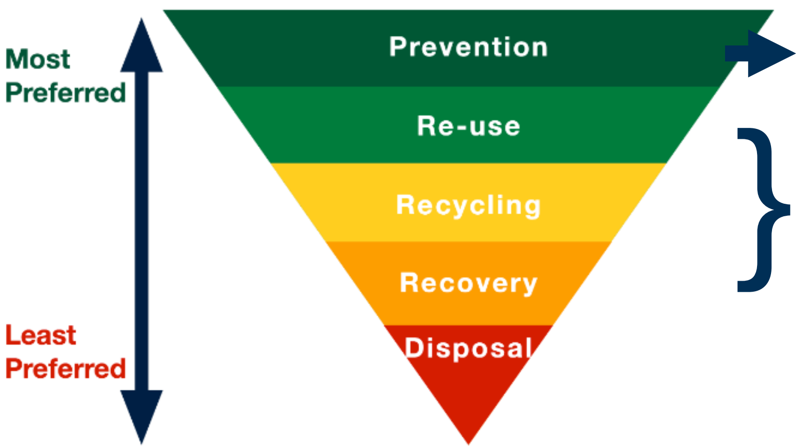
The UK is predicted to spend £124bn on nuclear decommissioning in the next 120 year or so. This cost can be brought down using new technologies.

UKAEA are uniquely placed to research these problems and develop new technologies from the decommissioning of JET.

Guiding Principles for JET Decommissioning

Guiding Principles

- JDR is important for UKAEA… for fusion… for decommissioning
- JDR may be the only opportunity to generate supporting evidence for Design For Waste and Design For Remote which will shape future fusion including the ITER Hot Cell and STEP
- JDR may be a good route to evidence UK Fusion Regulation



e.g. Touch once; hands-off

Detritiation

Vision - A system of systems

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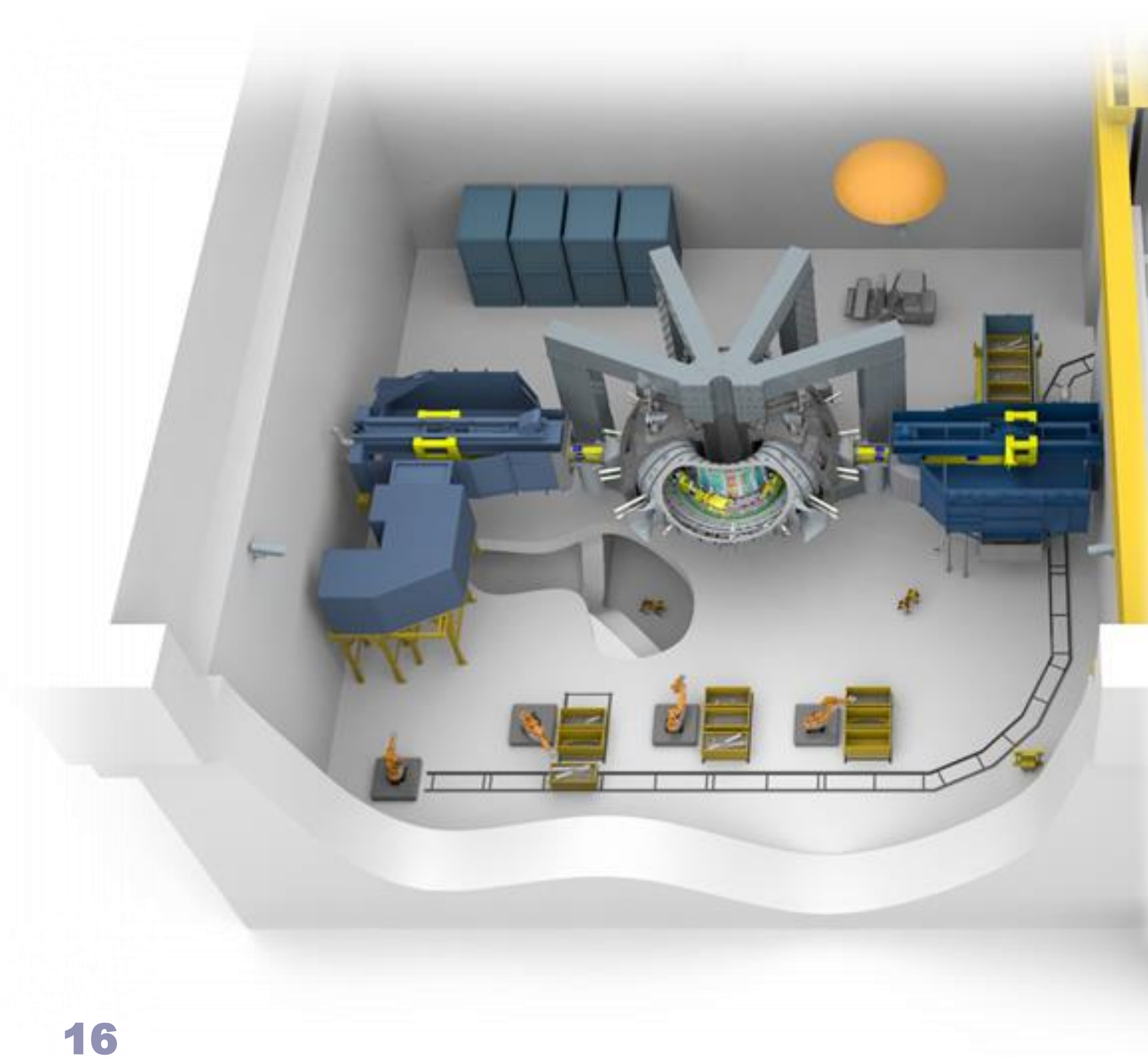
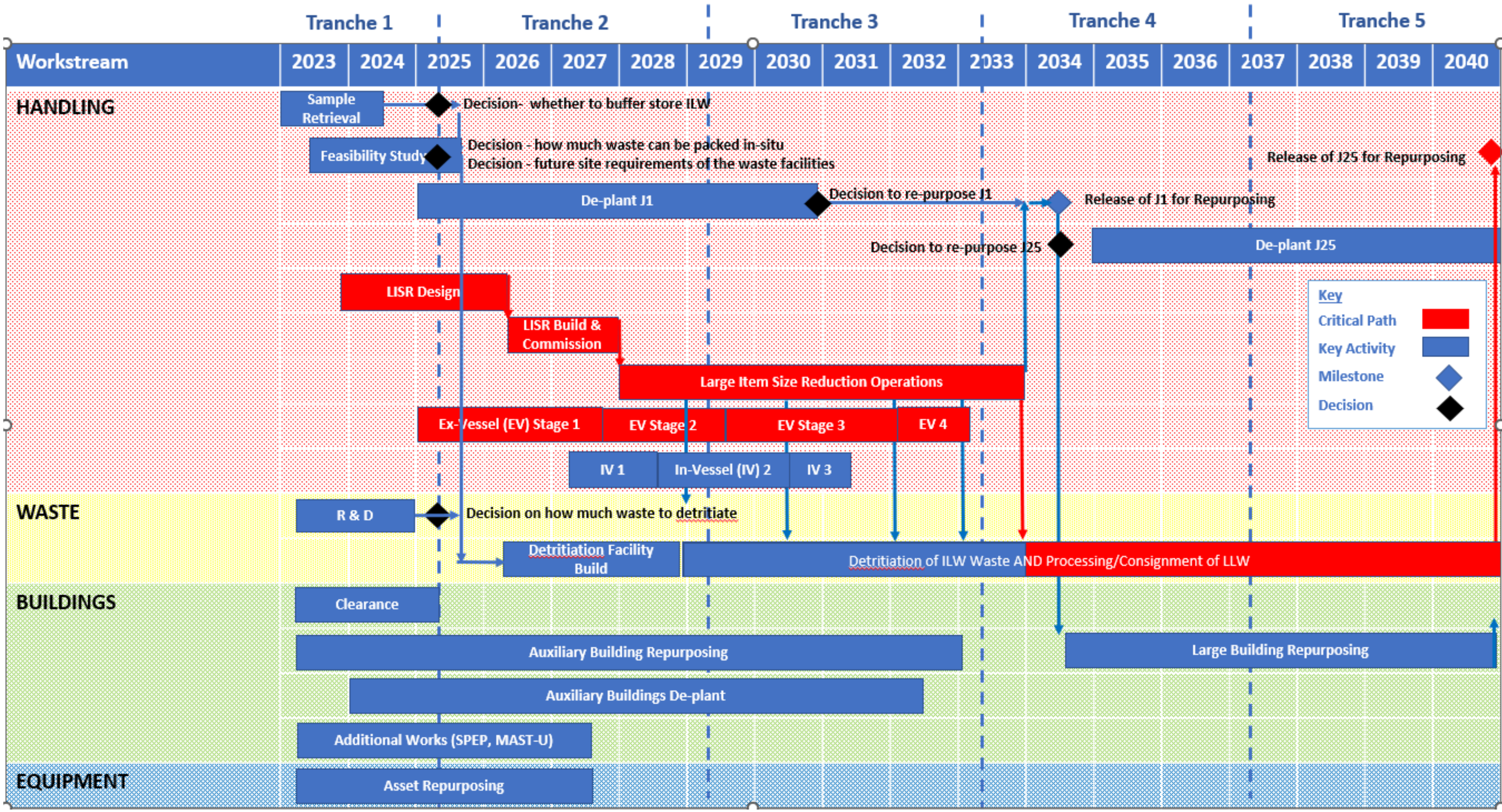


