July 25, 2023

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Idaho National Laboratory

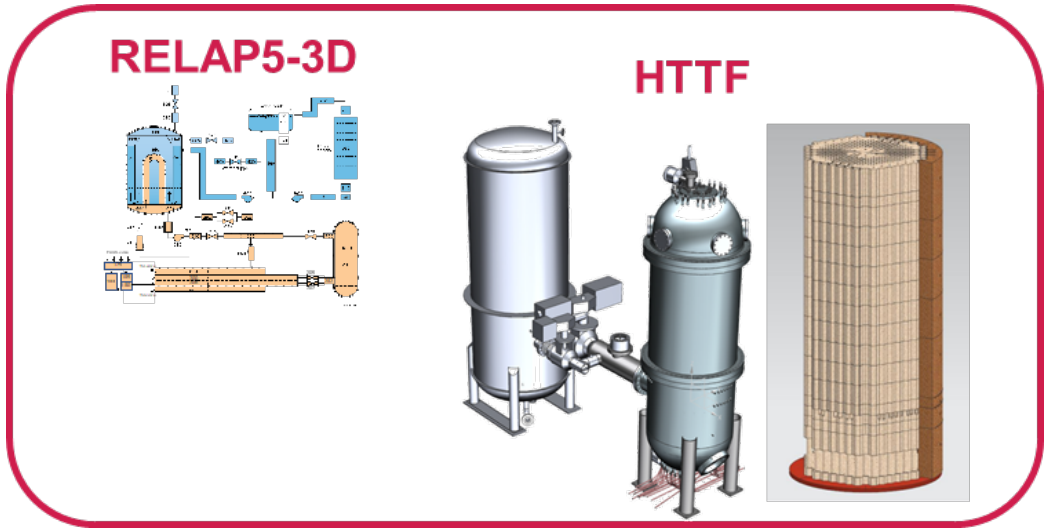
# DOE Advanced Reactor Technologies Gas-Cooled Reactor Program Overview

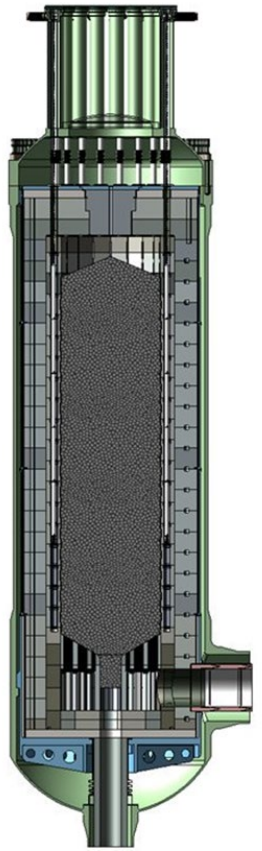
**DOE ART Gas-Cooled Reactor (GCR) Review Meeting**
Virtual Meeting
July 25 – 27, 2023

ART
Advanced Reactor Technologies

# Purpose of ART-GCR Program Review

- Provide overview of ART-GCR program objectives, status and activities
- Identify research areas and outcomes that will benefit stakeholders and clients (HTGR designers, suppliers, regulators, DOE-NE, etc.)
- Identify remaining R&D gaps and future needs



