

Fusion Reactor Technology II

(459.761, 3 Credits)

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Week 9. Radioactivation

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Week 14. Fuel Cycle System

Fusion Plasma Technology

Reactor Technology

Blanket and Material Technology

Safety Technology

Operation and Maintenance

Technology

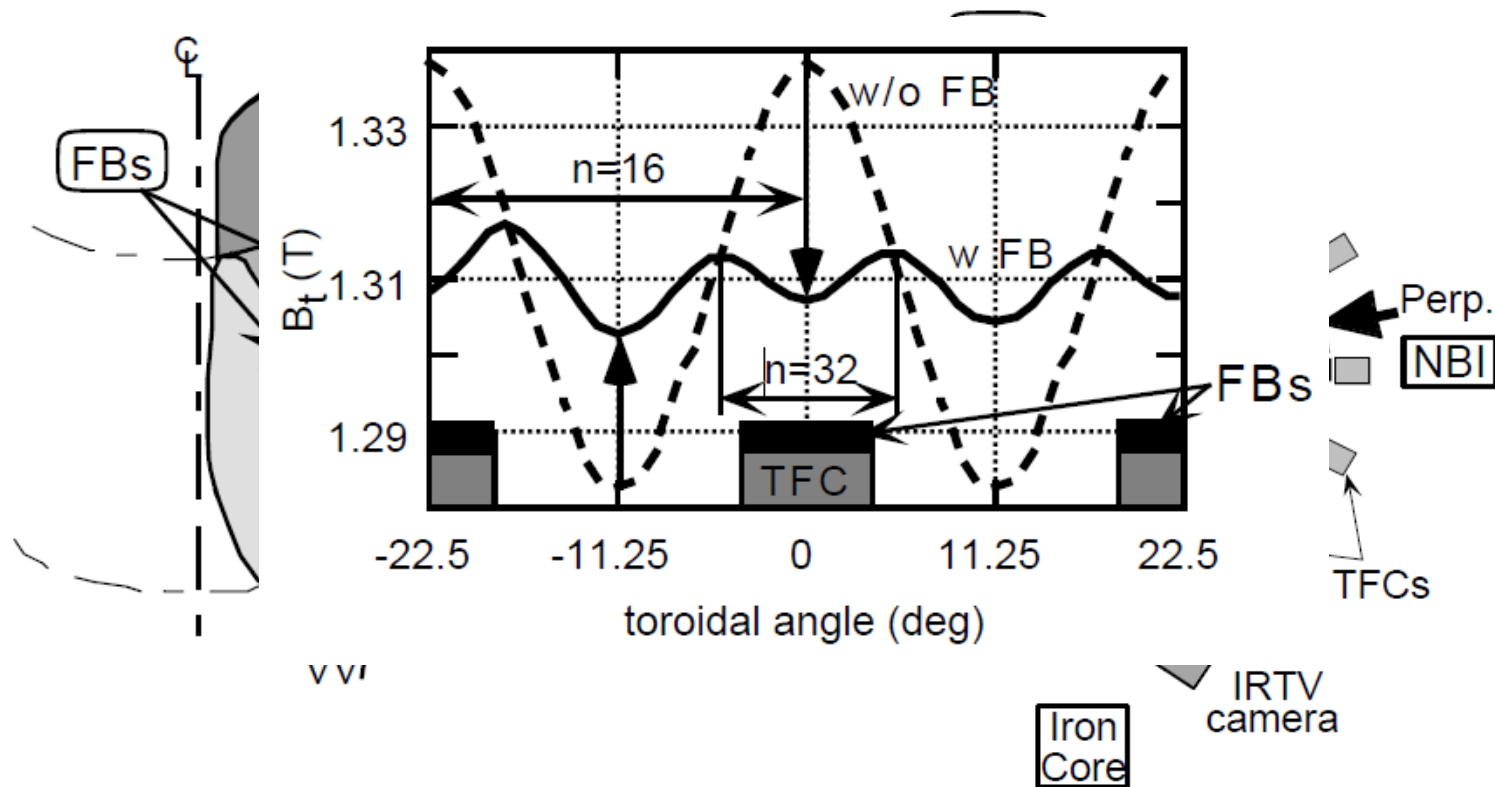
Advanced material and plasma wall interaction

Advanced material

- Requirements
 - Low activation
 - High heat conductivity
 - Minimal swelling
- Advanced material
 - Reduced-activation ferritic steels (RAFS, RAFM)
 - Vanadium alloys
 - SiC/SiC composites