Our vision is to apply 'targeted innovations' alongside human operations where they can:

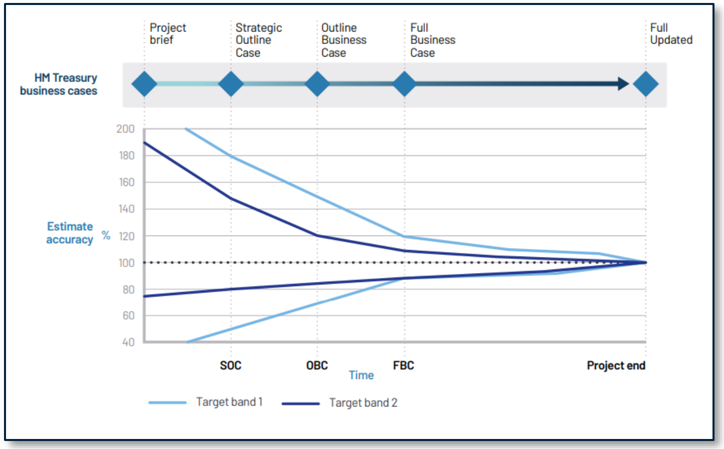
- reduce programme costs
- reduce exposure to hazards
- reduce risks for future fusion
- help us learn lessons for future fusion
- maximise the benefits from JET as a lead and learn site for NDA, Sellafield, TEPCO…,

Building fusion capability and knowledge at Culham and beyond

Tranche Overview Schedule (Indicative)

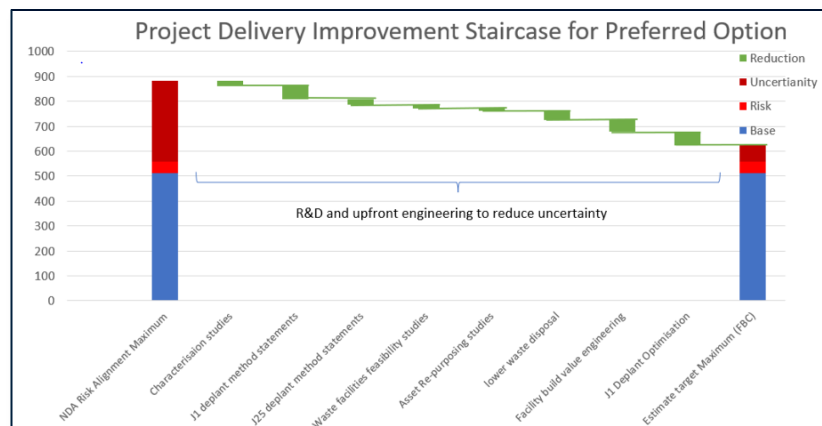


Why a Tranche based approach?



- At OBC it is acceptable to have 20% uncertainty for the work contained in the scope of the OBC.
- The technical advisory committee (TAC) cost review concluded that uncertainty levels were too high to submit the whole programme to OBC.
- JDR is a highly uncertain programme which will require a series of decision points based on robust studies.

- The work contained in Tranche 1 will aim to provide technical and management evidence to enable these key decisions.
- The aim is to reduce uncertainty in the totality of the programme and to develop a cost-effective delivery strategy.



Tranche 1 Milestones

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Key Milestone	Key Decisions to inform Tranches
Detritiation Work Packages 1-9 complete and approved - Mar-25	Decision on how much waste to detritiate and how to achieve value for money.
Studies for Size Reduction R&D Phase complete and approved – Nov-24 Feasibility & Planning Studies for JET Ex-Vessel Stage 1 complete and approved – Jul-24	Decision on which components can be size reduced/packed in-situ to reduce waste handling
Characterisation of samples from Sample Retrieval Campaign part 1 complete – Mar-25 Studies for ILW processing R&D phase complete and approved – Sept-24	Decision on whether to buffer store ILW or to go directly into waste processing
JET handover from Science Operations to Decommissioning – Dec-23	Decision on whether the waste facilities will provide an enduring capability to site

Stakeholder Engagement, Quality Assurance

Robust Waste Characterisation Data

How will JDR be structured to deliver these milestones?

Work streams – keeping existing teams together… but with a new goal

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Handling

Decommissioning and handling of components and assemblies from their installed locations to a point of handover for waste processing or repurposing

Waste

Processing of waste materials from the point of handover to the point of consignment and transport