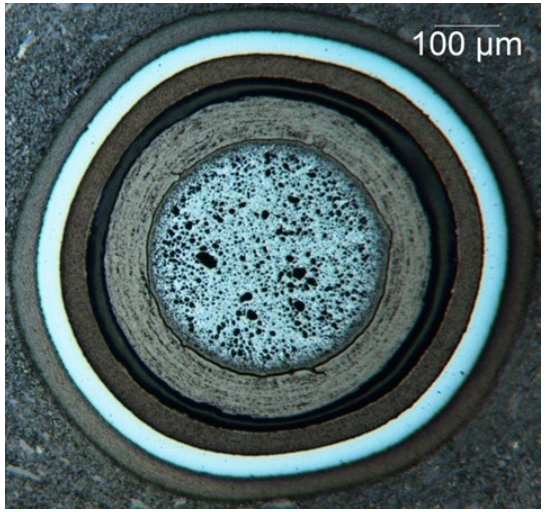
# DOE ART-GCR Program Elements

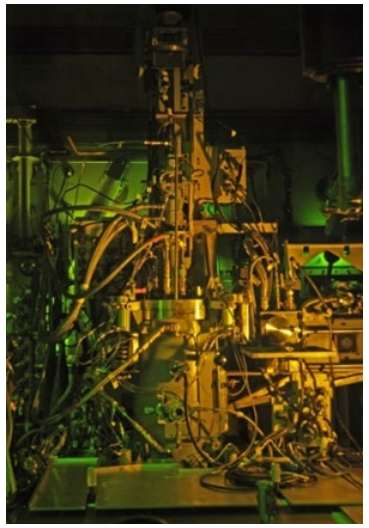
*Fuel development and qualification*

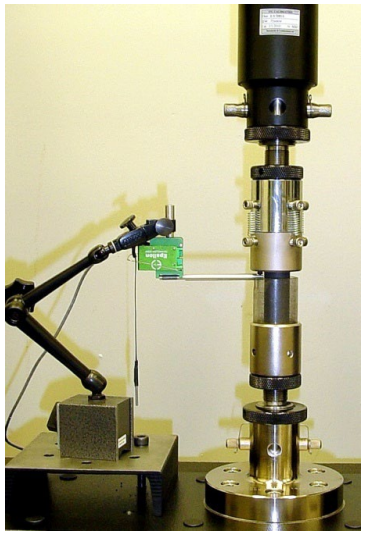
- Establish a domestic commercial TRISO fuel fabrication capability.
- Generate UCO TRISO fuel performance data to support fuel qualification.

*Graphite qualification*

- Select, irradiate, and characterize existing nuclear grades.
- Qualify nuclear grade graphite and establish design rules for use in HTGR core.





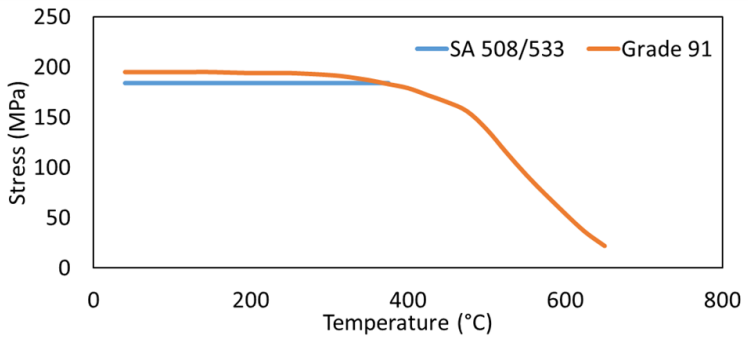
# ART-GCR Program Elements

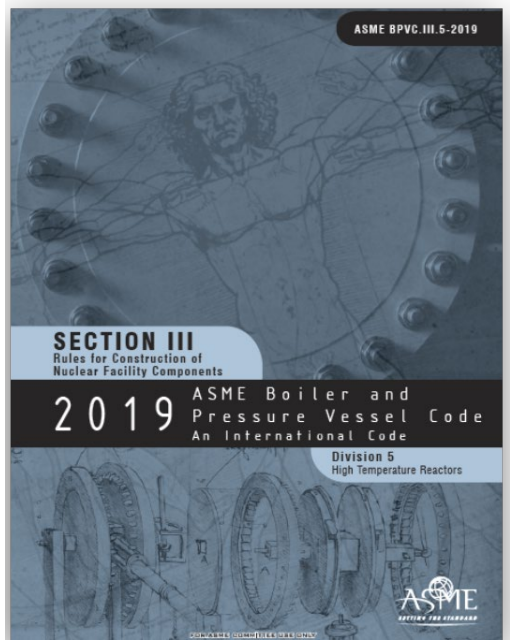
## *Advanced materials codification*

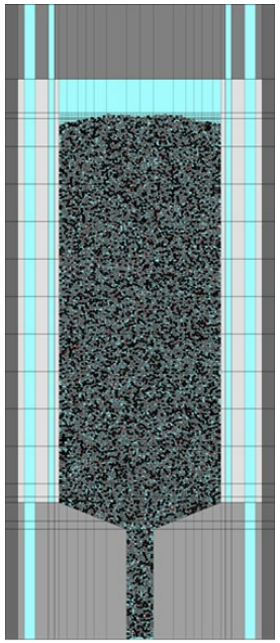
- Achieve ASME codification of alloys and design methods for high-temperature duty pressure vessel, heat exchanger, and other primary circuit components.

