Overview of the Fusion Roadmaps in the World

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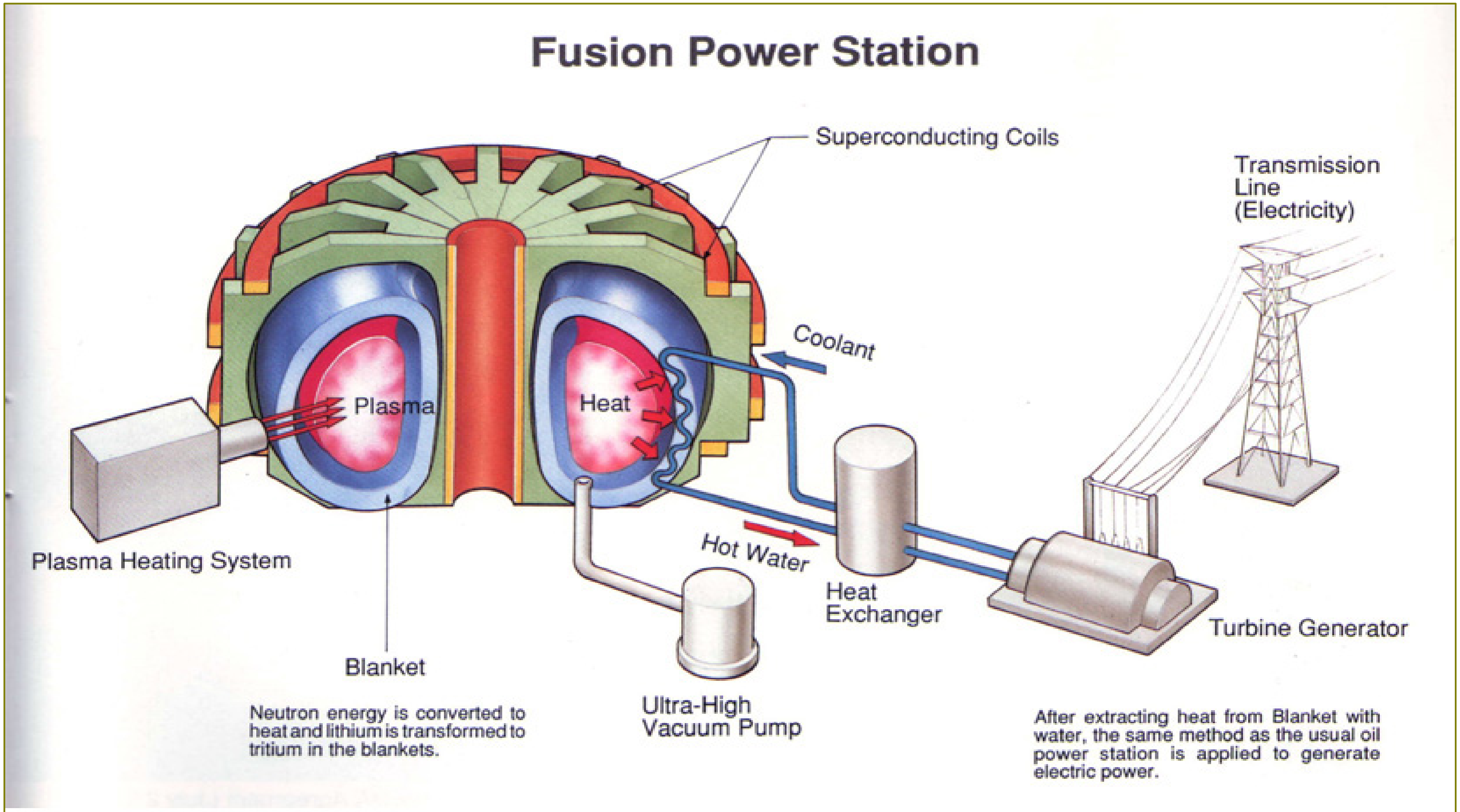
27 th SOFT 2012 Liege Belgium

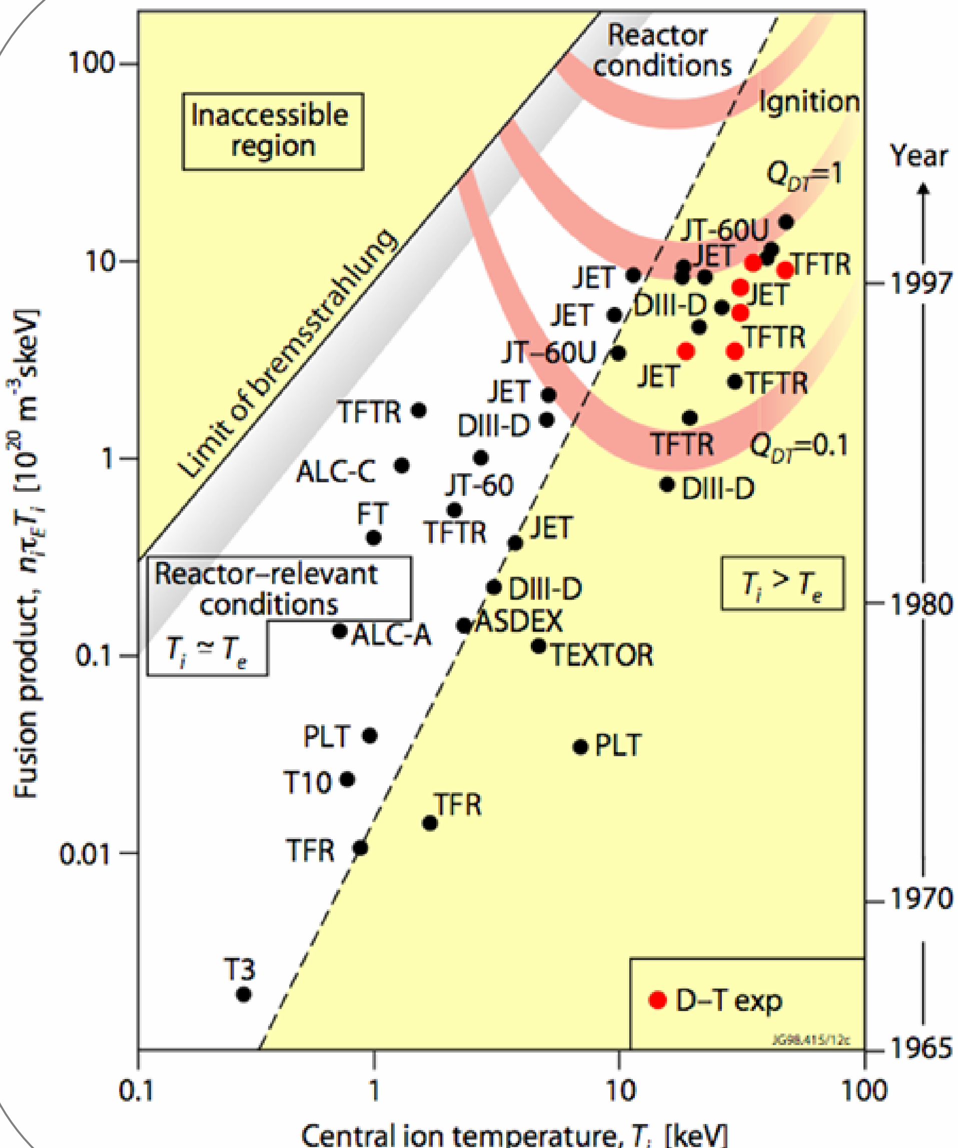
Final goal is to obtain realistic FE (FPP)



D-T burning plasma with the SSO or high duty time

Content

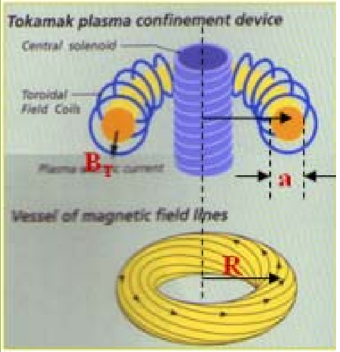
- Milestones which led the demonstration that scientific feasibility of MFE has been achieved
- ITER- it is the most important bridge to go to realistic FE (FPP)
- The roadmaps in the world, which are under studying, discussion and consideration for making further decisions
- Summary



- T-3
- ASDEX
- DIII-D
- Discovers from many medium size devices and theory progress
  - q → I_p
  - Density limit
  - β limit
  - P_{L-H}
  - Tech. developments: NBI,ICR,ECR,LH,
  - **ST - T- 7,Tore Supra, Traim ,EAST KSTAR, SST-1 for SSO**
  - ………………
- **TFTR, JT-60, JET**

ITRT

The most important discovers



key parameters

B_T

R

a/b

I_p

- $q = (5abB_T / R\, I_p) \geqslant 3;$
- $n \leqslant n_{GW} = I_p / \pi ab;$
- $\beta_N = \beta\, a\, B_T / I_p < 2.5;$
- *L-H transition*

$$P_{L\text{-}H} = 2.84\, M^{-1}\, B_T^{0.82}\, n^{0.58} R^{1.00}\, a^{0.81}$$

- *Scaling laws on confinement*

$$\tau_E \propto I_p^{0.93} B_T^{0.15} n^{0.41} P^{-0.69} R^{1.97} M^{0.19}\, \kappa^{0.78}\, \varepsilon^{0.58}$$

$$\tau_{E,th}^{IPB98(y,2)} = 0.0562 H_{IPB98(y,2)} I_p^{0.93} B_T^{0.15} \overline{n}_e^{0.41} P^{-0.69} R^{1.97} M^{0.19} \kappa_a^{0.78} \varepsilon^{0.58}$$

The goal emphasized to investigate whether or not the burning plasma can be achieved on MF device (before ITER)

$$P_f \propto n * T * \tau_E > 10^{21}\ m^{-3} * s * kev$$

Before ITER

The most important issue for fusion research is to improve the confinement

$$\tau_{E,p}$$

The most important issue for fusion energy is to sustain the burning time

$$t_{burning}$$

Practical energy resources should be SSO !!

$$P_{fusion} \propto n * T * \tau_E > 10^{21}\ m^{-3} * s * kev$$

$$E_{fusion} \propto (n \times T \times \tau_E) \times t_{burning}$$

Steady-State Operation (SSO)

The long burning time for FE is a basic requirement

$$t_{\textit{\textbf{burning}}}$$

- Are there good basis of physics and technologies for SS burning plasma operation ? I think we have not !!
- And how to achieve ?

- How to achieve the T- self-sustain by Blanket ?
- What will be happened for key in-vessel components and related materials under high flux irradiation by 14 MeV neutrons ?