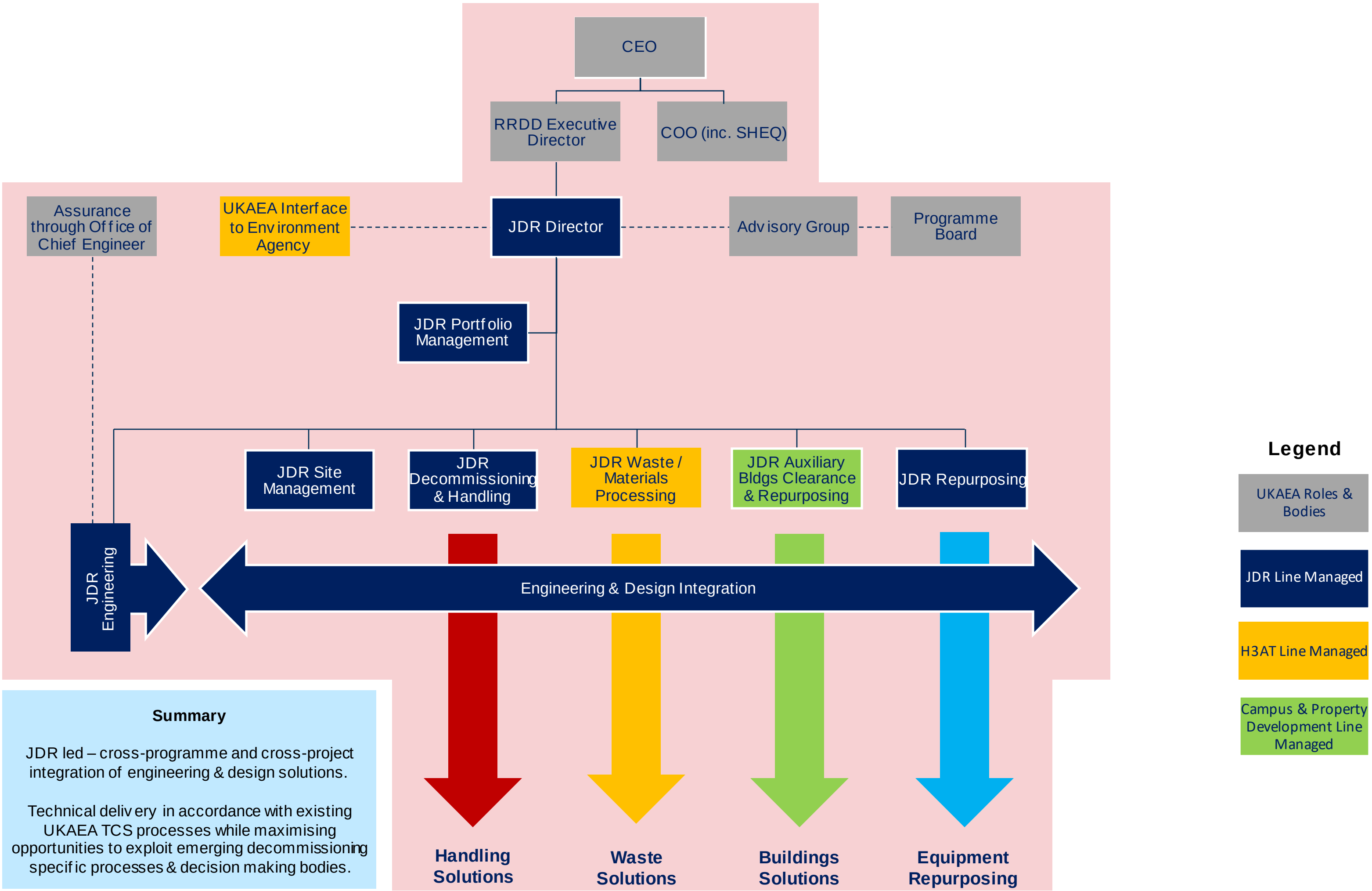
Buildings

De-plant, clear and repurpose auxiliary buildings and land for future development and occupancy

Equipment

Preparation of repurposing strategy, and agreements for buildings and assets

Engineering Governance & Integration Structure



Summary

JDR led – cross-programme and cross-project integration of engineering & design solutions.

Technical delivery in accordance with existing UKAEA TCS processes while maximising opportunities to exploit emerging decommissioning specific processes & decision making bodies.

Cross Department working to achieve a new goal…. communicating the vision

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Waste hierarchy	JDR aims
Prevention (future)	• Knowledge for STEP and ITER to prevent future waste *by design*
Prevention (now)	• Precise, 'real time' characterisation – data driven processing • Remote operations to reduce hazard to humans and soft waste arisings • In-situ decommissioning to avoid transport • 'Touch once' to avoid spreading contamination
Re-use	• Re-use of 3H as part of 3H management (see also Recovery…) • Re-use and repurposing of equipment, buildings and site services
Recycling	• Recycling of recoverable materials such as copper
Recovery	• Treatment of tritiated materials using detritiation techniques
Disposal	• Some, ideally in-situ, processing and consignment of waste to storage after all the above options have been exhausted • Continuous processing to minimise work in progress (hence interim storage) • Modular approach to avoid fixed facility build

Cross Department Working to Realise Benefits

	Benefit
B1	Reduction in the total public cost of JET decommissioning
B2	Reduction of the nuclear hazard in JET decommissioning
B3	Reduction in the quantity and level of waste stored as a result of JET decommissioning
B4	New exportable fusion decommissioning skills and IP in the UK
B5	Inform the development of an enabling regulatory framework through globally unique experience
B6	Reduced environmental impact and enhanced sustainability of decommissioning techniques applicable to wider nuclear estate
B7	Enhanced public and private sector innovation capability through efficient re-use of JET assets
B8	Increased efficiencies and investor confidence in private fusion technology firms
B9	Increased human capital though efficient retention of highly trained JET workforce in the UK for the future fusion sector

Knowledge and Information Capture

Sources of Knowledge

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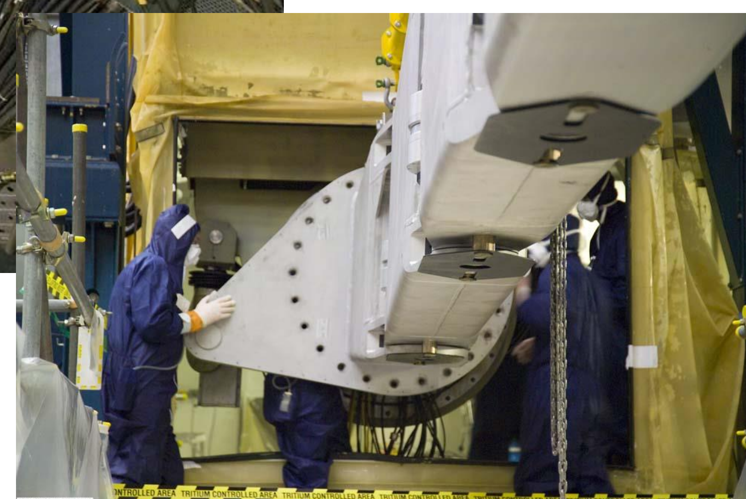
- Photographs and videos of previous shutdowns
- Original designs for JET - some in paper archives
- Sharepoint sites and technical document control systems
- Interviews and videos with current JET staff
- “Organisation knowledge” – keeping a team with key knowledge together is important
- Individuals with operational experience
- Apprentices and skills growth to learn the expertise – young people will be extremely important in absorbing knowledge

