ITC-12/APFA'01
December 10-14, 2001
Toki, Gifu, Japan

Fusion Technology R & D in Japan

- Goes into the 21st Century under the Unified Structure -

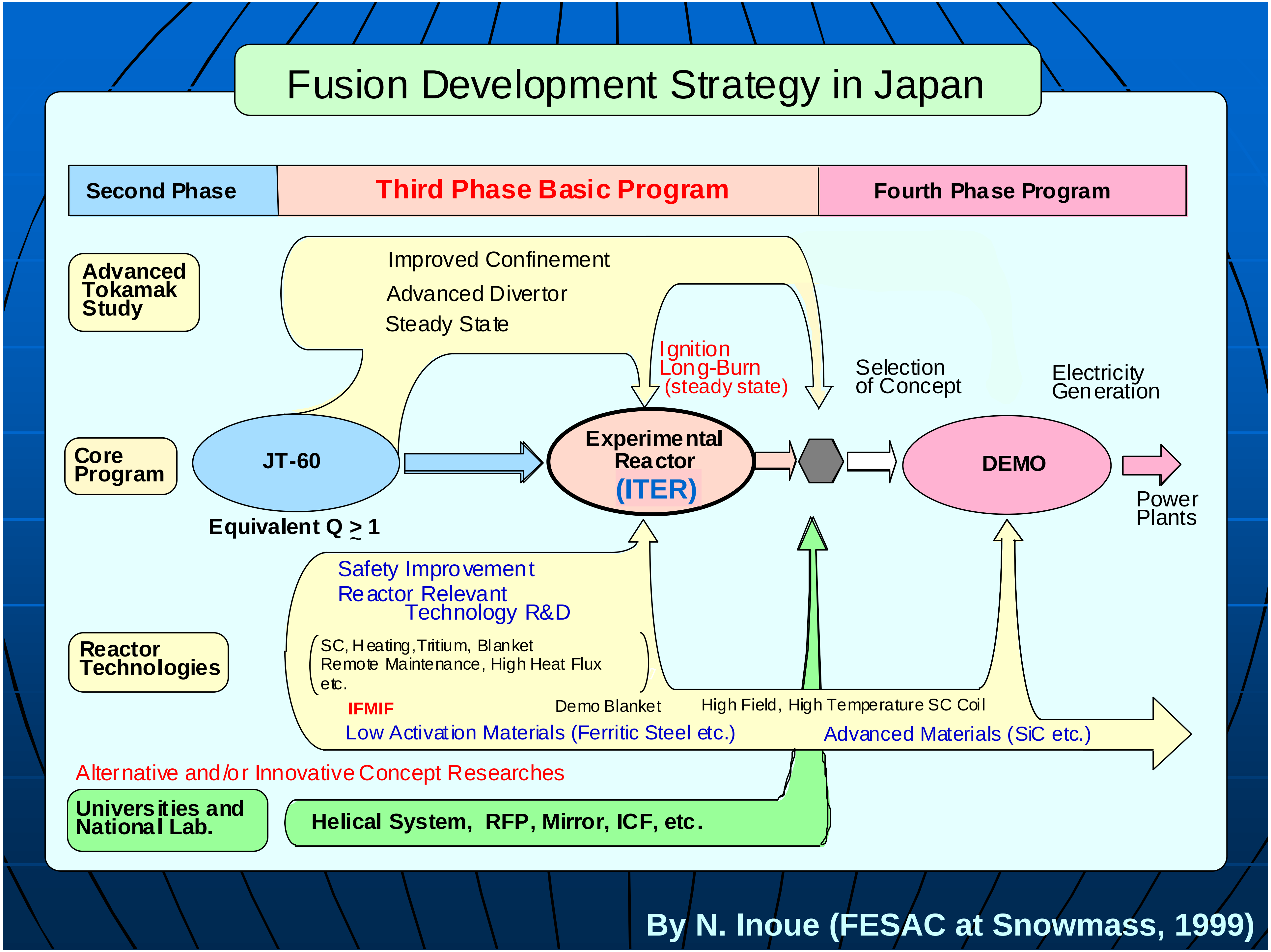
Akira Kohyama
Institute of Advanced Energy,
Kyoto University

Fusion Program in Japan

by N. Inoue (Chair of Fusion Council, Japan)

Institute of Advanced Energy, Kyoto University

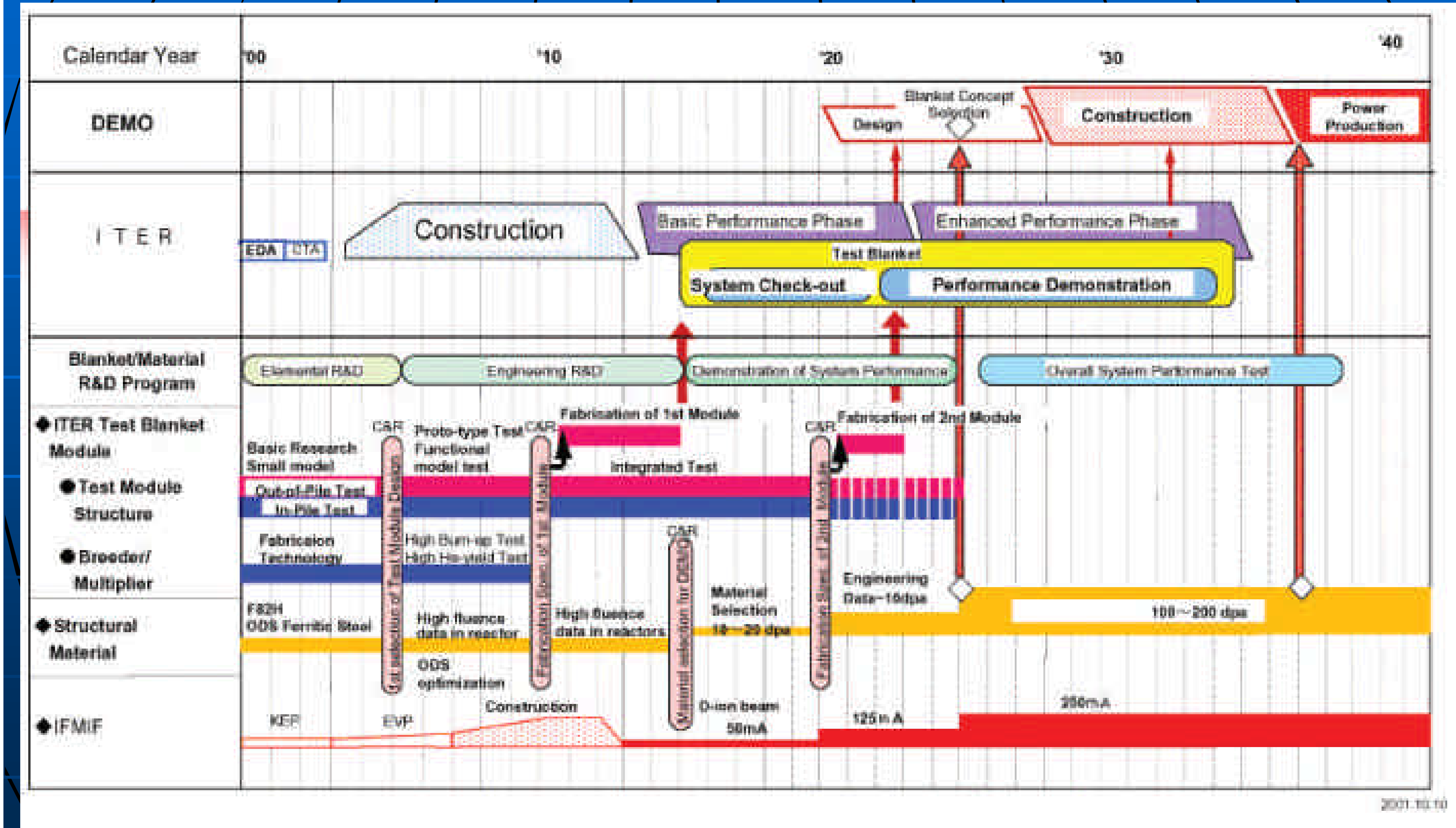
- Japan intends to develop fusion as a viable energy option for the future
- Construction of experimental reactor has the highest priority
- Serious discussions have been and are being made to make a confident decision on ITER construction
- In parallel, Japan studies various concept improvements in plasma confinement, as well as *materials development and reactor technology*



Fusion Development Strategy in Japan
Second Phase
Third Phase Basic Program
Fourth Phase Program
Advanced Tokamak Study
Improved Confinement
Advanced Divertor
Steady State
Ignition
Long-Burn
(steady state)
Selection of Concept
Electricity Generation
Core Program
JT-60
Experimental Reactor
(ITER)
DEMO
Power Plants
Equivalent Q ≳ 1
Safety Improvement
Reactor Relevant Technology R&D
SC, Heating, Tritium, Blanket
Remote Maintenance, High Heat Flux
etc.
Reactor Technologies
IFMIF
Demo Blanket
High Field, High Temperature SC Coil
Low Activation Materials (Ferritic Steel etc.)
Advanced Materials (SiC etc.)
Alternative and/or Innovative Concept Researches
Universities and National Lab.
Helical System, RFP, Mirror, ICF, etc.
By N. Inoue (FESAC at Snowmass, 1999)

Material/Blanket R & D Strategy

Institute of Advanced Energy
, Kyoto University



Fusion Technology R & D in Japan
- Goes into the 21st Century, under the Unified Structure -

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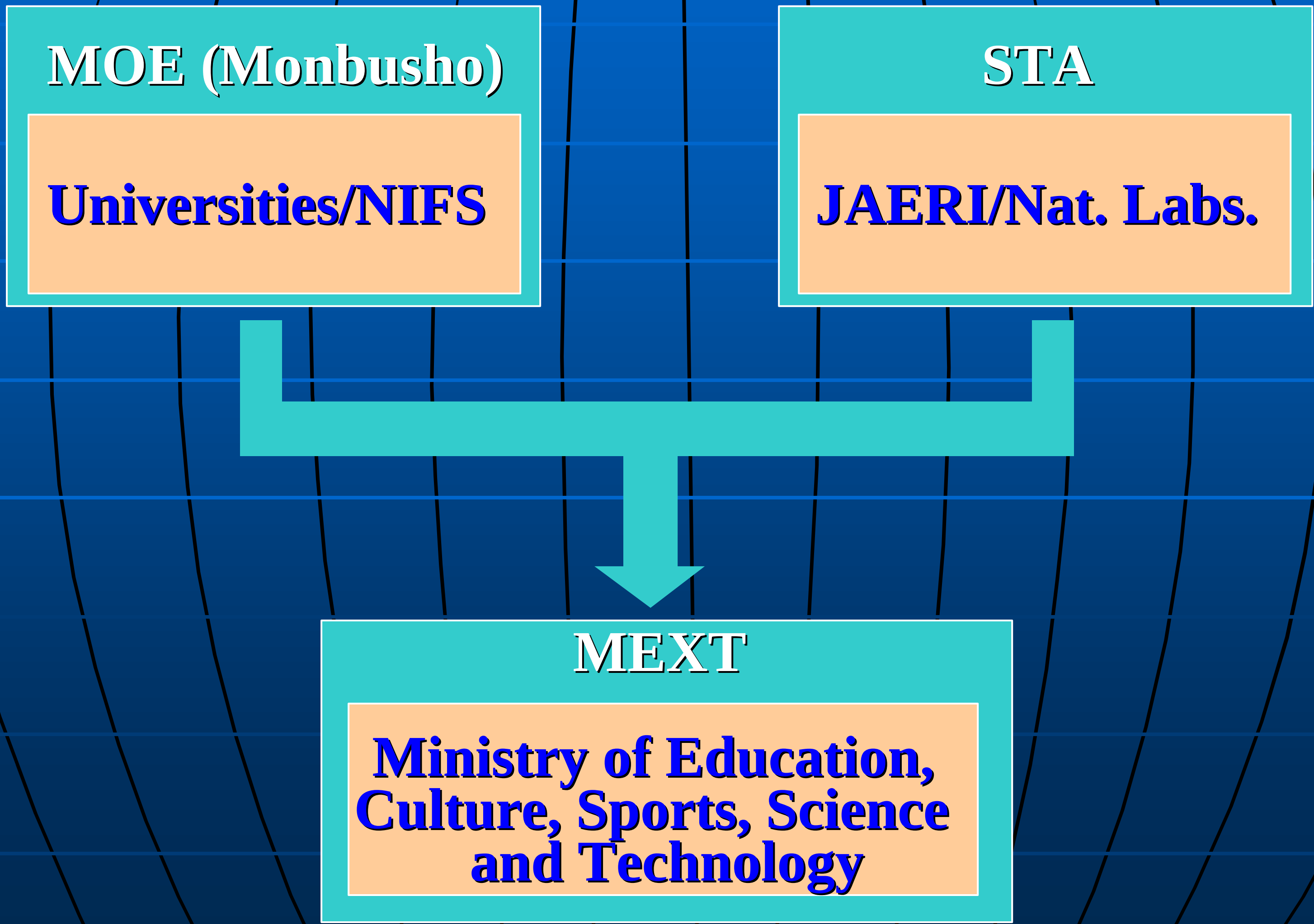
From April, 1, 2001:



Fusion Technology R & D in Japan
- In the past, under the dual structure -

Institute of Advanced Energy, Kyoto University

MOE (Monbusho)

Universities/NIFS

STA

JAERI/Nat. Labs.

