Ministry of Science, Education and Sports of Republic of Croatia

Regional Information Day on the Euratom Framework Programme for Nuclear Research and Training Activities (2012-2013)

Zagreb, 1 October 2012

"Fusion Energy Research - Main Features and Strategic Orientation"

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Directorate K – Energy

European Commission

Outline

- Main features of the Euratom Fusion Programme (2012-2013)
- European contribution to ITER
- Strategic orientation for 2014-2020

Euratom Framework Programme (2012-2013)
Council Decision on 19 December 2011

DG-RTD
indirect actions

Fusion Energy

€ 2209 million
(ITER: € 2077 million)

DG-RTD
indirect actions

Nuclear Fission, Safety and Radiation Protection

€ 118 million

JRC
direct actions

Nuclear Safety and Security

€ 233 million

Total budget: € 2560 million

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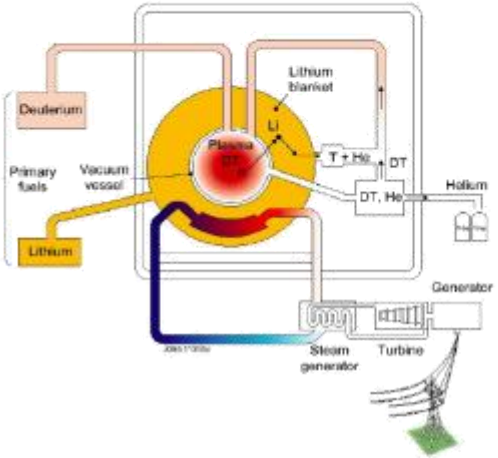
Fusion as a potential energy source

- **Fuels**
  - abundant and distributed world-wide
- **Safety, waste, the environment**
  - no transport of radioactive fuel for normal operation, no meltdown accidents
  - waste not a burden for future generations (less than 100 years radiotoxicity)
  - no CO_2 emissions
- **Scale**
  - potential for production of base-load electricity (and H2)
- **Economics and social acceptability**
  - difficult to make long term predictions, but studies show promising results

The EURATOM Fusion Programme



- European fusion research is partly funded under the EU's Framework Programmes for R&I
- The objective in the present programme is: ***"Developing the knowledge base for, and realising ITER as the major step towards, the creation of prototype reactors for power stations which are safe, sustainable, environmentally responsible, and economically viable"***
- The programme is fully integrated at the European level, characterised by:
  - overall co-ordination by the European Commission,
  - extensive collaborations
  - large joint projects

➔ **Without this, ITER might not have been possible**

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Areas of activity in the Euratom Fusion Programme (2012-2013) [1/2]

- **The realisation of ITER**
  - Governance of ITER-IO and European Joint Undertaking for ITER (F4E)
  - Construction of equipment and installations and support to the project
  - R&D activities (development and testing) in support to ITER construction
- **R&D in preparation of ITER operation**
  - Focused physics and technology programme to consolidate ITER project choices and prepare start-up of ITER operation
  - Assessment of ITER technologies through exploitation of JET enhancements
  - Exploration of ITER operating scenarios through targeted experiments
- **Limited technology activities in preparation for DEMO**
  - Fusion materials testing and modelling. Further work on IFMIF-EVEDA
  - Development of key technologies including blankets. DEMO conceptual design

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Areas of activity in the Euratom Fusion Programme (2012-2013) [2/2]

- **R&D activities for the longer term**
  - Preparation of operation of W7-X stellarator
  - Plasma theory and modelling
- **Human resources, education and training**
  - Support mobility of researchers
  - High-level training for engineers and researchers, including use of facilities
- **Infrastructures**
- **Technology transfer, industry involvement and innovation**
  - Promotion of innovation and exchange of know-how
  - Support to patents and promotion of the Fusion Industry Innovation Forum

Main players in the Euratom Fusion Programme

- **The European Commission**
  - In charge of programme management, including funding
- **Euratom Fusion Associations**
  - A total of 26 'Contracts of Association' between Euratom and national programmes and laboratories of EU Member States (plus Switzerland), in which R&D activities are performed
- **EFDA (European Fusion Development Agreement)**
  - A multi-lateral framework partnership agreement among all Associates and Euratom aimed at co-ordinating the research activities of those Fusion Associations, and at exploiting collectively JET (Joint European Torus)
- **The Joint Undertaking for ITER and the Development of Fusion Energy, or so-called "Fusion for Energy" (F4E)**
  - Domestic agency for ITER, and Implementing agency for 'Broader Approach' projects with Japan, including preparations for IFMIF construction