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400 MW burning plasma can be obtained on ITER is predicted

$$P_{L\text{-}H} = 2.84\, M^{-1}\, B_T^{0.82}\, n^{0.58} R^{1.00}\, a^{0.81}$$

For ITER : $P_{L\text{-}H} \sim$ **50 MW**

$$\tau_{E,th}^{IPB98(y,2)} = 0.0562 H_{IPB98(y,2)} I_p^{0.93} B_T^{0.15} \overline{n}_e^{0.41} P^{-0.69} R^{1.97} M^{0.19} \kappa_a^{0.78} \varepsilon^{0.58}$$

For ITER *(inductive operation)* $\tau \sim$ **3.7 S**

$$P_f \propto n * T * \tau_E$$

For ITER : $P_f \sim$ **400-500 MW** (Q ~10)

The scientific goals of ITER

ITER is the burning plasma device and its **scientific goals** are:

- to produce a plasma dominated by α-particle heating
- produce a significant **fusion power amplification** factor ($Q \geq 10$) in long-pulse operation (300 - 500s)
- aim to achieve steady-state operation of a tokamak ($Q=5$)
- retain the **possibility** of exploring controlled ignition ($Q \geq 30$)
- demonstrate integrated operation of technologies for a fusion power plant
- **test** components required for a fusion power plant
- test **concept**s for a tritium breeding module

Gaps between ITER and FPP

Even if ITER can make great contribution to long pulse or SSO burning plasma but it is mainly on physics and not on real fusion energy because of the real burning time during it's 14 years D-T operation is only about 4 %, which results:

1. **There is no enough fusion energy produced for utilization.**
2. **As the consequent the total neutron flux is not enough to demonstrate the real tritium breeding for self sustainable of tritium by blanket.**
3. **No enough neutrons to do the material tests in high flux fusion neutron radioactive environments.**

Gaps between ITER and FPP

4. Therefore there only are shielding blankets for ITER.
5. Even if adding the TBM with addition budget but it is only concept testing for tritium breeding and not real self sustainable blanket and related material tests .

Conclusion: the engineering test reactor is necessary to be constructed parallel with or after ITER and before the fusion power plant (FPP).

By this reason almost all of partners of ITER project are seriously interest to develop the roadmap from ITER to FPP at the multiple levels such as research groups, institutes, international workshops, task groups supported by government etc. Following roadmaps or considerations which I collected here are mainly from Monaco International ITER Fusion Energy Days (MIIFED), 23 Nov. 2010 and the International Workshop on MFE Roadmapping in the ITER Era, PU, Princeton, NJ, U.S.A. 7 - 10 Sept. 2011

It can be believed that the more information will come in with the progress of ITER project.

Content

- **Milestones which led the demonstration that scientific feasibility of MFE has been achieved**
- **ITER- it is the most important bridge to go to realistic FE (FPP)**
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- **Summary**

Dr. Anil Kakodkar

Member, Atomic Energy Commission of India

Indian Fusion Program

Power Plant **2050**

Fusion Power Reactor

DEMO **2037**

- Qualification of Technologies
- Qualification of reactor components & Process
- Qualification of materials

2 x 1GWe Power plant by 2060

Indigenous Fusion Experiment

SST-2 **2027**

ITER Participation **2005**

scientific and technological feasibility of fusion energy

SST-1 **1996**

Steady State Physics and related technologies

Note: Years represent start of project

ADITYA **1984**

First Tokamak

Dr. Anil Kakodkar
Member, Atomic Energy Commission of India
By R.Srinivasan

Plasma parameters	SST-2
R_0	4.4
a	1.5
A	3.0
B_t (T)	5.4
I_p(MA)	11
f_{bs}(%)	11.5
P_{loss}(MW)	40
P_{fusion} (MW)	100
P_{aux}(MW)	20
Q	5
n/n_{GW}	0.93
<T> keV	4.5
β_N	1.31

Plasma parameters	Indian DEMO
R_0	7.7
a	2.6
A	3.0
B_t (T)	6.0
I_p(MA)	17.8
f_{bs}(%)	50
P_{loss}(MW)	720
P_{fusion} (MW)	3300
P_{aux}(MW)	110
Q	30
n/n_{GW}	0.93
<T> keV	21.5
β_N	3.3

By R. Srinivasan

Conclusion

- Current energy situation in Korea : highly far from being self-sufficient (2-3%).
- Long-term perspective (~2030): expand low carbon green energy, in particular nuclear energy.
- Nuclear fusion energy represents a great potential energy source: low carbon and limitless source.

Dr. Kijung Jung
Director-General, ITER Korea

Why Fusion Energy in Korea?

Lack of Energy Resources

- 97% of Energy imported from abroad
- Need of unlimited (if possible) resources
- Need of options for future energy security

Fusion Energy

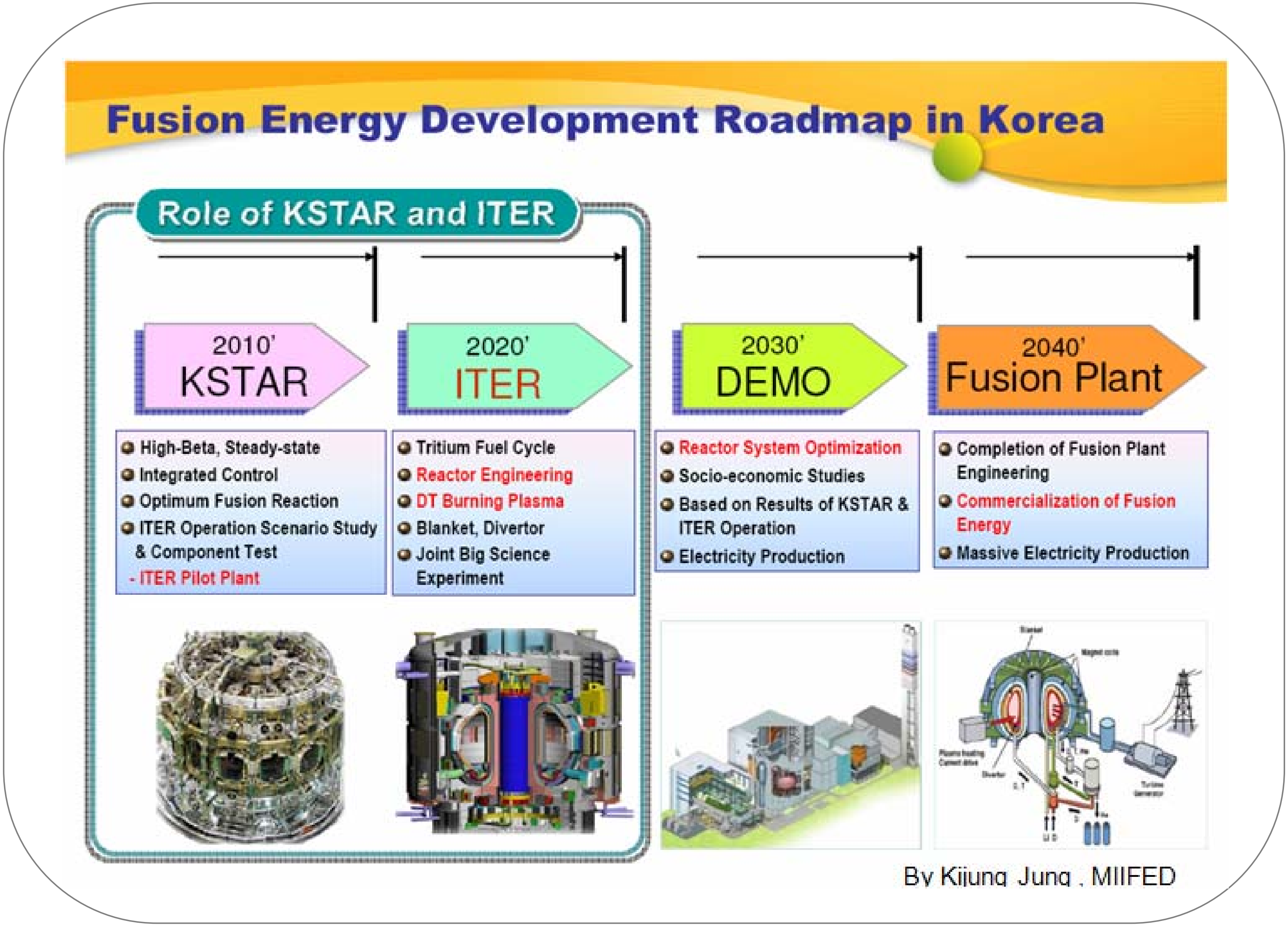
Conditions of Future Energy Resources

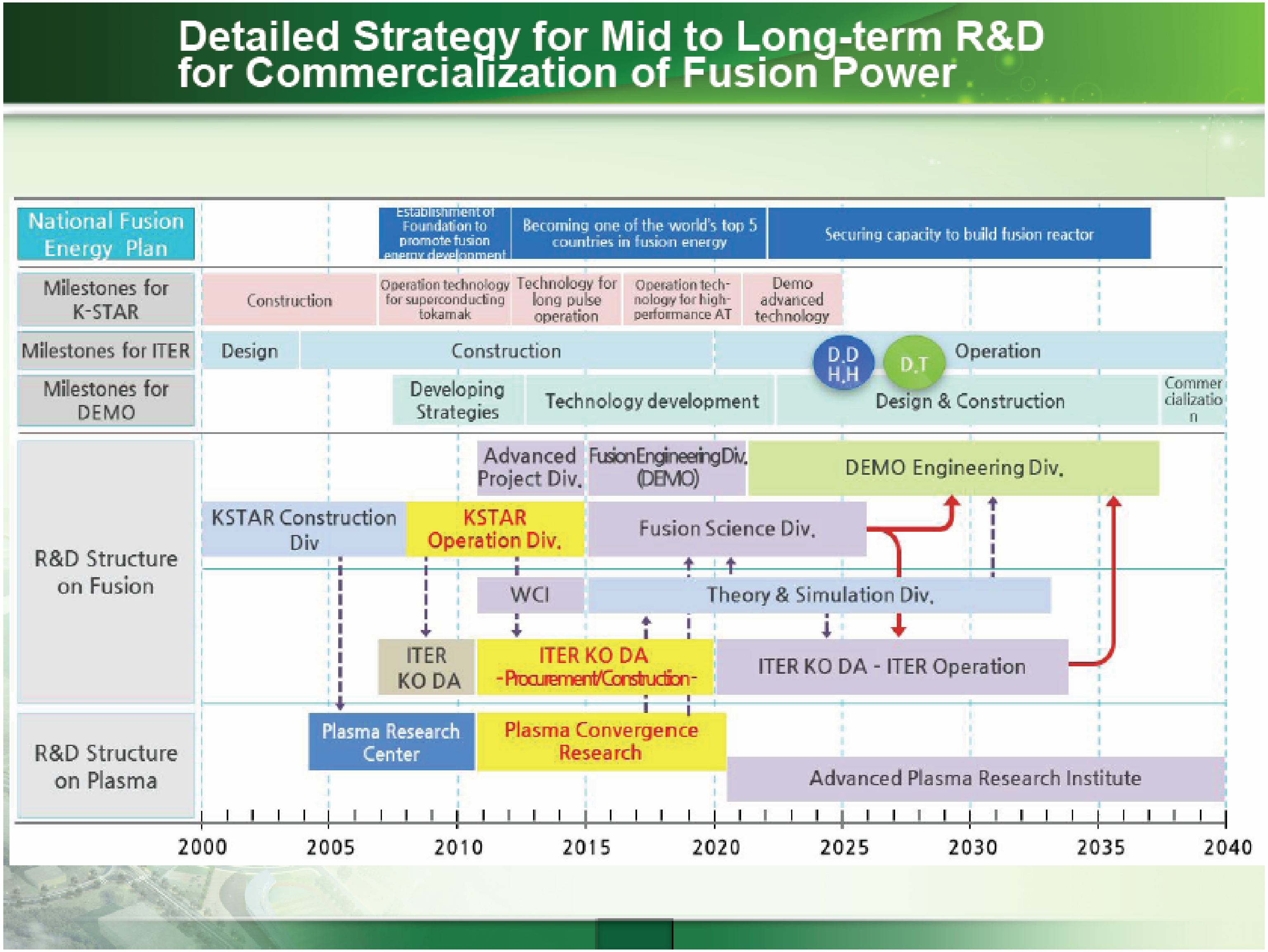
- Environmentally Friendly
- Limitless in Resources
- Intrinsically Safe
- Economic

- Abundant Fuel: D and T (transmutation by Lithium)
- No CO_2 emission and No air pollution
- No high-level and long-lived Radioactive Wastes
- Intrinsically Safe: If fuel supply is stop, fusion reaction stops.