Long-Term R & D Issues
Basic/Fundamental Research

Fusion Engineering Network
MOE/US-DOE Collaboration

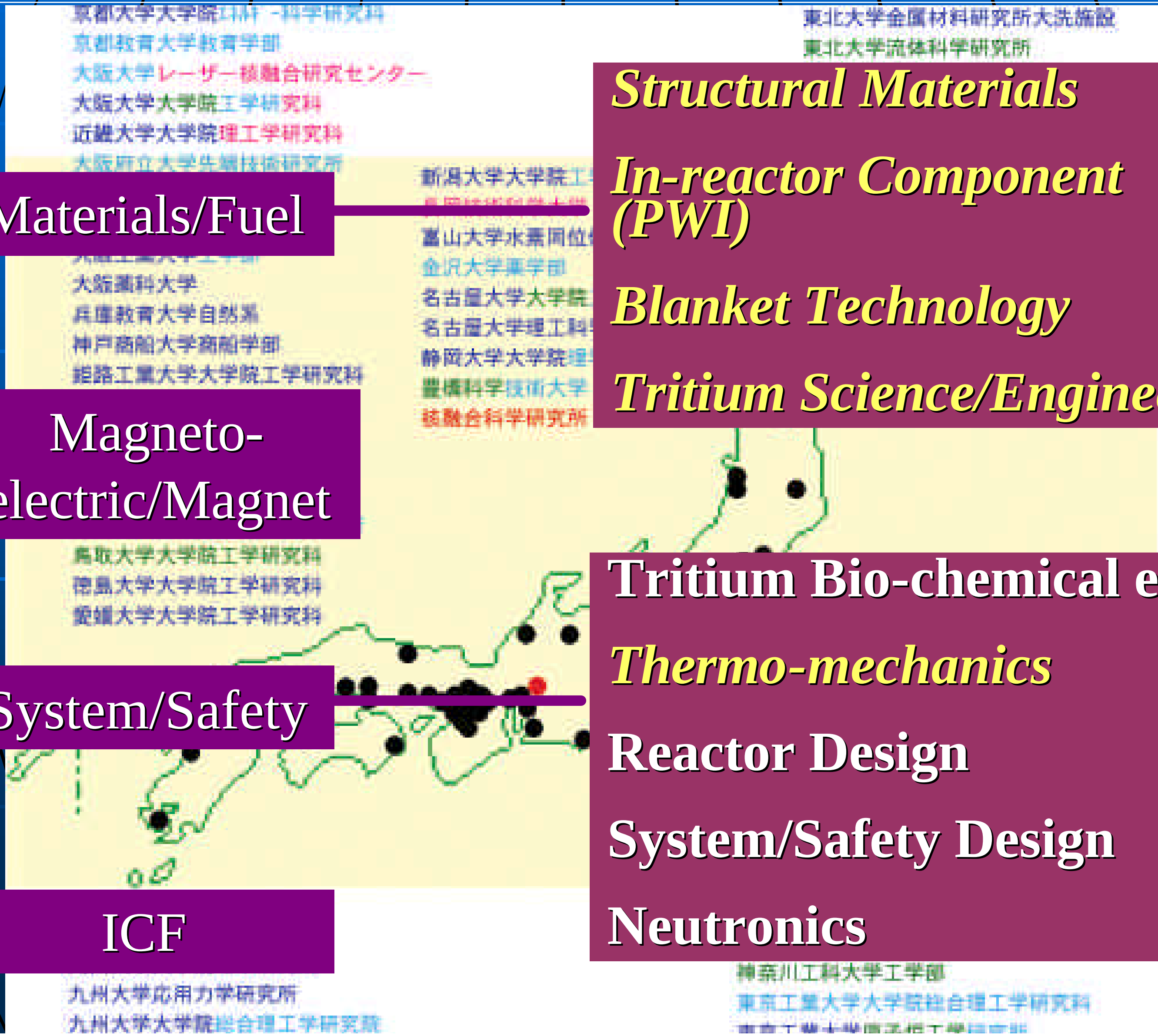
Near-Term R & D Issues
Energy Emphasized Efforts

ITER-EDA
JAERI/ORNL Collaboration

There have been *Many* efforts for Interaction/Collaboration

Fusion Engineering Network Activity

Institute of Advanced Energy, Kyoto University



- Materials/Fuel
  - *Structural Materials*
  - *In-reactor Component (PWI)*
  - *Blanket Technology*
  - *Tritium Science/Engineering*
- Magneto-electric/Magnet
- System/Safety
  - **Tritium Bio-chemical effects**
  - *Thermo-mechanics*
  - **Reactor Design**
  - **System/Safety Design**
  - **Neutronics**
- ICF

A Good Example can be seen in Materials R & D
- In the past, under the dual structure -

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,
Kyoto University

MOE (Monbusho)	STA
DOE/Monbusho Collaboration	JAERI/ORNL Collaboration

RTNS-II (14MeV effect)	*Austenitic Stainless Steel (Fundamental)*
FFTF/MOTA (High dpa effects)	*Austenitic S. S. (Weldment/Component)*
JUPITER (Dynamic/Varying/ Cumulative effects)	*Reduced Activation Ferritic Steels (Fundamental)*
JUPITER-2 (Integration for Advanced Blanket)	*Reduced Activation Ferritic Steels (weldment/He effects,,)*

Another Good Example can be seen in ITER EDA
- ITER/Japan Team with University participations -

There are many extinguished accomplishments
In Fusion Engineering R & D
(well known 7 accomplishments)

Many supporting activities in Japanese Universities

Examples of ITER EDA Accomplishments
- Fusion Engineering -

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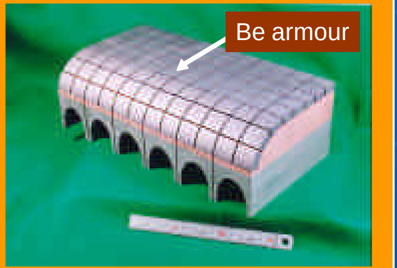
Blanket Technology

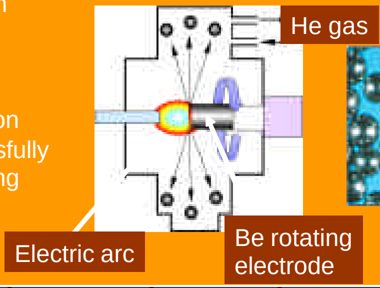
(1) Development of ITER Shielding Blanket

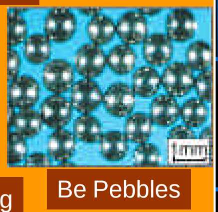
Beryllium-armored full-width First Wall panel (DSCu/SS) has successfully fabricated by HIP technique first time.



(2) Development of Breeding Blanket

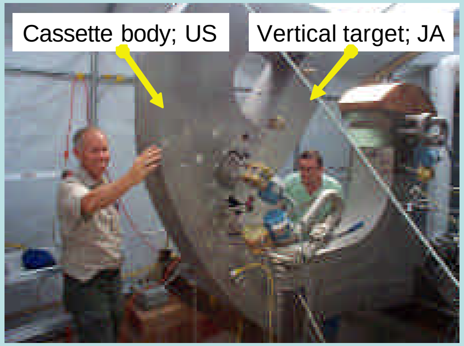
- Effects of thermal cycles on the pebble bed structure has been investigated.
- World's first mass production technology of Beryllium neutron multiplier pebbles has successfully been developed by the Rotating Electrode Method.





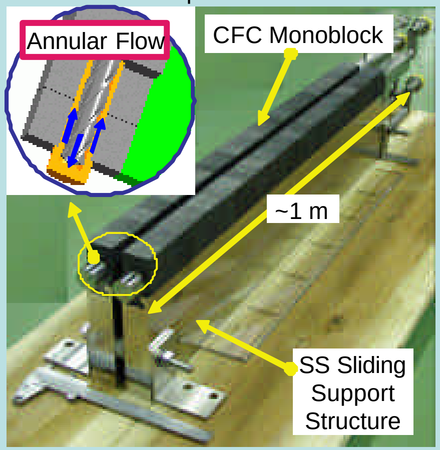
Development of ITER Divertor

L5 Divertor Project



Integration Tests of JA and US components were successfully completed.

Development of New Cooling Structure
- Save space and cost -

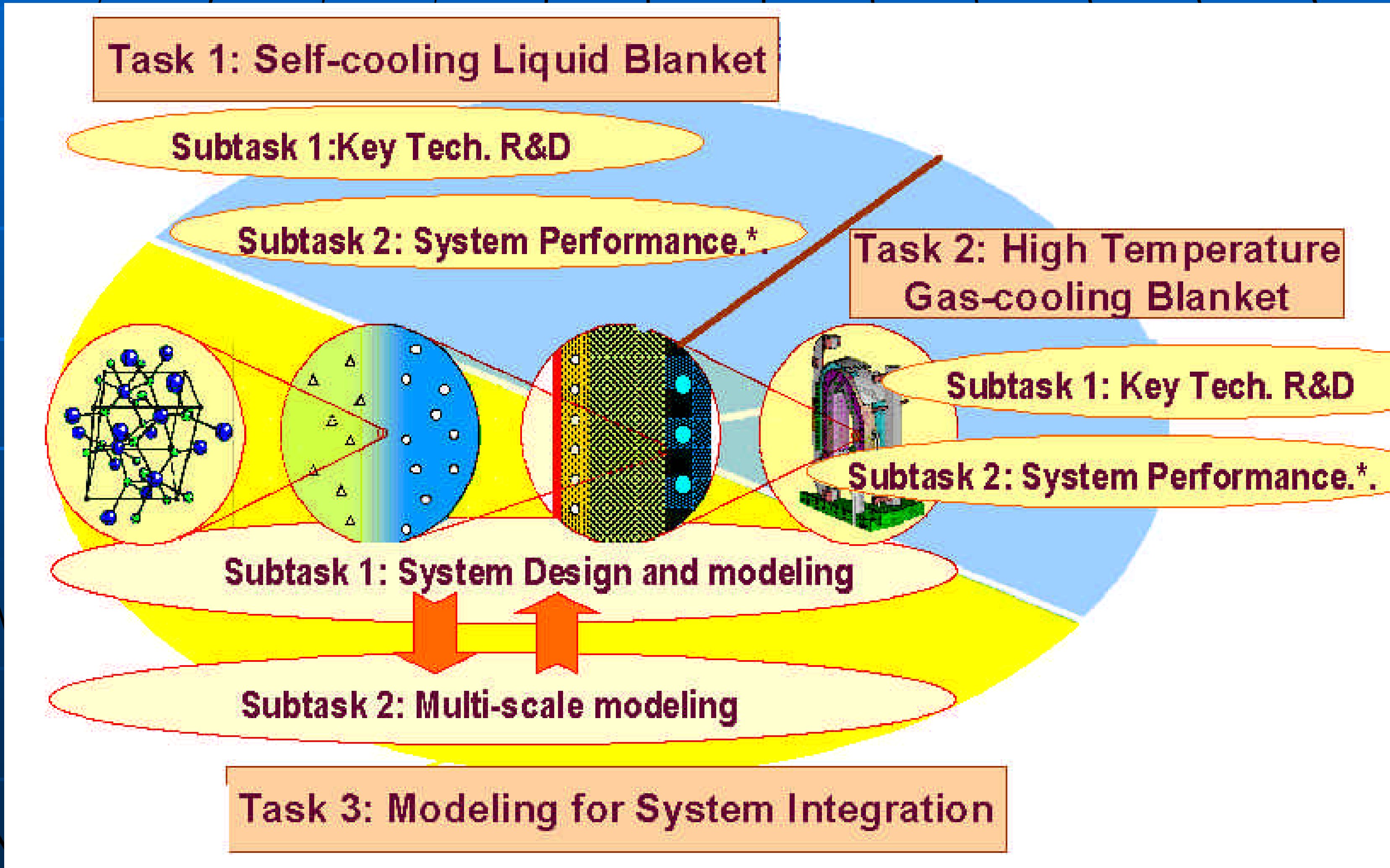


The vertical target mock-up with annular flow has successfully withstood a heat load of 20 MW/m^2, 10s for 1000 cycles.