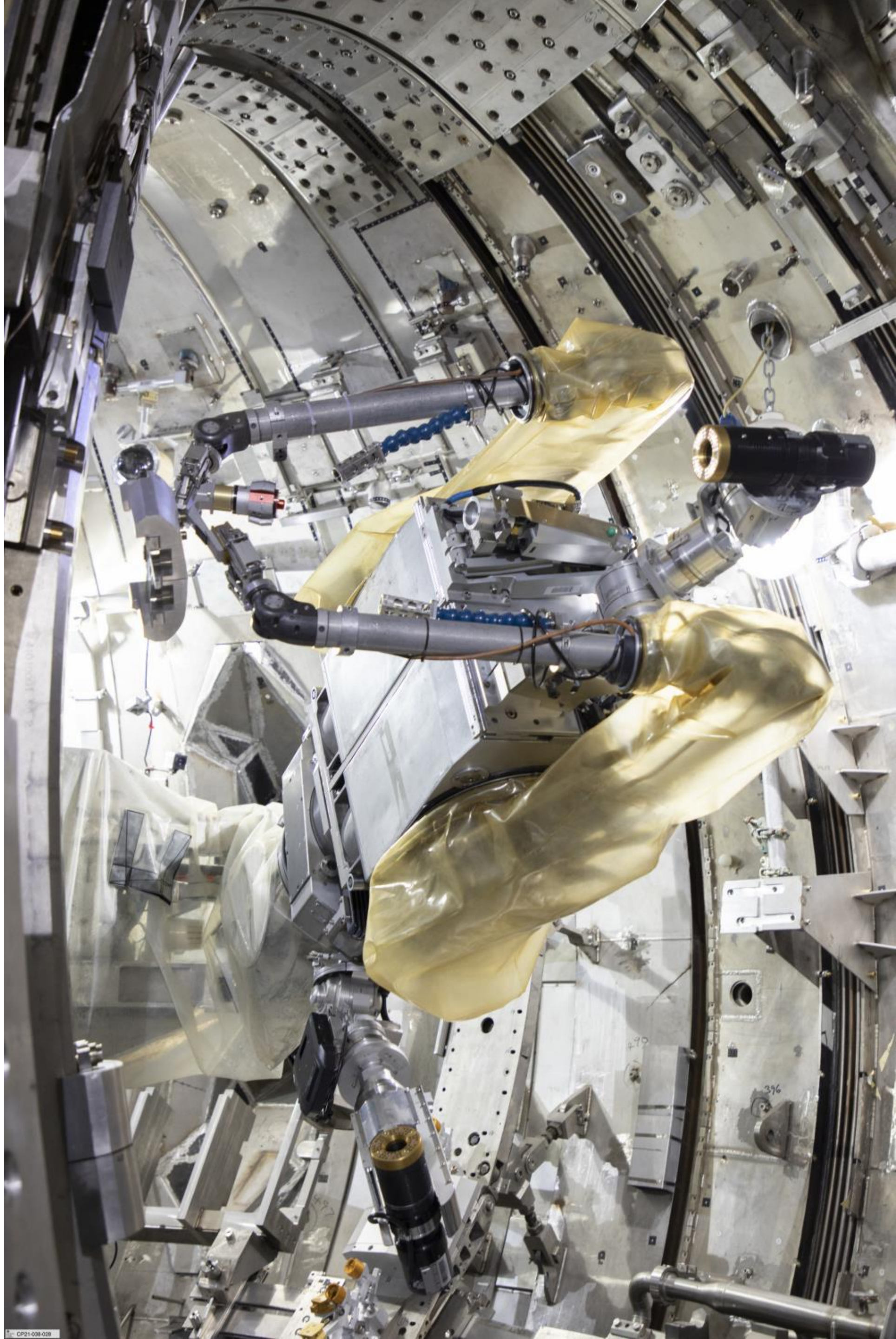
Re-use equipment and methodology from Enhancements Phase 2 (EP2), 2009 - 2011

Oct 5

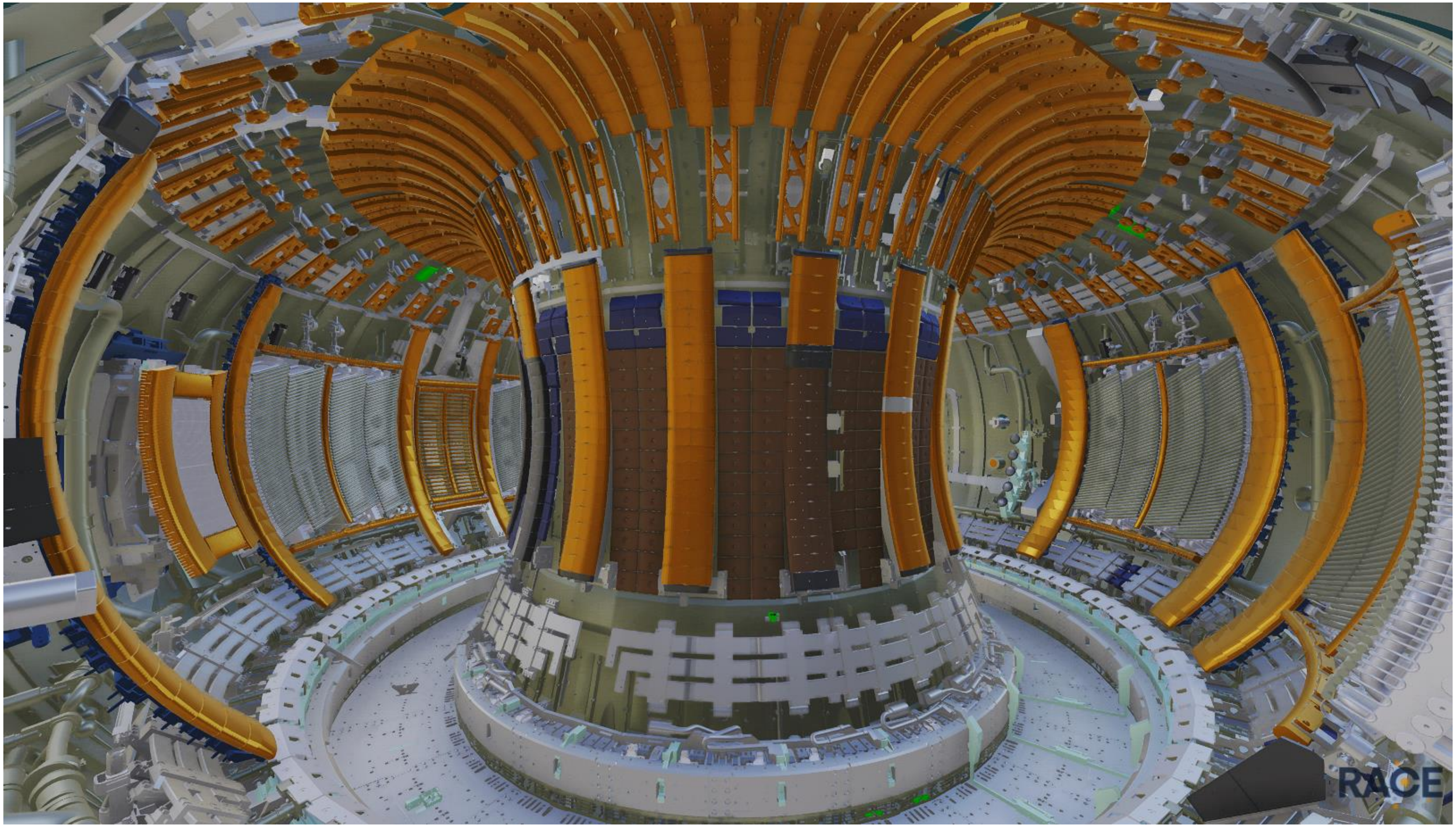
Oct 1



Remote handling work “in-vessel” to remove components in two phases using robotic arms – update with new systems and end effectors for decommissioning