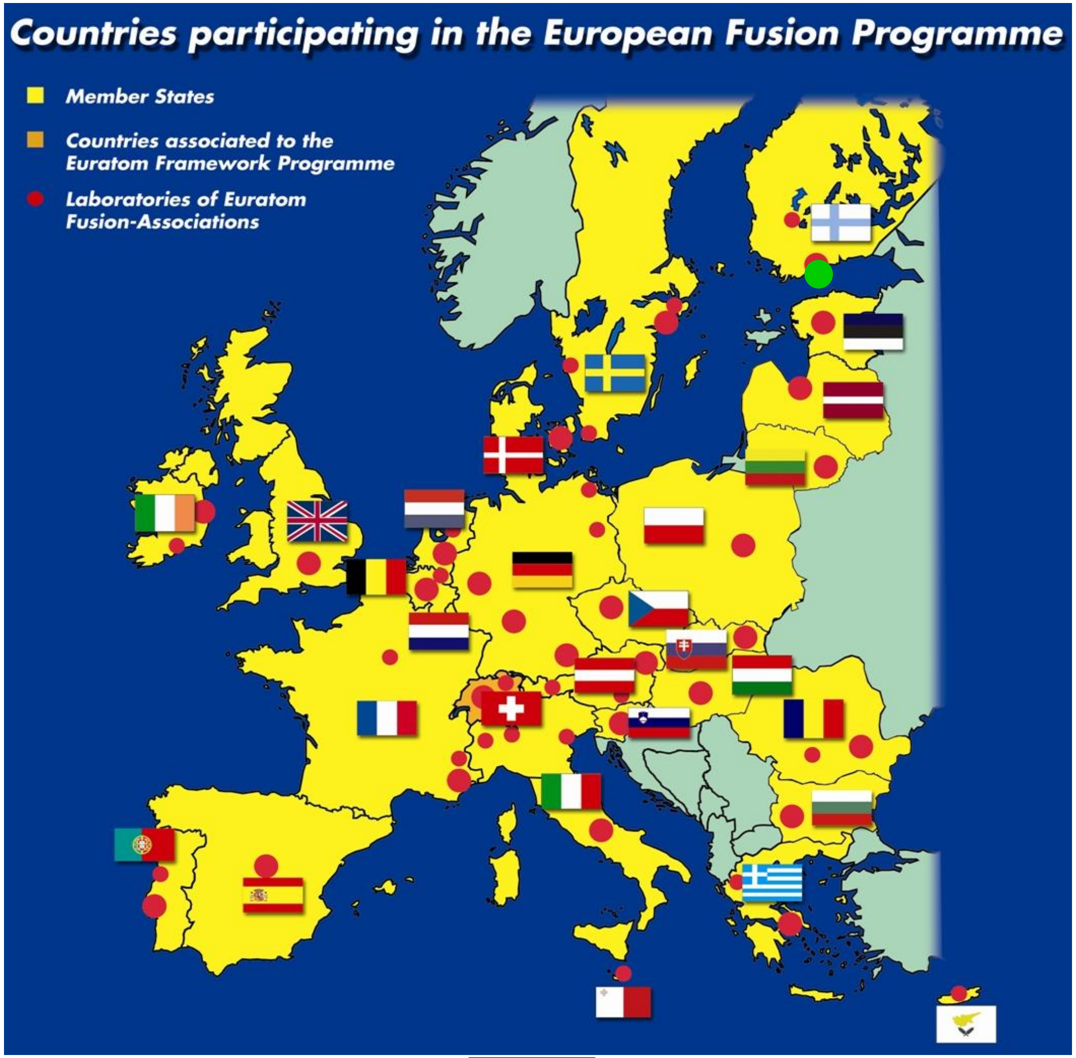
European Commission

The European Commission (EC)

- Representation of the European Atomic Energy Community (Euratom)
- In charge of the overall programme management (including funding)
- Management of the Associations' programmes through joint Steering Committees with the national partners
- Co-funding of the Fusion Associations, EFDA and F4E activities
- Management of the "Mobility Agreement" which promotes collaboration between Associations by funding travel and subsistence costs
- Implementation of a Fusion Training Scheme for young engineers
- Funding of co-ordination and support actions in fusion education, fusion materials research, atomic data and modelling
- Representation of the programme internationally (multilateral, as well as bilateral Fusion Co-operation Agreements)

R&D in an Integrated Programme of 26 Associations

- **Euratom - CEA** **(1958)** France
- **Euratom – ENEA** **(1960)** Italy (incl. Malta)
- **Euratom – IPP** **(1961)** Germany
- **Euratom – FOM** **(1962)** The Netherlands
- **Euratom – FZJ** **(1962)** Germany
- **Euratom - Belgian State** Belgium **(1969)** (incl. Luxembourg)
- **Euratom - DTU** **(1973)** Denmark
- **Euratom - CCFE** **(1973)** United Kingdom
- **Euratom – VR** **(1976)** Sweden
- **Euratom - Conf. Suisse** Switzerland **(1979)**
- **Euratom – KIT** **(1982)** Germany
- **Euratom - CIEMAT** **(1986)** Spain
- **Euratom – IST** **(1990)** Portugal



- **Euratom - TEKES** **(1995)** Finland (incl. Estonia)
- **Euratom - DCU** **(1996)** Ireland
- **Euratom – ÖAW** **(1996)** Austria
- **Eur.- Hellenic Rep** **(1999)** Greece (incl. Cyprus)
- **Euratom - IPP.CR** **(1999)** Czech Rep.
- **Euratom – HAS** **(1999)** Hungary
- **Euratom – MEdC** **(1999)** Romania
- **Euratom – Univ. Latvia** Latvia **(2002)**
- **Euratom – IPPLM** **(2005)** Poland
- **Euratom– MESCS** **(2005)** Slovenia
- **Euratom – CU** **(2007)** Slovakia
- **Euratom – INRNE** **(2007)** Bulgaria
- **Euratom – LEI** **(2007)** Lithuania

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Euratom Fusion Associations

- The Euratom Programme supports R&D in the Member States and Switzerland through bilateral Contracts of Association (CoA) with programmes and national laboratories of the EU Member States
  - About 4000 people over 27 EU Member States plus Switzerland
  - Operating 12 plasma devices and ~ 40 technology facilities (NBI testing , DTP-2 mock-up, JUDITH, Magnum-PSI, Tecnofusion, SULTAN & EDIPO, gyrotron, etc.)
  - Overall expenditure ~ € 300 million a year (incl. Euratom and Member States funds)
  - CoA will be replaced in 2014 - Each CoA includes a specific 'Work Plan' to be yearly revised by the corresponding SC resulting in an 'Annual Work Programme' (with fixed structure to facilitate cross-cutting and coordination) and an 'Annual Mobility Plan'
- The Associates:
  - Carry out a focused physics and technology programme for consolidation of ITER project choices and in preparation for a rapid start-up of ITER operation
  - Carry out longer term fusion R&D, developing competences and enlarging the knowledge base in strategically relevant fields
  - Participate in procurements for ITER under contracts from F4E

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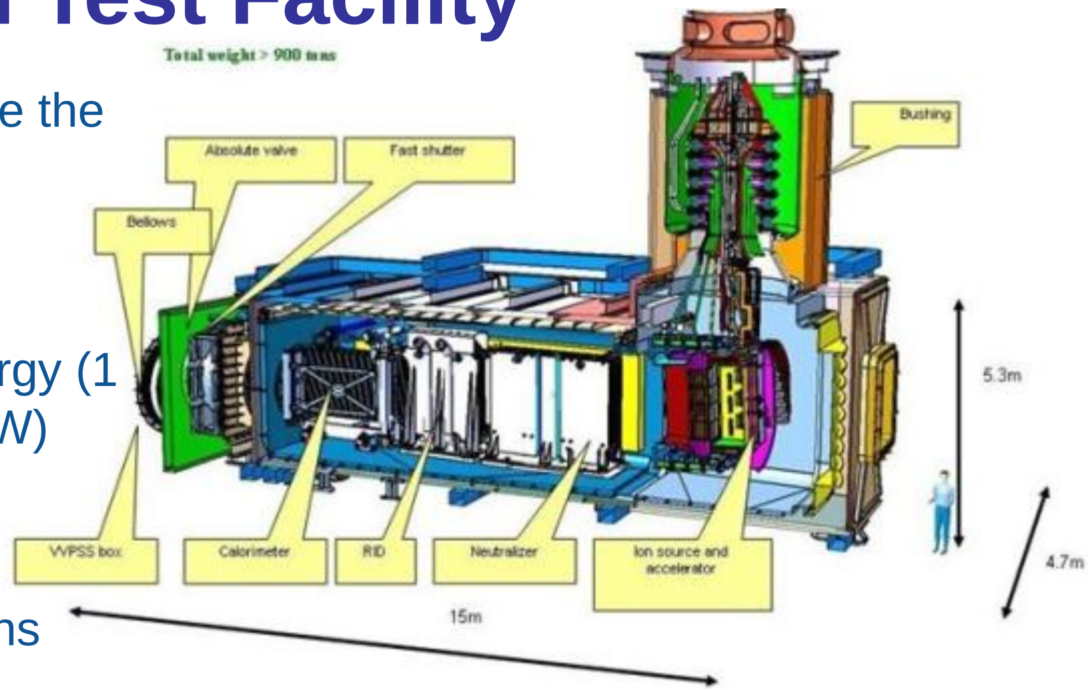
Neutral Beam Test Facility