Reduced-activation ferritic steel

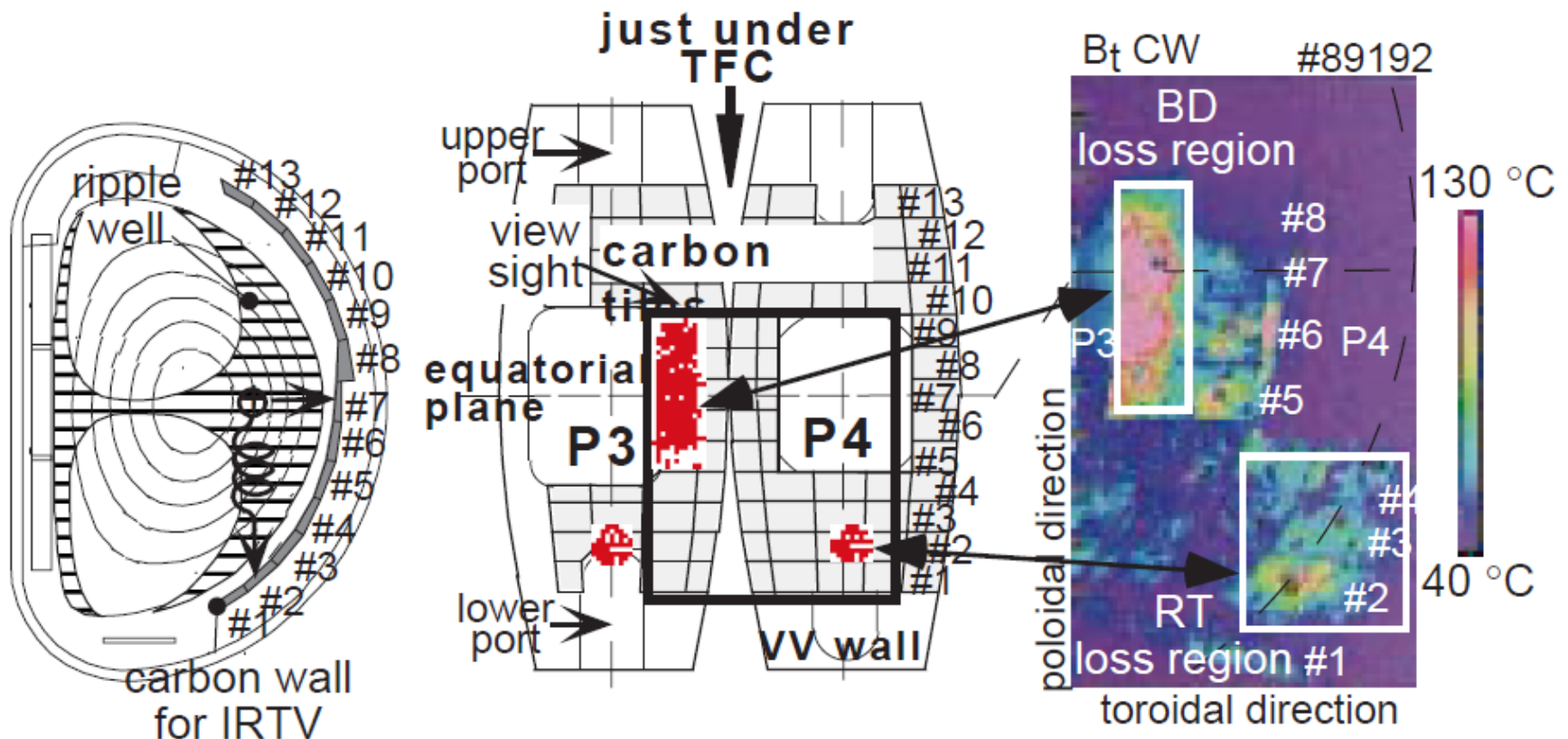
- Ferritic board (F83H: ferromagnetic) for ripple reduction in AMTEX(Advanced Material Tokamak Experiment) at JFT-2M



H. Kawashima et al, Nucl. Fusion **41** 257 (2001)

Reduced-activation ferritic steel

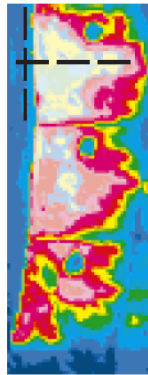
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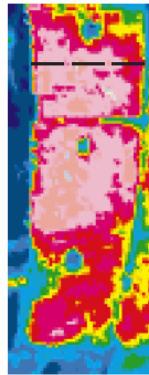
Reduced-activation ferritic steel