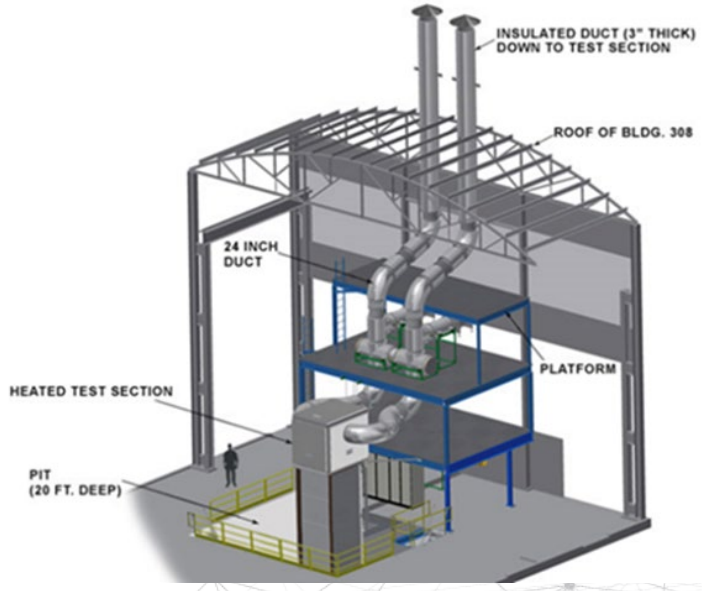
## *Experimental and simulation methods*

- Develop prismatic and pebble bed HTGR core analysis methods
- Validate codes via experiments, code-to-code benchmarks, and uncertainty analyses.