New Project JUPITER-II (2001 - 2006)

- Materials integration utilizing reactor irradiation and related basic research for advanced blankets -

Institute of Advanced Energy, Kyoto University



Targets of Fusion Power Reactors

- Attractive Options -

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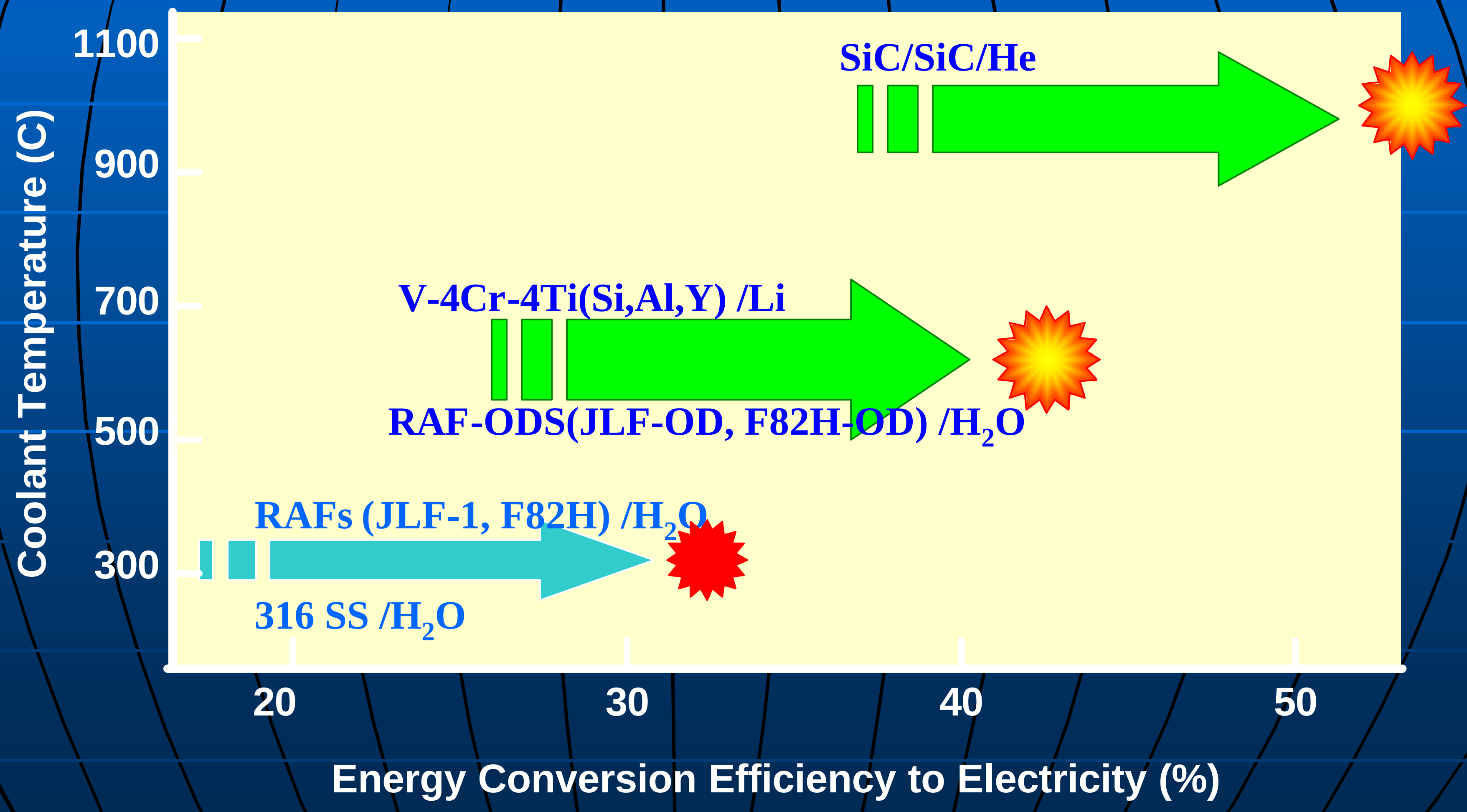


Blanket R&D in Japan

Institute of Advanced Energy, Kyoto University

"Medium-term research plan for power generating breeding blanket"
August 2000, by Fusion Council

- R&D for DEMO blanket. Blanket module test in ITER: important milestone.
- Three C&Rs and selections scheduled

- JAERI: core institute for solid blanket development
  Universities (NIFS): fundamental studies to obtain perspective on liquid blanket, material development, various fundamental studies on solid and liquid blankets

Reference blanket JAERI: lithium ceramics cooled by supercritical water
NIFS: FFHR, flibe as breeder and coolant

Advanced blanket concepts with high coolant temperature, advanced safety, high resistance for large neutron flounce
Flibe Blanket, Liquid Lithium with Vanadium Alloy, Solid Breeder and SiC/SiC

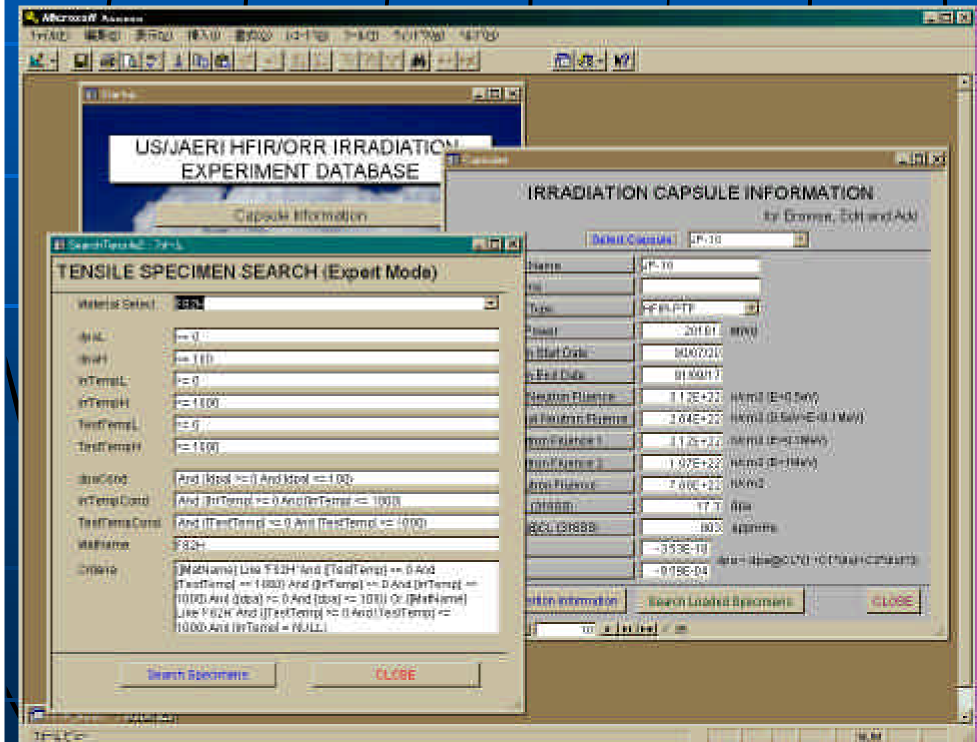
JUPITER-II: Japan-MEXT US-DOE collaborative project on advanced blankets 2001-2006, mainly using facilities at INEEL, UCLA, ORNL, ANL

Reduced Activation Ferritic Steel R&D in Japan

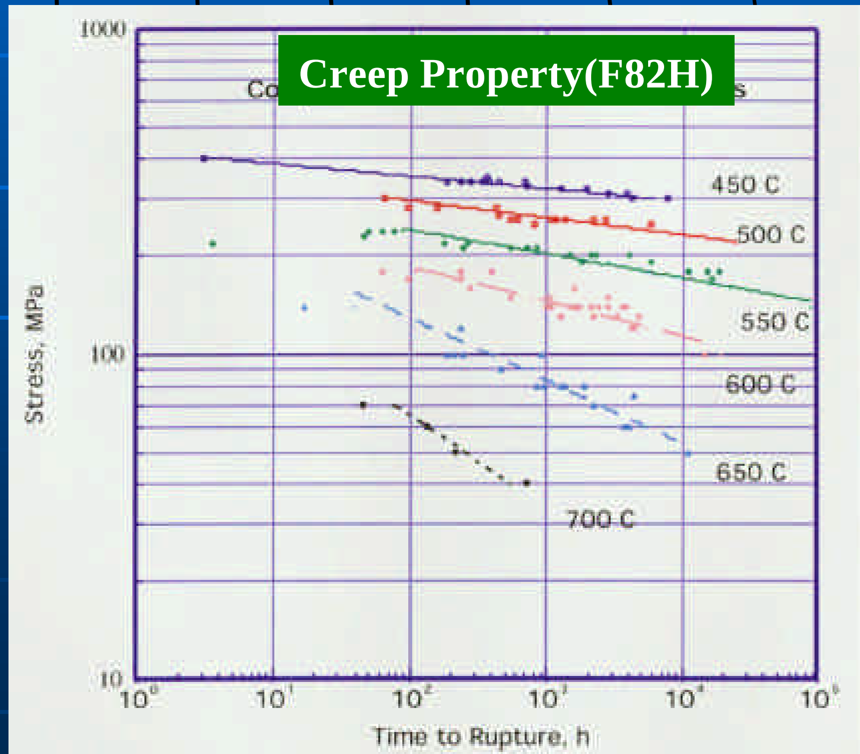
Institute of Advanced Energy
, Kyoto University

RAF Database (F82H/JLF-1)

Since '92 for a decade, Under the Japanese initiative, RAF database has been constructed (IEA RAF WG)



Display Modes (Example)

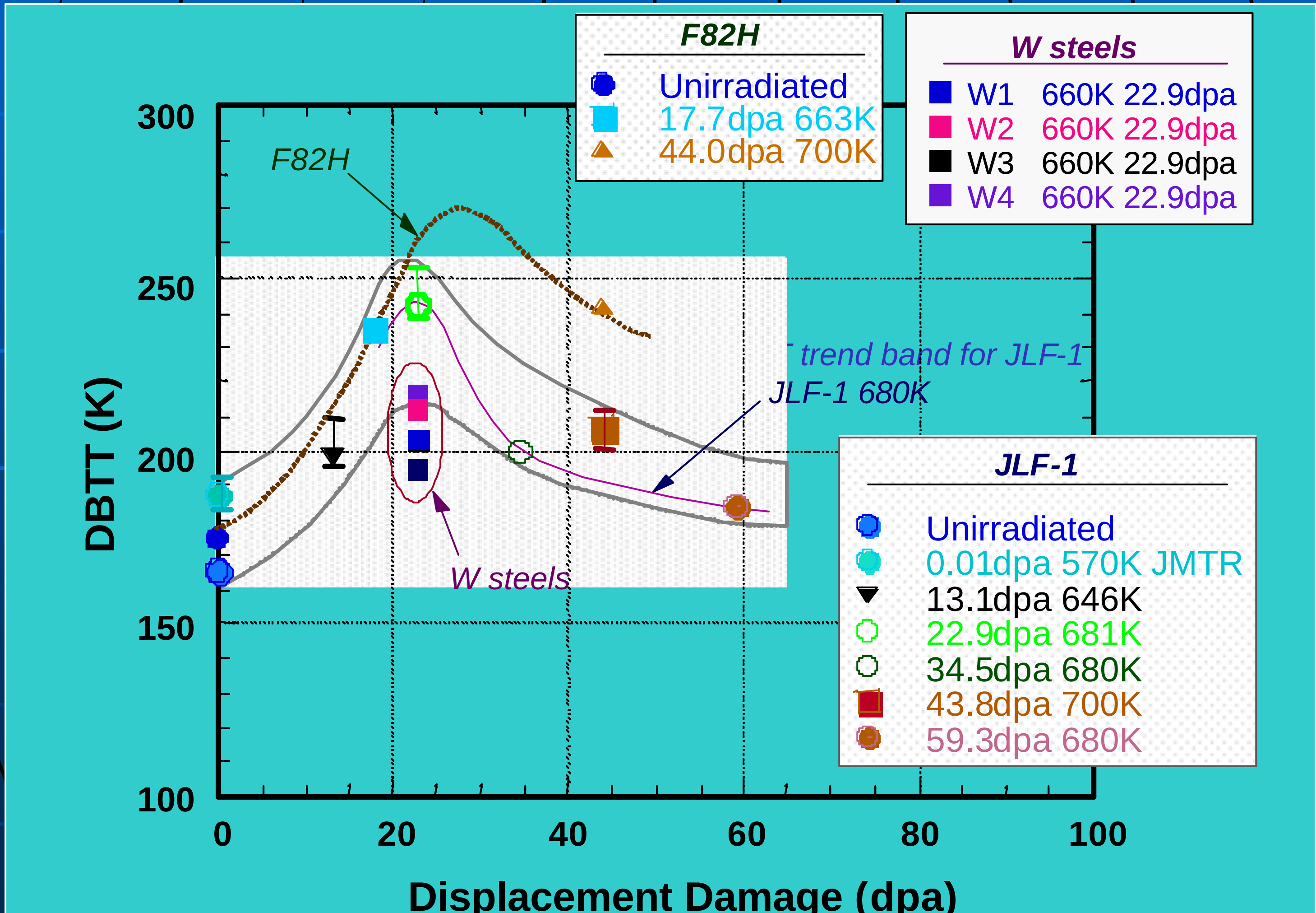


Data Plot (Example)