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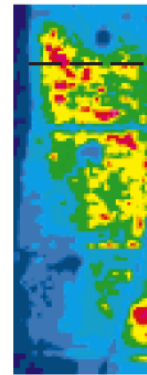
W/O FB, $B_{t0}=1.3T$



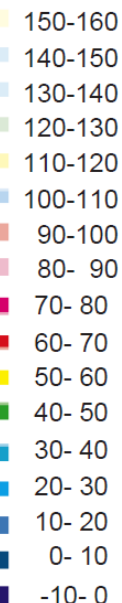
W FB1, $B_{t0}=1.3T$



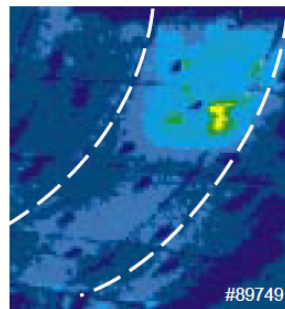
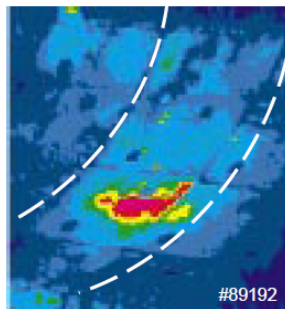
W FB2, $B_{t0}=1.0T$



ΔT_s (°C)



BD loss region



RT loss region



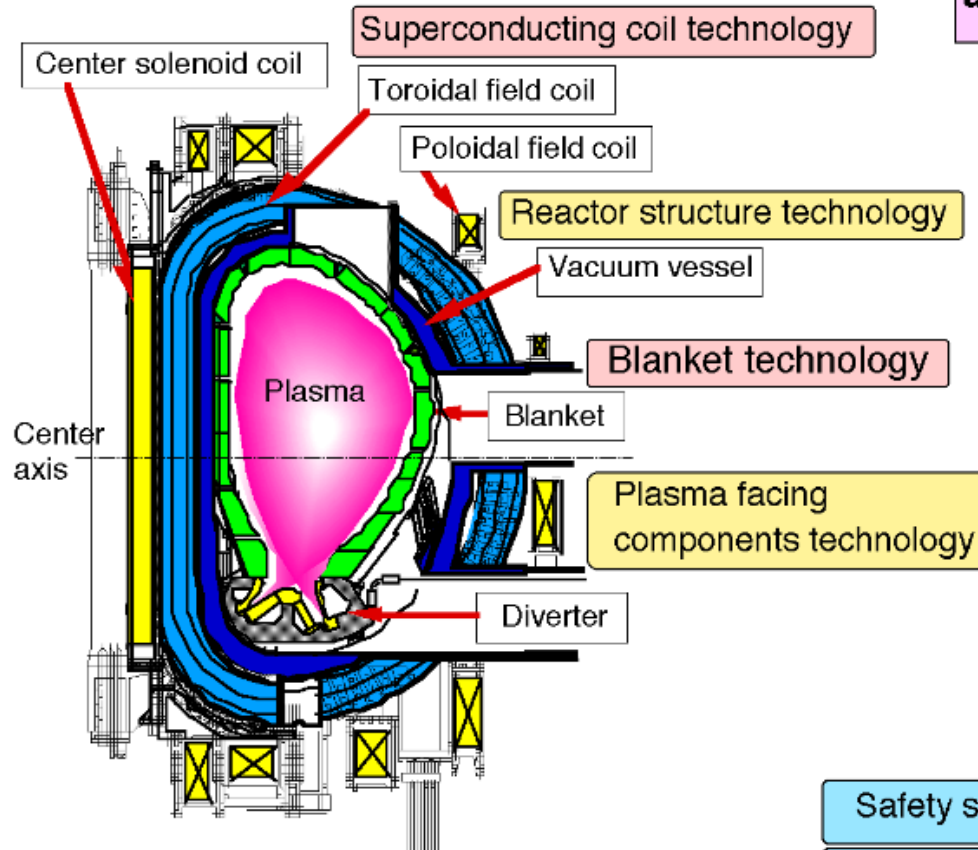
Advanced material

- Vanadium alloys
 - Principal structural material of the ARIES-RS (USA)
 - Embrittlement caused by the occlusion of hydrogen or helium during the tokamak operation
- SiC/SiC composites
 - DREAM (JAERI), ARIES-I
 - Characteristics of Plasma-wall interaction not identified

