Fusion Power Plant Design

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IAEA/NE/NENP/NPTDS

FUSION POWER PLANT DESIGN CONTENT

- FUSION POWER PLANT PROGRAM MANAGEMENT
- A BRIEF OVERVIEW OF TOKAMAK SYSTEMS
- FUSION TECHNOLOGIES IN DEVELOPMENT

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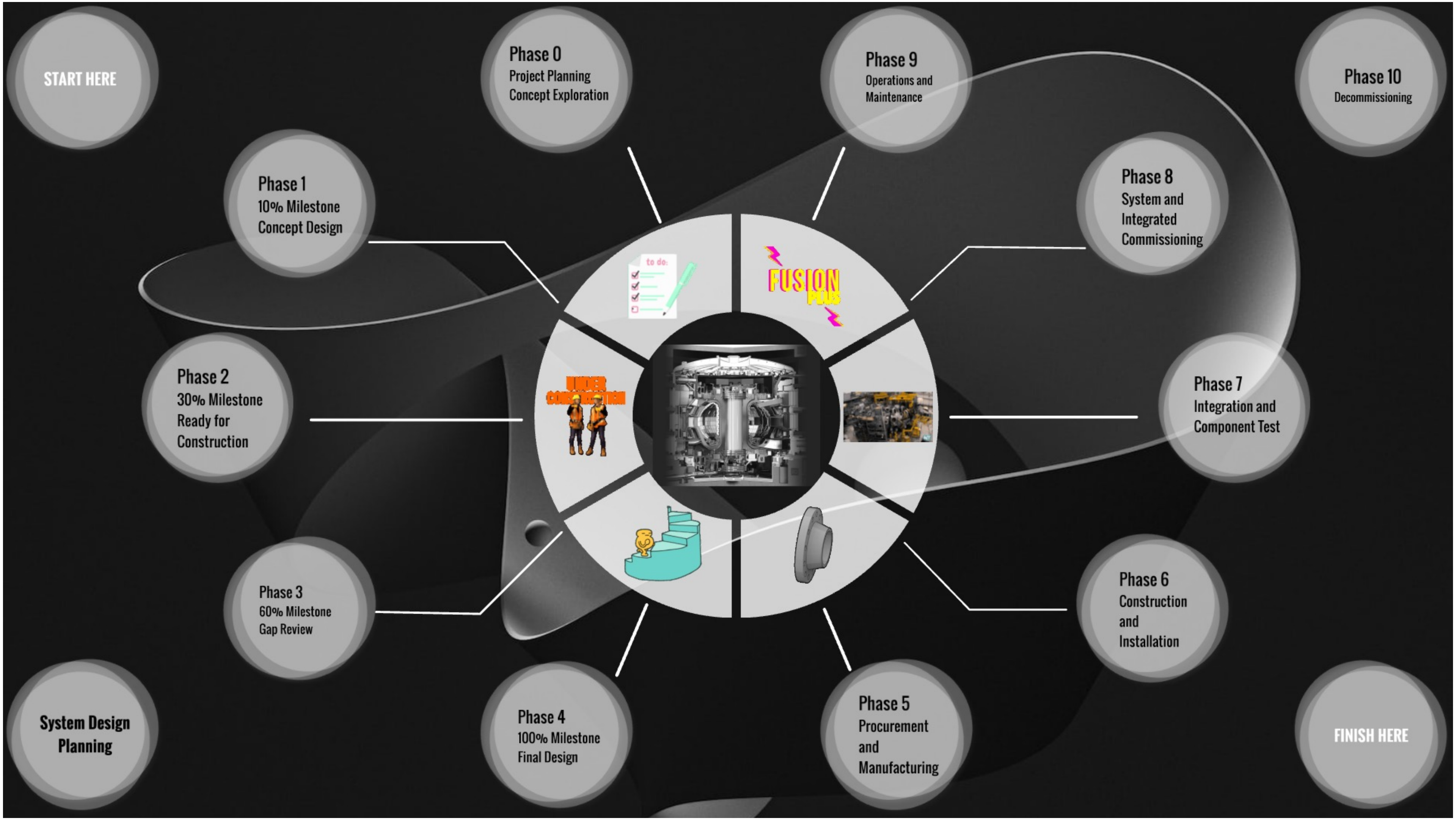

START HERE
Phase 0
Project Planning
Concept Exploration
Phase 9
Operations and
Maintenance
Phase 10
Decommissioning
Phase 1
10% Milestone
Concept Design
Phase 8
System and
Integrated
Commissioning
to do:
FUSION
PLUS
UNDER
CONSTRUCTION
Phase 2
30% Milestone
Ready for
Construction
Phase 7
Integration and
Component Test
Phase 3
60% Milestone
Gap Review
Phase 6
Construction
and
Installation
System Design
Planning
Phase 4
100% Milestone
Final Design
Phase 5
Procurement
and
Manufacturing
FINISH HERE

FUSION PROJECT DEVELOPMENT

The following phases are not intended to be completed sequentially. Each system will have its own development life cycle. Some system designs will need to be completed earlier to ensure availability during construction and installation.

- Phase 0 – Project Planning and Concept Exploration
- Phase 1 – 10% Milestone: Concept Design
- Phase 2 – 30% Milestone: Ready for Construction
- Phase 3 – 60% Milestone: Gap Review
- Phase 4 – 100% Milestone: Final Design
- Phase 5 – Procurement and Manufacturing
- Phase 6 – Construction and Installation
- Phase 7 – Integration and Component Test
- Phase 8 – System and Integrated Commissioning
- Phase 9 – Operations and Maintenance
- Phase 10 – Decommissioning

PHASE 0 – PROJECT PLANNING CONCEPT EXPLORATION

During this phase, the engineering program is outlined in a framework. Everyone works in the framework to ensure consistency of design and to ensure timelines. The physics basis for the energy system is developed into a concept that will be the baseline for design activities.

ENGINEERING DESIGN POLICY

- R2A2 – ROLES, RESPONSIBILITIES, ACCOUNTABILITIES & AUTHORITIES
- DESIGN BASIS AND REQUIREMENTS DEFINITION
- GENERAL REQUIREMENTS DOCUMENT
- PLANT BREAKDOWN STRUCTURE
- THE DESIGN PLAN
- CALCULATIONS
- CONFIGURATION MANAGEMENT PLAN
- REQUIREMENTS MANAGEMENT PLAN
- VERIFICATION AND VALIDATION

PHASE 1 – 4: SYSTEM DEVELOPMENT AND R&D

Project milestones Phase 1 – 4 give management a pause to review if we are achieving project objectives. These milestone are to be defined for each project.

The purpose, expectations, criteria, and deliverables are different for each milestone. It's an iterative process, so expect deliverables to mature as milestones are achieved.

An example of project milestones:

- 10% Milestone: Design Concept – We have achieved the physics basis for the machine.
- 30% Milestone: Ready for Construction – Green/Brown site has been selected, and the design is of sufficient maturity to begin construction. In a "fast track" project, you are designing systems as you construct buildings. This is done at-risk because you are assuming you've sized the buildings to fit the systems.
- 60% Milestone: Grouped System/Gap Review – Grouped systems have achieved preliminary design; the program is reviewed for gaps (ex. Grounding).
- 100% Milestone: Final Design – Grouped systems have achieved final design, interfaces between systems are well defined.

PHASE 5 – PROCUREMENT AND MANUFACTURING

In the perfect world, the Procurement and Manufacturing phase begins with the outputs of the final design phase. Often this is not the case, some components will need to be procured or manufactured well before the final system design is achieved.

During this phase, multiple Procurement Work Packages and/or Manufacturing Work Packages are assembled and reviewed by the development team prior to submittal to the supplier/manufacturer.

- Long lead time component manufacturing or procurement will begin at-risk prior to completion of final system design. These risks should be tracked until closure.
- Build-to-Spec Systems: commercial 'off-the-shelf' systems such as cooling water or house systems (HVAC, instrument air), require procurement work packages listing expected deliverables with requirements and guidelines for system development.
- Build-to-Print Systems: for systems designed but do not require manufacturing. Procurement work packages are similar to build-to-spec systems.
- Manufacturing Work Packages: may include 2D and 3D models, assembly drawings, datasheets, parts and materials lists, detailed BOM, etc. Suppliers of manufactured components should be engaged as early as possible to ensure manufacturable systems.

PHASE 6 – CONSTRUCTION AND INSTALLATION

Construction is the process of fabricating a building or infrastructure. Construction begins with the identification of construction risks. A construction readiness review should be conducted to discuss schedule, responsibility, procedures, safety, and open items.

Tip: If construction is required, engage an Engineering, Procurement, and Construction firm with the appropriate experience as soon as possible! Use an EPC firm to ensure they are prepared to design and procure house systems such as cooling water, HVAC, instrument air, and electrical.

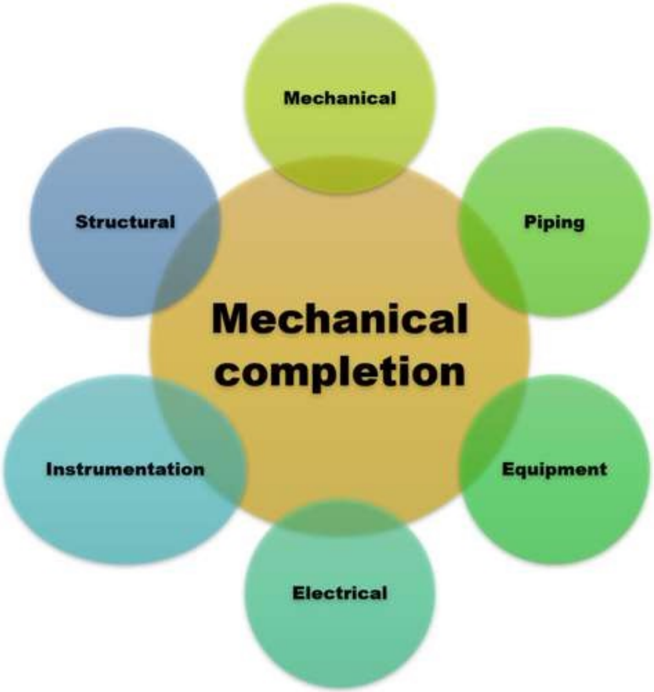
PHASE 7 – INTEGRATION AND COMPONENT TEST

Planning for installation, integration, and component testing begins in the conceptual design phase. During the Integration and Component Test (Mechanical Completion) phase, activities are performed to assemble, integrate, test, and commission components and systems.

Tip: A good EPC firm should be able to install and test most non-fusion systems. They usually have good I&C integrators on call to assemble I&C equipment and cabinets.

Tip: In general, there are no short-cuts during this phase. If something can go wrong it will, so add a generous contingency in your schedule to account for issues during installation and testing.

Note: Component testing, or mechanical completion, is not commissioning! For commissioning, the components need to be functionally tested as part of the system. They need to perform their required function.



PHASE 8 – SYSTEM AND INTEGRATED COMMISSIONING

Component and System Commissioning is performed following completion of construction, installation, and integration activities. Integrated commissioning is where multiple systems are tested prior to the start of operations.

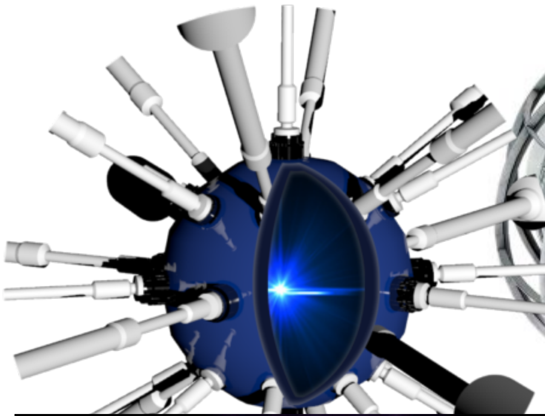
Tip: The handover from construction to the operations team should be well defined in the EPC contract and the commissioning plans for each system.

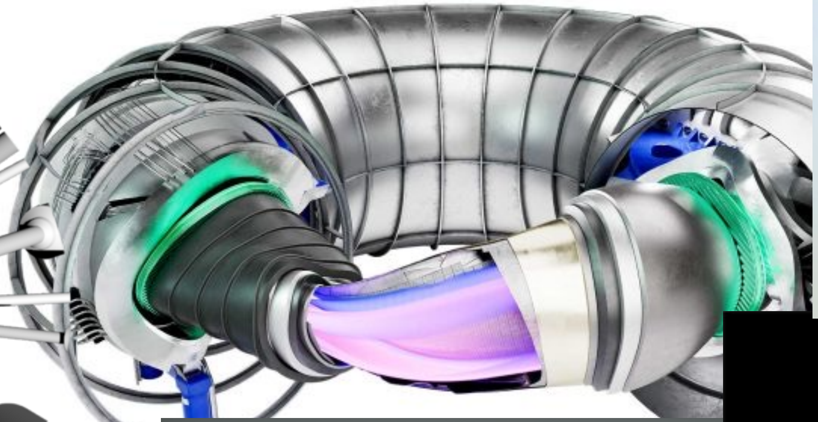
Note: The construction team will close out installation activities with a 'punch list'. They'll walk down the equipment checking off activities on the punch list with a member of the operations team.

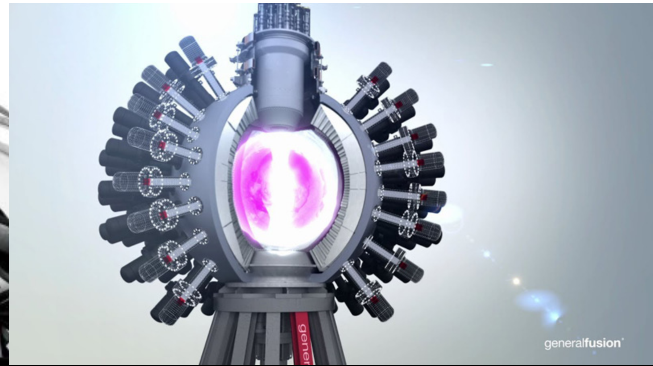
Tip: allow sufficient time in the schedule for integrated commissioning. Some systems will not behave when operated with other integrated systems.

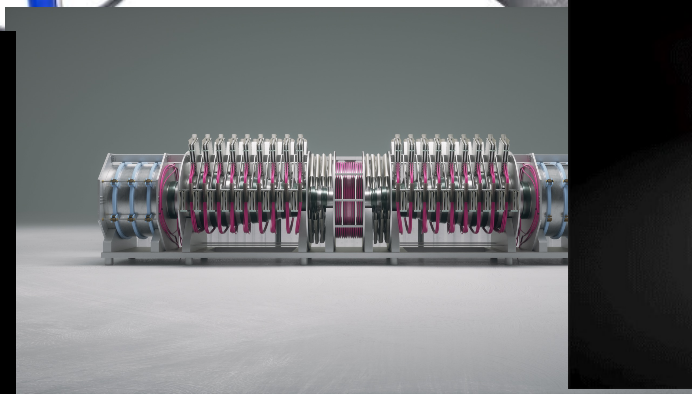
PHASE 9 – OPERATIONS AND MAINTENANCE

Initially defined in the Concept of Operations, the operations and maintenance period is the fun part (commissioning is also fun). Operations and maintenance plans and procedures should be developed by the operations team and may impose requirements on some system



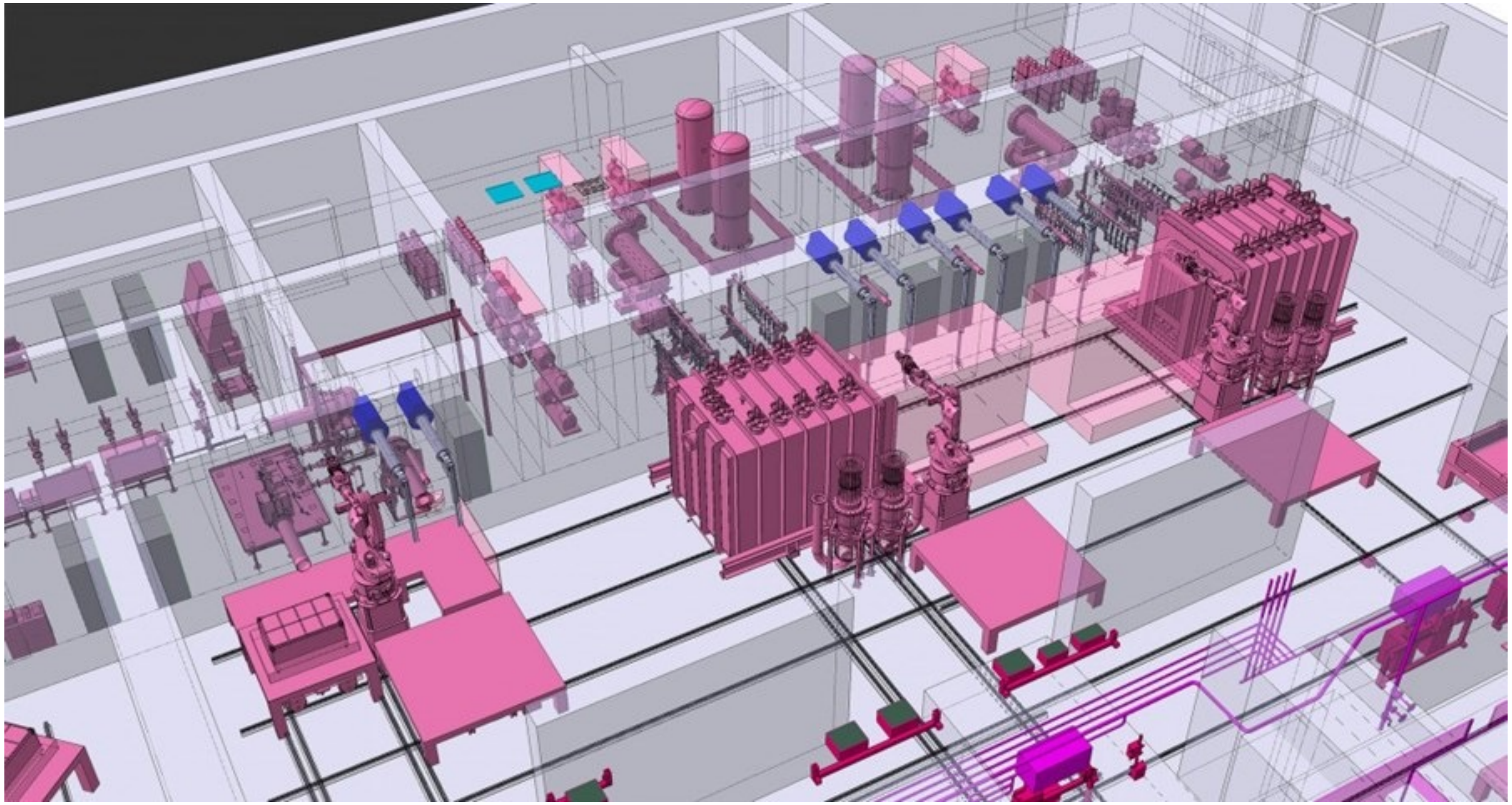






PHASE 10 – DECOMMISSIONING

Always consider decommissioning during the design phase. How do you plan to dispose of activated materials? Do you need remote handling? Do you need a hot cell?



