HTGR Development in JAEA / US-Japan Collaboration on HTGR

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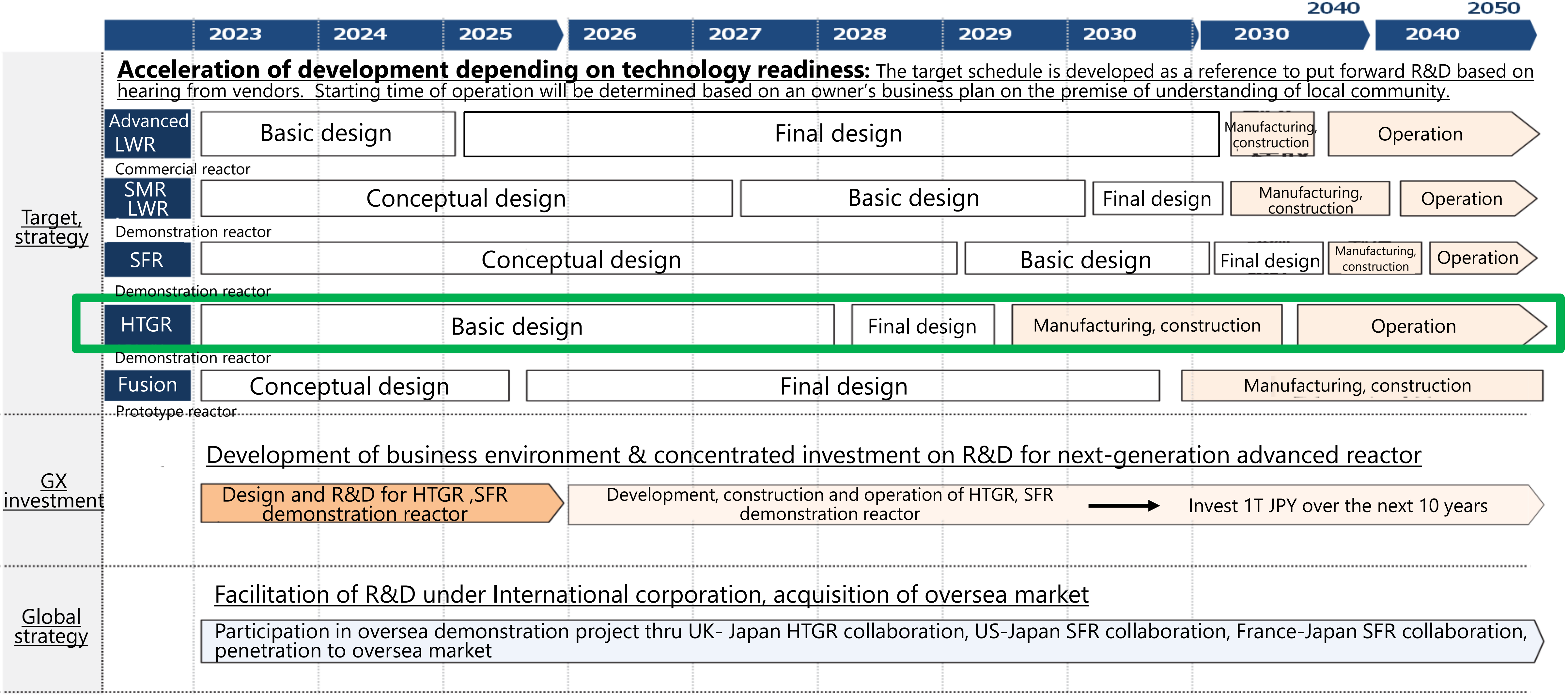
Hiroyuki Sato (Email: sato.hiroyuki09@jaea.go.jp)
Japan Atomic Energy Agency

Document Overview

- Policies of HTGR Development in Japan
- HTTR Technical Features
  & Licensing Experience, Future Tests
- Collaboration with US on HTGR

Basic Policy for GX Implementation

Government put forward development and construction of next-generation advanced reactors that incorporate new safety mechanisms on the premise of reactor safety



2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2030–2040 | 2040–2050

Target, strategy

Acceleration of development depending on technology readiness: The target schedule is developed as a reference to put forward R&D based on hearing from vendors. Starting time of operation will be determined based on an owner's business plan on the premise of understanding of local community.