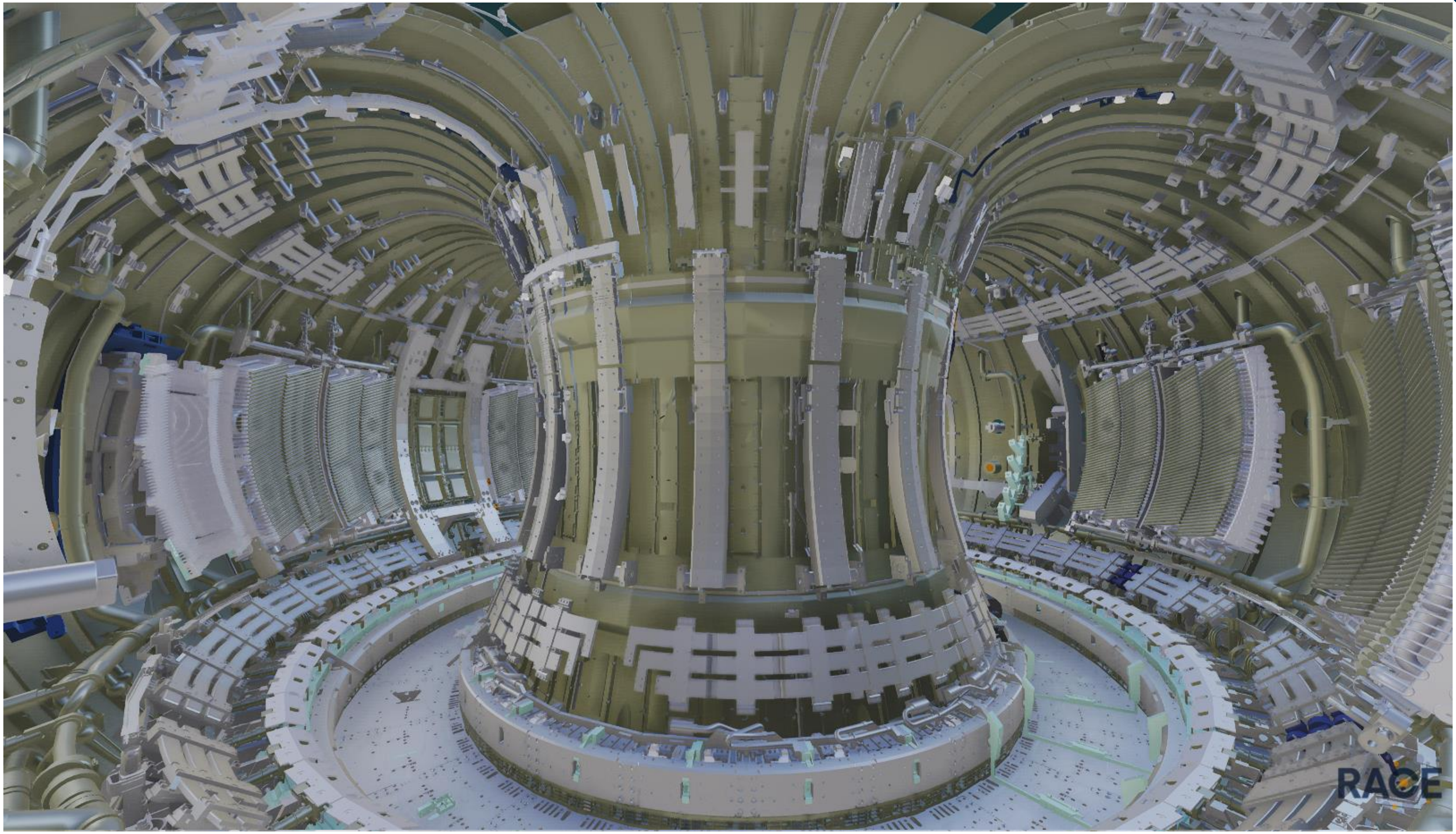


In-vessel dismantling .... EP2 in reverse!



Items removed in phase 1.0 - 1.5 *–Inner Lower Be Saddle Tiles, Outer Lower Be Saddle Tiles, LBSRP Tiles, Inner Divertor Carriers, Outer Divertor Carriers, LBSRP Adaptor Plates, Divertor Base Carriers Inner Lower Gap Protection Tiles.*

In-vessel dismantling .... EP2 in reverse!



Items removed in phase 1.5 - 1.8 *– Outer Upper Be Saddle Coils, Outer Lower Saddle Coil Shine Through Tiles & Adaptor plate, Upper Inner Wall Protection Tiles Inner Wall Protection Tiles (Inconel) Inner Wall Protection Tiles (CFC)ILW Poloidal Limiter Tiles, Poloidal Limiter Tiles, Top & Bottom, IWGL Tiles, IWGL Transmission Tiles (CFC)IWGL Transmission Adaptor, IWGL Bottom Adaptor, A2 Protection Tiles, A2 Separator Tiles, LHCD Tiles, ICRH Poloidal Limiter Tile, ICRH Septum Tiles, ICRH Cross Beam Tiles and Adaptor Plates, ICRH Private Limiter Tiles, ICRH Screen Bars, Inner Wall Shine Through, Poloidal Limiter Side Protection, Poloidal Limiter Shine Through Tiles, TAE Antenna Protection Tiles, Mushroom Tiles, Mushroom Shunt Tiles, Restraining Ring Tiles, Dump Plate Tiles, KG1 Mirror Protection Tiles (Oct 7), Lost Alpha Protection Tiles, Pellet Launcher Shine Trough Protection Tiles, Octant 7 Mirror Protection Tiles, OPA and MHD Coils, HRTS Beam Dump, Divertor Bolometers, Deposition Monitors, KG6 Wave GuideKC1 CoilsKY06 Mirror, TRS Activation Foils, Sticking Monitors, Louver SampleClips, KL5 Periscope Tile, Be Evaporator, Long Term Dust Collection Pots Oct 4 & 6IWGL Extension Block, ICRH Top Hook Clamp*

RACE: JET Repurposing – Vessel Strip Out, Rory Steadman

In-vessel dismantling …. EP2 in reverse!

***Items removed in phase 1.8 – 2.1** – IWGL Beams, Poloidal Coil Plate, Oct4 & 8, OPA Lower Beam Oct 4 & 8, KC1X Beam Oct 8, Shine Through Adaptor Plates Oct 1 & 5, Poloidal Limiter Beams, ICRH Cross Beam, A2 Antenna, LHCD Antenna, TAE Antenna, Lost Alpha Beam and Support*

In-vessel dismantling …. EP2 in reverse!

***Items removed in phase 2.2** – Saddle Coil Bars (All IL, OL, OU), Restraining Ring.*

RACE: JET Repurposing – Vessel Strip Out, Rory Steadman

In-vessel dismantling …. EP2 in reverse!

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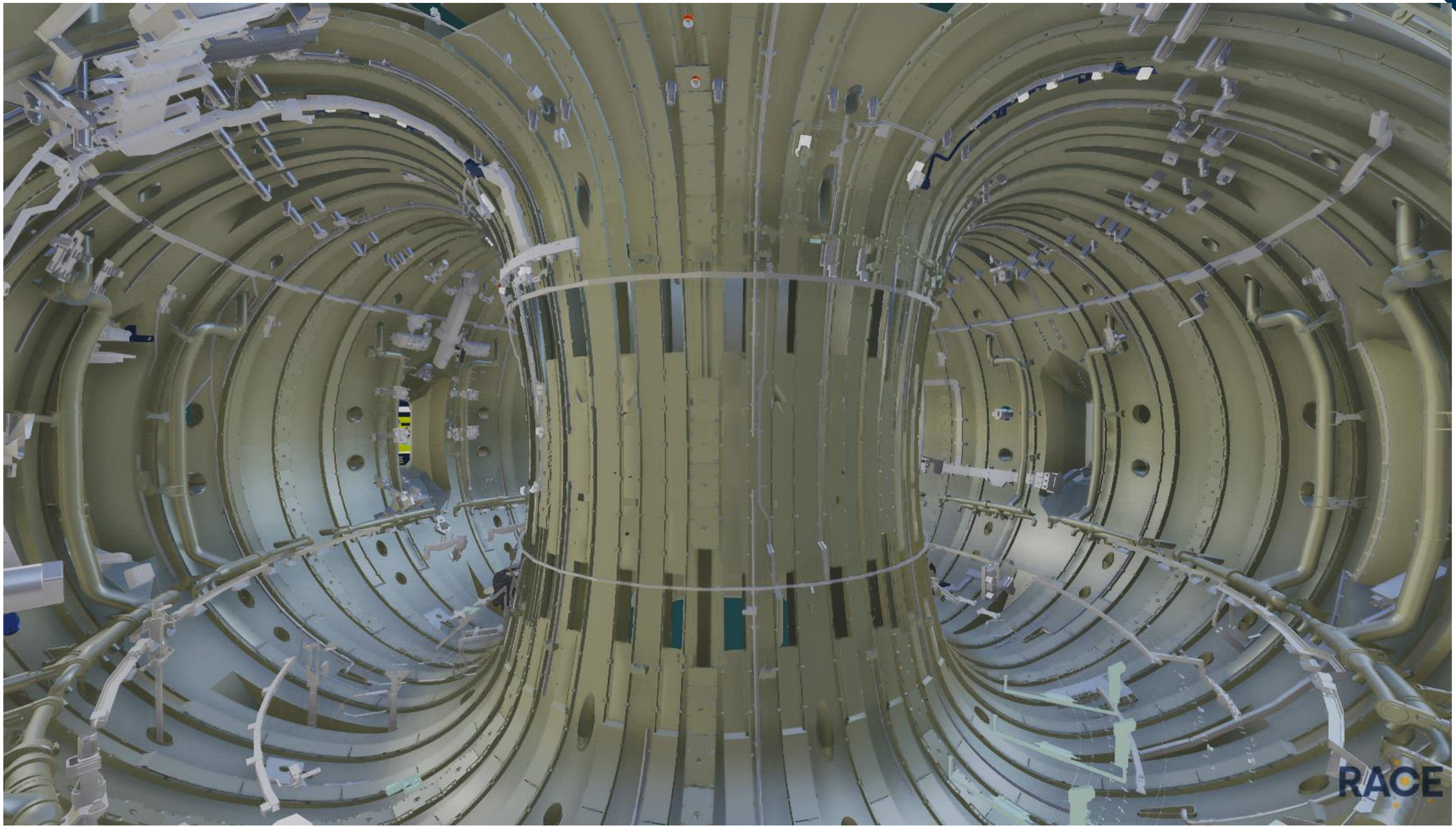

