Highlights of 2009 IAEA TM on Power Plant Designs and Safety

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University of Wisconsin-Madison

ARIES-Pathways Project Meeting
August 26 - 27, 2009
Georgia Tech
Atlanta, GA

Two Technical Meetings with 1-day Joint Session

Misleading Name !?

3rd IAEA TM on 1st Generation Fusion Power Plants

Tuesday July 14	Wednesday July 15	Thursday July 16	Friday July 17

9th IAEA TM on Fusion Power Plant Safety

Misleading Name !?

Attendees

- **~ 80 attendees from ~16 countries**:
  - US (6)
  - JA
  - ITER
  - EU:
    - UK
    - Germany
    - Austria
    - Belgium
    - France
    - Italy
    - Ukraine
    - Slovakia
    - Kazakhstan
  - Russia
  - China
  - S. Korea
  - India
  - Pakistan

Topics and Publications

- **Main Topics**:
  - Power plant designs
  - New concepts
  - ITER TBM
  - Safety and environment
  - Fusion-fission synergies

- **Panel discussion**: How fast commercial fusion can become a reality, assuming no funding constraints?

- **Publications**:
  - All presentations available on CD
  - Papers will be published by IAEA on CD with ISBN #.

Agenda

3rd IAEA TM on 1st Generation Fusion Power Plants

Tuesday, 14 July 2009

08:30 – 09:00	Welcome & Opening Remarks Mr. N. Ramamoorthy – DIR-NAPC
	Approval of the Agenda
09:00 – 09:15	Welcome and scope of the TCM G. Mank

Contributed Papers – Tuesday 14 July - 09:00 – 13:00 h

09:15 – 09:45	Neutronics Analysis and Comparison for Test Blanket Modules, Testing Facilities and DEMO Based on HCPB Blanket Concept S. Zheng
09:45 – 10:15	Need for Online Adjustment of Tritium Bred in Blanket and Implications for ARIES Power Plants L. El-Guebaly
10:15 – 10:45	Corrosion, Erosion and Activation in Fusion Power Plant Cooling Loops P. Karditsas
10:45 – 11:00	Coffee break
11:00 –11:30	Positron Annihilation Lifetime Study of Implanted Defects in Advance FE-CR Alloys V. Slugen
11:30 –12:00	Indian Program on Materials Development for Test Blanket Module A. Suri
12:00 – 12:30	Analysis of long term environmental behavior of tritium using numerical model T. Shibata
12:30 – 13:00	Fusion-Biomas Hybrid Concept and its Implication in Fusion Development S. Konishi
13:00 – 14:00	Lunch Break

Contributed Papers – Tuesday 14 July - 14:00 – 15:00 h

14:00 –14: 30	Current Drive in Demo D. Ward
14:30 – 15:00	Stellarator-mirror fusion driven system V. Moiseenko
15:00 – 15:30	Coffee break

Panel Discussion Session - Tuesday 14 July 15:15 – 17:30

"How fast commercial fusion can become a reality assuming No funding constraint"

4 Panelist present their personal views (10 minutes' each) Followed by a group discussion

Agenda

Joint Session

Joint Session Wednesday, 15 July 2009

08:45 – 09:00	Opening remarks G. Mank
Overviews – 09:00 – 12:15	
09:00 – 09:30	40 Years of Power Plant studies: Brief Historical Overview and Future Trends L. El-Guebaly
09:30 – 10:00	Study Activities of DEMO Plant at SWIP K. Feng
10:00 – 10:30	ITER, a Fusion Nuclear Installation C. Alejaldre
10:30 – 10:45	Coffee break
10:45 – 11:15	Demonstration of Fusion Safety - US Contributions and Pathways for ITER and Beyond P. Sharpe
11:15 – 12:00	Discussions
12:00 – 13:30	Lunch Break

Hybrids and Proliferation 13:00 – 15:00

13:30 – 14:00	Proliferation Risks of Fusion: Clandestine Production, Covert Diversion, and Breakout R.J. Goldston
14:00 – 14:30	Re-evaluation of Fusion-Fission Hybrid Reactors for Energy Production, Fuel Breeding and Waste Transmutation Y. Wu
14:30 – 15:00	Discussion on Hybrids and Proliferation
15:00 – 15:30	Coffee break
Waste Management, 15:30 – 17:00	
15:30 – 16:00	Integrated Management for Fusion Activated Materials: US Position and Regulations L. A. Guebaly
16:00 – 16:30	Critical Issues for Disposal, Recycling, and Clearance of Fusion Radioactive Materials: the European Viewpoint M. Zucchetti
16: 30 – 17:00	Positron Lifetime Model Calculations of Defect in Fusion Materials Containing Hydrogen and Helium T. Troev
17:00 – 17:45	Discussion on Waste Management

