April 16-18, 2024

David Holcomb
Molten Salt Reactor Technology Lead

MSR International and Safety Activities

Virtual Campaign Review Meeting

Battelle Energy Alliance manages INL for the
U.S. Department of Energy's Office of Nuclear Energy

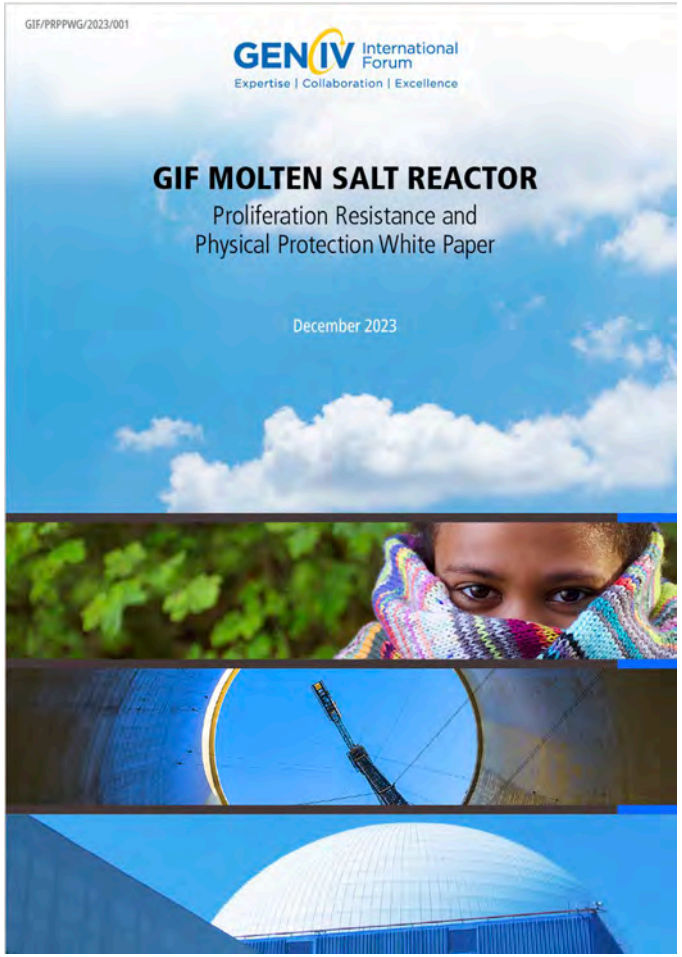
Idaho National Laboratory

Molten Salt Reactor (MSR) Campaign Continues to Support International Cooperation

- Generation IV International Forum (GIF) and International Atomic Energy Agency (IAEA) remain primary (but not exclusive) collaboration venues
  - GIF MSR provisional system steering committee (pSSC)
    - Issued MSR Proliferation Resistance and Physical Protection White Paper – December 2023
  - IAEA Interregional Training Course on Non-Water-Cooled Reactors and Small Modular Reactors
    - Daylong overview of fundamental aspects of MSR safety provided – February 2024
  - IAEA – Consultancy (May 2024) and Technical Meetings (October 2024) on Severe Accident Analysis and Management for Non-Water Cooled Reactors
  - IAEA Issued Technical Report Series No. 489 *Status of Molten Salt Reactor Technology* – November 2023
  - IAEA Safety Reports Series No. 123 – *Applicability of IAEA Safety Standards to Non-Water Cooled Reactors and Small Modular Reactors* – December 2023
- European Commission focusing on common approaches to safety adequacy evaluation
  - Putting Science into Standards Workshop on MSR Technologies – March 2024
- CEA (France) has indicated that initial bi-lateral cooperation on MSRs should be on safety
  - Two workshops (one virtual one physical anticipated in 2024)

Proliferation Resistance and Physical Protection White Paper Issued by GIF

- Jointly prepared by the Proliferation Resistance and Physical Protection Working Group and the Molten Salt Reactor provisional System Steering Committee
  - David Holcomb, Lap Cheng, Benjamin Ciptiti – US contributors
- Methodology provides designers and policy makers a technology neutral framework and a formal comprehensive approach to evaluate MSR Proliferation Resistance (PR) and Physical Protection (PP) characteristics
- MSRs subdivided into three broad classes
  1. Liquid-fueled with integrated fuel salt processing
  2. Liquid-fueled without integrated processing
  3. Solid-fueled with salt coolant
- https://www.gen-4.org/gif/jcms/c_218192/msr-prpp-white-paper