Items removed in phase 2.2 – 2.9 *– KG1 Mirror Supports, French Horns, OP Tile Supports, Divertor Louvers, Divertor Outer Modules/ Ring, Divertor Inner Modules / Ring, Divertor Base Modules, Divertor Coil Conduits, Cryopanels (on DC1) - Siclanic Material, Divertor Coil 1, Divertor Coil 4, Divertor Coil 2 & 3, Divertor coil mounting brackets*

RACE: JET Repurposing – Vessel Strip Out, Rory Steadman

In-vessel dismantling …. EP2 in reverse!

***Phase 3.0 –** Various Manifold and Pipes, Vessel Clean-up to within 100mm*

RACE: JET Repurposing – Vessel Strip Out, Rory Steadman

Use plant knowledge to dismantle to outside components (ex-vessel)

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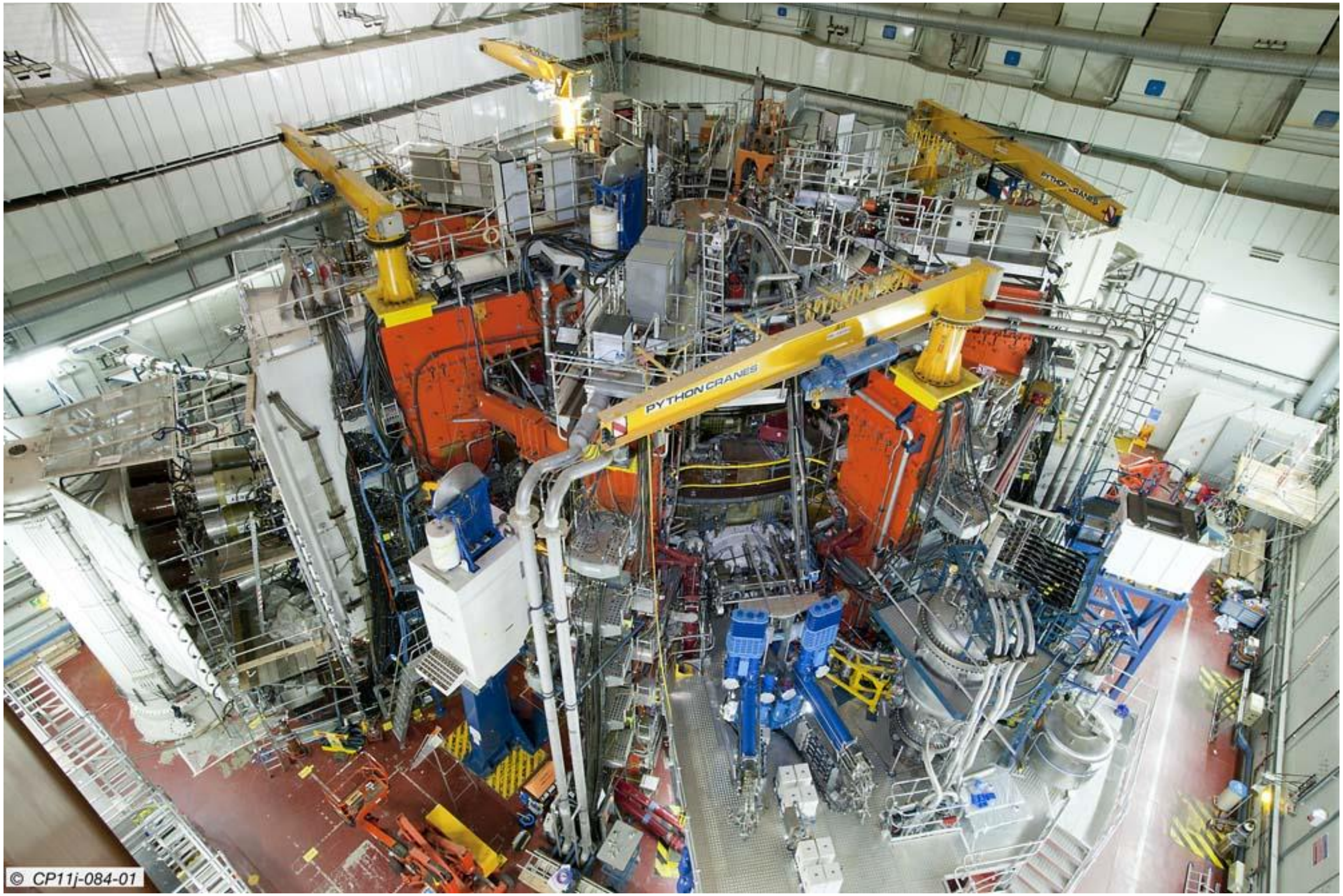

