Joint ICTP-IAEA Workshop on Innovative Nuclear Energy Systems
ICTP Leonardo da Vinci Building-Euler Lecture Hall, 20-24 August 2018

Innovative Nuclear Energy Systems: Reactor Design and Structural Designs

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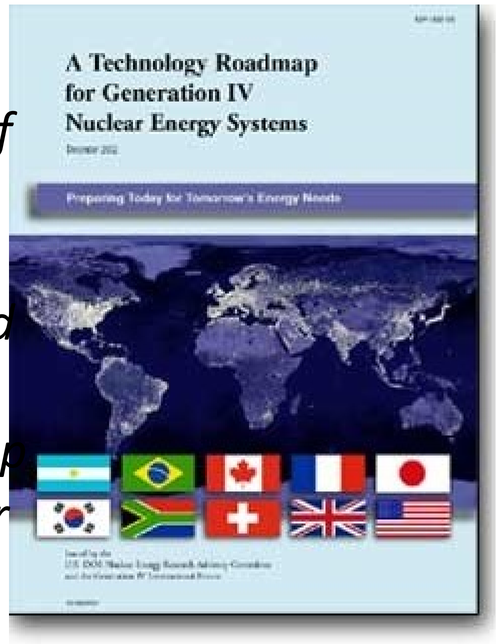
Content

1. *Reactor Concepts of GenIV SFR*
2. *Innovative Technologies in Reactor Design of GenIV SFR*

Liquid Metal-Cooled Fast Reactor Systems

➢ *The liquid metal-cooled fast reactor systems feature fast spectrum reactors and closed fuel recycle systems.*

- *High potential to operate with a high conversion fast spectrum core for increasing resource utilization*
- *Capability of efficient and nearly complete consumption of transuranics as fuel*
- *High level of safety obtained by the use of innovative and reliable solutions, and, as needed or possible, inherent and passive measures*
- *Enhanced economics achieved with the use of high burn-up fuels, fuel cycle (e.g. disposal) benefits, reduction in power plant capital costs and lower operation costs*



Masakazu ICHIMIYA, "Activities for GIF (Generation IV International Forum) on Sodium-Cooled Fast Reactor System," IAEA Education and Training Seminar/Workshop on Fast Reactor Science and Technology, CNEA Bariloche, Argentina, 21 – 25 February 2011

