EUROfusion

ICTP-IAEA Fusion Energy School 2026

How to operate a fusion device

Eva Belonohy

EUROfusion Consortium

UK Atomic Energy Authority

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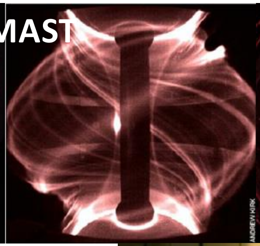
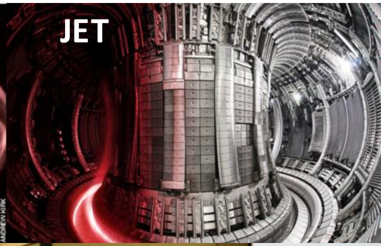
Background





Operational role in the control room

Session Leader (physics pilot) of ASDEX Upgrade, MAST and JET

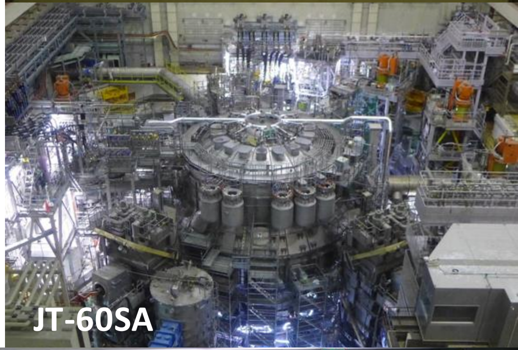
Background in Tokamak Operations

2009-11 Post-Doc in Tokamak Operation involving 6 European tokamaks

2012-19 European Operations Group of JET

- Operations management (scarce and machine resources, commissioning & campaigns)
- Responsible for the JET session leaders during campaigns incl. training
- Led the technical rehearsals for the JET tritium operations.

2019-22 EU Naka-site (deputy) leader and Operations leader of the EUROfusion contributions to JT-60SA Integration Commissioning and Operations



Current roles:

Coordinates Operations activities under EUROfusion

- Chair of the EUROfusion Operations Network
- Member of the ITER Operations Network

EUROfusion Training, Education and Knowledge Management

Outline

What is plasma operation?

- Tokamak product lifecycle
- Major and minor operational faults

Control room roles

- Operator roles
- Operation of various fusion devices

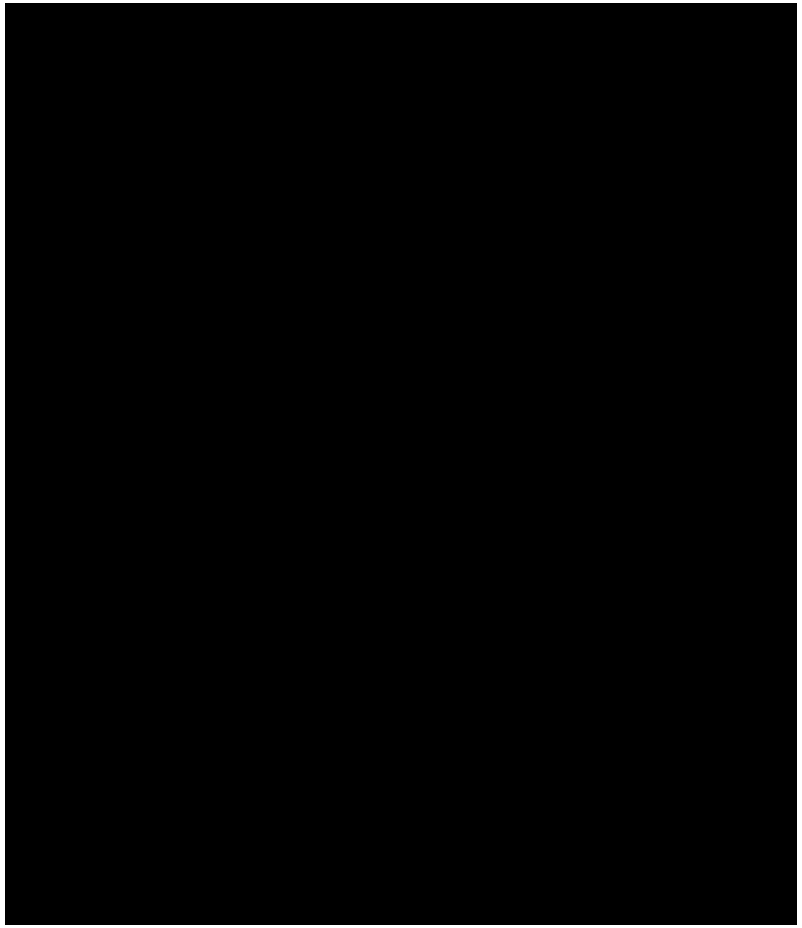
Safety and Protection

- Operating limits

Operation of future devices

What is Tokamak Operations?

Operation involves all activities following the manufacturing of a plant system, particularly plant commissioning (individual), integrated commissioning (joint), routine operation, maintenance, repair of various plant/hardware and software systems.



Objectives:

1. Provide the best conditions and most time for experiments

- High operational reliability and performance (-> JET has 80% availability in sessions)
- Plant performance increase (-> increase heating power, pellet survivor)
- Improve plasma reliability and performance (-> breakdown, scenario development)

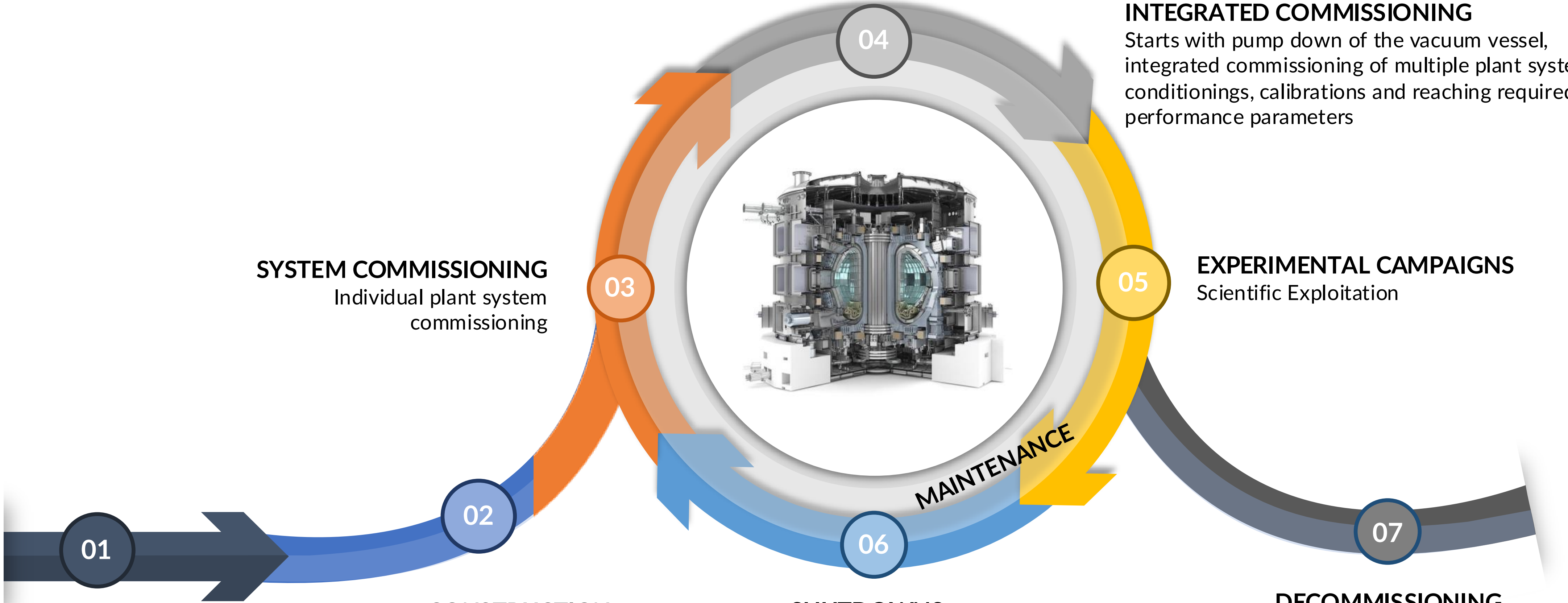
2. Do the experiments well – achieve scientific targets, many pulses

- Achieve the objectives of the scientific experiment with the least number of pulses
- Stay within machine and plasma constraints (operating limits, protection systems)
- Quick, accurate diagnoses of plasma and plant, improve next discharge

3. Do the experiments safely

- Protect the machine and the personnel

Tokamak Product Lifecycle Management (PLM) – as planned



INTEGRATED COMMISSIONING
Starts with pump down of the vacuum vessel, integrated commissioning of multiple plant systems, conditionings, calibrations and reaching required plant performance parameters

SYSTEM COMMISSIONING
Individual plant system commissioning

EXPERIMENTAL CAMPAIGNS
Scientific Exploitation

DESIGN
1. Feasibility and concept design
2. Preliminary design
3. Detailed design

CONSTRUCTION
1. Procurement
2. Manufacturing
3. Assembly

SHUTDOWNS
Plant enhancements, Repairs, (Regulatory) Inspections

DECOMMISSIONING
Following nuclear operation
&
REPURPOSING
Use of plant equipment, diagnostics in other devices or functionality

Tokamak Product Lifecycle Management (PLM) – as planned

Operation

04

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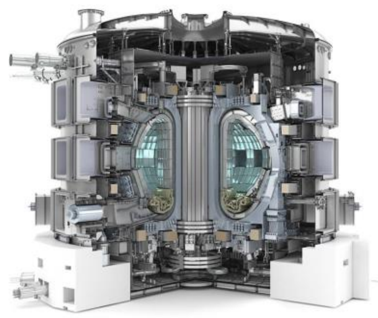
Starts with pump down of the vacuum vessel, integrated commissioning of multiple plant systems, conditionings, calibrations and reaching required plant performance parameters

03

SYSTEM COMMISSIONING
Individual plant system commissioning



05

EXPERIMENTAL CAMPAIGNS
Scientific Exploitation

MAINTENANCE

01

DESIGN

1. Feasibility and concept design
2. Preliminary design
3. Detailed design

02

CONSTRUCTION

1. Procurement
2. Manufacturing
3. Assembly

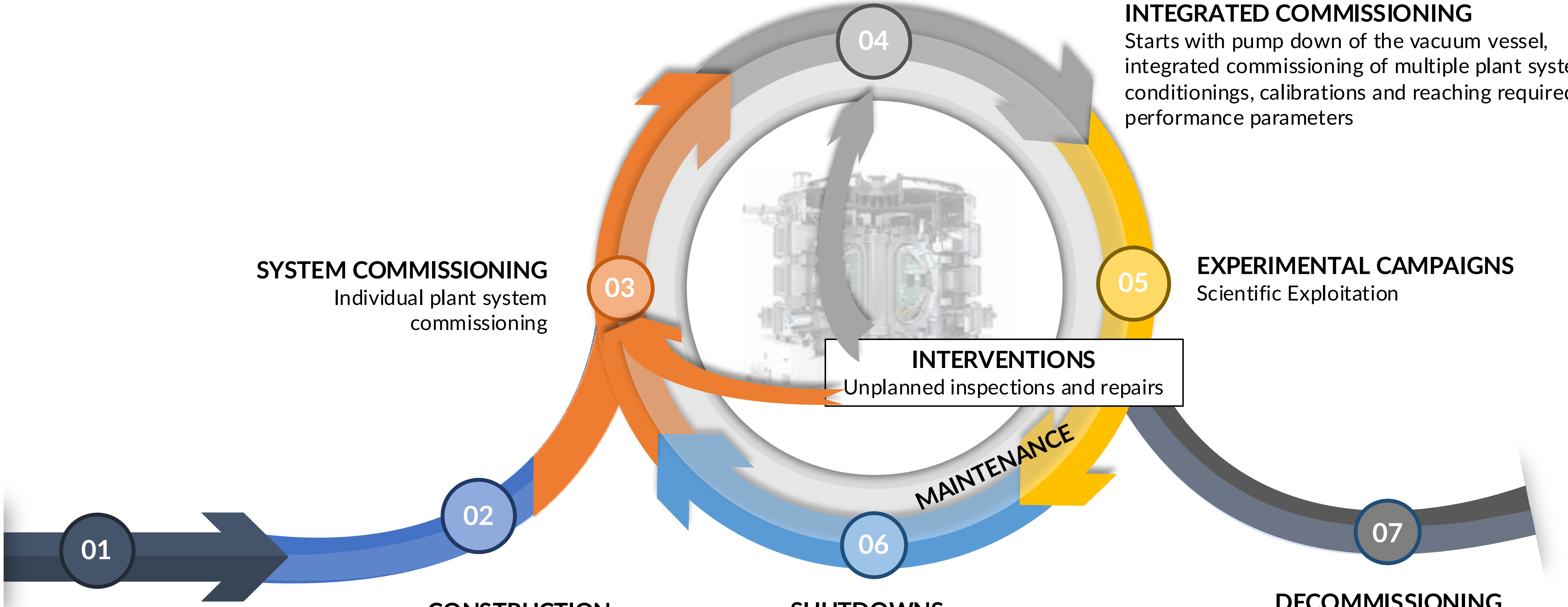
06

SHUTDOWNS
Plant enhancements, Repairs, (Regulatory) Inspections

07

DECOMMISSIONING
Following nuclear operation
&
REPURPOSING
Use of plant equipment, diagnostics in other devices or functionality