Reduced Activation Ferritic Steel R&D in Japan

Institute of Advanced Energy, Kyoto University

Improvement in DBTT



Radiation Effect on Stress Amplitude

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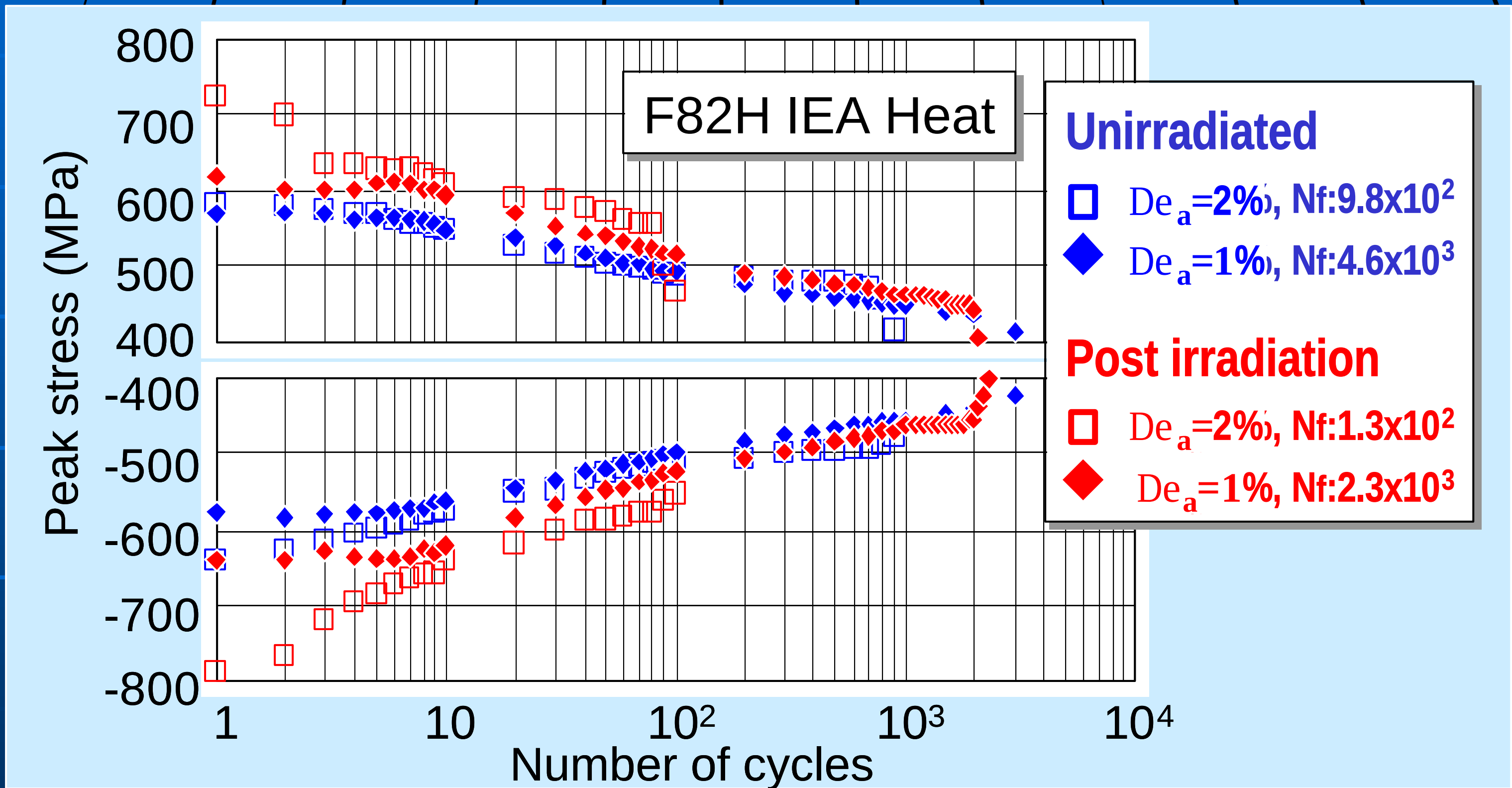
JMTR ~0.005dpa ($3.1\times10^{19}cm^{-2}$ / Irr. Temp. ~90C)



- The increase of initial stress amplitude was 292MPa at $\Delta\varepsilon_a$= 2%, and 116MPa at $\Delta\varepsilon_a$= 1%.
- Number of cycles to failure of $\Delta\varepsilon_a$= 2% case was reduced to 13% of unirradiated case.

R & D of Ferritic Steels for Fusion

- from Fundamental Materials R & D *to Technology/Engineering Integration -*

Institute of Advanced Energy, Kyoto University

Data base development toward DEMO.

Ferromagnetic effects.

Development of high heat-resistant super steels and ODS steels.

Development of welding/joining technology and ODS-clad processing.

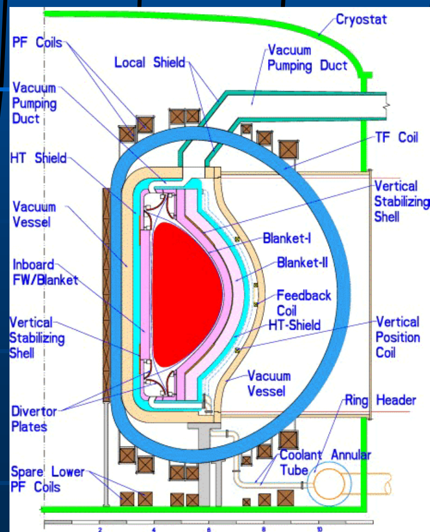
Compatibility with pressurized water and super critical water.

Performance Evaluation and Improvement under

Neutron Environment
Blanket Environment

Technology/Engineering Integration for

Blanket/Reactor Components Fabrication



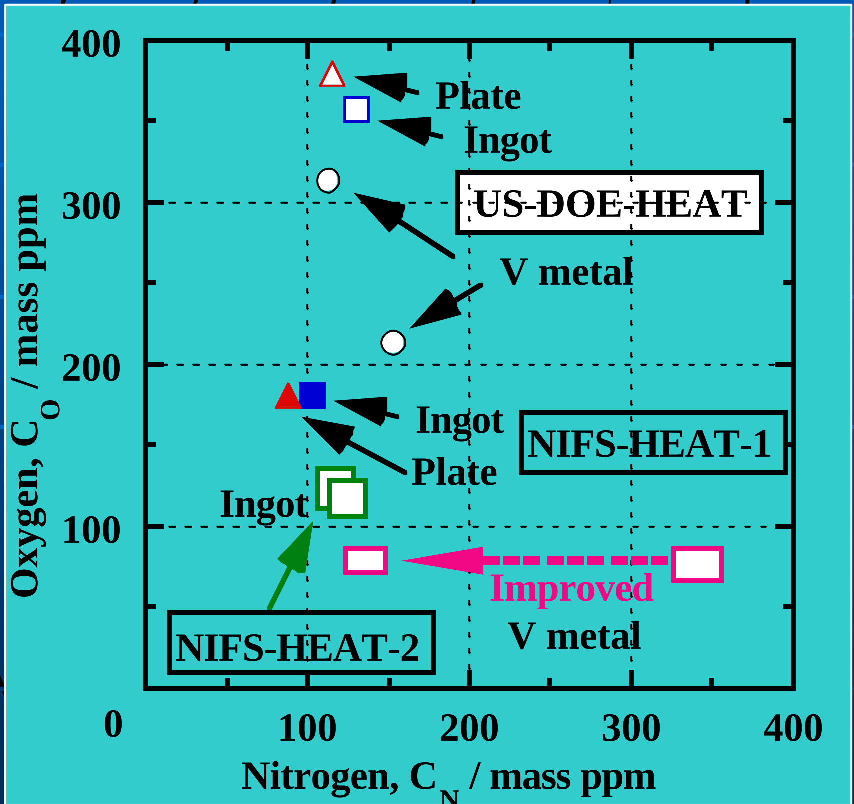
SSTR or ASSTR

Fabrication of High Purity Large Products of V-4Cr-4Ti (NIFS-HEATs)

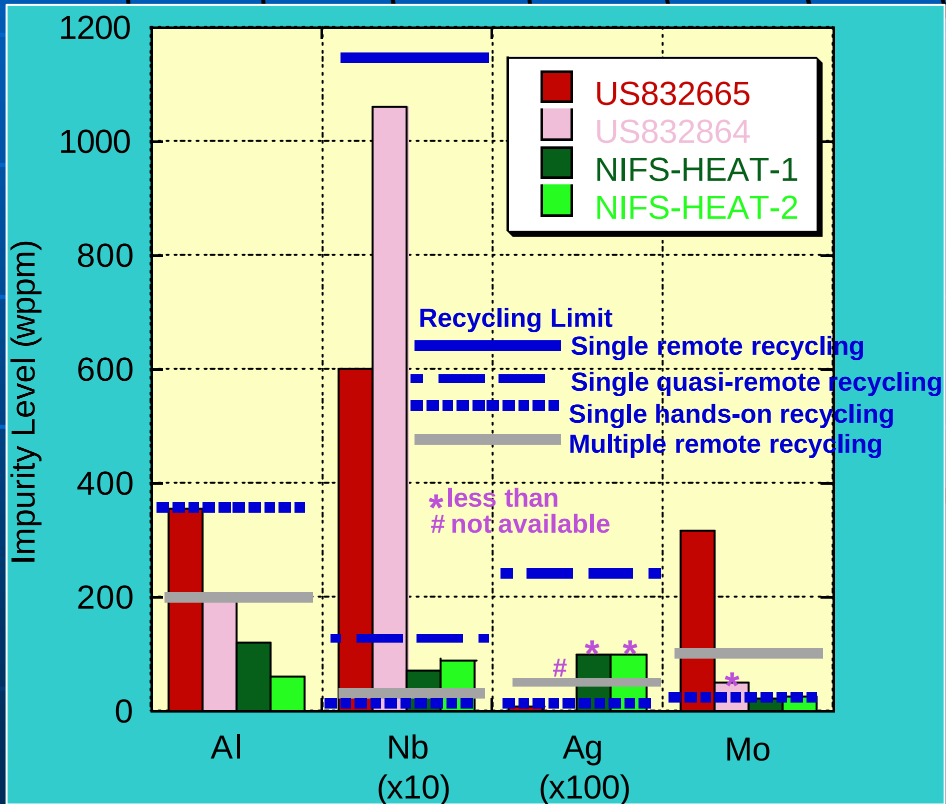
Large V-4Cr-4Ti ingots with reduced impurity levels were produced in NIFS

Feasibility of recycling by quasi-remote (simply shielded) processing was verified

The resulting products were used for Round-robin test by international collaboration



Impurity level of NIFS- and US- HEATs

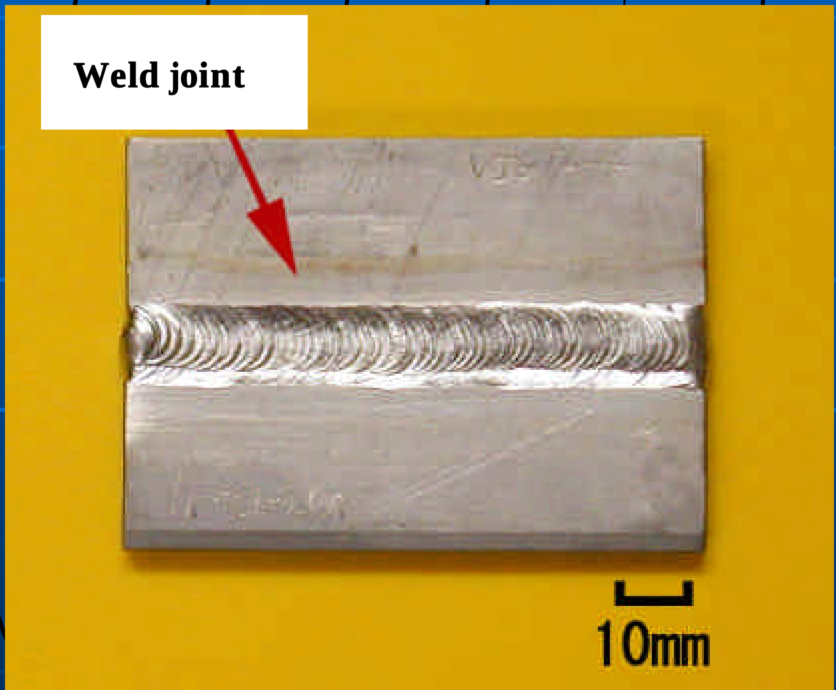


Impurity level and recycling criteria

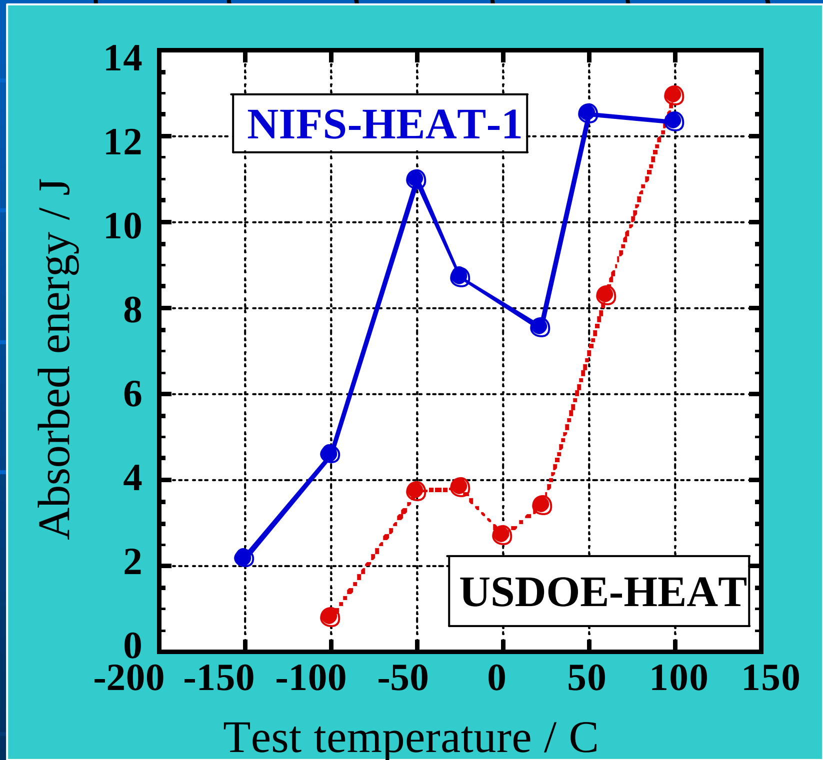
(Muroga, Nagasaka, Heo, NIFS)

