Advanced Reactor Developments and GIF (Generation IV International Forum) Activities

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Sector of Fast Reactor and Advanced Reactor Research and Development

Sustainability of Energy Supply: Environmental Burden

- Construction foot print

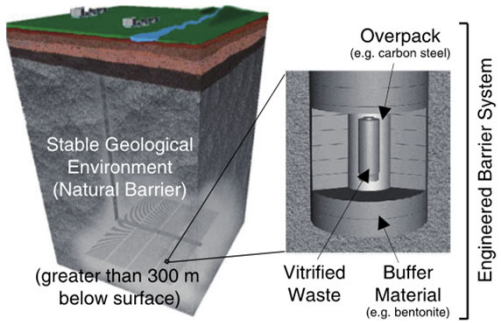
*1

Light Water Reactor (LWR) site
- 1.0 GWe
- 0.6 km^2 (example)

*2

Mega Solar site
- 0.1 GWe
- 2.2 km^2 (example)

- Waste



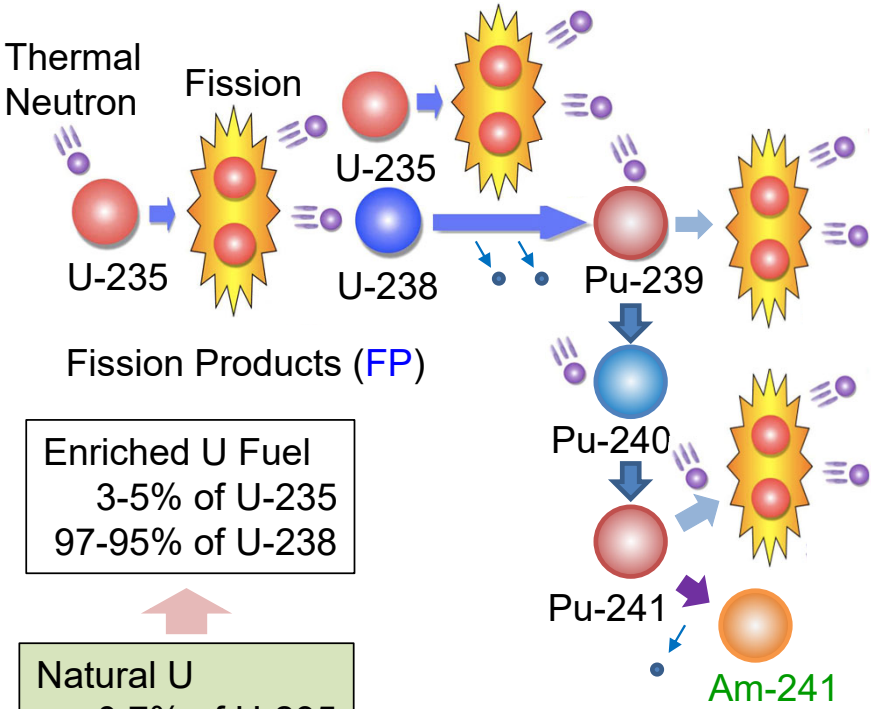
Nuclear
- Radioactive waste
- Geological disposal of High Level Waste (HLW)

Thermal Power Plant
- Large amount of waste
- Green House Gas

*1; Image by Kurt K. from Pixabay, *2: by skeeze, *3 : by Rebecca Human

Sustainability: Waste Management of Nuclear

● Nuclear Reactions in LWR Cycle

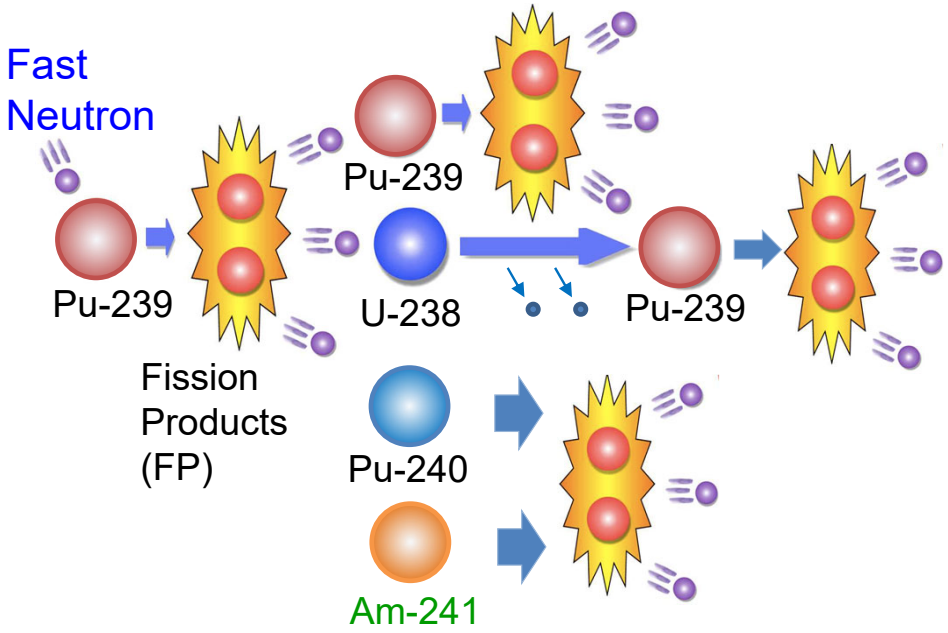


Enriched U Fuel
3-5% of U-235
97-95% of U-238

Natural U
0.7% of U-235
99.3% of U-238

Depleted U (U-238)

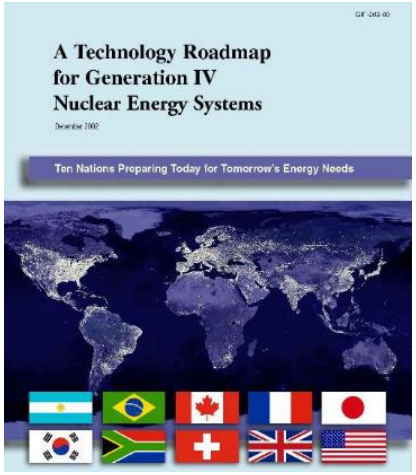
● by Fast neutron reactors



Pu and U mixed Fuel (MOX)
- Pu ~ 20%
- Depleted U (U-238)
- Minor Actinides (MA) 0 ~3%

Genesis of Generation IV Concept

- In 1999, low public and political support for nuclear energy
  - Oil and gas prices were low
- USA proposed a bold initiative in 2000
  - The vision was to leapfrog LWR technology and collaborate with international partners to share R&D on advanced nuclear systems
  - 9 Countries and EU joined USA in developing the initiative
  - Oil prices jumped soon thereafter
- Gen IV concept defined via technology goals and legal framework
  - Technology Roadmap released in 2002
    - 2 year study with more than100 experts worldwide
    - Nearly 100 reactor designs evaluated and down selected to 6 most promising concepts
  - First signatures collected on Framework Agreement in 2005; first research projects defined in 2006

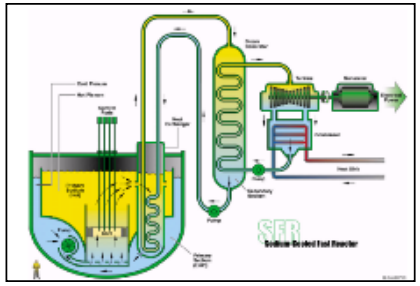


"This may have been the first time that the world came together to decide on a fission technology to develop together."
William Magwood IV, First Chairman of the Generation IV International Forum