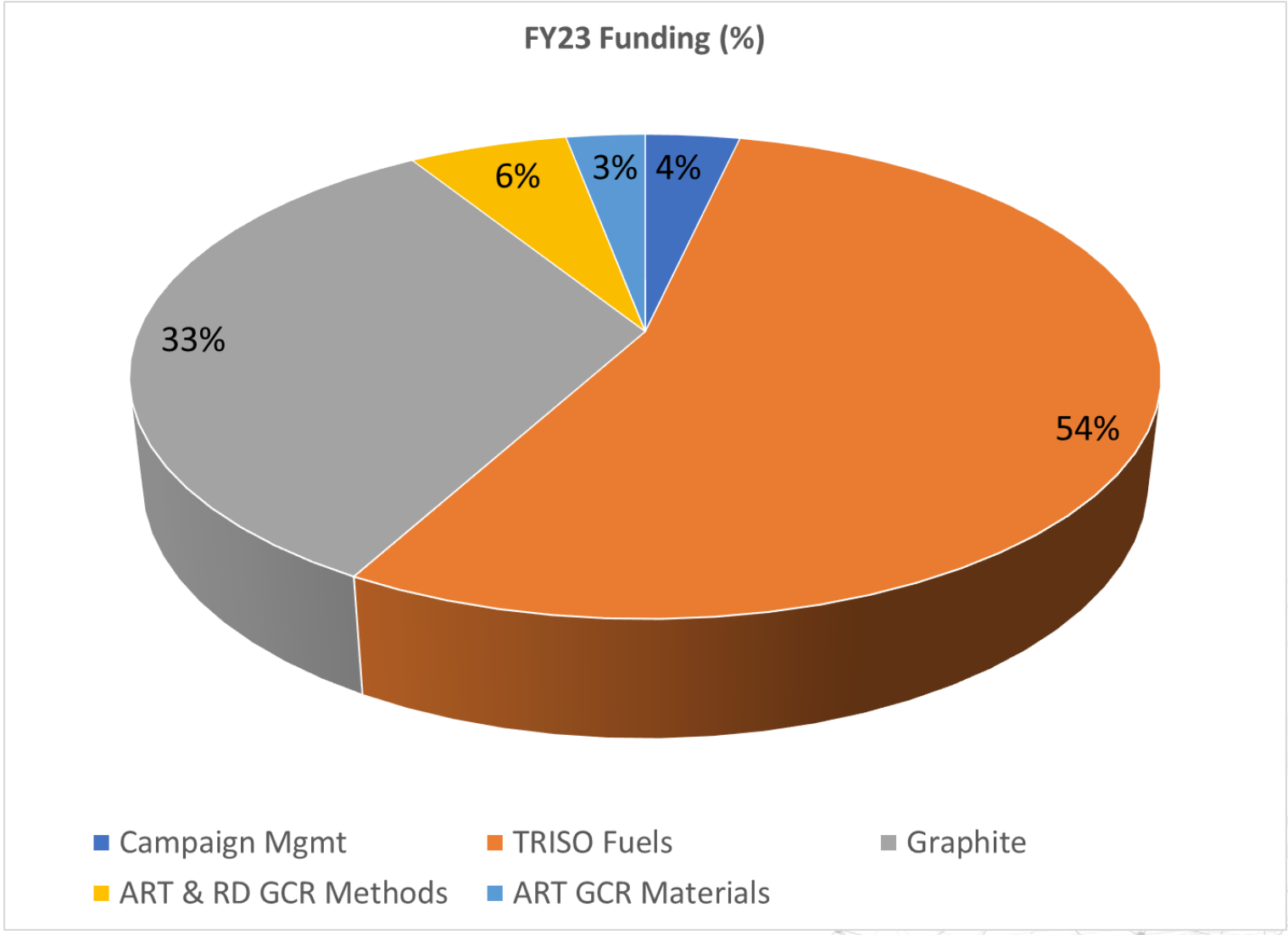





# ART-GCR FY 2023 Funding Profile

- ART-GCR is primarily a Fuel (54%), Graphite (33%) and High-Temperature Advanced Materials (3%) characterization and qualification program
- Experimental and Core Simulation Methods component (6%)



# ART-GCR: Impact and Return on 20-year DOE-NE Investment

- **Support industry interaction with the regulator during licensing activities**
  - The June 2023 joint report by the Canadian Nuclear Safety Commission (CNSC) and the US Nuclear Regulatory Commission (NRC) establishes a common regulatory position on TRISO fuel qualification.
  - The two regulators aimed to work together "*to establish a common regulatory position on TRISO fuel qualification based on existing knowledge and to identify any potential analytical or testing gaps that would need to be addressed to enable TRISO use in advanced reactor licensing applications*".