Fusion Plasma Technology
Reactor Technology
Blanket and Material Technology
Safety Technology
Operation and Maintenance
Technology

Development of component technology for tokamak type fusion reactor

Tokamak Machine Technology



Tokamak related components and system technology

Remote maintenance technology

Tritium engineering /safety technology

Auxiliary heating/current drive components technology

Plasma measurement technology

Fuel injection and exhaust technology

Safety standard/safety evaluation

Demo reactor Tritium Breeding blanket R&D

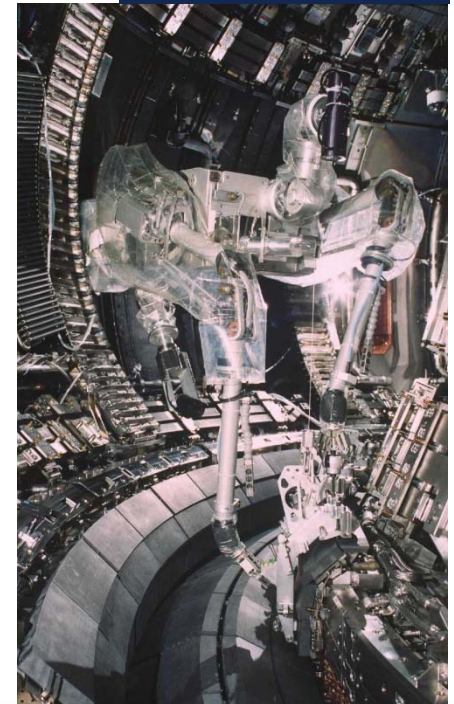
Material R&D

Development of component technology for tokamak type fusion reactor

- Technologies of tokamak component
 - Blanket Technology:
to develop the blanket that surrounds plasma and converts the kinetic energy of neutrons and other particles into heat and also shields the superconducting magnets from radiation
 - Plasma Facing Components Technology:
to develop the divertor that captures the high-energy particles and absorbs the heat load from plasma
 - Reactor Structural Technology:
to develop the vacuum vessel and support structures that will sustain the high vacuum for generation of plasma and contain the blanket and divertor
 - Superconducting Magnet Technology:
to develop the superconducting magnet that provide magnetic field to confine plasma, which is a magnetohydrodynamic fluid, and induces a current in the plasma by varying the magnetic field