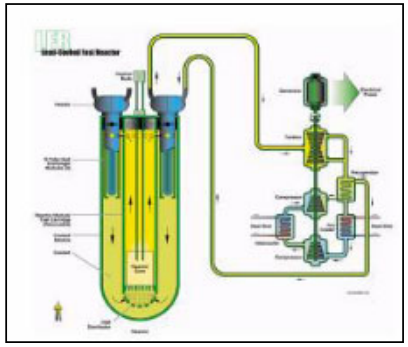
GIF Goals for Generation-IV Reactor Systems

- Sustainability
  - Long term fuel supply
  - Minimize waste and long term stewardship burden
- Safety & Reliability
  - Very low likelihood and degree of core damage
  - Eliminate need for offsite emergency response
- Economics
  - Life cycle cost advantage over other energy sources
  - Financial risk comparable to other energy projects
- Proliferation Resistance & Physical Protection
  - Unattractive materials diversion pathway
  - Enhanced physical protection against terrorism

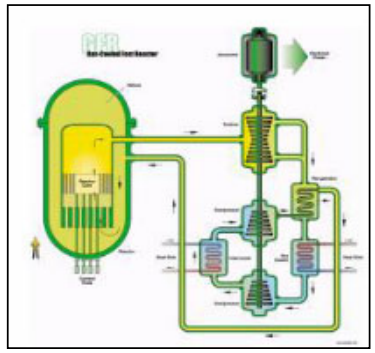
Gen-IV Nuclear Reactor Systems



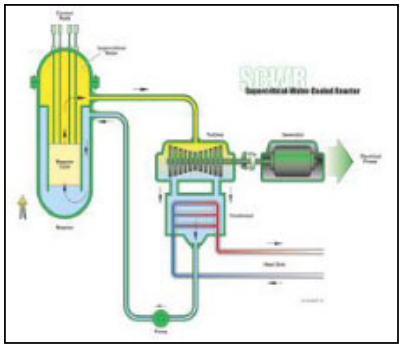
Sodium-cooled Fast Reactor (SFR)



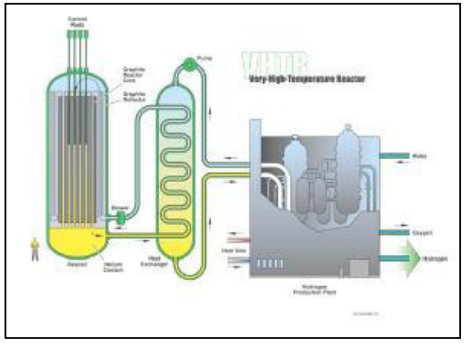
Lead-cooled Fast Reactor (LFR)



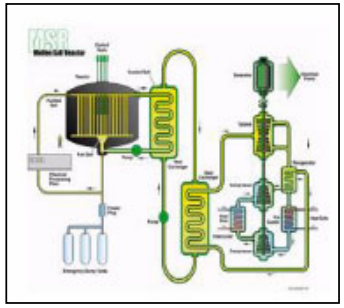
Gas-cooled Fast Reactor (GFR)



Supercritical Water cooled Reactor (SCWR)



Very High Temperature Reactor (VHTR)



Molten Salt Reactor (MSR)

Comparisons of Major Specifications

System	Neutron Spectrum	Coolant	Outlet temp. (Degree C)	Fuel cycle
Sodium-cooled Fast Reactor (SFR)	Fast	Sodium	500-550	Closed
Lead-cooled Fast Reactor (LFR)	Fast	Lead	480-570	Closed
Gas-cooled Fast Reactor (GFR)	Fast	Helium	850	Closed
Molten Salt Reactor (MSR)	Thermal/ Fast	Fluoride/Chloride salts	700-800	Open/ Closed
Supercritical Water-cooled Reactor (SCWR)	Thermal/ Fast	Water	510-625	Open/ Closed
Very High Temperature Reactor (VHTR)	Thermal	Helium	900-1000	Open

Current Missions of GIF

- Market Opportunities and Challenges for Deployment
  - Enhanced interaction with industry, incl. with SMR vendors
- Safety and Regulation
  - Increased interaction with the regulators, e.g. in the frame of the NEA Working Group on Safety of Advanced Reactors (WGSAR→WGNT) and IAEA
  - Development of system-specific Safety Design Criteria (SDC) and Guidelines (SDG)
- Enhancement of R&D cooperation
  - Use of R&D infrastructures to improve international collaboration
- Improved communication of GIF Results to Citizens, Policy makers, Regulators, Industry
  - Network with CEM (NICE Future Initiative), IFNEC, WNA….
- Education & Training as well as Knowledge Management

GIF Organization

Policy Group (PG)

Expert Group (EG)

GEN IV International Forum℠
Expertise | Collaboration | Excellence

Senior Industry Advisory Panel

Policy Director and Technical Director
Technical Secretariats

Methodology / Opportunity Working Group (WG)

- Risk and Safety WG (RSWG)
- Proliferation Resistance and Physical Protection assessment methodology WG (PRPPWG)
- Economic Modelling WG (EMWG)
- Education & Training WG (ETWG)
- Advanced Manufacturing and Material Engineering WG (AMME-WG)

Task Force (TF to solves specific issue)

- Non-Electric applications of Nuclear Heat TF (NEaNH-TF)

System Steering Committees

- Sodium-cooled Fast Reactor (SFR)
- Very High Temperature Reactor (VHTR)
- Supercritical-water-cooled Reactor (SCWR)
- Gas-cooled Fast Reactor (GFR)
- Lead-cooled Fast Reactor (LFR)
- Molten Salt Reactor (MSR)

Project Management Boards

- System Integration Assessment
- Advanced Fuel
- Safety and Operation
- Component Design & Balance-Of-Plant

- Fuel and Fuel Cycle
- Code Verification
- Materials
- Hydrogen Production
- (System Integration Assessment)

- Thermal-hydraulics and Safety
- Water Chemistry and Materials
- (System Integration Assessment)

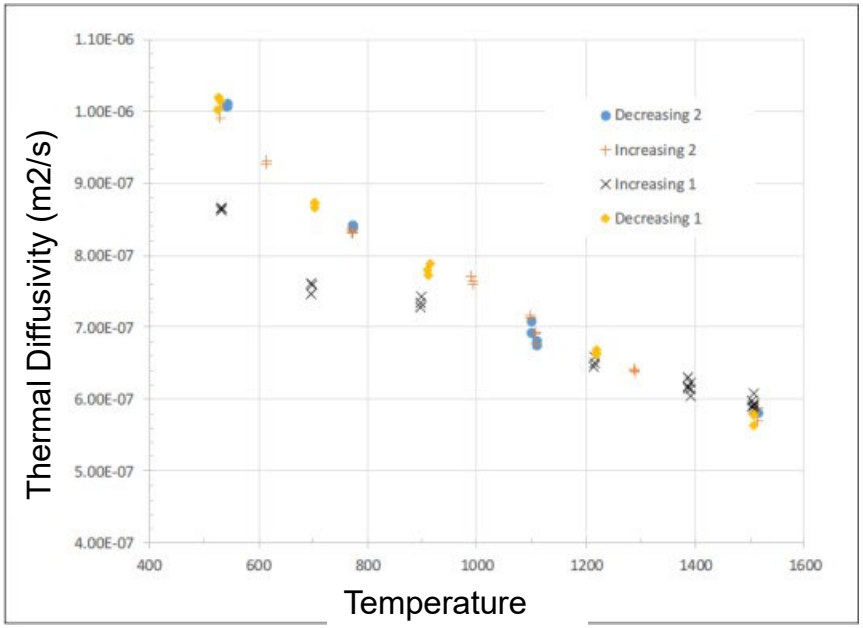
- Conceptual Design and Safety
- (Fuel and Core Materials)

