Nuclear Academics Meeting
University of Birmingham
September 2013

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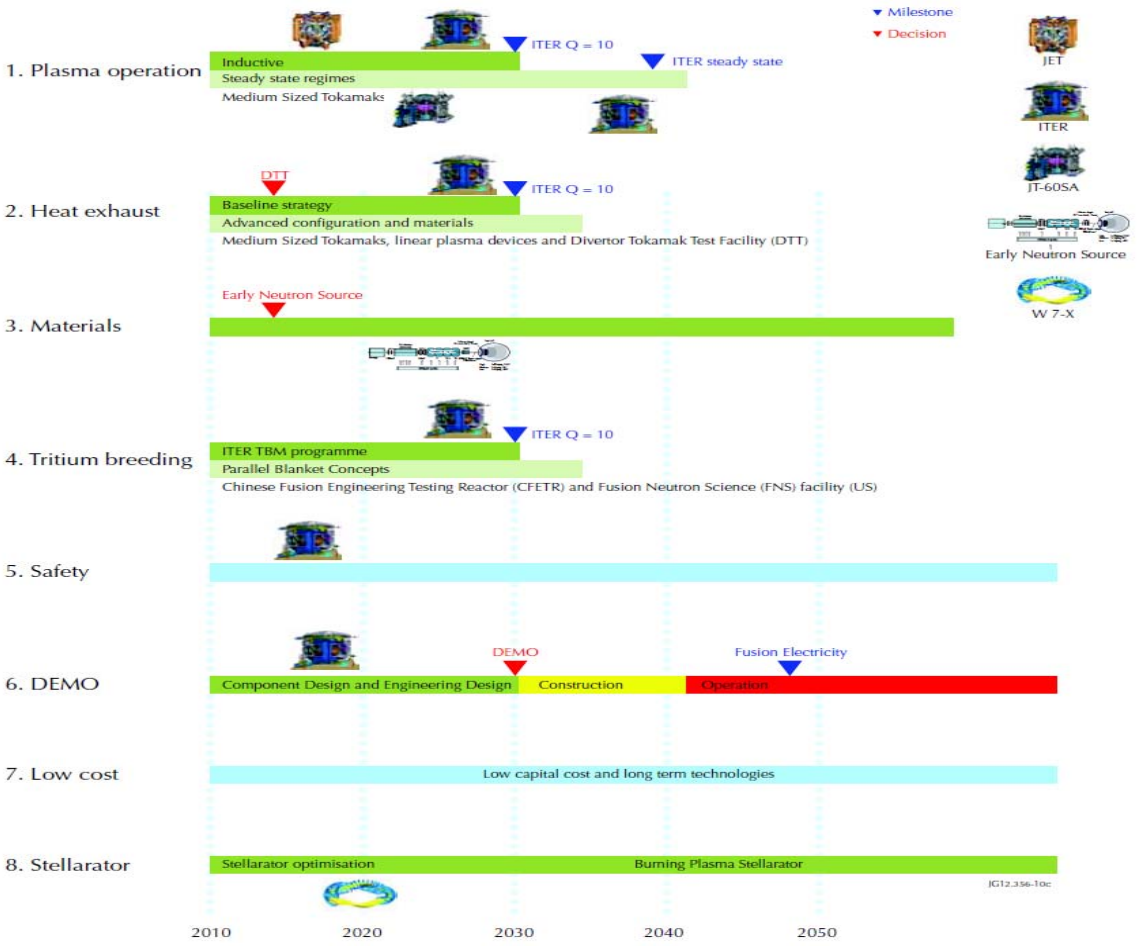
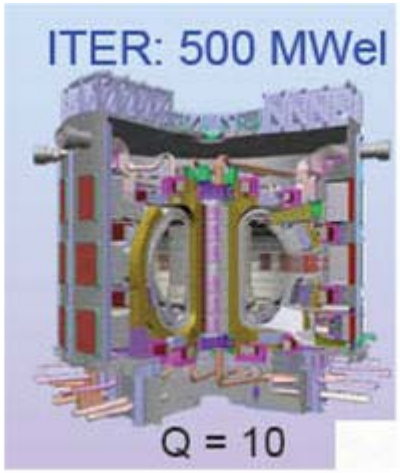
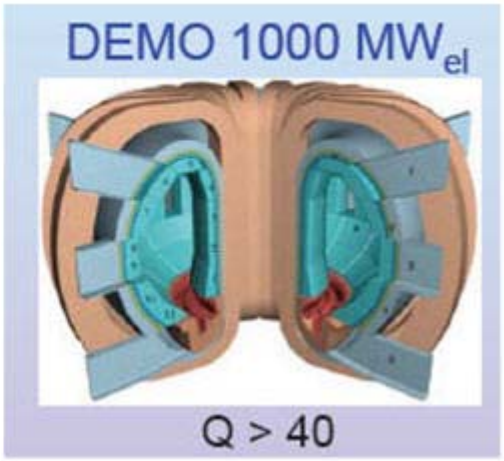


The missions to the realisation of fusion electricity

An exciting time for fusion

Operating Under construction EU roadmap 2040s





CCFE paid by Europe to operate JETs – around 500 staff mainly engineers and physicists, including nuclear aspects – tritium, waste, remote handling.