Tokamak Product Lifecycle Management (PLM) – unplanned



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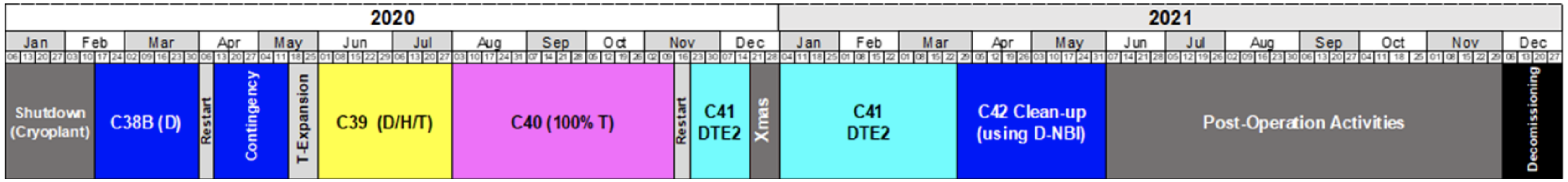
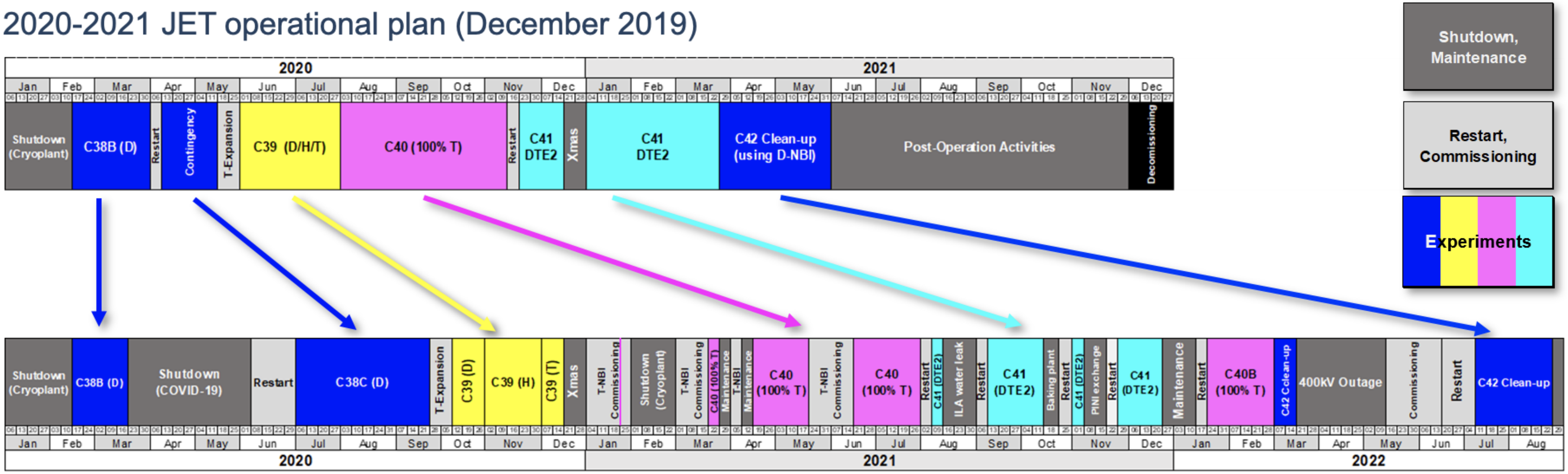
JET timeline – Plan vs. Reality

2020-2021 JET operational plan (December 2019)



JET timeline – Plan vs. Reality



2020-2022 actual JET timeline

Major delays:

Delay of the start of T-NBI commissioning (~2 months)

T-NBI commissioning (~4 months)

ILA water leak (4 weeks)

Baking plant water leak (2 weeks)

PINI exchange (3 weeks)

JET statistics 2000-2018

Q. What do you think, how much time is spent on shutdown, campaign and restart activities?

Q. What will be the distribution in future fusion reactors?

Q. Can you give an example of a major and minor fault?

JET statistics 2000-2018

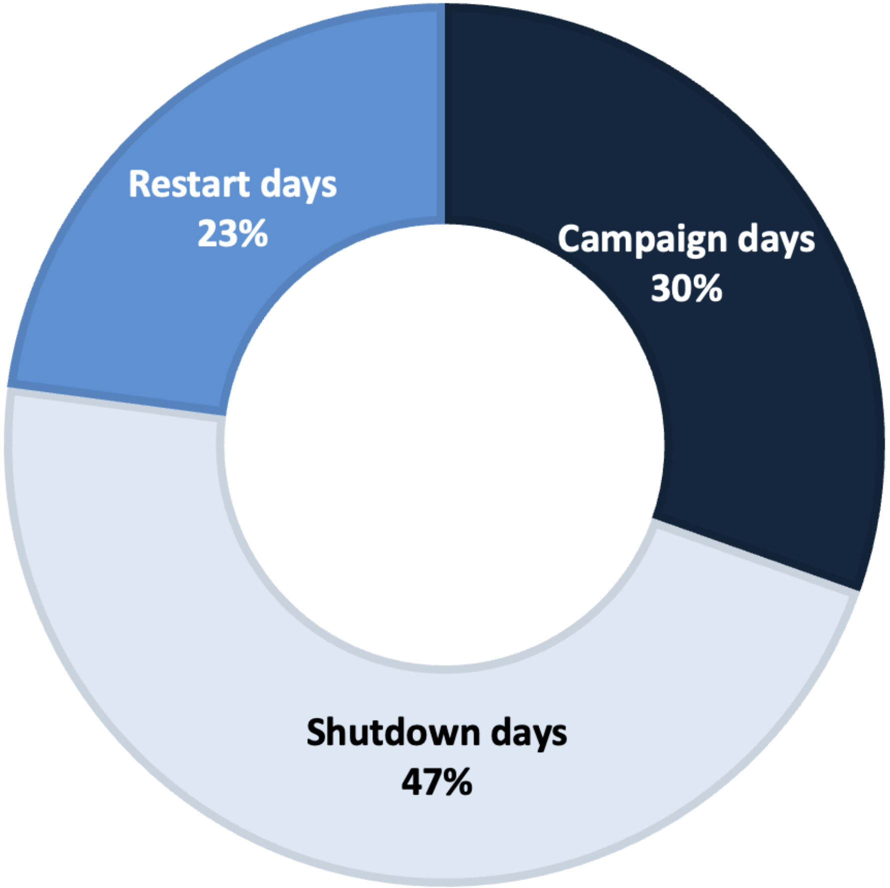
Q. What do you think, how much time is spent on shutdown, campaign and restart activities?

Q. What will be the distribution in future fusion reactors?

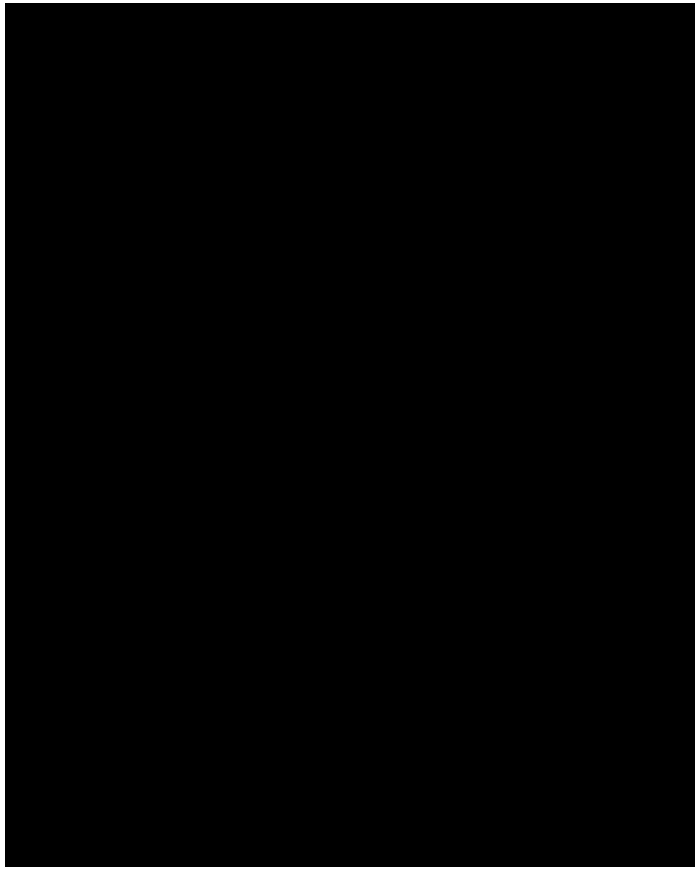
Operational availability = “plasma time”
Current devices: up to 1%
DEMO: design requirement is 30% (2600 hours / year)

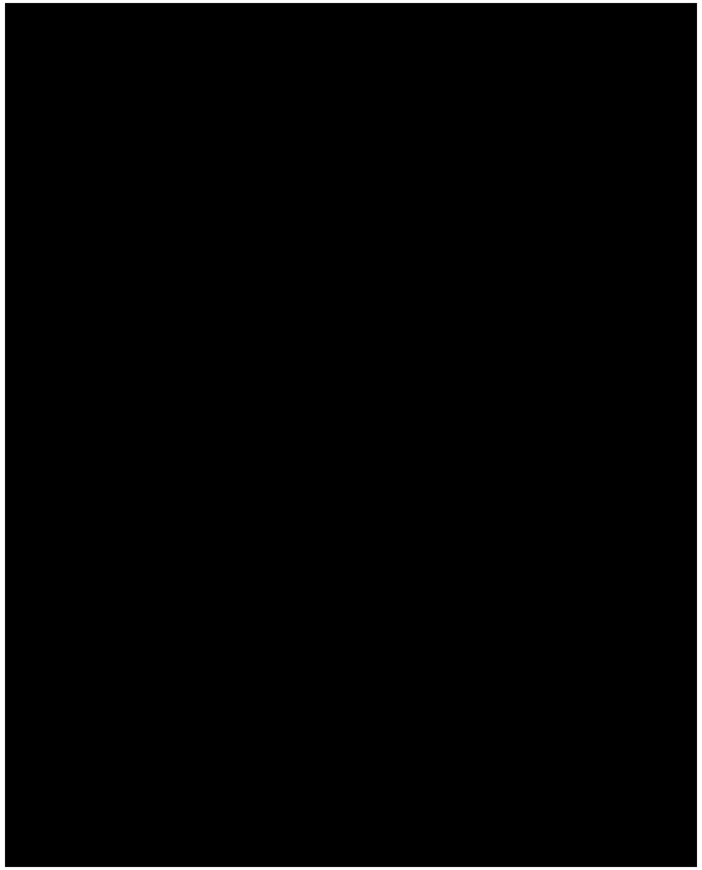
Q. Can you give an example of a major and minor fault?

JET operated at 80% system availability during campaigns. Thus, campaigns were organized with 20% contingency (extra sessions to recover experimental time lost due to faults).



Interventions – major faults





Q. Can you guess what happened here?

Interventions – major vs. minor faults

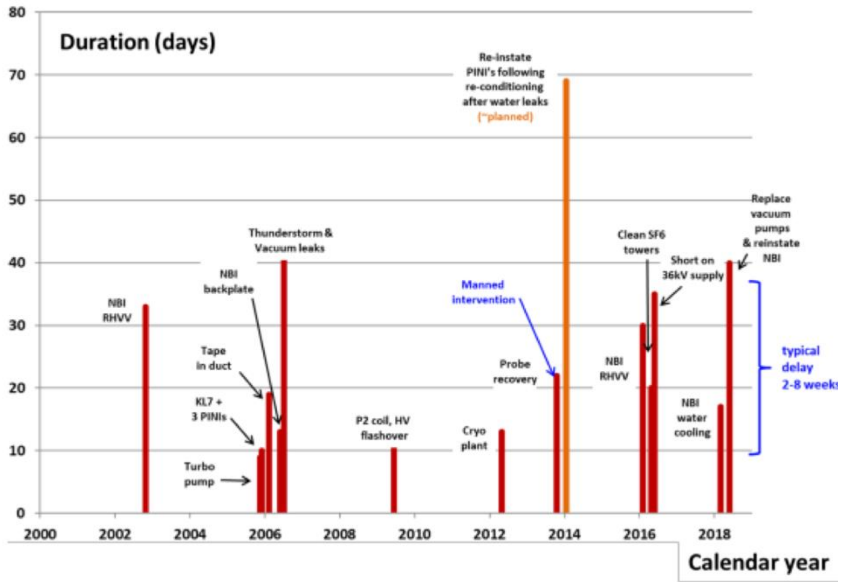
Major faults/incidents are often well remembered.