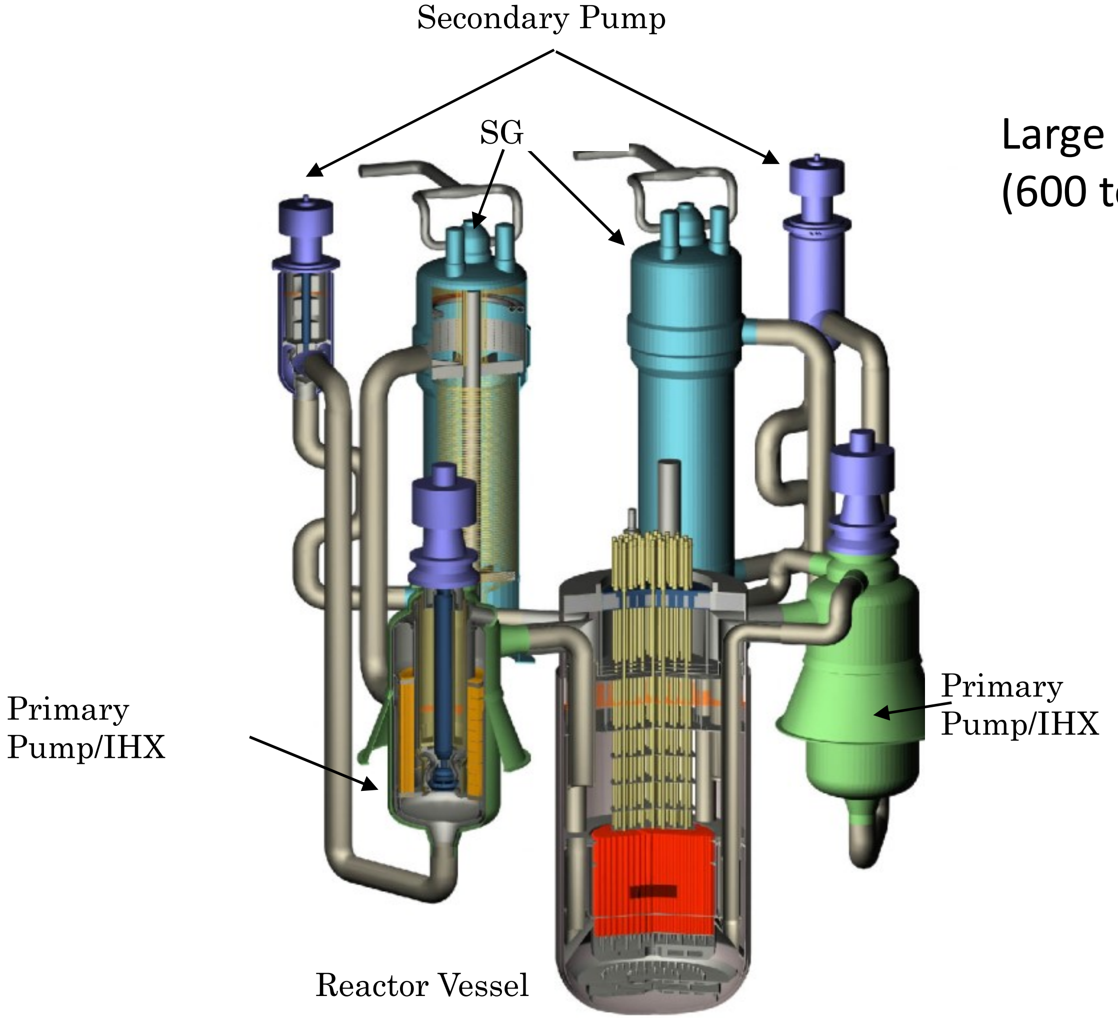
Development Targets for SFR -1-

1. *Safety Assurance*
   - *To render the risk of installing the SFR cycle system sufficiently small compared with other risks existing in society.*
   - *Passive safety function, exclusion of energetic sequences due to nuclear excursion*
2. *Economic competitiveness*
   - *Cost-competitiveness with other means of electricity production and a variety of market conditions*
3. *Reduction in environmental burden*
   - *Further reductions in the exposure dose and risks associated with disposal by utilizing TRU burning characteristics*

Development Targets for SFR -2-

4. *Efficient utilization of resources*
   - *Long-term demand for energy will keep increasing on a global scale.*
   - *SFR system should possess the flexibility to adopt to changing energy needs by adjusting its actinide management capability.*
5. *Resistance to nuclear proliferation and enhanced physical protection*
   - *To exclude pure-Pu state throughout system flow.*
   - *Inclusion of MA and highly radioactive FP enhance the difficulty of accessing the nuclear materials and lower their attractiveness.*