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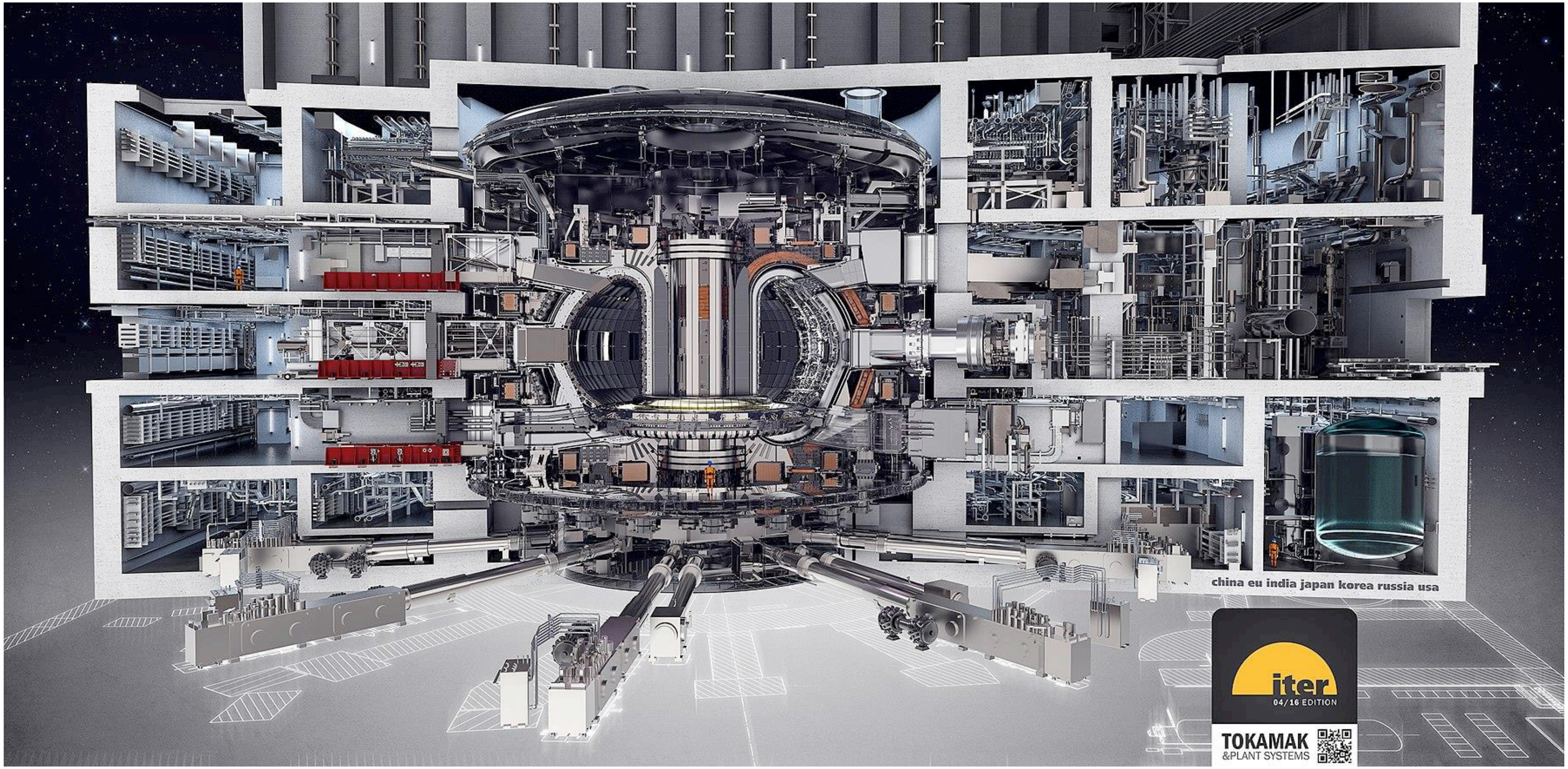
THE ITER TOKAMAK – MAGNETIC CONFINEMENT



ITER Members - **China**, the **European Union**, **India**, **Japan**, **Korea**, **Russia** and the **United States**

THE ITER TOKAMAK – MAGNETIC CONFINEMENT

ITER – not just a tokamak

Credits:
ITER Organization
Ryan Wagner (IAEA):
"Fusion Power Plant Design (Tokamaks+)"
presented at Fusion Industry School, Oxford, UK, 2024

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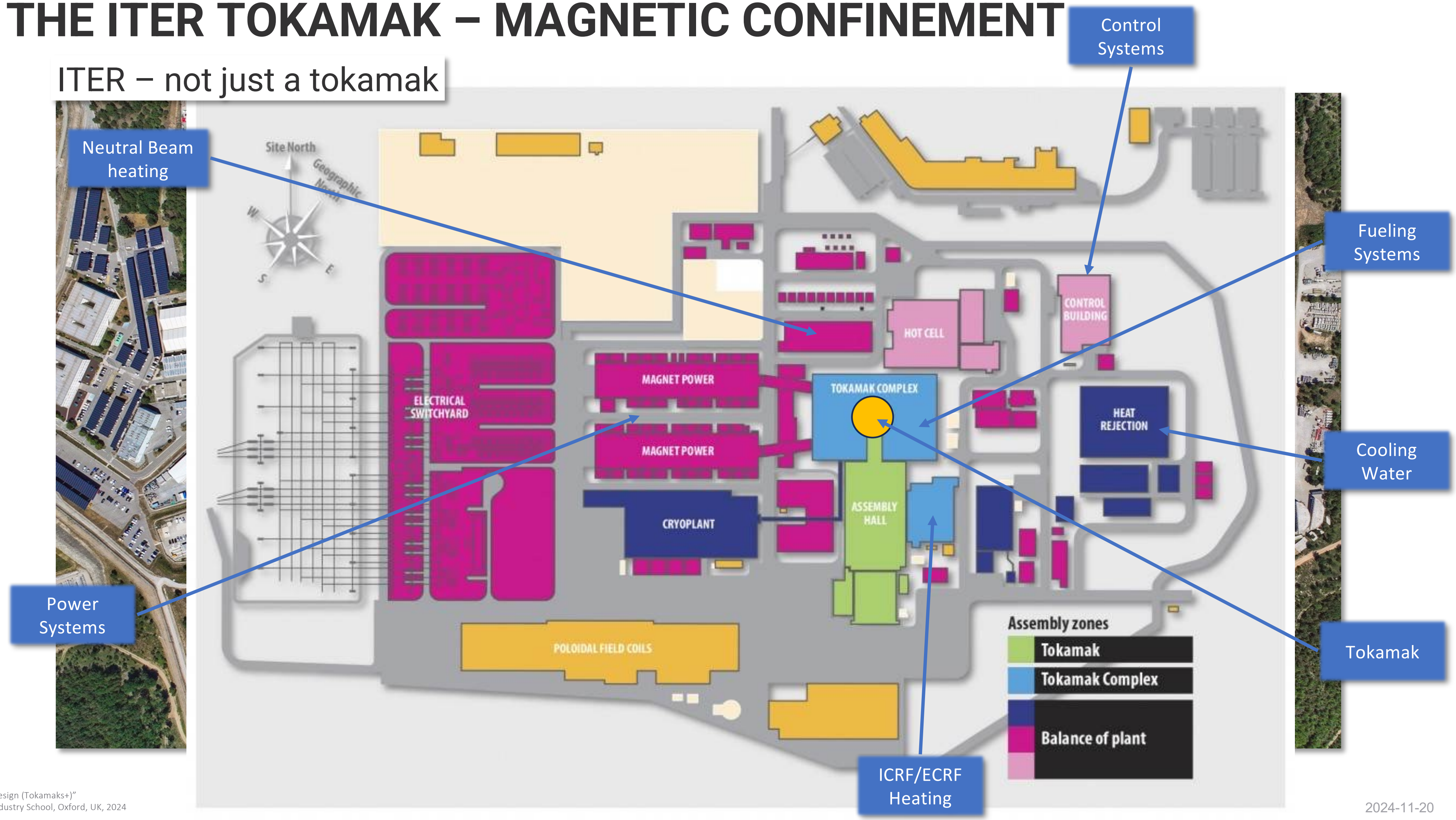

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PLANT BREAKDOWN STRUCTURE (PBS)

At Level-0, you have a fusion device. At Level-1, you have collections of similar systems grouped by like functions and managed by at least one person.

Level-1 Functional Analysis:

- Preconditions – including interfacing systems
- Basic course of operation
- Conventional Control, Protection Functions (machine protection), Fast Functions
- Postconditions
- Issues to be determined or resolved

Level-1 systems can be further decomposed into subsystems at Levels-2 & 3. Subsystems should be maintained at a level where you have at least one person assigned. For example, you wouldn't have a subsystem for ductwork, or flanges.

Level 1	Name	PBS	Level 2	Name
MAGS	Magnet Systems			
		001	TF	Toroidal Field Coils
		002	PF	Poloidal Field Coils
		003	CS	Central Solenoid
		004	DIVC	Divertor Coils
		005	EFCC	Error Field Correction Coils
		006	REMC	Runaway Electron Mitigation Coil
		007	FEED	Feeder Systems
EPDS	Electric Power Distribution			
		011	SSPW	Steady State Power Systems
		012	PPWR	Pulsed Power Systems
VACV	Vacuum Vessel Systems			
		016	VV	Vacuum Vessel
		017	TVC	Tokamak Vessel Conditioning Systems
		018	CRST	Cryostat
		019	TS	Thermal Shield
		020	PPLG	Port Plugs
		021	PFC	Plasma Facing Components
		022	DIV	Divertor System
VACP	Vacuum Pumping Systems			
		026	TPMP	Torus Pumping System
		027	CPMP	Cryostat Pumping System
		028	SPMP	Service Pumping System
CRYO	Cryogenics			
		032	TFCC	TF Coil Cooling
		033	PCCC	PF/CS Coil Cooling
		034	CCC	Copper Coil/TS Cooling
FUEL	Fueling Systems			
		038	TRIT	Tritium Handling Systems
		039	FINJ	Fuel Injection Systems
		040	DMS	Disruption Mitigation Systems
		041	ELM	ELM Pellet Injection Systems
RFHT	RF Heating			
		045	ICRF	Ion Cyclotron RF System
		046	ICDC	Ion Cyclotron Discharge Cleaning
		047	ECRF	Electron Cyclotron RF System
		048	ECDC	Electron Cyclotron Discharge Cleaning
		049	LHCD	Lower Hybrid Current Drive
		050	NB	Neutral Beam System
ENVP	Environmental Protection			
		054	RMC	Radiation Monitoring and Control
		055	SHLD	Neutron Shielding Systems
		056		
CNTL	Control Systems			
		060	PCS	Plasma Control System
		061	CCS	Central Control System
		062	MPS	Machine Protection System
		063	SCS	Safety Control System
		064	ACS	Access Control System

CONTROL SYSTEM ARCHITECTURE – PCS, MPS, PBS, ACS

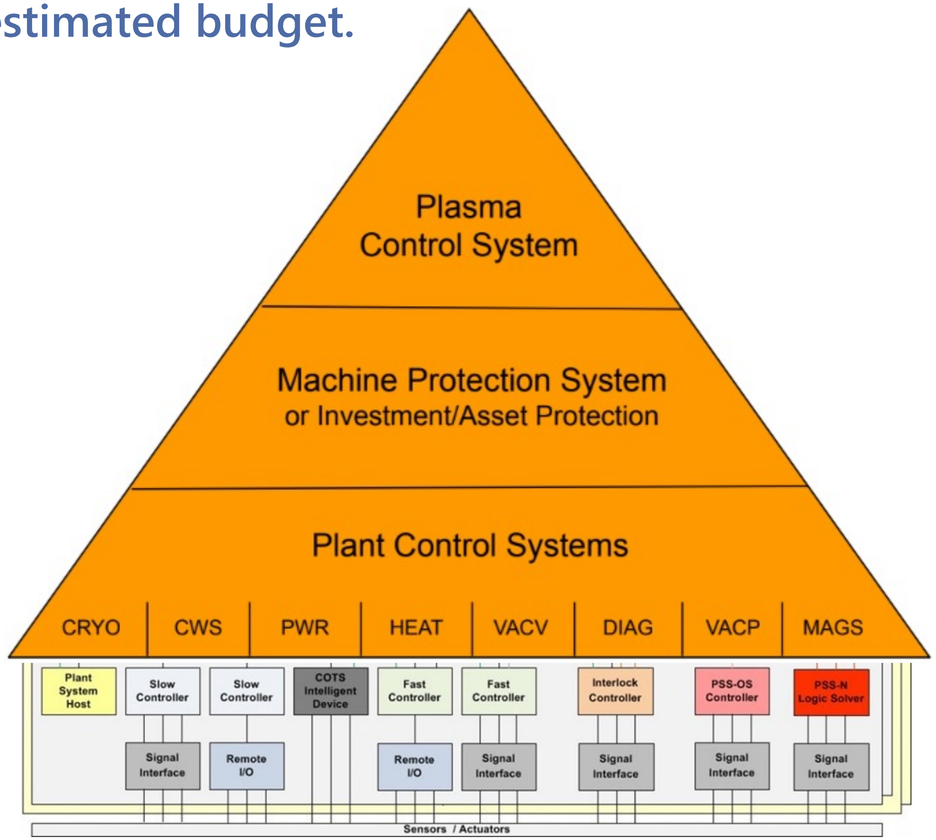
The control systems are typically critical path for large projects. Don’t underestimate the level of effort required to develop control systems. Rule of thumb, control systems including sensors and actuators are 10% of your estimated budget.

- The Plasma Control System (PCS) is a real-time control system using diagnostic systems for feedback control of plant systems; the PCS is the first line of defense if anomalies are detected

- The Machine Protection System (MPS) takes input from diagnostics to determine if events requires termination of plasma pulse

- Plant Control Systems (PBS) control all plant systems; each plant control system has its own master controller coordinating activities

- The Access Control System (ACS) prevents people from accessing hazardous environments

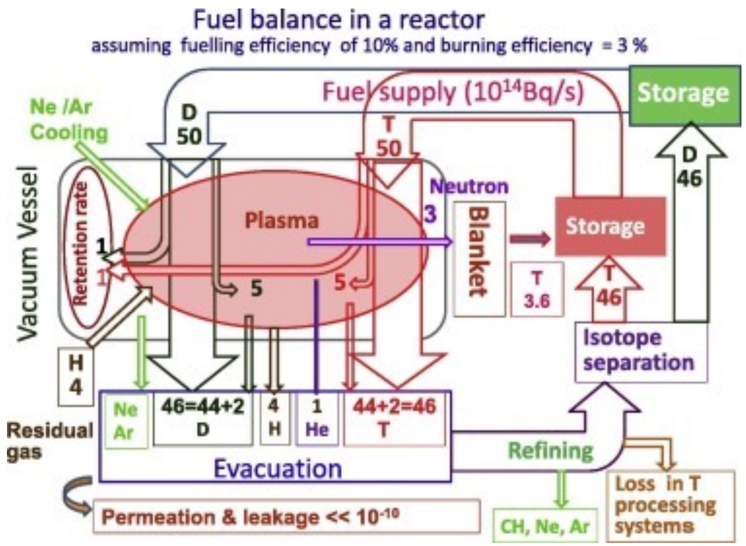


FUELING SYSTEMS – TRIT, FINJ, DMS

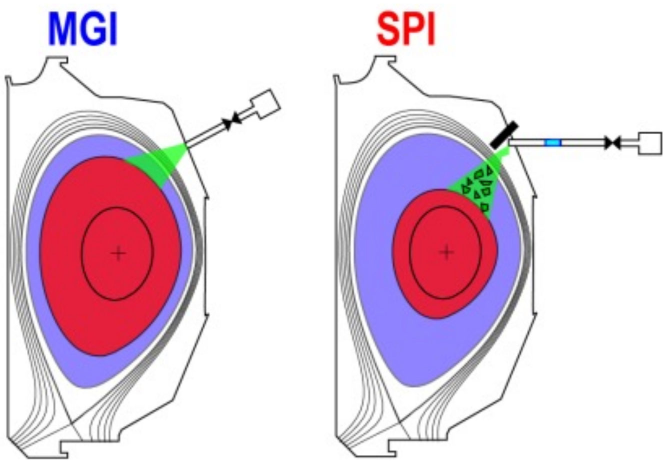
The Tritium Handling System (TRIT) manages the tritium inventory and supplies fueling for the plasma, TRIT also provides detritiation

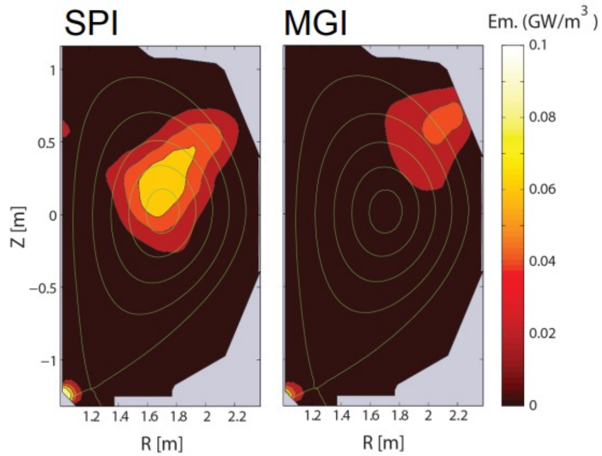
The Fuel Injection System (FINJ) injects various gases into a plenum for mixing and fuel injection by gas puffing

*MPS: The Disruption Mitigation System (DMS) uses various methods such as massive gas injection (MGI), or shattered pellet injection (SPI) to protect the tokamak from forces resulting from a plasma disruption



[Tritium fuel cycle in ITER and DEMO: Issues in handling large amount of fuel - ScienceDirect]