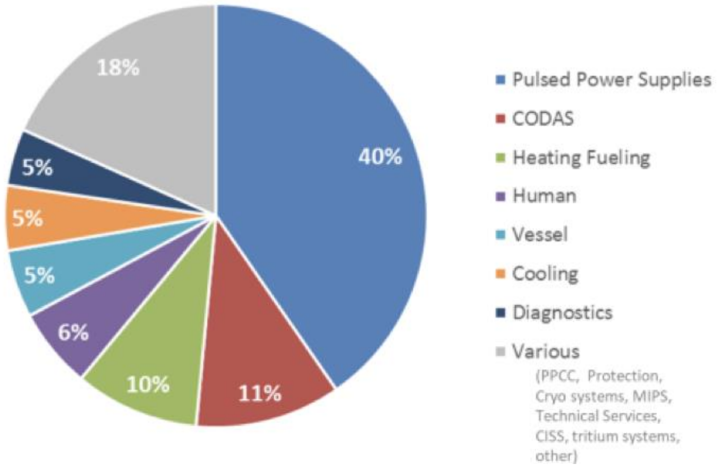
- Water leaks
- Oxygen leak during GDC
- Falling tiles or reciprocating probes

They often require stopping operations for several weeks as well as repeating the vacuum conditioning of the vessel (if the torus was exposed to air).

Minor faults or long operational processes occur repeatedly and can cause equally long delays although less noticeable.

- Delays due to gas species change
- Power supply issues.



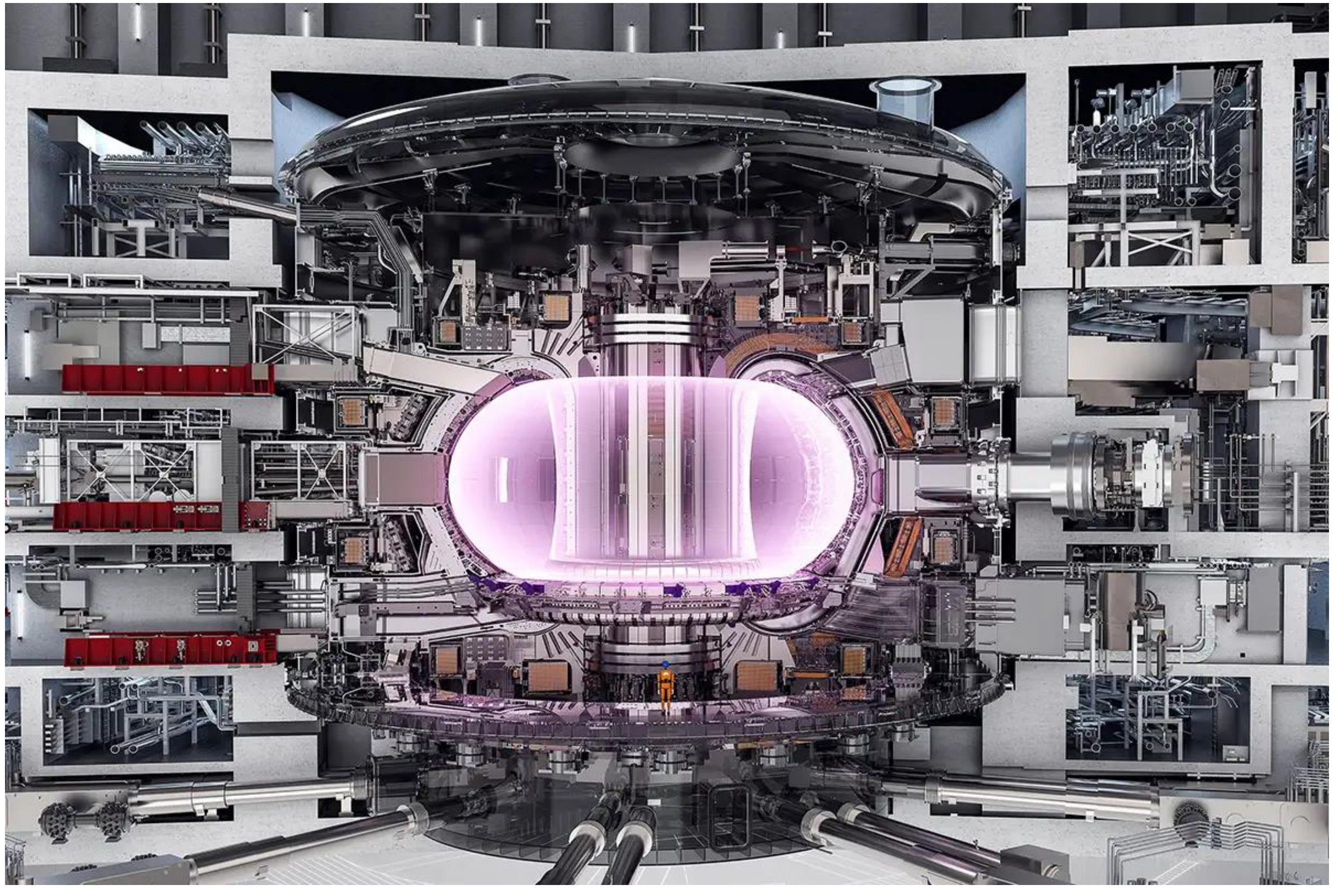


[G. Sips et al. (2018)]

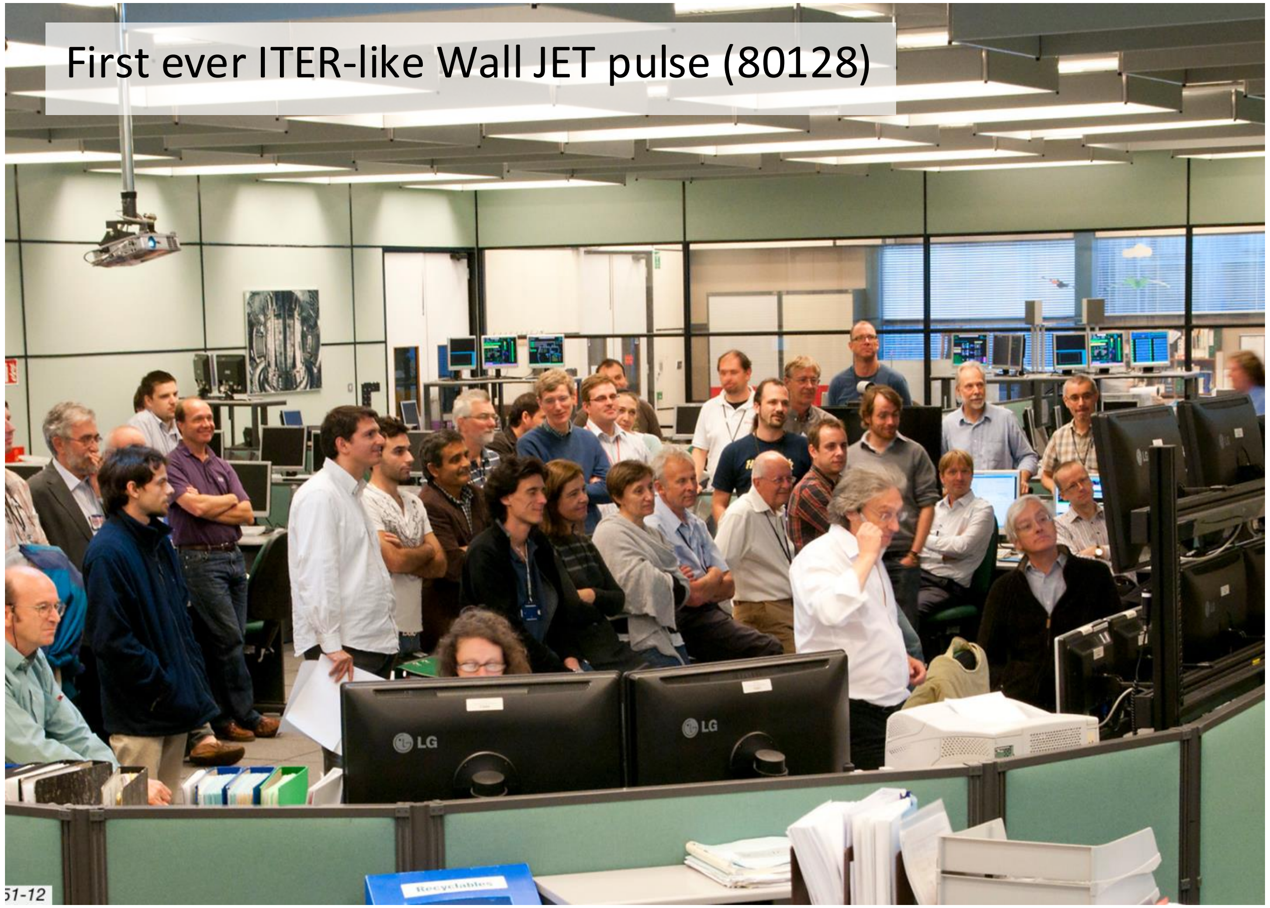
Operations teams

Operation of large-scale facilities can involve 30-50 roles, areas and ~ 500 people

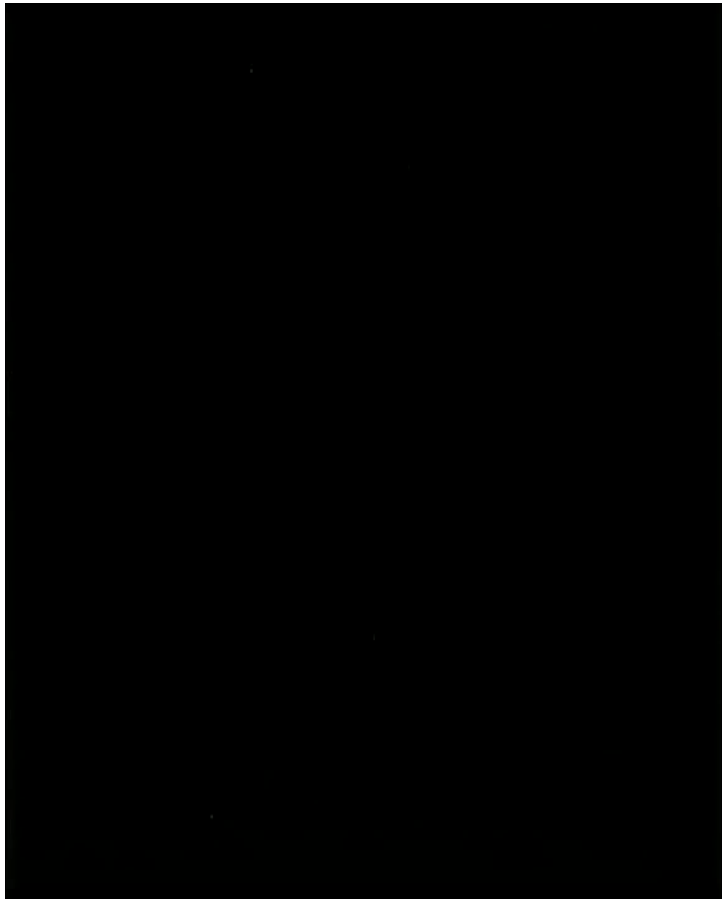
- Site services (water supply, etc.)
- Power supplies – magnets, heating systems
- Vacuum and gas (vacuum conditioning)
- Cryogenics
- Dedicated plants for beryllium, tritium
- Heating systems – NBI, ECRH, ICRH, LH
- Pellets
- Diagnostics
- **Plasma operations**
- Real-time Control (plant, protection
- systems, scientific real-time networks)
- IT systems (CODAS/CODAC)
- Disruption mitigation (DMV, SPI)
- Maintenance services
- Safety (personnel and machine)
- Health physics, safety case
- Protection systems
- Waste management



Control room – a team effort

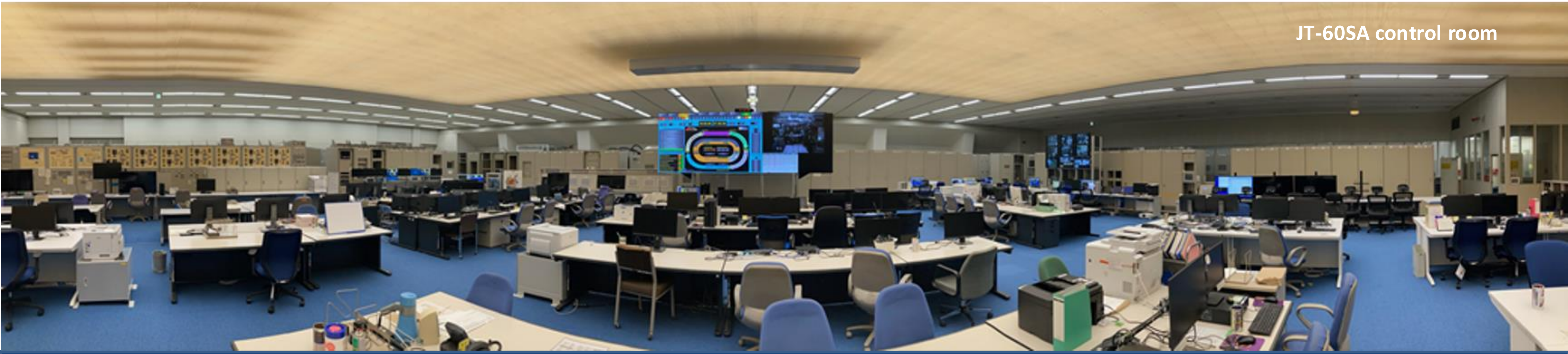


First ever ITER-like Wall JET pulse (80128)