IAEA Interregional Training Course on Non-Water-Cooled Reactors and Small Modular Reactors

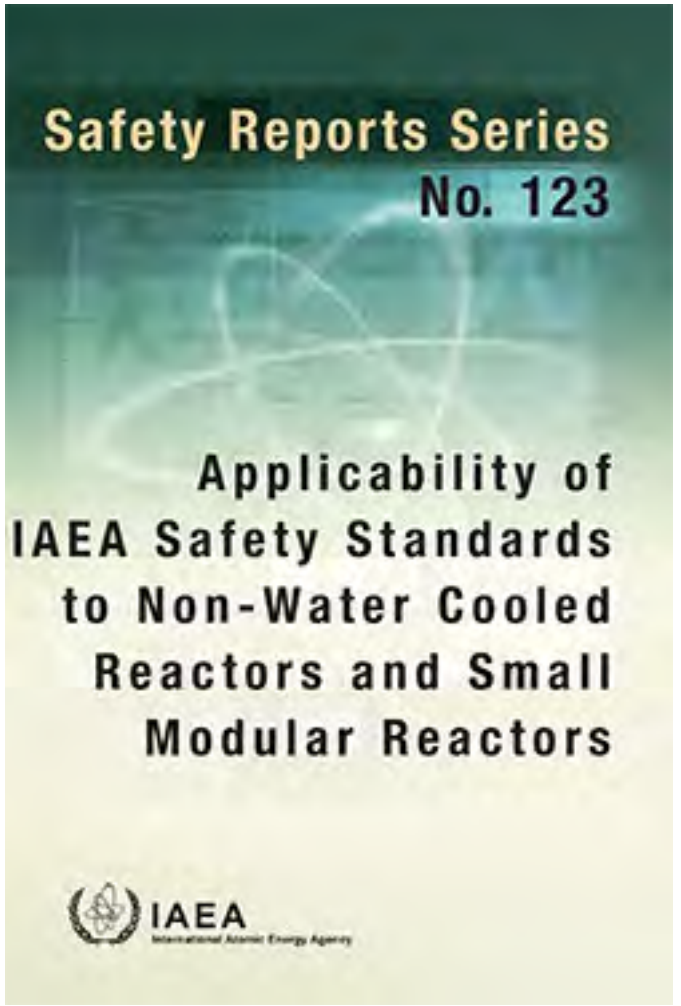
- Held at IAEA headquarters in Vienna, Austria
  - Attended by 42 individuals from 37 countries
- Participants primarily represented countries considering a nuclear power program with an SMR as its first reactor

1. MSR Overview
2. Operating History of MSRs
3. MSR Core and Fuel Design
4. MSR Main Plant Systems
5. Design Characteristics Important to Safety
6. Defense-in-Depth
7. Typical Potential Accidents
8. Waste Management