Highlights related to SFR

- **Most active GIF system (together with VHTR) with four R&D Projects running:**
  - System Integration and Assessment (SIA)
  - Safety and Operations (S&O)
  - Advanced Fuel (AF)
  - Component Design and Balance of Plant (CD&BOP)
- **Five SFR Design Concepts:**
  - Loop Option (JSFR Design Track)
  - Pool Option (KALIMER-600, ESFR, and BN1200 Design Tracks)
  - Small Modular Option (SMFR-ANL Design Track)
- **World**: Construction of two pilot SFR units (CFR-600) is ongoing in China
- **Europe**: Euratom collaborative project **ESFR-SMART** focuses on enhancing the safety of Generation-IV SFRs

https://www.gen-4.org/gif/jcms/c_95916/gif-sfr-safetyassessment-20170427-final
https://world-nuclear-news.org/Articles/China-starts-building-second-CFR-600-fast-reactor http://esfr-smart.eu/

ESFR-SMART
sodium fast reactor safety

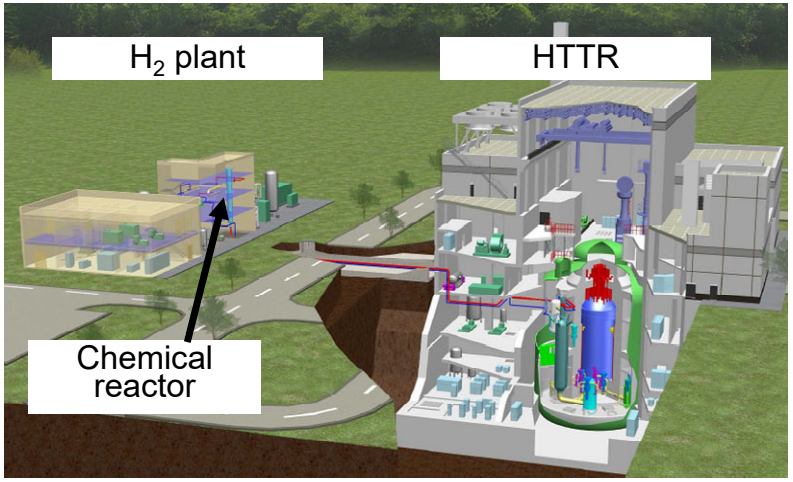


Thermal diffusivity measurements of $(U,Am)O_{2-x}$ at JRC Karlsruhe

Highlights related to VHTR

- **Four active VHTR "pre-competitive" Projects**
  - **Materials:** Graphite, metals, ceramics - corrosion, joining, irradiations
  - **Fuel:** Fabrication, characterisation, qualification, waste management
  - **Hydrogen Production:** Iodine-Sulphur (850°C), Copper-Chlorine (530°C), High temperature electrolysis (650°C)
  - **Computer Tools for Design and Licensing:** Thermal-hydraulic analysis (CFD), Neutronics and nuclear cross-section data, Radioisotope chemistry and transport, Reactor and plant dynamics
- Development of **VHTR Safety Design Criteria** on the basis of IAEA TECDOC and in cooperation with RSWG
- **World:** HTTR of High Temperature engineering Test Reactor restarted in Japan. Hydrogen production using HTTR is planned.

  Demonstration HTR-PM reaches full power in China
- **Europe**: Euratom collaboration project **GEMINI+** project is ongoing, in which partners are working together towards the demonstration of high temperature nuclear cogeneration.



Test Plan of HTTR-heat application

https://www.gen-4.org/gif/jcms/c_103659/gifvhtr-safety-assessment-finaldec2018
https://www.world-nuclear-news.org/Articles/JAEA,-MHI-team-up-for-HTTR-hydrogen-project
https://www.world-nuclear-news.org/Articles/China-s-demonstration-HTR-PM-reaches-full-power
http://www.gemini-initiative.com/geminiplus/

Highlights related to MSR

- A large interest around the MSR technology, with more than 40 concepts of a large variety being developed worldwide
- Collaborations of the MSR system are carried out under the Memorandum of Understanding (MoU) as basic technology developments
- Three (3) **Project Arrangements** are under development:
  - Fuel and coolant salt properties
  - Materials and components
  - System integration and cross-cutting issues
- Safety aspects have been identified as a key driver for the R&D Roadmap → ongoing interactions with GIF RSWG to create Task Force on the **MSR safety approach**
- **World**: Prototype MSR - TMSR-LF1 - is under construction in China
- **Europe**: Euratom collaborative project **SAMOSAFER** focuses on development of DiD approaches, development of theoretical models for safety-relevant phenomena, as well as related experimental setups

https://samosafer.eu/

TMSR-LF1

SAMOSAFER

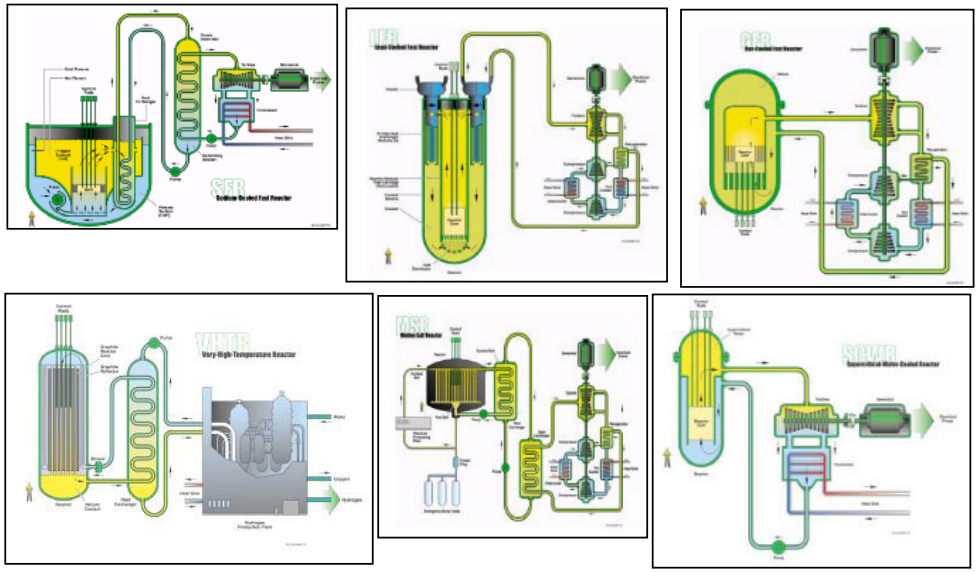
Successful synthesis of UCl_4 at JRC Karlsruhe

Task Force: Non-electric Application of Nuclear Heat (NEaNH)

Task Force of NEaNH for higher Flexibility to cover all Gen-IV systems and required R&Ds

- Heat application will be a key for Nuclear to contribute to the Carbon Neutral

Reactor Types



SFR, LFR, GFR
VHTR, MSR, SCWR
(High Temperature Systems)