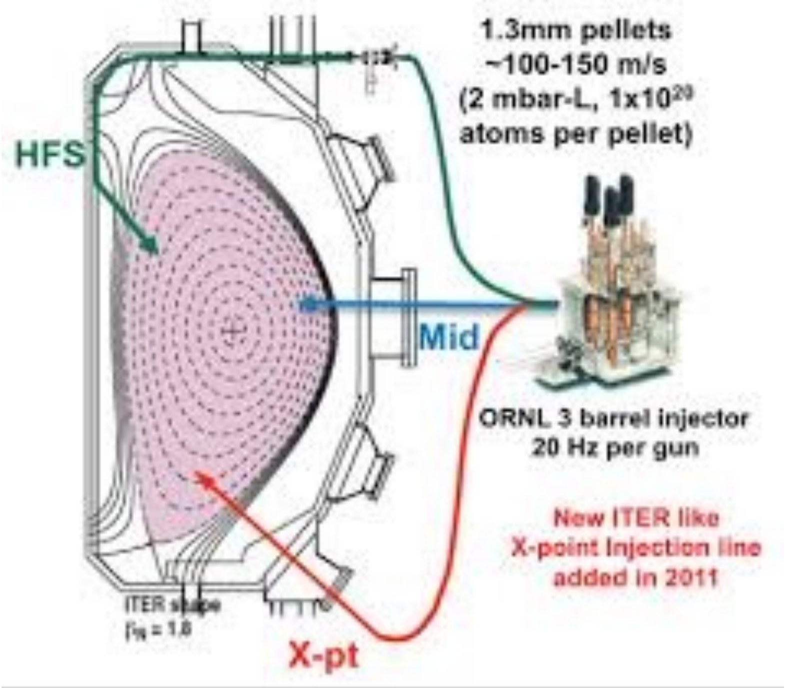


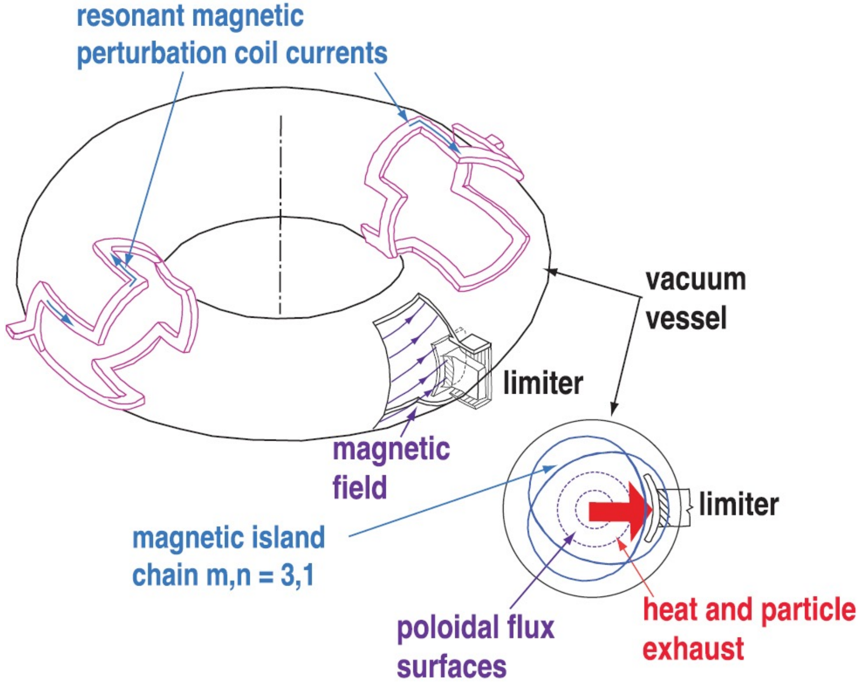
LW

FUELING SYSTEMS – ELM

*MPS: The ELM Pellet Injection System (ELM) inject fuelling pellets to protect the tokamak from edge localized modes, a plasma instability in the edge region of the plasma

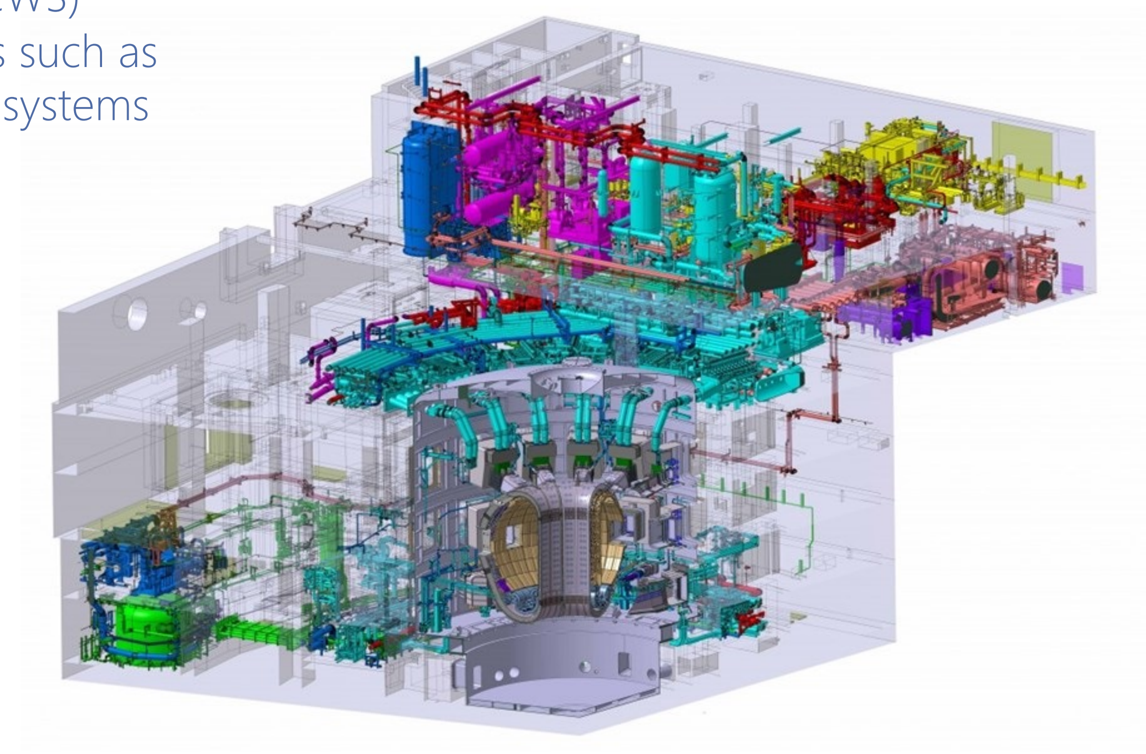
Resonant Magnetic Perturbation Coils can manage ELMs by "flicking" the plasma (think flicking a water ballon)





COOLING WATER SYSTEMS (CWS) – TCWS, CCWS, CLWS, HRS

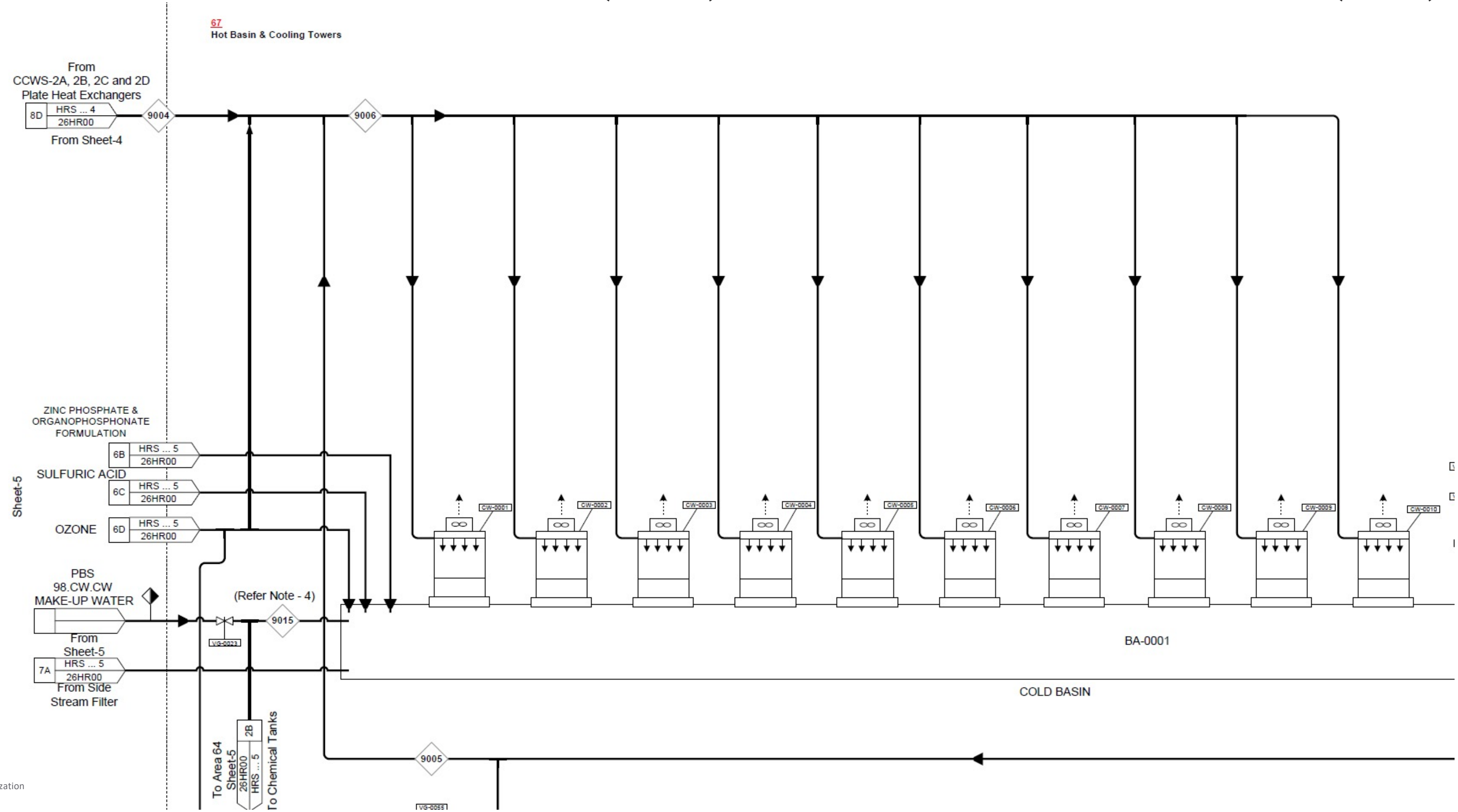
- The Tokamak Cooling Water System (TCWS) provides cooling water for tokamak systems such as the first wall blanket and divertor
- The Component Cooling Water System (CCWS) provides cooling water for auxiliary systems such as the HVAC, auxiliary heating and diagnostic systems
- The Closed Loop Cooling Water System (CLWS) provides cooling water for systems which may be contaminated by tritium or activated materials
- The Heat Rejection System (HRS) rejects heat collected from other cooling water systems through heat exchangers and cooling towers to the atmosphere



@ITER – CWS provides 1500MW of heat removal

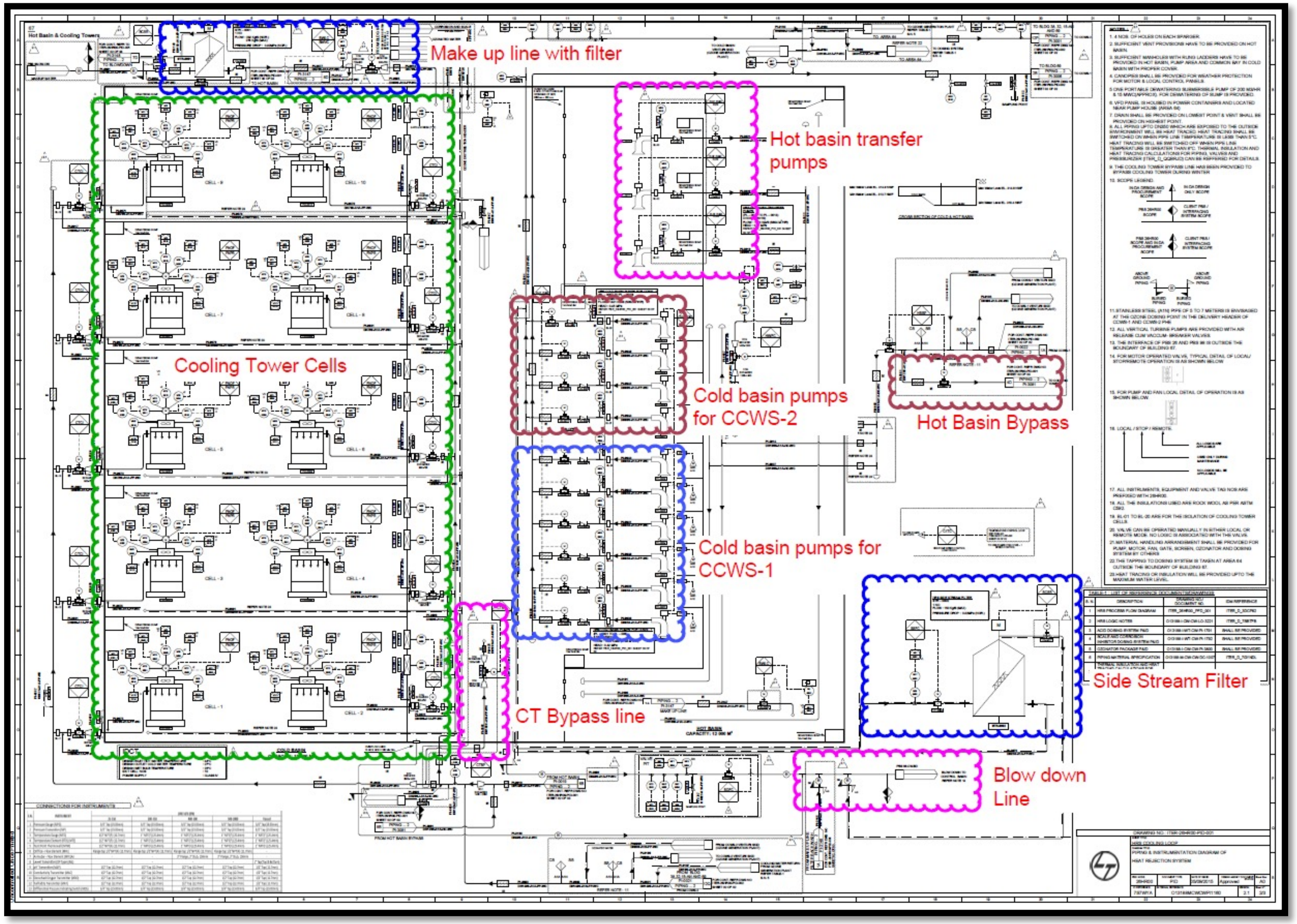
Credits: ITER ORganization

COOLING WATER SYSTEMS (CWS) – PROCESS FLOW DIAGRAM (PFD)



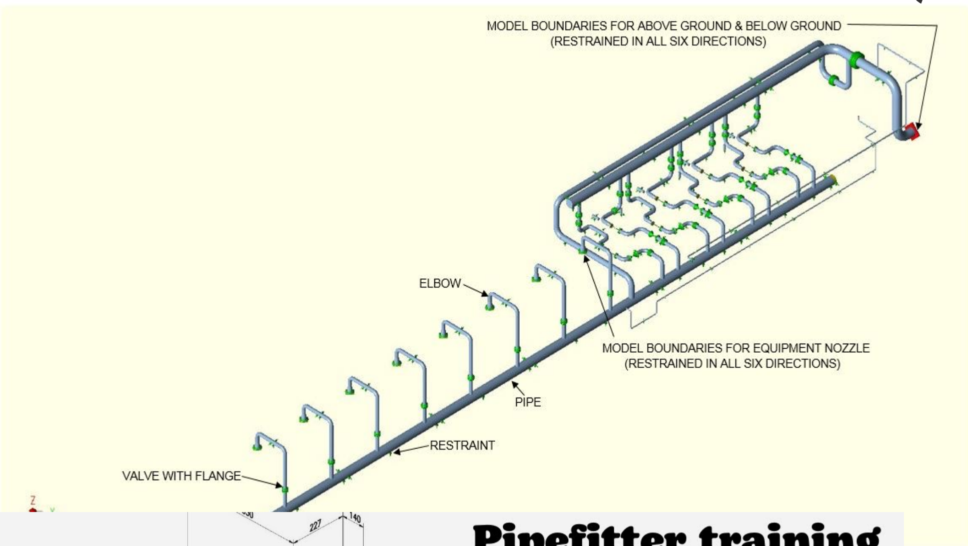
Credits: ITER ORganization

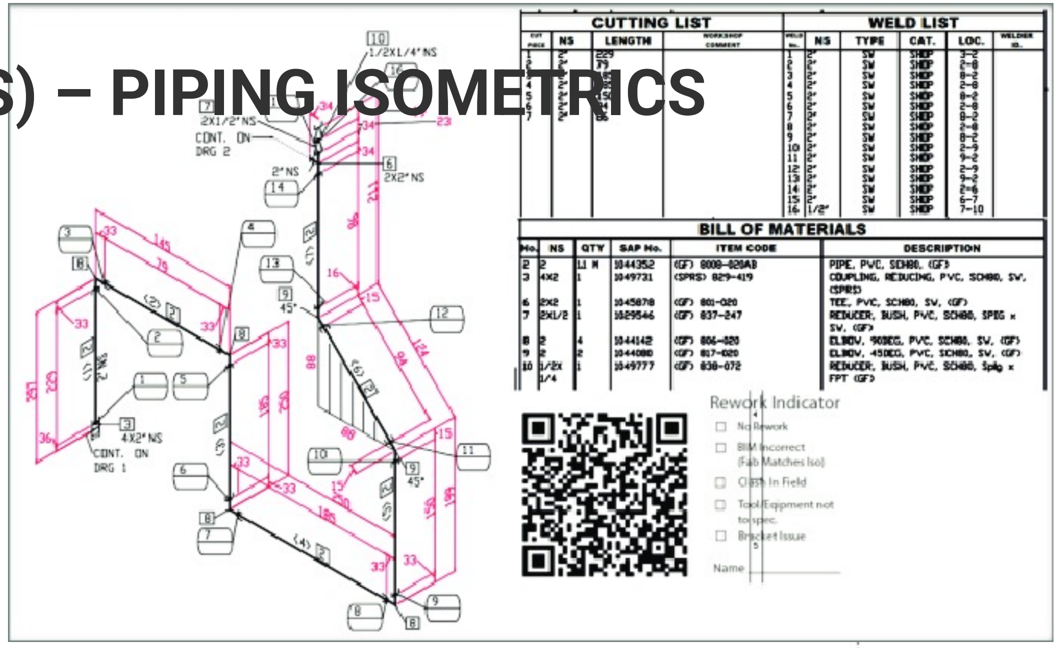
COOLING WATER SYSTEMS (CWS) – PIPING AND INSTRUMENTATION DIAGRAM (P&ID)