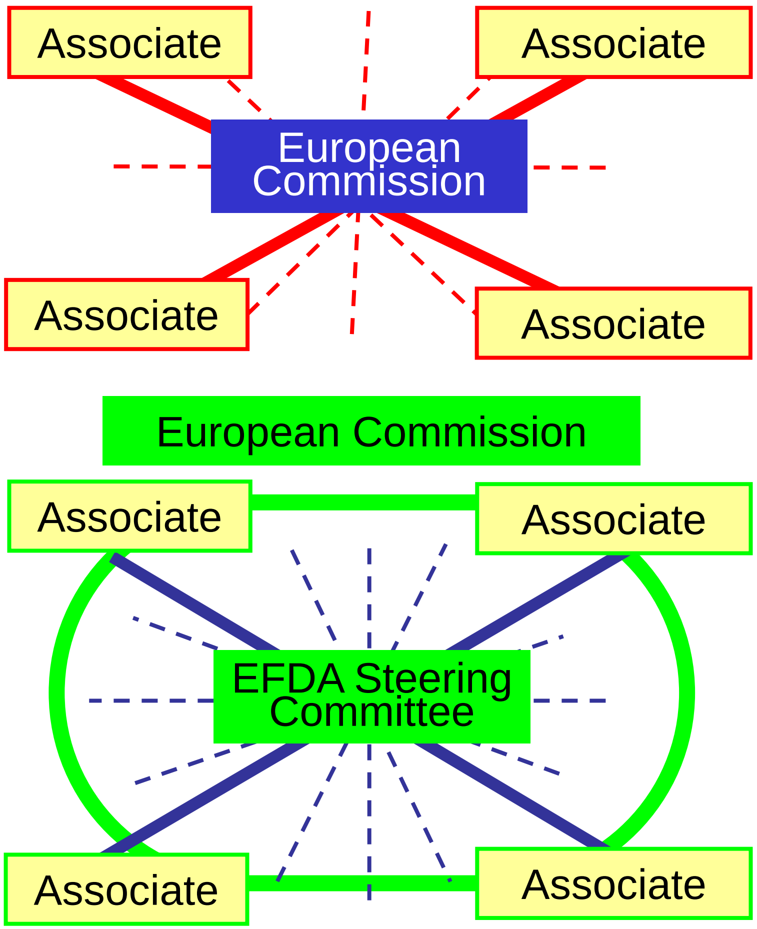
- Plasma heating in ITER will include the injection of powerful beams of high energy hydrogen atoms ("neutral beams")
- ITER needs a level of particle energy (1 MeV) and total beam power (33MW) with a pulse
  duration up to 3600 seconds
- Such very demanding specifications have never been achieved before
- Europe is building the Test Facility to develop prototypes of these neutral beam sources and to test the production versions



This major facility builds on the world class expertise of Europe in this field.

It is being built in **Padova** (IT)

EFDA and the Fusion Associations [www.efda.org]



Contracts of Association

link each Association to the Commission

EFDA

partnership agreement linking all the Associates and the Commission together

Main EFDA Tasks

- Focussed physics and emerging technologies
- JET Operations plus other devices
- Co-ordination of Associations' activities

The European Fusion Development Agreement (EFDA) [www.efda.org]

- **Partnership agreement between all fusion Associates and Euratom**
  - Coordinated research of the Associations on physics in support to ITER and on longer-term technology – also through 2 Tasks Forces and 5 Topical Groups
  - European collective scientific exploitation of JET by the Associations through the JET Implementing Agreement (JIA), and JET orders and notifications
  - Joint Operation Contract (JOC) between Euratom and UK
  - Implementing Agreement for High Performance Computer (HPC)
  - Implementing Agreement for Power Plant Physics and Technology (PPP&T)
  - Training and career development of researchers, promoting links to universities and carrying out support actions
  - Located in Garching (Germany) and Culham (United Kingdom)

- **Accession to EFDA by Third States feasible**
  - Collaboration with the JET facility operation and exploitation

Power Plant Physics & Technology (PPP&T) - Implementing Agreement under EFDA

- Aimed at developing the physics and the technologies for, and the conceptual design of, future tokamak-based fusion power plants
  - Integration of physics, technologies and system engineering
- Programmatic objectives:
  - Consolidation of physics basis and integrated scenarios
  - Consolidation of Engineering Design basis
  - Efficiency, pulse length and reliability of heating and current drive systems
  - Plasma diagnostics and control strategies
  - Fuel cycle, including tritium breeding and handling; and plasma fuelling
  - Materials
  - Divertor concepts; in-vessels components; remote handling
  - Advanced superconductors (e.g. high temperature)
- Composed of Euratom Fusion Associations
  - Already launched with entering into force before summer 2012

Fusion devices in the Euratom Fusion Programme

JET	Tokamak	Euratom EFDA Culham, UK	1983
TORE SUPRA	Tokamak	CEA Cadarache, France	1988
FTU	Tokamak	ENEA Frascati, Italy	1990
ASDEX Upgrade	Tokamak	IPP Garching, Germany	1991
TCV	Tokamak	CRPP Lausanne, CH	1992
ISTTOK	Tokamak	IST Lisbon, Portugal	1992
TEXTOR-94	Tokamak	KFJ Jülich, Germany	1981 (1994)
TJ-II	Heliotron	CIEMAT Madrid, Spain	1997
MAST	Sph. Tokamak	UKAEA Culham, UK	1998
RFX	Rev. Field Pinch	ENEA Padova, Italy	1991 (2000)
EXTRAP–T2R	Rev. Field Pinch	VR Stockholm, Sweden	1994 (2000)
COMPASS	Tokamak	IPP.CR Prague, Czech Republic	2009
Wendelstein 7-X	Stellarator	IPP Greifswald, Germany	(2015)
[Wendelstein 7-AS	Stellarator	IPP Garching, Germany	closed 2002]

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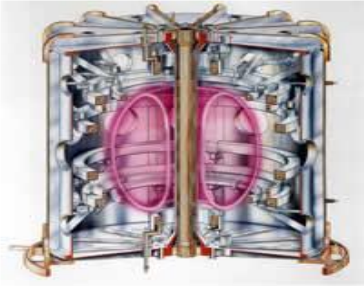
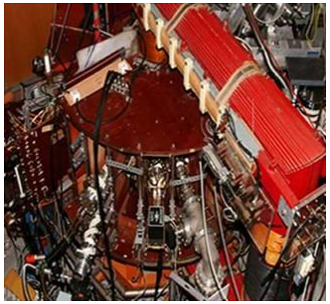
European tokamaks in operation