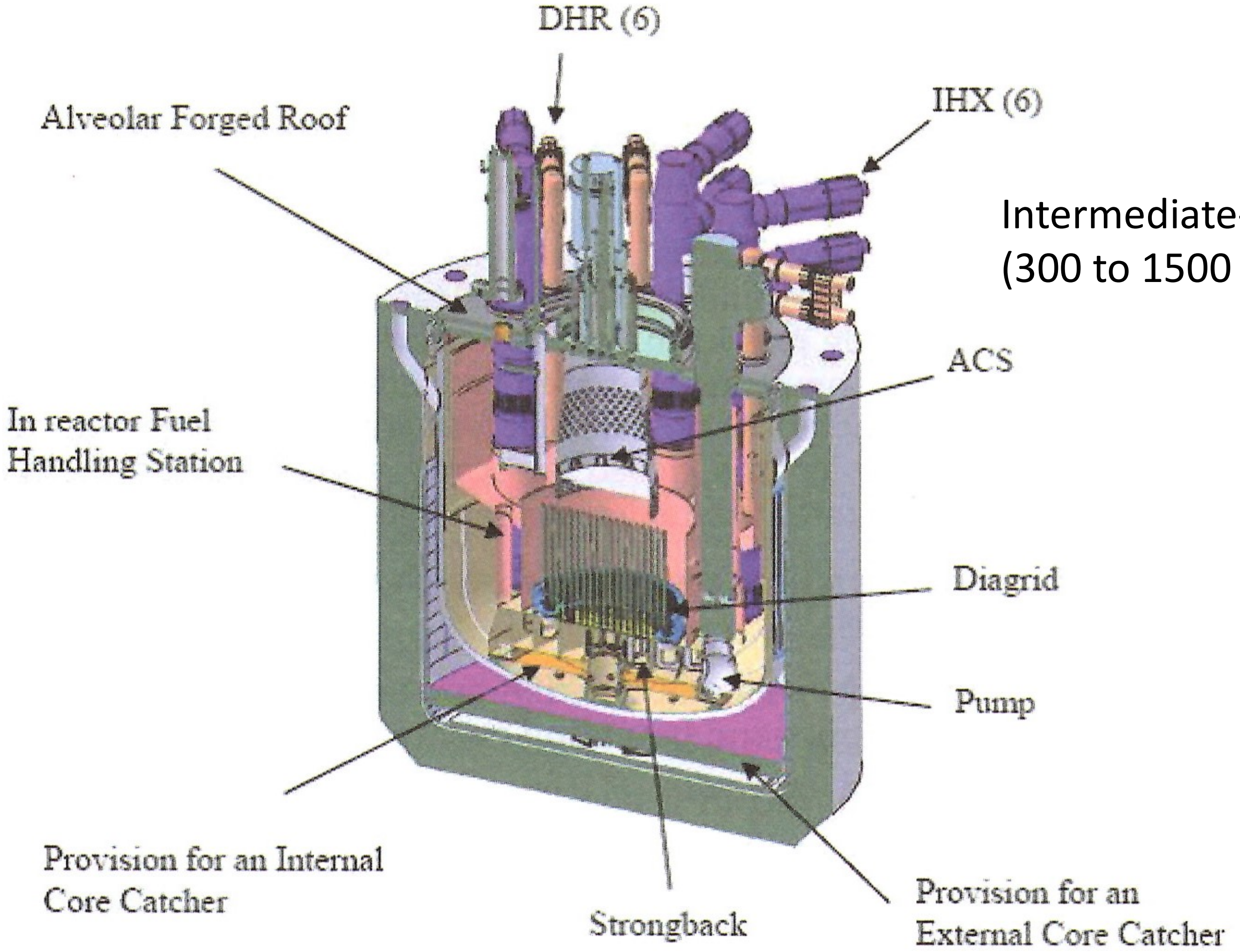
Japanese sodium-cooled fast reactor (loop-configuration SFR)



Large size
(600 to 1500 MWe)

Ref: GEN IV International Forum, Annual Report 2016.

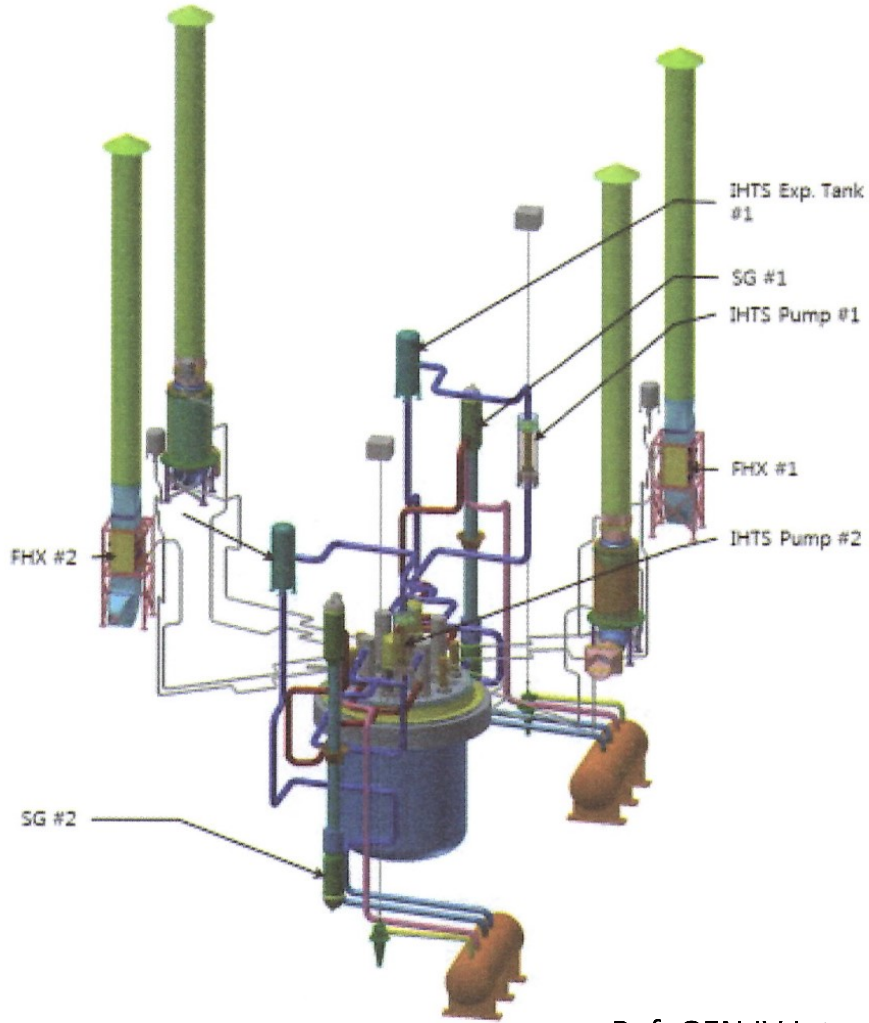
Example sodium fast reactor (pool-configuration SFR)