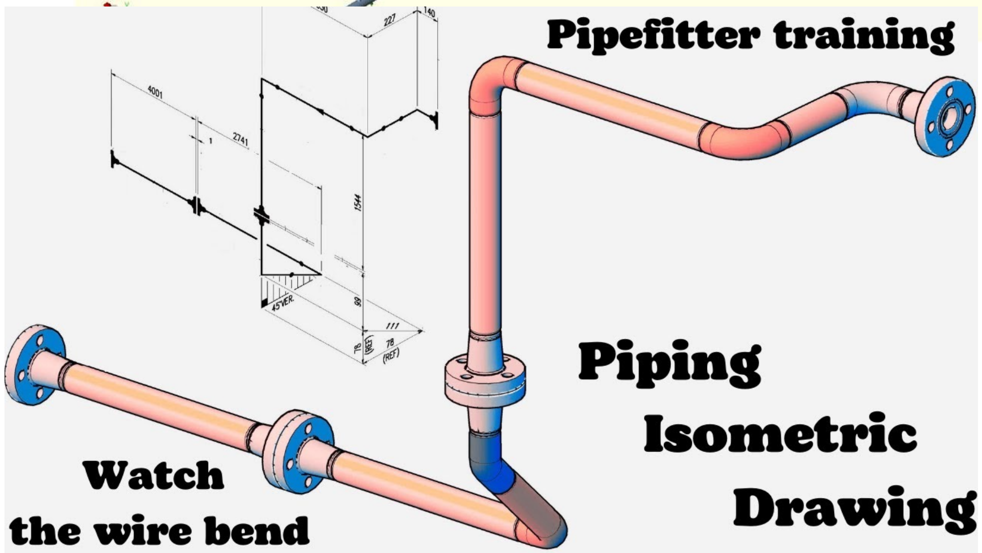


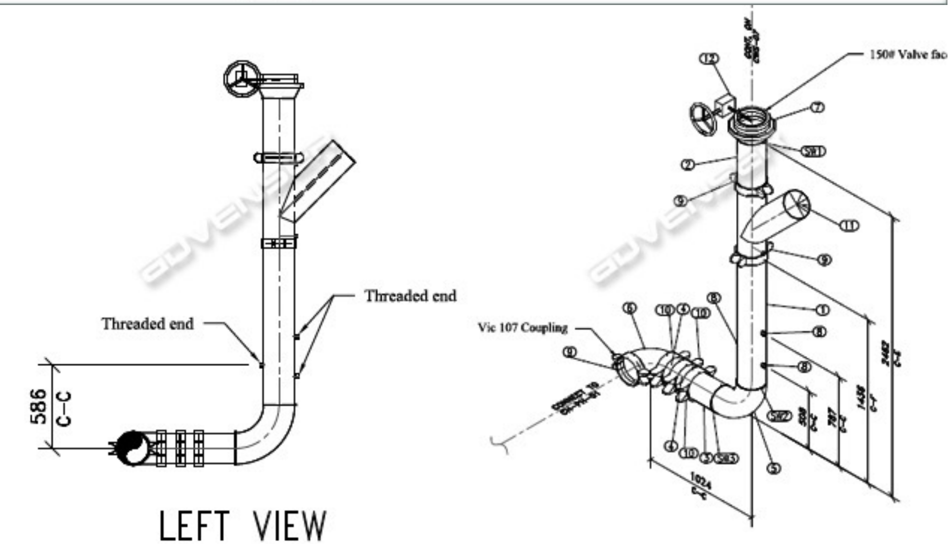
Credits: ITER ORganization

COOLING WATER SYSTEMS (CWS) – PIPING ISOMETRICS









COOLING WATER SYSTEMS (CWS) – CONSTRUCTION WORK PACKAGES

Process Documents	Mechanical Documents
Block Flow Diagram [BFD] – (REF)	General Arrangement Drawings [GA] – (P)
Process Flow Diagrams [PFD] – (REF)	Ancillary Steel/Platform Details – (P)
Process & Instrumentation Diagram [P&ID] – (P)	Insulation Requirements – (P)
	Mechanical Equipment Lists – (P)
Piping Documents	Specialty Lists – (P)
Piping Plan Drawing – (P)	Equipment Specifications – Mech Procurement – (P & F)
Piping Detail Drawings – (P)	
Piping Specifications – (P)	**Electrical Documents**
Piping Line Lists - (P)	Electrical Single Line Diagram [SLD] – (P)
Tie-In Lists – (P)	Electrical Load List – (P)
Piping Isometric Drawing [ISOs] – (P & F)	Electrical Equipment List – (P)
	Equipment Specifications – Electrical Pro
	Conduit/Cable Tray Routing Drawing – (
	Power Cable Schedule – (P & F)
	Equipment Grounding Drawing – (F)

(REF) Reference (P) – Pathways Package (F) – Final Install Package (C) – Controls Package (BC) – Building Constructior

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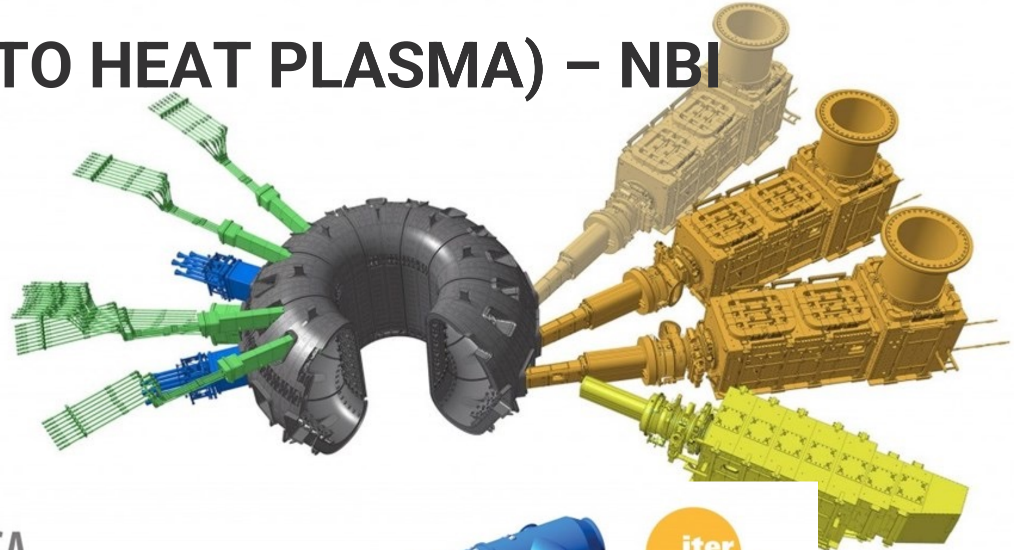
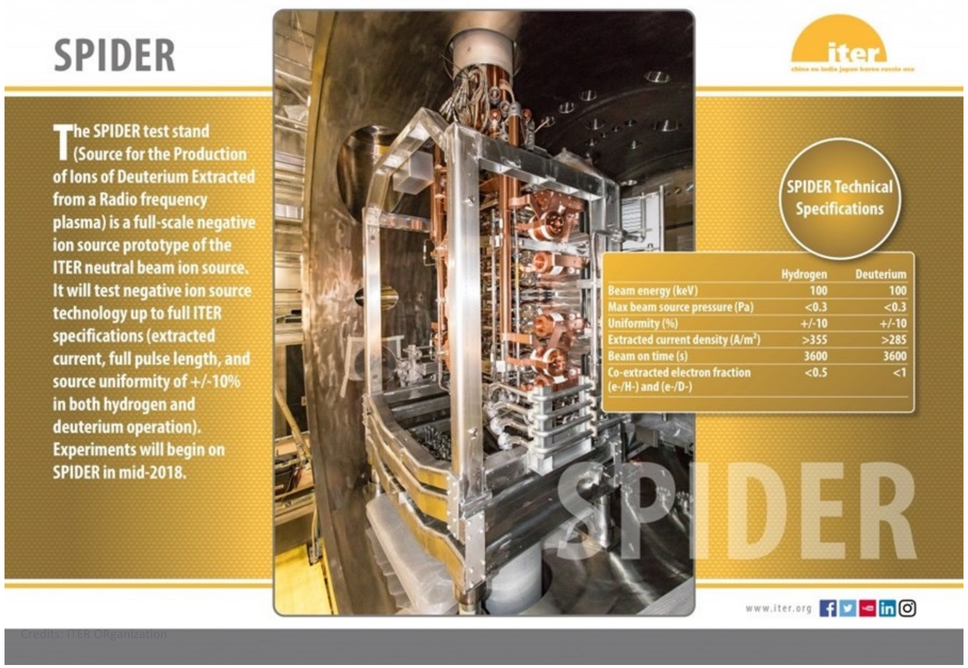
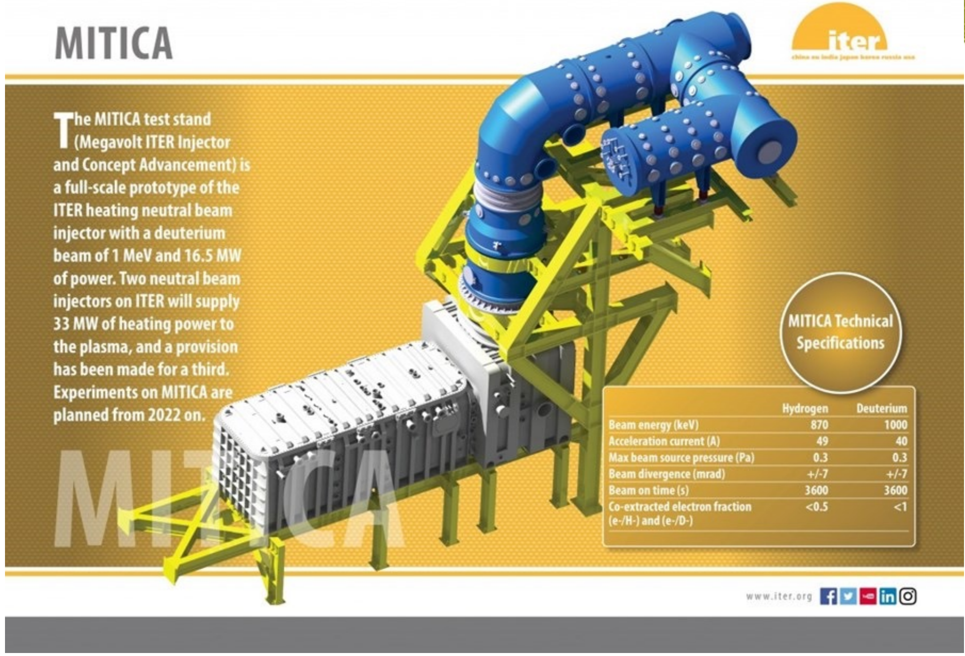
AUXILIARY HEATING SYSTEMS (TO HEAT PLASMA) – NBI

The Neutral Beam Injection (NBI) system shoots uncharged high-energy particles into the plasma where, by way of chaotic motion and collision (friction), they will transfer their energy to the charged plasma particles (the work horse)

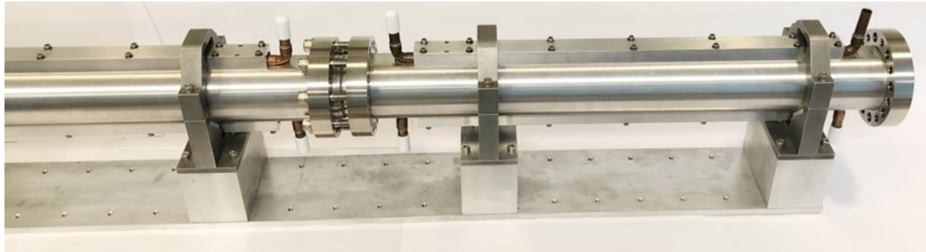


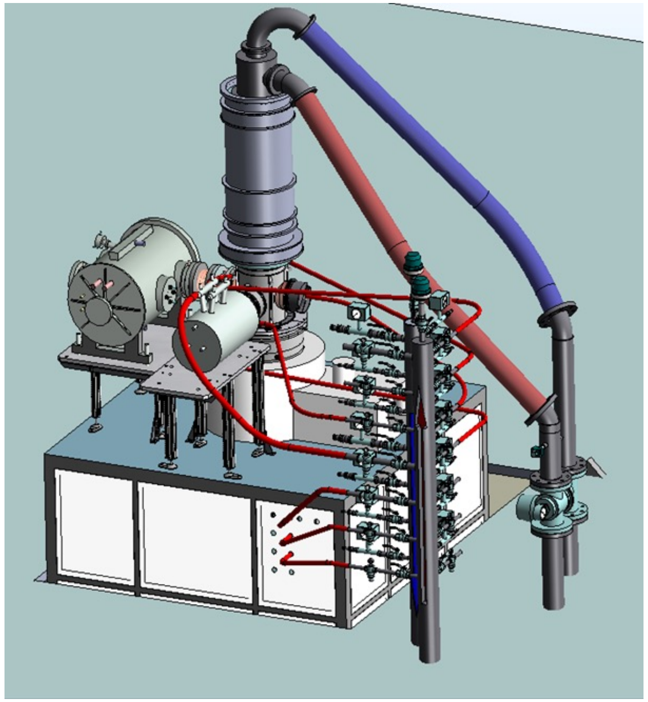


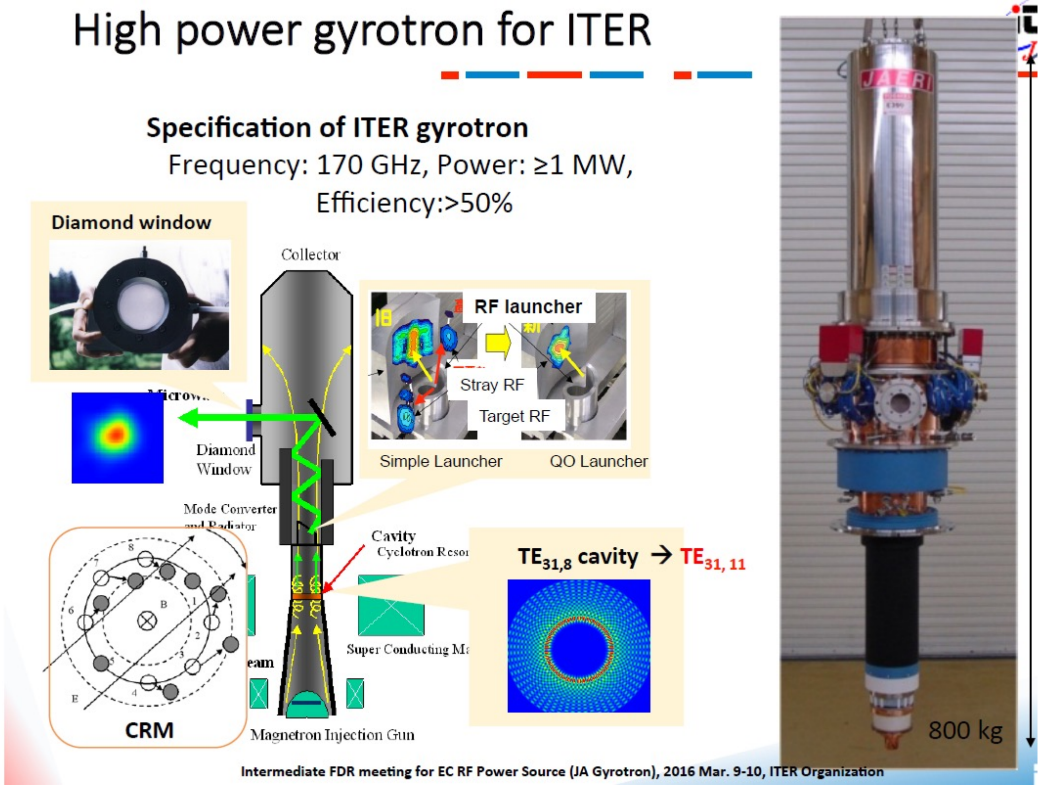


AUXILIARY HEATING SYSTEMS (TO HEAT PLASMA) – ECRF

The Electron Cyclotron Resonance Heating (ECRF) system utilizes gyrotrons to heat the electrons in the plasma with high-intensity beam of electromagnetic radiation at a frequency of 140 – 210 GHz, depending on the plasma



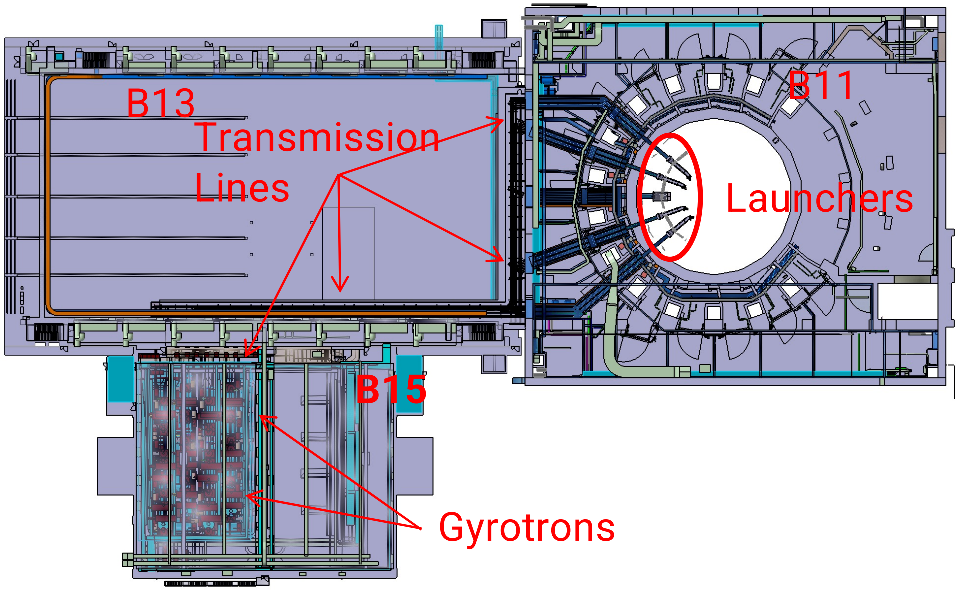


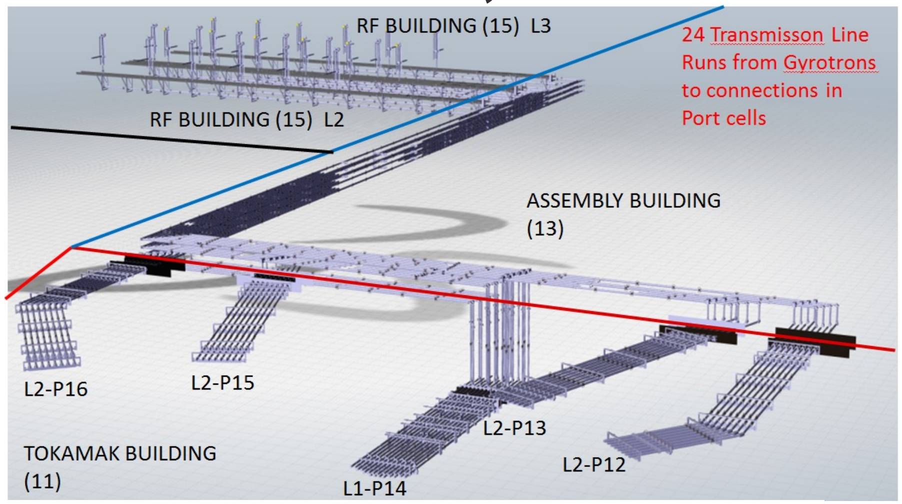


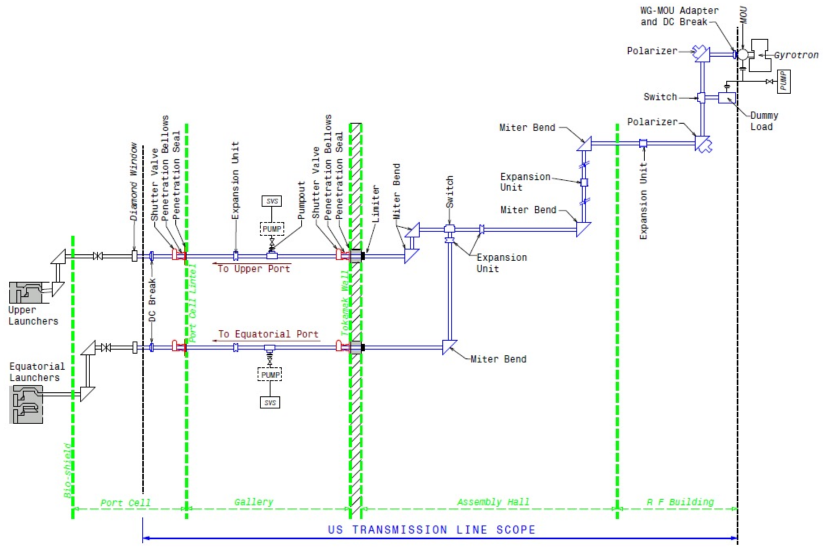
Credits: ITER ORganization

AUXILIARY HEATING SYSTEMS (TO HEAT PLASMA) – ECRF

24 Waveguides (~4 km total length) each carry 1 MW mm wave power (designed for 1.5MW). Switches and Mitre bends control beam path. Elliptical and Plane polarizers control beam profile delivered to launcher mirrors.