Training In-Progress at IAEA Headquarters

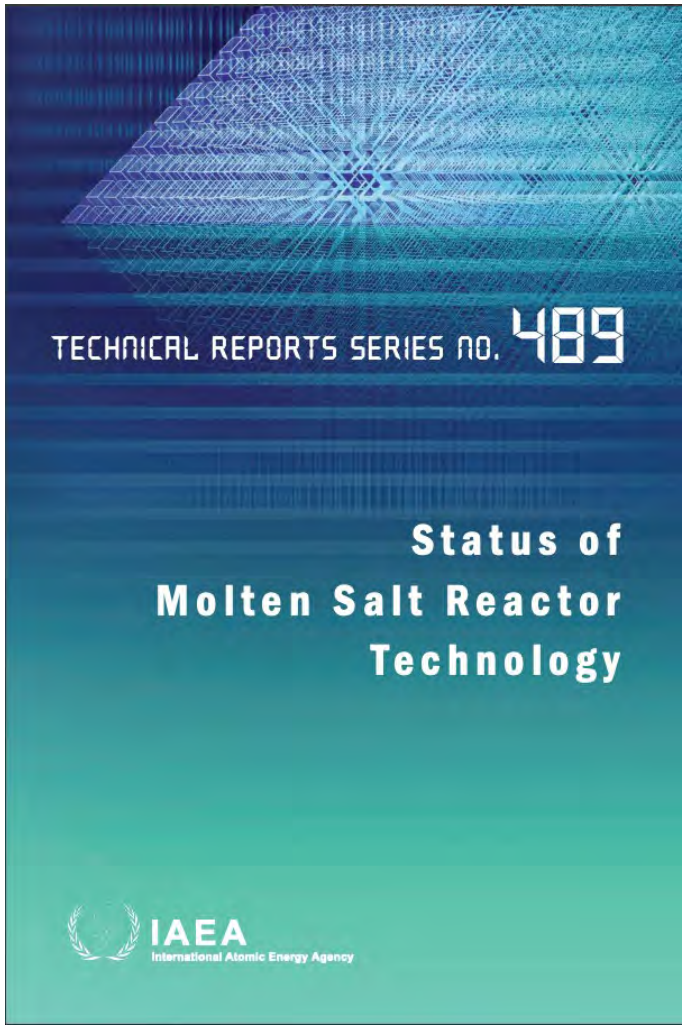
IAEA Focusing on MSR Severe Accident Management During 2024

- Address the identified gaps in IAEA Safety Report 123 "*Applicability of IAEA Safety Standards to Non-Water Cooled Reactors and Small Modular Reactors*" – December 2023
- Consultancy meeting aims to design the subsequent technical meeting to effectively, foster comprehensive technical discussions
  - Primarily concentrate on HTGRs and MSRs
- Topics for both meetings
  1. General design and safety assessment for the prevention and mitigation of severe accidents,
  2. Severe accident phenomenology and analysis,
  3. Severe accident management in general, and
  4. Other topics related to regulation or licensing issues.



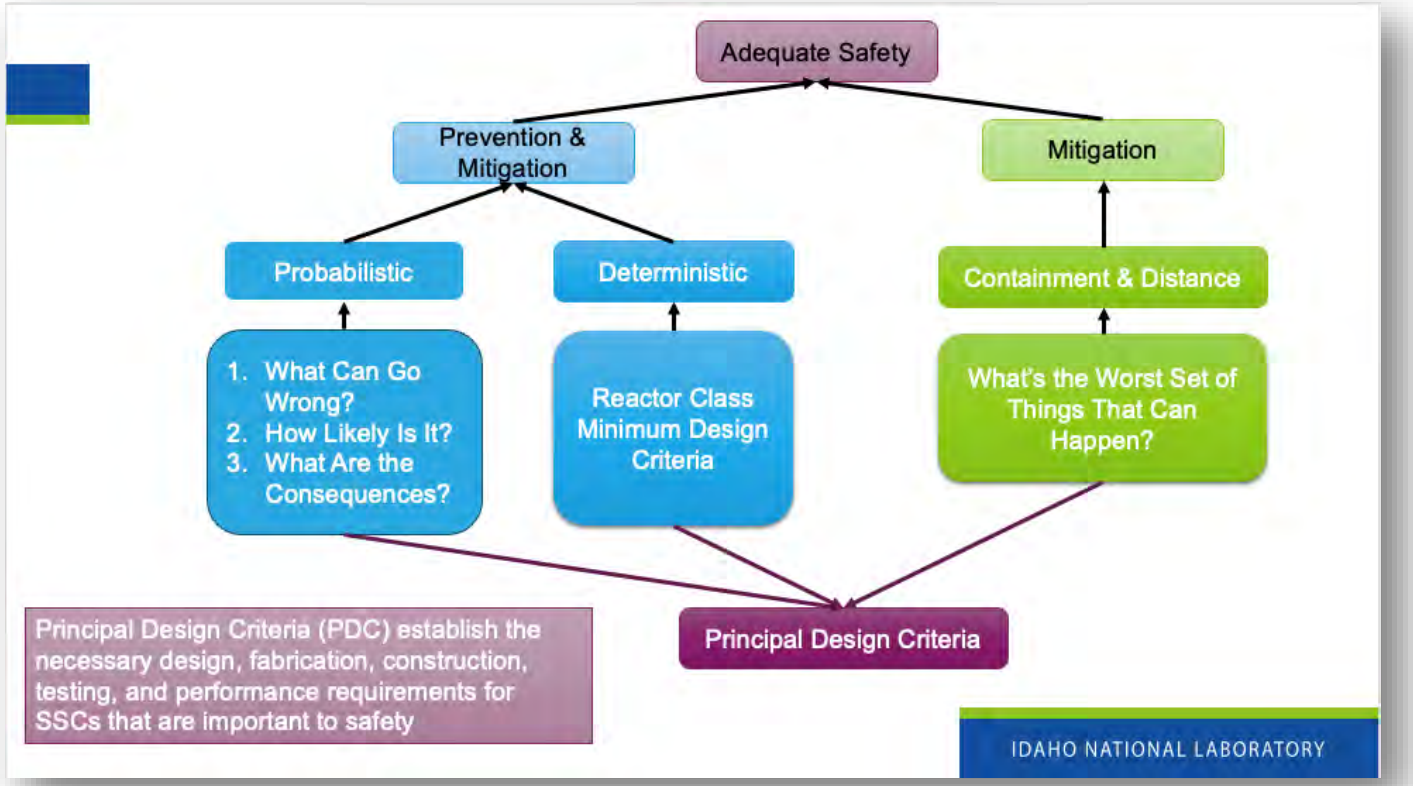
IAEA Issued Technical Report Series on Status of Molten Salt Reactor Technology