- **Advanced LWR** (Commercial reactor): Basic design → Final design → Manufacturing, construction → Operation
- **SMR LWR** (Demonstration reactor): Conceptual design → Basic design → Final design → Manufacturing, construction → Operation
- **SFR** (Demonstration reactor): Conceptual design → Basic design → Final design → Manufacturing, construction → Operation
- **HTGR** (Demonstration reactor): Basic design → Final design → Manufacturing, construction → Operation
- **Fusion** (Prototype reactor): Conceptual design → Final design → Manufacturing, construction

GX investment

Development of business environment & concentrated investment on R&D for next-generation advanced reactor

Design and R&D for HTGR ,SFR demonstration reactor → Development, construction and operation of HTGR, SFR demonstration reactor → Invest 1T JPY over the next 10 years

Global strategy

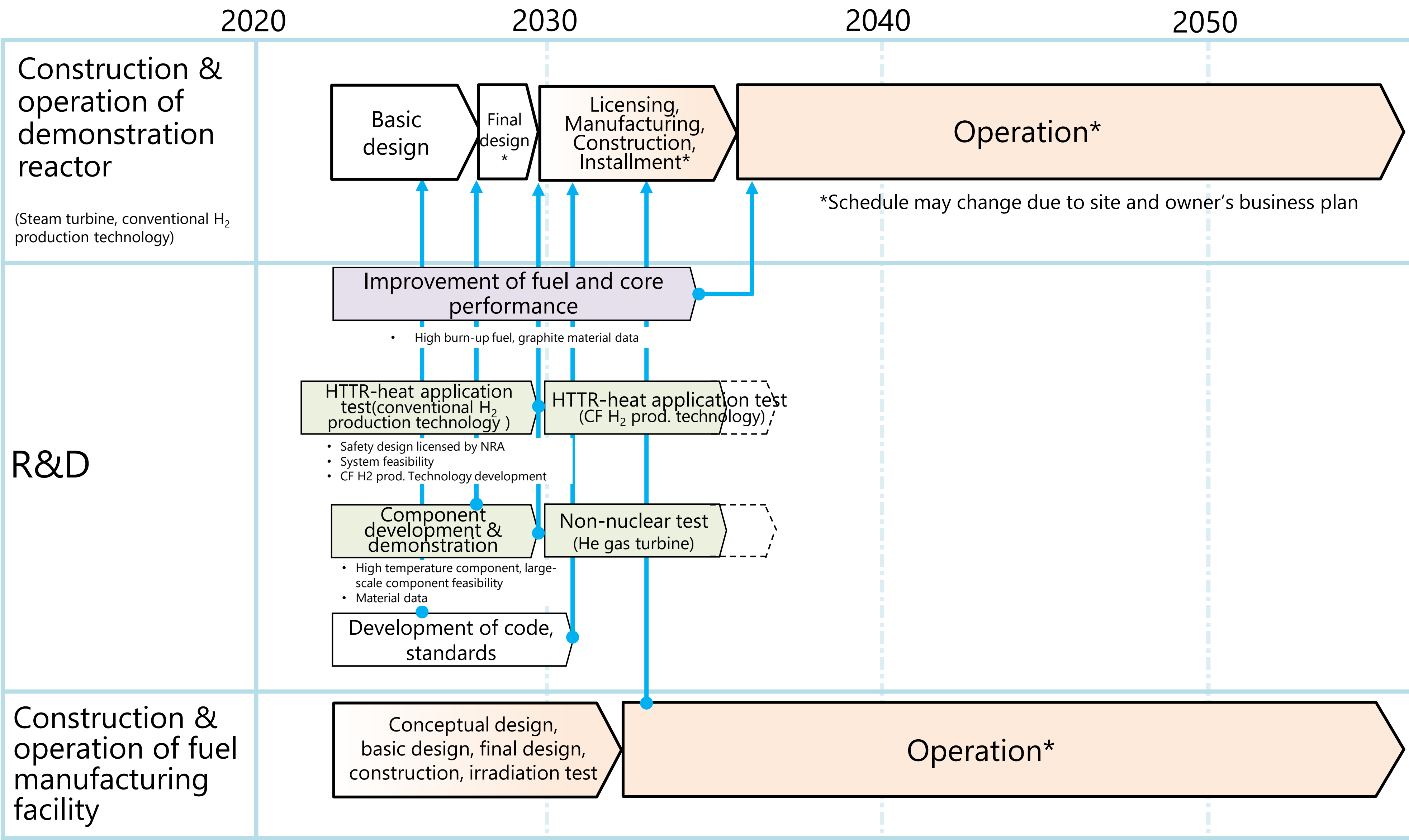
Facilitation of R&D under International corporation, acquisition of oversea market

Participation in oversea demonstration project thru UK- Japan HTGR collaboration, US-Japan SFR collaboration, France-Japan SFR collaboration, penetration to oversea market

HTGR Demonstration Reactor Development Project
JPFY2023 48B JPY（JPY2023-JPY2025 431B JPY）

Draft Basic Policy for GX Implementation,
https://www.cas.go.jp/jp/seisaku/gx_jikkou_kaigi/dai5/siryou2.pdf