Control room

Scientific roles	Engineering roles
Physics pilot: Session Leader	Lead engineer
Lead diagnostician	**Shift Technician** (always there, all systems)
Scientific Coordinator	Power supplies
Cameras	Heating systems
Real-time control	Pellets
Diagnosticians	Vacuum
Scientists	Cryogenic systems, pumps
Experts for MHD, TRANSP, …	Safety
Disruption experts	IT systems



Role of the Physics Pilot (Session Leader at JET)

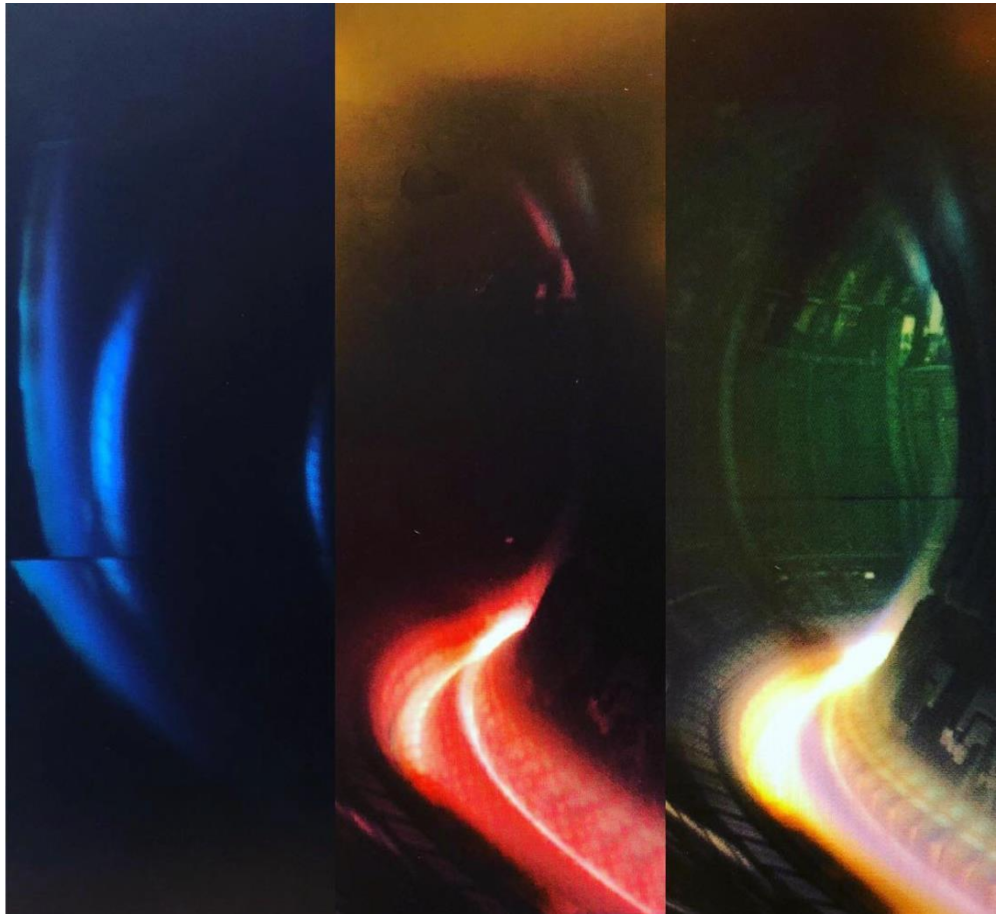
Session Leader (SL): physics pilot of a tokamak responsible for development of a pulse schedule based on discussion with the scientific coordinator. Manages the scientific roles in the control room and is the lead scientific contact to engineering competences.

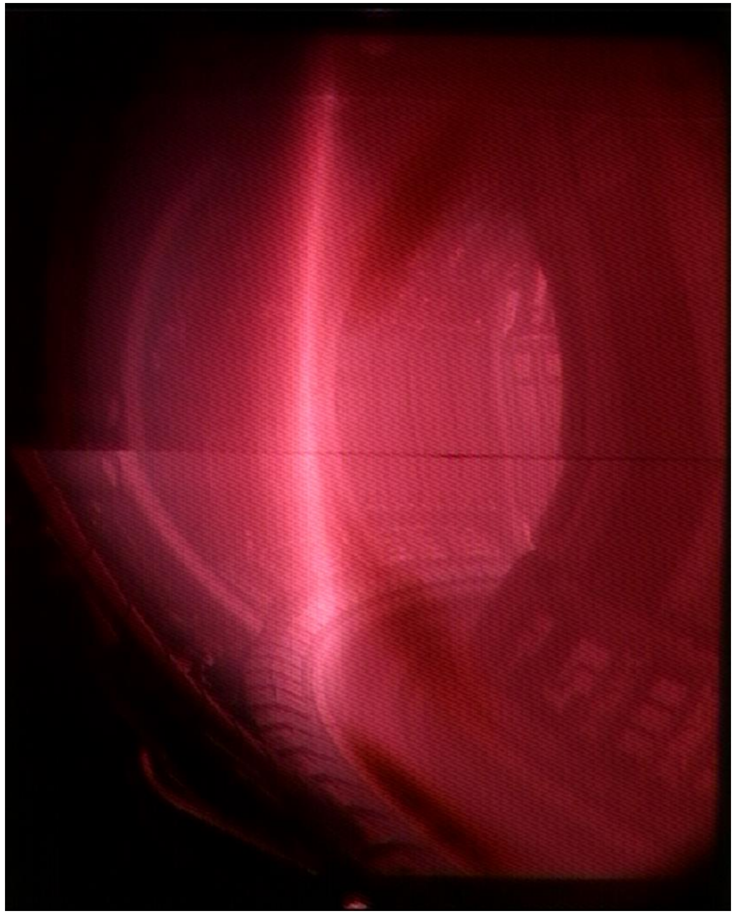
JET SL Training:

1. 1-2-week(s) course every few years since 1995
2. Practical control room training as SL2 (Optimal: 1 session/week)
3. Licensing based on plasma current & disruption force
4. Continuous training with seminars, forums, email updates (ensure exposure/awareness to current issues and solutions)

Machine/License	Time to license	No. of shifts to obtain license
Small device / Full	Weeks	
Medium device / Full	Months	
JET / license A (Ip<2MA)	1+ year	21 (13-43)
JET / license B (Ip<3MA)	1+ year	15 (8-22)
JET / Full (Ip<4MA)	1+ year	22.5 (21-24)
JET / Expert	10+ years	

Special Operations



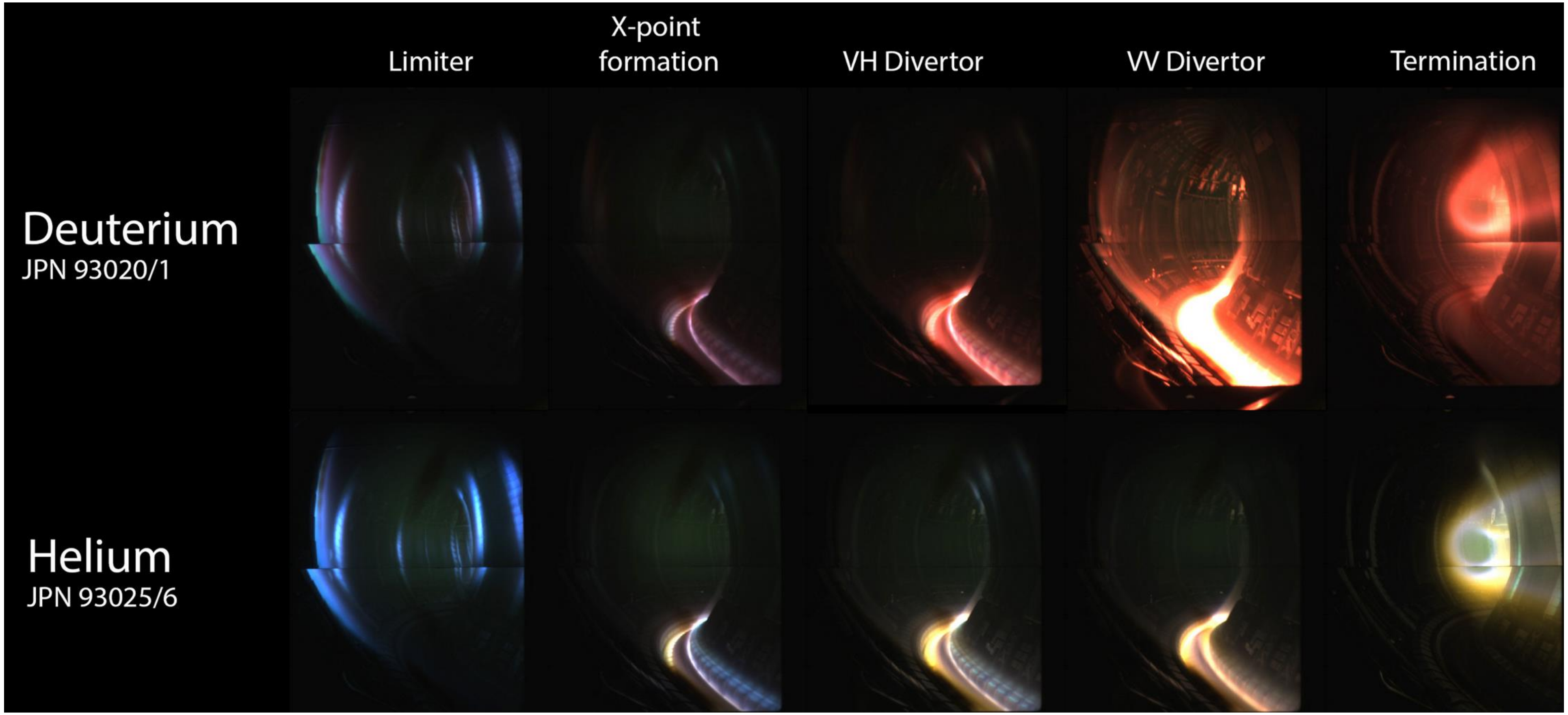


Q. Can you guess what happened in these pictures?

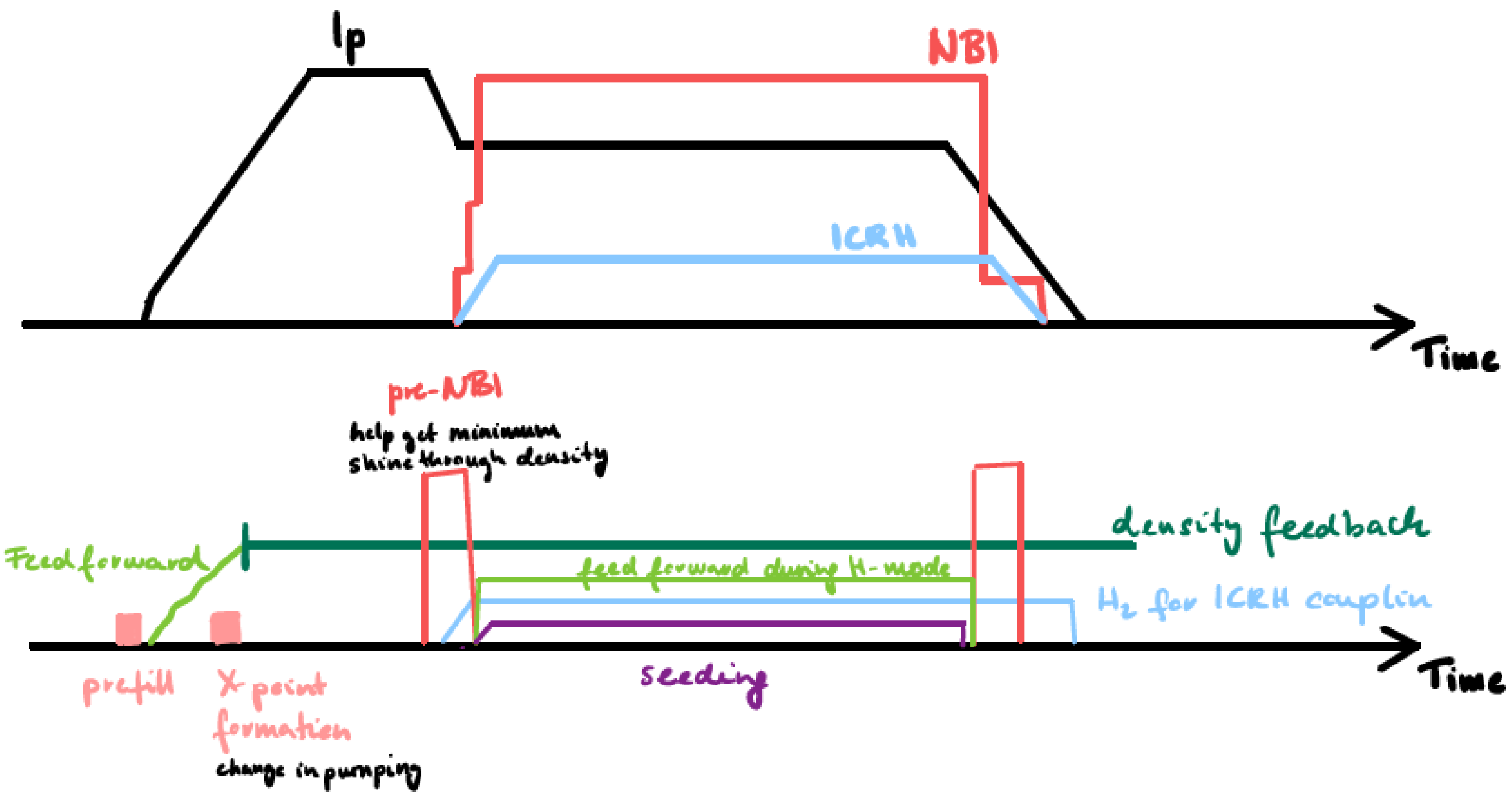
Q. Can you guess the highest plasma current achieved on JET?