  - It reflects a major accomplishment, largely funded by a series of DOE projects (NGNP QA Program, AGR Program) in close coordination with industry (DOE-EPRI topical report), NRC (QA Program) and EPRI (topical reviews), and NRC's cooperation with CNSC.
  - This significantly reduces North American regulatory uncertainty for TRISO-fueled reactors.


https://www.nrc.gov/docs/ml2317/ml23172A242.pdf
https://www.world-nuclear-news.org/Articles/Canadian,-US-regulators-publish-joint-TRISO-report

# HTGR Core Simulation: Importance of Validation Data

*“Computational results are believed by no one, except the person who wrote the code”.*

***- Max Gunzburger***

# HTGR Core Simulation: Importance of Validation Data

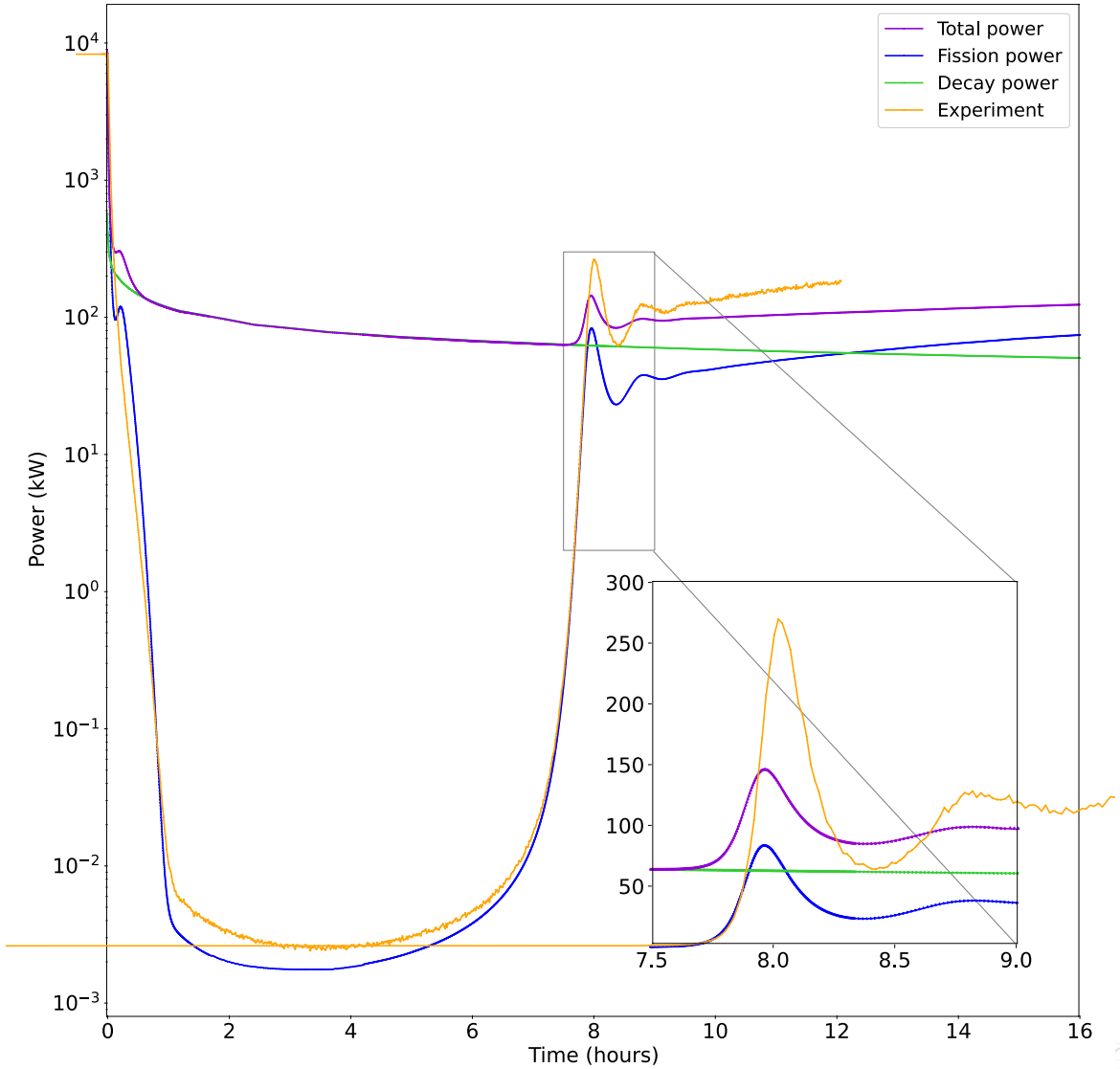
*“Computational results are believed by no one, except the person who wrote the code”.*