A Technology Roadmap for Developing HTGRs



2020 2030 2040 2050

Construction & operation of demonstration reactor

(Steam turbine, conventional H_2 production technology)

Basic design

Final design *

Licensing, Manufacturing, Construction, Installment*

Operation*

*Schedule may change due to site and owner's business plan

R&D

Improvement of fuel and core performance

- High burn-up fuel, graphite material data

HTTR-heat application test(conventional H_2 production technology)

- Safety design licensed by NRA
- System feasibility
- CF H2 prod. Technology development

HTTR-heat application test (CF H_2 prod. technology)

Component development & demonstration

- High temperature component, large-scale component feasibility
- Material data

Non-nuclear test (He gas turbine)

Development of code, standards

Construction & operation of fuel manufacturing facility

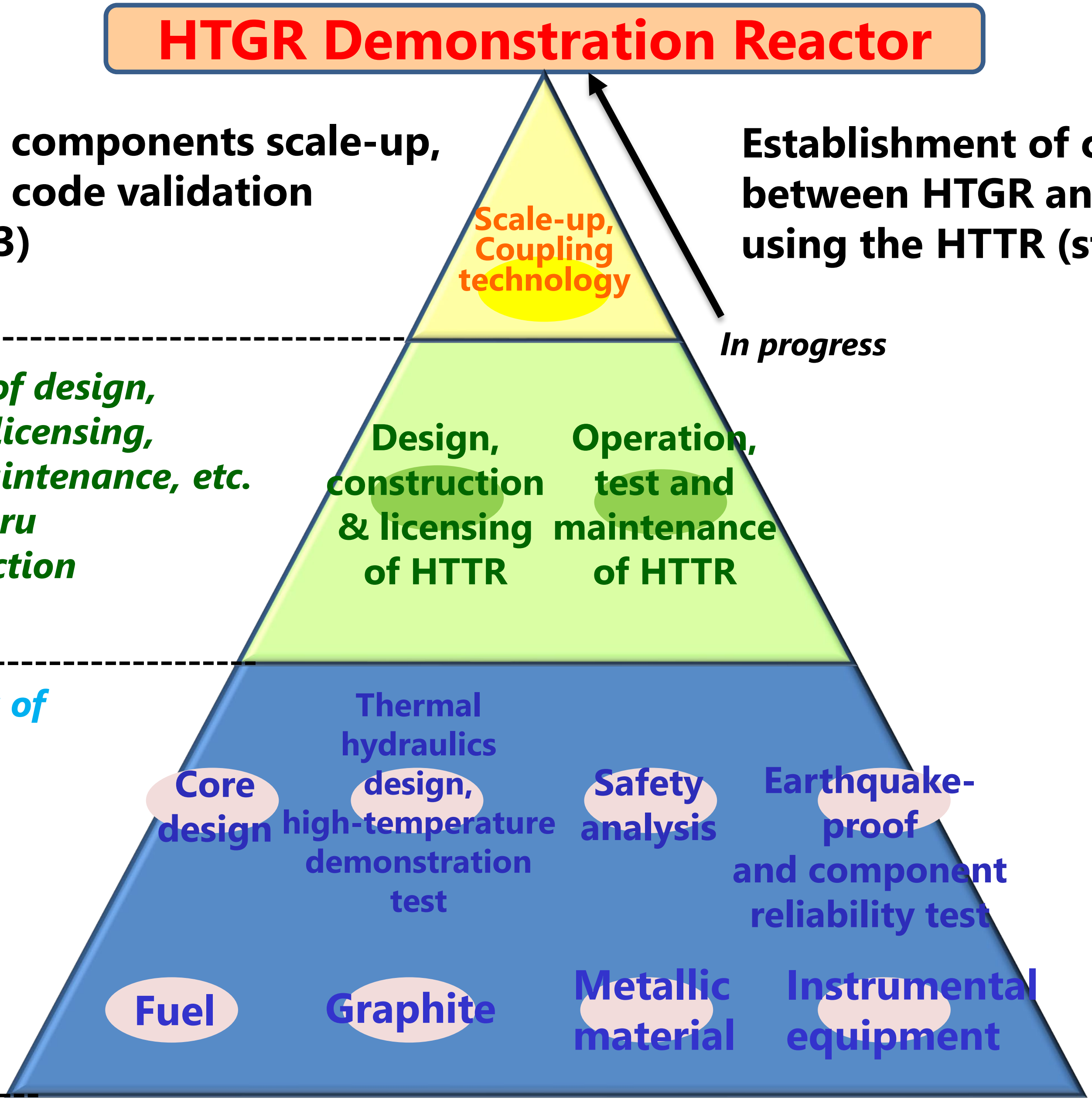
Conceptual design, basic design, final design, construction, irradiation test

Operation*

CF: Carbon-free

*https://www.meti.go.jp/shingikai/enecho/denryoku_gas/genshiryoku/kakushinro_wg/pdf/004_03_00.pdf, accessed on September 2, 2022.