➡ **Fusion Energy, an Ideal energy source if realized**

Dr. Kijung Jung
Director-General, ITER Korea


Fusion Energy Development Roadmap in Korea
Role of KSTAR and ITER
2010' KSTAR
2020' ITER
2030' DEMO
2040' Fusion Plant
High-Beta, Steady-state
Integrated Control
Optimum Fusion Reaction
ITER Operation Scenario Study & Component Test
- ITER Pilot Plant
Tritium Fuel Cycle
Reactor Engineering
DT Burning Plasma
Blanket, Divertor
Joint Big Science Experiment
Reactor System Optimization
Socio-economic Studies
Based on Results of KSTAR & ITER Operation
Electricity Production
Completion of Fusion Plant Engineering
Commercialization of Fusion Energy
Massive Electricity Production
By Kijung Jung , MIIFED


Detailed Strategy for Mid to Long-term R&D for Commercialization of Fusion Power
National Fusion Energy Plan
Establishment of Foundation to promote fusion energy development
Becoming one of the world's top 5 countries in fusion energy
Securing capacity to build fusion reactor
Milestones for K-STAR
Construction
Operation technology for superconducting tokamak
Technology for long pulse operation
Operation technology for high-performance AT
Demo advanced technology
Milestones for ITER
Design
Construction
D.D H.H
D.T
Operation
Milestones for DEMO
Developing Strategies
Technology development
Design & Construction
Commercialization
R&D Structure on Fusion
Advanced Project Div.
Fusion Engineering Div. (DEMO)
DEMO Engineering Div.
KSTAR Construction Div
KSTAR Operation Div.
Fusion Science Div.
WCI
Theory & Simulation Div.
ITER KO DA
ITER KO DA -Procurement/Construction-
ITER KO DA - ITER Operation
R&D Structure on Plasma
Plasma Research Center
Plasma Convergence Research
Advanced Plasma Research Institute
2000
2005
2010
2015
2020
2025
2030
2035
2040

by kwon

Toichi Sakata

Senior Advisor, Ministry of Education, Culture, Sports, Science and Technology (MEXT)

Road Map to Fusion DEMO Reactor

The middle of the 1980's
~ The latter half of the 2000's

Scientific Feasibility

Achievement of Break-Even Plasma Condition

The latter half the 2000's
~ The latter half on the 2030's

Scientific & Technological Feasibility

· Realization of Burning Plasma and Long-duration burning

· Formation of Fusion Technology Basis for DEMO Development

The latter half the 2020's
~ About 2050

Technological Demonstration & Economic Feasibility

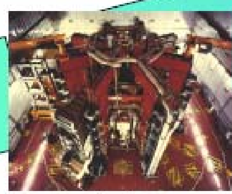
· Demonstration of Electric Power

· Improvement of Economic Efficiency

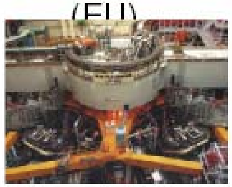
After 2050

Prospect of Practical use

JET (EU)



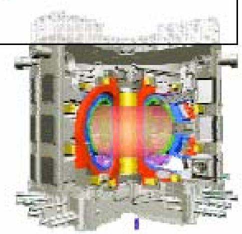
TFTR (US)



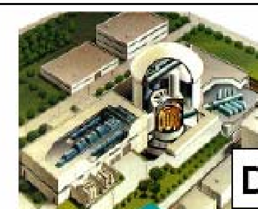
JT-60 (JA)

JT-60SA

BA Activities



ITER (Experimental Reactor)



DEMO Reactor

< Issues addressed in ITER project >

- Establishment of control technology towards steady-state sustainment of burning plasmas
- Demonstration of feasibility of fusion blanket for tritium breeding and collection, heat removal and generation of electricity

< Issues addressed in Broader Approach activities >

- Development of high performance plasmas for reducing electricity cost
- Development of fusion reactor materials used under high neutron flux environment etc

Toichi Sakata
Senior Advisor, Ministry of Education, Culture, Sports, Science and Technology (MEXT)

The ITER Project & the Broader Approach Activities

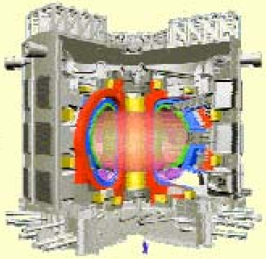
The BA Activities

- Parties: JA, EU
- Site: Rokkasho and Naka, Japan
- Plan: 10 years
- Projects
  - IFERC (International Nuclear Fusion Energy Research Centre)
    - Demo design and R&D coordination Centre
    - ITER Remote Experimentation Centre
    - Computational Simulation Centre
  - IFMIF/EVEDA (Engineering Validation and Engineering Design Activities for International Fusion Materials Irradiation Facility)
  - Satellite Tokamak Programme

Naka City (Ibaraki)

The ITER Project

- Parties: JA, EU, US, RF, CN, KO, IN
- Site: Cadarache, France
- Fusion power: 500MW
  (No electric generation is required.)
- Director-General: Mr. O. MOTOJIMA
- JA's contribution:
  Construction : 9.1%
  Operation: 13%
- Schedule: Total of 35 years
  Construction 10 years
  Operation 20 years
  Deactivation 5 years



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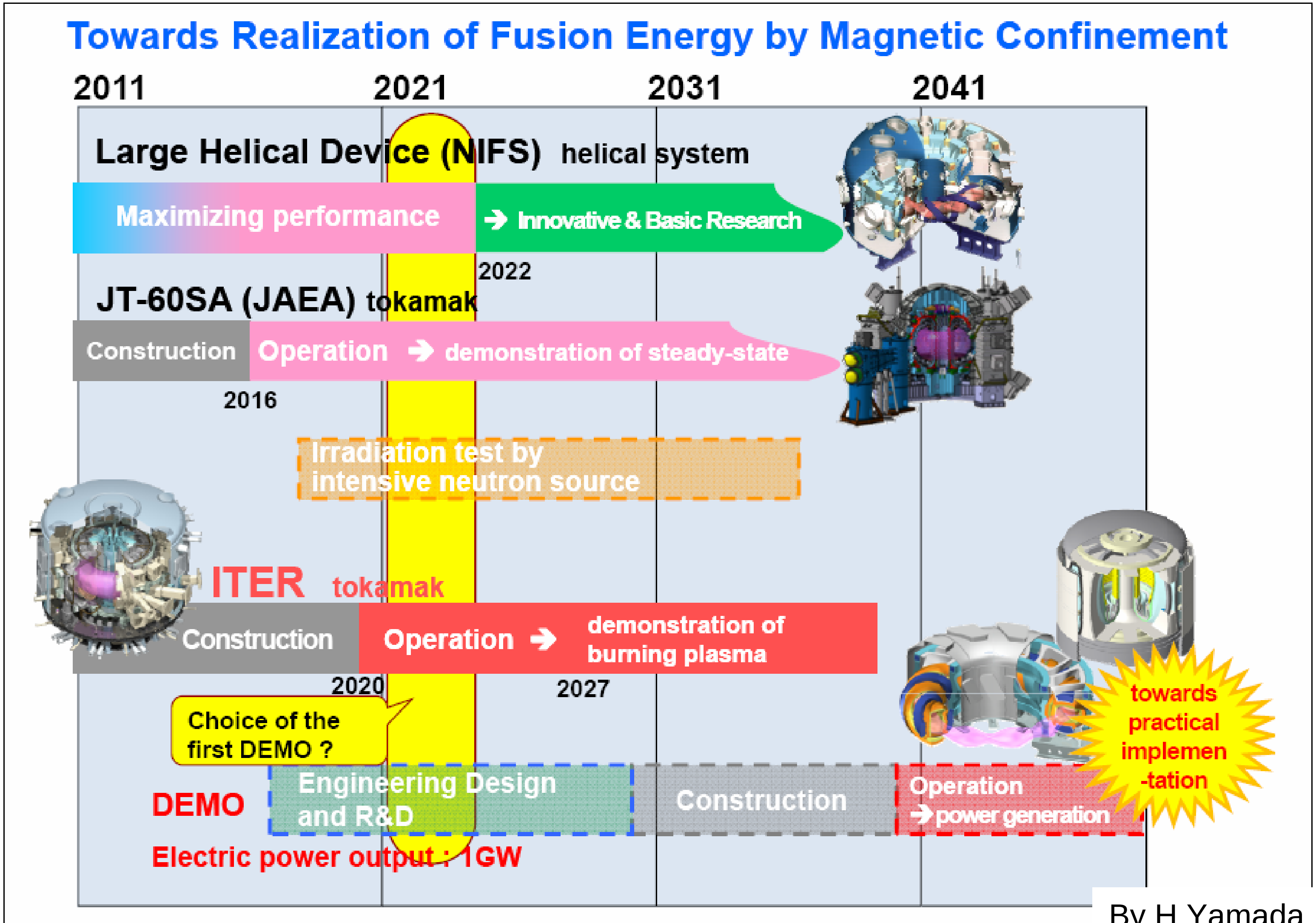
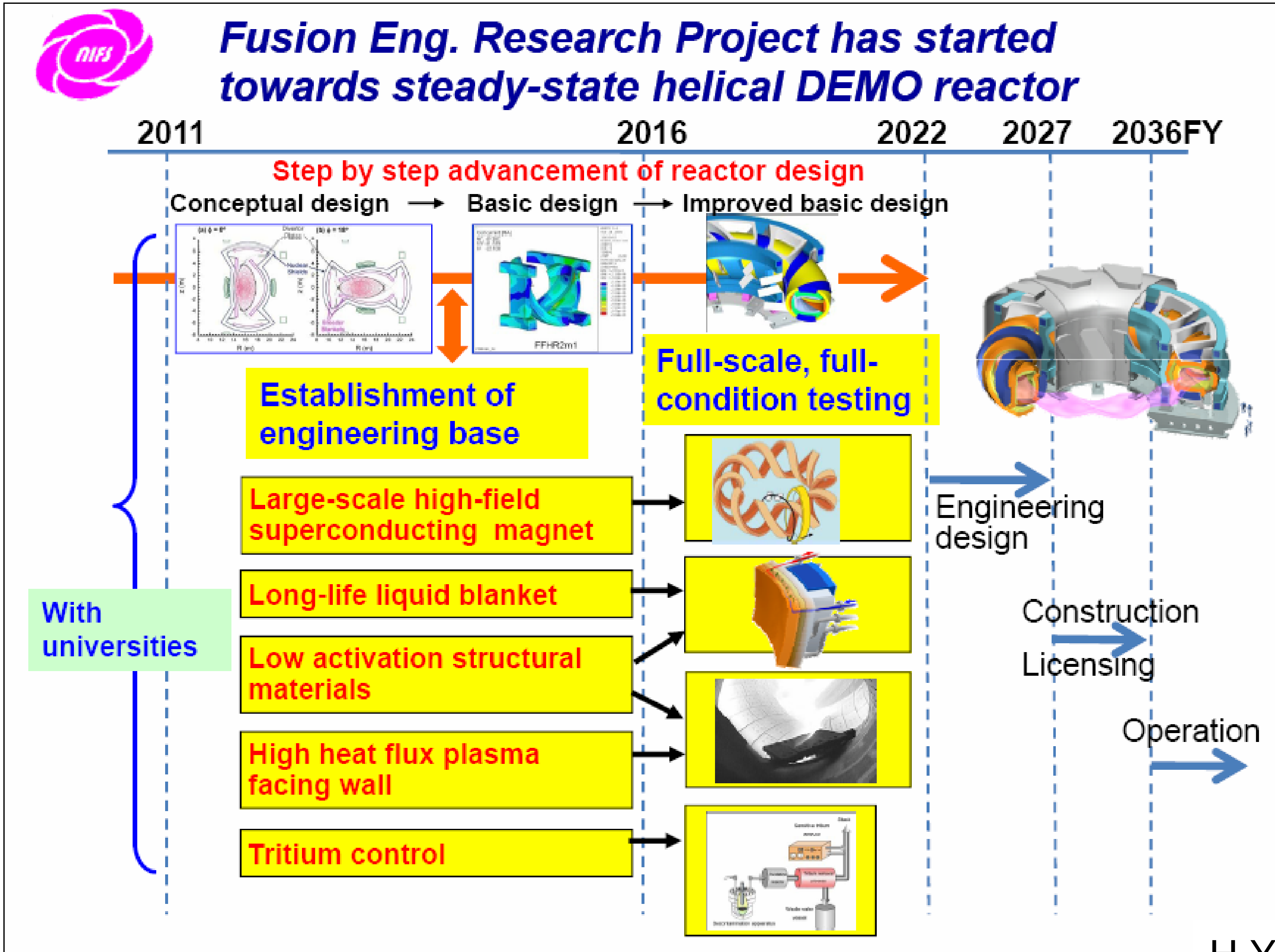
Senior Advisor, Ministry of Education, Culture, Sports, Science and Technology (MEXT)