- First major MSR technology report ever issued by IAEA
  - Likely to serve a primary reference
- Represents combined effort of 48 authors
- Highlights the importance of the U.S. in both originating the technology and advancing the state-of-the-art



European Commission Focusing on Common Approaches to MSR Safety Assessment

- Historically been substantial differences between national approaches to safety evaluation
- Focus is on options to demonstrate adequate safety that could be accepted by multiple national regulators
- Active and knowledgeable discussion
  - Focus on what is needed to support first generation MSR deployment
- Fuel qualification likely to follow U.S. template established in NUREG/CR-7299

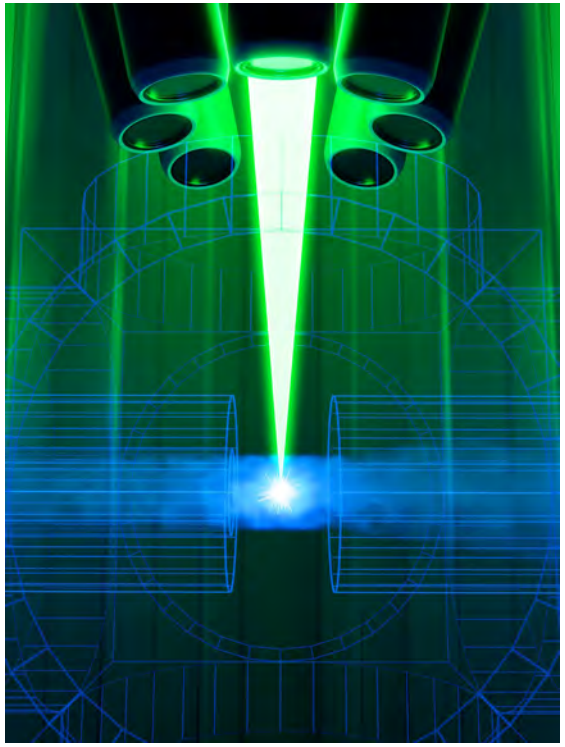


GIF MSR pSSC Safety Collaboration

- Limited to exchange of open/fundamental information
- Focus of collaboration is on developing and exchanging information suitable for providing technical basis for safety adequacy assessment
  - Multiple alternative methods for safety adequacy assessment are possible
- Technical basis derives from fundamental data
  - Fuel salt thermophysical and thermochemical properties
  - Safety system, structures, and component (SSC) performance
  - Accident progression experiments and simulations
- Employing open data for safety adequacy decisions can increase public acceptance of nuclear power
  - Accident progression demonstrations have not yet been at sufficient scale to necessitate collaborative activities