Japan’s HTGR Technology Capabilities



HTGR Demonstration Reactor

Reactor core & components scale-up, Computational code validation (start in FY2023)

Establishment of coupling technologies between HTGR and H_2 production system using the HTTR (started in FY2022)

In progress

Scale-up, Coupling technology

Technologies developed

Technologies of design, construction, licensing, operation, maintenance, etc. established thru HTTR construction & operation.

Design, construction & licensing of HTTR

Operation, test and maintenance of HTTR

Establishment of fundamental technologies

Core design

Thermal hydraulics design, high-temperature demonstration test

Safety analysis

Earthquake-proof and component reliability test

Fuel

Graphite

Metallic material

Instrumental equipment

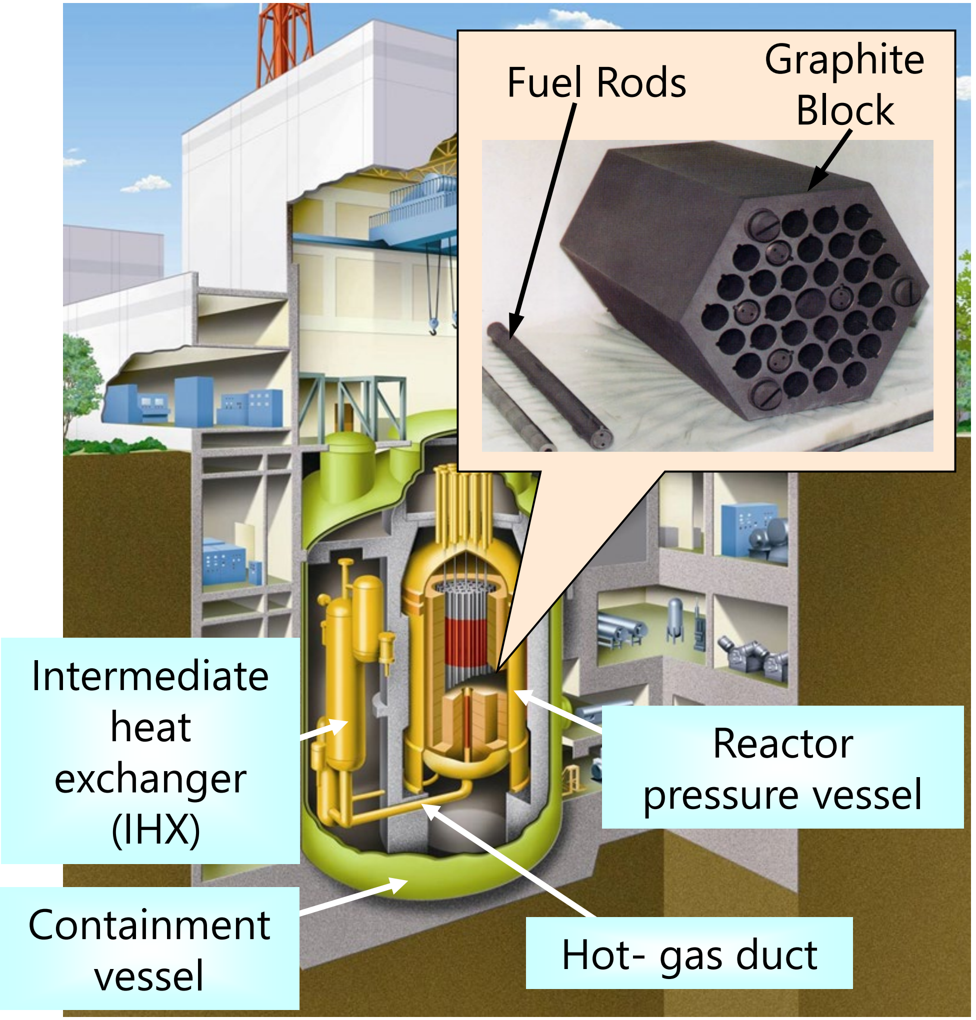
Owner of technologies

- JAEA
- MHI
- Toshiba
- Hitachi, etc.

- JAEA
- NFI
- ToyoTanso, etc.