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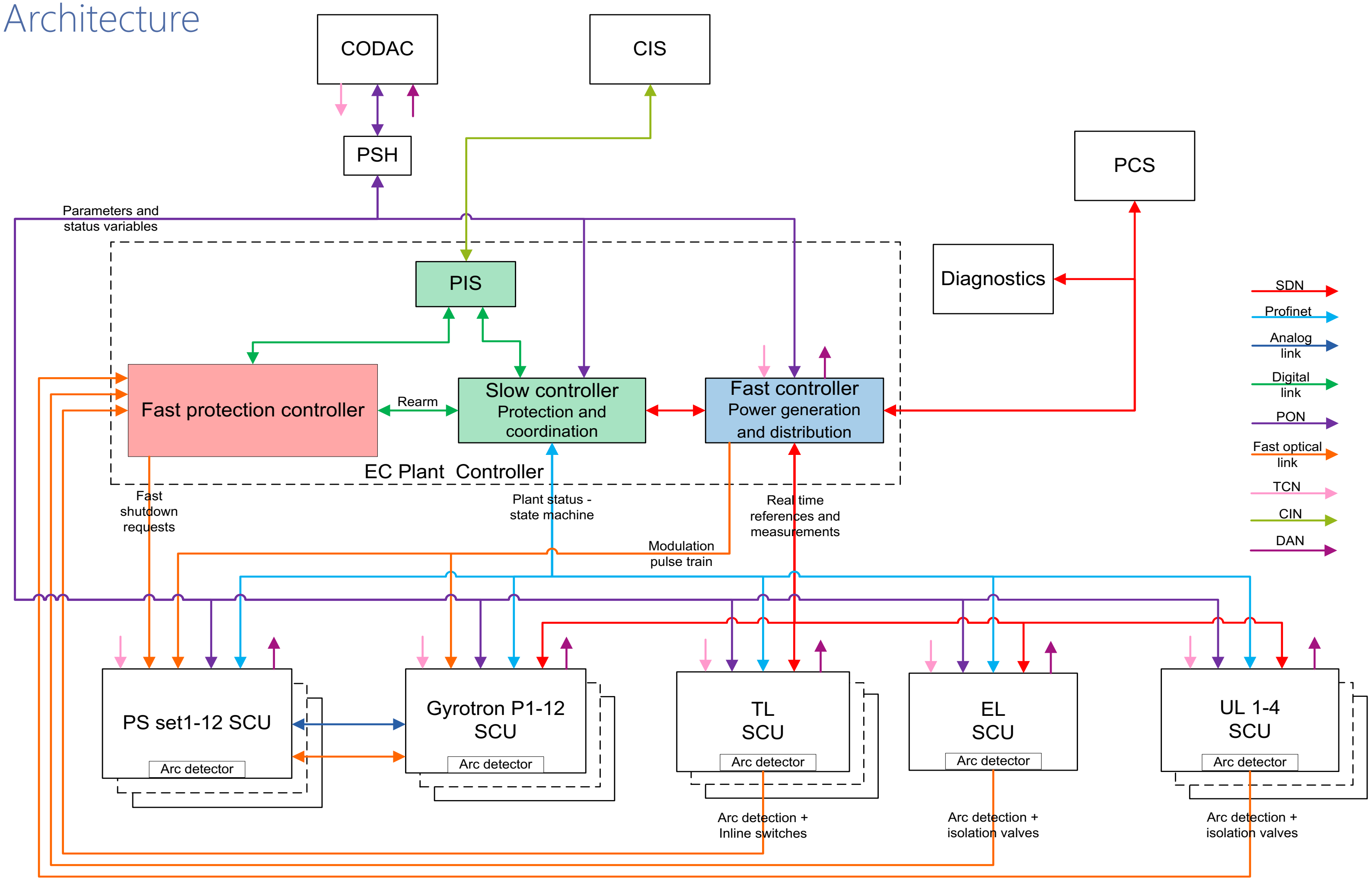
AUXILIARY HEATING SYSTEMS (TO HEAT PLASMA) – ECRF

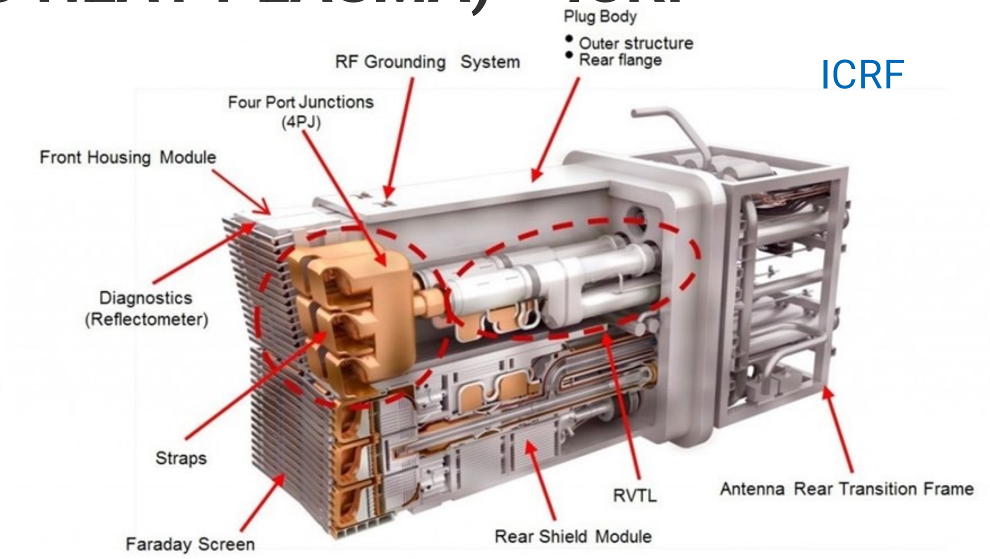
ECRF I&C Architecture

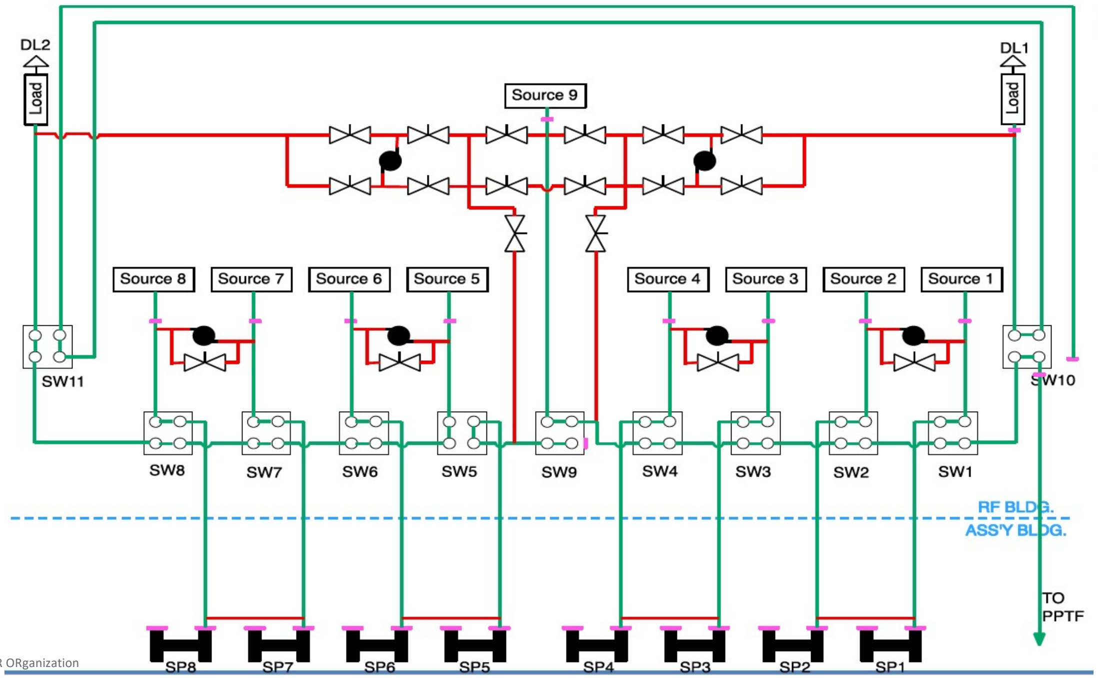


Credits: ITER ORganization

AUXILIARY HEATING SYSTEMS (TO HEAT PLASMA) – ICRF

- The Ion Cyclotron Resonance Heating (ICRF) system transfers energy to the ions in the plasma through a high-intensity beam of electromagnetic radiation with a frequency depending on the plasma
- Transmission lines are nitrogen cooled





Credits: ITER ORganization

- The transmission lines are coaxial lines between RF Sources and Loads
- Antenna must couple with the plasma, or resonate at the same frequency, or the RF waves will bounce off the plasma
- RF Sources amplify the RF waves to MW power injected to the plasma

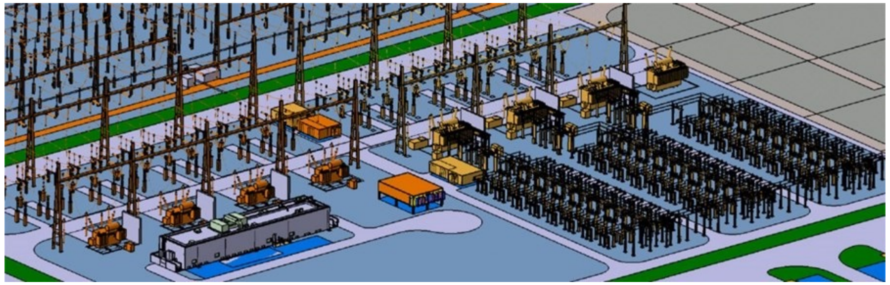
POWER SYSTEMS – TFPS, HPS, UPS, EDG, PFPS, CSPS, DIVP, MG, RPC

- The power systems are broken down into two main systems: the steady state power system and the pulsed power system

- Steady state powers the Toroidal Field coils (TFPS), house systems (HPS) (HVAC, instrument air, etc.) and include the uninterruptible power supplies (UPS) and emergency diesel generator (EDG)

- Pulsed power powers the Poloidal Field coils (PFPS), the Central Solenoid (CSPS), Divertor Sweep Coils (DIVP) and includes a motor generator (MG), or reactive power compensation (RPC) (depending on the project)

- Recent developments find super capacitor banks replacing some traditional pulsed power systems



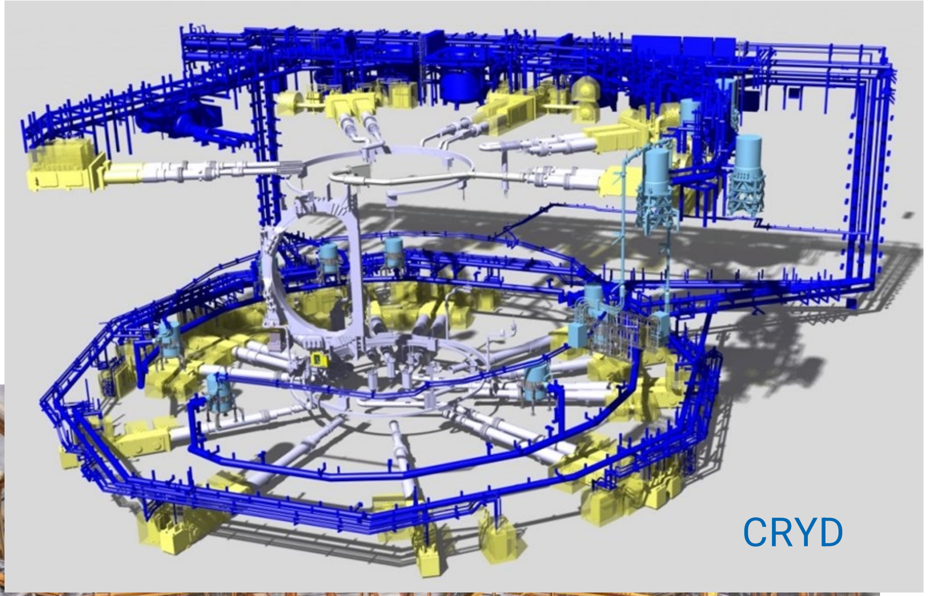
Credits: ITER ORganization

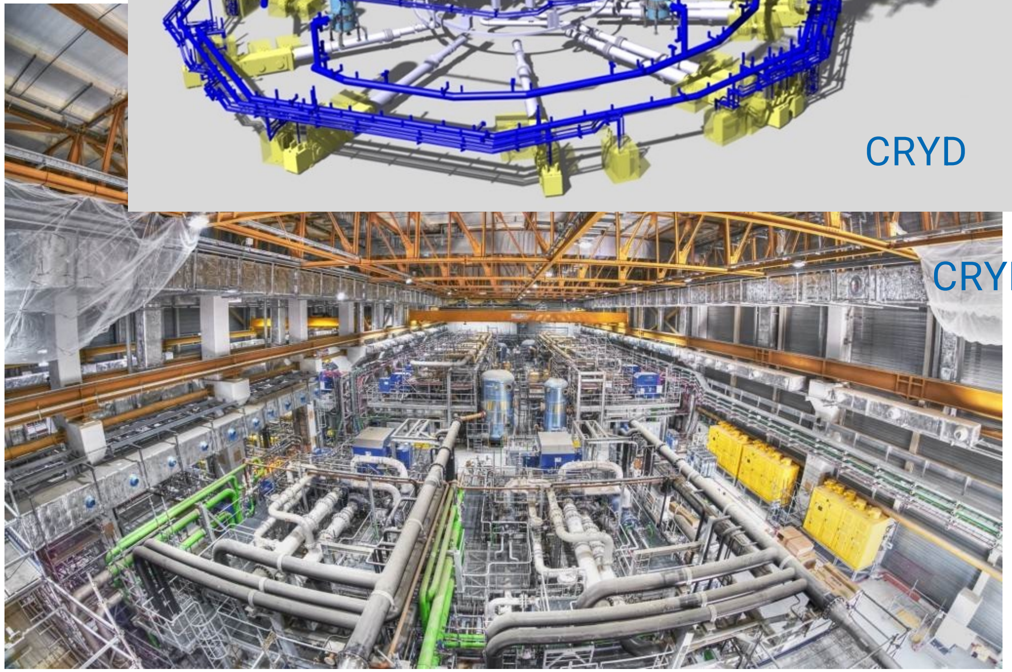
CRYOGENICS SYSTEMS – TFCC, PCCC, CCC, FDC, CRYD

- The Cryogenics Systems can be broken down into two main systems, the cryoplant (CRYP) and cryodistribution (CRYD)

- The Cryoplant provide cryogenics cooling to the Toroidal Field coils (TFCC), the Poloidal Field and Central Solenoid (PCCC), and the electric power feed system (FDC)

- The Cryodistribution system (CRYD) distributes cryogenics to the associated systems at varying temperature for the application (ex. the feeder system might require nitrogen cooling @80k, while the TF coils might require helium @4k)