Overview of the Fusion Roadmaps in the World



By H.Yamada



Fusion Eng. Research Project has started towards steady-state helical DEMO reactor
2011
2016
2022
2027
2036FY
Step by step advancement of reactor design
Conceptual design → Basic design → Improved basic design
FFHR2m1
Establishment of engineering base
Full-scale, full-condition testing
Large-scale high-field superconducting magnet
Long-life liquid blanket
Low activation structural materials
High heat flux plasma facing wall
Tritium control
With universities
Engineering design
Construction
Licensing
Operation

H.Yamada

Evgeny Velikhov

Chairman of the ITER Council
and President of the Kurchatov Institute

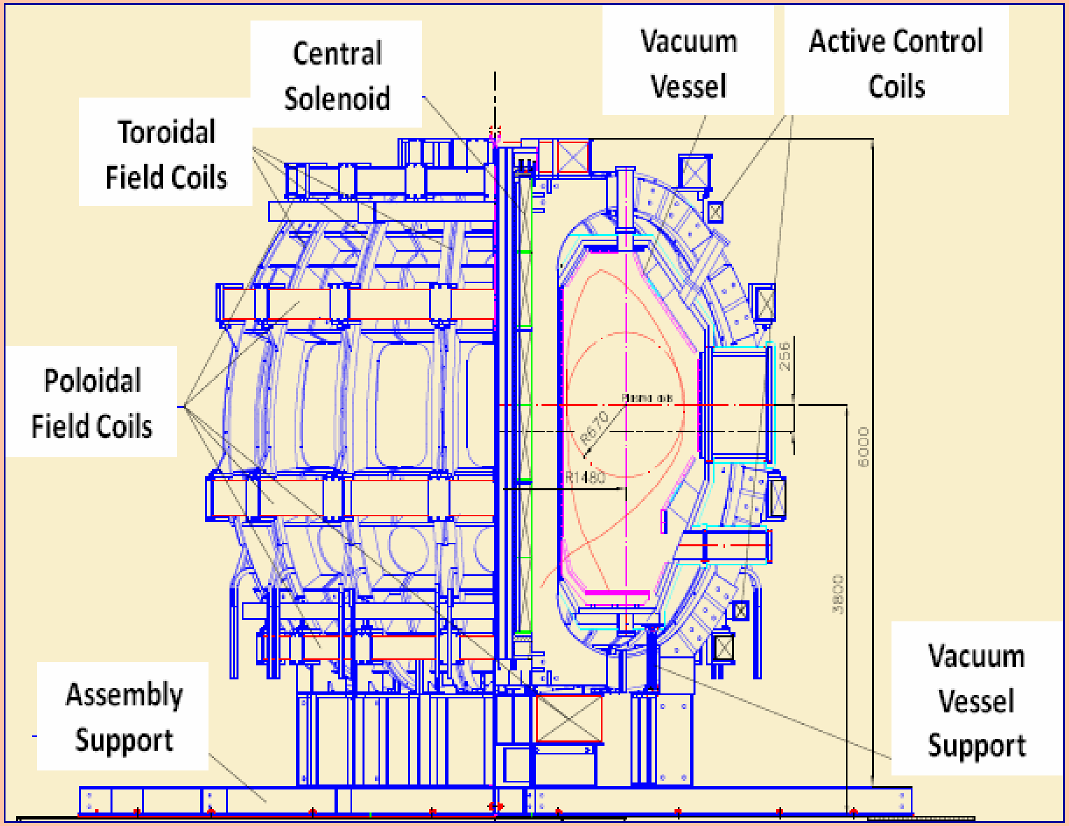
The Russian program of fusion research will be concentrated on:

- support of ITER program
- development of fusion neutron source as a part of hybrid system for solution of some actual problems of nuclear energy

The first step on the way to create the fusion neutron source (FNC) is to design and construct of tokamak T-15MD as physical prototype of FNS

Evgeny Velikhov
Chairman of the ITER Council
and President of the Kurchatov Institute

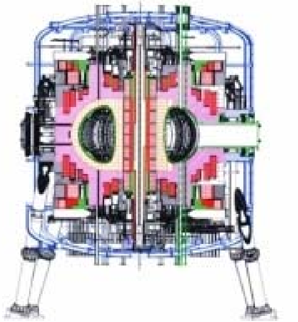
Base parameters of Tokamak T-15MD

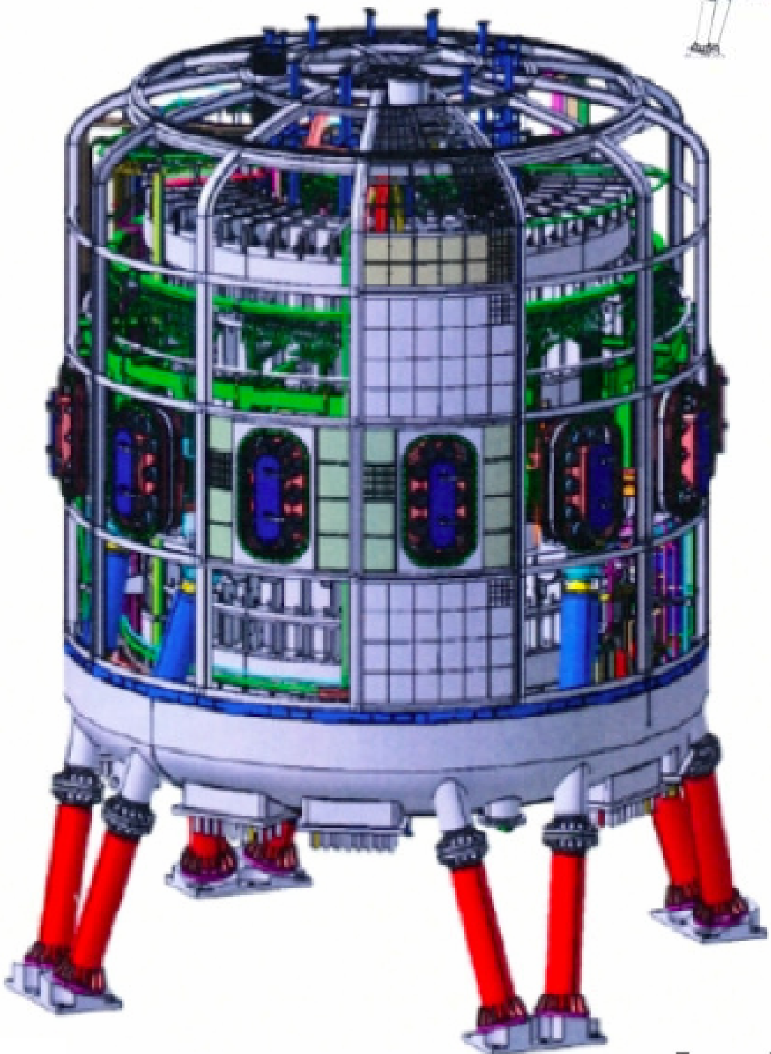


Plasma current I_P, MA	2
Toroidal magnetic field at plasma axis B_t, T	2
Major radius of torus R, m	1.48
Aspect ratio A	2.2
Elongation, k_{95}	1.7 – 1.9
Triangularity, δ_{95}	0.3 – 0.4
Pulse duration Δt, s	10
Plasma density, 10^{20} m^{-3}	0.5
Plasma temperature $T_i(0)$, $T_e(0)$, keV	4 – 5
Normalized beta β_N	1.5
Power of auxiliary plasma heating P_{AUX}, MW	15

Evgeny Velikhov
Chairman of the ITER Council and President of the Kurchatov Institute

New project aims for fusion ignition





MIT-led Ignitor reactor could be the world's first to reach major milestone, perhaps paving the way for eventual power production.

David L. Chandler, MIT News Office
May 10, 2010

Russia and Italy have entered into an agreement to build a new fusion reactor outside Moscow that could become the first such reactor to achieve ignition, the point where a fusion reaction becomes self-sustaining instead of requiring a constant input of energy. The design for the reactor, called Ignitor, originated with MIT physics professor Bruno Coppi, who will be the project's principal investigator.

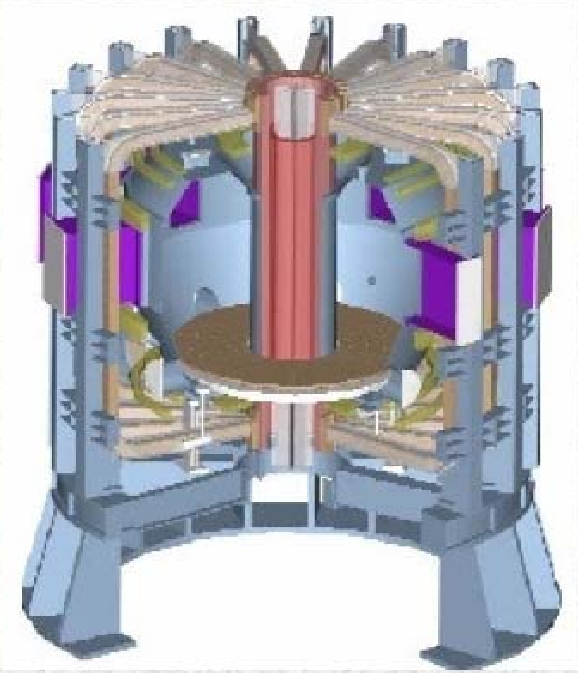
The concept for the new reactor builds on decades of experience with MIT's Alcator fusion research program, also initiated by Coppi, which in its present version (called Alcator C-Mod) has the highest magnetic field and highest plasma pressure (two of the most important measures of performance in magnetic fusion) of any fusion reactor, and is the largest university-based fusion reactor in the world.