Development of component technology for tokamak type fusion reactor

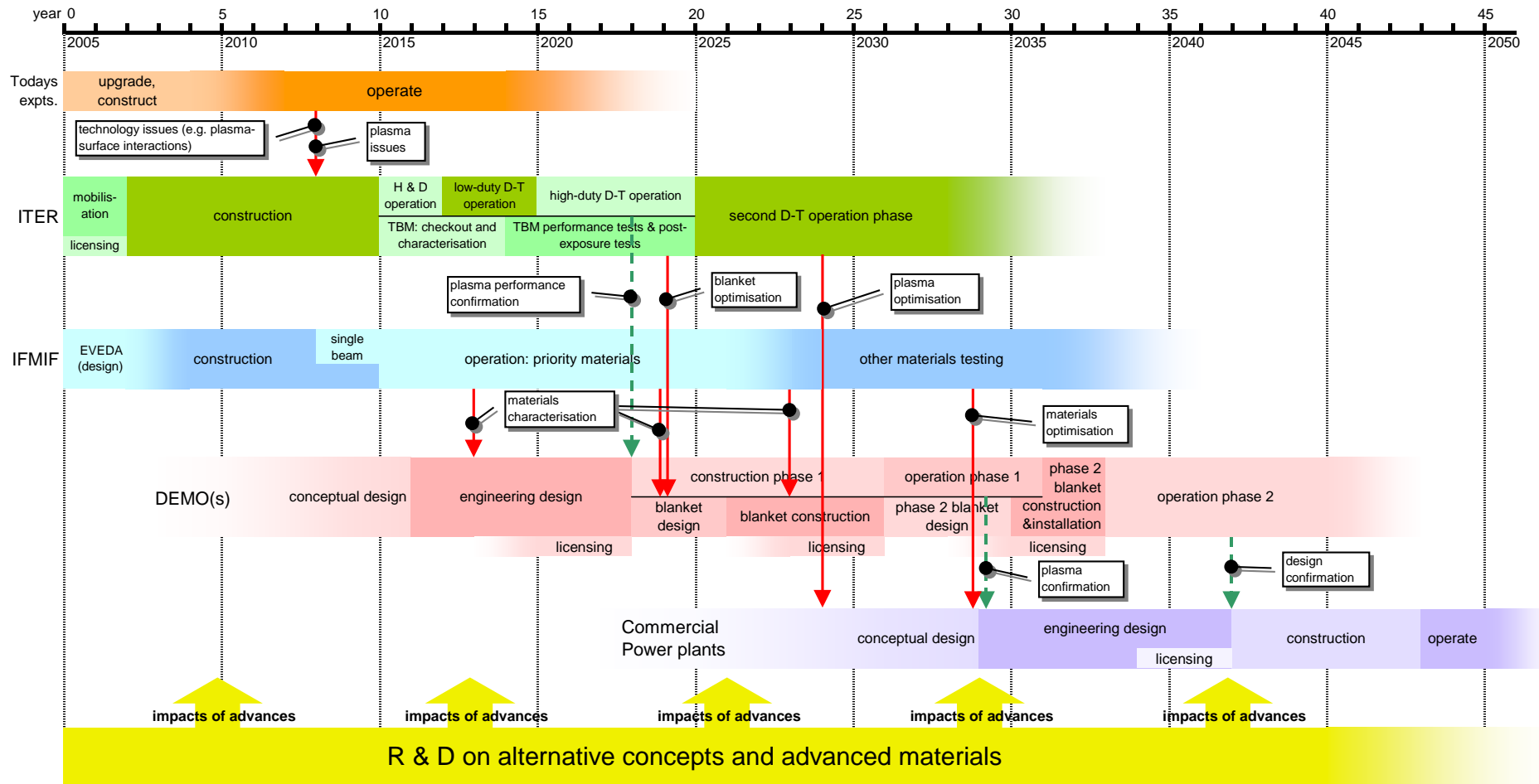
- Component technologies related to the tokamak
 - Auxiliary Heating and Current Drive Equipment Technology: to heat the plasma and drive the plasma current
 - Plasma Measurement Technology: to measure the temperature and density of plasma to form and control the plasma
 - Fuel Injection and Exhaust Technology: to inject and exhaust fuel
 - Tritium Engineering /Safety Technology: to recycle tritium safely, which is radioactive and do not exist naturally