Reactor Size

Power Reactor
SMR
Micro Reactor

Applications

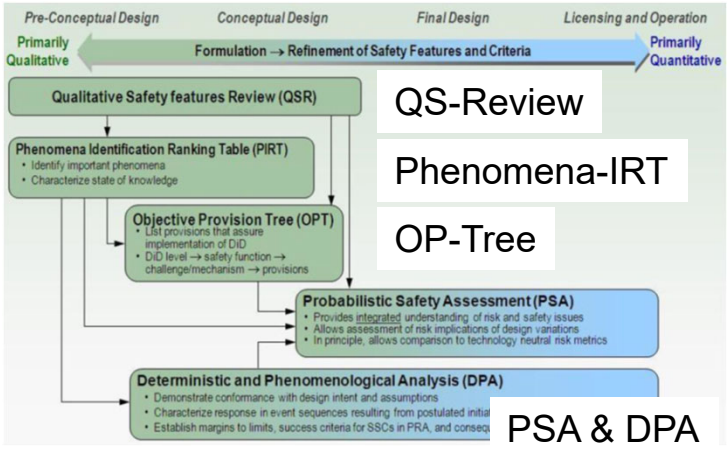
- ✓ Cogeneration application
- ✓ Hydrogen production
- ✓ Seawater Desalination
- ✓ Process heat
- ✓ Synthetic Fuel and Chemicals
- ✓ Cooling application
- \+ Heat Storage

Matrix of 6 x 3 x 6

GIF Methodologies

❑ RSWG – Risk and Safety WG

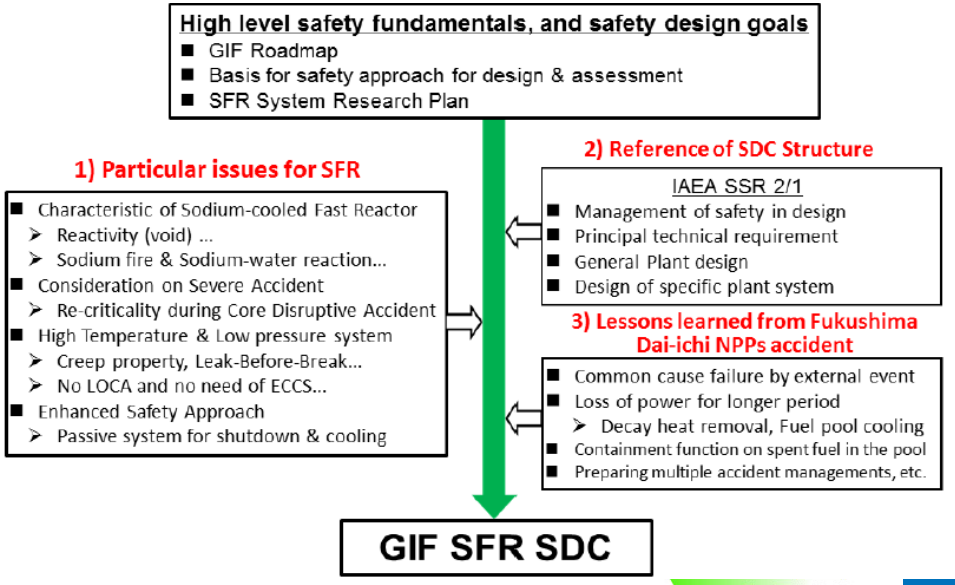
- ➢ Develop "Basis for the Safety Approach for Design and Assessment of Generation IV Nuclear Systems"
- ➢ Developed white papers on Integrated Safety Assessment (ISAM) implementation & safety systems



➢ Safety Design Criteria (SDC)

- Develop SDC and Safety Design Guidelines (SDGs) for the sodium-cooled fast reactor (SFR)
  - ✓ Reviewed by IAEA, OECD/NEA (WGSAR), and Regulatory Bodies of several countries (US NRC, France IRSN….)
- Extension to other GIF systems (LFR, VHTR, MSR…)

https://www.gen-4.org/gif/jcms/c_93020/safety-design-criteria
for "SFR SDC" & "Safety Approach and Design Conditions, SFR SDGs"

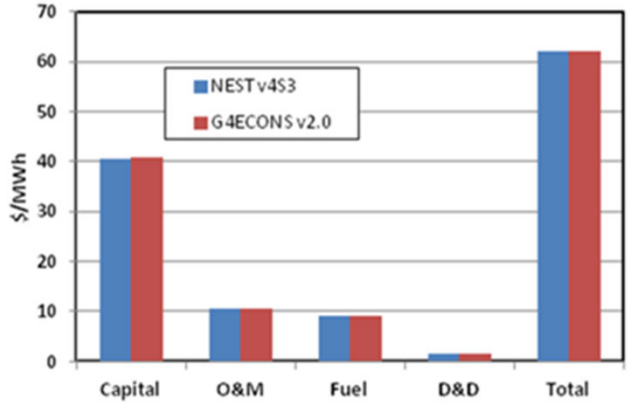


GIF Methodologies

❑ EMWG – Economics Modelling WG

- ➢ Developed the G4ECONS software (freely available)
  - Assess the costs of Gen IV designs and identify cost drivers
- ➢ Approaches on life-cycle cost reduction
- ➢ Financial Issues on Gen-IV systems deployments
  - Report on Nuclear Energy: an ESG Investable Asset Class

https://www.gen-4.org/gif/jcms/c_9364/economics for "Cost Estimating Guidelines", "Impact of Increasing Share of Renewables", and "Nuclear Energy: An ESG Investable Asset Class"



Benchmarking (G4ECONS vs. IAEA NEST)

❑ PRPPWG – Proliferation Resistance and Physical Protection WG

- ➢ Through a case study, developed a methodology to evaluate & facilitate the introduction of PRPP features at the earliest possible stage of design
- ➢ With SSCs, white papers on the six GIF systems

ACCIDENT INITIATORS → SYSTEM RESPONSE → CONSEQUENCES

THREATS → SYSTEM RESPONSE → OUTCOMES

- ***Safety and PR&PP should be considered from the earliest stages of design***
  - ***Flow diagrams: preliminary safety hazard and PR&PP target identification and categorization***
  - ***Physical arrangement: external events shielding, access control***

https://www.gen-4.org/gif/jcms/c_9365/pr-pp for "Evaluation Methodology Report", "Workshop materials", and "Case Study Report of ESFR"