Evgeny Velikhov
Chairman of the ITER Council
and President of the Kurchatov Institute

KTM Facility General View

Basic Parameters

Plasma major radius	0.9 m
Plasma minor radius	0.45 m
Aspect ratio, A	2.0
Plasma elongation, K95	1.7
Toroidal magnetic field, Bto	1.0 T
Plasma current	0.75 MA
Duration of current plateau	4 - 5 s
Additional RF-heating power	5 MW
Thermal load on the divertor tiles	2 –20 MW/m2



Evgeny Velikhov
Chairman of the ITER Council
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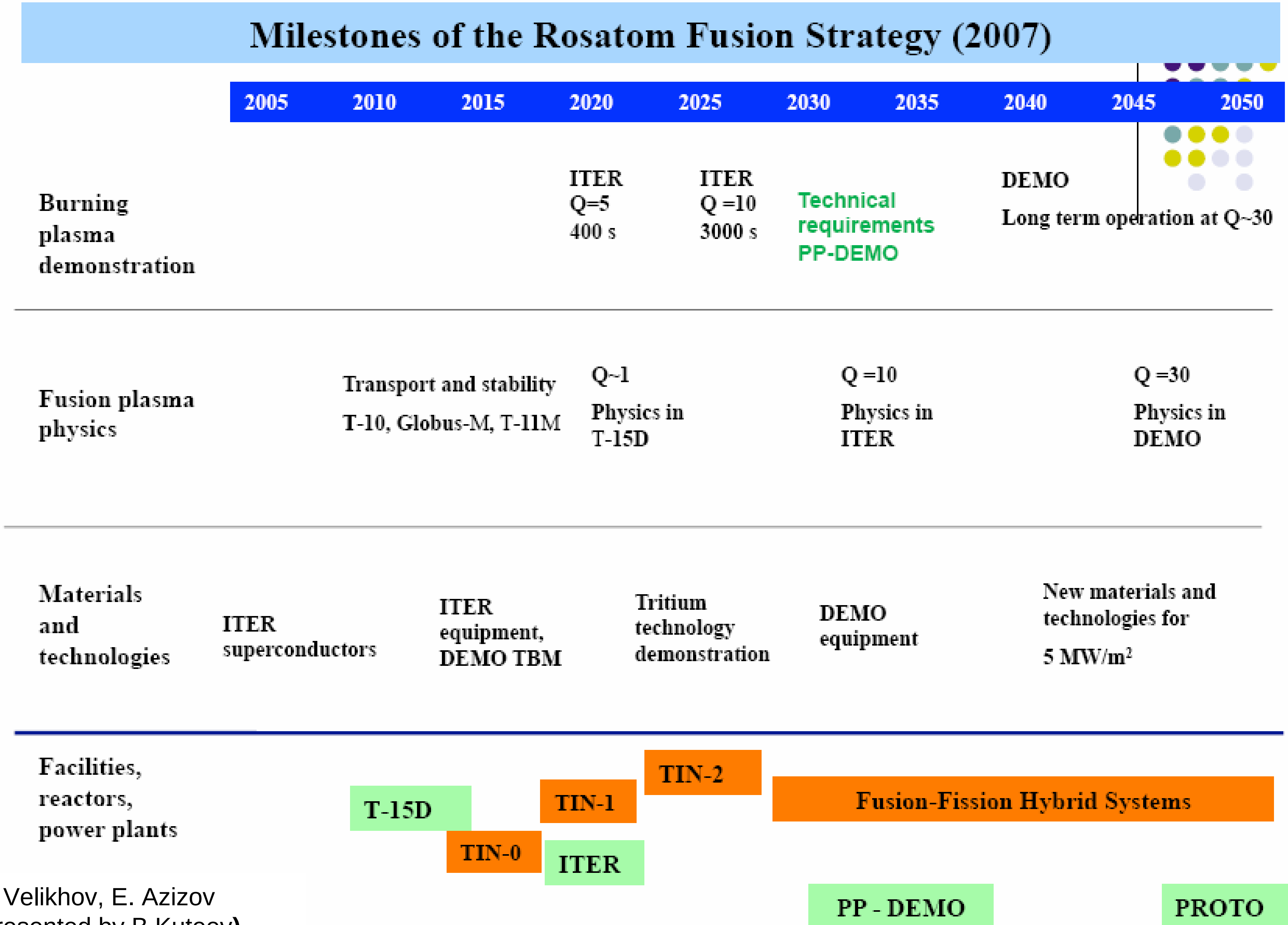

E. Velikhov, E. Azizov
(presented by B.Kuteev)

NATIONAL RESEARCH CENTER
"KURCHATOV INSTITUTE"

Strategy Goals

- Building a pure thermonuclear fusion reactor, using reaction of deuterium and tritium in high temperature magnetically confined plasma

  This goal should be reached through active participation in ITER project, national research on upgraded national fusion facilities and broad international collaborative research,

  including development of international DEMO project

- Development and building of Fusion Neutron Sources for solving problems of Atomic Energy and accelerating fusion applications

  This goal should be reached through development of fusion-fission hybrids for neutron production, transmutation and nuclear fuel production

  in accordance with demands of thermal and fast fission reactors and other Rosatom tasks

E. Velikhov, E. Azizov
(presented by B.Kuteev)

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Conclusions

1. Russian Fusion Strategy up to 2050 and Program for 2011-2020 are approved by Rosatom and their realization has been started
2. The Strategy is aimed at building Commercial Fusion Power Plant
3. The Program is aimed at ITER support, DEMO conceptual design and building steady state Fusion Neutron Sources for multipurpose Fusion-Fission Hybrid Systems
4. The Program takes into account necessity of developing alternative to tokamak devices like stellarators and mirror machines
5. Upgrading the experimental fusion facilities and test beds is a key issue of the Program
6. The Program supports staff education through Center of Excellence net in fusion and a broad international cooperation

E. Velikhov, E. Azizov
(presented by B.Kuteev)

Dr. Rudolf Strohmeier
Deputy Director-General
Scientific Advances

Policy Presentations

Monaco ITER International Fusion Energy Days (MIIFED)

Long-term perspectives in energy development and the potential role of fusion energy

Words on energy and climate change

Our starting point is that the world's dependence on energy will increase dramatically in the coming years. As the population grows, energy demand in the next 50 years is likely to double. Currently, fossil fuel supplies amount to around 80% of current energy needs and we all know that this dependency is also largely responsible for greenhouse gas emissions which alter our climate and environment.

The G8 committed in July last year to 50% reduction of global emissions by 2050. They also supported a goal of developed countries reducing emissions of greenhouse gases in aggregate by 80% or more by 2050 compared to 1990 or more recent years.

Moreover, the European Union is faced with a situation where it now imports more than 50% of its energy.

On the supply side of energy provision, renewable technologies are starting to contribute significantly to our energy mix. But deployment of renewables is unlikely to fill in the energy gap in the future by itself. On the demand side, energy efficiency gains will be actively pursued but such improvements also may not suffice.

In such a landscape **fusion cannot be omitted**.

Towards a demonstration fusion reactor (DEMO)

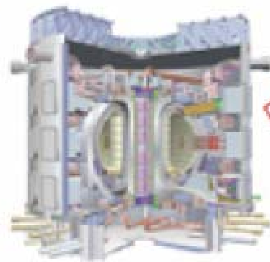
ITER is not an end in itself: it is the bridge toward a first demonstration fusion power plant that produces electrical power.

The strategy to achieve this long-term aim includes a number of different elements: firstly, the development of ITER, research into special materials, development and use of existing fusion devices.

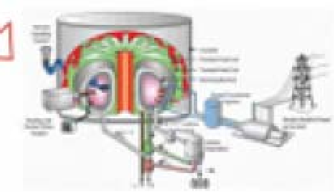
This will be followed by a demonstration fusion reactor (DEMO).

The expectation is that after DEMO, the first commercial fusion power stations can be constructed.

DEMO: bridge the gap between ITER and the first fusion power plant



ITER: scientific and technological (partially) feasibility of fusion



Fusion Power Plant: economically acceptable, safe and environmental friendly

FAST TRACK SCENARIO

Safety & Environment

Topics for discussion

Our on-going considerations on the fusion roadmap allow to put more emphasis than before on two specific points.

Firstly, how to build up the future team that will operate and exploit ITER?

- How will ITER operate? “Users’ facility” or “centralised team”?
- How do we train future ITER scientists and operators? On existing machines within the framework of an ad-hoc cooperation scheme?

We believe that JET should be part of these machines because of its unique features (ITER-like wall, DT operation).

by D. Maisonnier

Topics for discussion (cont'd)

Secondly, we need the definite precisely of the programmatic objectives of DEMO and of its accompanying programme.

To do so, we need to answer the following question: will there be only one DEMO†, or several DEMO's, or several "next step" facilities?

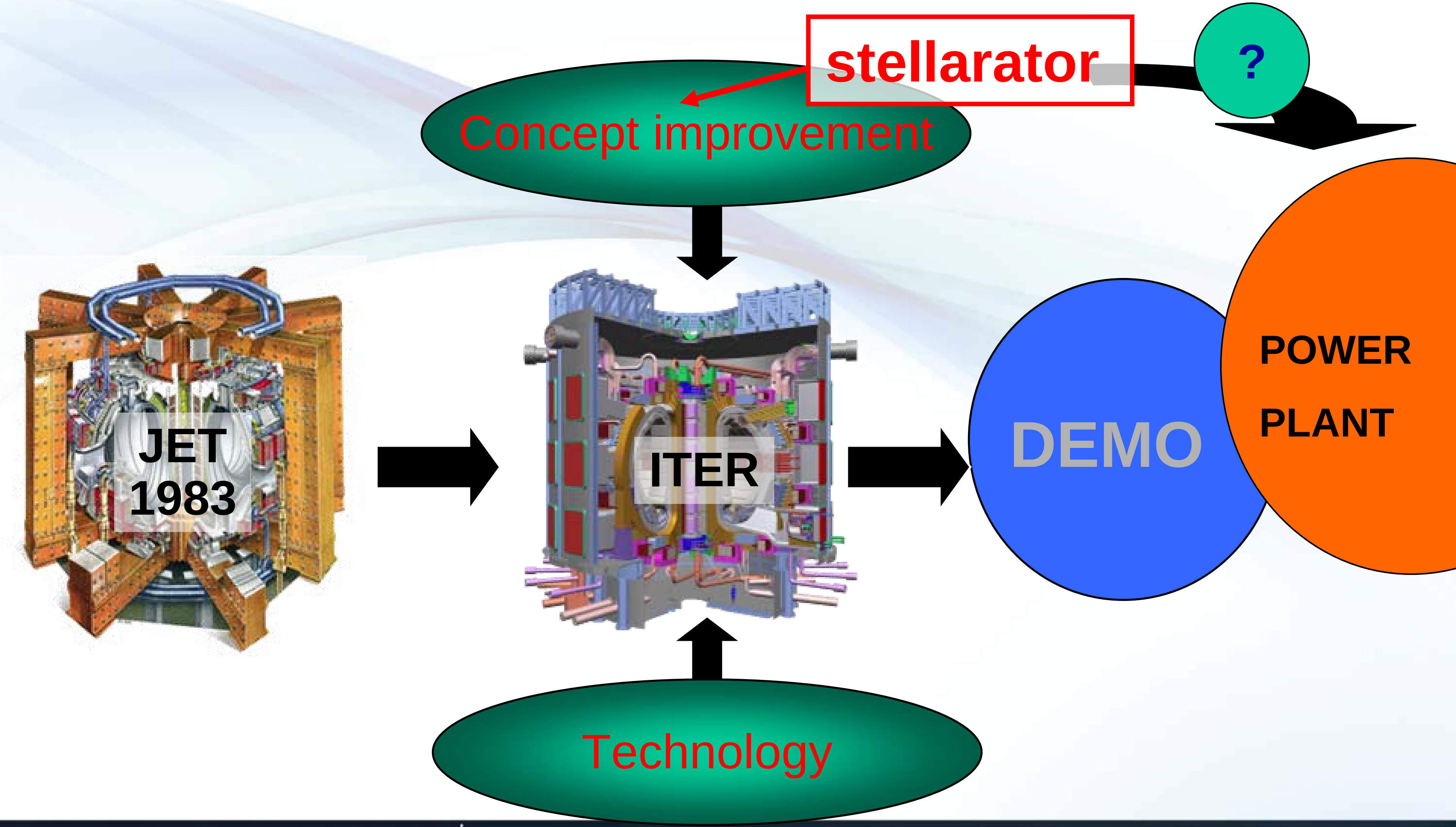
I believe we should seriously consider a scenario where more than one device will be build.