Intermediate-to-large size
(300 to 1500 Mwe)

Ref: GEN IV International Forum, Annual Report 2016.

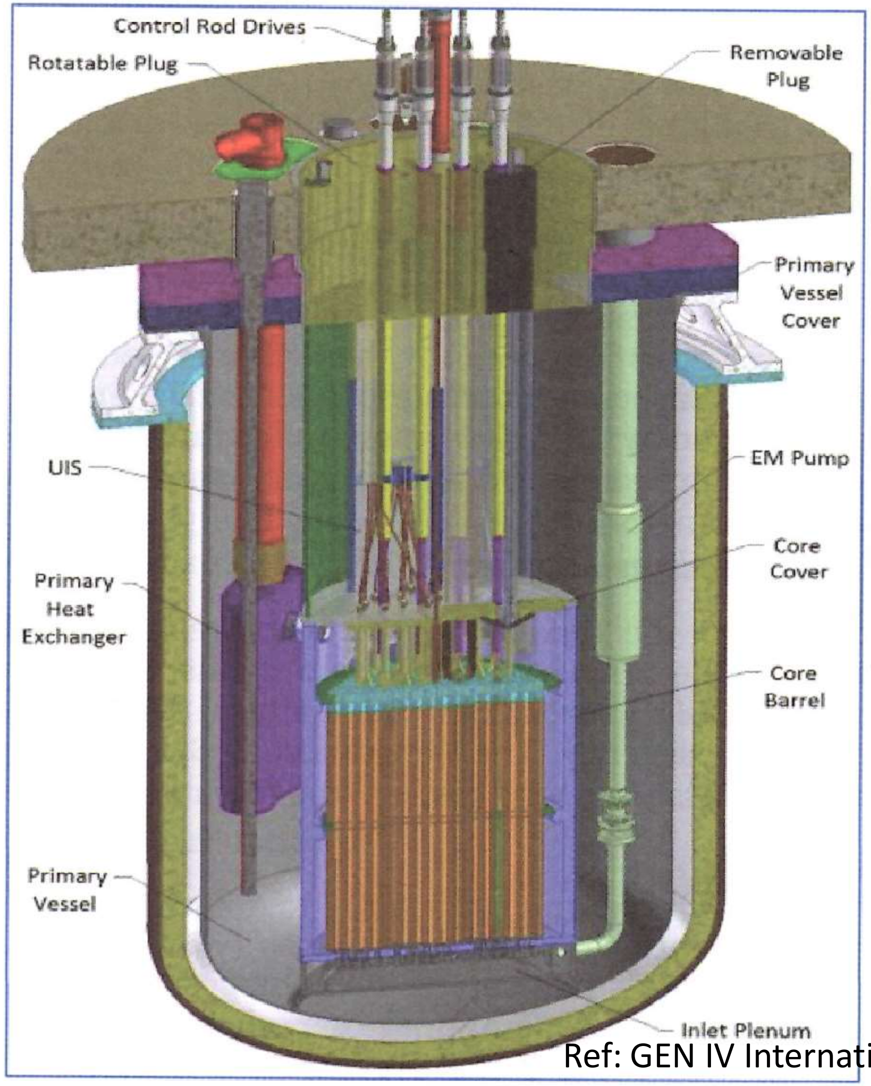
Korea advanced liquid metal reactor (pool-configuration SFR)



Intermediate-to-large size (300 to 1500 Mwe)

Ref: GEN IV International Forum, Annual Report 2016.