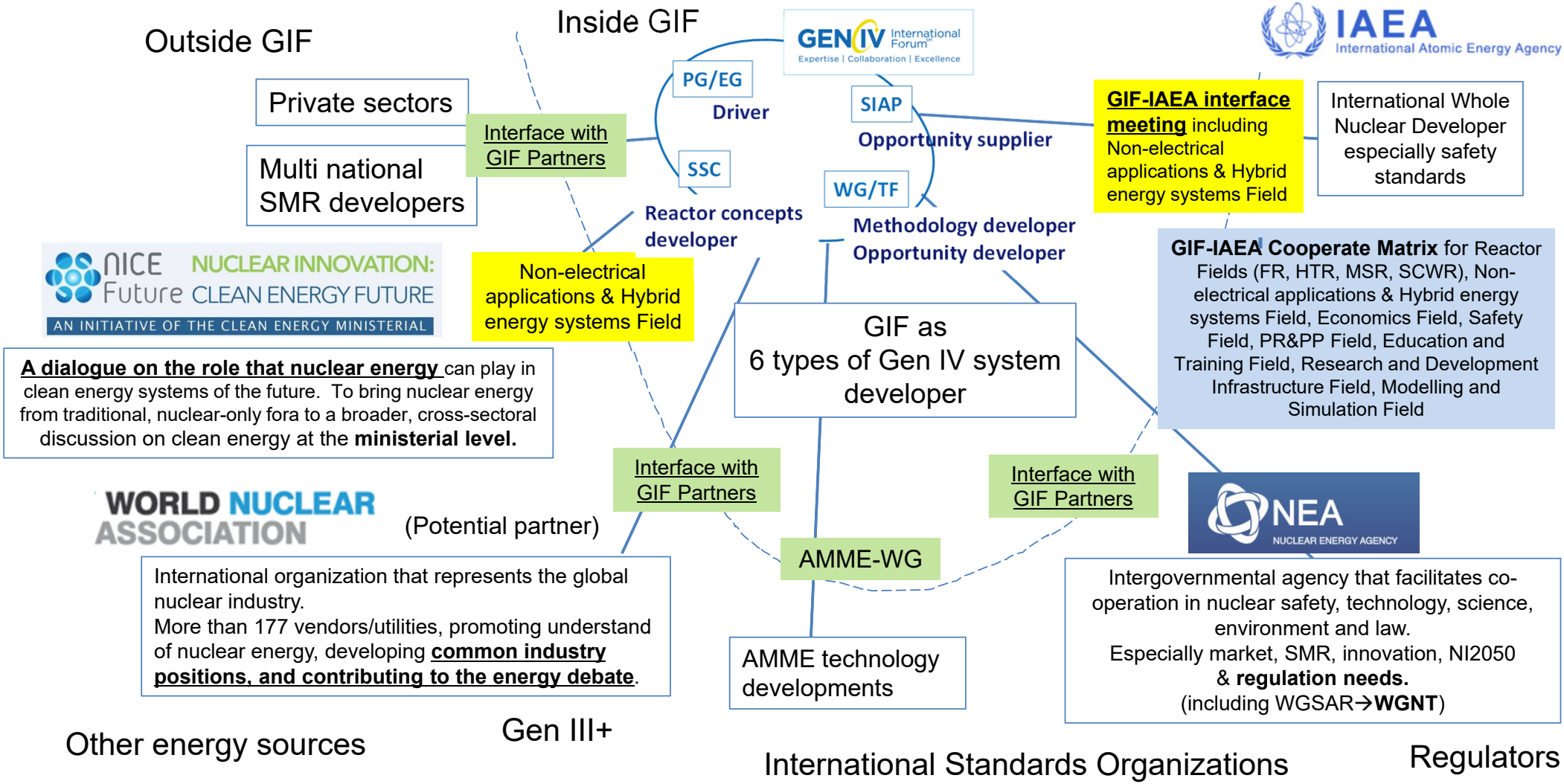
SeFARD

GIF Methodologies

❑ AMME-WG; Advanced Manufacturing and Material Engineering Working Group

- AMME is a key for cooperation with Industry (SMR Vendors…)
  - Innovation for Safety and Economy of construction, operation, and maintenance, inspections. AI is also significant issue
- Advanced Manufacturing Workshop held at NEA in Feb. 2020
- AMME-WG was launched based on its Task Force activities.
  - Qualification, Demonstration and Deployment
    - New approaches and methods for qualification are key to the deployment of advanced manufacturing. The first focus is to identify these commonalities in qualification across different reactor systems.
  - Design and Modelling
    - Meeting the need to capture and share processes and methodologies for ensuring product quality by a) collecting experience, b) sharing, and c) benchmarks (including data driven AI approaches).
  - Sessions of AMME in G4SR-4, Toronto Canada, 2022

Enlargement of Cooperation with world Organizations



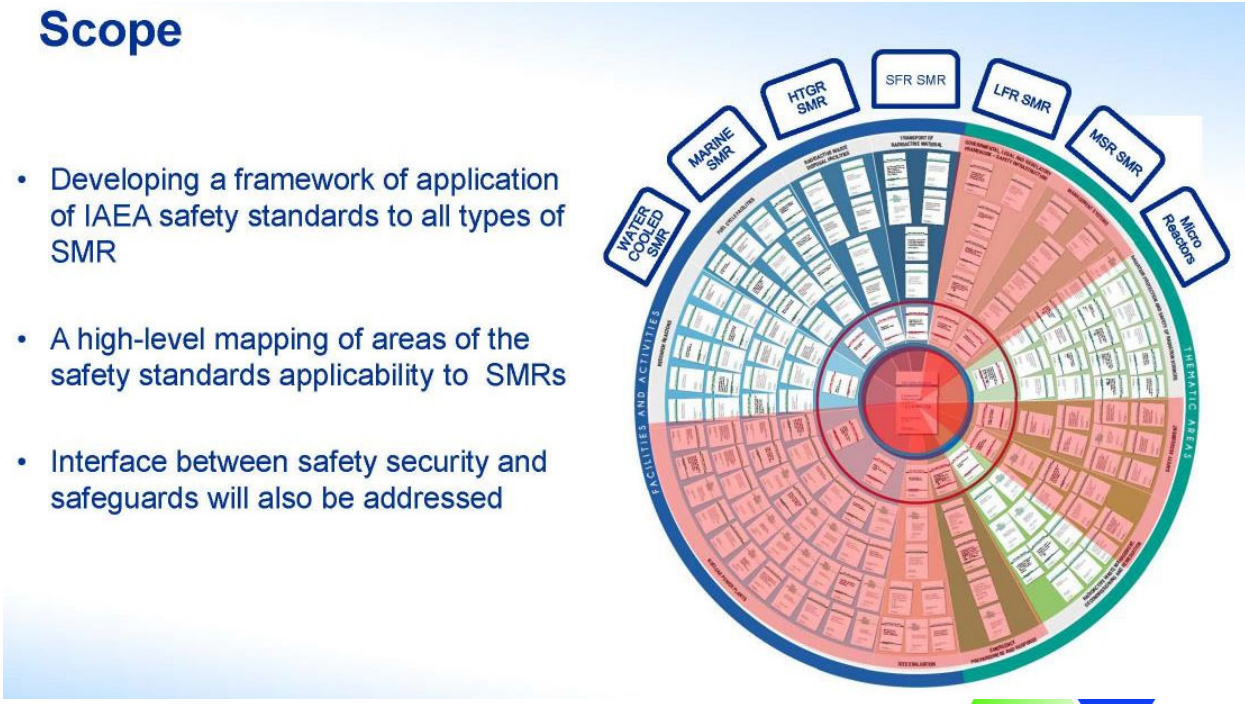
Cooperation with IAEA

❑ GIF-IAEA Interface meeting

- 2021 July: The IAEA and the Generation IV International Forum (GIF) have agreed to expand their cooperation, nuclear heat applications and advanced manufacturing. (IAEA Website news)
- 2022 April: GIF-IAEA-NEA Joint Webinar on “Role of Nuclear Energy in Reducing CO2 Emission”

❑ Regulatory issues of Gen-IV systems

- GIF-IAEA LMFR safety workshop
  - ✓ Reviews of SFR SDC/ SDG and LFR SDC by IAEA
- SMR safety documents development in IAEA
  - ✓ SMR Regulators Forum
  - ✓ GIF members have joined several consultancy meetings



iaea_smr_safety_webinar_presentation_29_october.pdf, Page 8

Education & Training WG Activities

https://www.gen-4.org/gif/jcms/c_82831/webinars

Web search by GIF and Webinar

Webinars

In 2016, the GIF Education and Training Task Force began organising a webinar series which features speakers from around the world, explaining why GEN IV reactor systems are crucial for the sustainability of the nuclear fuel cycle. The webinar series was launched with a presentation by former GIF Chair John Kelly on "Atoms for Peace – the Next Generation" and includes monthly webinars. The Task Force was elevated to a Working Group in November 2019.