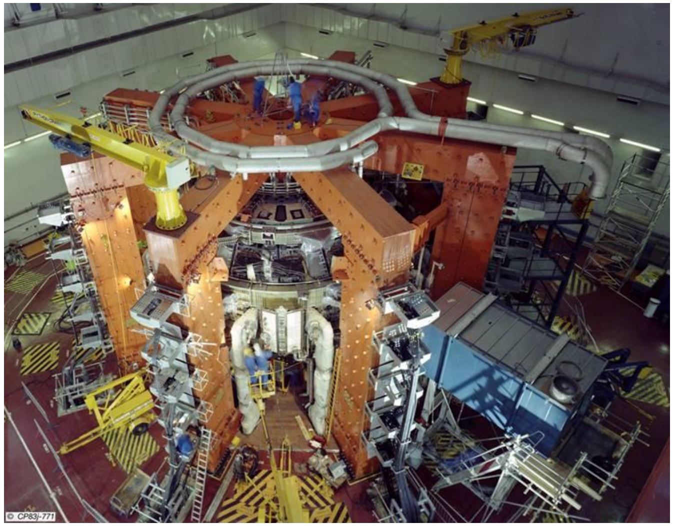
FTU, Italy



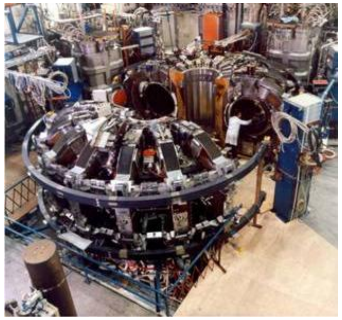
MAST, U.K.



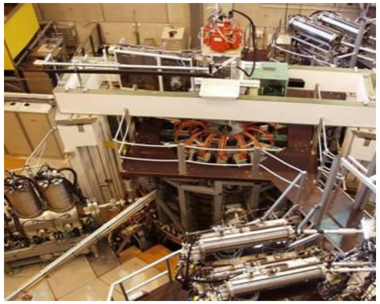
ISTTOK, Portugal



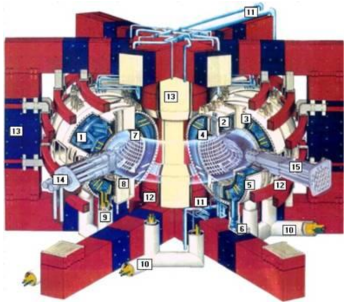
JET, Euratom



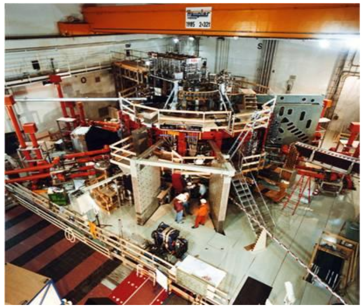
TEXTOR, Germany



TCV, Switzerland



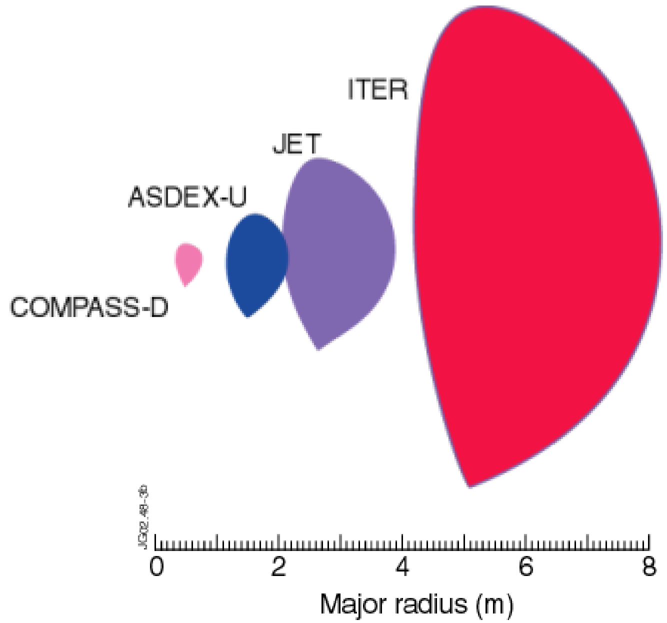
Tore Supra, France

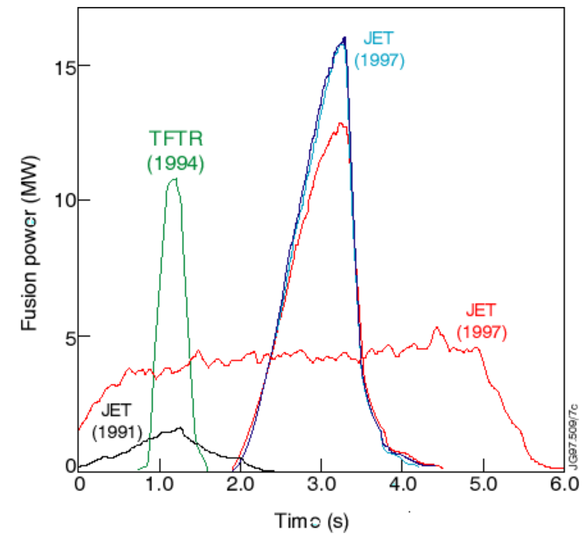


ASDEX-U, Germany

COMPASS-D, Czech Rep.

JET, the Joint European Torus



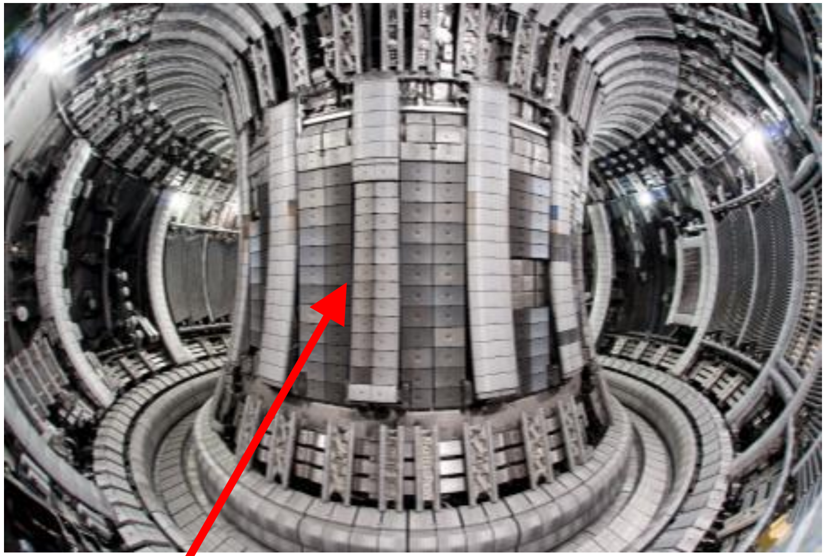


- JET is closer in size to ITER than any other tokamak
- It has a plasma shape similar to ITER
- It is the only tokamak in the world able to operate with the fusion fuel tritium which will be used in ITER

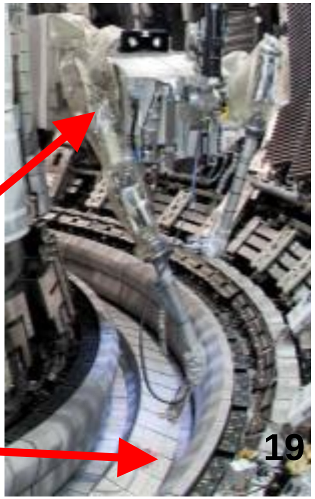
A major upgrade of JET in support of ITER