 - Remote Maintenance Technology: to remotely maintain and repair the components that are radio-activated by neutrons generated from the plasma. Furthermore, toward the safety review for licensing and the future power reactor development



Development of component technology for tokamak type fusion reactor

- Component technologies related to the tokamak
 - Preparation of safety standards required for safety review for licensing, and data and evaluation methods required for safety evaluation
 - Research and development of the Tritium breeding blankets for the future power reactors
 - Development of first wall materials are required.

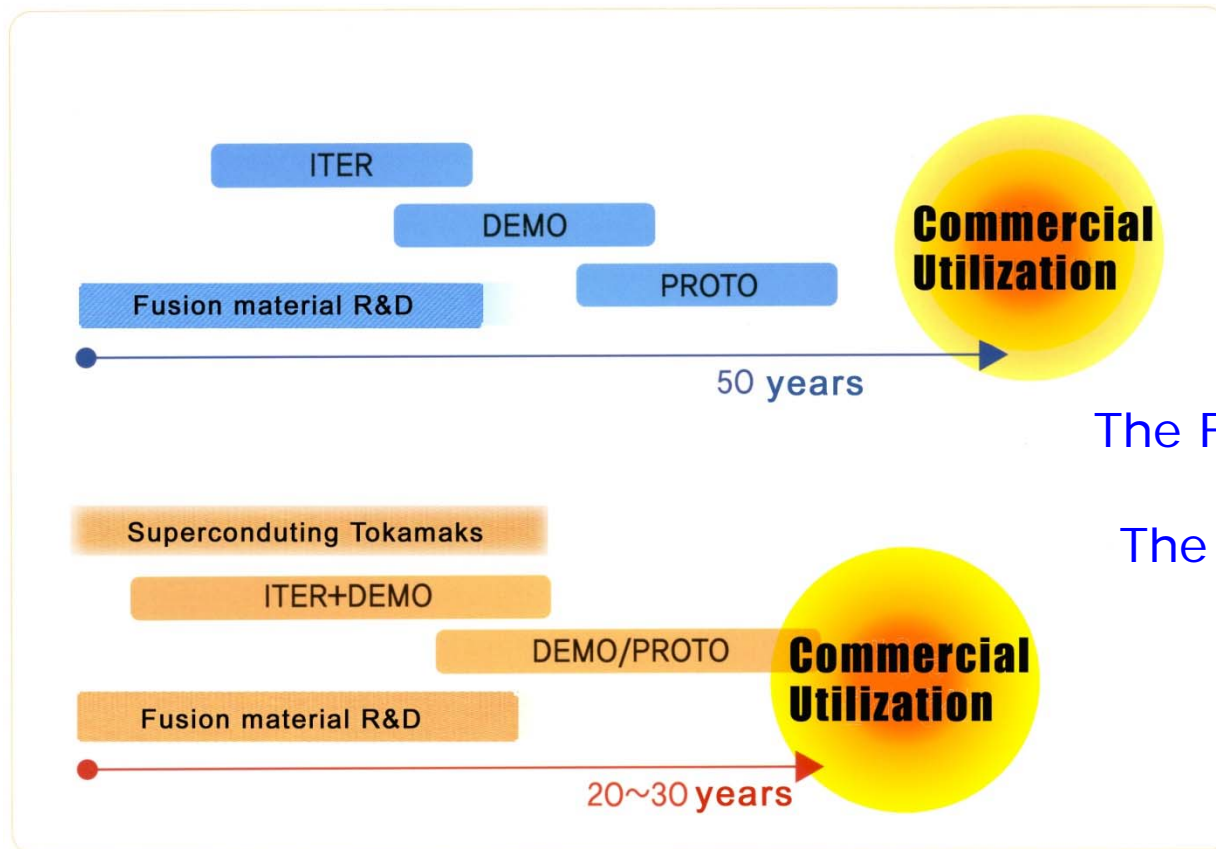
Phased integration of reactor technology development