Agenda

9th IAEA TM on Fusion Power Plant Safety

Thursday, 16 July 2009

ITER safety and licensing

09:00 – 09:45	Key issues in the safety and licensing of ITER N.P. Taylor
09:45 – 10:30	EU Safety Activities for ITER Licensing W. Gulden
10:30 – 10:45	Coffee break
10:45 – 11:15	Dust and Tritium Management F. Le Guern
11:15 – 11:45	Hydrogen Safety Analysis for the ITER Licensing Using CFD code GASFLOW J. Xiao
11:45 – 12:15	The Application of New MAGARC Code Capabilities to an Unmitigated Magnet Quench B. Merrill
12:15 – 13:30	Lunch break
13:30 – 14:00	Postulated Initiating Event-Potential Impacts Table on ITER DFLL-TBM System L. Hu
14:00 – 14:45	Discussion on ITER safety and licensing Session chair
14:45 – 15:15	Coffee break

Occupational Safety

15:15 – 15:45	Workers and members of the public radiation protection concerns for ITER and fusion power plants P. Cortes
15:45 – 16:15	Use of the MCR2S system for high-resolution occupational radiation exposure estimates in ITER A. Davis
16:15 – 16:45	ITER ORE assessment outline and last achievements in the diagnostic systems M.T. Porfiri
16:45 – 17:15	Personnel Safety for Magnetic Fusion Power Plants L. Cadwallader
17:15 – 18:00	Discussion on Occupational Safety Session chair

Friday, 16 July 2009

09:00 – 09:30	Development of Strategic Technology Roadmap for Establishing Safety Infrastructure of Fusion Energy S. Cho

Tritium Safety and inventories

09:30 – 10:00	Tritium migration through concrete enclosures of tritium handling facilities S.Fukada
10:00 – 10:30	Study of Accumulation and Gas-Release of Hydrogen Isotopes in Beryllium under Irradiation I.L. Tazhibayeva
10:30 – 10:45	Coffee break
10:45 – 11:15	Current Tritium Issue in the Fusion DEMO Plant designed by JAEA H. Nakamura
11:15 – 11:45	Summary Session on Tritium Safety and inventories Session chair
11:15 – 12:30	Summary by the chair of the meeting
12:30	Closing G. Mank

Highlights

3rd IAEA TM on 1st Generation Fusion Power Plants

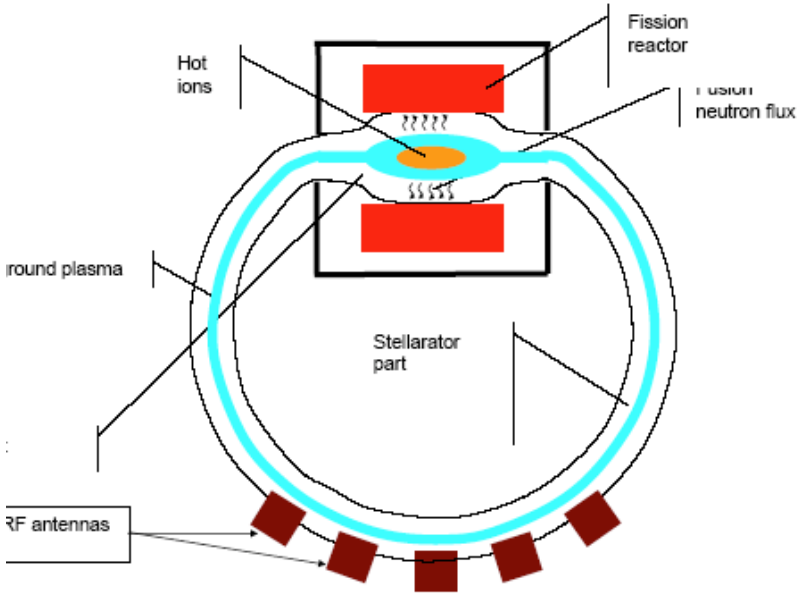
- **Indian TBM** (Sure - India)
  - Titanate (Li_2TiO_3) - solid breeder
  - LiPb: coolant and multiplier
  - FS structure with self-healing Al_2O_3 coating
  - He purge gas for T removal
  - He cooled FW
  - Be coated FW.

- **Current Drive in Demo** (Ward - UK)
  - Crucial milestone for steady-state DEMO is development of reliable, efficient CD systems, particularly **NBI** (best option because of its high current drive efficiency)
  - Current drive power and its contribution to recirculating power will be important in DEMO.
  - It is advantageous to have high beam energies (> 1 MeV) for DEMO.
  - With NBI, DEMO could lose up to 5% of tritium generation; this may equate to around 5% of FW area.
  - Pulsing increases costing by 20-30%. This can have substantial (-ve) impact on role of fusion in future energy market.