HTTR: High Temperature Engineering Test Reactor

The only prismatic-type High Temperature Gas-cooled Reactor (HTGR) in operation in the world



Major Specifications

Thermal power	30 MW
Fuel	Coated fuel particle / Prismatic type
Core material	Graphite
Coolant	Helium
Inlet temperature	395°C
Outlet temperature	950°C
Pressure	4 MPa

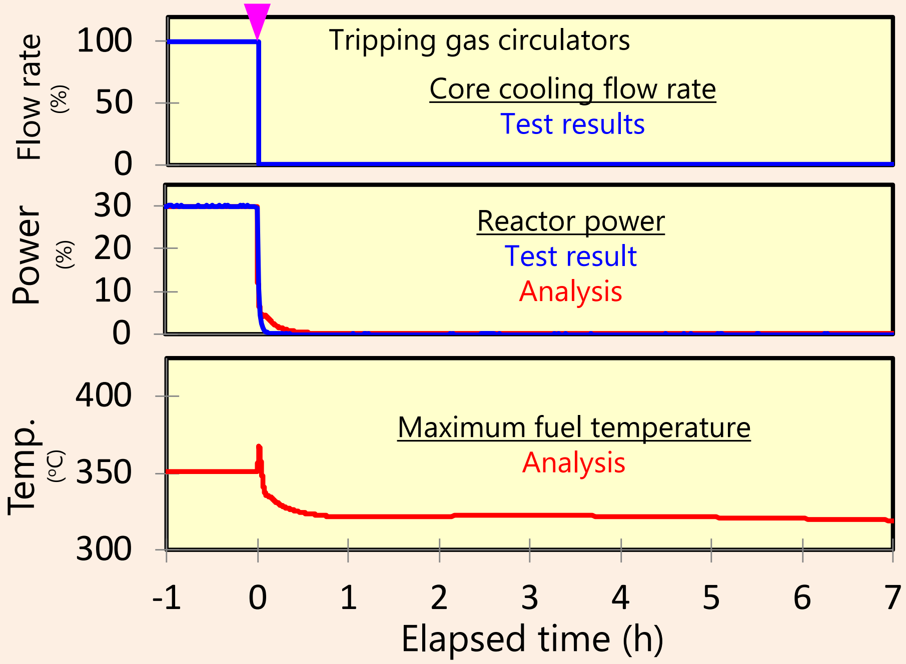
Major Achievements

First criticality	: November, 1998
Full power operation	: December, 2001
50 days continuous 950ºC operation	: March, 2010
Obtain permission of changes to reactor installation in conformity to New Regulatory Requirements	: June, 2020
Restart operation	: July, 2021

Licensing Experiences of HTTR – Seismic Classifications

HTTR safety demonstration test

- ➢ Initial power 30% (9MW)
- ➢ Reducing core flow rate to zero by tripping all circulators
- ➢ VCS operation maintained
- ➢ No scram operation (No CR insertion)



◆ Reactor intrinsically shut down as soon as the core cooling flow rate to zero.

◆ Reactor is kept stable long after the loss of core cooling

Safety characteristics of the HTTR

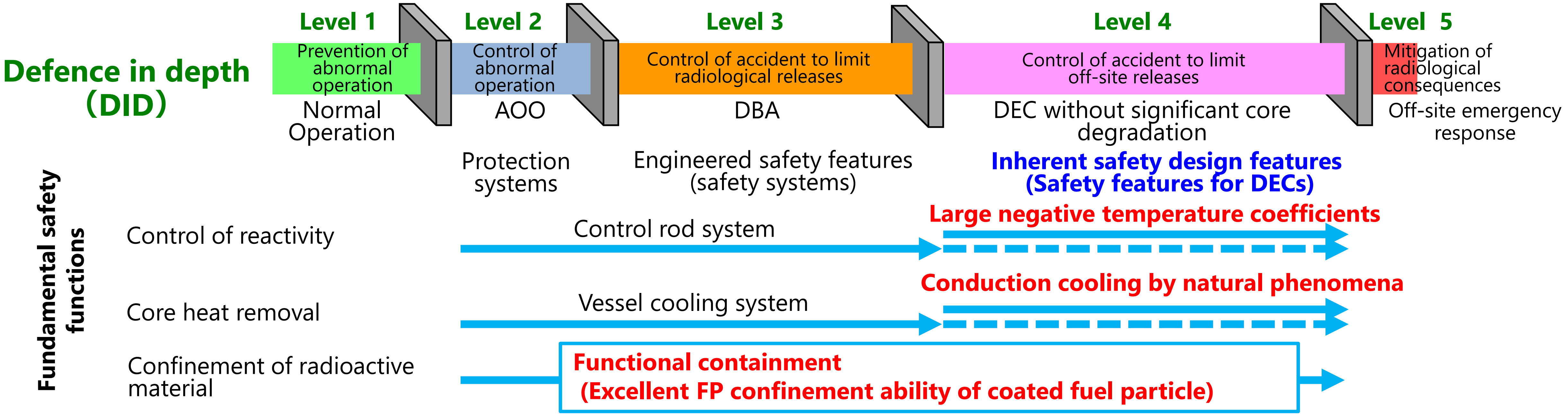
Because of the inherent characteristics of basic elements, i.e. refractory coated fuel particles, inert, single-phase helium coolant and graphite moderator with large heat capacity, the HTTR can maintain in a stable state under loss-of-cooling and/or reactivity control conditions.

