

GAIN

Gateway for Accelerated Innovation in Nuclear

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*Additive Manufacturing for Reactor Materials & Components
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What is the GAIN Initiative?

Gateway for Accelerated Innovation in Nuclear

What are the issues?

- Time to market is too long
- Facilities needed for RD&D are expensive
- Capabilities at government sites have not been easily accessible
- Technology readiness levels vary
- Some innovators require assistance with regulatory processes

What do we need to do?

- Provide nuclear innovators and investors with single point of access into DOE complex
- Provide focused research opportunities and dedicated industry engagement
- Expand upon DOE's work with Nuclear Regulatory Commission (NRC)

What is the DOE initiative?

- Private-public partnership, dedicated to **accelerating** innovative nuclear energy technologies **time to market**

DOE recognizes the magnitude of the need, the associated sense of urgency and the benefits of a strong and agile private-public partnership in achieving the national goals.

GAIN Vision

By 2030,

The U.S. nuclear industry is equipped to lead the world in development of innovative nuclear technologies to supply urgently needed abundant clean energy both domestically and globally.

GAIN is,

A private-public partnership framework aimed at rapid and cost-effective development of innovative nuclear energy technologies towards market readiness.

GAIN Mission

Mission:

Provide the nuclear energy industry with access to technical, regulatory and financial support necessary to move innovative nuclear energy technologies toward *commercialization* in an accelerated and cost-effective fashion

GAIN is:

The organization principle for relevant, federally-funded nuclear energy RD&D programs.



TRISO Fuel Particle

Where is nuclear innovation needed?

Advanced Reactor Concepts (engineering, licensing, construction, advanced fuels/materials, modular designs, fuel cycle research, etc.)

Components (cables, materials, etc.)