Highlights (Cont.)

3rd IAEA TM on 1st Generation Fusion Power Plants

- **Stellarator-Mirror Fusion Driven System**
  (Moiseenko - Ukraine)



- **Panel discussion**:
  How fast commercial fusion can become a reality, assuming no funding constraints?
  - **UK**: Early construction of Demo; start design in 5 y. Demo operation by 2020 (before ITER!).
  - **JA**: 10-fold increase in fusion funding is impossible.
    Start Demo after ITER in 2030. Build PP before 2050.
  - **China**: Develop nuclear power ASAP. Demo by 2035.
  - **US** (Goldston): Put electricity on grid fast:
    - Pilot plan combined with CTF. Net electricity on grid by 2027.

Highlights

Joint Session

- **40 Years of Power Plant Studies** (El-Guebaly - USA)
  - Brief **history** of *magnetic* fusion development since 1950
  - Timeline and main features of **large-scale magnetic fusion power plants** designed since early 1970s in US and worldwide
  - Fusion **roadmaps** in US, EU, Japan, and China with limited and unlimited funding (will be discussed shortly).

- **Chinese presentations** (Feng and Wu - China)
  - Hybrid is essential for China (need 240 GW carbon-free energy by 2050)
  - Chinese Demo will support this mission
  - Series of hybrid developed since 1990.

- **Radwaste management presentations** (El-Guebaly (US) and Kolbasov (RF))
  - Recycling and clearance are preferred options for fusion materials; avoid geological disposal
  - Detritiation of all components is essensial.

Highlights

Joint Session

- **Discussions**:
  - **Which concept for Demo**?
    - **US**: Tokamak is main concept, but need to address disruption and maintenance.
      Goldston: Stellarator is backup.
    - **Russia**: Tokamak + other concepts for n source, hybrid, etc
    - **Korea**: Most studies on tokamak for Demo and PP. Interest in ST as n source
    - **India**: Tokamak
    - **China**: Hybrid
  - **International collaboration on Demo,** proposed by China.
    - There are many definitions for Demo. It's difficult to agree on single Demo.
  - **Hybrid**
    - **Najmabadi**: Developing technology for hybrid may take longer than expected
    - **Goldston**: It's better to develop CTF than hybrid
    - **El-Guebaly**: Fusion developed to be safe with LAM, no HLW, and no evacuation plan. Hybrid offer benefits to fission industry, but defeat purpose of developing fusion.
    - **Mank**: This is not the way to go for fusion. IAEA does not support hybrid.

Highlights

9th IAEA TM on Fusion Power Plant Safety

- **Key Issues in Safety and Licensing of ITER** (Taylor - ITER)
  - ITER obtained construction permit
  - Licensing document submitted last year. 60 Qs received from French authority. Most critical Qs:
    - Prove that detritiation efficiency is 99%
    - Validate MELCORE code
  - Safety assessments assume:
    - 1 tonne dust of W or Be
    - 1 kg tritium – mainly absorbed in dust
  - Cryostat is not confinement barrier anymore. VV, detritiation system, and building walls (of T plant, hot cells, radwaste building, etc) are.

Magnetic Fusion Roadmaps
(El-Guebaly)

- Since 1970, researchers developed roadmaps with end goal of operating 1st fusion power plant in **50 years** (⇒ by 2020 !)

- Recently, optimism about magnetic fusion resurfaced with construction of ITER.

- Worldwide, main magnetic concept supporting path from ITER to power plant is tokamak.

- **Key strategic questions**:
  - What **technologies** remain to be developed and matured for viable tokamak power plant?
  - What other **facilities** will be needed between ITER and first power plant?
  - **How long** will it take to construct 1st fusion power plant?