Special Operations

1. Highest plasma current reached on JET was 7MA (before the installation of the divertor)
2. ICRH resonance line at given magnetic field in an Ion Cyclotron Wall Conditioning discharge
3. Helium plasma discharge (blue – limiter, green – divertor) vs. Deuterium (salmon pink)



Setup plasma discharge



Edit the plasma discharge:

- Reference pulse,
- Main parameters - I_p, B_t, n_e
- **Shape**
- Breakdown and ramp-up
- **Heating** – NBI, ECRH, ICRH
- **Fueling** - Gas and pellet
- Protection systems and termination
- Control

Direct other operators:

- Diagnostics
- Real-time control
- Plant systems

Operating Instructions

UNCONTROLLED COPY UNLESS STAMPED 'CONTROLLED COPY' IN RED

JET FACILITY OPERATION INSTRUCTION	No. 5.3 Issue 20/11 Page 1 of 1	ISSUED NOVEMBER 2020	VALIDITY From **04.11.2020** until further notice

NECESSARY PLASMA DIAGNOSTICS

The following plasma diagnostics are mandatory to ensure compliance with various Operation Instructions according to the nature of the pulses to be run. The EiC must ensure that they have been flagged "Essential".

The requirement for KH1 to be essential may be overridden where the session leader has agreed that the plasma configurations have a low likelihood of generating runaway electrons and when approved via MO13. In this case the EiC should ensure that the KH1 RO is informed.

Plasma Configuration	Diagnostic	Computer
1. Dry Run	Magnetics: KC1D	DA
2. Plasmas without any additional heating (NBI, ICRH, LHCD) or pellets	Magnetics: KC1D Neutrons: KN1 Note 1 Runaways: KH1 Density: KG1 or KS3. Expert session leaders can run these plasmas without validated density. A wide angle, visible view must be available in real time to the SL and EiC.	DA DD DD DF(DD) DA
3. Plasmas with additional heating other than lower hybrid	Magnetics: KC1D Neutrons: KN1 Note 1 Runaways: KH1 Density: KG1 and KS3 Divertor thermocouples: KD1D A wide angle, visible view must be available in real time to the SL and EiC. IR systems and pyrometers as required by OI 2.6.	DA DD DD DF(DD) DB DA
4. Plasmas with additional heating including lower hybrid (see O.I 4.12 for KT2 and KB5V)	Magnetics: KC1D Neutrons: KN1 Note 1 Runaways: KH1 Density: KG1 and KS3 Divertor thermocouples: KD1D Bolometers: KB5V VUV spectroscopy: KT2 A wide angle, visible view must be available in real time to the SL and EiC. The KL10-P4LA camera view must be available in real time to the LH operators. IR systems and pyrometers as required by OI 2.6.	DA DD DD DF(DD) DB DB DF DA

Note 1: When a 14 MeV neutron budget is set in the Machine Configuration Overview, KM7D neutron diagnostic (on computer DD) must also be set essential.

Responsible Officer: K-D Zastrow	Torus ATO Holder: R Marshall	Chief Engineer: M Porton	Senior Manager: J Milnes	JET Exploitation Manager: C Ibbott

JET Operating Instructions (JOIs): define soft and hard operating limits as agreed with

- the Machine Protection Working Group,
- the Responsible Officer of the plant system
- Chief Engineer and
- the European Commission representative*.

Exceptions can be negotiated above the soft but below hard limits using blue and gold forms.

Let's look at limitations related to gas as an example…

Q. What gas limits can you think of?

JET Operating Instruction 5.3 –
Essential diagnostics for JET operations

JET Operating Instructions – Maximum Gas Limits

Explosive Gas Limit: limit of hydrogen isotope gas in the torus and NBI systems that can potentially explode during a loss of vacuum incident (incursion of oxygen).

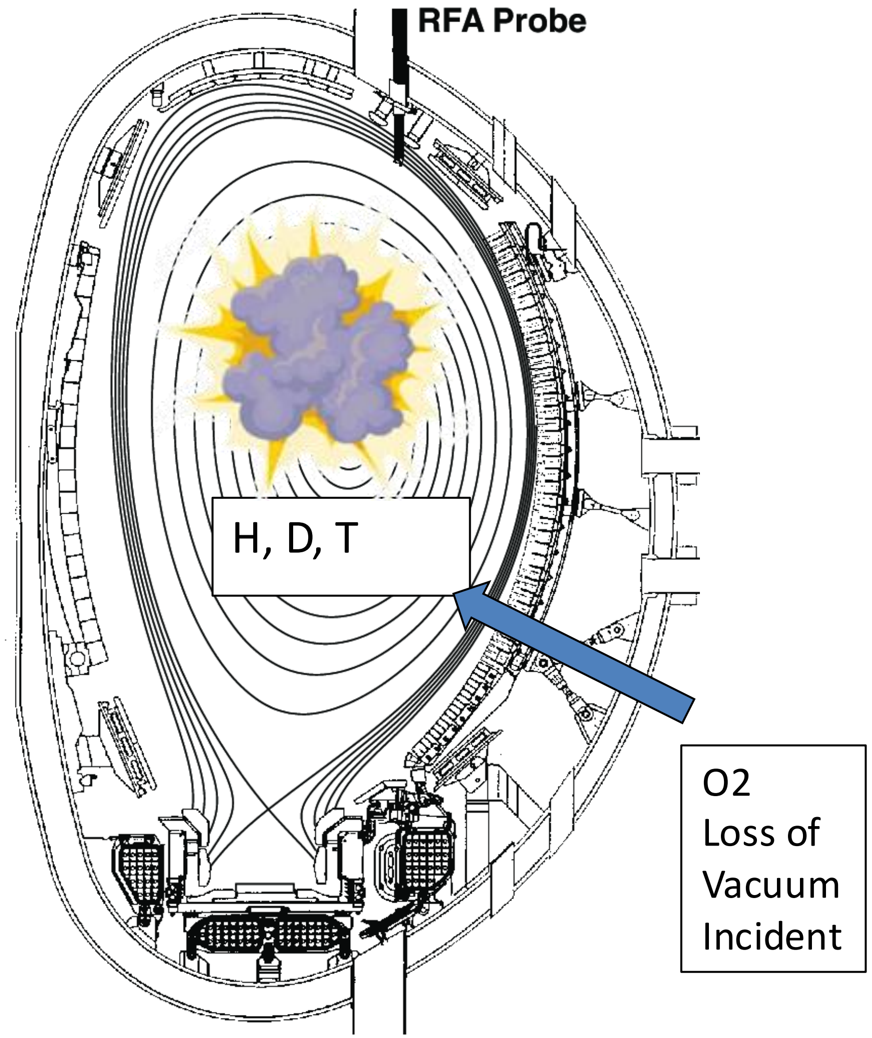
- Limits how much can be injected before the cryo pumps need to be regenerated (heated up to remove the collected hydrogen gas).

  Limit = 3 x 330barl D2 to torus and the 2 NBI systems

Implementation:

- Pre-session gas estimate (default 150barl) -> approval
- Pre-pulse estimate – worst case scenario with maximum opening of feedback gas valves
- Post-pulse gas inventory

ITER: sequential cryo regeneration during pulses for the torus, but not for the NBI cryopumps



JET Operating Instructions – Minimum Gas Limits

Minimum gas limits:

- **for ICRH coupling:** minimum hydrogen gas for ICRH coupling to avoid fast particle generation.

  -> Session Leader responsibility

- **For NBI shinethrough:** minimum density to allow absorption of the NBI power and limit damage to inner wall.

  -> real-time density check of approved list of diagnostics

- **Avoidance of runaway electron generation at the plasma start:** gas requirement at the plasma startup to avoid conditions that can generate runaway electrons that can damage the inner wall.

  -> pre-pulse check

Table 1: Fundamental (N = 1) hydrogen minority heating scheme in D, T, DT or He^4 plasmas

Line integrated density measured by KG1V/LID3 (or equivalent as advised by the KG1 RO)	P = RF coupled power (ICRH/PTOT)	H concentration
$n_eL < 0.5\times10^{20}$ m^{-2}	P < 0.5 MW	No restriction, the natural level of H in the machine is enough
	0.5 MW < P < 4 MW	> 4 %
	P > 4 MW	> 6 %
0.5×10^{20} m^{-2} < $n_eL < 1\times10^{20}$ m^{-2}	P < 0.5 MW	No restriction, the natural level of H in the machine is enough
	0.5 MW< P < 5 MW	> 2 %
	P > 5 MW	> 4 %
$n_eL > 1\times10^{20}$ m^{-2}	P < 6 MW	No restriction, the natural level of H in the machine is enough
	P > 6 MW	> 2 %

Standard Alignment Normal Bank for Deuterium Beams

Maximum Beam Energy (keV)	Notch Min Ne (10^{18}m^{-2})	Pulse Min Ne (10^{18}m^{-2}) for Pulse Length t (s)						
		0<t≤1	1<t≤2	2<t≤5	5<t≤7.5	7.5<t≤10	10<t≤15	15<t≤20
80	18	5	9	15	17	19	21	23
90	20	13	19	25	28	29	32	34
100	24	22	29	36	39	41	43	46
110	39	36	44	52	55	57	60	63
115	44	41	49	58	61	63	66	69
125	53	53	61	70	74	76	79	83

Standard Alignment Tangential Bank for Deuterium Beams

Maximum Beam Energy (keV)	Notch Min Ne (10^{18}m^{-2})	Pulse Min Ne (10^{18}m^{-2}) for Pulse Length t (s)						
		0<t≤1	1<t≤2	2<t≤5	5<t≤7.5	7.5<t≤10	10<t≤15	15<t≤20
80	24	24	30	38	42	45	49	53
90	28	30	38	47	51	54	59	63
100	37	37	46	56	60	64	69	74
110	50	45	55	66	71	75	81	86
115	55	48	59	71	76	80	86	91
125	62	56	67	80	86	90	97	104

What to take away from Operations?