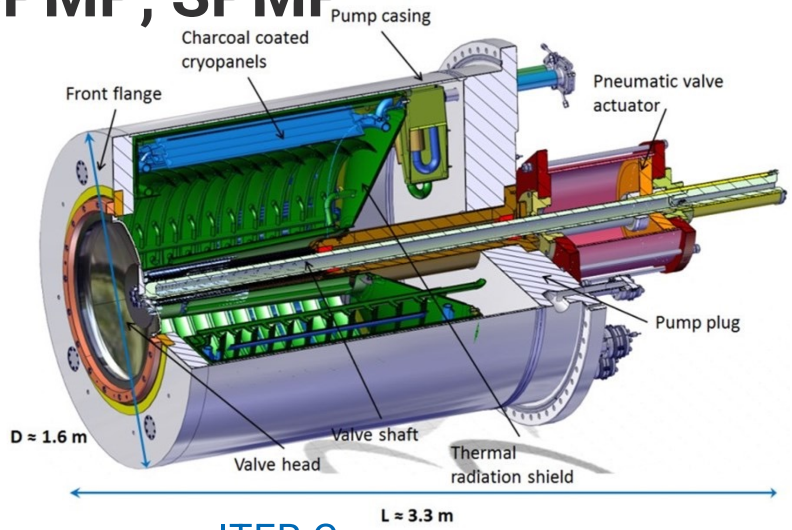




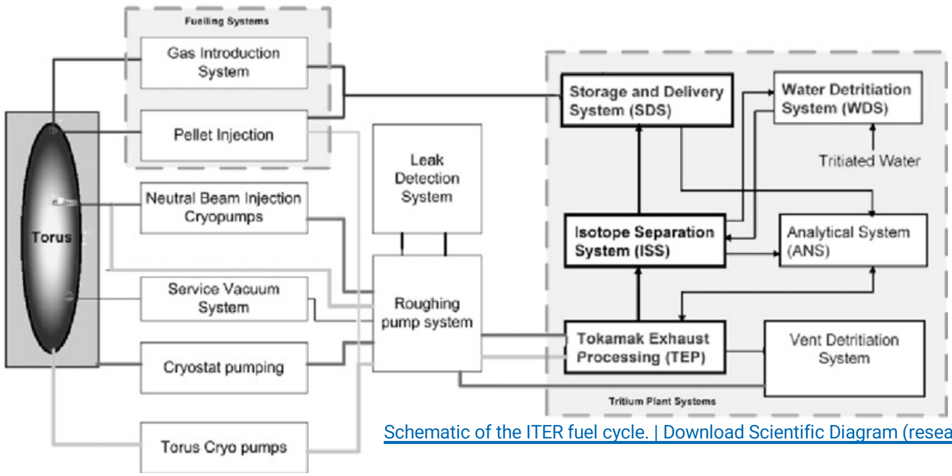
Credits: ITER ORganization

VACUUM PUMPING SYSTEMS – TPMP, CPMP, SPMP

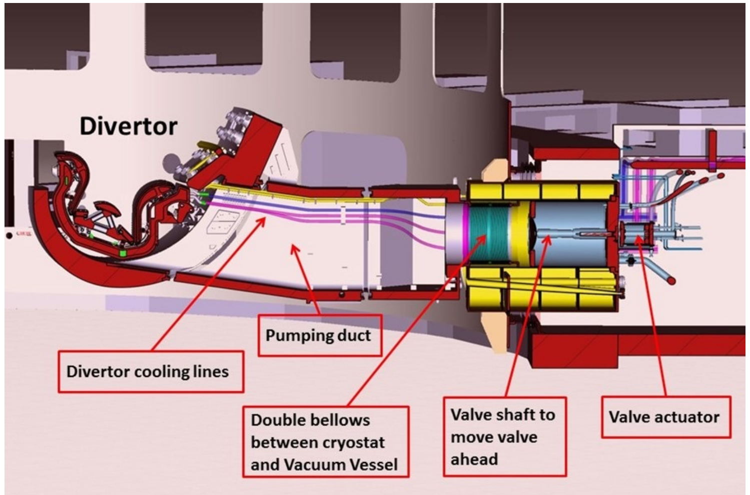
- The Torus Pumping System (TPMP) evacuates the tokamak vacuum chamber to high vacuum (10^{-5} Pascal)
- The Cryostat Pumping System (CPMP) evacuates the cryostat vacuum chamber to a high vacuum (10^{-4} Pascal)
- The Service Pumping System (SPMP) provides vacuum pumping for auxiliary systems (NBI, port cells, cryopumps, etc.), the vacuum requirements depend on the application
- Pumping systems are closely integrated with fuelling systems and leak detection



ITER Cryopump



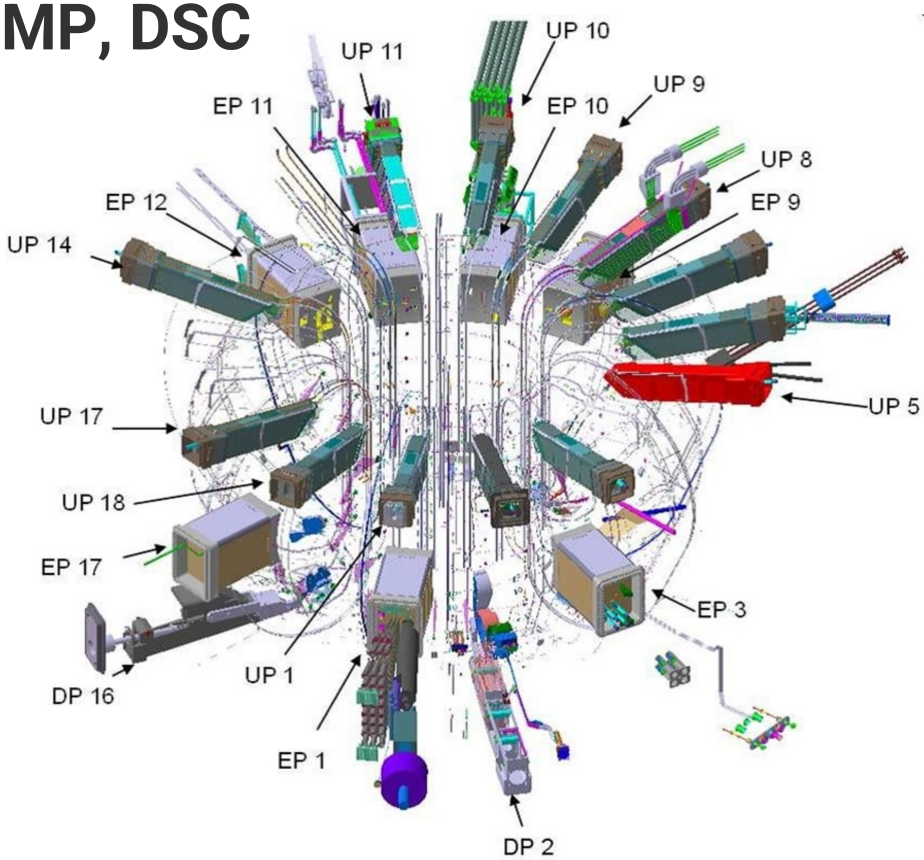
Schematic of the ITER fuel cycle. | Download Scientific Diagram (researchgate.net)



Credits: ITER ORganization

DIAGNOSTICS SYSTEMS – DOPS, DMP, DSC

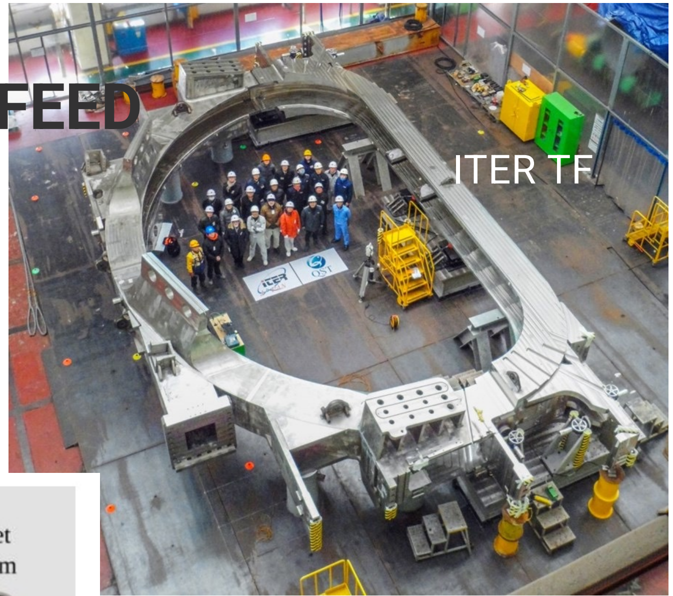
- Diagnostics for Tokamak Operations (DOPS) provide input to the PCS to maintain the plasma and to detect anomalies for ultra-fast protection
- Diagnostics for Machine Protection (DMP) provide input for a simple on-off based on detected parameters; if the PCS doesn't take action, the DMP will provide input to the MPS to terminate the pulse
- Diagnostics for Science (DSC) provide input for those characteristics desired by scientists to learn more about the plasma; these diagnostics may not be needed for commercial fusion operations, but are likely to exist in demonstration facilities

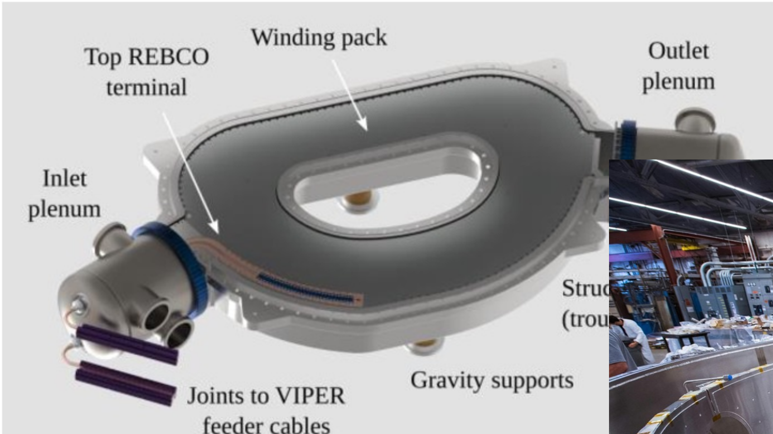


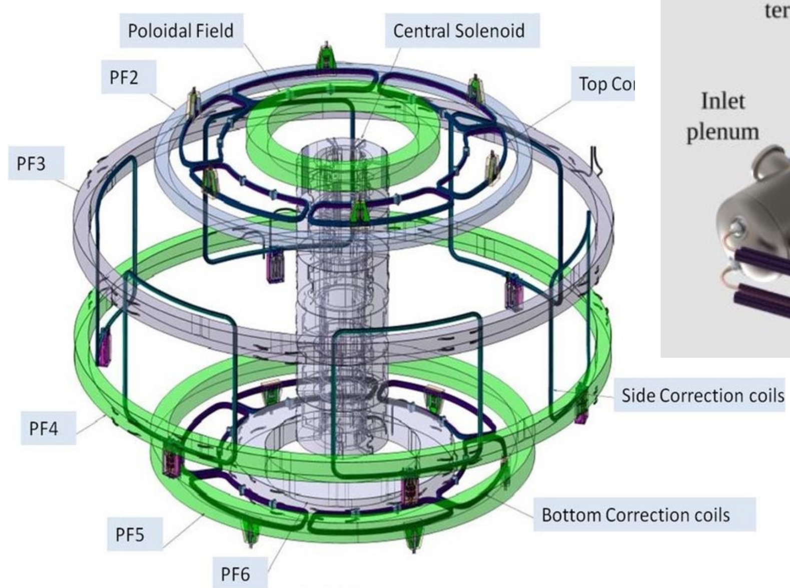
Technology | The many wonders of ITER diagnostics

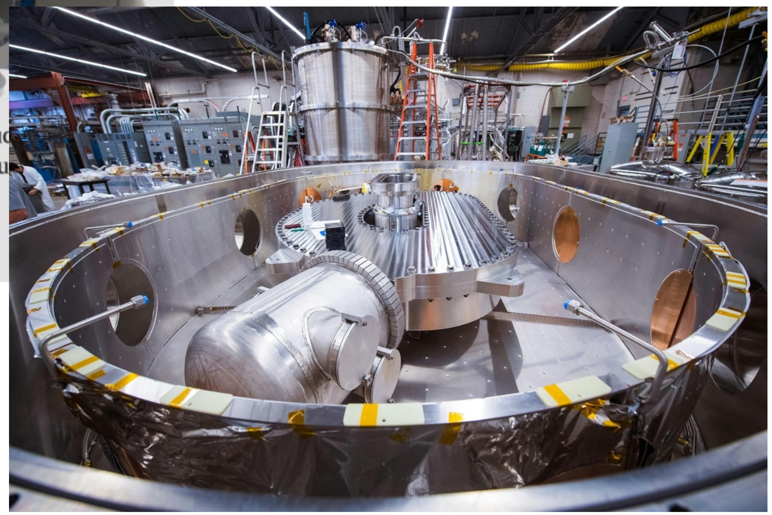
MAGNET SYSTEMS – TF, PF, CS, DIVC, EFCC, FEED

The Magnet Systems are the sexy systems in magnetic confinement fusion, these along with other tokamak systems are what people think of when they think about tokamaks or stellarators, hopefully by now you realize the complexity of these machines since you've learned about the many other systems involved







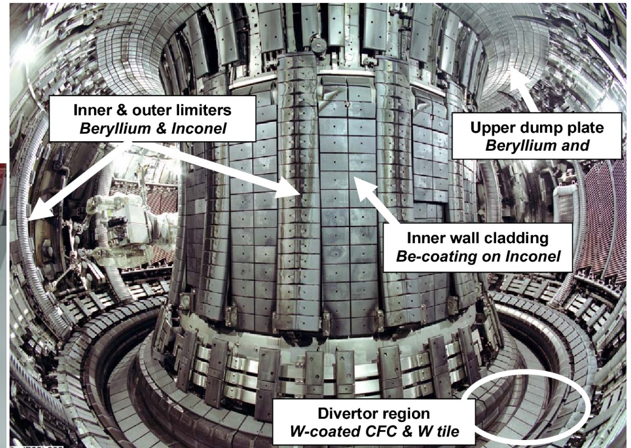


[Overall view of the 18 ITER Error Field Correction coils with the... | Download Scientific Diagram (researchgate.net)]

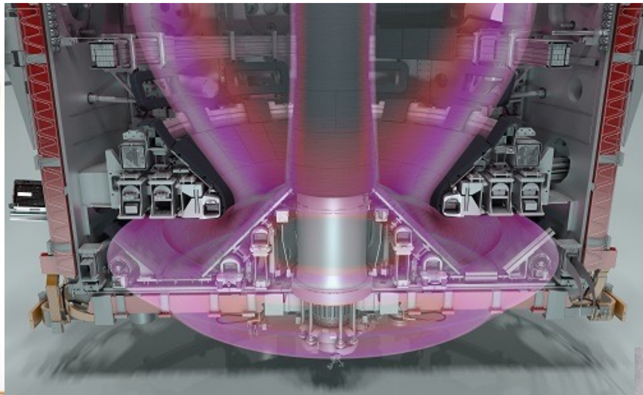
[CAD rendering of the TFMC magnet showing the principal components. | Download Scientific Diagram (researchgate.net)]

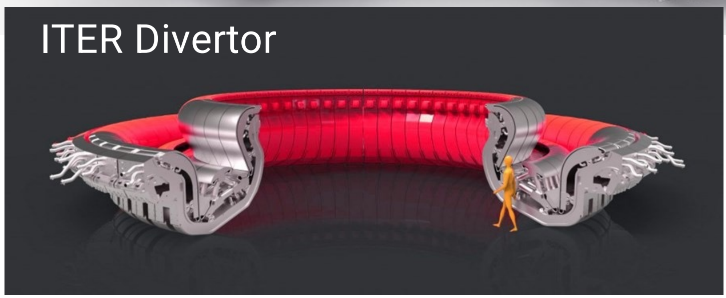
TOKAMAK SYSTEMS – VV, CRST, TS, PPLG, PFC, DIV

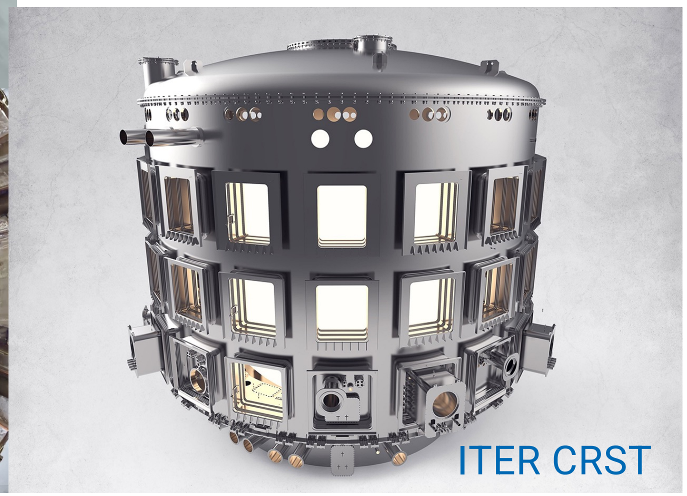
In addition to the magnet systems, other tokamak systems include the vacuum vessel (VV), the cryostat (CRST), thermal shields (TS), port plugs (PPLG), plasma facing components (PFC), and divertor systems (DIV)



R&D on tungsten plasma facing components for the JET ITER-like wall project


New insights in Super-X divertor region - EUROfusion (euro-fusion.org)

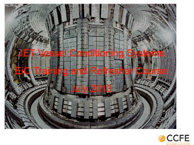




TOKAMAK SYSTEMS – WALL CONDITIONING

Wall conditioning is essential to remove impurities from the first wall. This is needed to achieve H-mode (high-confinement mode) where the plasma is stable (reduction in turbulence) and fusion conditions are ripe (adding into the mix new challenges like ELMs).