AFR-100
(small modular SFR configuration)



Small size
(50 to 150 Mwe)

Ref: GEN IV International Forum, Annual Report 2016.

Examples of Innovative Technologies

- Masakazu ICHIMIYA, “The Status of Generation IV Sodium-Cooled Fast Reactor Technology Development and its Future Project,” ANUP, Chennai, India, Oct.11-14, 2010.

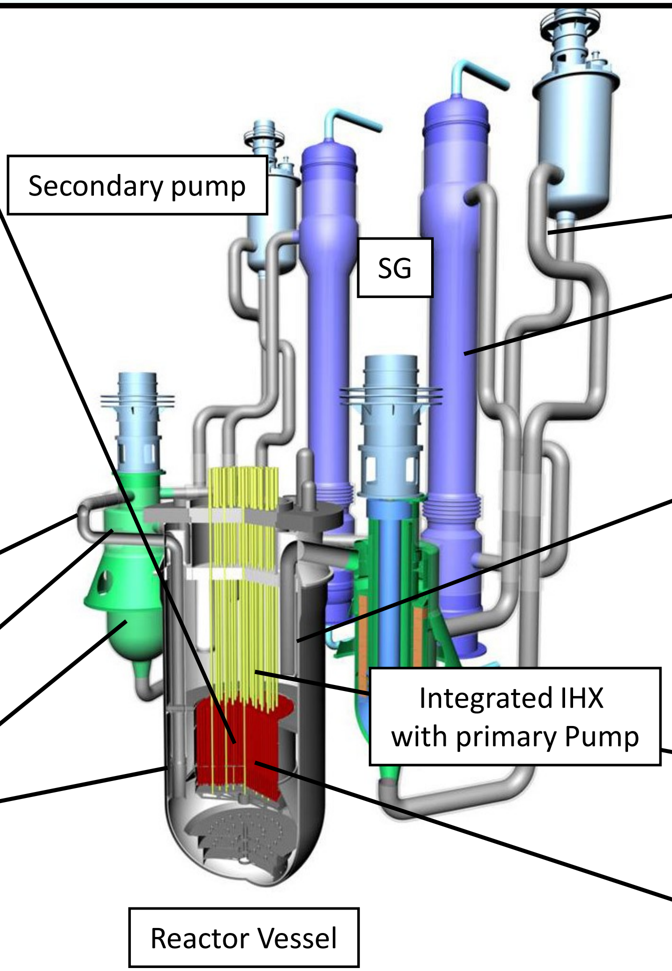
Innovative technologies in SFR

- *1,500 MWe large-scale Sodium Cooled FBR with MOX fuel,*
- *Innovative technologies for enhancement of reactor core safety, high economic competitiveness and countermeasures against specific issues of sodium*

ODS cladding to achieve high burn-up with elevated temperature

Innovative technologies to reduce plant materials and reactor building volume

- Two-loop cooling system
- Shortening of piping with high chromium steel
- Integrated Pump-IHX Component
- Compact reactor vessel