JET – Octants with no equipment

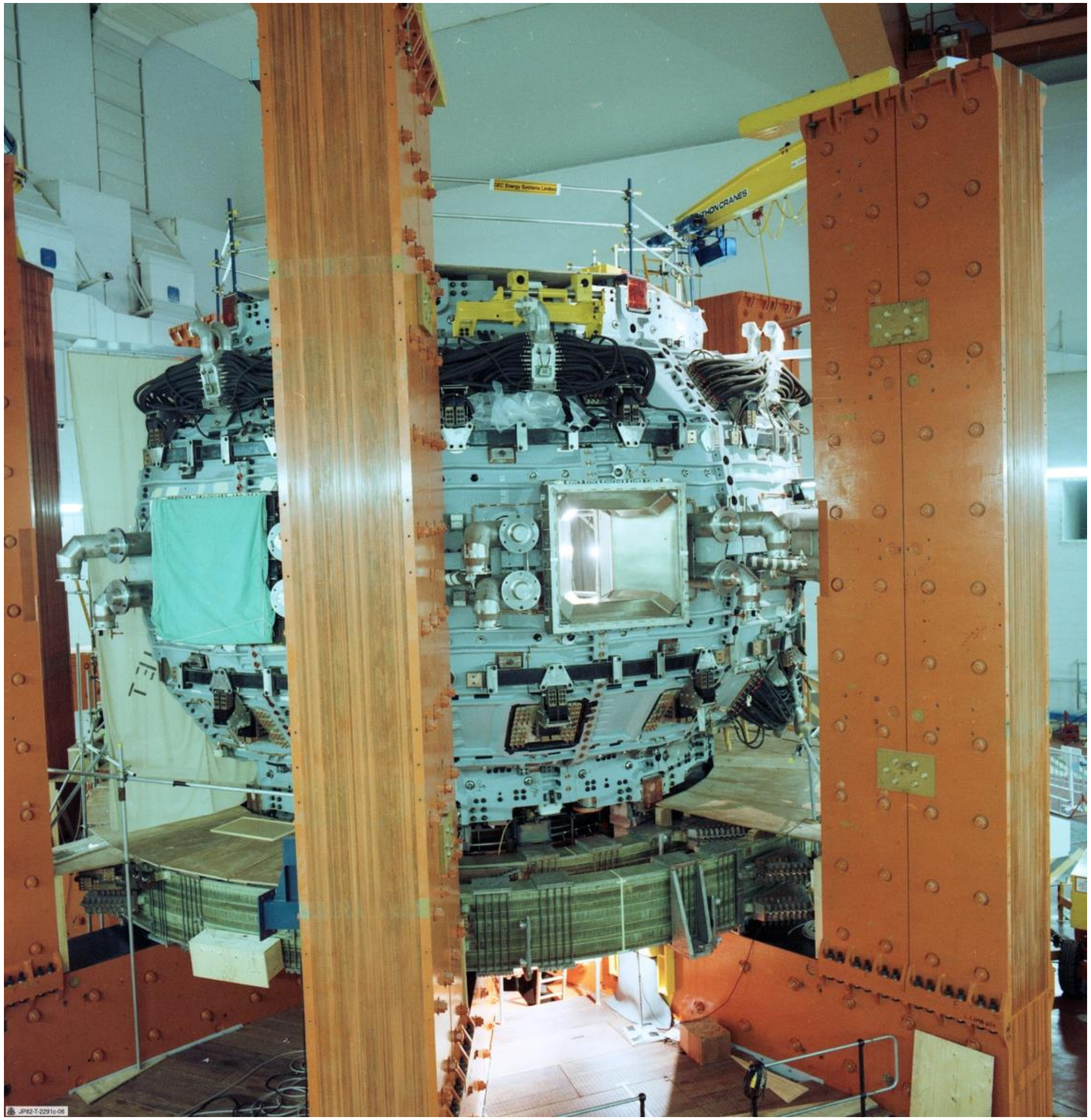

Photo from 1982 - construction of JET to help visualise JET with no equipment around it at the end of the ex-vessel phase

Many photos are stored in the JET Media archive and will be used as information sources.

Image taken from JET media archive

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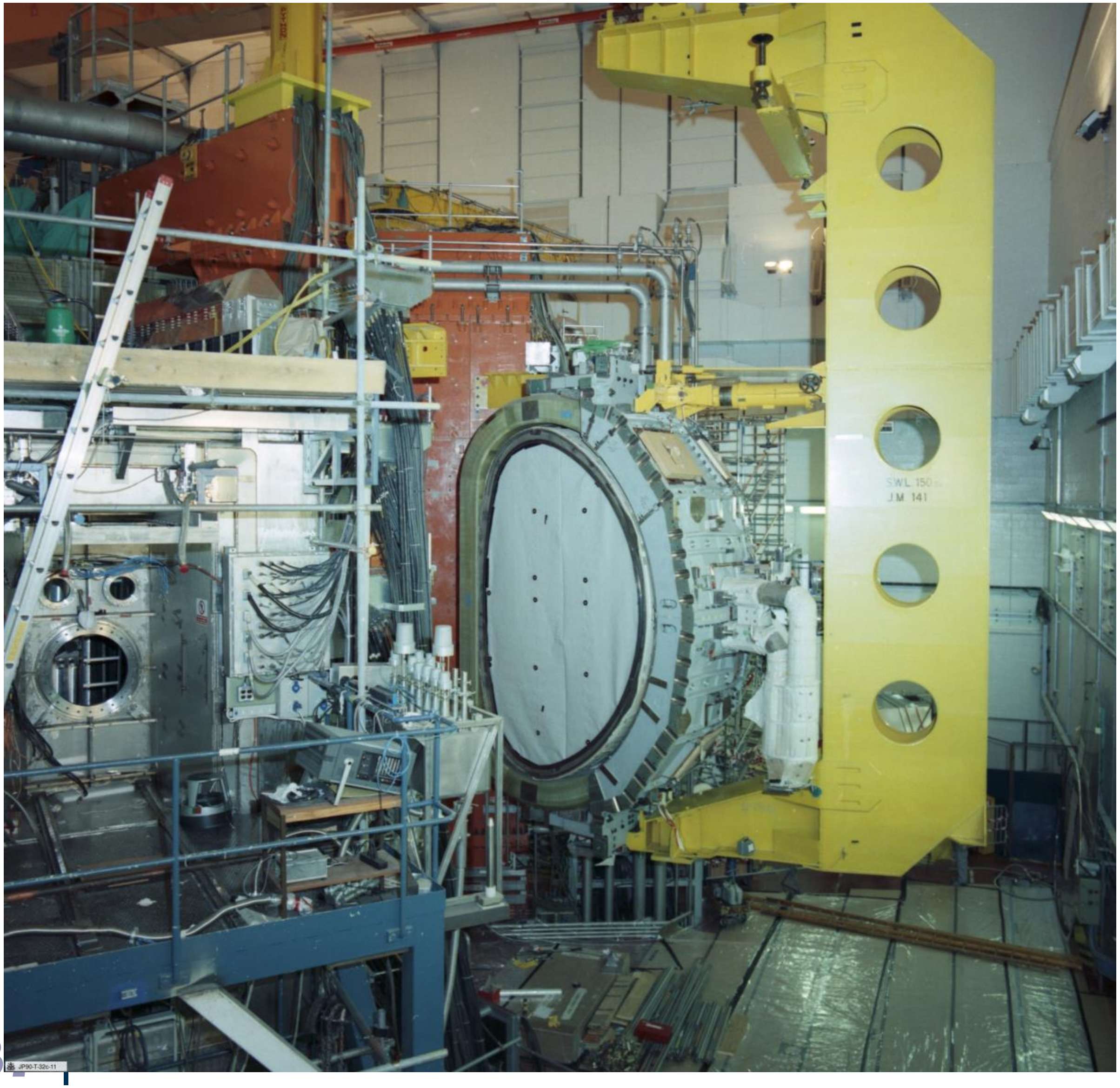
Re-use equipment and draw on experience to remove JET octants



The EP1 shutdown which removed an octant is in living memory of many people at JET

Capturing this knowledge from them now is essential as it will help us to dismantle the machine.