Improvement of Welding Property

Reduction of oxygen level in NIFS-HEAT resulted in significant enhancement of the mechanical property of the weld joint



TIG weld joint of NIFS-HEAT-1



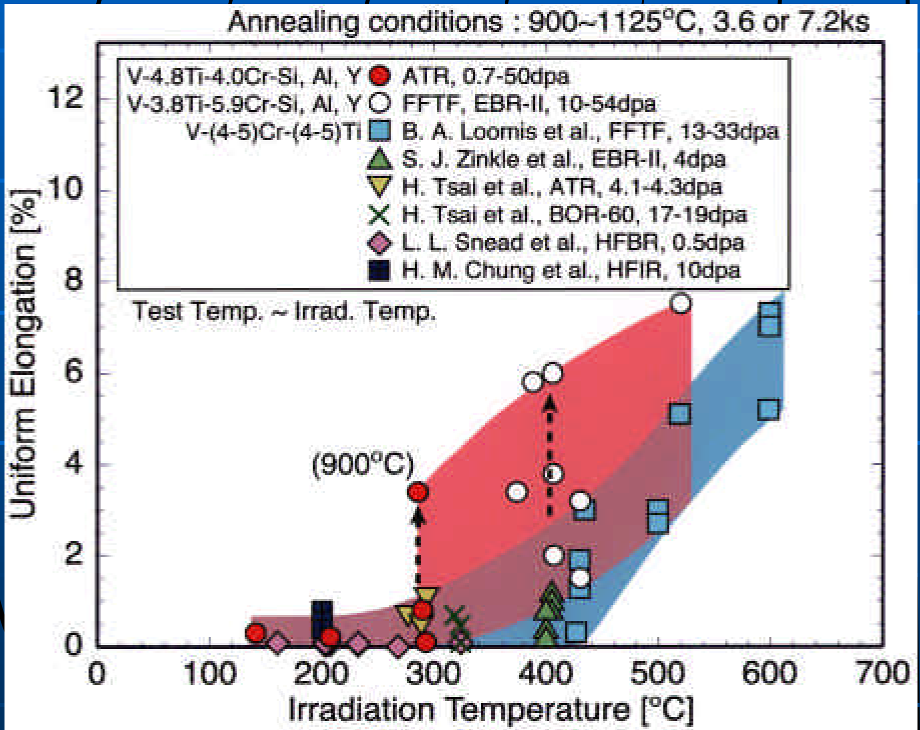
Impact property of the TIG weld joint

(Muroga, Nagasaka, Heo, NIFS)

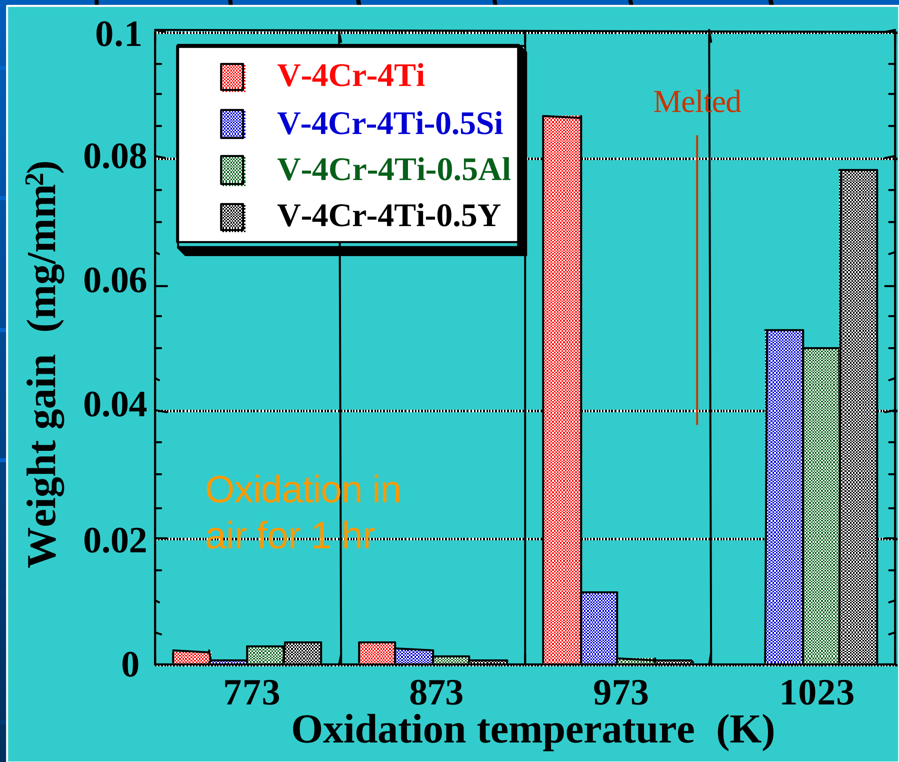
Improvement of Resistance to Radiation and Oxidation by Addition of Si, Al and Y

Ductility after irradiation at 300~400C was significantly enhanced

Oxidation during exposure to air was strongly suppressed to 973K



Uniform elongation of irradiated alloys

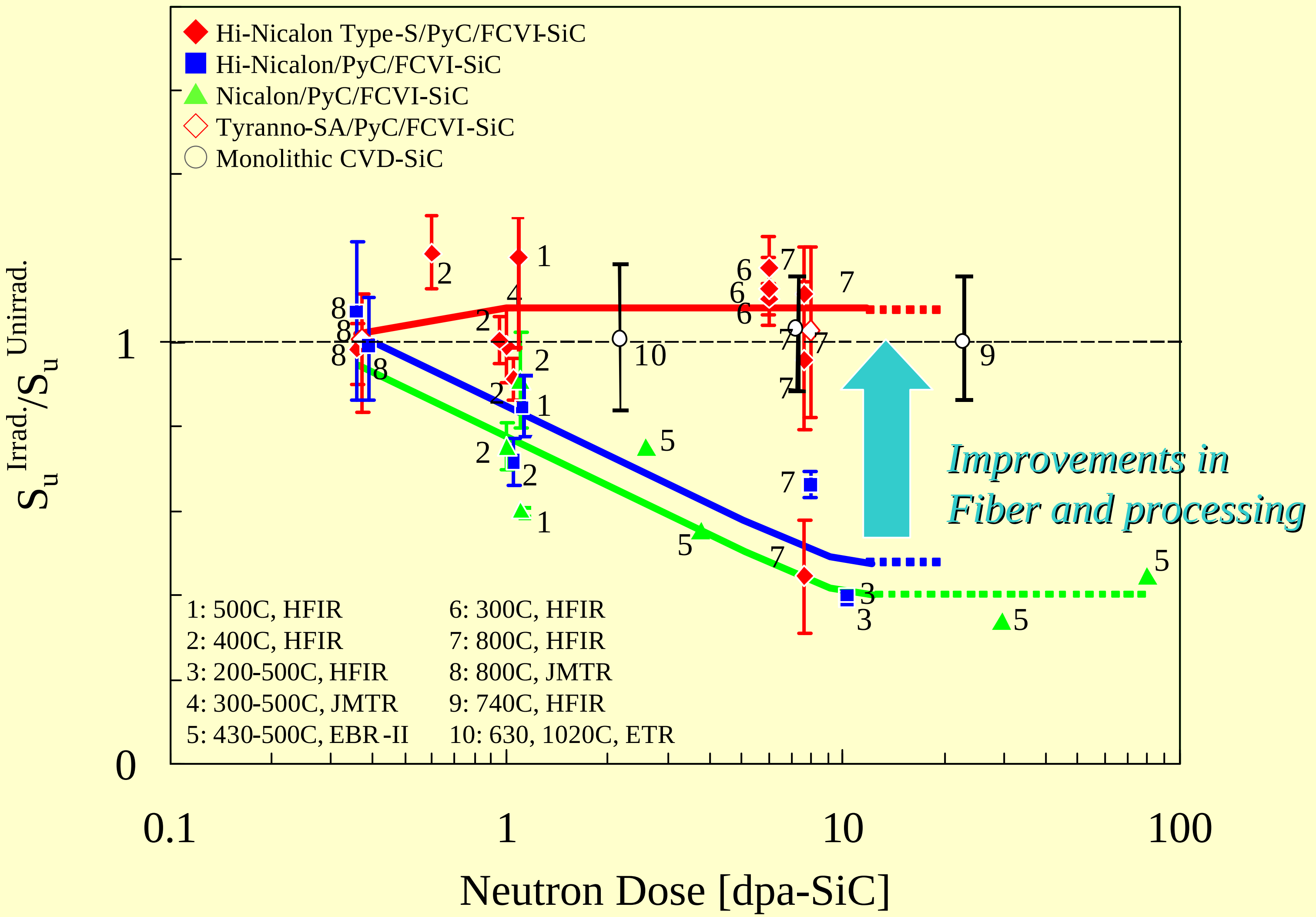


Weight gain by exposure to air

(Abe, Satou, Fujiwara, Chuto, Tohoku University)

Irradiation Effects on Mechanical Properties of SiC/SiC

Institute of Advanced Energy, Kyoto University



Improvement in Thermal Stress Figure of Merit
- by LPS-SiC/SiC -

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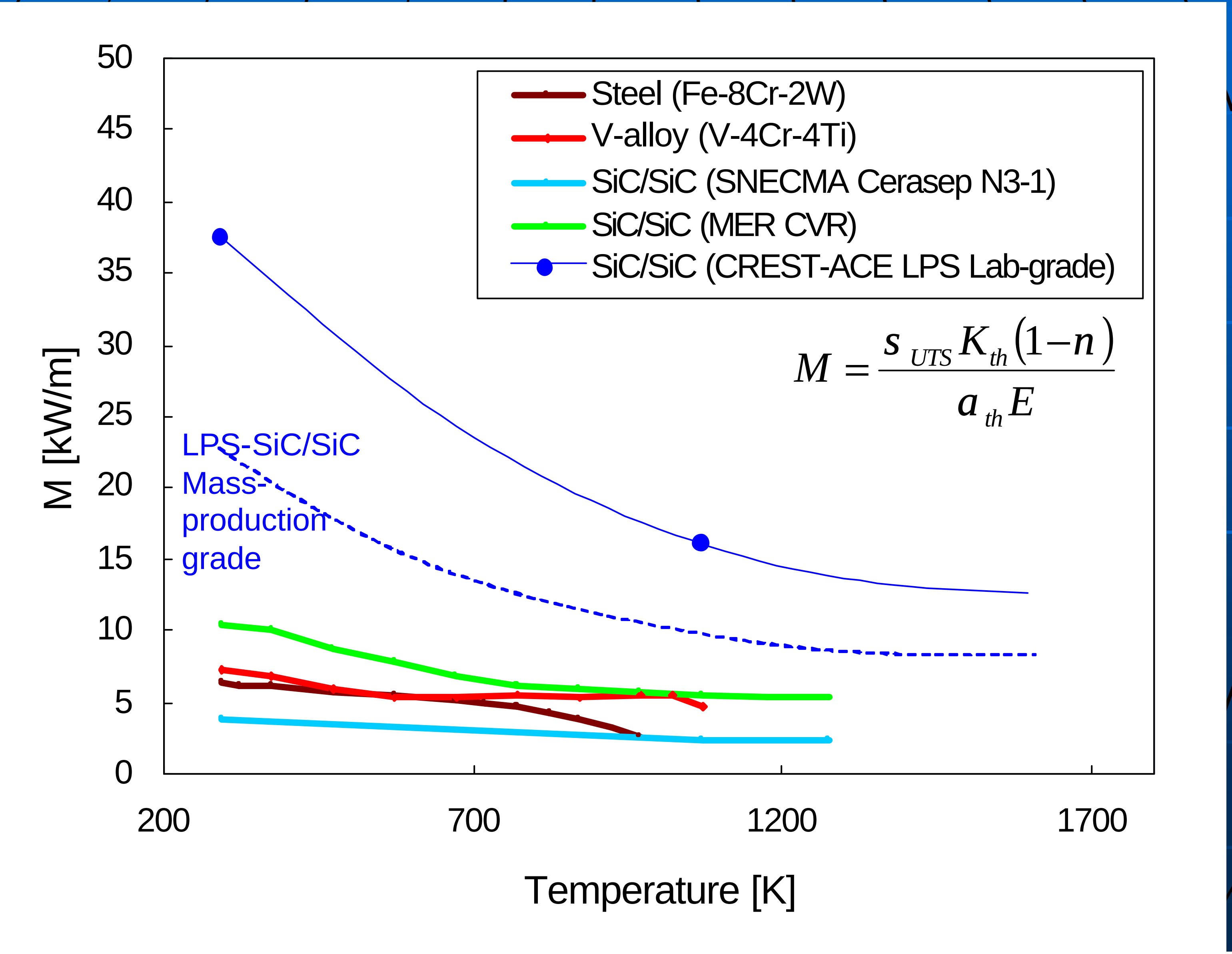