- Carbon is usually used for interior components with a high heat load
- But, carbon absorbs hydrogen - not good when tritium fuel is to be used
- Tungsten is the best substitute - refractory and does not absorb tritium
- ITER is likely to abandon carbon for the start-up phase and go straight to tungsten - a large cost saving
- There are important issues to be resolved in operation of a tokamak with an all-metal wall and divertor

➔ **A major upgrade of JET**

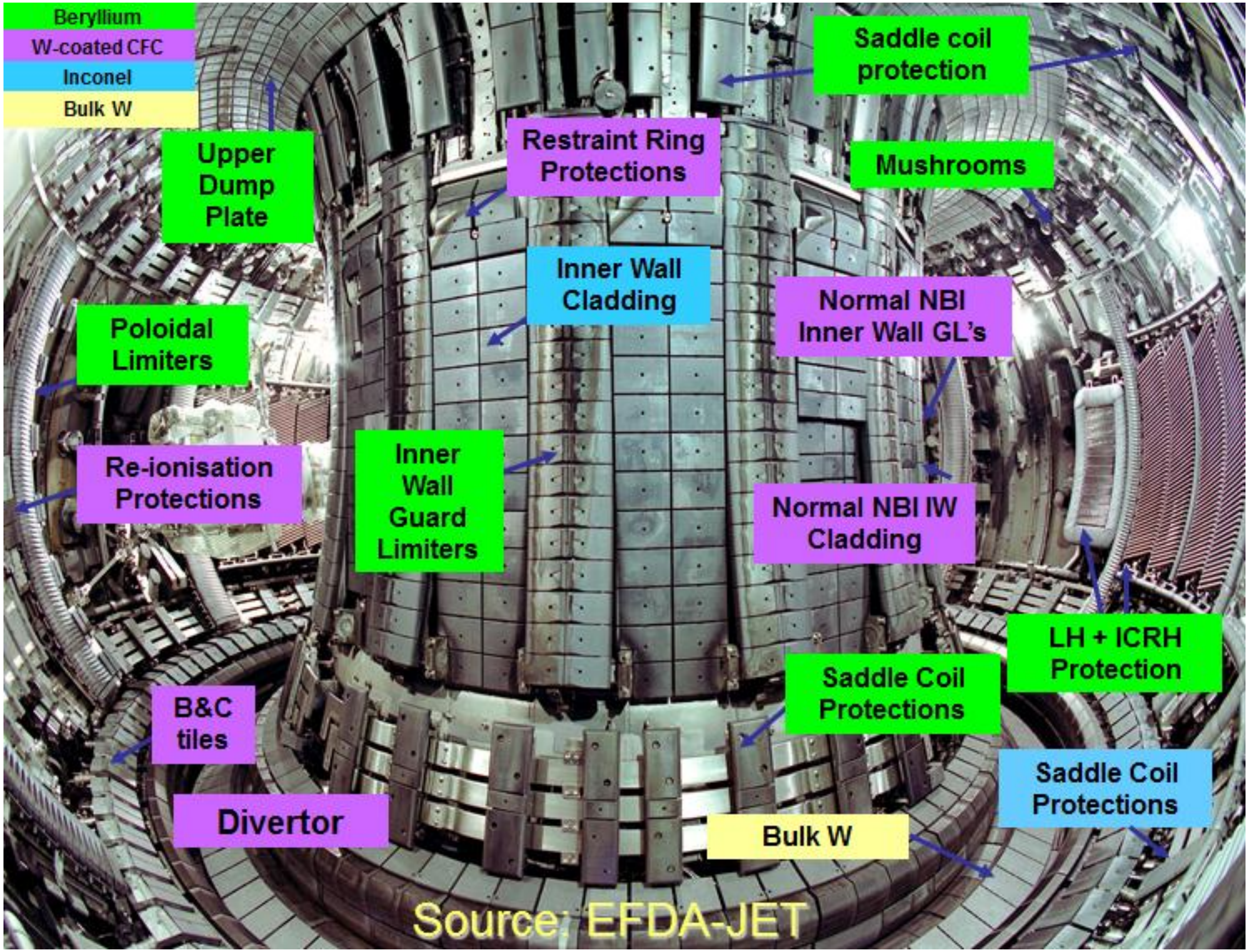


Interior of the JET vacuum vessel



Installation of components using remote handling technology

Divertor tiles


Beryllium
W-coated CFC
Inconel
Bulk W
Saddle coil protection
Upper Dump Plate
Restraint Ring Protections
Mushrooms
Inner Wall Cladding
Normal NBI Inner Wall GL's
Poloidal Limiters
Re-ionisation Protections
Inner Wall Guard Limiters
Normal NBI IW Cladding
LH + ICRH Protection
Saddle Coil Protections
B&C tiles
Saddle Coil Protections
Divertor
Bulk W
Source: EFDA-JET

EFDA- Joint European Torus (JET) [1/2] [www.jet.efda.org]

Relevant role of EFDA-JET infrastructures in the consolidation of ITER design choices and in the preparation for the ITER operation and exploitation in terms of:

- Operating scenarios, ITER-like First Wall, Deuterium-Tritium (DT) operation, high frequency pellet injector, data acquisition and control systems, start-up requirements, etc.
- DT experiments should provide crucial information on access to the high confinement regimes required for ITER burning plasmas
- The present reference scenario until 2015 includes ITER-like First Wall experiments and DT operation

EFDA- Joint European Torus (JET) [2/2] [www.jet.efda.org]

EFDA-JET programmes 2011-2012 developed as a coherent block of experiments for initial exploitation of the ITER-like Wall (ILW)

– After first plasma in August 2011

1 - Characterisation of ILW

- Fuel retention and material migration; Material limits and long term samples; Transient and steady state power loads

2 - Exploration of ITER operating scenarios with ILW

- Develop plasma scenarios; Assess plasma scenarios with regard to power loads, their mitigation and control; Explore scenarios in domains closest to ITER dimensionless parameters

3 - Physics issues essential to the efficient exploitation of ILW and ITER

- Divertor and scrappe-off layer physics; Confinement, pedestal and ELM physics; Disruptions, MHD and fast particle physics

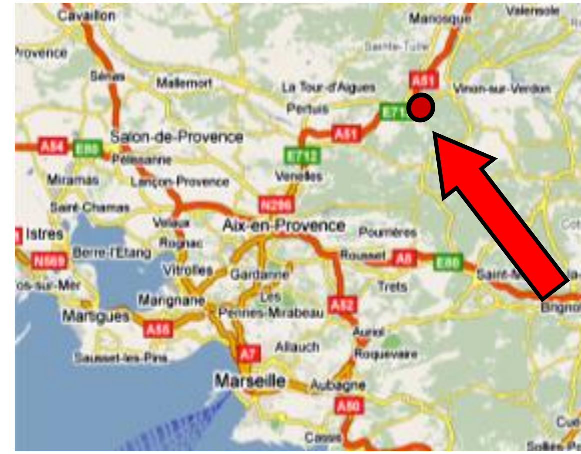
The European Joint Undertaking for ITER and the Development of Fusion Energy (F4E) [http://fusionforenergy.europa.eu]