Obtained permission from NRA to reclassify seismic classification of SSCs to lower class

- ➢ Core heat removal: S class to B class
- ➢ Reactor internal structure: S class to B class.

E. Ishitsuka, “Experience of HTTR Licensing for Japan’s New Nuclear Regulation,” GIF Webinar Series 52, April 21, 2021.

Licensing Experiences of HTTR - BDBA -



Defence in depth (DID)

	Level 1	Level 2	Level 3	Level 4	Level 5
	Prevention of abnormal operation	Control of abnormal operation	Control of accident to limit radiological releases	Control of accident to limit off-site releases	Mitigation of radiological consequences
	Normal Operation	AOO	DBA	DEC without significant core degradation	Off-site emergency response
		Protection systems	Engineered safety features (safety systems)	**Inherent safety design features (Safety features for DECs)**	

Fundamental safety functions

Control of reactivity: Control rod system → **Large negative temperature coefficients**

Core heat removal: Vessel cooling system → **Conduction cooling by natural phenomena**

Confinement of radioactive material: **Functional containment (Excellent FP confinement ability of coated fuel particle)**

- **The NRA review concluded that (1) significant core degradation including core melting may not occur by postulated BDBAs* and (2) specific SSCs are not required to cope with BDBAs***
- **HTTR has restarted its operation without significant additional reinforcements due to the inherent safety features**

- **DID implementation for commercial HTGR is reasonable**
- **The safety design established through the licensing will be the basis of commercial HTGR**

*HTTR BDBAs DBA + failure of reactor scram
DBA + failure of heat removal from the core
DBA + failure of containment vessel

E. Ishitsuka, “Experience of HTTR Licensing for Japan’s New Nuclear Regulation,” GIF Webinar Series 52, April 21, 2021.

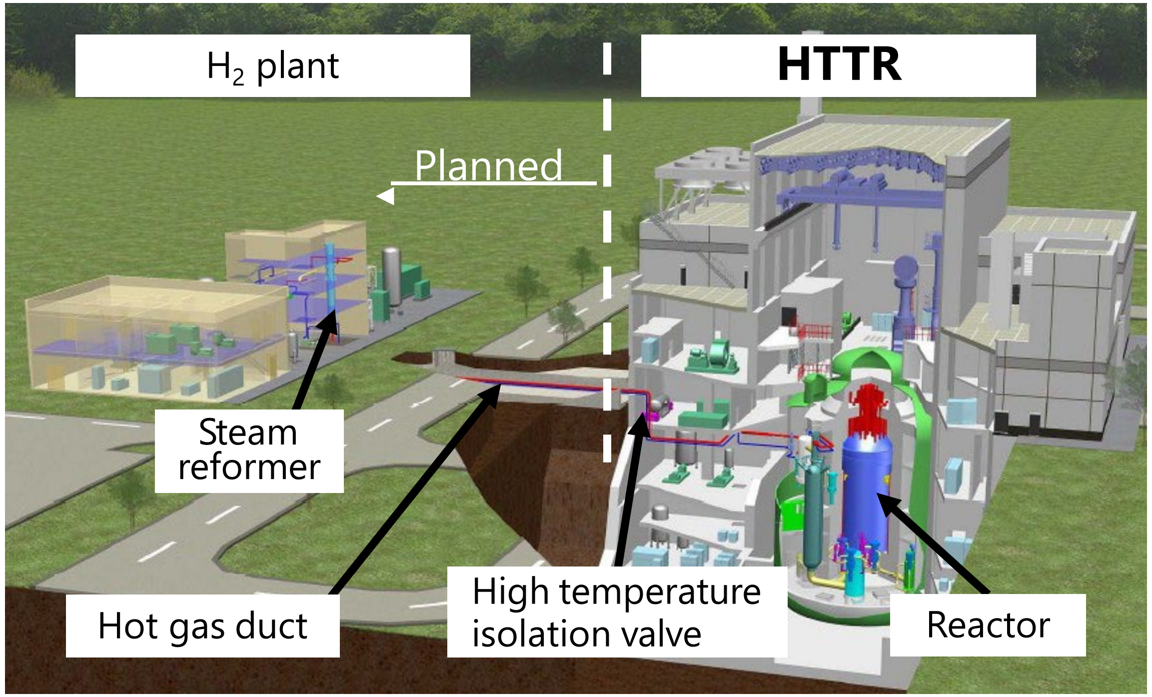
H_2 Production Demonstration Program Using HTTR