International Roadmaps

China

CN is considering the construction of the next major device around 2020, even though the exact specifications are not yet finalised. They are prepared to take some risk.

The CN strategy is “learning by doing”. All options are indeed open.

United States

Various proposals from the US including:

– CTF (component test facility)

– FNSF (fusion nuclear science facility)

– Pilot Plant (replaces CTF and FNSF)… but 3 possible configurations: advanced tokamak, spherical tokamak,or compact stellarator

No strategic roadmap defined – significant science programme.

Europe

The EU roadmap for DEMO with the demonstration of electricity to the grid in the 2040’s.

Fusion development:

science-driven, lab-based →industry / technology-driven

- Moreover, non-nuclear →nuclear technology
- ITER is the first step in this triple transition,
  which is also driven by the development of DEMO

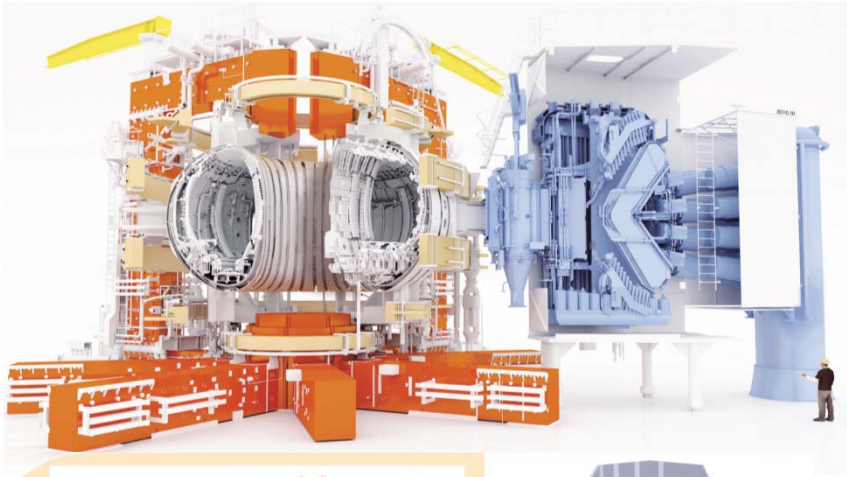
… and its implications

Different competences will be needed for fusion workforce

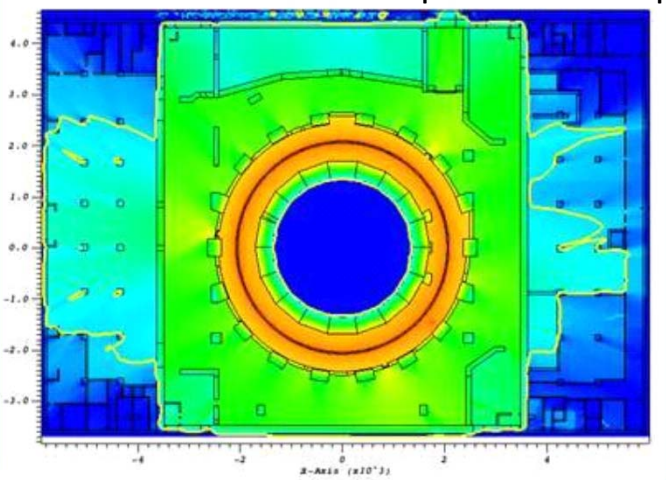
- Industry becomes a big player and home of a significant fraction of workforce
- Transition in the workforce will be gradual, but:
  education & training programs must anticipate required workforce by 5 to 10 years
- Forward-looking action plan on education & training to be implemented

Nuclear Skills for Fusion Technologies

- **Neutronics:- technical skills requirements**
  - Radiation transport tools/methods
    - Code familiarity, modelling complex geometries (CAD interface tools), parallel computing/acceleration methods
  - Radioactive Product Inventory Analysis
    - Activation mapping, shut-down dose rate mapping (maintenance)
  - Validation and underpinning nuclear data
    - Cross section and decay data, processing tools, experimental capabilities
  - Multi-physics/engineering analysis
    - coupled transport activation, thermal hydraulics, stress analysis, electro-magnetic analysis
  - Safety and licensing
    - Radioactive waste & decommissioning
  - Project management and team working
  - Good communication, reporting skills



CCFE activation radiation map for ITER complex (L1)



CCFE DEMO work examples

- Systems Modelling and Integration
  Development of EU DEMO plant baselines using CCFE's PROCESS systems code to allow detailed plant performance and economic trade-off studies.
  Systems engineering/integration on DEMO conceptual design

- Balance of Plant (power cycles, sizing/costing components (e.g. turbines), interfacing with grid)
  CCFE undertaking exploratory power cycle modelling and supporting technology studies in collaboration with UK industry to identify viable plant configurations.