Prevention of sodium chemical reactions

- Double-wall piping
- High reliable SG with double-wall tube

Inspection and repair technology under sodium

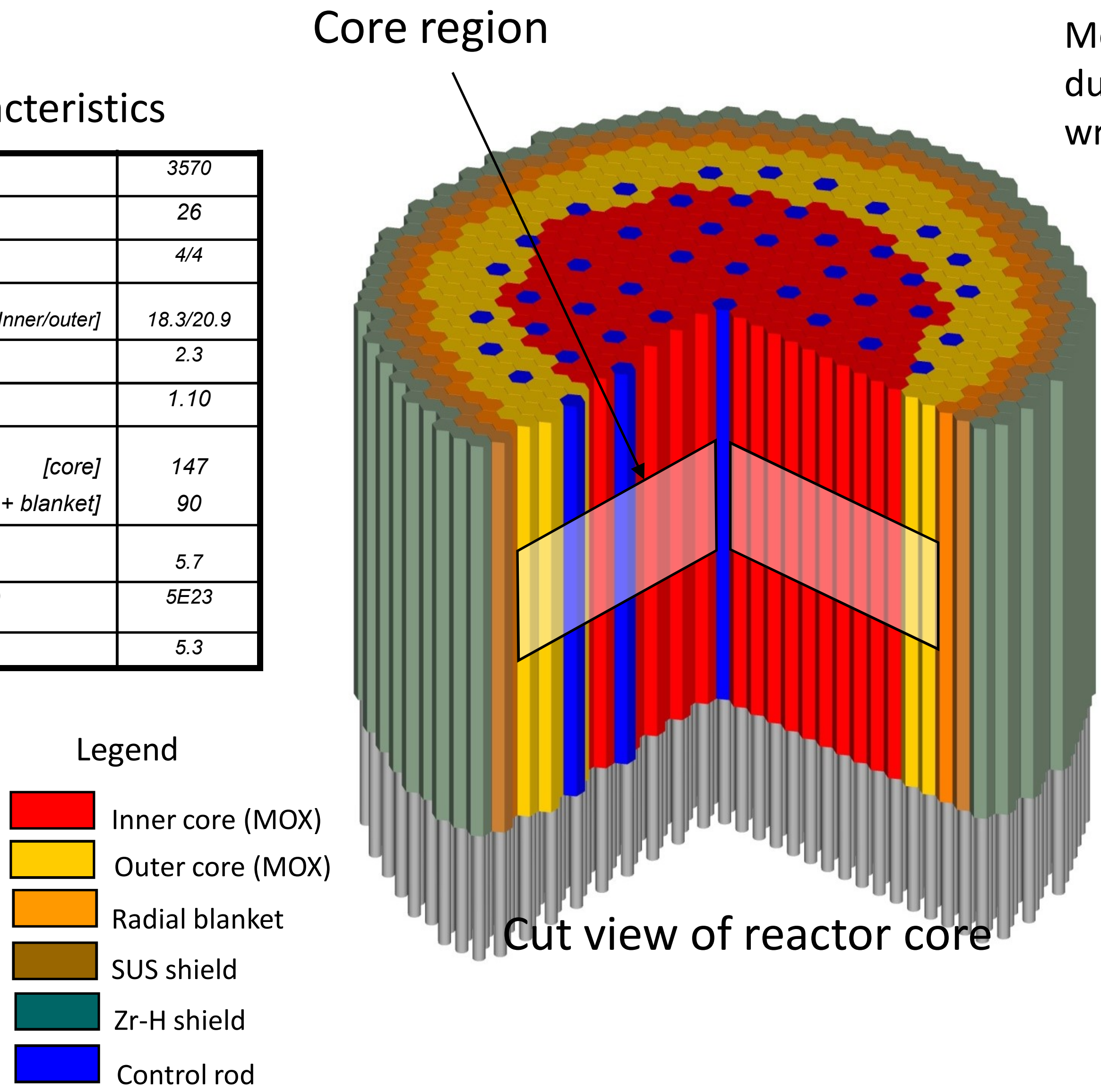
Enhancement of reactor core safety

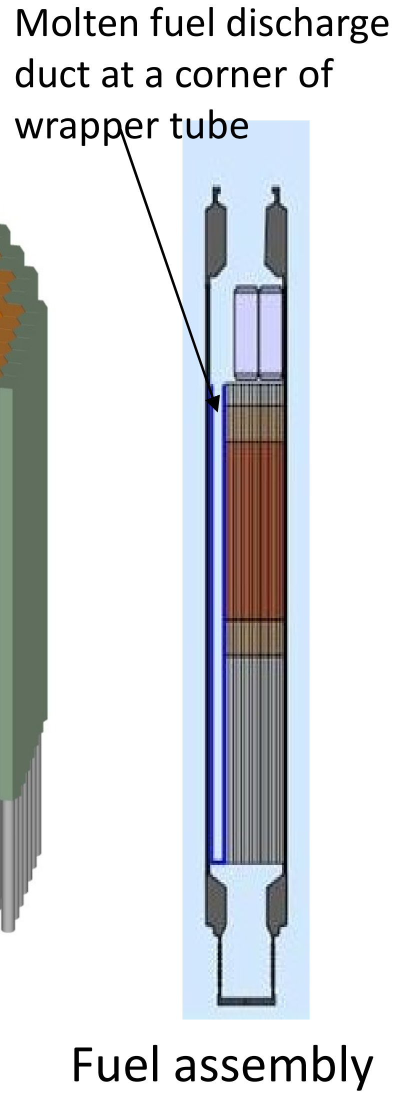
- Passive reactor shutdown system and decay heat removal by natural circulation
- Re-criticality free core