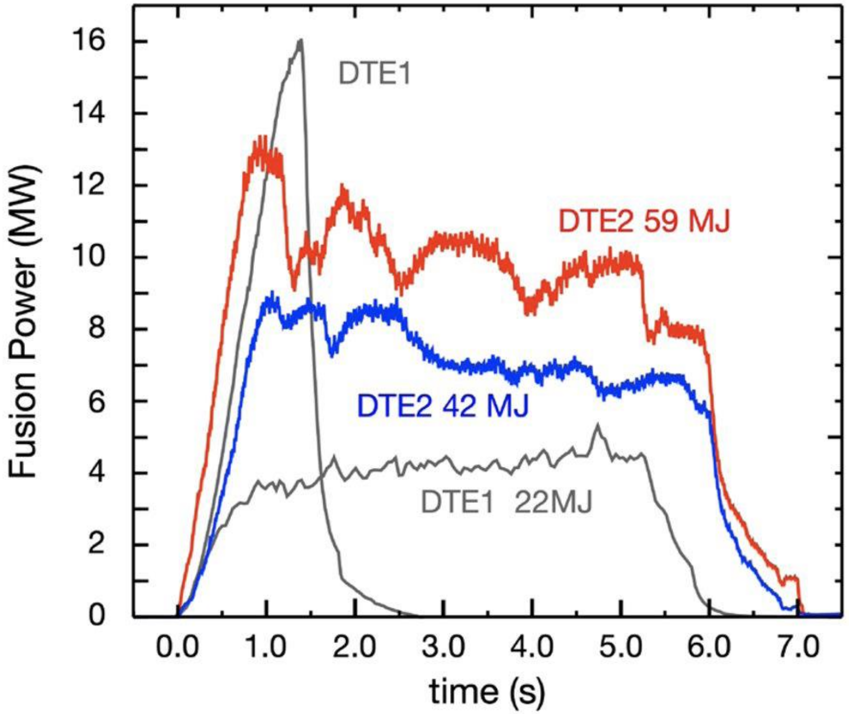
Understanding the plant and plasma limitations, boundary conditions can enable you to

- develop better experimental proposals, support session preparation (exploit plant system to the highest performance)
- work better with the operators (provide relevant information, know your options)
- build connection with diagnosticians and operators to better understand what happened in the pulse, how to avoid it.
- get big picture view of a plasma discharge, quick and efficient analysis of discharge components and interactions

Learn time management, prioritization and work as a team

- Find the right reference pulse -> particularly important for dimensionless scaling experiments
- Use first pulse of the session as reference -> Compare if conditions are the same when pulses spread across multiple experimental days. Standard H-mode as first plasma pulse at ASDEX Upgrade every day.
- Know the next two pulses. -> Plan ahead what your next pulse is going to get more good pulses in the session.
- Change as little from pulse to pulse as you can -> for optimal comparisons -> breakdown, ramp-up often kept the same

Special Operations – DT



M. Maslov *et al*., accepted for publication in Nuclear Fusion

J. Hobirk *et al*., accepted for publication in Nuclear Fusion

Backup

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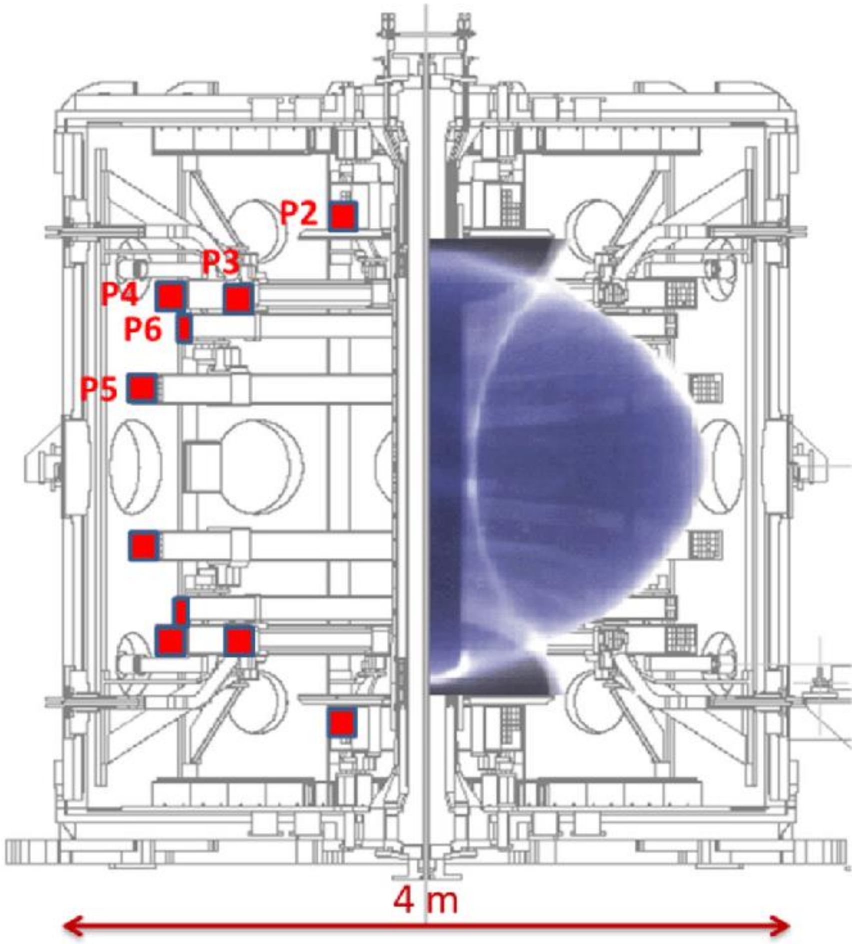
Are all tokamaks run the same way?

Mega Ampere Spherical Tokamak (MAST) – operator impression (small)

- Short 0.5s plasmas -> NBI power has to come up within 50ms
- (Almost) all plasmas disrupt -> at Ip~1MA not a problem
- Poloidal field coils inside Carbon first wall vessel
  - -> density feedback very difficult
  - -> 7-minute GDC between every pulse
- Power supplies shared with JET – cannot operate at the same time
  - -> JET has absolute priority, does not know about MAST operations
  - -> “Race” JET as big brother for pulses
- 2-shift operation but at normal working hours (9.00-18.00)
  - -> Wake up at normal hours, can catch the train home
  - -> Can eat in the control room, have lunch at the desk
- Small operations team, less and lower risk damaging the tokamak
  - -> Engineer and technician start up machine in the morning
  - -> If all okay, plasma operator runs three roles (lead physicist, engineer and technician) – even pushing red button to start the plasma discharge
- Use of the DIII-D plasma control system and discharge editor



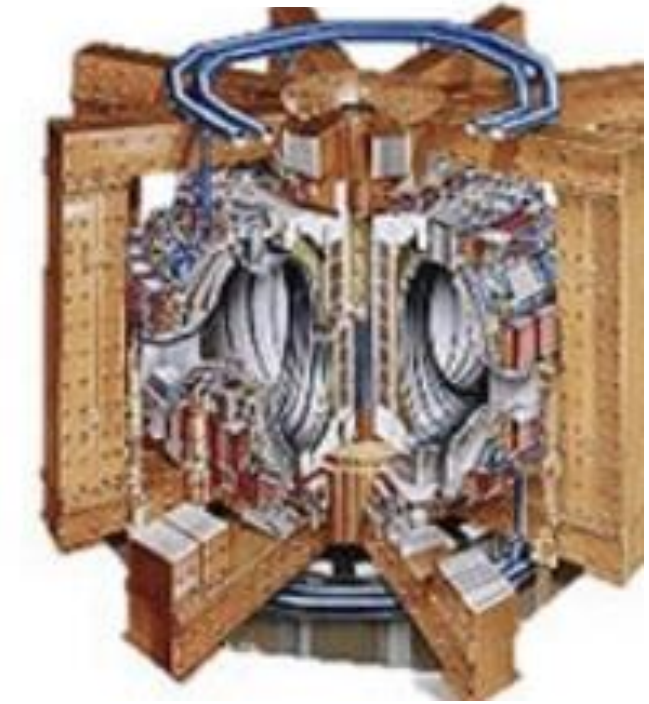
Are all tokamaks run the same way?

ASDEX Upgrade – operator impression (medium)

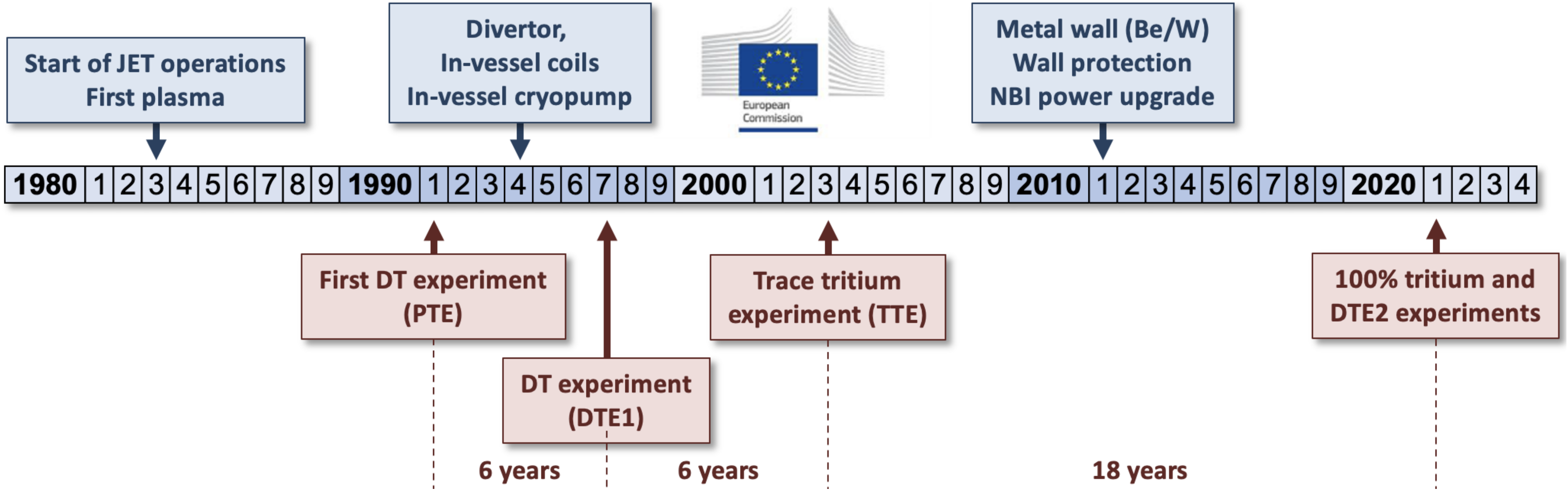
- Still ~1MA plasmas for <10s, but high heating power (NBI, ECRH, ICRH), W-wall
- Only programme the flattop phase using a table-based discharge editor.
- Ramp-up, ramp-down, terminations and protections are pre-set or from a predefined list.
- 2 experiment leaders, pulses were often prepared during the session.
- Worked on a number of "good pulses" instead of sessions.
- Operation in German. 2 sessions per day, 2-3 days a week.
- Faults are quick to repair and recondition the device.

Joint European Torus (JET) – operator impression (large)

- High current (up to 4MA) -> defined operating instructions, limits, checks.
  - Disruption mitigation valve required in protection mode >2MA, disruption checks.
  - Conditioning following disruptions are not often required (Beryllium first wall)
- Scarce resource (gas, high Bt, neutron …) approval and request for dedicated operators
- Session preparation weeks in advance -> pulse preparation few hours days before.
- Session Leader programmes all discharge phases including 3-5 pages of protection system responses and up to 7 different termination scenarios.
- 2-shift operation 5(-6) days a week (Shift 1: 6.30-14.30, Shift 2: 14.00 – 22.00)
- All time scales are slower – isolations, fault recovery, commissioning, time between pulses



Special Operations – JET tritium operation

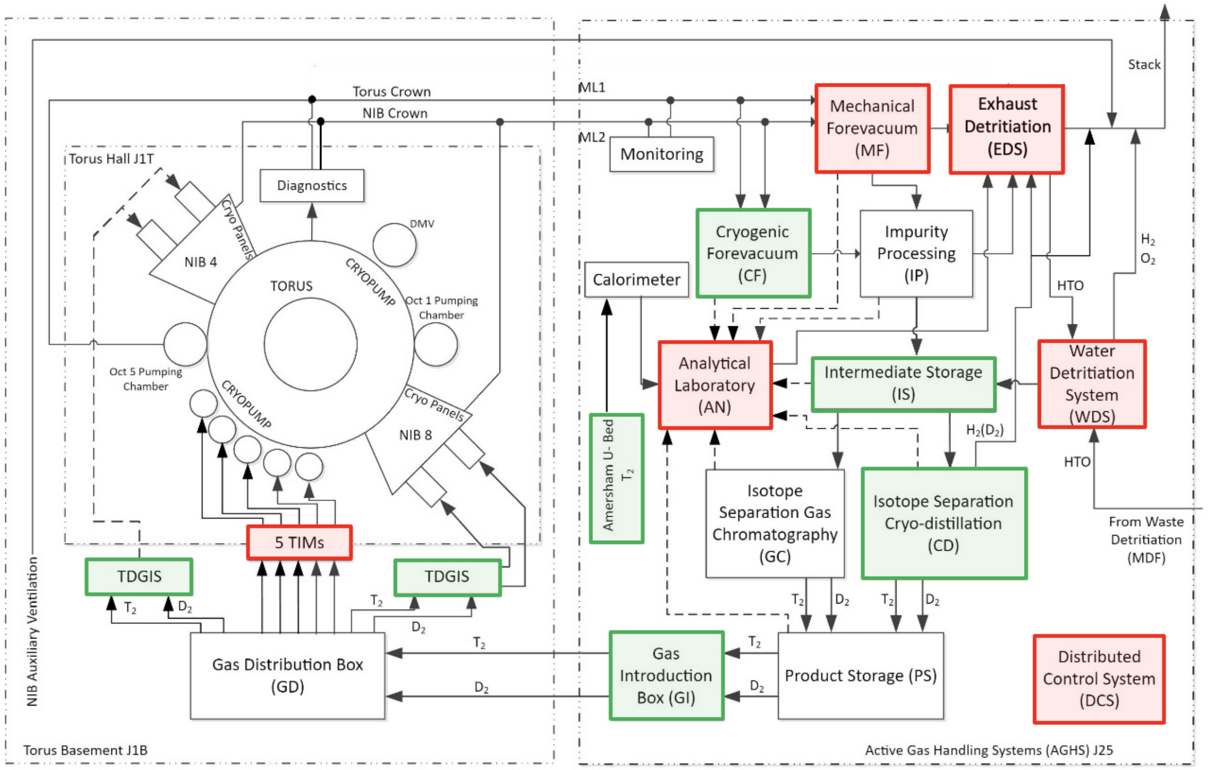


Q. What systems and processes do you need to operate with Tritium?

Special Operations – JET tritium operation – Tritium handling

- Device designed and built to be suitable and compatible with tritium operations (e.g. secondary gas containment). An already build fusion device cannot be upgraded to handle tritium.