- B2D6 – boronization of the wall to prevent hydrogen and impurities from getting into the wall materials
- GDC – glow discharge cleaning, the GDC discharge is a dc low-temperature plasma discharge, operated in the absence of the toroidal magnetic field, between one or more anodes inserted into the vessel, and the entire vessel wall serving as a cathode.
- ICDC – Ion Cyclotron discharge cleaning
- ECDC – electron cyclotron discharge cleaning
- Baking the vessel – low and high temperature baking during campaigns and maintenance periods



Presentation on JET WC

Good paper on wall conditioning

Initial phase wall conditioning in KSTAR

Good paper on ECDC

Hydrogen removal by electron cyclotron wall conditioning with neon gas and its impact of tokamak plasma start-up on the QUEST

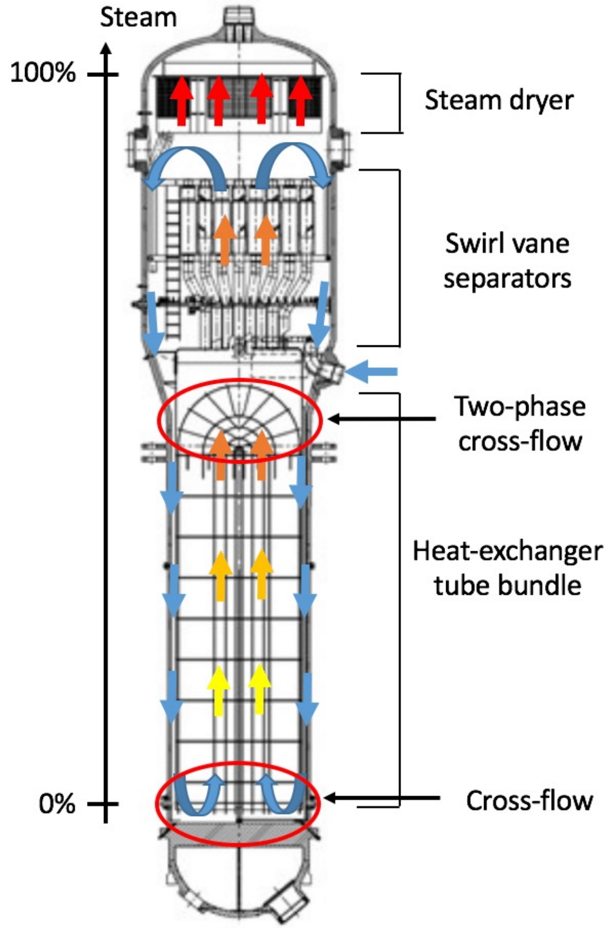
Good paper on ICDC

Ion Cyclotron discharges for Tokamak wall conditioning in presence of a magnetic field recent experimental results on Tore Supra

TURBINE ISLAND

Additional systems will need to be developed for a fusion power plant

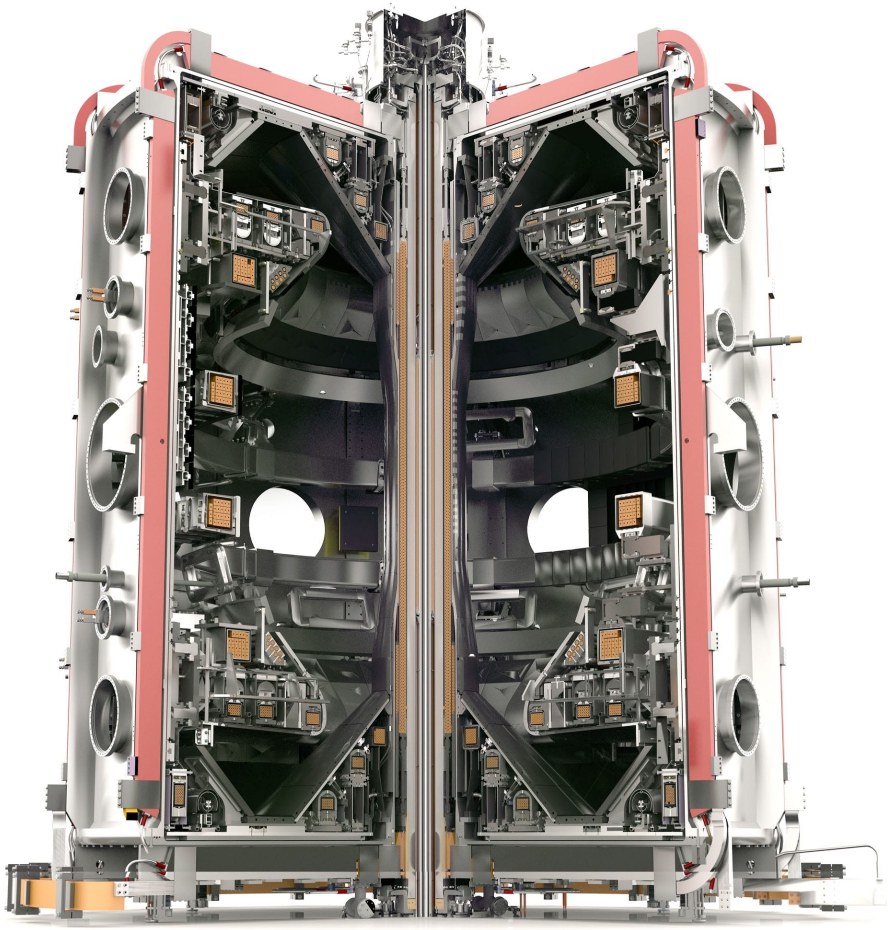
- Pumps and heat exchangers for molten salts/liquid metals and steam generators
- The turbine island itself with steam turbine and generator can be developed using existing technology
- Some private companies are developing direct to energy conversion systems (Helion D-^{3}He fuel, Marvel Fusion p-^{11}B fuel)



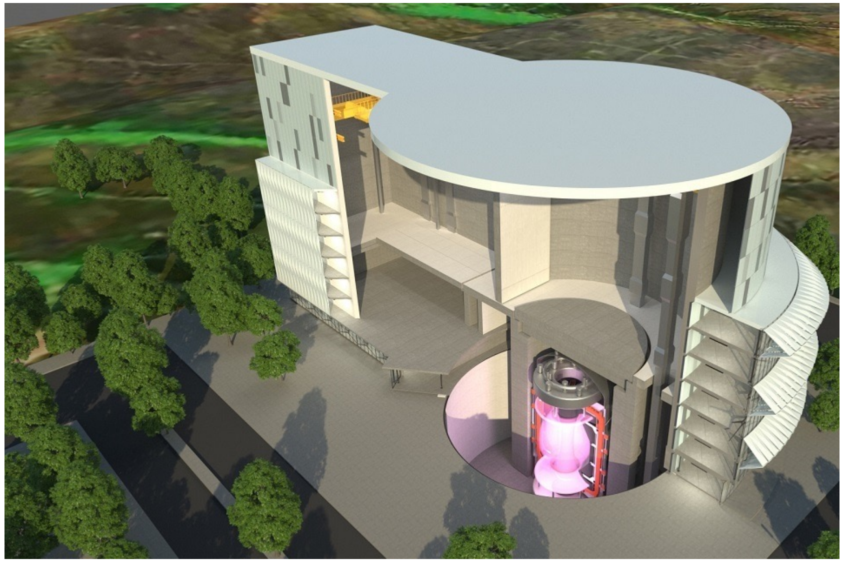
FUSION POWER PLANT DESIGN CONTENT

- FUSION PROGRAM MANAGEMENT
- A BRIEF OVERVIEW OF TOKAMAK SYSTEMS
- FUSION TECHNOLOGIES IN DEVELOPMENT

UKAEA SPHERICAL TOKAMAK FOR ENERGY PRODUCTION (STEP)



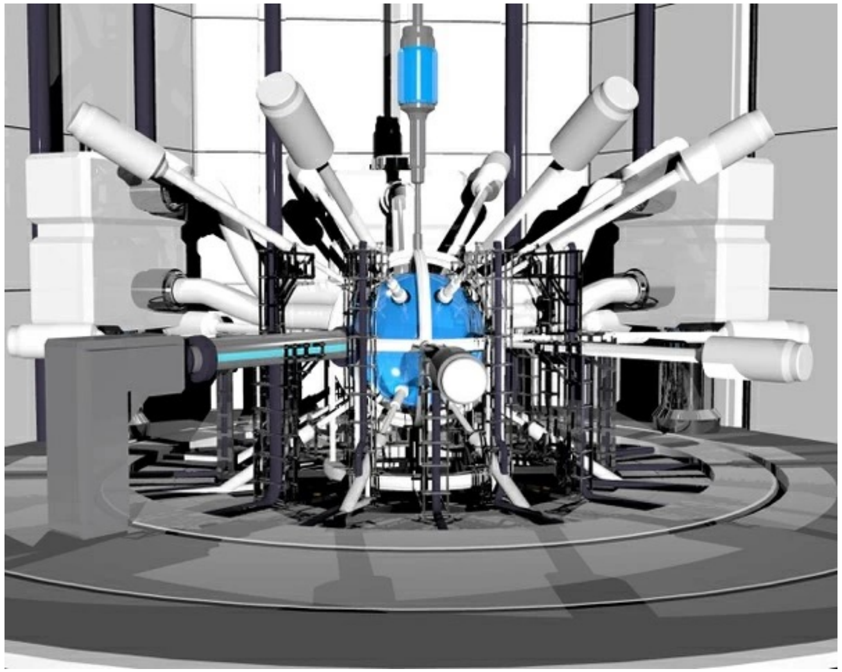
October 2022, UKAEA announced site selection in West Burton at a retired coal plant, site prep is underway

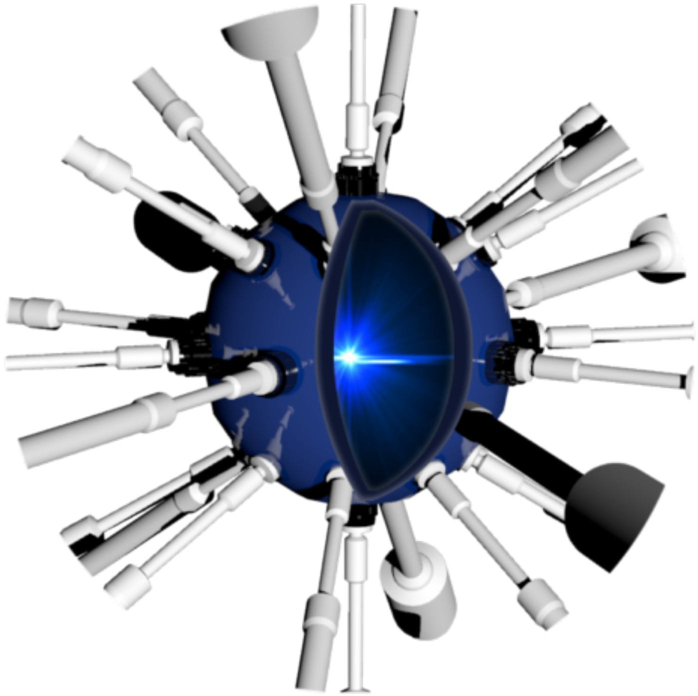


STEP - Spherical Tokamak for Energy Production

United Kingdom

EX–FUSION – INERTIAL CONFINEMENT FUSION





[Japan aims to destroy space debris using lasers on Earth - Telegraph - Telegraph]

[Japanese Laser Fusion Company, EX-Fusion, Raises $1.8 billion yen as Seed Round with Plans to Advance Laser Fusion Research and Development | EX-Fusion / en]

Japan

COMMONWEALTH FUSION SYSTEMS – HIGH FIELD TOKAMAK

Magnetic Confinement Fusion (D-T Fuel)

[Virginia wants to be the home of the world's first commercial nuclear fusion power plant]

United States

COMMONWEALTH FUSION SYSTEMS (CFS) – SPARC CONSTRUCTION

Devens Concept
~June 2020

Italy's Eni and CFS speed up plans for fusion energy

Commonwealth Fusion Systems Selected by U.S. DOE for Milestone Program to Accelerate Commercial Fusion Energy

Assembly starts of SPARC, as ITER cryopumps completed - World Nuclear News

United States

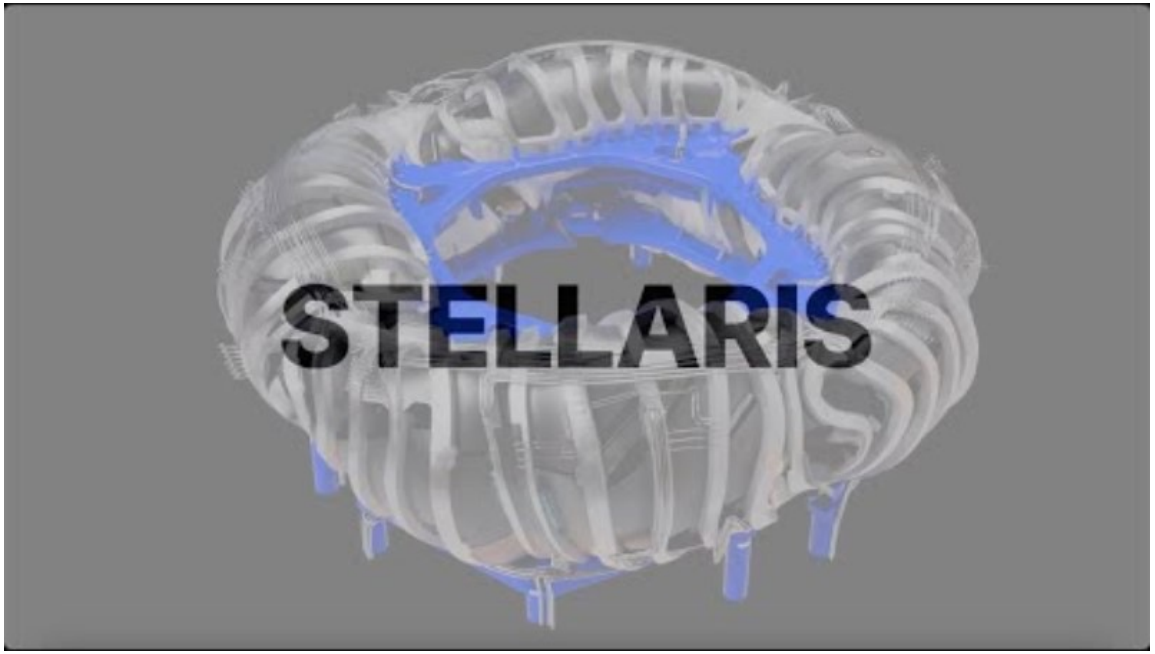
Start of Construction in June 2021

Devens Reality
Pictured - 27 October 2023

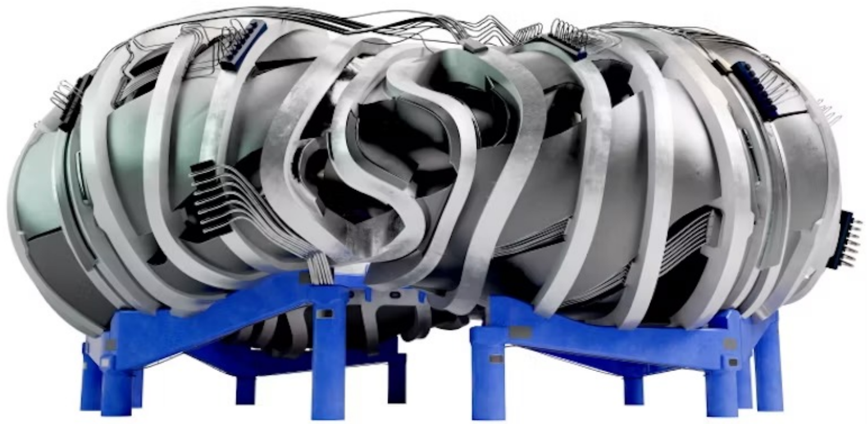
PROXIMA FUSION – QUASI-ISODYNAMIC STELLARATOR

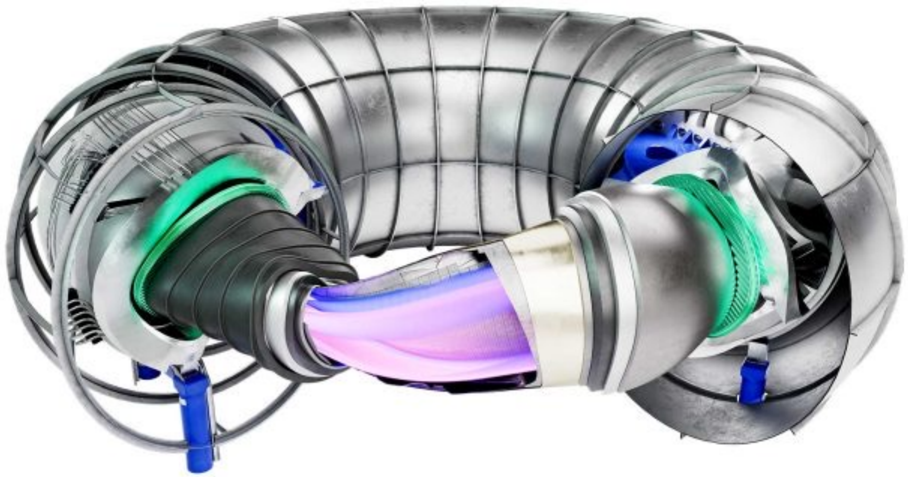
Magnetic Confinement Fusion (D-T Fuel)

Proxima Fusion starts cooperation with other startups – Munich Startup (munich-startup.de)



Proxima Fusion unveils concept for commercial fusion power plant





Germany

HELION ENERGY - REVERSED FIELD CONFIGURATION

Magneto-Inertial Fusion (D-He^3 Fuel)

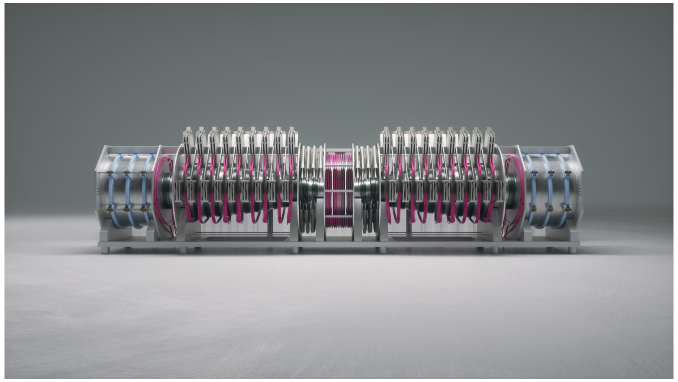
Everett Washington
27 July 2021

[Microsoft agrees to buy electricity generated from Sam Altman-backed fusion company Helion in 2028]

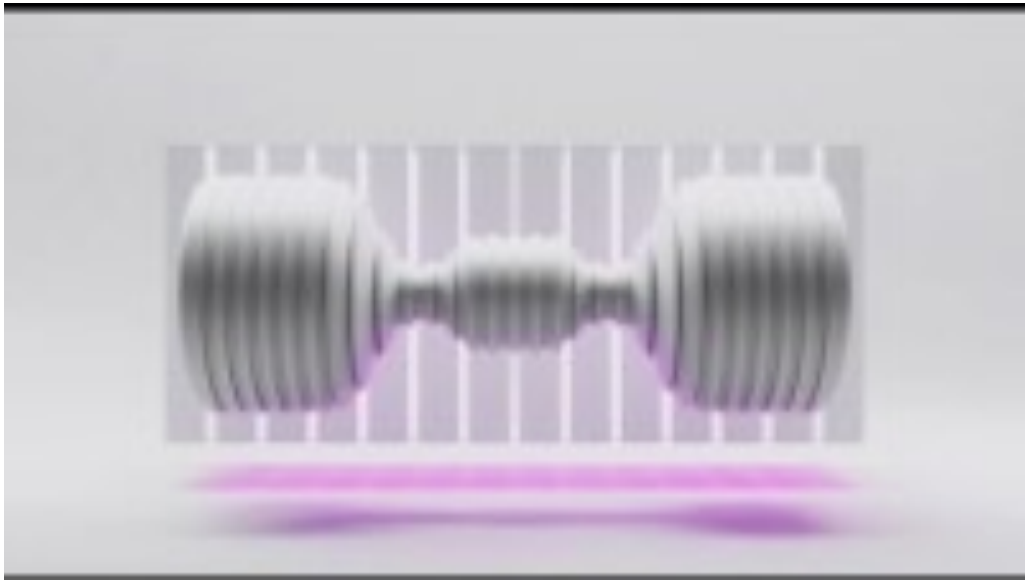
[Nucor and Helion to Develop Historic 500 MW Fusion Power Plant (prnewswire.com)]

[Nuclear fusion startup Helion to build 'world's first' power plant after raising $425 million]

United States

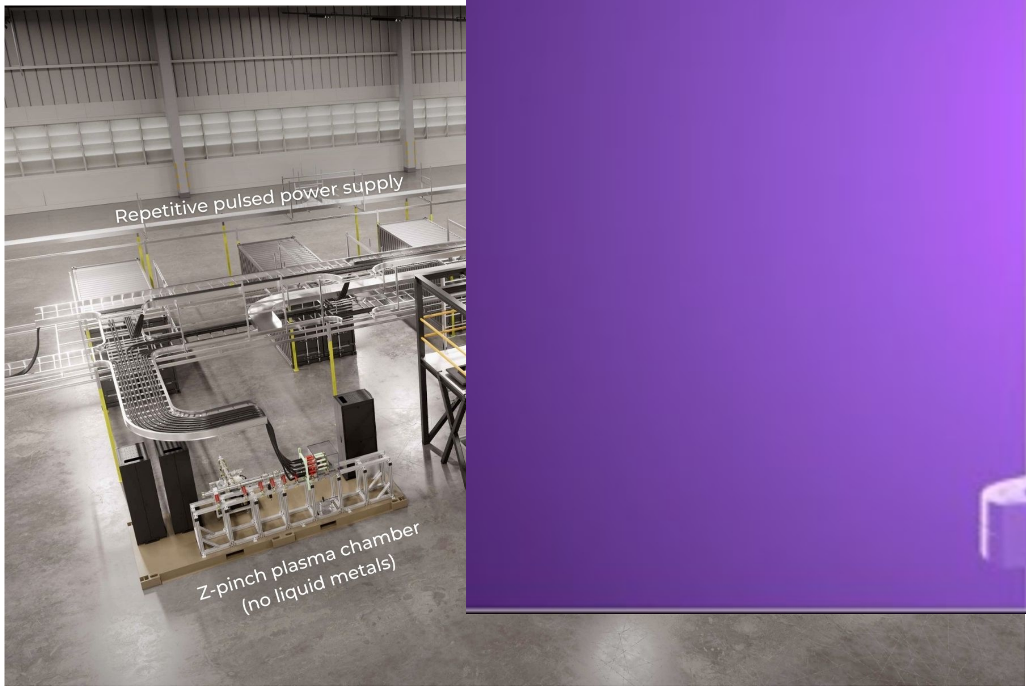


How it works.