US Fusion Roadmap

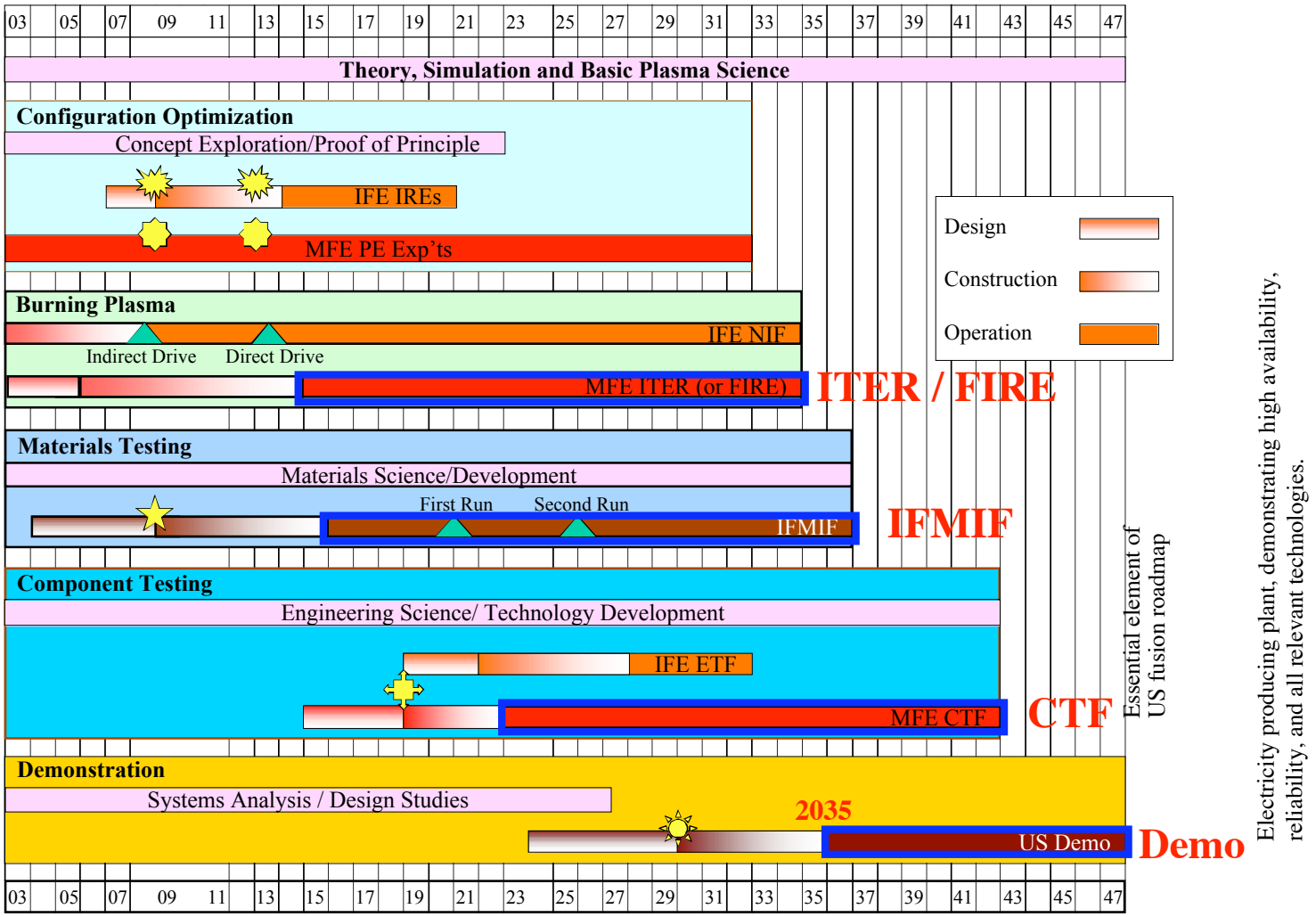
(R. Goldston - PPPL - 2003;
2003 FESAC 35 Year Fusion Development Plan for MFE and IFE)

Unofficial

2003 FESAC 35 Year Fusion Development Plan for MFE and IFE

Key Decisions:

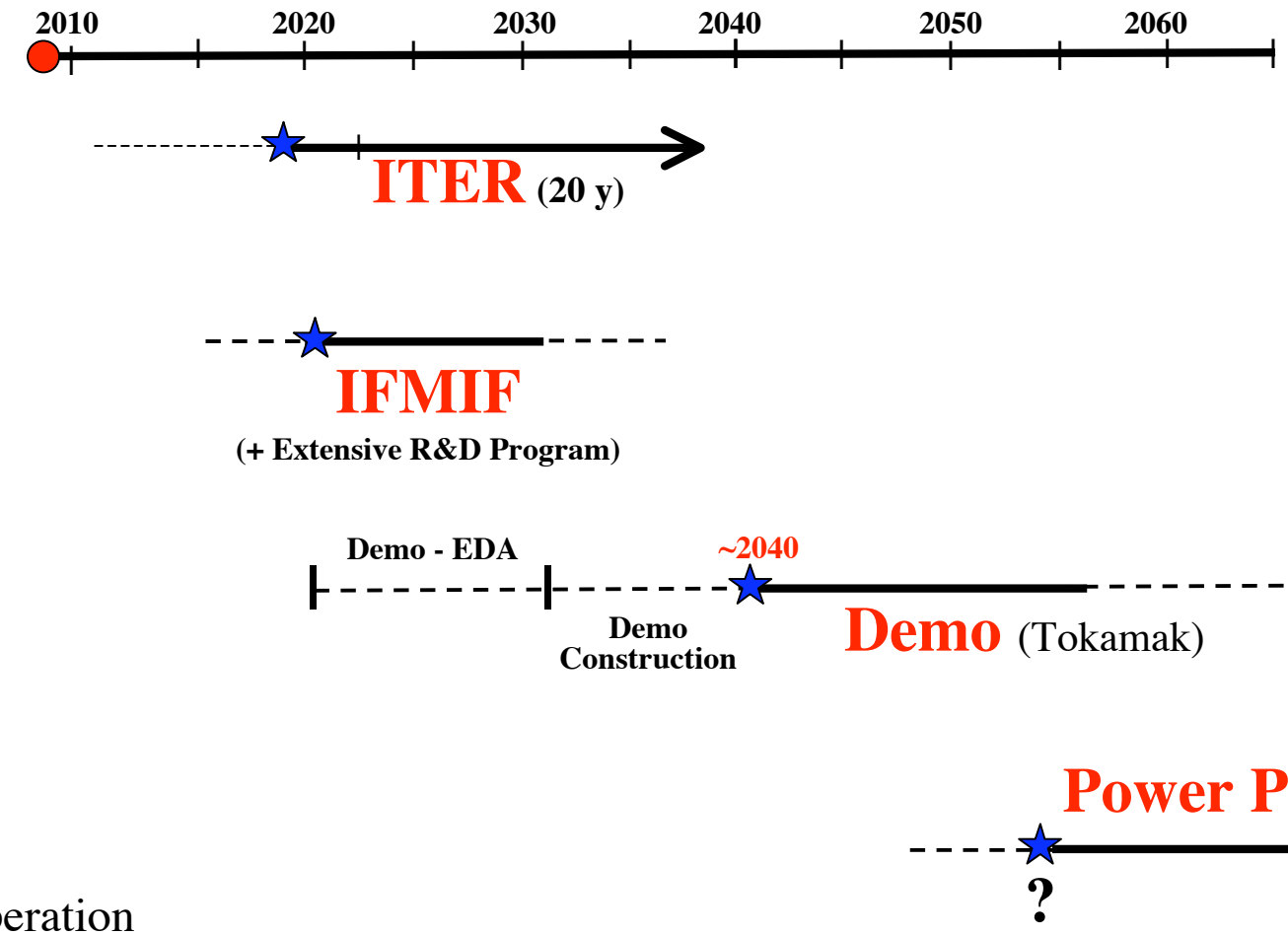
- IFE IREs
- MFE PEs
- IFMIF
- MFE or IFE
- Demo



EU Fusion Roadmap

(D. Maisonnier - EC - 7/09)

Unofficial



Japan Fusion Roadmap

Unofficial

(National Policy of Future Nuclear Fusion Research and Development, Advisory Committee on Nuclear Fusion, AEC, 2005)

http://www.aec.go.jp/jicst/NC/senmon/kakuyugo2/siryo/kettei/houkoku051026_e/index.htm

4-Phase Program (suggesting advanced operating mode for Demo; no mention of CTF)

- **Ongoing 3rd phase** helps make decision to construct tokamak Demo.
  Supporting elements include:
  - Strong R&D program and BA activity
  - Experimental facilities: ITER, IFMIF, JT-60SA, LHD, FIREX.

- **4th phase** will assess technical feasibility of **Demo.**
  Characteristics: Steady-state tokamak
  High plant efficiency
  Tritium Breeding Ratio > 1
  10-20 MWy/m^2 neutron fluence
  1 MW/m^2 heat flux at FW.