- Component Design
  Development of novel high heat flux concepts to manage the large tokamak exhaust heat loads – e.g. MAST-U divertor design.

- Magnets
  Investigation of high temperature superconducting magnets, investigating possibility of demountable joints (in collaboration with Durham Uni.)

- Remote Handling
  CCFE leads EU in design of maintenance schemes, remote joining techniques. Further experience from next JET DT phase, decommissioning.

- Materials manufacturing and development
  Latest additive manufacturing techniques being exploited to yield new high performance alloys and fabrication of innovative components (in collaboration with Birmingham, Cranfield, Manchester, Sheffield, Oxford universities).
  Establishment of Materials Research Facility at CCFE as part of National Nuclear Users Facility.
  Proposal of the novel, intermediate fusion neutron source FAFNIR in a broad collaboration with UK Public Sector Research Establishments and universities.

Post-Graduate Opportunities in Fusion

(see Martin O'Brien for more information)

We have links with about 20 universities. Most include post-graduate training. The emphasis on nuclear technology is increasing.

•Summer projects for taught masters students (Birmingham, Cambridge, York). We lecture at some masters courses (Imperial, Cambridge, York)

•About 40 PhD students at any one time
- plasmas, materials and technology
- half based at CCFE and half at their university
- some CASE, some on other arrangements.
- Annual PhD fair (December this year) – a dozen universities come and talk to students about fusion and related projects

•We hope there will be nuclear Centres for Doctoral Training. We can provide projects and some financial support

•Two Culham Fellowships a year for very talented post-docs

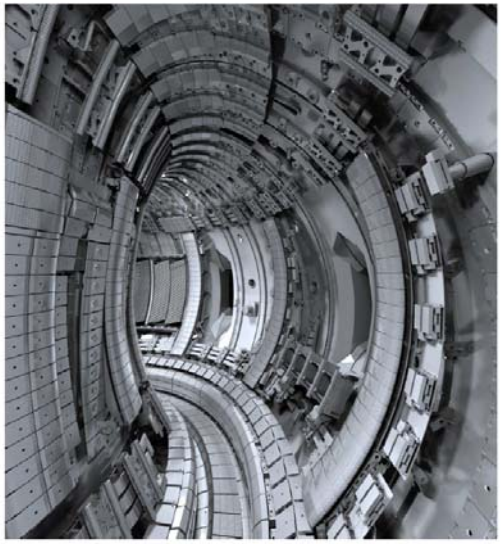
Prof. Paul Mummery (Manchester) talking to a student at CCFE's annual PhD fair

CCFE's need for Materials Scientists will grow

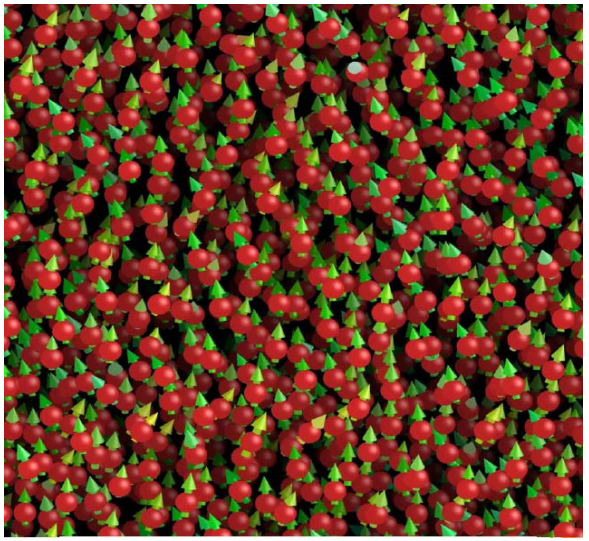
Fusion R&D is shifting from plasma science to materials and technology

•We have a strong materials theory group. Ranges from atomic scale (Density Functional Theory) through Molecular Dynamics to Dislocation Dynamics. Mainly interested in steels (correct treatment of magnetism essential) and tungsten and its alloys.

•Our experimental materials science is restricted to plasma-surface interactions - erosion and tritium retention in JET tiles (Be, W). We will grow this and expand into micro-characterisation of neutron-irradiated materials to collaborate with universities using our new NNUF Materials Research Facility



Beryllium and tungsten-coated tiles line the inside of JET



"Spin Lattice Dynamics" – correct treatment of atomic spins in molecular dynamics calculation of iron

Culham Equipment – in use for non-active material

- Dual beam FIB, Nanoindenter, SEM
- Available now for non-active specimens, new building with hot cells operational in 2015
- Bristol and Oxford using it already, discussions with Imperial starting
- See CCFE staff at this meeting – Damian Brennan, Chris Hardie and Martin O'Brien

SEM Fracture image of novel Hf-containing ODS steel, from mechanical alloying followed by hot isostatic pressing and hot forging, for possible Gen-IV fission and fusion applications

Courtesy M Gorlay (Oxford University)