- **Active gas handling system (AGHS)** responsible for the storage, distribution, recovery, analysis and processing of tritium gas and deuterium/tritium mixtures.



New components:

- Exhaust detritiation system
- Mechanical forevacuum
- Analytical laboratory
- Water detritiation system
- Control system
- Tritium introduction modules (TIMs)

Extensive upgrades:

- Amersham uranium beds
- Cryogenic forevacuum
- Intermediate storage
- Cryo-distillation
- Gas introduction box
- NBI tritium and deuterium modules (TDGIS)

Special Operations – JET tritium operation - Diagnostics

Real-time near-IR cameras for protection of the metal first wall (Be)

DD operation:

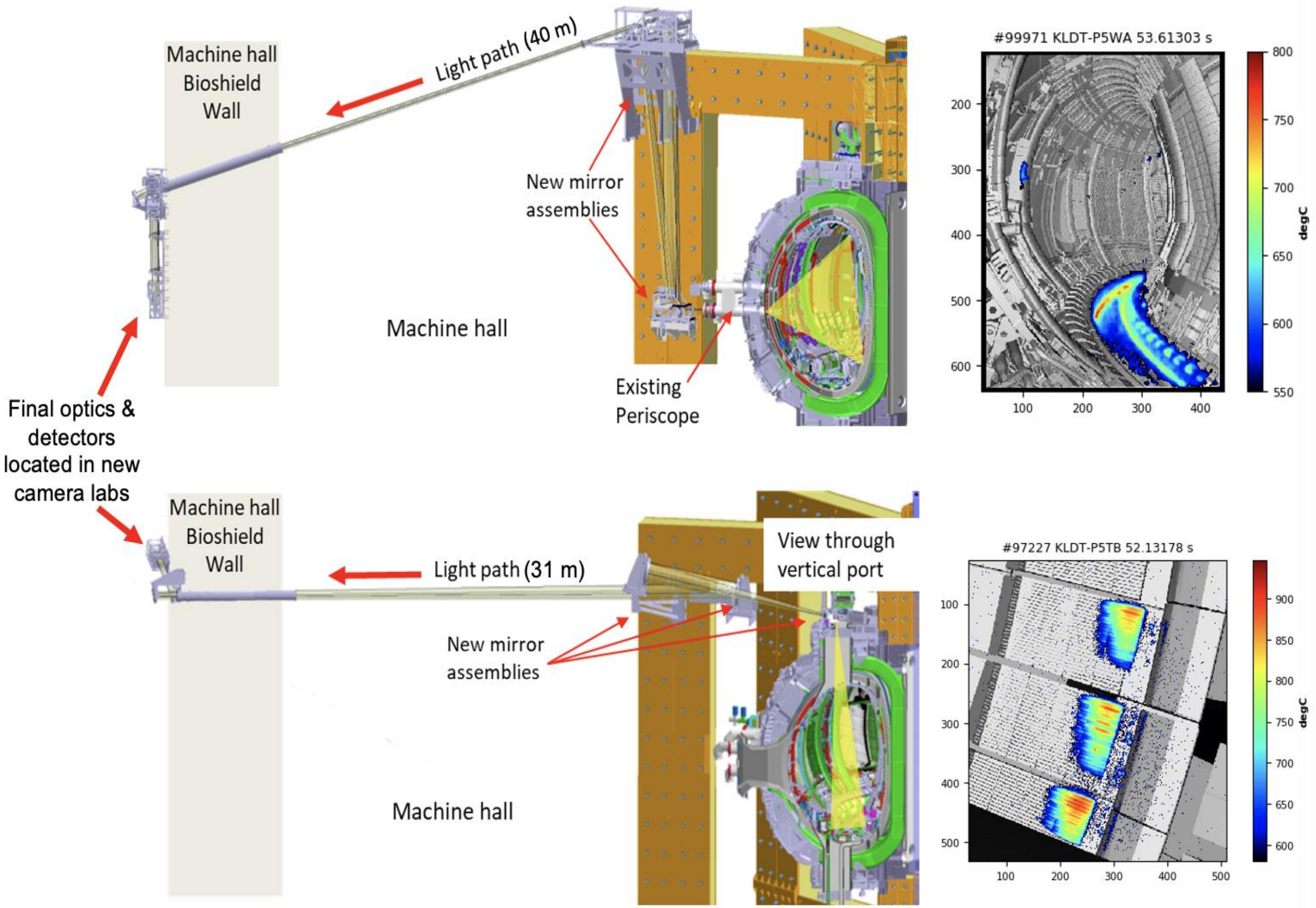
~30 cameras sharing 9 imaging views

➔ not radiation tolerant before DTE2

DT operation:

- Cameras were moved outside of the biological shield
- 2 views for wide angle & divertor

All diagnostics were reviewed,
some removed or used until possible.

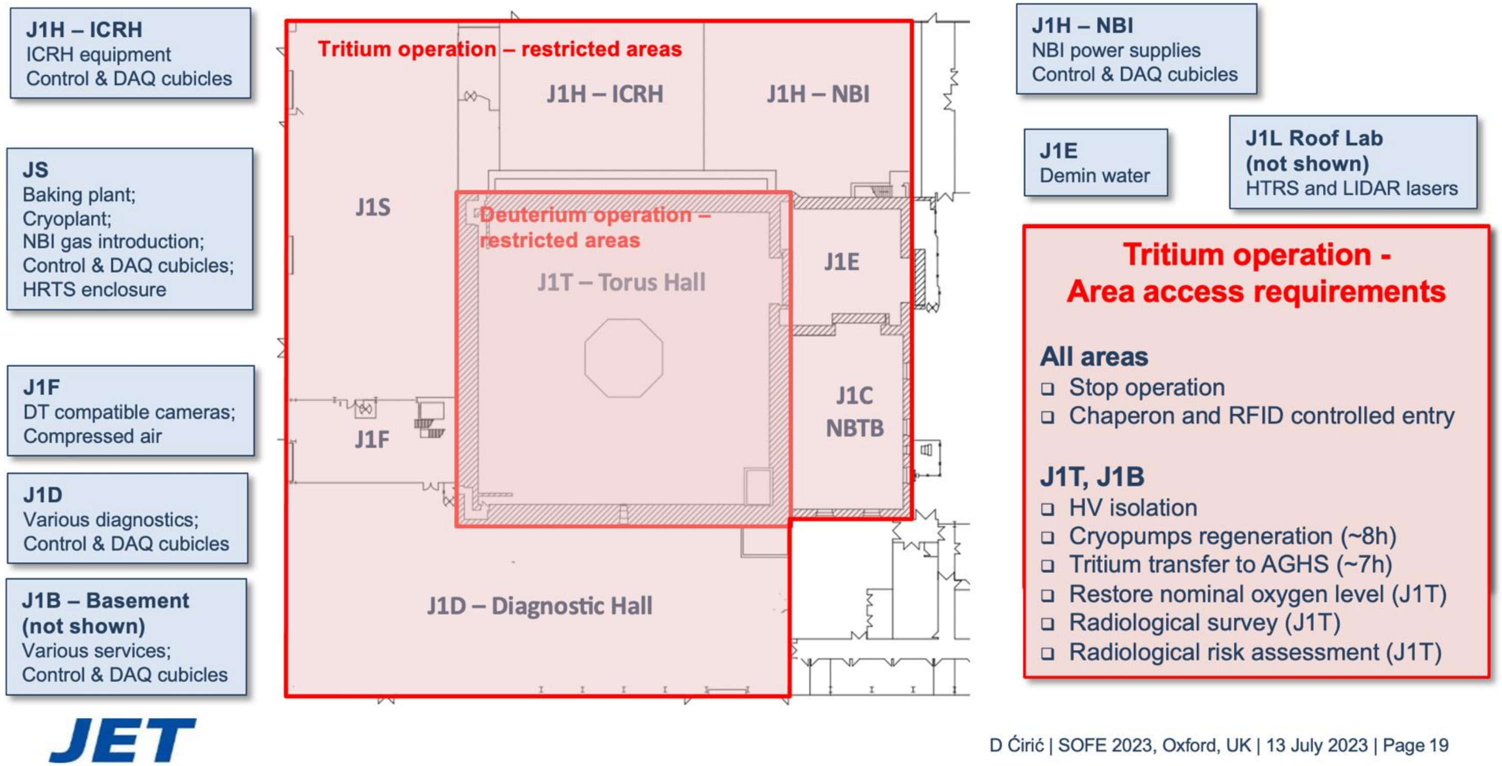


Special Operations – JET tritium operation - Safety

DT safety case revision to review and update fault scenarios.

How to deal with potential leaks, radiation, fire?

- Access restriction
- Torus hall atmosphere depression (pressure difference)
- Torus hall depletion (reduce O2 level to avoid open fire until tritium is pumped back to Active Gas Handling System to allow access to area)

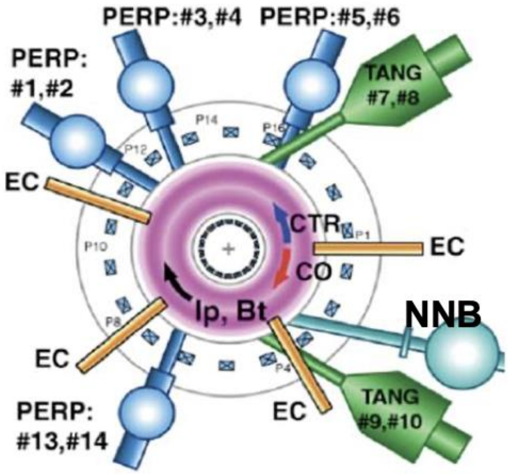


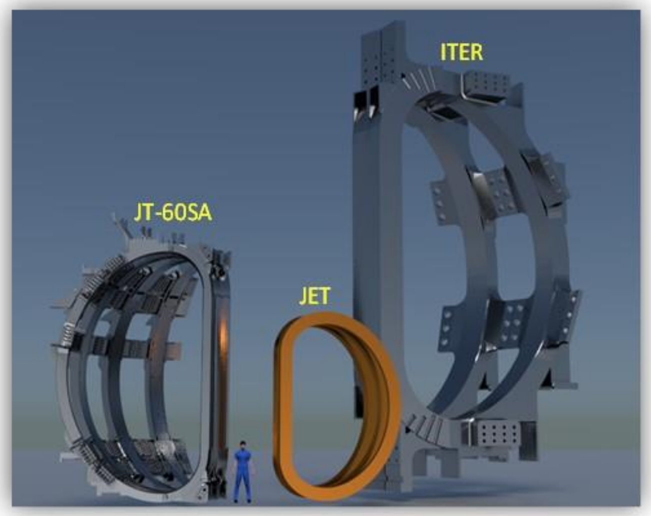
Operation of future devices – JT-60SA

Superconducting coils -> Long pulse operation (JET 10s -> JT-60SA 100s)

High current and triangularity shape at large scale

-> High confinement (similar to JET but with Carbon first wall, both with Tungsten divertor at later stages)





High electron and flexible heating:

- Positive NBI (85 keV, 24 MW) system
- Negative NBI (500 keV, 10 MW) system
- ECRH (7MW 100s @ 110/138GHz, 1s @82GHz)

-> Energetic particles, ITER & DEMO scenarios, control

(JET P-NBI, ICRH, LH only vs. JT-60SA much needed N-NBI & ECRH)

Parameters	JET	JT-60SA	ITER
Major radius [m]	2.96	~3.0	~6.2
Minor radius [m]	1.25	<1.18	<2
Plasma current [MA]	(<4.8)	<5.5	<15
Toroidal field [T]	4	<2.3/NbTi	<5.3/Nb3Sn
Plasma volume [m3]	~100	~140	~840
Pulse length [s]	~10	~100	>400

Pellet and MGI system, (SPI under discussion) (similar to JET)

Error field correction coils & resistive wall mode control coils, stabilizing plates (not available at JET)

Route to ITER!