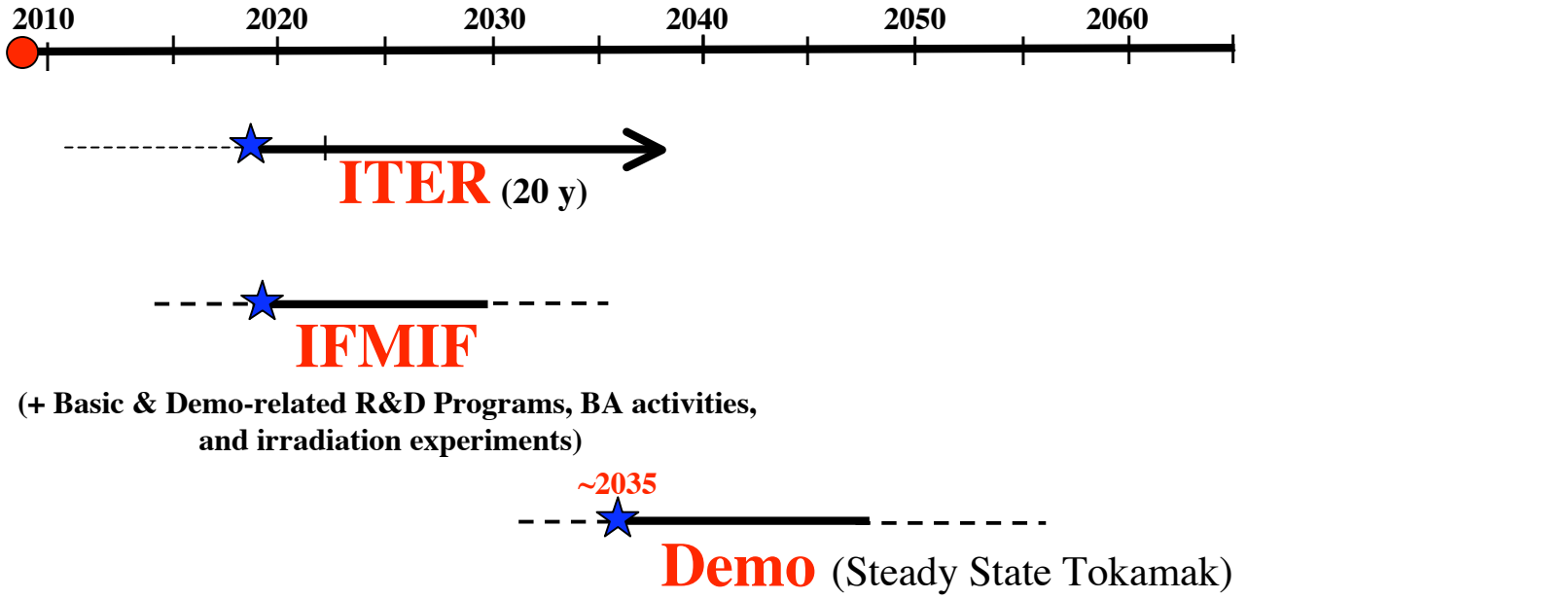
Japan Fusion Roadmap (Cont.)

Unofficial

"A Roadmap and Technological Strategy toward the Commercial Use of Fusion Energy"

(Fusion Energy Forum of Japan: ITER・BA Technical Promotion Committee's Report, 2008)

(Shimizu's TOFE-2008 presentation: Overview of Recent Japanese Activities and Plans in Fusion Technology)

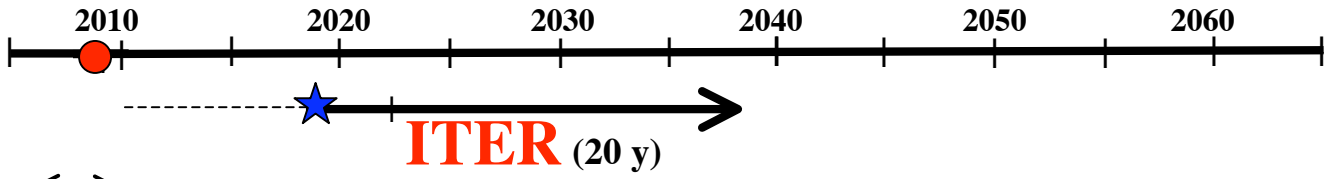


China Fusion Roadmap

(Y. Wu - Chinese Academy of Sciences - 6/09)

Unofficial

3-Step Program (steady-state tokamaks and spherical tori):



2006-2010: Speed-up Domestic Fusion Program

2011-2020: Establish Solid Domestic MFE Base

(EAST, HT-7, and HL-2M **experiments** play essential role in establishing physics and technology bases for steady-state tokamaks)

2021-2040: Fast Track for Demo Construction

Major new facilities to be constructed by 2040:

FDS-I Hybrid tokamak power plant with 150 MW P_f for transmutation of fission wastes and breeding of fissile fuels

Demo → **FDS-II** Electricity generator tokamak power plant with high power density and high thermal efficiency:
DCLL or semi-static He-cooled LiPb blanket

FDS-III High temperature power plant for hydrogen production:
SiC/LiPb or DCLL blanket with multilayer of FCI

FDS-ST Spherical torus to examine innovative approaches.

US Fusion Roadmap

with Unlimited Funding

(Personal View)