All webinars are also accessible on "YouTube" under the "GIF Education and Training Working Group".

By following the links below, you will access all past webinars:

2022 2021 2020 2019 2018 2017 2016 - or GIF Portal - Webinar - (jaea.go.jp)

NEW 2023 SERIES (from 73 to 84)

GIF Webinar in 2023

- Series 75: Advanced Reactor Safeguards and Materials Accountancy Challenges 30 March 2023
  Dr. Ben Cipiti from Sandia National Laboratories, USA
- Series 76: Overview of Nuclear Graphite R&D in Support of Advanced Reactors 5 April 2023
  Dr. Will Windes, INL, USA
- Series 77: Graphite-Molten Salt Interactions, 24 May 2023
  Dr. Nidia Gallego, ORNL, USA
- Series 78: International Knowledge Management and Preservation of SFR, 21 June 2023
  Panel Session: Cal Doucette, Clean Energy, Canada; Joel Guidez, retired from CEA, France; Hiroki Hayafune, JAEA, Japan; Patrick Alexander, Terrapower, USA and Ron Omberg, PNNL, USA
- Series 79: Off-gas Xenon Detection and Management in Support of Molten Salt Reactors, 26 July 2023
  Hunter Andrews, ORNL, USA and Praveen Thallapally PNNL, USA

GEN IV International Forum

GIF international site (English)
GIF Japanese site (Japanese)

Home > GIF Webinar Guide

GIF Webinar Guide

https://gif.jaea.go.jp/webinar/index_eng.html

Generation IV International Forum (GIF) shares GIF knowledges through GIF Webinars. The GIF Education and Training Working Group invites you to participate in monthly webinars presented by worldwide experts explaining GEN IV policies and technologies leading the next nuclear generation. Launched in September 2016, the current webinar series includes over 40 recordings of lectures already conducted. GIF webinar series are categorized into 8 genres as below and you can watch the webinar which you feel interest, and the latest monthly GIF webinar is here!

Structured Index of past webinar

1. Introduction to seizing opportunity
2. Safety, Quality, Economics and Regulation
3. Fuel Cycle, Sustainability, PRPP and Disposal
4. Generation IV System Design and Related Technology
4-1. Fast Reactors System Designs and related projects
4-2. Advanced Reactors System Designs with specific motivations and related projects
5. Life cycle designs, Operational experiences, Inspections, Coolant quality control, Test loops
6. Fuel, Core Design
7. Thermal hydraulics, Structure, Material designs
8. Winning Webinars by young generations
9. Others

Each page of GIF Webinar Guide

2. Safety, Quality, Economics and Regulation

Safety of Generation IV Reactors

Presenter: Dr. Luca Ammirabile, Euratom, EU

Excellence in safety and reliability is among the goals identified in the technology roadmap for Generation IV nuclear reactors. This webinar will give an overview of the activities of the GIF Risk and Safety Working Group done in support of the six Generation IV nuclear energy systems towards the fulfilment of this goal. Topics include a presentation of the safety philosophy for Generation IV systems, the current safety framework for advanced reactors, and the methodology developed by the group for the safety assessment of Generation IV designs. Other ongoing activities between the group and the designers of Generation IV systems will be also highlighted.

Summary; Author introduction, Major contents

Watch You-Tube | **Presen. File** | **Webinar Flyer**

Guide Book | **Text Data**

These contents are available.

Guide Book of GIF Webinar

GEN IV International Forum
Expertise | Collaboration | Excellence

Safety of Generation IV Reactors

Summary / Objectives:

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Meet the Presenter:

Dr. Luca Ammirabile works at the European Commission (EC), Joint Research Centre in Petten, the Netherlands, where he is Group Leader of the NUclear Reactor Accident Modelling (NURAM) team of the Nuclear Reactor Safety and Emergency Preparedness Unit. His group deals with Nuclear Reactor Safety assessment for current and innovative reactors, focusing on the safety issues related to the prevention and mitigation of Severe Accident conditions and Source Term estimation. His current research activities are core thermal-hydraulic analyses, deterministic code application and development, and safety assessment of advanced reactors. Since 2014, he has been co-chairman of the working group on Risk and Safety of the Generation IV International Forum. He is also the EC representative on the OECD/NEA Working Group for the Analysis and Management of Accidents (WGAMA) and the Working Group for the Safety of Advanced Reactors (WGSAR). Prior to joining the European Commission in 2007, Luca worked at Tractebel Engineering (now Tractebel Engie) in Belgium in the Thermal-hydraulics and Severe Accident Section, where he was engaged, among other projects, in the development of innovative methodologies in support of the safety assessment of the Belgian Nuclear Power Plants.
Luca received his doctorate from the Imperial College London in 2003 and his master's degree in nuclear engineering from the University of Pisa, Italy in 1999.

GEN IV International Forum
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Risk and Safety Working Group :

The primary objective of GIF Risk and Safety Working Group (RSWG) is "Promote a consistent approach on safety, risk, and regulatory issues between Generation IV systems".

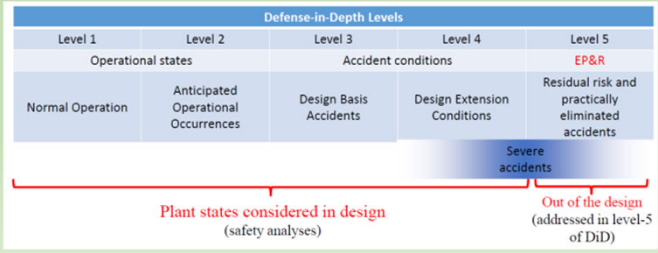
For this purpose, RSWG developed and have promoted a technology-neutral Integrated Safety Assessment Methodology (ISAM).

System	Neutron Spectrum	Coolant	Pressure (MPa)	Temperature (°C)	Fuel Cycle	Size (MW)
GFR	Fast	Helium	~9	850	Closed	1200
LFR	Fast	Lead	0.1+ (atm.)	480–800	Closed	45-1500
MSR	Fast or Thermal	Fluoride or chloride salts	0.1+ (atm.)	700–800	Closed	1000-1500
SFR	Fast	Sodium	0.1+ (atm.)	550	Closed	50–1500
ScWR	Thermal or fast	Water	~25	510–625	Once-through or Closed	10–over 1000
VHTR	Thermal	Helium	~5.5	900–1000	Once-through	250–300

Explanation of Safety & Reliability Goals (Defence in Depth) :

GIF Safety & Reliability Goals are corresponding with the concept of Defence in Depth.