Re-use equipment and draw on experience to remove JET octants

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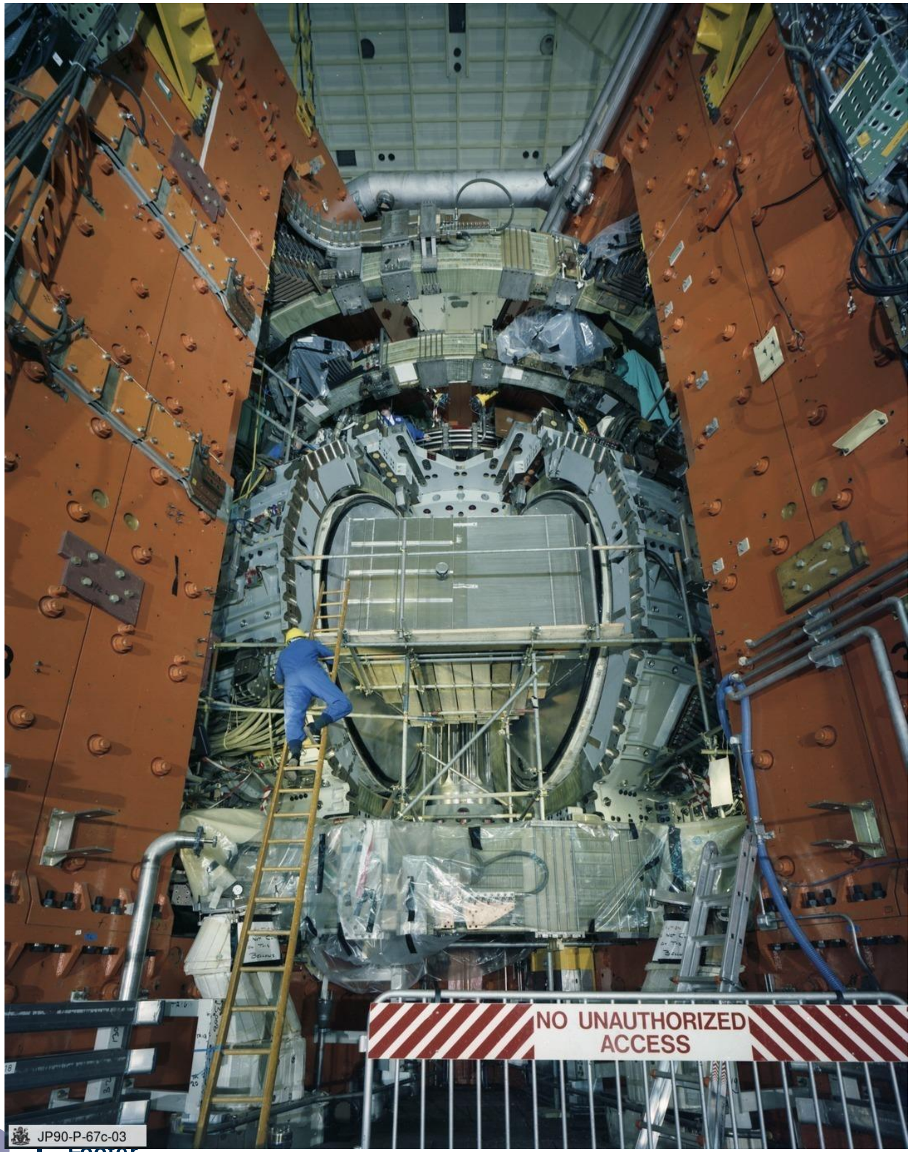
The jigs used for this lift are still stored at Culham.

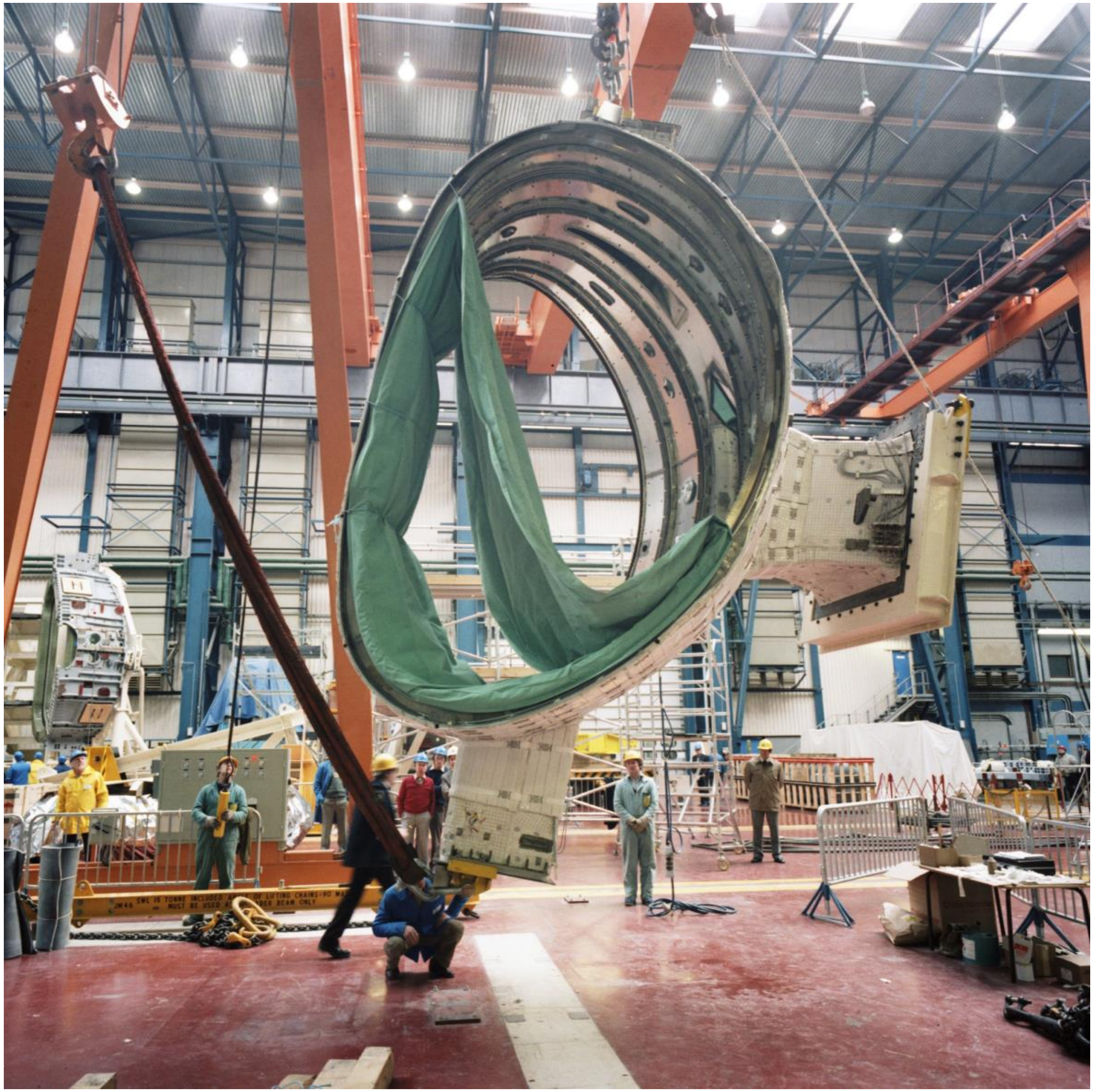
The 150t crane pictured here was built for the assembly of JET and can be used again in decommissioning with the jigs.

Re-use equipment and draw on experience to remove JET octants



Knowledge on fitting the blanking plates and experience gained in controlling tritium will be crucial.

Size Reduction of Octants



Octants will need to be reduced in size - the challenge will be to do as much size reduction and packing in situ to avoid building large waste facilities.

Image taken from JET Media Archive:

1982 – JET construction – turning of the JET Octant Section

Detritiation and R&D

Material detritiation has been conducted on former JET components – mainly Inconel and Carbon-Fibre-Composite (CFC).

The JET ‘ITER-like wall’ has many more unique materials such as beryllium, tungsten, etc

The JET ‘ITER-like wall’ materials have also been exposed to significantly greater levels of tritium than former JET components previously treated

Significant amount of R&D into optimising detritiation for known materials and developing treatment parameters for new materials.