Commercial considerations will make international collaboration more difficult to finalise than it has been the case for ITER, but there will be more to gain than to loose to establish a collaboration scheme between the Parties planning to build a "next step" facility.

(†) excluding facilities for the qualification of materials

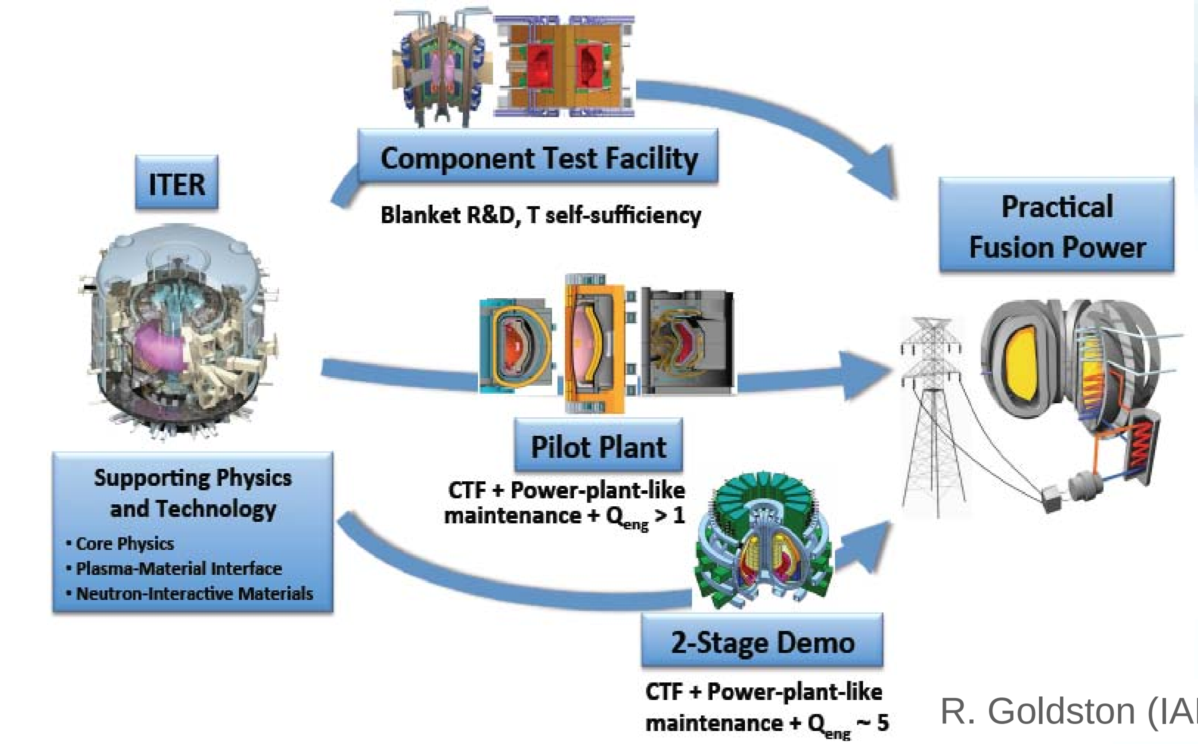
by D. Maisonnier

EU strategy towards Fusion Energy



Topics for discussion (cont'd)

There is, today, a divergence of opinion on how to bridge the gap between ITER and the first FPP.



- ❖ EU (and JA?): DEMO and IFMIF;
- ❖ US: CTF or a Pilot Plant and no dedicated materials test facility.

R. Goldston (IAEA TM, June 2011)

by D. Maisonnier

Conclusion

The EU is currently developing a new fusion roadmap.

The focus is to define the framework programme 2014-2020.

The fusion roadmap should aim at:

- ❖ Regain credibility for fusion.
- ❖ Ensure the success of ITER:
  - ITER construction within scope schedule and cost;
  - Start building up the team of future ITER operators and scientists, possibly within the framework of an international collaboration scheme.
- ❖ Clarify the programmatic objectives of DEMO.
- ❖ Consider a “multi-DEMO“ scenario.

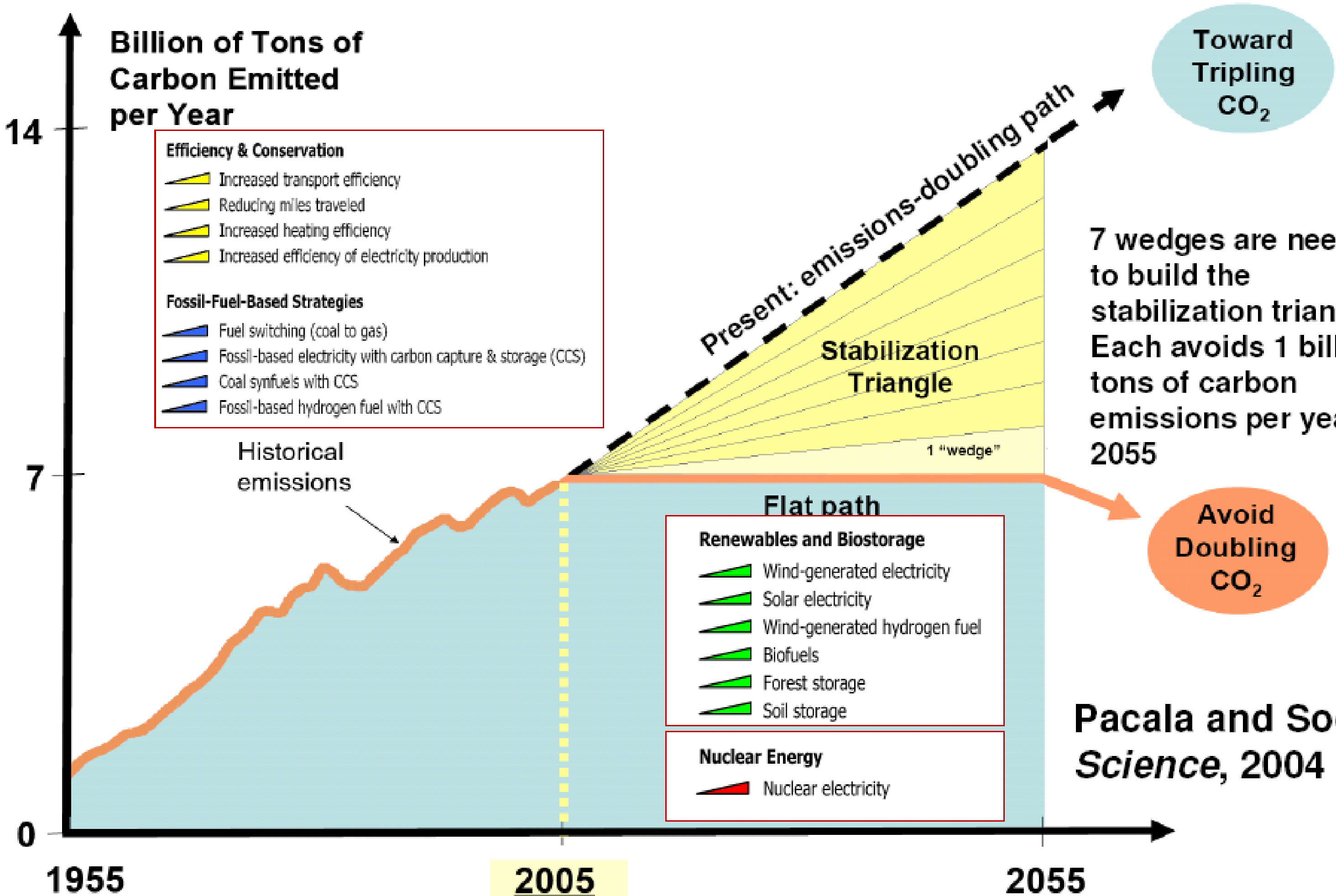
by D. Maisonnier

Dr. Edmund J. Synakowski

Director for Fusion Energy Sciences

U.S Department of Energy

Starting point: with existing technologies, carbon emissions can be *stabilized…*



7 wedges are needed to build the stabilization triangle. Each avoids 1 billion tons of carbon emissions per year by 2055

Pacala and Socalow *Science*, 2004

Energy Facts 2010

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Long term: if fusion is available by the second half of this century, it can be a significant player in the energy economy by 2100

- Assume ITER, DEMO, and supporting research establish the basis for fusion energy by 2050. Then

  - **Conservative assumption**: Note that **fission grew from 1975 through 1990 at 1.2%/year** of the world electric market. Then **if fusion grows at < 0.9%/year of after 2050,**

  ➔ ***fusion can deliver at least 30% of the world's energy production by 2100****

  ** Goldston, Grisham, Hammett, IAEA 2010, "Climate Change, Nuclear Proliferation, and Fusion Energy"*

  ➔ fusion can also contribute to fuel-switching strategies (e,g, off-peak hydrogen production)

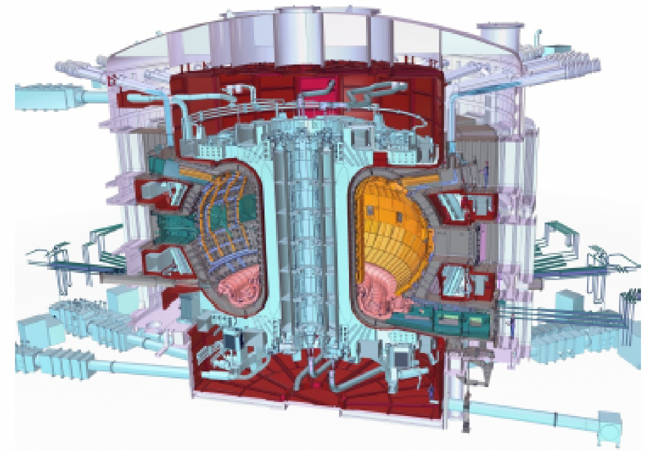
Fusion can deliver in time to have a major impact this century