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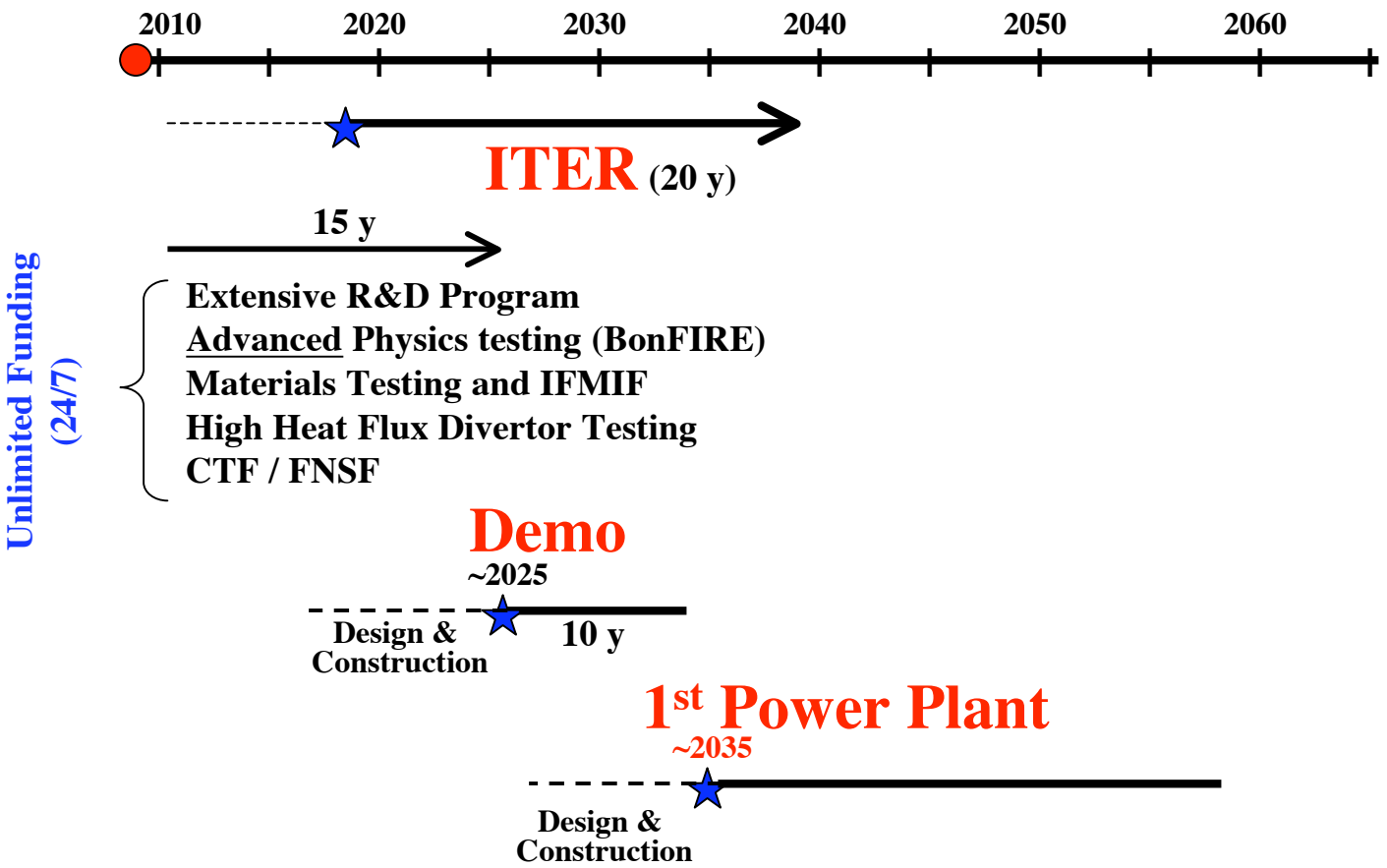