*“Experimental results are believed by everyone, except the person who ran the experiment”.*

***- Max Gunzburger***

# HTTR 9MW LOFC Simulation Results

- Q: What is the difference between the simulation results and the measured experimental data?

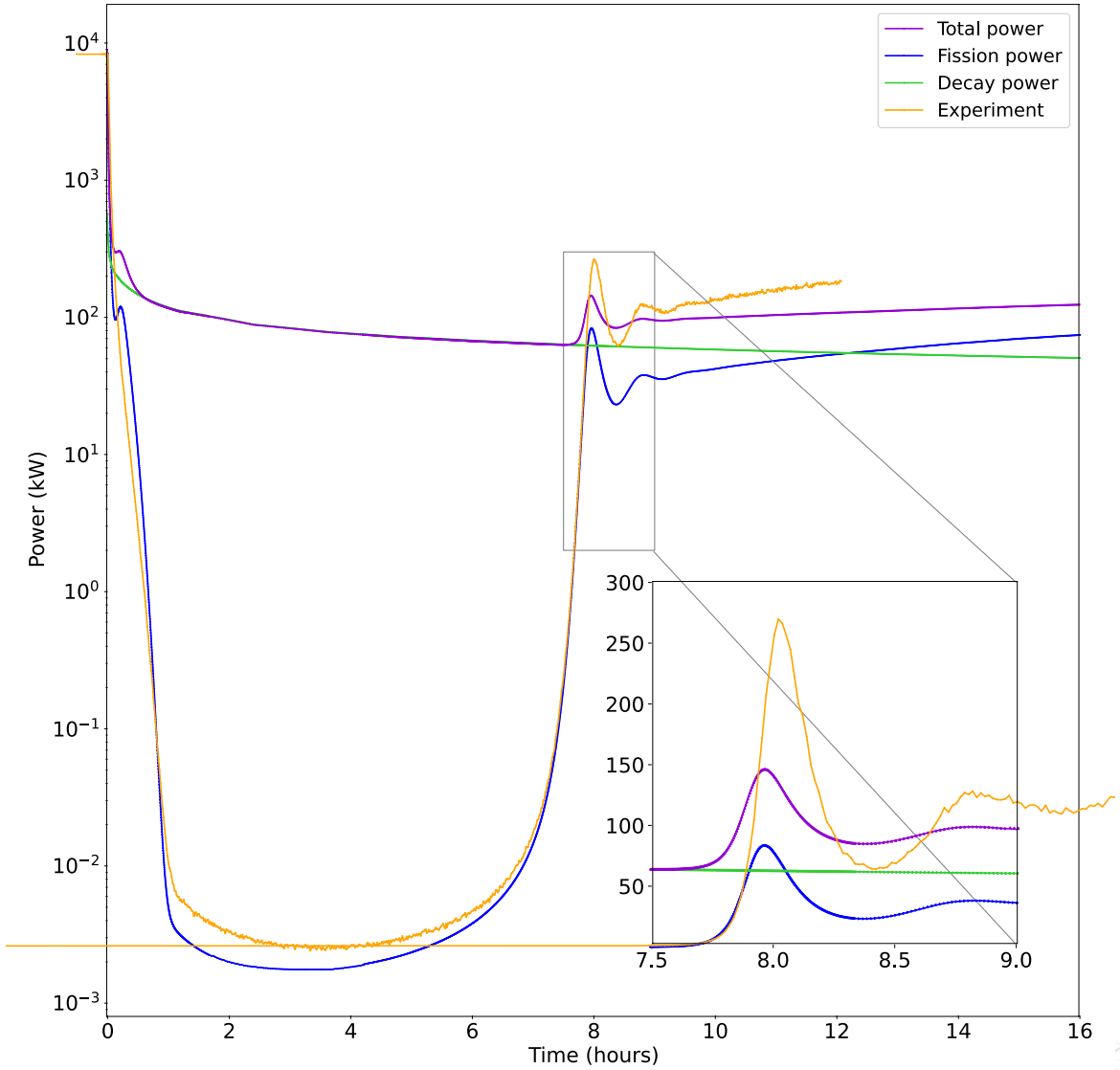





*"FY22 Status Report on the ART-GCR CMVB and CNWG International Collaborations", https://www.osti.gov/biblio/1893099*

# 9MW LOFC Simulation Results

- Q: What is the difference between the simulation results and the measured experimental data?
- A: > $100 Million



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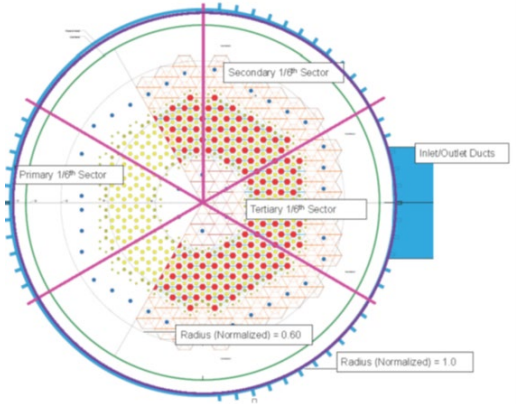
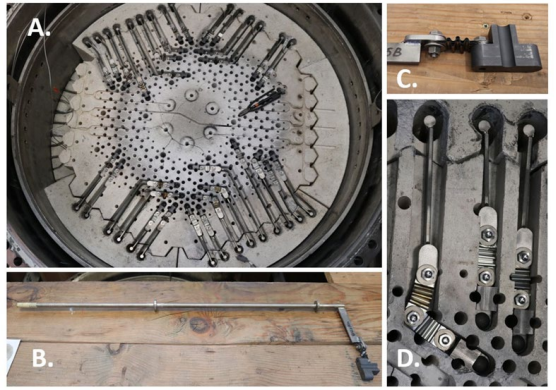
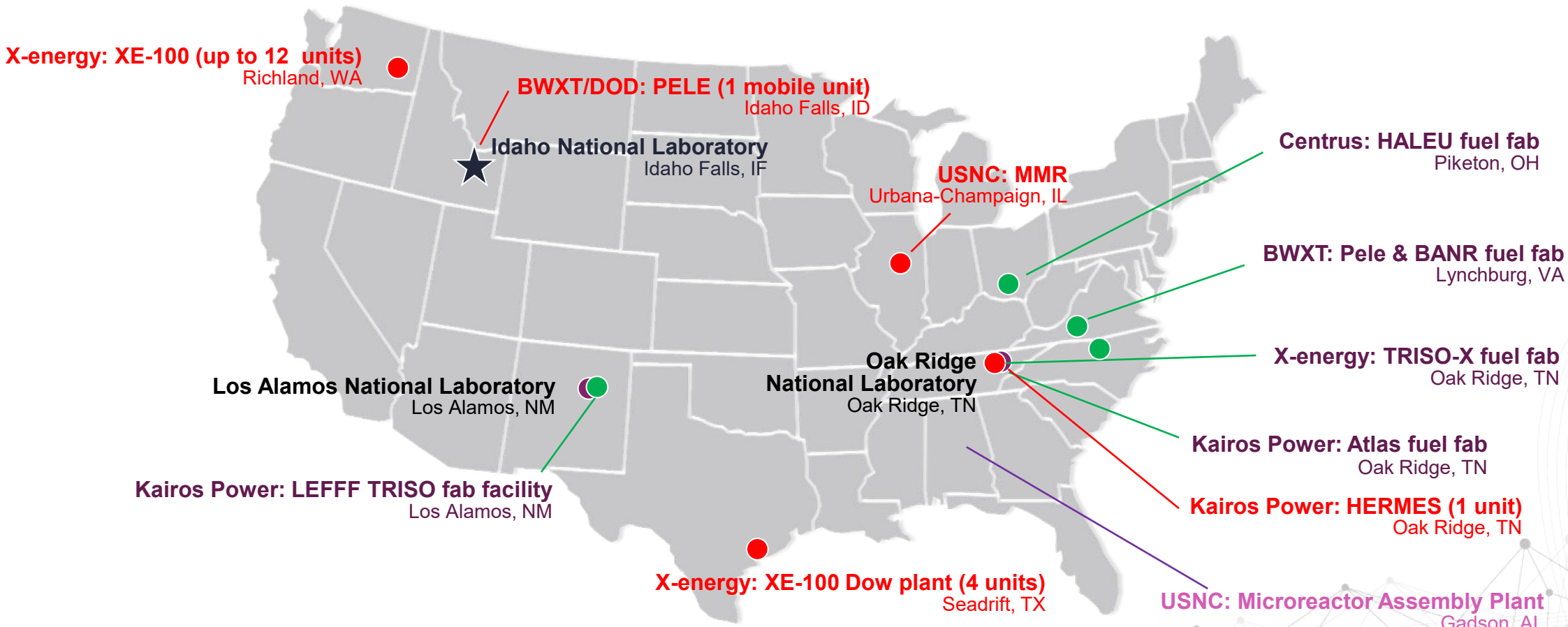
# HTGR Core Simulation: Importance of Validation Data