"The Path to Fusion Power"

by C. L. Smith (Director, UKAEA Culham), KAST (10 October, 2006) ¹⁵

Phased integration of reactor technology development

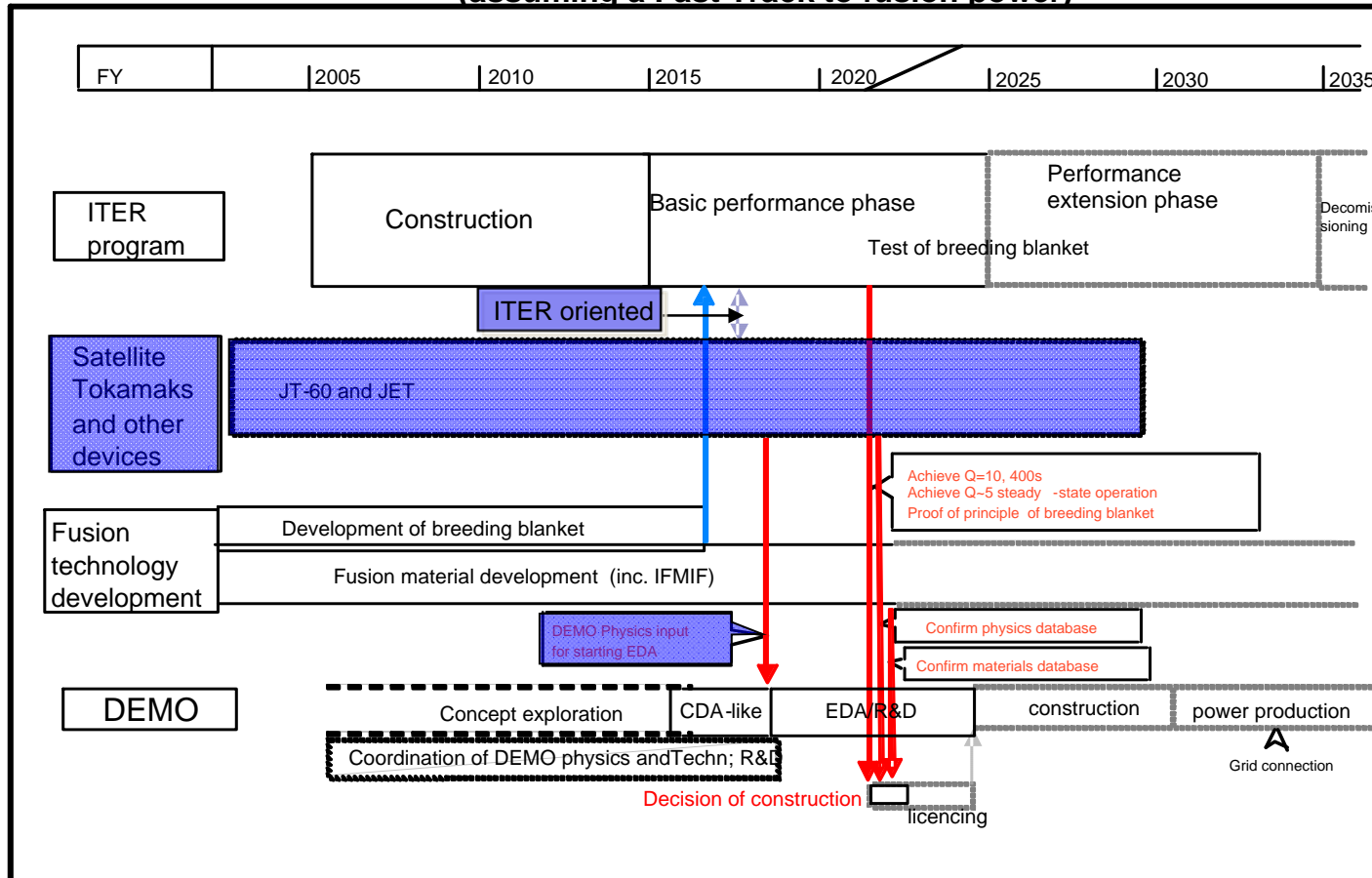


The Fast Track Approach
&
The Broader Approach

Phased integration of reactor technology development

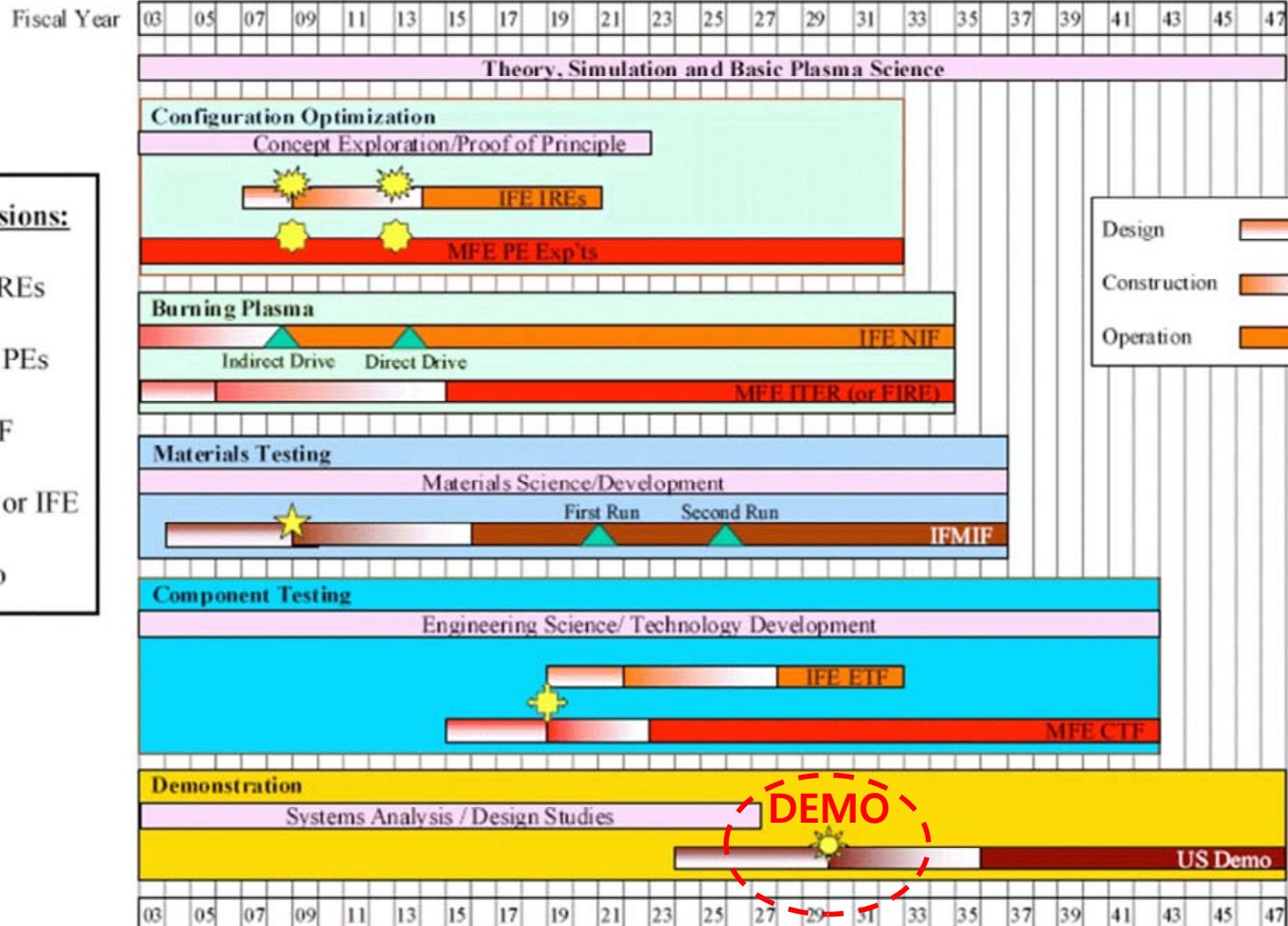


The broader approach leading to construction of DEMO (assuming a Fast Track to fusion power)



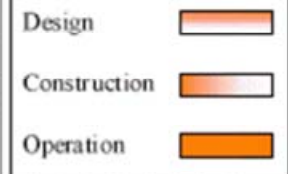
"Overview of NCT Proposal" M. Kikuchi (November 3-4, 2005)

Phased integration of reactor technology development



Key Decisions:

- IFE IREs
- MFE PEs
- IFMIF
- MFE or IFE
- Demo



DEMO

Phased integration of reactor technology development



Strategic Timeline—Fusion Energy Sciences*

2003 2005 2007 2009 2011 2013 2015 2017 2019 2021 2023 2025

The Science

Burning Plasma Demonstration

- Initiate experiments on the National Ignition Facility (NIF) to study ignition and burn propagation in IFE-relevant fuel pellets (2012)

ITER

- Complete ITER experiments to determine plasma confinement in parameter range required for an energy-producing plasma (2017)

- Complete experiments on NIF to advance the science of ignition and burn propagation needed to design optimized fuel pellets for an Inertial Fusion Energy plant (2020)
- Complete experiments on ITER to determine the impact of the fusion process on the stability of energy-producing plasmas (2020)

- Achieve high fusion power for long durations on ITER to define engineering requirements for fusion power plants (2025)

Fundamentals of Plasma Behavior

Tokamaks

- Achieve a fundamental understanding of tokamak transport and stability in pre-ITER plasma experiments (2009)

- Major aspects relevant to burning plasmas have been observed in experiments prior to full operation of ITER are predicted with high accuracy and are understood (2015)
- Determine the physics limits that constrain the use of inertial fusion energy drivers in future key integrated experiments needed to resolve the scientific issues for inertial fusion energy and high-energy density physics (2015)

Fusion Simulation Project