Three ingredients:

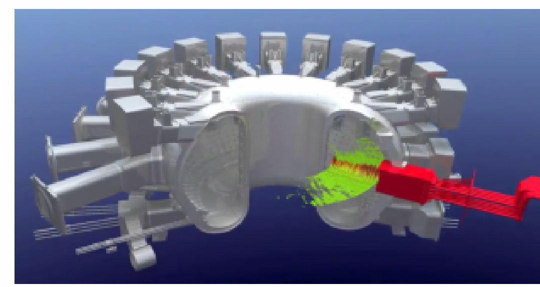
- **ITER**: the fundamental science of a burning plasma. ITER will establish the science of robustly and attractively controlling fusion plasmas that heat themselves

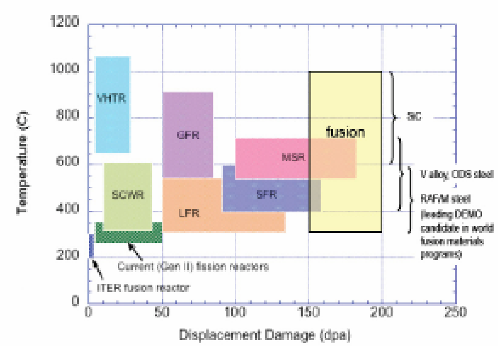
- **Validated predictive capability**: a supporting world program in experimentation and theory/simulation to
  - complement ITER and develop its operating scenarios
  - Develop the predictive science required for optimizing beyond ITER

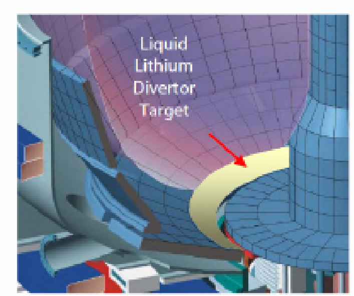
- An aggressive program in **fusion materials and the technology** to harness the fusion power from a burning plasma



Simulation of lower hybrid wave heating on ITER







NSTX

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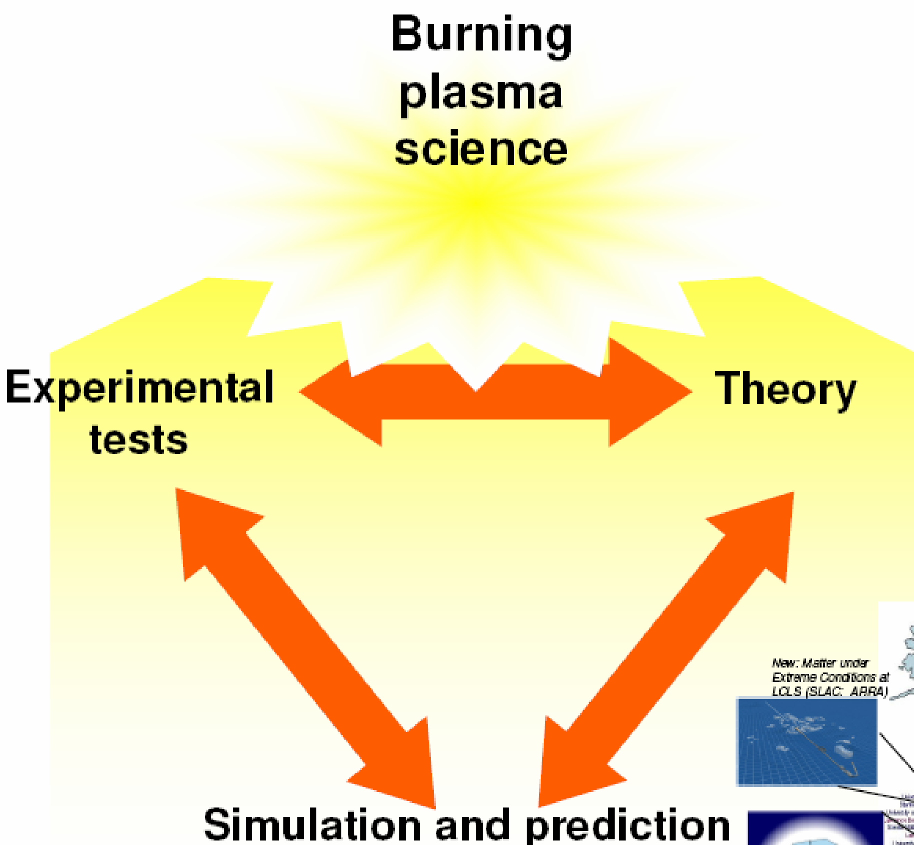
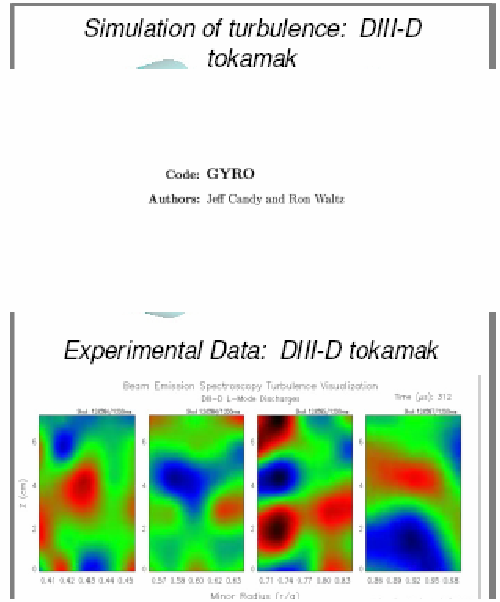
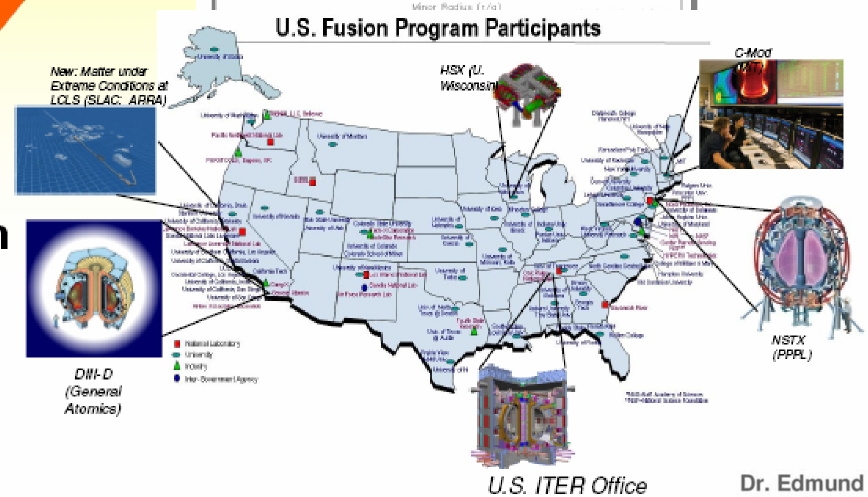
In the U.S., fusion joins the ranks of other sciences that will be called upon to solve the energy and climate challenges





A leading intellectual challenge is developing an integrated, validated predictive capability for burning plasmas



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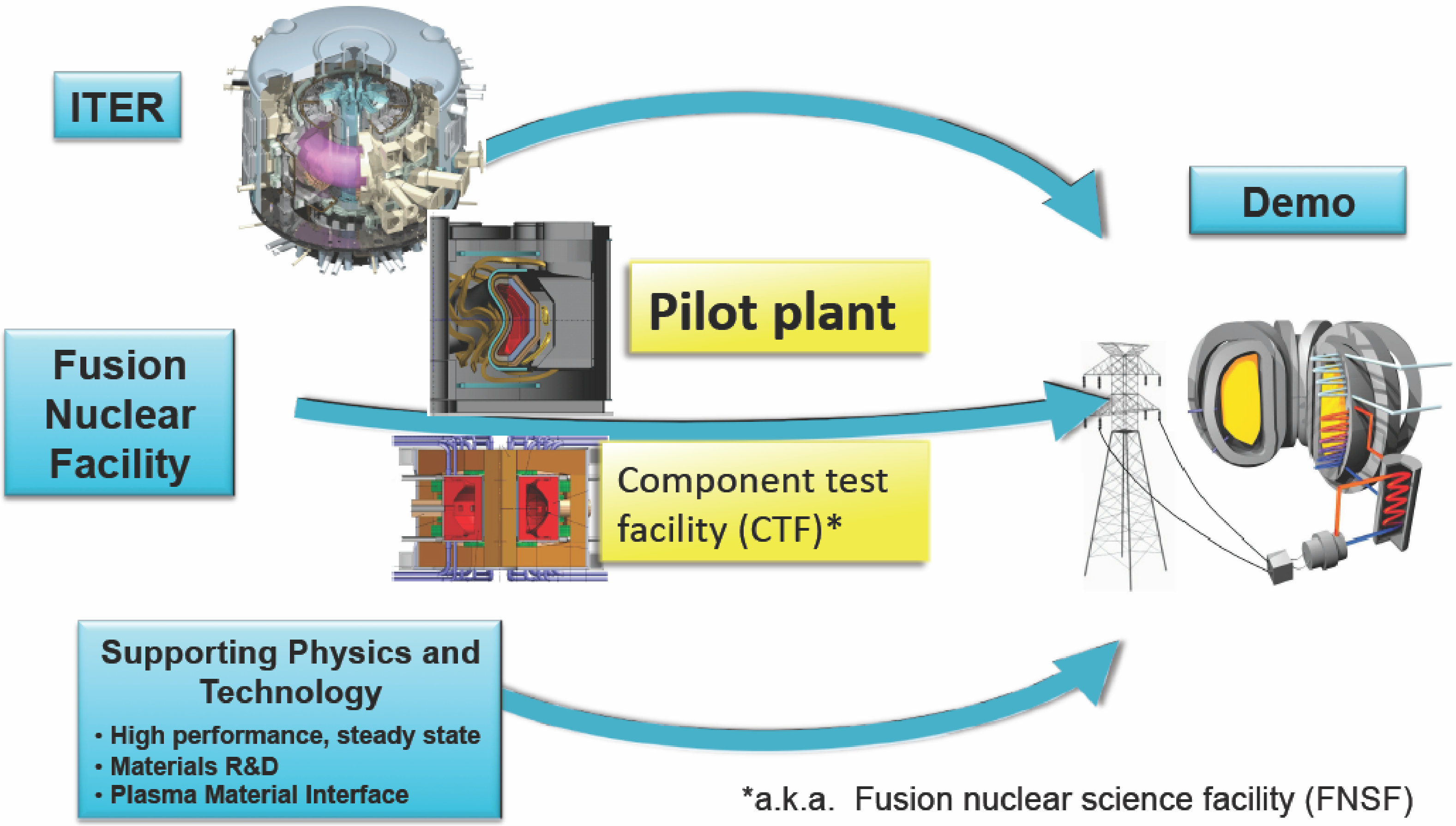
Charting the Roadmap to Fusion Energy: Options for a Nuclear Next Step



*a.k.a. Fusion nuclear science facility (FNSF)

Requires a technical evaluation of missions, requirements, and prerequisites for Demo and next-step facilities.