★ Operation

Fusion Roadmap

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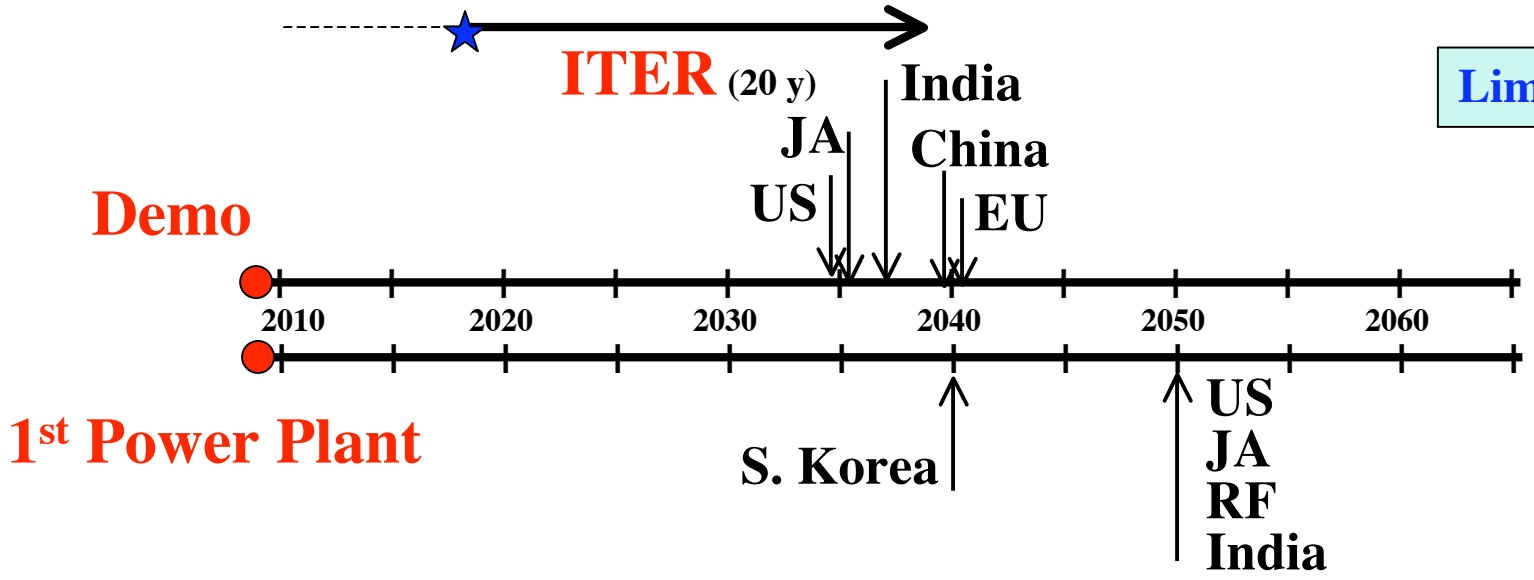
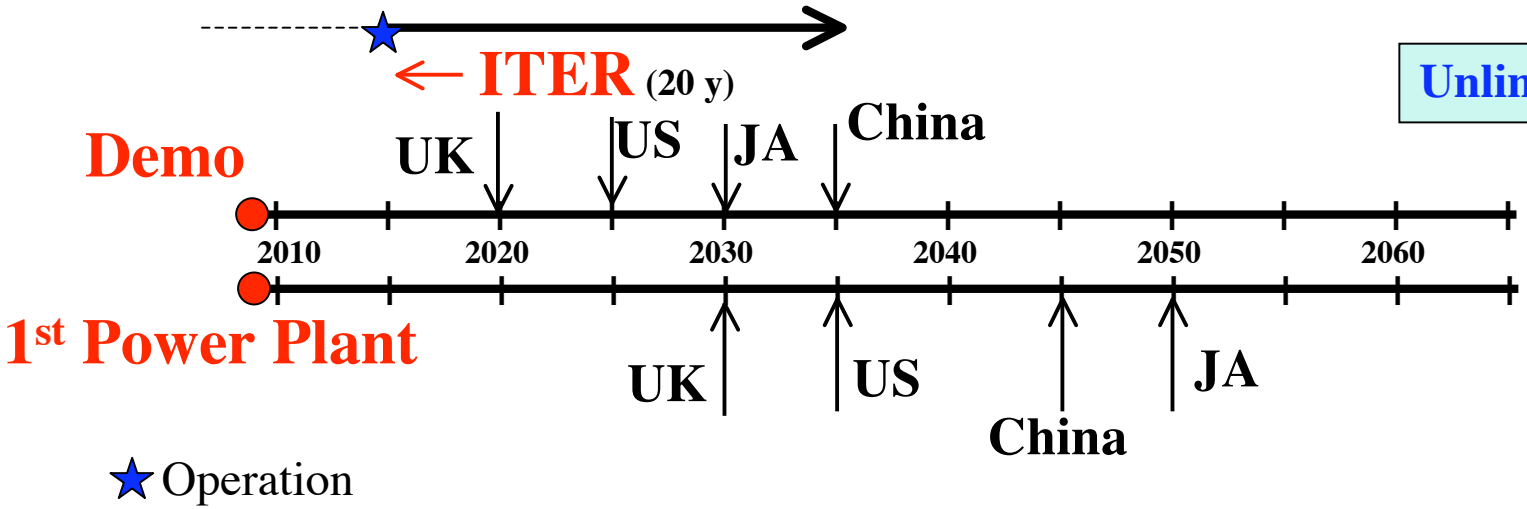


Limited Funding



Unlimited Funding

General Observations

- Philosophy adopted in international designs varies widely in degree of physics extrapolation, technology readiness, and economic competitiveness:
  - **US view**: PP must be economically competitive with other available electric power sources ⇒ advanced physics and advanced technology should be developed before building Demo.
  - **EU/JA view**: First generation of PPs will enter energy market because of major safety/environmental advantages and large fuel reserve, even if they produce electricity at somewhat higher cost.

- Worldwide roadmaps take different approaches, depending on degree of extrapolation beyond ITER.

- **Several tokamak Demos should be built** in US, EU, Japan, Russia, China Korea, India and other countries to cover wide range of near-term and advanced fusion systems.

- With **limited funding and no clear vision**, timetable could extend beyond the *famous* 50 years.

- With **unlimited funding**, 1st fusion power plant could add electricity to grid by 2030-2035.