- ART-GCR utilize the new codes developed in the DOE-NE NEAMS program (Griffin, Pronghorn, Bison) to perform various verification and validation benchmarks
- Current efforts include the NEA HTTR LOFC and HTTF benchmarks
- International collaborations provide valuable data: (Coordinated Research Projects (IAEA), bi-lateral agreements (Civil Nuclear Working Group (CNWG) with JAEA), Generation-IV Forum (GIF)
  - Example: HTR-PM first start-up core physics benchmark shared by China within GIF VHTR Computation Methods Validation and Benchmarks (CMVB) activity.
- *Outcome:* Validated high-fidelity codes that industry can use for comparisons against legacy tools for safety, margin and uncertainty assessments



# Commercial and Demonstration Projects: Planned HTR Reactors and Fuel Fabrication Facilities

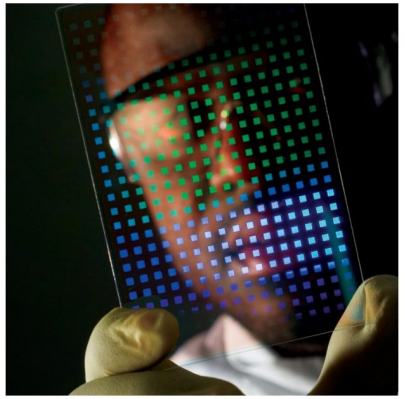


# ART-GCR Future Outlook

- Some argue we're already building & demonstrating HTR reactors; what is the continued need for tax-funded baseline program R&D?
  - Innovation of new materials, simulation codes, TRISO fuel and graphite performance does not stop because we're demonstrating HTGRs; it's just the beginning!


*"With more than $3 billion invested annually in research and development,* ***Boeing*** *drives innovation that will transform aerospace and defense as we know it".*

***DOD:*** *"The FY 2024 budget request once again includes a record investment in research, development, test, and evaluation (RDT&E) of $145 billion".*