Liao Xiaohan

Deputy Director-General,
Ministry of Science and Technology

Common understanding

- The CFETR must be built before the fusion power plant in China
- ITER can be a good basis for CFETR both on SSO burning plasma physics and some technologies;
- The goals of CFETR should be different with ITER and aimed to the problems related with fusion energy;
- Both physic and technical basis of the CFETR should be more realistic and basic when it is designed.

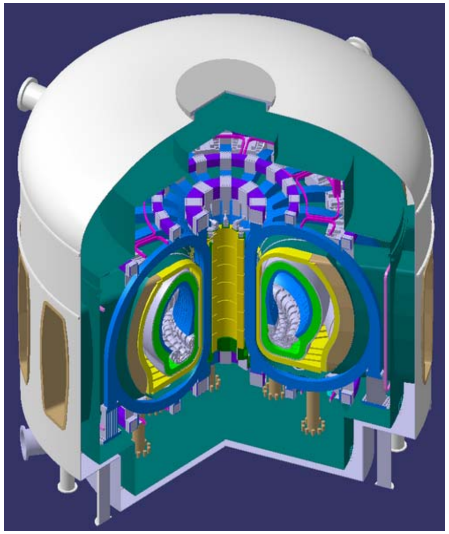
The Mission and Design goal of the CFETR

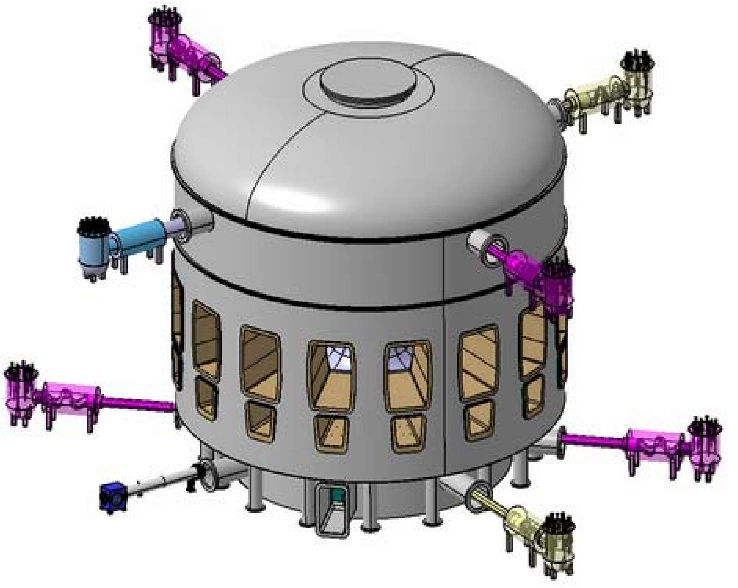
- A good complementarities with ITER
- Demonstration of fusion energy with a minim $P_f = 50 \sim 200MW$
- Long pulse or steady-state operation with duty cycle time ⩾ 0.3 ~ 0.5；
- Demonstration of full cycle of T self-sufficiency with TBR ⩾ 1.2
- Relay on the existing ITER physical（k<1.8, q>3, H~1) and technical bases (higher B_T , diagnostic, H&CD);
- Exploring options for DEMO blanket & diverter with a easy changeable core by RH；

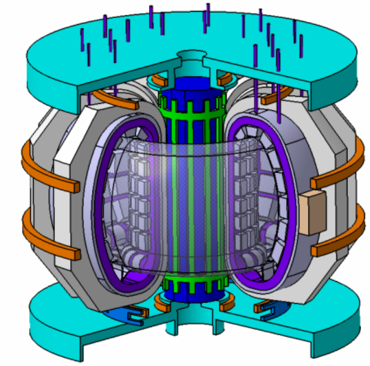
Working target

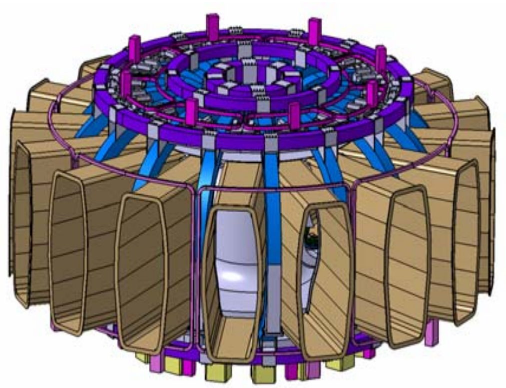
Mission	Sub-missions	Results	Required answer by design groups		Remarks
CW or long pulse burning plasma	**P_f = 50 -200 MW** (with H mode and duty cycle time ≧0.3-0.5 no requirement on Q)	• Suitable size of device; • Require enough addition P_H and P_{CD}; • Require large amount of T consumptions;	What are the key required parameters of CFETR ?	**B_t = 4.5-5.0 T** **R_0 = 5.5-5.7** **b/a ~ 1.8** **a = 1.6** **I_P = 7.5-10MA** **β_N = ~ 2** **P_{ad} ~100MW**	SC/ Cu coils
	Duty time≧ 0.3- 0.5	CW P_{CD} and P_H	What kind of and how high of P_{CD} and P_H are required ? What kind of diverter and material could be used?		
		T consumptions per year:≧6 Kg	Is it right and possible?		Assuming P_f = 200MW
	TBR ≧ 1.2	Produce T ≧ 6 Kg/year	Is it right and possible? What kind of blanket and the dimension are required?		Assuming P_f = 200MW

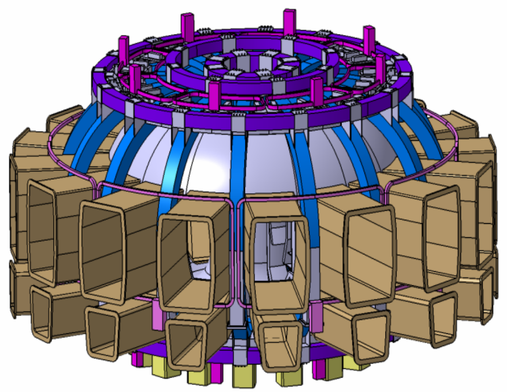
Several versions of CFETR are under comparison











B_t = 4.5-5.0 T
R_0 = 5.5-5.7
b/a ~ 1.8
a = 1.6
δ ~ 0.5
I_P = 7.5-10MA
β_N = ~ 2
P_{ad} ~ 100MW

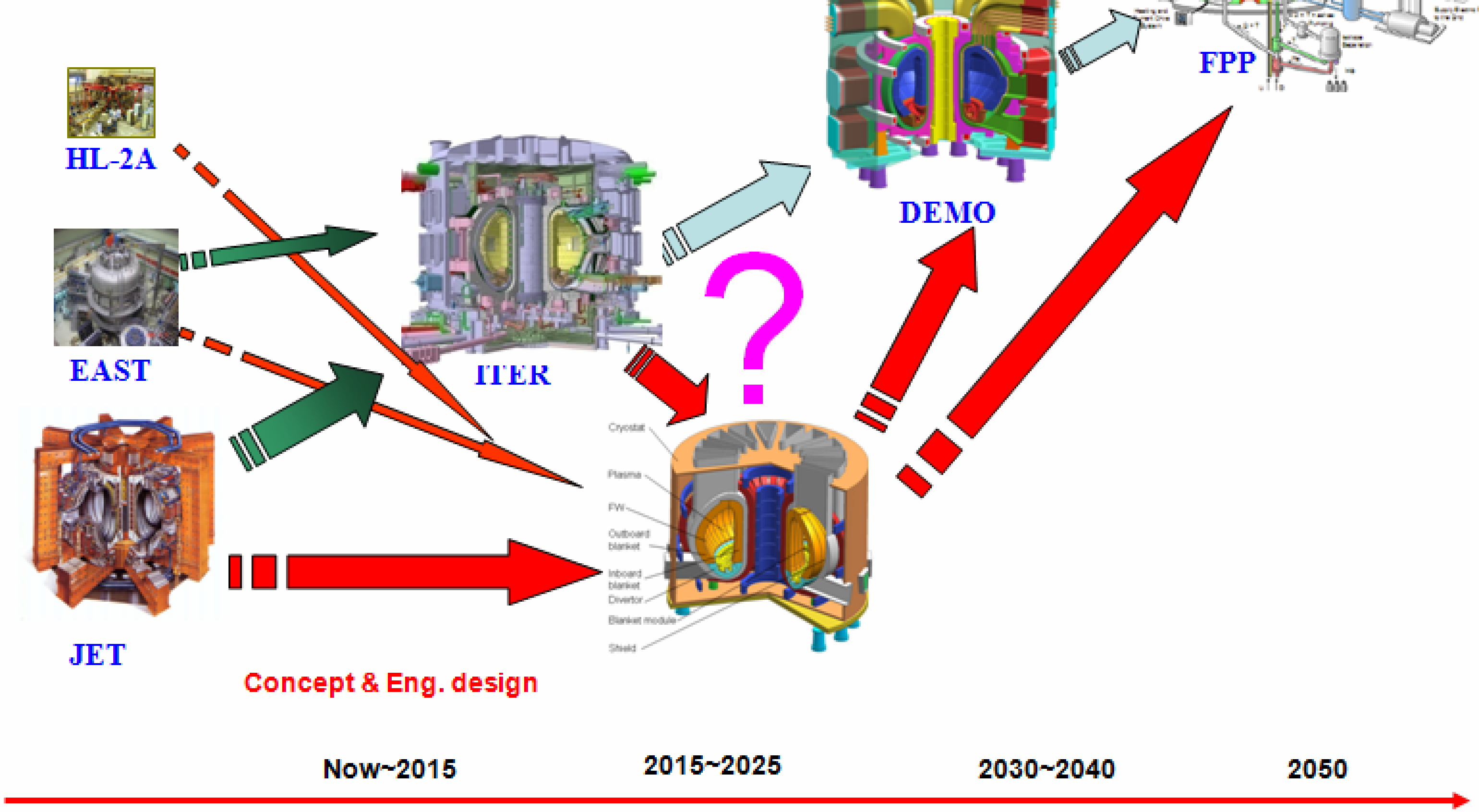
Working task and schedule

- **Now- 2014:** provide **two** options of engineering concept design of CFETR which should include in:
  - Missions
  - Type
  - Main physics basis
  - Main techniques basis to be taken
  - **The concept engineering design for all sub-systems**
  - Budget & Schedule
  - Location
  - Management system
  - List of the key R&D items
  - The plan for 200 PhD students / year

- **2015:** will make the proposal to government to try to get permission for CFETR construction;

Under discussion → *final option*

What is Possible Road map of Fusion to DEMO in China



Summary-1

- **Indian： 2×1GWe power plant by 2060; ADS-Th-U**
- **Korea： 2030 DEMO 2040 Fusion Plant**
- **Japan： 2000-2030 BA & ITER; 2025-2050 DEMO; after 2050 practical use of FE**
- **Russian: T-15MD;Ignitor; KTM; HBR**
- **EU ： ITER; fast track scenario; rediscuss**
- **U.S.A： MFE or IFE ??; Pilot ?; CTF ?**
- **China： CFETR is under conceptual design**

Summary-2

- ITER is the most important bridge to FPP, ITER must be success via international collaboration and hard work of all partners;
- Based on the ITER all partners are seriously consider the roadmap aimed to FPP;
- High duty or SSO burning plasma, Tritium self sufficiency and materials will be big challenges before FPP can be built.
- But fusion energy is vital for the future of mankind. The big challenges should and will be overcome by the collaboration and complementarity by roadmaps of partners and fusion power plants must be built in future.

Thanks for your attention!