- Established as a Joint Undertaking in Barcelona (Spain) under the Euratom Treaty and largely financed by through the Euratom Framework Programme
- Domestic agency with the main responsibility of providing and manage the **contribution of Euratom to ITER-IO** within scope, schedule and cost. F4E is responsible for the placement and execution of contracts for manufacturing ITER components
- Implementing agency coordinating the contribution of Euratom Voluntary Contributors to specific projects of the **'Broader Approach Agreement'** between Japan and Euratom
- F4E also implements a programme of long term R&D activities in preparation for a future demonstration fusion reactor (DEMO)

"Broader Approach" Agreement between Euratom and Japan

- **"Broader Approach" (BA) projects:**
  - Design of a materials test facility (IFMIF-EVEDA) to allow testing and qualification of advanced materials → IFMIF available for DEMO
  - Satellite Tokamak Programme: upgrade the Japanese JT-60 tokamak in Naka (JP) as advanced superconducting satellite tokamak → exploitation of ITER
  - International Fusion Energy Research Centre (IFERC) in Rokkasho (JP) aimed at coordinating DEMO design and R&D, and launching the Computational Simulation Centre (CSC) and the ITER Remote Experimentation Centre
  - Voluntary contributors: France, Italy, Spain, Germany, Belgium, Switzerland
- **Wider internationalisation of BA projects is possible**
  - Enforced guidelines on participation of ITER Parties to BA
- **The BA projects complement the construction of ITER towards fusion power deployment**

ITER - Overview



- The ITER tokamak is the essential next step to demonstrate the **scientific and technical feasibility** of fusion power
- A joint **international project** hosted by Europe in Cadarache, France
  - 7 partners: China, EU, India, Japan, South Korea, Russia, USA
  - Almost all components will be provided "in-kind" by the partners
  - An international organisation, staffed by the partners

- The **EU has a special responsibility** as the ITER host, is the largest contributor through **F4E**, and has a leading role

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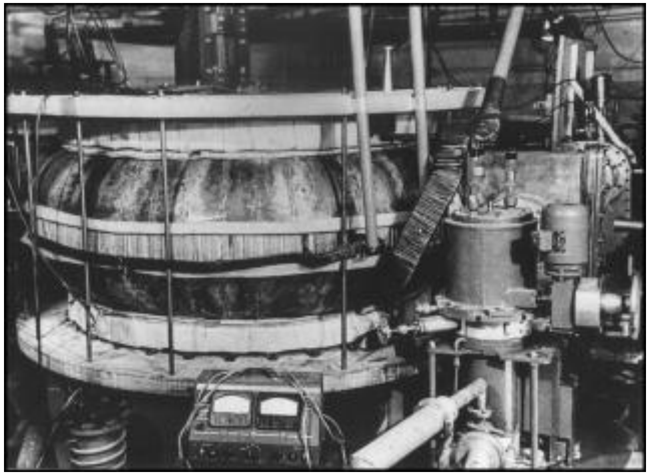
The aims of ITER

iter

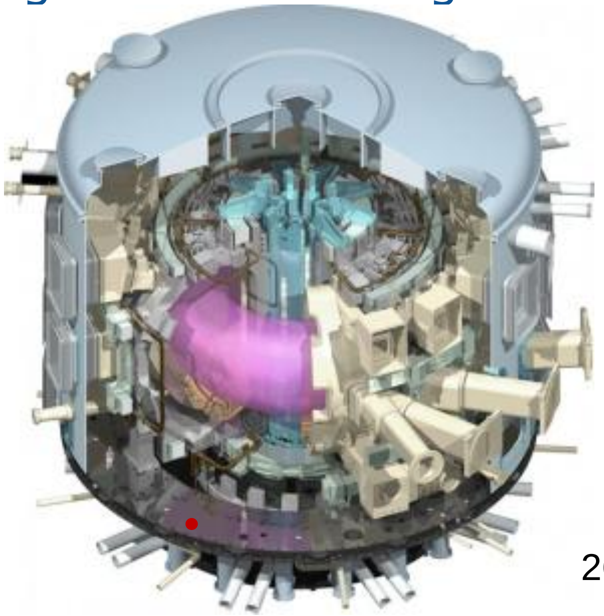
china eu india japan korea russia usa

- Produce and study burning plasmas at an energy multiplication factor of 10 for about 400 sec
- Aim at producing steady-state burning plasma
- Demonstrate the availability and integration of essential fusion reactor technologies
- Test components for a future reactor including tritium breeding module concepts



The first tokamak, T1 (1968)