SiC/SiC R & D Goals and Status
- 2000 -

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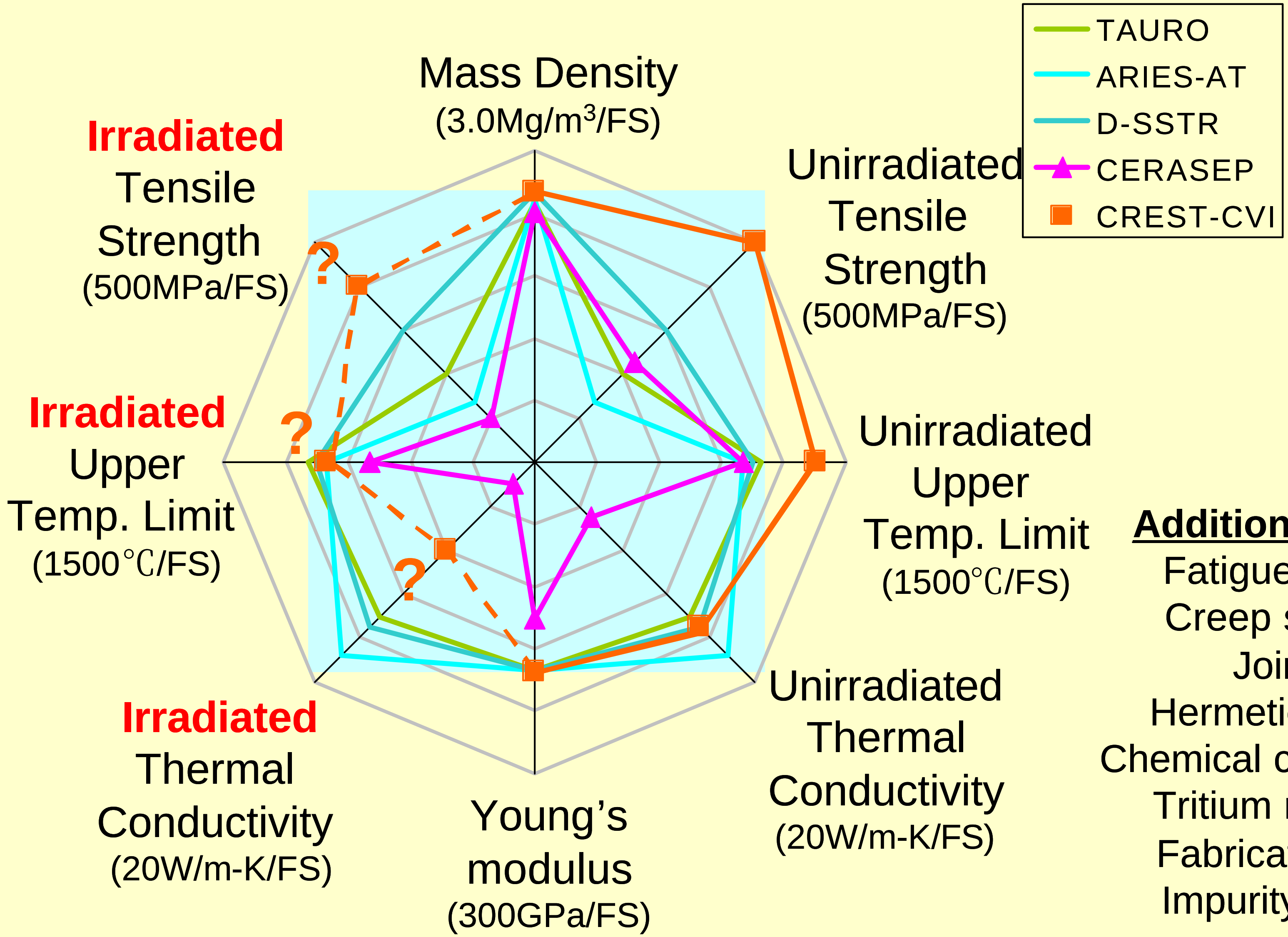


Additional Issues

Fatigue lifetime
Creep strength
Joining
Hermetic sealing
Chemical compatibility
Tritium retention
Fabrication cost
Impurity control

PWI and Plasma Facing Materials

Institute of Advanced Energy, Kyoto University

Major Subjects

(1) High Z plasma facing materials and interaction with plasma
Nagoa Univ., Doshisha Univ., Fukuoka Univ. of Education, Kyoto Univ., NIFS, etc. (IEA-TEXTOR Collaboration)

(2) Measurement of tritium in the plasma facing materials of fusion experimental devices
Toyama Univ., Nagoya Univ., NIFS (IEA-TEXTOR Collaboration)

(3) Developments and evaluation of high-Z plasma facing materials
Tohoku Univ., Kyushu Univ., NIFS, Kagoshima Univ., etc. (LHD Joint Projects)

(4) H and He irradiation experiments of W-coated materials with plasma simulators
Kyushu Uinv., NIFS (J-US Collaboration)

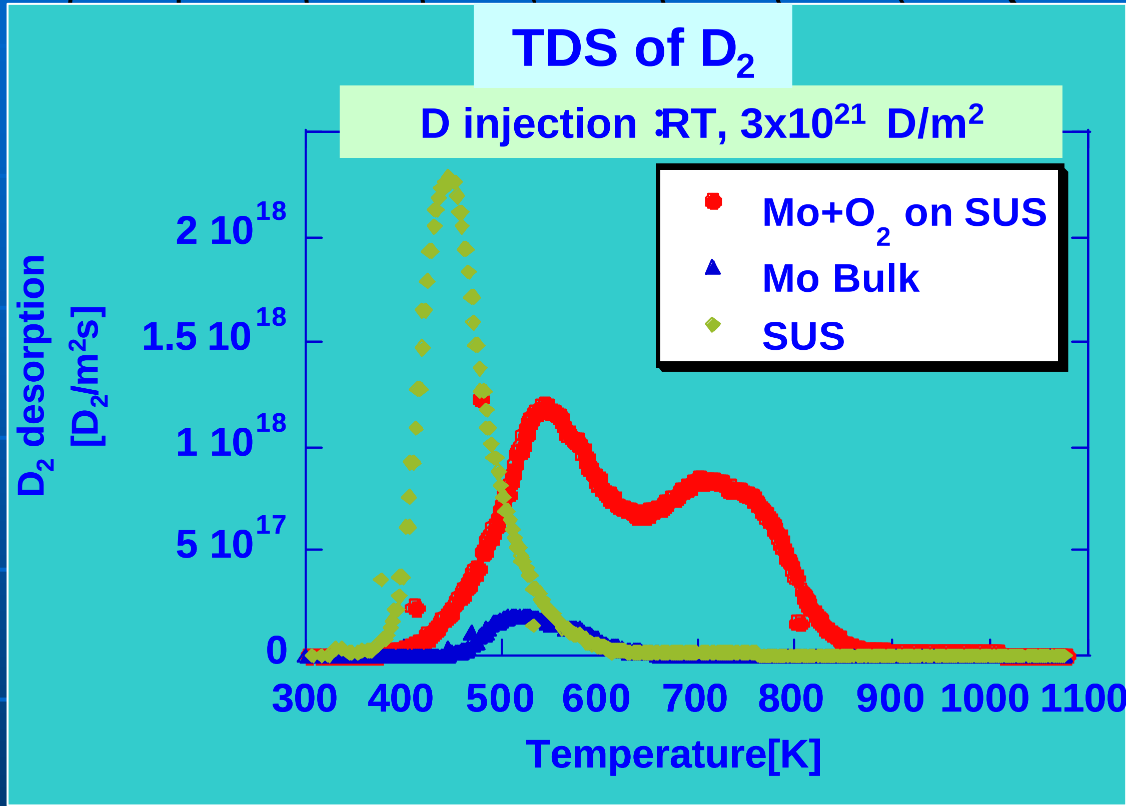
(5) Analysis of the first wall of TRIAM-1M and LHD
Hokkaido Univ., NIFS (LHD Joint Projects, NIFS Joint Projects)

Deposit of TRIAM-1M Tokamak

Fusion Group RIAM Kyushu University

TRIAM-1M deposit

Fine fcc crystals, 1nm

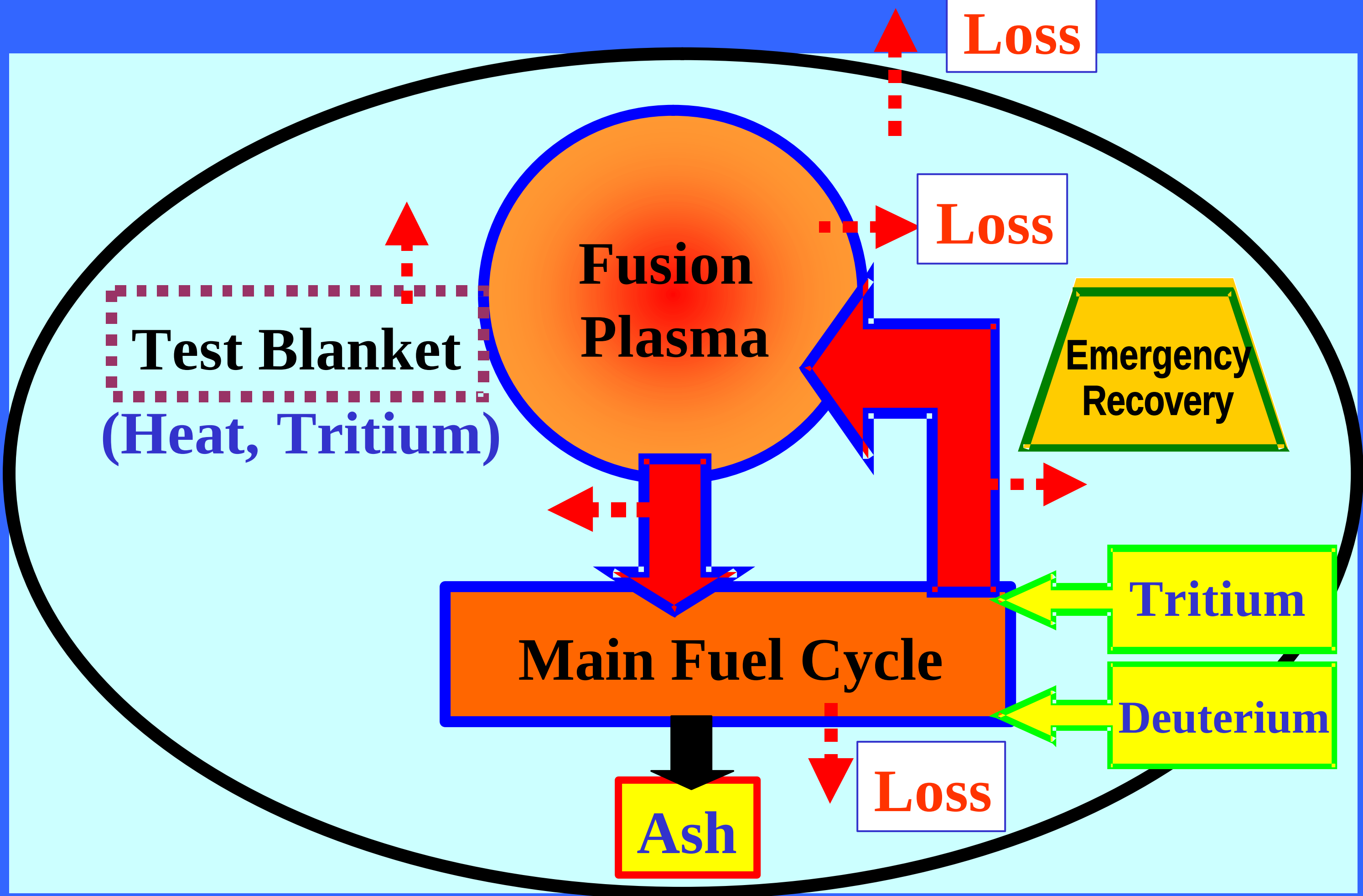


Due to the co-deposition of Mo with residual Oxygen, structure and properties of the wall surface change completely.
High D retention change hydrogen recycling.