Tokamak Product Lifecycle Management (PLM) – as planned

Joint European Torus (JET)

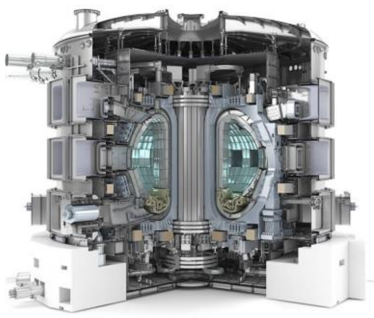
- Joint European experiment funded by the European Commission
- 40 years of operations
- Originally planned for 10 years
- 100k+ pulses

25/6/1983 – 1st JET plasma

04

INTEGRATED COMMISSIONING
Starts with pump down of the vacuum vessel, integrated commissioning of multiple plant systems, conditionings, calibrations and reaching required plant performance parameters

"Restart" – 8-24 weeks



03

SYSTEM COMMISSIONING
Individual plant system commissioning

05

EXPERIMENTAL CAMPAIGNS
Scientific Exploitation

1983 – 2023
42 campaigns in 23 years

MAINTENANCE

1973 -

01

DESIGN
1. Feasibility and concept design
2. Preliminary design
3. Detailed design

1977 -

02

CONSTRUCTION
1. Procurement
2. Manufacturing
3. Assembly

06

SHUTDOWNS
Plant enhancements, Repairs, (Regulatory) Inspections

Few months – 2 years

07

DECOMMISSIONING
Following nuclear operation
&
REPURPOSING
Use of plant equipment, diagnostics in other devices or functionality

2024 – (2036)
12 years
17 projects

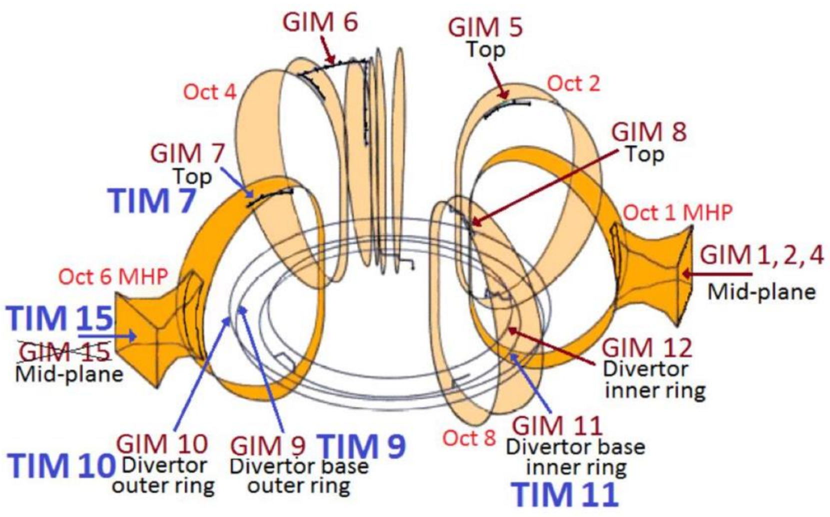
JET gas setup

Species during Campaign	Deuterium	Hydrogen	Tritium
Prefill	D_2	H_2	H_2
Main plasma species	D_2	H_2	T_2
Pellets	D_2	H_2	H_2
Disruption mitigation*	D_2+10% Ar	H_2+10%Ar	H_2+10%Ar
Shattered pellet injector	D_2 with Ar, Ne	H_2 with Ar, Ne	-
RF minority	H_2, ^4He, ^3He	D_2, ^4He, ^3He	H_2, ^4He, ^3He
Seeding	N_2, Ne, Ar	N_2, Ne, Ar	**N_2 not allowed**, Ne, Ar

Consider **function**:

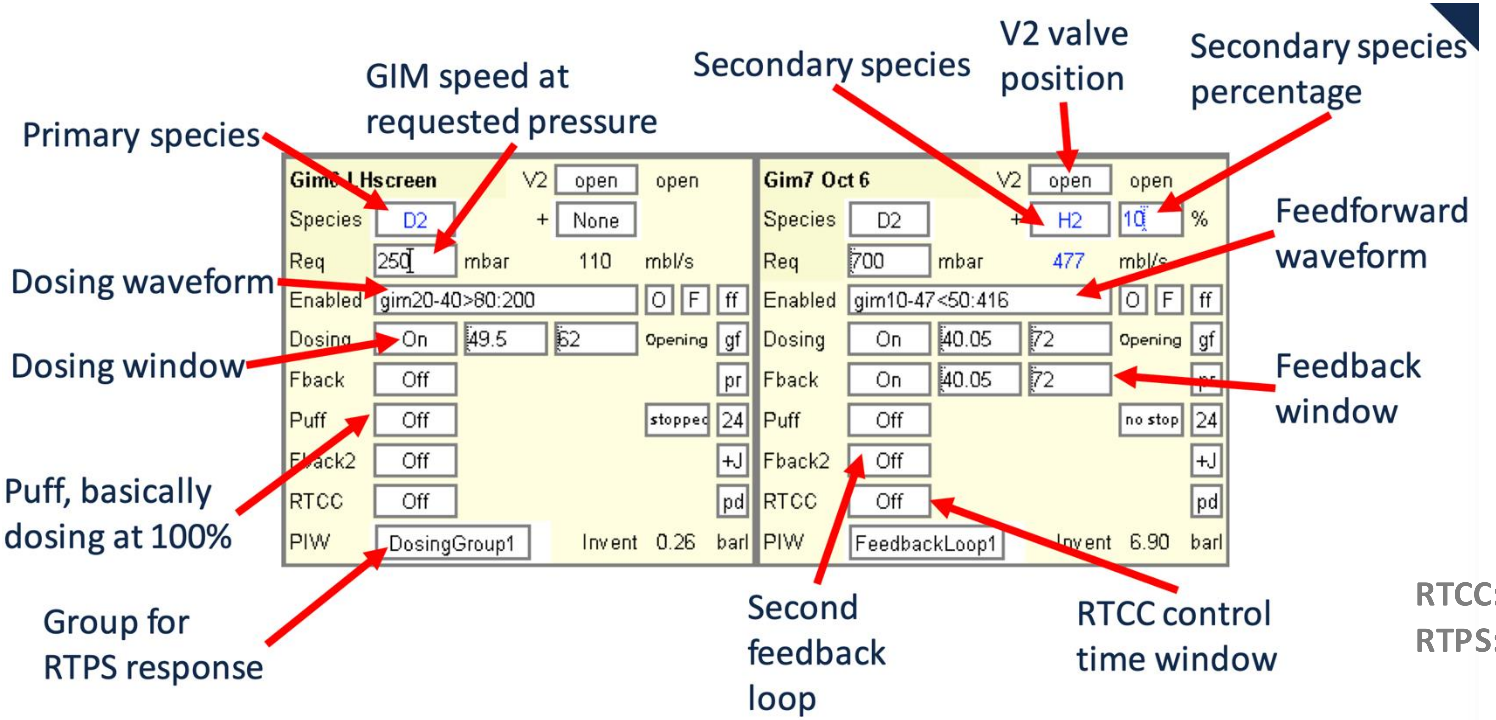
- main species (dosing/feedback/real-time control, pre- and post-heating, optimal gas for ICRH coupling, termination),
- minority species for ICRH,
- special gases for radiation or diagnostics.

Select **location** (top, midplane, divertor)



GIM: Gas introduction volume (H, D, special gases)
TIM: Tritium introduction volume (T, D)

Gas Introduction Module setup



RTCC: Scientific real-time protection
RTPS: Real-time Protection system

Select **volume** (standard or V2 large)

Request and Select **species**, set **pressure** (p*V = N*k*T), programme time evolution of the **waveform** (opening of the valve)

Consider pumping speed (species, location), pressure reduction over time, hysteresis of the valve

Set **feed forward, feedback, real-time** control and role in **protection** response

Safety and Protection System

Extensive safety and protection systems

- More involvement from the operators

Levels – example disruptions

1. Administrative

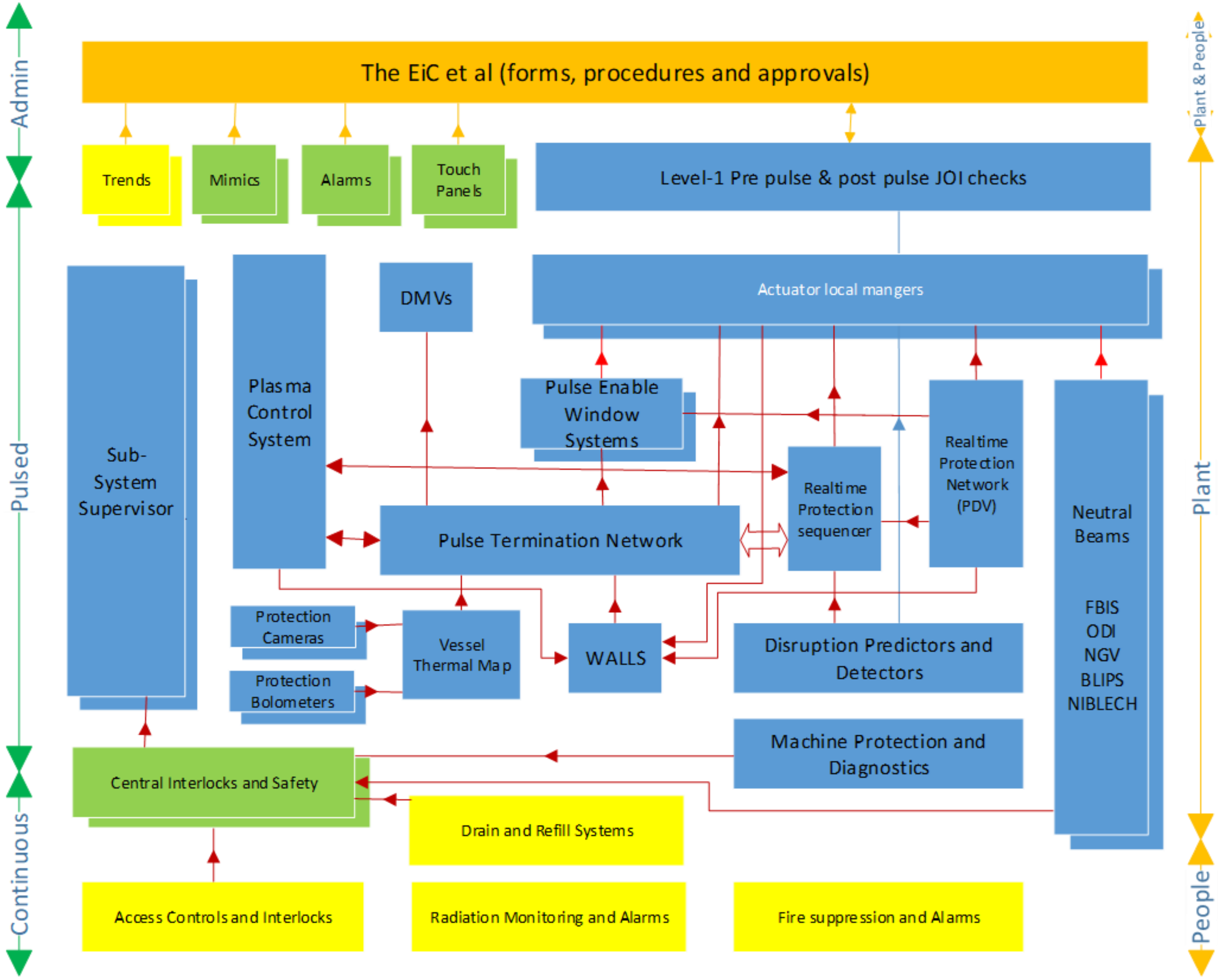
- JET operating instructions on number of disruptions, disruption checks and avoidance
- Request higher number of disruptions – approved as scarce resource

2. Pulse-based

- Scenario setup
- Disruption mitigation valve compulsory >2MA
- Alarm levels and reactions, disruption alarms -> DMV trigger, termination

3. Continuous

- Disruption checks – vessel displacement, disruption force -> call Chief Engineer above predefined level



J. Waterhouse

EUROfusion

Student Opportunities in Fusion

Eva Belonohy

EUROfusion Training and Education Office

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Overview

LEVEL	EUROFUSION ACTIVITIES	COLLABORATORS' ACTIVITIES
Schools, outreach	Class notes in national languages for schools. (via FuseNet) Teachers's day (via FuseNet)	ITER visit for teachers – funded by the European Commission. ITER internships
Bachelor students	1st Fusion Hackathon (via FuseNet) Student day (online, via FuseNet)	ITER internships F4E traineeships
Master students	6 weeks to 6 months internships (via FuseNet) Participation in summer/winter schools (via FuseNet) Student day (online, via FuseNet) Contribute to salary, missions, training, conferences, equipment, goods and services, supervisor – EUROfusion Education budget Repository of MSc thesis on the EUROfusion pinboard	ITER internships F4E internships
PhD students	PhD day (in-person event, via FuseNet) Contribute to salary, missions, training, conferences, equipment, goods and services, supervisor – EUROfusion Education budget. Participation in the JT-60SA International Fusion School. Repository of PhD thesis on the EUROfusion pinboard	ITER PhD scholarships.
Early career	EUROfusion Researcher Grants (within 2 years of PhD) EUROfusion Engineering Grants (within 6 years of MSc) Participation in the JT-60SA International Fusion School.	
ALL	Fusion Education and Learning Hub – eLearning platform FuseNet repository of educational material	INFUSED – ITER's repository of educational materials. IAEA connect platform to be extended to fusion training content.

Any questions?

Please contact us with any questions or feedback on the current schemes and needs.

Email:

- education@euro-fusion.org
- training@euro-fusion.org

Reports:

Download our reports at https://euro-fusion.org/eurofusion/roadmap/:

- **European Research Roadmap to the Realisation of Fusion Energy**
- **EUROfusion Human Resource Survey and Workforce Development Report**
- **EUROfusion Knowledge Management Strategy**