- Excel in Operational Safety and Reliability
  - DiD Level 1-2 [N.O., AOO]
- Very low likelihood & degree of reactor core damage
  - DiD Level 2-3 [Design for severe accident prevention]
- Eliminate the need for offsite emergency response
  - DiD Level 4 [Design for severe accident mitigation]



Pitch Your Generation IV Research, 2023

Encourage Young Researchers for innovative Generation IV reactor technologies

Total of Applications: 47

14 papers were selected for video competition

Schedule

April 1, 2023 - Popular voting begins

April 30, 2023 - Popular voting ends

End of May 2023 – Three Winners were announced with Video

Examples of SMRs / Non-light water Reactors

Organizations	Project or Reactor	Coolant	Characteristics
NuScale Power	VOYGR	Light Water	PWR base, Multi units in a pool
GE-Hitachi	BWRX-300	Light Water	BWR base
ROSATOM	Akademik Lomonosov	Light Water	PWR base, Floating power unit
CEA, EDF,…	NUWARD	Light Water	PWR base
MSIT	SMART	Light Water	PWR base
Oklo	AURORA	Heat Pipe	Fast Reactor
TerraPower	NATRIUM	Sodium	Fast Reactor
ARC Clean Energy	ARC-100	Sodium	Fast Reactor
Westinghouse	Demo. LFR	Lead	Fast Reactor
X-energy	Xe-100	Helium	High Temperature gas cooled Reactor (HTGR)
USNC	MMR	Helium	HTGR
U-Battery	U-Battery	Helium	HTGR
Terrestrial Energy	IMSR	Fluoride Salt	Molten Salt Reactor (MSR), Thermal Reactor
TerraPower	MCFR	Chloride Salt	MSR, Fast Reactor

GIF Industry Forum with G4SR-4 conference

G4SR-4: 4th International Conference on Generation IV and Small Reactors

organized by Canadian Nuclear Society (CNS)

Toronto, October 3-6, 2022

- Report the achievements of GIF collaborative research on advanced nuclear energy systems.
- Explore collaboration opportunities between private and public sectors to accelerate the demonstration of Gen IV systems.

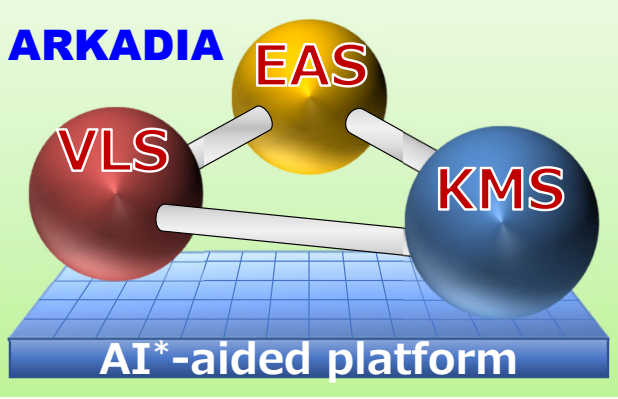
Topics identified for collaboration with GIF

- ✓ Range from specific technology to design/methods sharing
- ✓ Willingness to engage with Projects

Discussion of a new Project on SFR with Private Sectors is ongoing.

ARKADIA as a Digital Triplet for Reactor Design

- Support evaluation of various innovative reactor concepts represented by a sodium-cooled fast reactor
- Optimize plant lifecycle of an advanced reactor automatically by using state-of-the-art simulation technologies and knowledge



*Artificial Intelligence

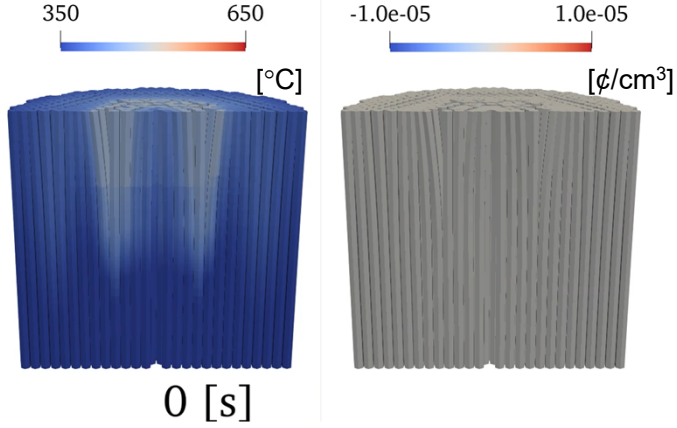
- Virtual Plant covering its life cycle
- Knowledgebase of Experiment, Simulation, Design, Maintenance...
- Design optimization with AI

- VLS: Virtual plant Life System,
- KMS: Knowledge Management System,
- EAS: Enhanced and AI-aided design optimization System

ARKADIA-Design

optimizes core design, plant structure design, and maintenance program

Example coupled simulation by VLS (Neutronics, thermal hydraulics, structure)

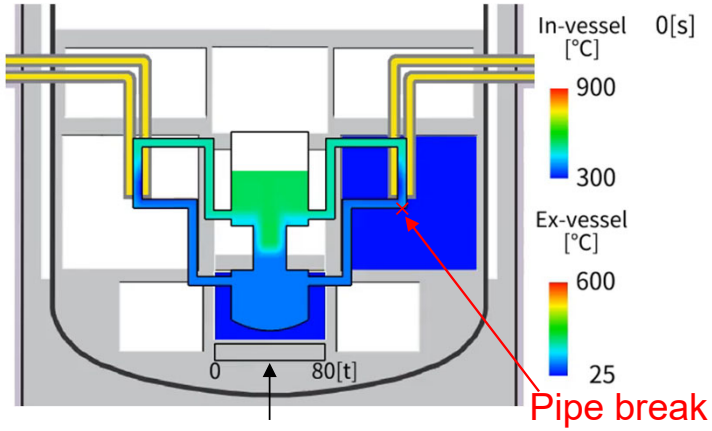


Temperature Deformation Reactivity

ARKADIA-Safety

provides design satisfying requirements of safety and economics from SA* simulation

Example SA simulation by VLS (loss of rector level)



Leaked debris * Severe Accident

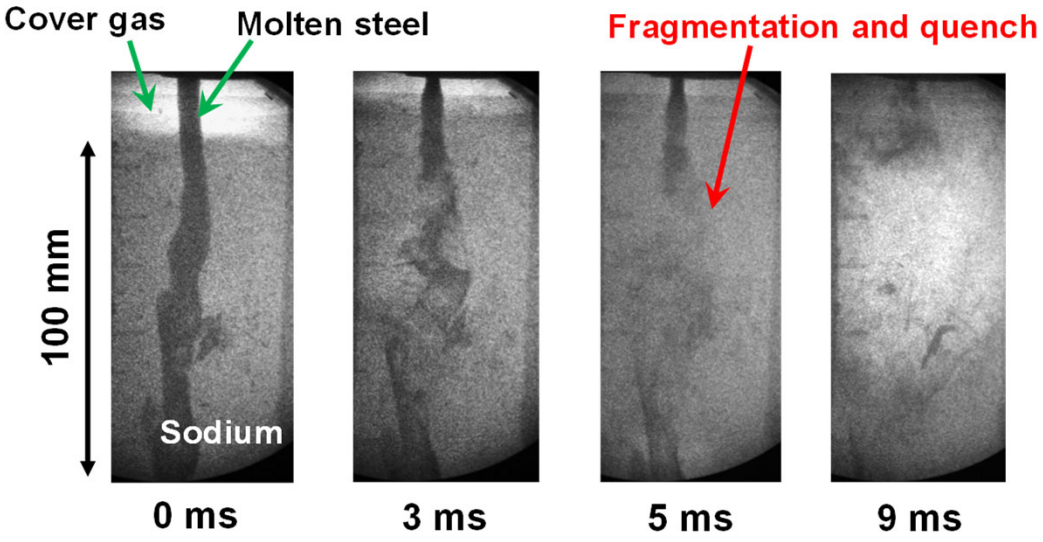
Components of VLS for Design and Safety Evaluations

Sodium experiments on Safety Issues

➢ *In-vessel retention of Core melt Accident*

MELT facility:

Utilized for experimental studies to clarify the molten-core material behavior during severe accidents of SFR

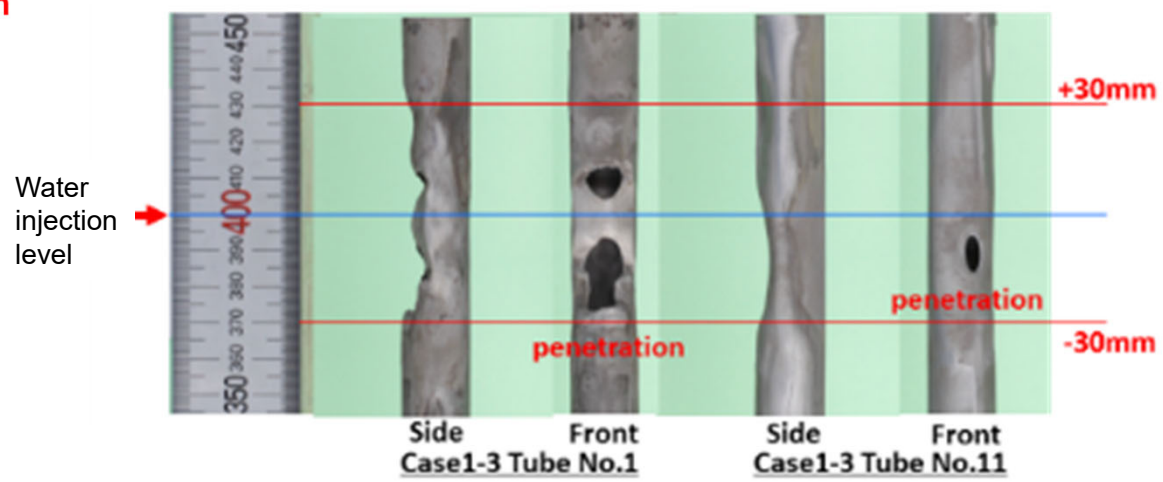


X-ray images of melt behavior in sodium

➢ *Sodium Water Rection*

SWAT-3R Facility:

Sodium-water reaction (SWAT-3R) test simulating high temperature and pressure steam-water jets into sodium in SG

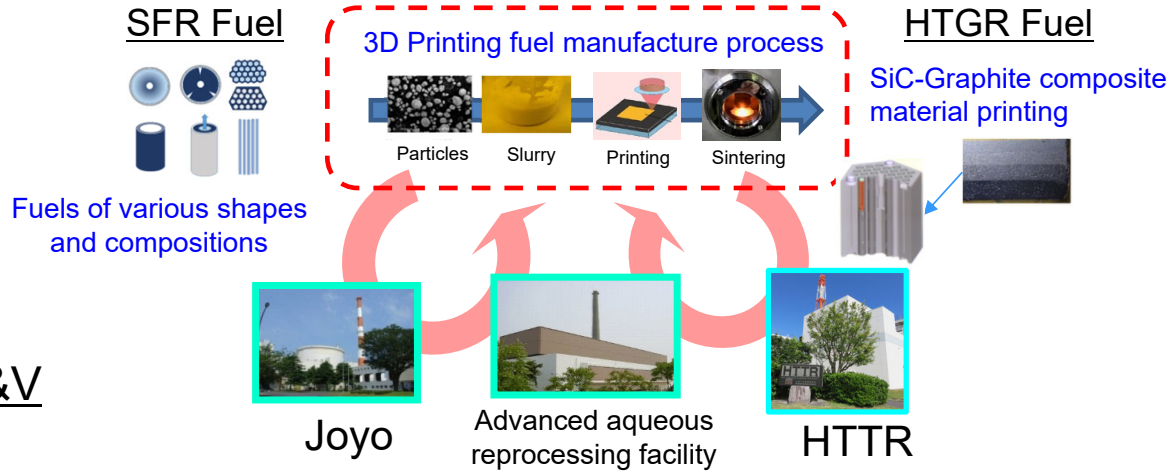


Example of Test: Penetrating failure tubes

Nuclear Innovation: 3D Printing Ceramic Fuel Technology

■ Development Goals :

- Fuel cycle synergy for SFR and HTGR
- Enable advanced fuel features
- Enhance safety and economics

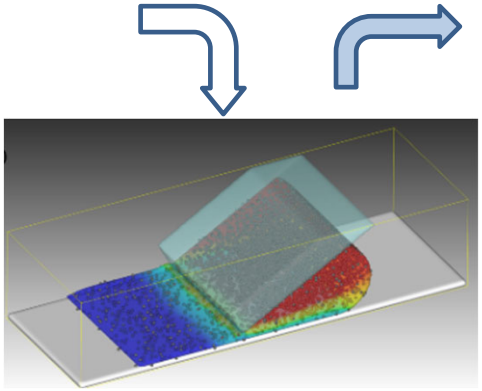


Research on 3D Printing CAE Simulation and V&V

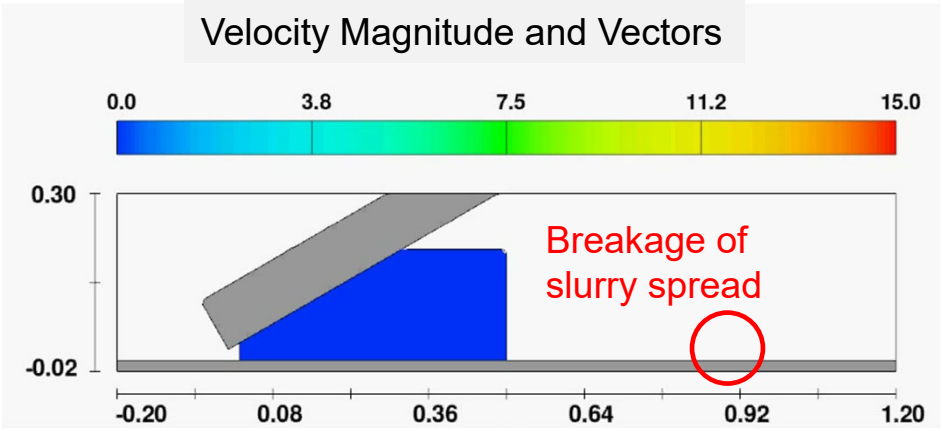
(Computer-Aided Engineering)

- ✓ Particles and slurry
  Complex behavior re-produced by CFD
- ✓ Stereolithography printing
- ✓ Spark plasma sintering
- ✓ Irradiation performance

CAE will greatly accelerate deployment of 3D printing fuels



Slurry Spreading Process



Summary

- Sustainability of Nuclear Energy Use
  - Efficient use of Uranium
  - Reduction of waste; Greenhouse Gas and volume/ toxicity of High Level radioactive Waste
- Potential of Generation IV Reactor Systems thanks to fast neutron and high temperature output (> 500 degree C)
- International Cooperation of Gen-IV development by GIF
  - 6 Reactor Systems; SFR, LFR, GFR, SCWR, VHTR, and MSR
  - Safety design criteria and guidelines
  - Non-electric Heat Application, Advanced Manufacturing
  - Webinar of Gen-IV Technologies and Knowledge Management
- Synergy of GIF and SMR developments

This presentation material includes some of the results of the "Technical development program on a commercialized FBR plant" and "Technical development program on a fast reactor international cooperation, etc." and "Technical development program on a common base for fast reactors" entrusted to JAEA by the Ministry of Economy, Trade and Industry in Japan (METI).