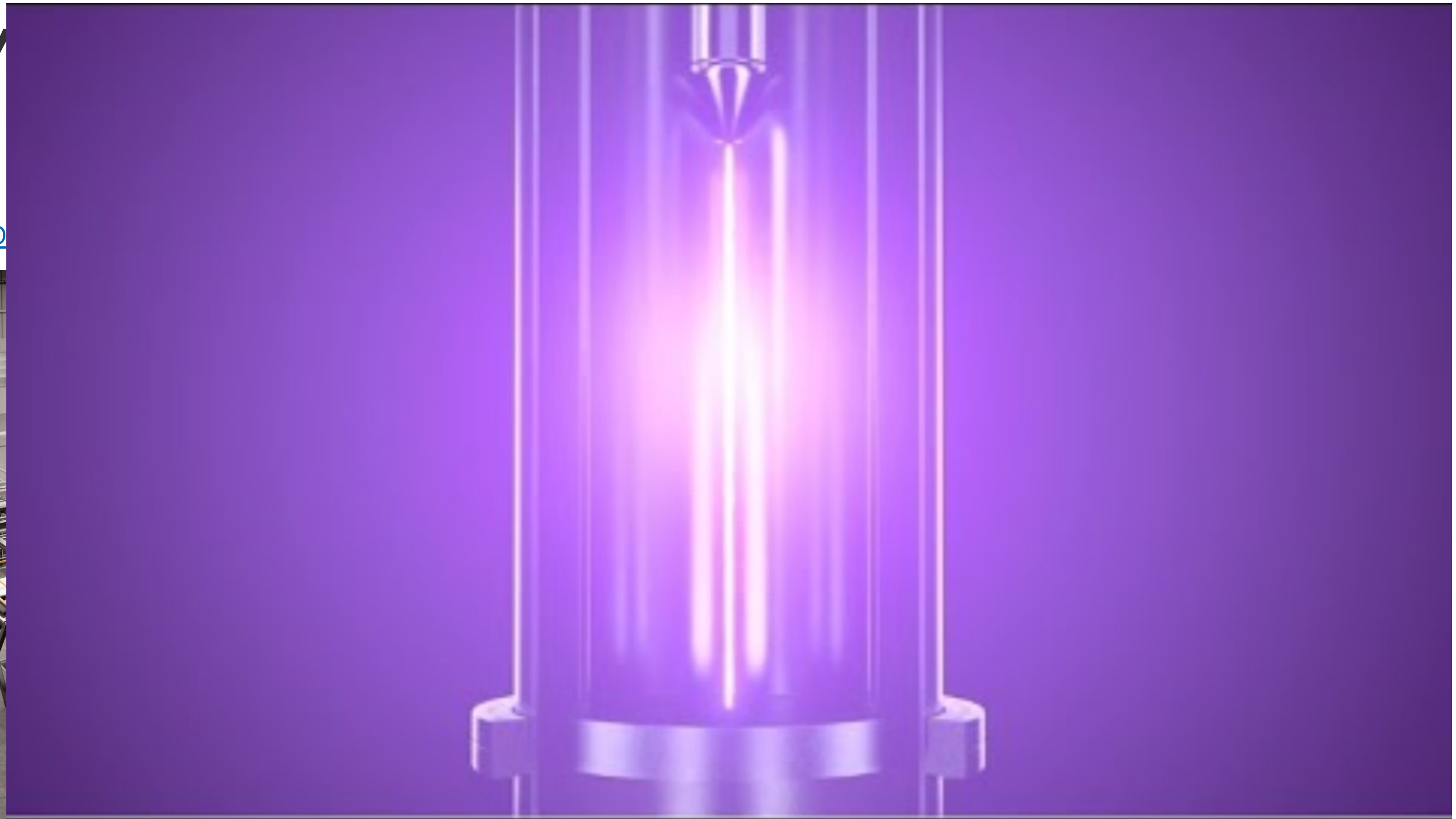


ZAP ENERGY

Zap Energy: Fusion po



Zap Energy's nuclear device brings US closer to limitless energy



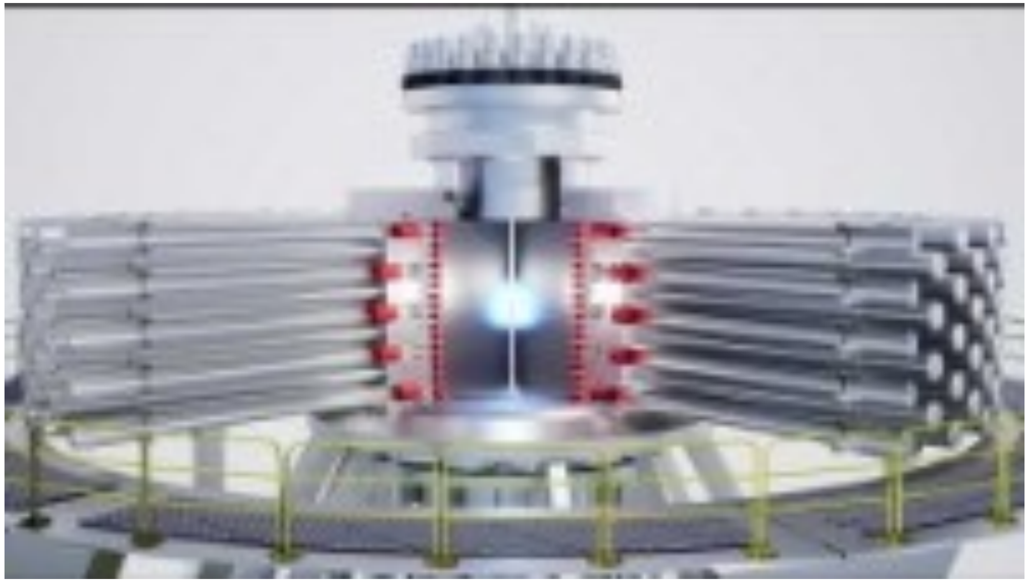
Zap Energy unveils fusion power plant tech, attracts $130M funding

United States

GENERAL FUSION: MAGNETIZED TARGET FUSION

Magneto-Inertial Fusion (D-T Fuel)

[Technology - YouTube]

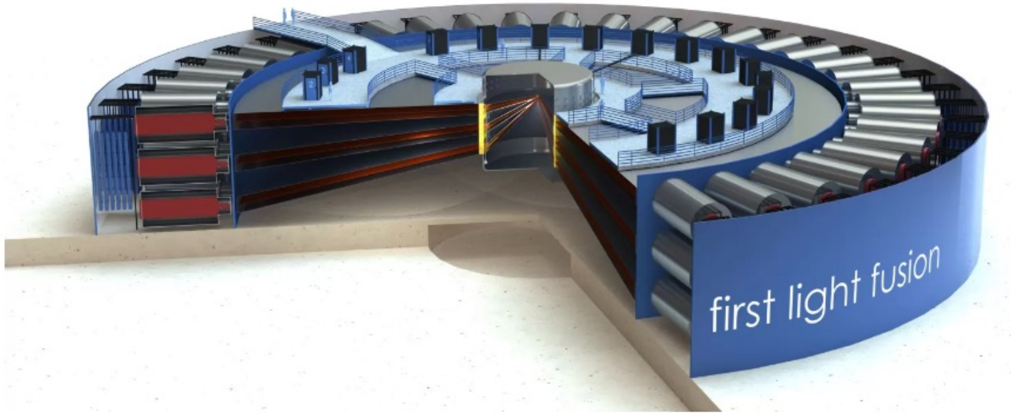


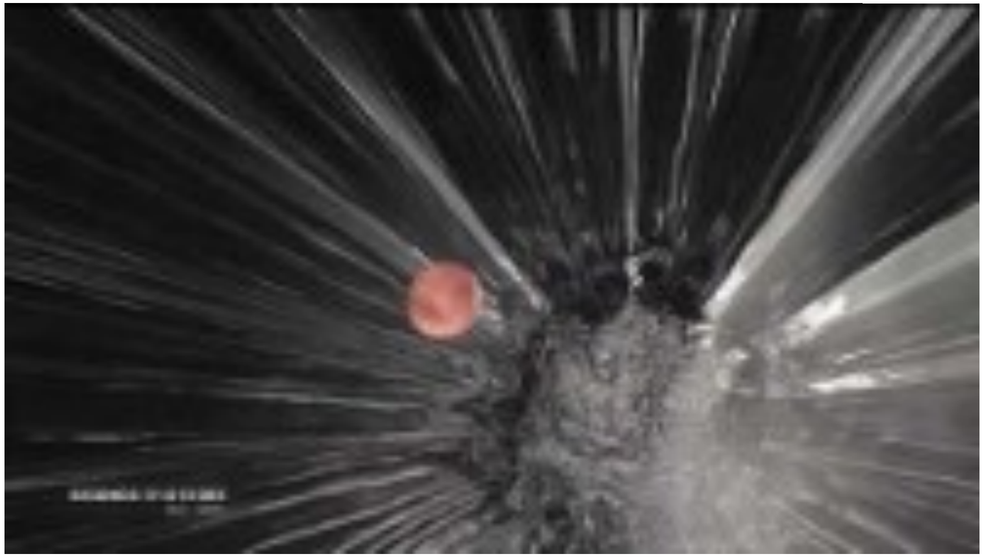
[General Fusion achieves plasma breakthrough - Nuclear Engineering International]

Canada

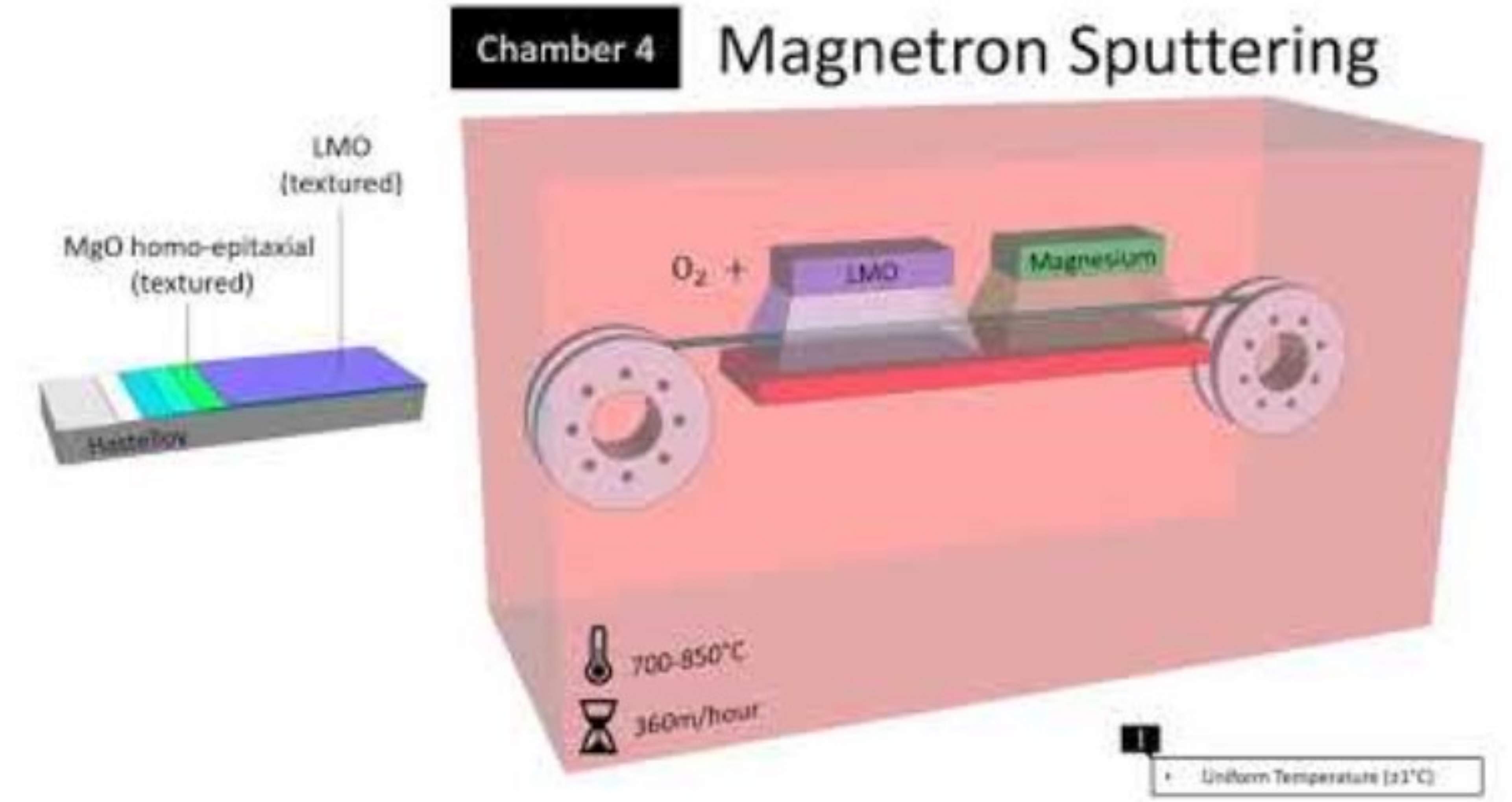
FIRST LIGHT FUSION (PROJECTILE FUSION)

[First Light reactor concept – YouTube](#)
[Projectile fusion – YouTube](#)

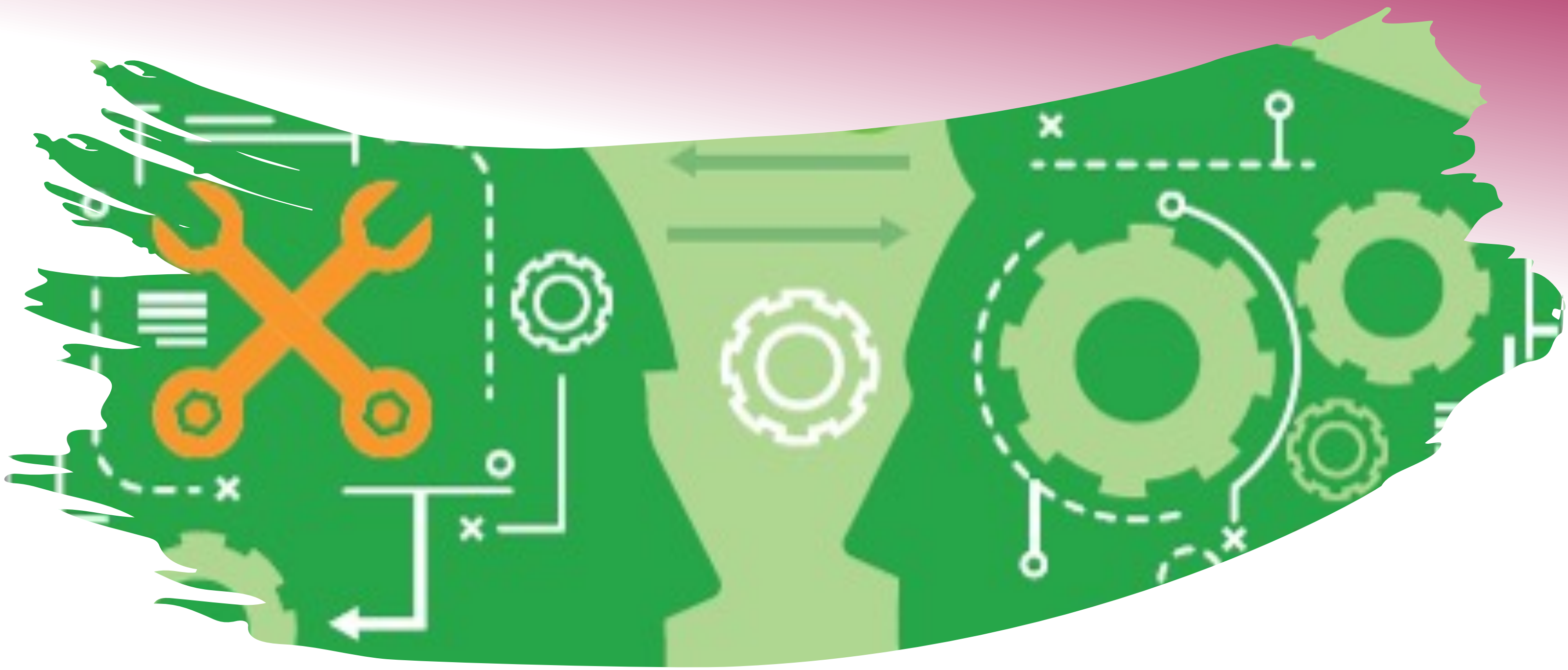




United Kingdom


Chamber 4
Magnetron Sputtering
LMO
(textured)
MgO homo-epitaxial
(textured)
Hastelloy
O_2 +
LMO
Magnesium
700-850°C
360m/hour
Uniform Temperature (±1°C)

France



Q&A

Thank you for your attention