Reactor Core Configuration

Neutronic Characteristics

Output power (MWt)	*3570*
Cycle length (months)	*26*
Refueling batch [core/RB]	*4/4*
Pu-enrichment (wt%) *[Inner/outer]*	*18.3/20.9*
Burnup reactivity (%dk/kk')	*2.3*
Breeeding ratio	*1.10*
Discharge burnup (GWd/t) *[core]* *[core + blanket]*	*147* *90*
Pu fissile inventory (t/GWe)	*5.7*
Maximum neutron dose (n/cm²)	*5E23*
Sodium void reactivity ($)	*5.3*





Safety

- *Risks caused by introduction of FR cycle should be small compared with risks that already exist in society.*

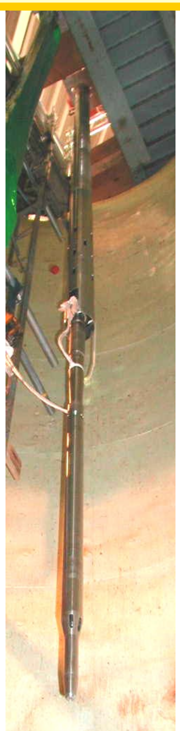
Enhance the passive prevention capability both for reactor shut-down and decay heat removal

→Self Actuated Shutdown System (SASS)