Objective

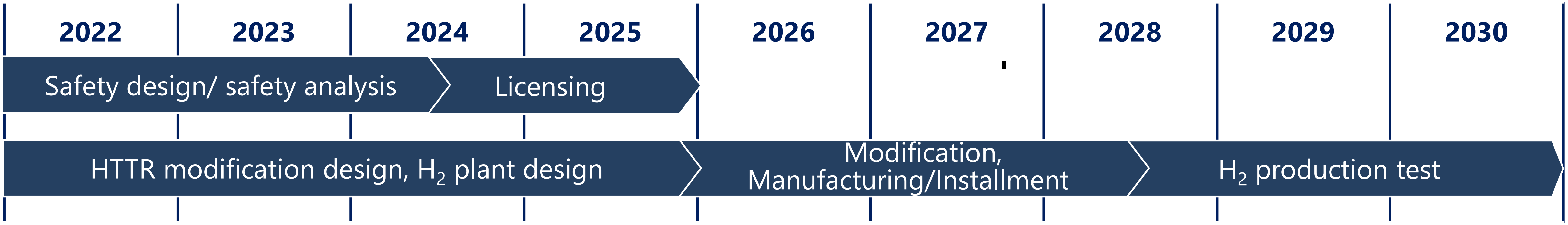
- Establish a safety design for coupling HTGR and H_2 plant through the licensing by Nuclear Regulation Authority.
- Demonstrate performance of components required for coupling between HTGR and H_2 plant e.g. high temperature isolation valves, hot gas duct, etc. using the HTTR.

Tasks

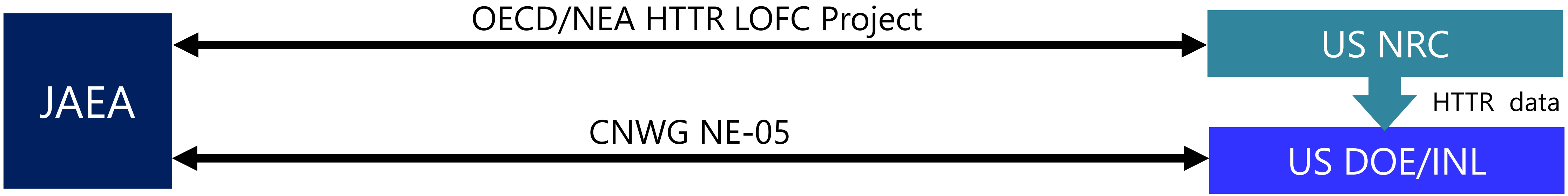
- Construct a steam methane reforming H_2 plant and connect to the HTTR.
- Conduct a continuous H_2 production test and plant dynamic tests.



Tentative Schedule



Ongoing Collaboration with US on HTGR



JAEA

OECD/NEA HTTR LOFC Project

CNWG NE-05

US NRC

HTTR data

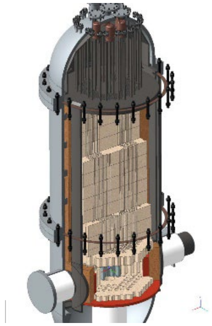
US DOE/INL

CNWG NE-05: Validation of High Temperature Reactor Simulation Methods and Models

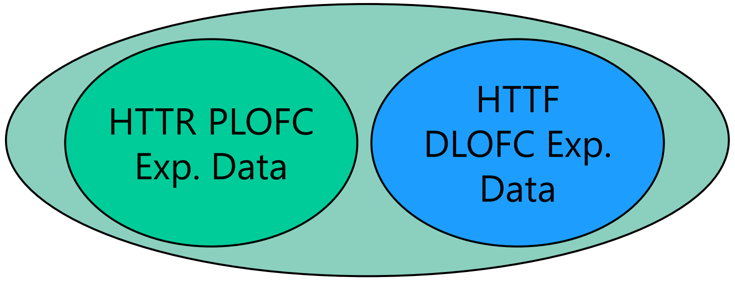
HTTR & HTTF Experiments

HTTR
(JAEA)

HTTF
(Oregon State University)