Critical issue for the control of steady state plasma

FUEL CYCLE!, SAFETY!

ITER



Tritium Flow in Fusion Reactor

(I)	(II)	(III)
Preparatory Plasma Experiment	**D-T Burning Plasma Experiment**	**Controlled Plasma Operation**

preparatory tritium study

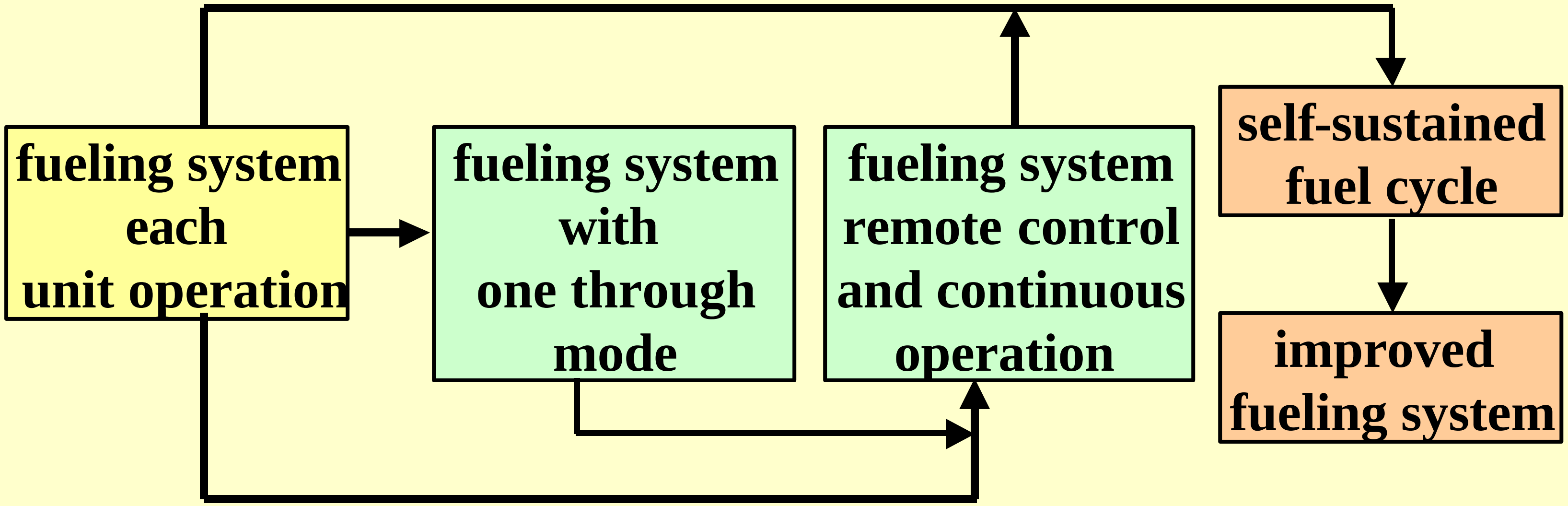
safety confinement

biological assessment

safety confinement (remote control)

environmental assessment

(preparation, settlement, measurement, control, regulation, waste treatment)



Where are we struggling ?

-Radiation Effects-

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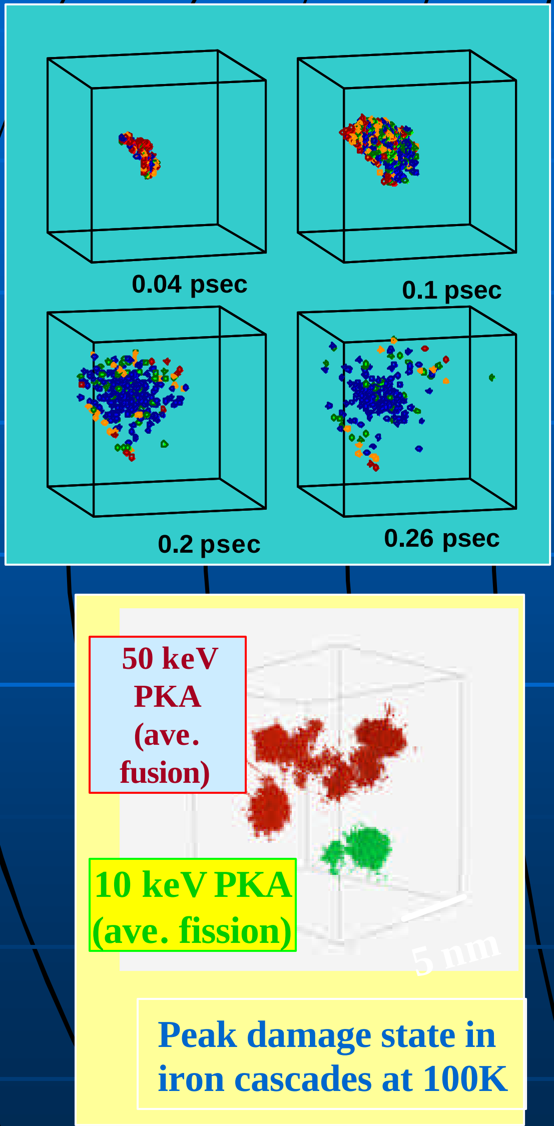
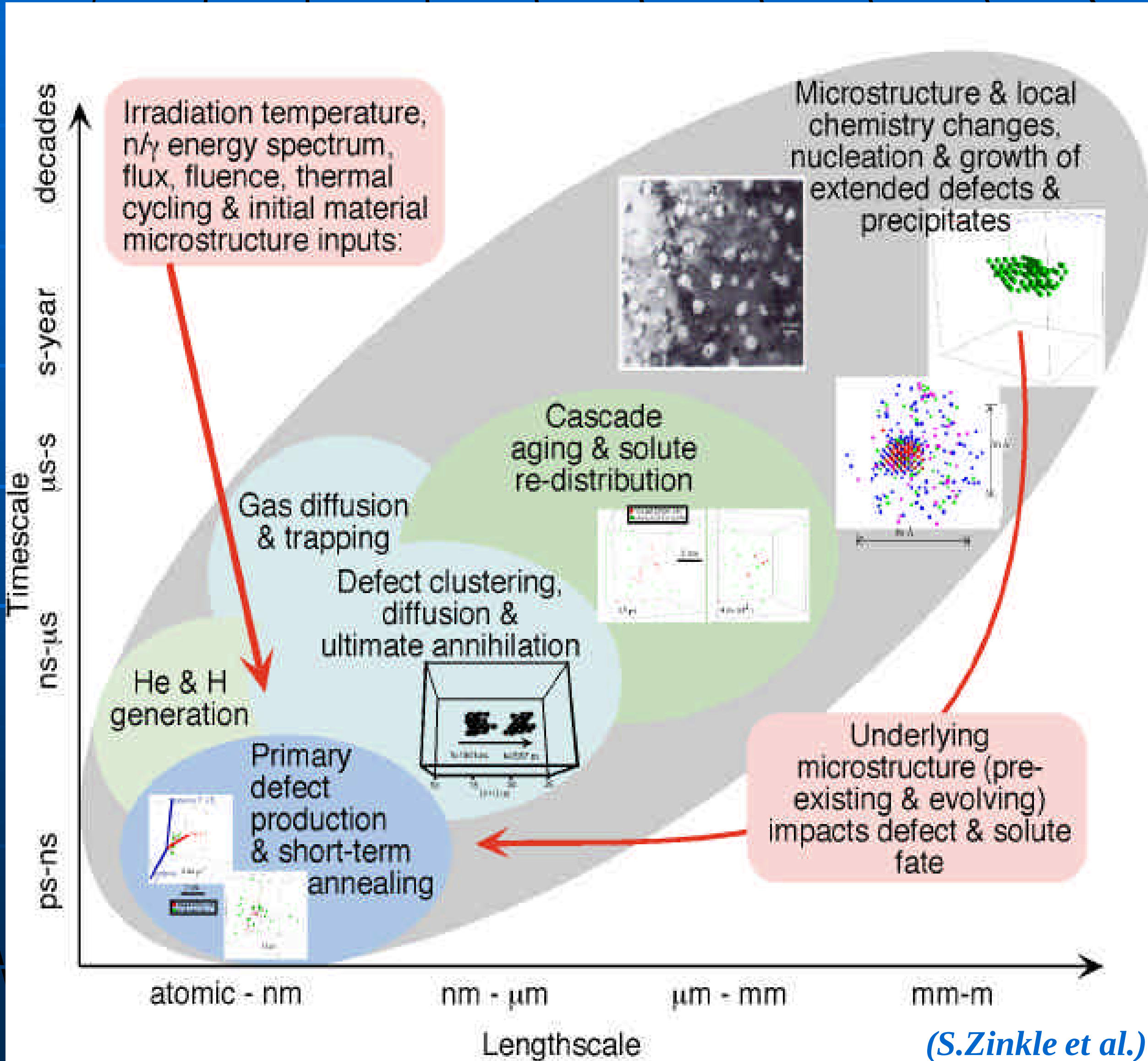
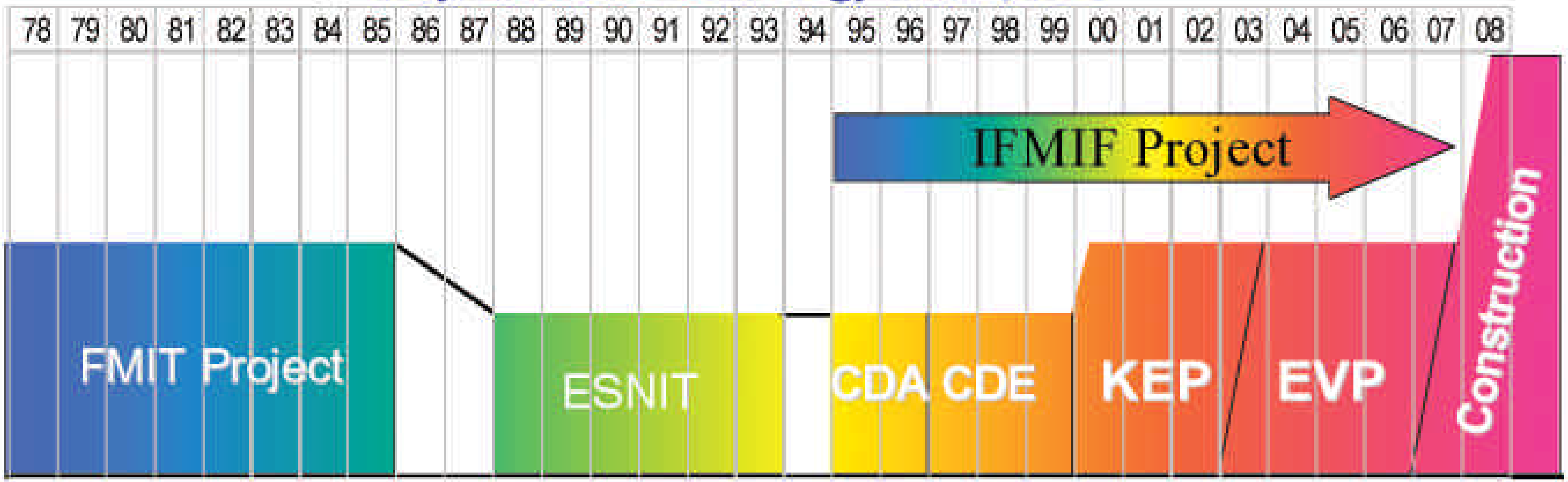




(S.Zinkle et al.)