ITER

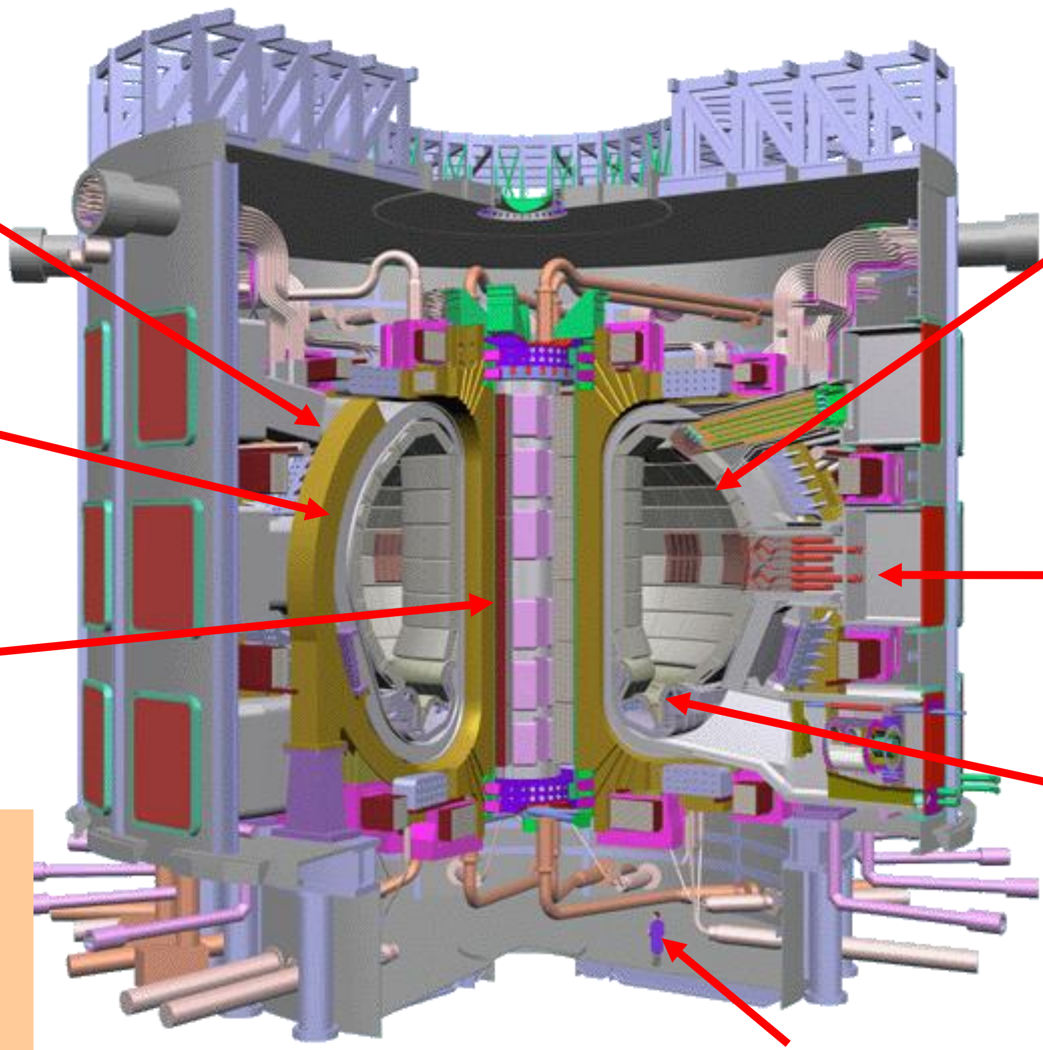


Main ITER components to be provided by the EU

Toroidal Field Coil
Nb_3Sn, 18 coils

Vacuum Vessel
9 sectors

Central Solenoid
Nb_3Sn, 6 modules



Blanket Module
421 modules

Additional Heating
IC, EC, NBI

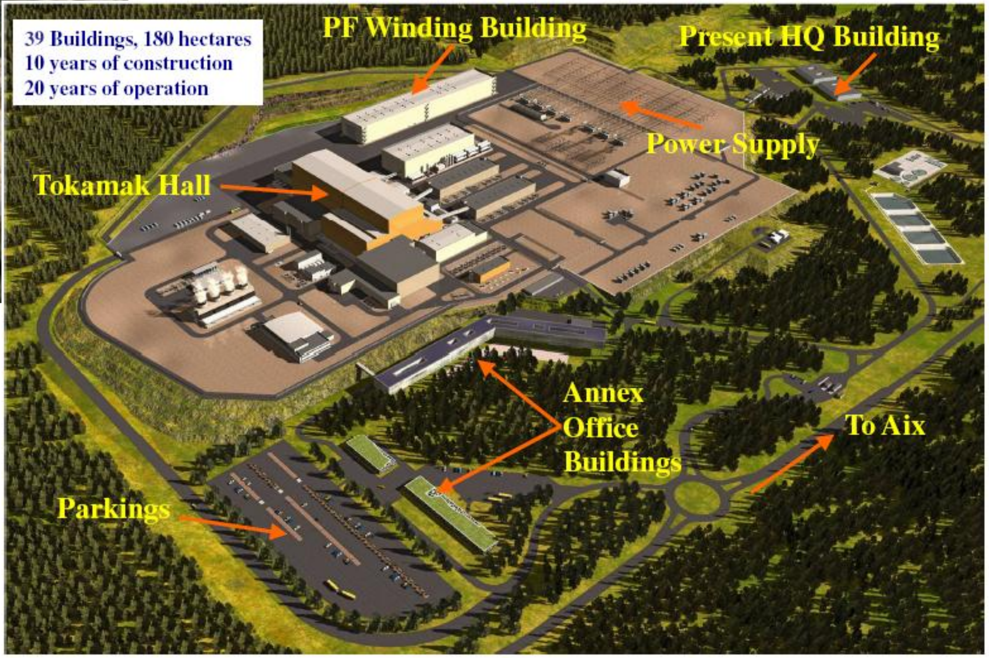
Inner Divertor
54 cassettes

Person

+ Diagnostics
Remote Handling
Tritium Plant
Pumping/Fuelling
Power Supplies…

Progress on the ITER site

The site in September 2011



Artist's impression of the completed facility

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The pit where ITER will be located

On top of the columns are the anti-seismic bearings which will support the nuclear buildings - a total weight of 360,000 tonnes (equivalent to a very large skyscraper)

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The Poloidal Field coil building

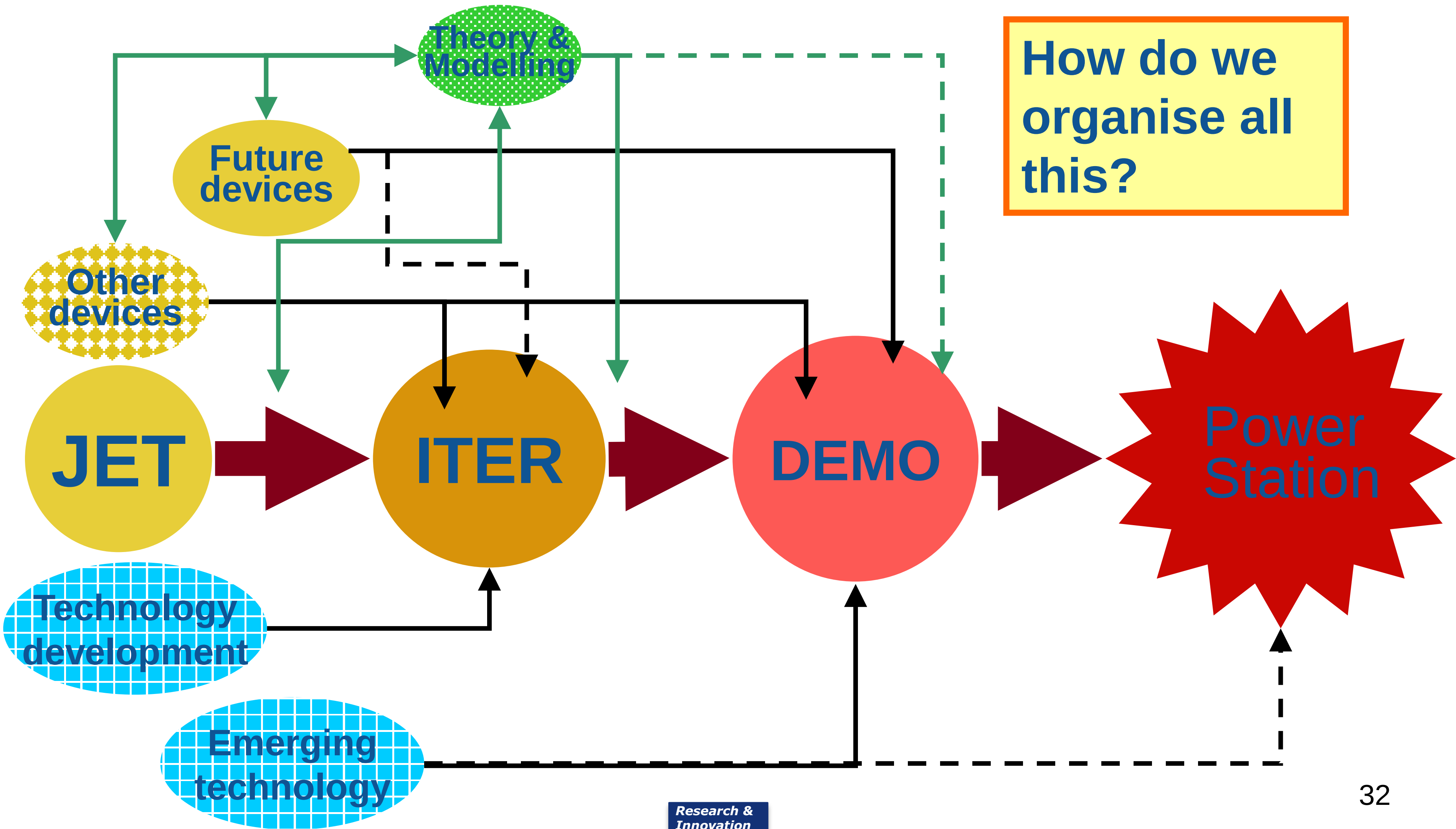
Some of the superconducting magnetic coils are too large to transport (18m diameter) and will be fabricated on-site in this building