- Deliver a complete integrated simulation of a power-producing plasma, validated with ITER results, that enables the design of fusion power plants (2020)

Plasma Confinement

NSTX

- Achieve long-duration, high-pressure, well-confined plasmas in a spherical torus sufficient to design and build fusion power-producing Next-Step Spherical Torus (2008)
- Demonstrate the feasibility of steady-state and self-generated plasma current to achieve high-pressure/well-confined steady-state operation for ITER (2008)

NCSX

- Evaluate the ability of the compact stellarator configuration to confine a high-temperature plasma (2012)
- Evaluate the feasibility/attractiveness of potential drivers, including heavy ion beams, dense plasma beams, and laser for fusion approaches involving high-energy density (2009)

Next-Step Advanced Facility

- Resolve key scientific issues and determine the confinement characteristics of a range of attractive confinement configurations (2015)

- Determine the potential of one or more of the promising plasma configurations (for example a spherical torus) for use as a component test facility or a fusion power source (2020)

Materials, Components, and Technologies

- Start production of superconducting wire needed for ITER magnets (2006)

- Deliver to ITER for testing the blanket test modules needed to demonstrate the feasibility of extracting high-temperature heat from burning plasmas and for a self-sufficient fuel cycle (2013)

Component Test Facility

- Complete first phase of testing in ITER of blanket technologies needed in power-producing fusion plants capable of extracting high-temperature heat from burning plasmas and having a self-sufficient fuel cycle (2014)

- Complete first round of testing in a component test facility to validate the performance of blanket technologies needed for a power-producing fusion plant (2025)

Future Facilities**

“The Development Path for Magnetic Fusion Energy” by R. Goldston (Director, PPPL) Global Climate and Energy Project Worksho on Fusion Energy (1 May, 2006)

*These strategic milestones are illustrative.

**For more detail on these facilities

Facilities for the Future of Sciences: A Twenty-Year Outlook.