Generation and Validation of Fundamental Data is a Key Element of GIF MSR Cooperation

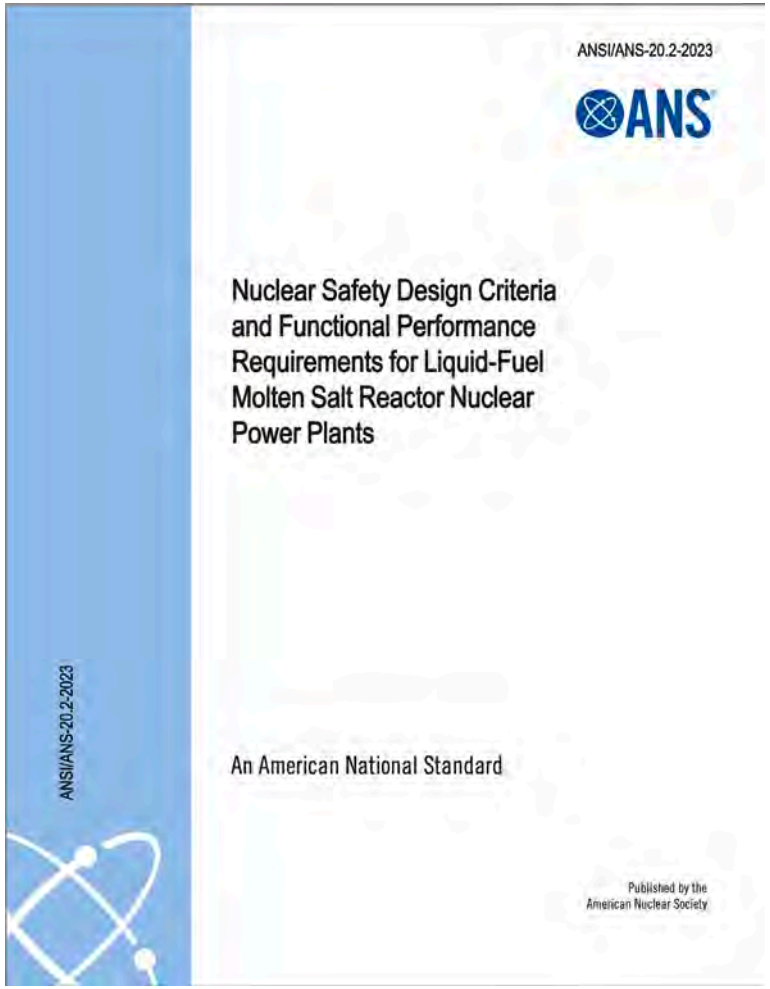
- Fuel salt thermochemical and thermophysical properties are central to understanding potential source term and accident progression
  - Multiple independent measurements decrease property uncertainty
  - Fundamental scientific data is published openly
- Multiple GIF participants independently contribute related information to safety-related topics
  - United States demonstrating laser induced breakdown spectroscopy for monitoring aerosolized species and gases in headspace
  - European Union (EU) recently published thermodynamic evaluation of release kinetics of CsI into headspace
  - Canada has been experimentally evaluating fission product releases from halide salts



Laser-Induced Breakdown Spectroscopy (LIBS) application to off-gas.

The American Nuclear Society Recently Released Its First Molten Salt Reactor Safety Standard: ANSI/ANS-20.2-2023

- Standard provides class-specific design criteria for liquid-fueled MSRs
  - Applicable to both fast and thermal spectrum reactors
  - Applicable to breeders, burners, and converters
- Developed over > 8-year period by a working group (WG) that included national regulators, utilities, prospective vendors, national laboratories, and universities
  - WG examined each GDC and ARDC with the objective of translating the specific technology to MSRs while preserving the safety intent
  - Additional MSR design criteria were developed to address MSR-specific issues
- Intended to support either a 10 CFR Part 50 or Part 52 licensing process
- Endorses use of ANSI/ASME/ANS RA-S-1.4-2021 as an alternate, probabilistic means to derive PDCs
- Currently under review for possible endorsement by the NRC



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