Summary of the European role in ITER

Europe is the biggest player in ITER:

- Europe contributes 45% of the construction cost, mainly through the provision, "in-kind", of components (including many of the most critical, such as the nuclear buildings)
- To support a revised "baseline design" of the project, the Council of the EU approved EU funding for ITER construction of €6.6B
- Europe provides the largest proportion of the staff of the ITER International Organisation
- The European fusion research programme has provided major inputs to the ITER design (experimental data, expertise) and continues to contribute to planning operational scenarios
- **If we maintain a vigorous R&D programme, European researchers will have the major role in ITER exploitation**

Fusion – how do we get there?



How do we organise all this?

Challenges for H2020 (2014-2020)

- A credible but ambitious goal-oriented European **roadmap** to help supporting electricity production from a DEMO "around the middle of the century"

- Successful **construction of ITER**

- Increased focus on **technologies** required for future advances

- Ensure that Euratom programme evolves so that it can promote significant progress along the roadmap during H2020

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Proposed strategy during H2020 and beyond

- A realistic and comprehensive **roadmap**
  - Strongly focused goal- and more technology-oriented programme receiving appropriate endorsement by the fusion community
- **Joint programming** of fusion activities
  - For better efficiency of the EU fusion programme
- Fostering innovation, competitiveness and growth
- Seizing **international collaboration** opportunities

Strategic orientation (under preparation) for 2014-2020 [1/4]

- **The ultimate objective of the Euratom fusion programme is to develop the knowledge base required to build the first commercial fusion power plant, through two major steps:**
  - ITER as demonstration of the S&T feasibility of fusion power
  - DEMO as demonstration of the economic viability of fusion power
- **Draft main objectives (2014-2020)**
  - <u>To construct ITER</u> within scope, schedule and cost
  - To secure the success of future <u>ITER operation</u>
  - To prepare the <u>ITER generation</u> of scientists, engineers and operators
  - To lay the foundations for <u>fusion power plants</u>
  - To promote innovation and <u>industry</u> competitiveness
  - To develop <u>international cooperation</u> pooling resources and decreasing risks

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Strategic orientation (under preparation) for 2014-2020 [2/4]

- **To construct ITER within scope, schedule and cost**
  - R&D activities concerning the systems for which procurements are to be made and for which detailed designs and technologies should be developed and validated (e.g. W-divertor, RMP coils)
  - Procurements for the ITER Organisation as per the ITER Baseline
- **To secure the success of future ITER operation**
  - Demonstrate ITER relevant scenarios and active plasma control to reach ITER performance
  - Demonstrate mitigation/avoidance of plasma disruptions, control of tritium and dust to ensure safe ITER operation
  - Develop tools for accurate predictive modelling of ITER operation
  - International networking of programmes and specific facilities

Strategic orientation (under preparation) for 2014-2020 [3/4]

- **To prepare the <u>ITER generation</u> of scientists, engineers and operators**
  - Review the staffing situation in the fusion research centres and ITER, provide coordinated training for operators of ITER, plasma physicists and engineers, and review needs of other fusion stakeholders (industry, regulators, etc) for targeted training actions
  - International networking of specific tokamaks aimed at training ITER operators
- **To lay the foundations for <u>fusion power plants</u>**
  - Develop scenarios for a reliable input to DEMO design; develop & qualify materials for DEMO including irradiation in a suitable neutron source; develop and validate the associated material modelling and exploit irradiation data
  - Develop and demonstrate advanced technologies for DEMO (e.g. TBM)
  - Improvement of knowledge on long pulse scenarios, burning plasmas and PWI
  - Deliver DEMO conceptual design

Strategic orientation (under preparation) for 2014-2020 [4/4]

- **To promote innovation and <u>industry competitiveness</u>**
  - Building competences in industry through transfer of knowledge from all fusion projects, especially ITER, in joint industry and research design activities for DEMO
  - Establishment of a European fusion technology transfer office, transfer of knowledge to industry and creation of spin offs to other sectors / Specific training actions
- **To develop <u>international cooperation</u> pooling resources and decreasing risks**
  - Fusion development is based on long-term cooperation with international partners (e.g. preparation of ITER operation & operators, exploitation of ITER, DEMO development, etc.)
  - Covering all collaborative activities between entities from both parties, and mainly developing cooperation on activities complementary of or in support to <u>ITER</u> (towards a sort of networking of ITER Satellite tokamaks) plus on long-term activities towards <u>DEMO</u>
  - Enforced bilateral Cooperation Agreements on fusion research: Switzerland (1979), Japan (1988), U.S. DOE (2001), Russia (2002), Ukraine (2002), Kazakhstan (2004), South Korea (2006), China (2008), India (2010) and Brazil (expected ratification in 2012)

The Euratom fusion programme and the challenges of the ITER era

- **ITER remains the axis and first priority** of the integrated Euratom fusion research programme, which is therefore fully aligned on ITER needs
  - The construction of ITER mobilises between 450-700 ppy/y with a large impact on individual associations' programmes → Euratom R&D is focussed to development of ITER components, as well as to risk mitigation and cost containment measures for ITER
  - Credibility of fusion developments depends on ITER success, and a full scientific return must be obtained from the investment in ITER → accompanying programme is essential
  - Potential international network of programmes and tokamaks in support to the preparation of the ITER operation, as well as to the multilateral training programme (strong mobility within that network) for future ITER operators, scientists and engineers

- A **roadmap** targeting common EU challenges, providing long-term vision and allowing prioritisation

- The **programme H2020** focusing on objectives and milestones
  - Joint programming to pool and leverage resources
  - Longer-term issues (e.g. materials research), increased industrial involvement and international cooperation

Ministry of Science, Education and Sports of Republic of Croatia

Regional Information Day on the Euratom Framework Programme for Nuclear Research and Training Activities (2012-2013)

Zagreb, 1 October 2012

Many thanks for your attention!

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