HTR Validation Set

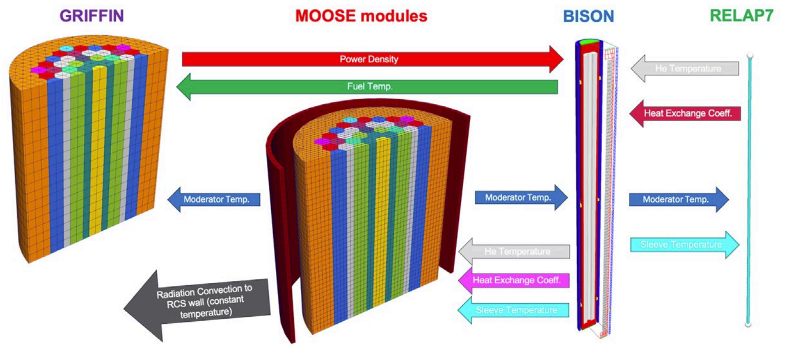


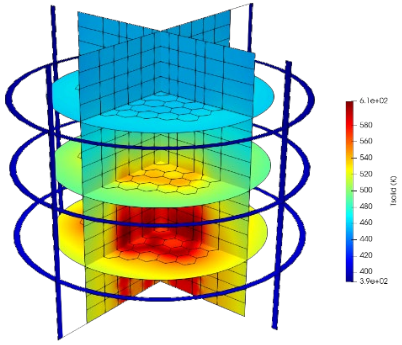
HTTR PLOFC Exp. Data

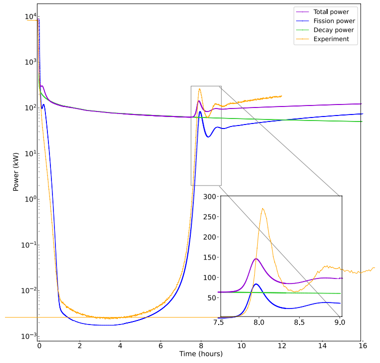
HTTF DLOFC Exp. Data

HTR Validation data

Validation of Advanced HTR Simulation Methods & Models







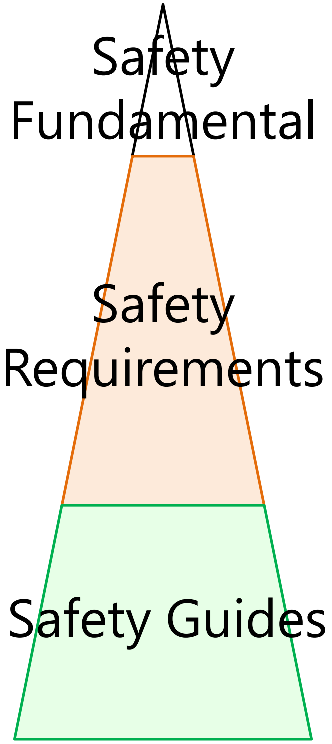
Potential Collaboration with US on HTGR

JAEA

Technical discussion related to HTGR safety standards & safety analysis

US NRC

JAEA's Contributions to HTGR Safety Standard Development Activities under IAEA Framework



IAEA Safety Standards

Approach and Methodology for SMR safety requirements development (Sep. 2019 – Feb. 2020)

- Methodology to develop "technology neutral SMR safety requirements" was examined
- Insights obtained in activities for safety requirement development under Atomic Energy Society of Japan (AESJ) were presented
- Technical report (IAEA-TECDOC-2010) was issued in Sep. 2022

Applicability of design safety requirements to SMRs (Feb. 2017 – May 2019)

- Applicability of IAEA safety requirements (SSR-2/1 Rev.1) to HTGR & LW SMRs was analyzed
- The draft safety requirements developed in AESJ were presented
- Technical report (IAEA-TECDOC-1936) was issued in Dec. 2020

IAEA TECDOC SERIES

IAEA-TECDOC-1936

IAEA-TECDOC-1936

Applicability of Design
Safety Requirements
to Small Modular Reactor
Technologies Intended
for Near Term Deployment

Light Water Reactors
High Temperature Gas Cooled Reactors

IAEA
International Atomic Energy Agency

Applicability of safety assessment guidelines to SMRs

(Nov. 2019 – Mar. 2022)

Applicability of safety design guidelines to SMRs

(July 2020 – Nov. 2020)

Summary

- Japanese government put forward development and construction of a HTGR demonstration reactor to be operated in 2030's.
- Japan's HTGR technology capabilities established thru HTTR construction and operation will be fully utilized for HTGR demonstration reactor construction.
- JAEA established safety design through licensing process by Nuclear Regulation Authority for changes to Reactor Installation of the HTTR in conformity to the New Regulatory Requirements based on the results of HTTR safety demonstration test.
- The H_2 production demonstration project using the HTTR was started in 2022 aiming to establish safety design for coupling H_2 plant to HTGR by 2030.
- Potential area for collaboration would be sharing experiences and insights for HTGR safety standards, safety guides and safety analysis.