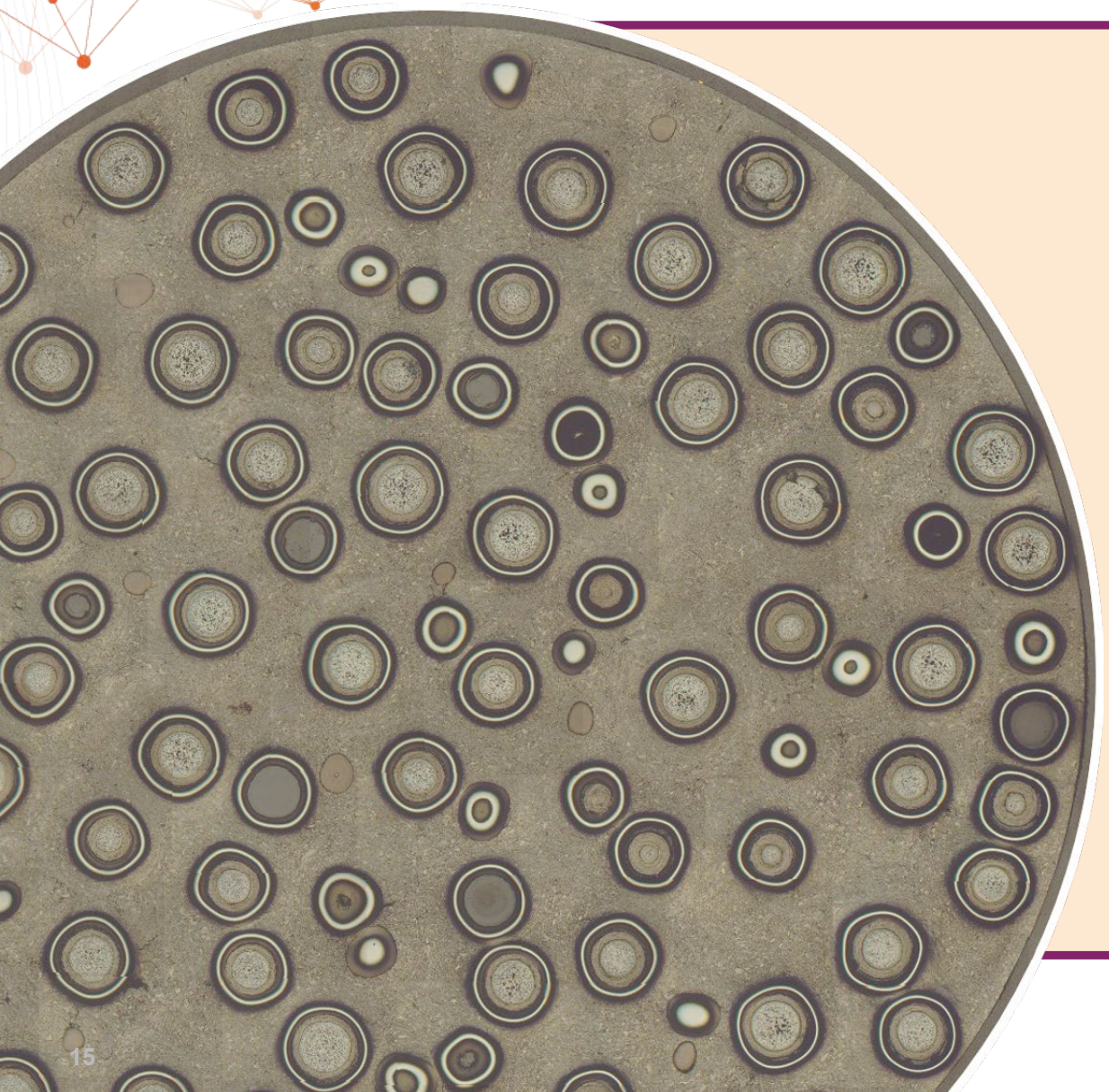


*"At* ***Corning,*** *we create an environment in R&D that enables the best scientific minds in the world to create the innovations that form the foundation of our future. We continue to reinvest approximately 10 percent of our revenues into R&D."*

DOD: https://www.defense.gov/News/Releases/Release/Article/3326875/
Boeing: https://www.boeing.com/innovation/
Corning: https://www.corning.com/in/en/about-us/news-events/resources/research-development.html

# ART-GCR Future Outlook

- **TRISO:**
  - Complete AGR-5/6/7 PIE and safety testing and compile AGR datasets for use by reactor designers
  - Assess future support of non-AGR coated fuel forms. Current AGR program and future scope will move to NE-4 in 2024.
- **Graphite:**
  - Complete high-dose graphite (HDG) experiments to provide baseline vs. irradiation performance data.
  - Continue ASME graphite codification efforts and salt-interaction assessments.
- **Advanced Materials:**
  - Qualify and incorporate Alloy 709 into the ASME Code as high temperature construction material for SFR, HTGR and MSR applications
  - Develop and implement high temperature design methodology needed for advanced reactor designs into the ASME Code
- **Core Simulation Methods:**
  - Complete NEA HTTF and HTTR LOFC Benchmarks and start GIF CMVB validation
  - NSTF at ANL: current water-based RCCS testing will end in FY25. Assessing future use of this facility (pebble bed or micro-reactor validation data support) ?



***Thank you for your attention!***

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