History of Intense Neutron Source

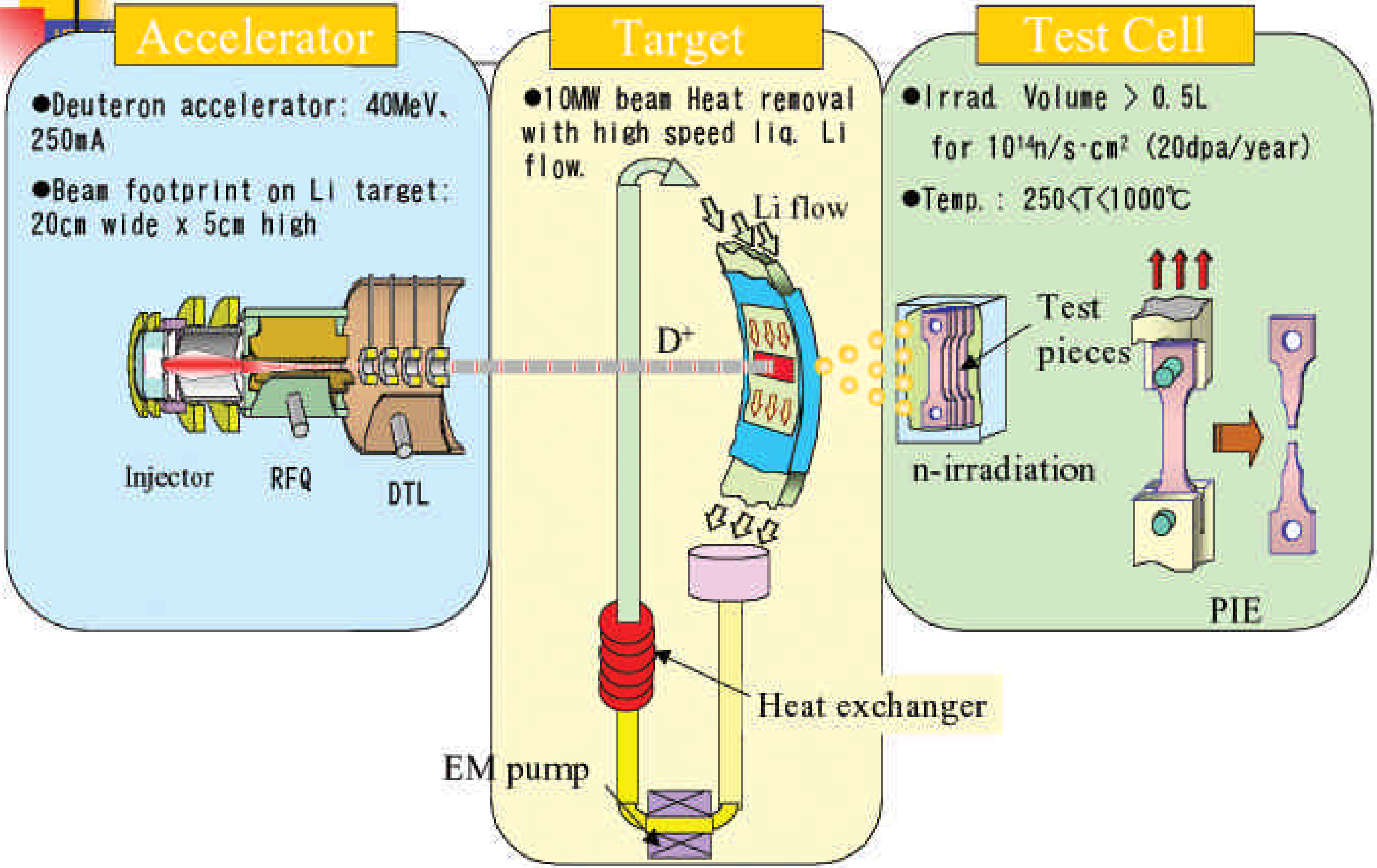
- **R&D over more than 20 years**
- **Current activity on neutron source**
  - *IFMIF* Project under auspices of IEA
  - Key Element Technology Phase, KEP



FMIT: Fusion Material Irradiation Test Facility
ESNIT: Energy Selective Neutron Irradiation Test Facility

CDA: Conceptual Design Activity
CDE: Conceptual Design Evaluation
EVP: Engineering Validation Phase

Three Major Components of IFMIF



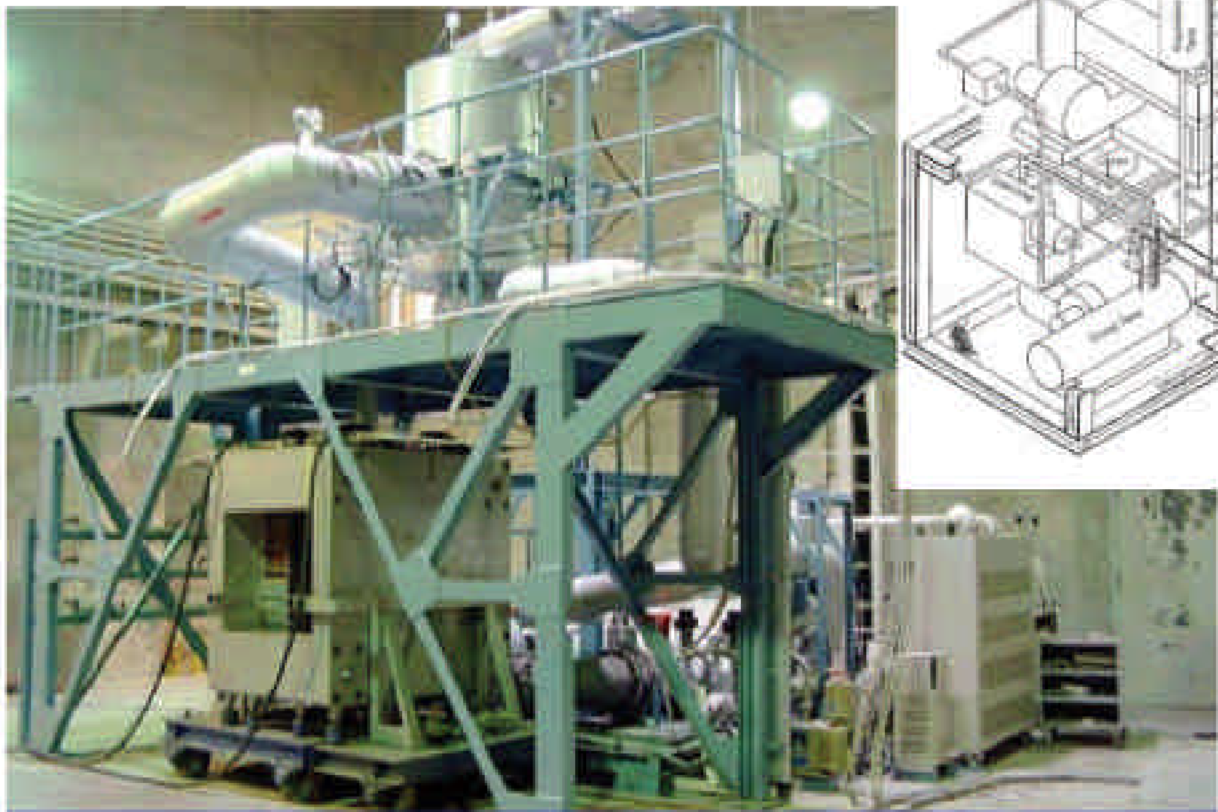
OSAKA UNIVERSITY

JAERI

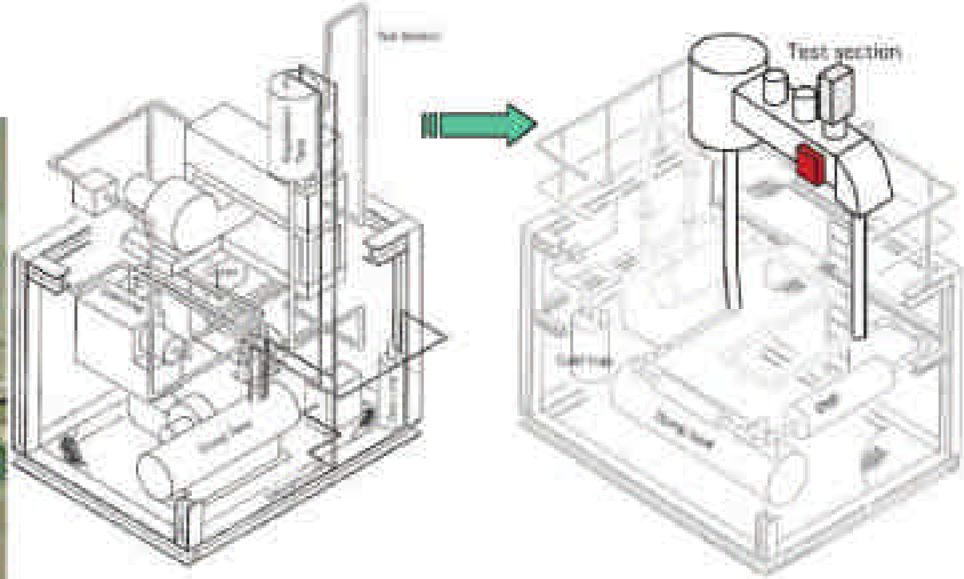
Li-loop Experiment

Modification of existing Osaka Univ. Loop

IFMIF



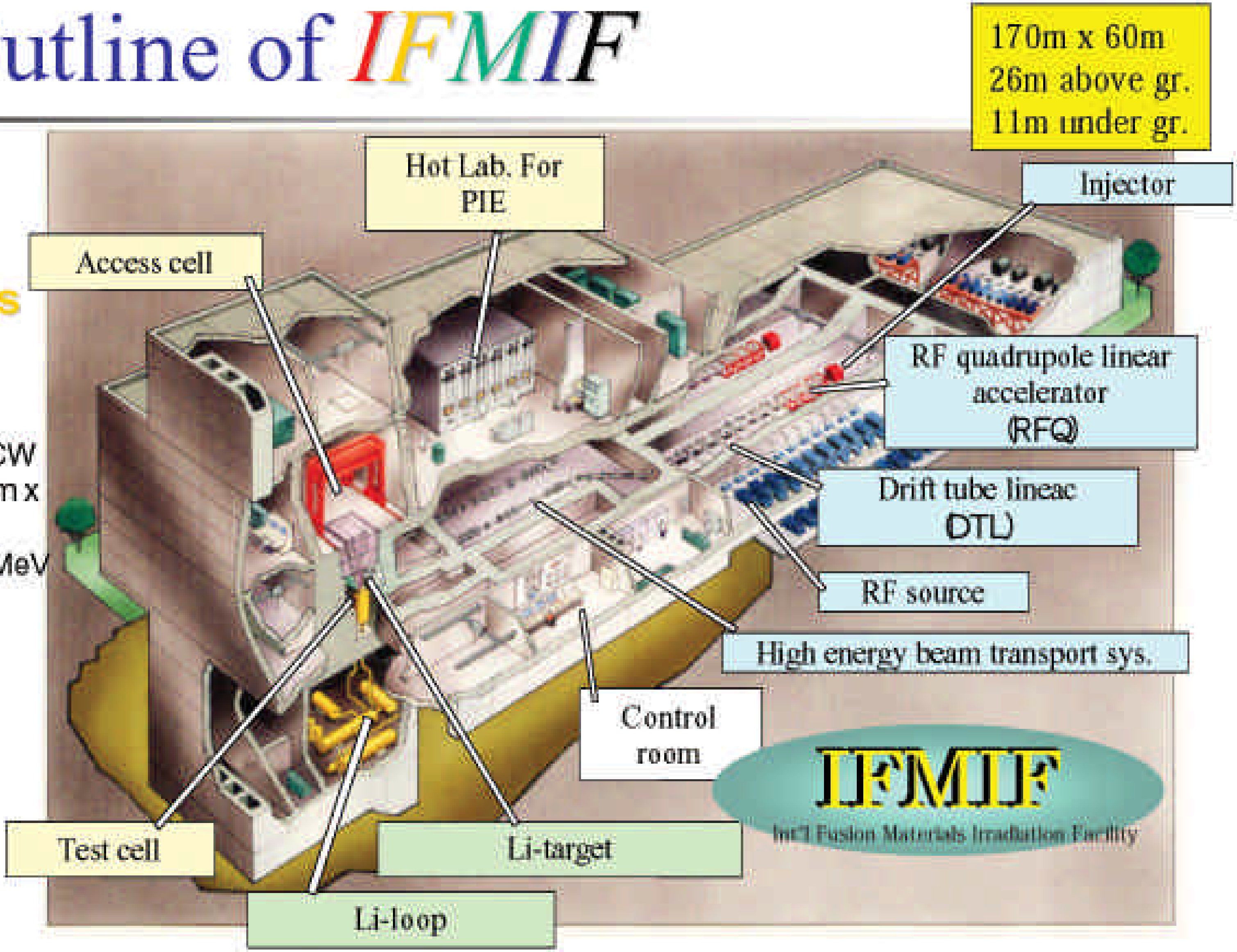
Osaka University Lithium Circulation Loop



Li inventory: 230Litter
Temperature: 300-550C
Max velocity: 15m/s

Outline of IFMIF

- **Specifications**
  - Type : D-Li
  - # of accelerators:2
  - Current: 250mA(125mAx2); CW
  - Beam footprint: 20cm x 5cm
  - Energy : 32, 36, 40MeV
  - Availability : >88%
  - Facility Lifetime : 40years



Conclusion

Fusion Engineering Activities in Japan are quite active and efficient under the newly unified structure, MEXT.

Near term issues, for ITER, and long term issues, for DEMO and Power reactor are simultaneously carried out, well balanced and well managed condition.

Fusion Engineering Activities in Japan will be strengthened and accelerated with the decision of the ITER invitation to Japan, in the near future.