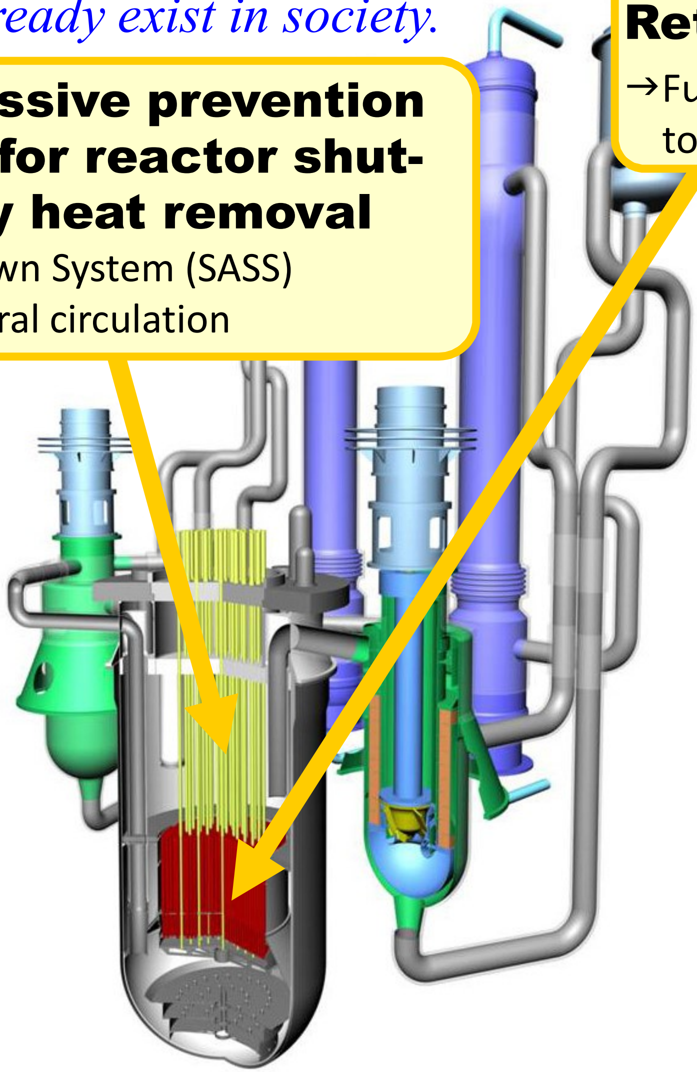
→Passive DHRS by natural circulation

Recriticality free and In-Vessel Retention against CDA

→Fuel Assembly with Inner Duct Structure to enhance molten fuel discharge



SASS

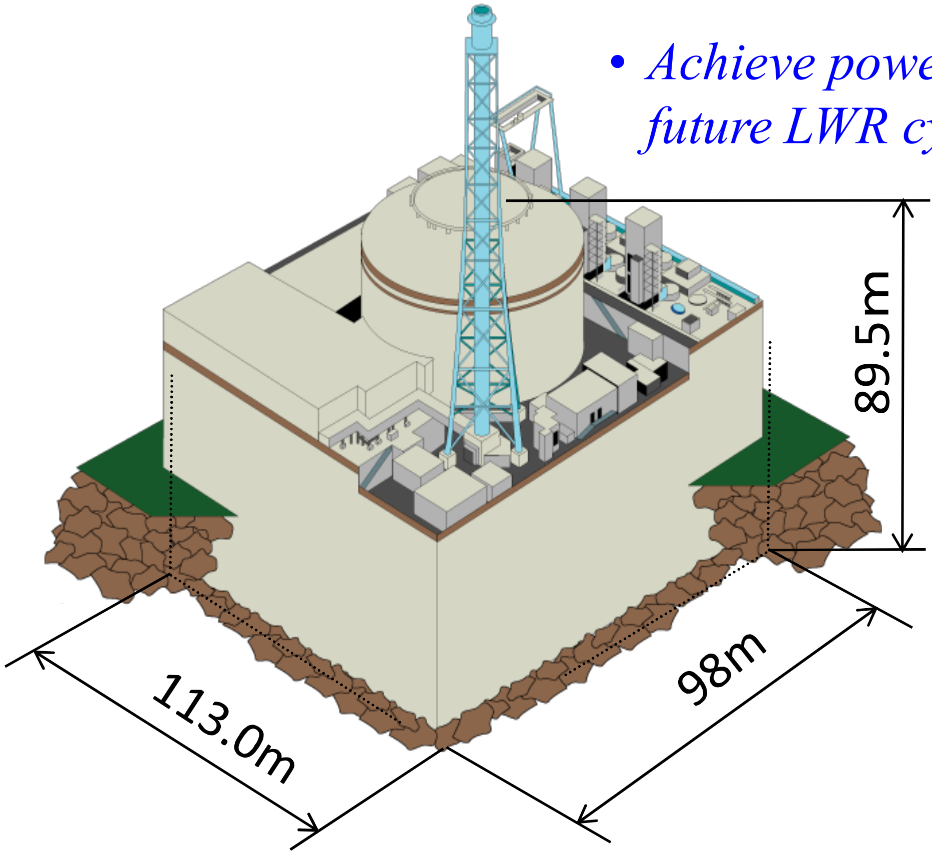


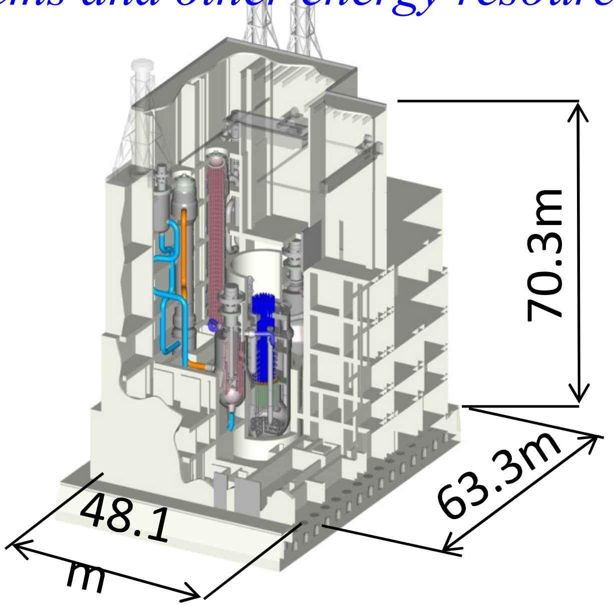
Out-of-pile facility

IGR in NNC of Kazakhstan

Economic Competitiveness

- *Achieve power generation cost comparable to that of future LWR cycle systems and other energy resources.*





Prototype FBR Monju

Thermal Output 714 MWt
Electricity Output 280 MWe

JAEA Sodium-cooled FR

Thermal Output 3570 MWt
Electricity Output 1500 MWe

Comparing with Monju,
Electricity output of FR is about 5 times
and site area is about 1/4.