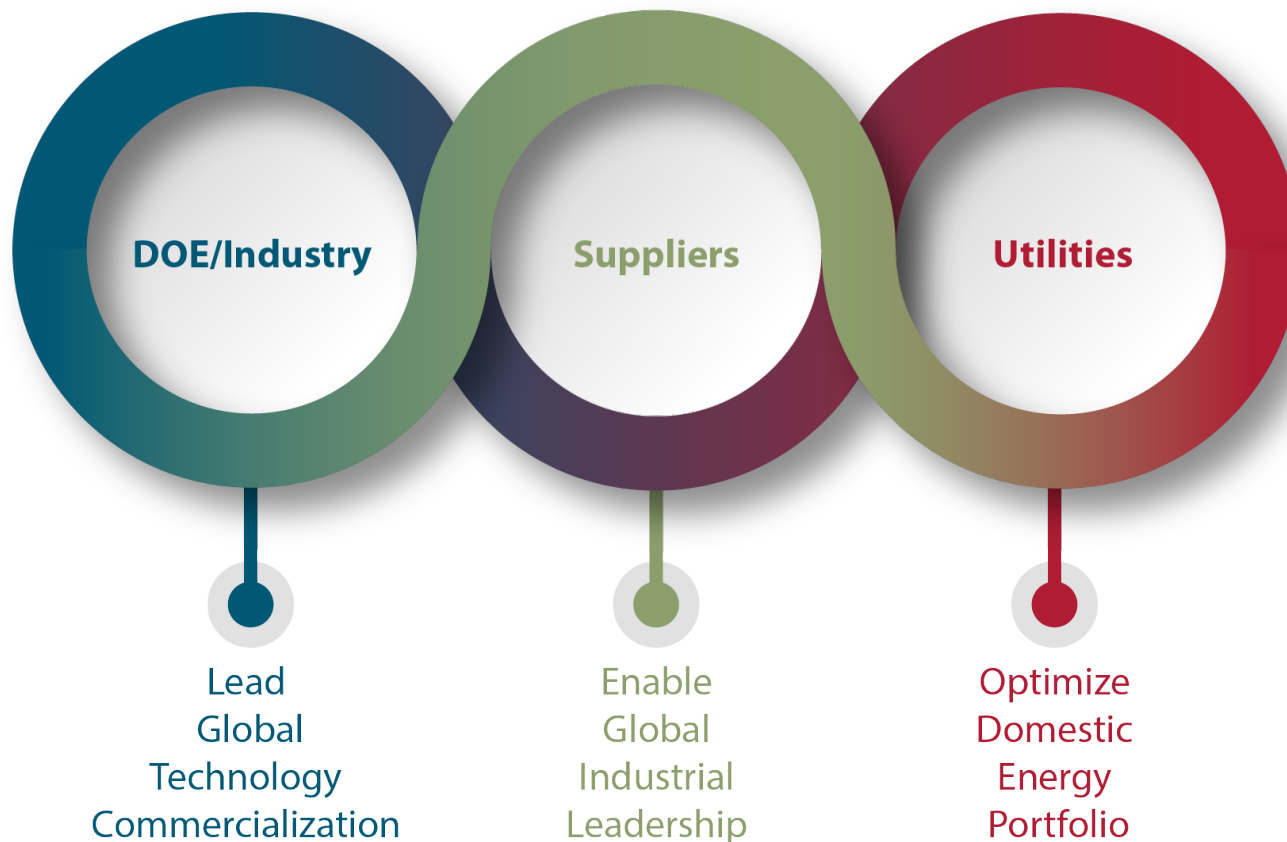
Advanced Methods & Processes

Collaboration (vision driven, trust, learning, etc.)

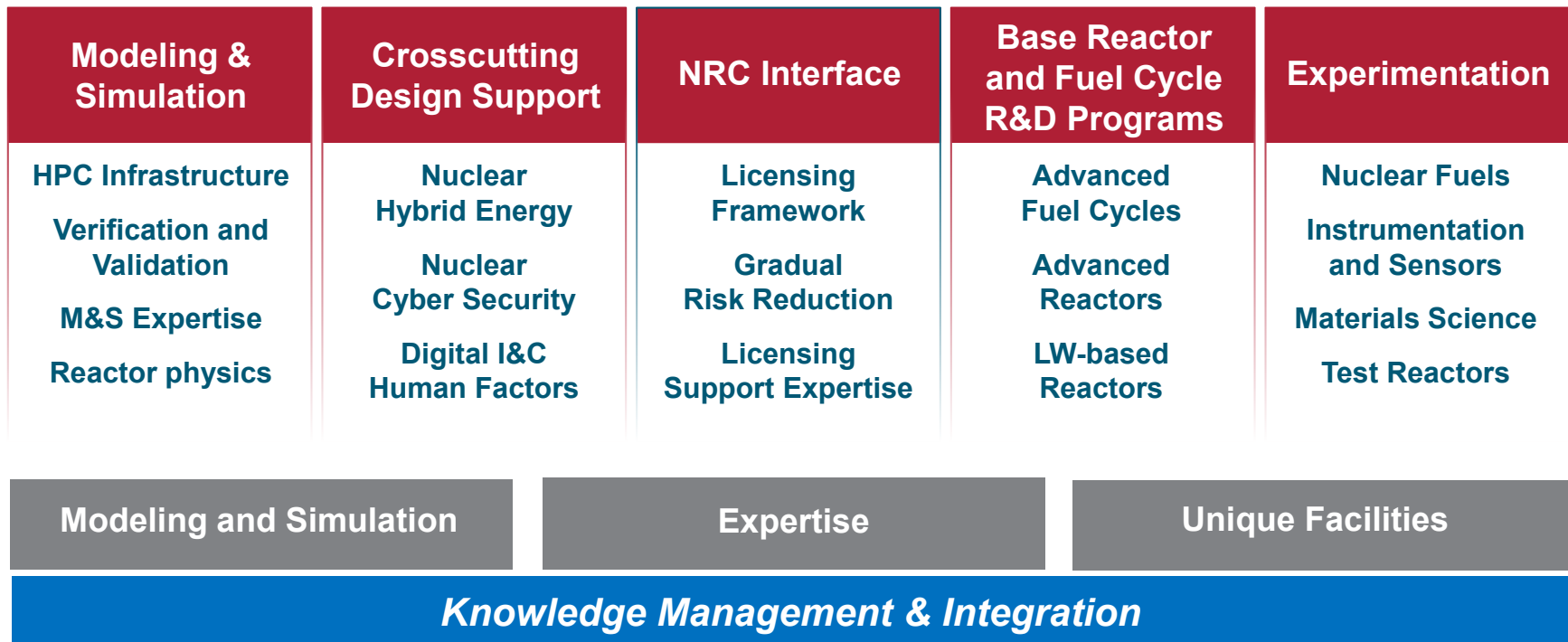
Safety / Security (Cyber, digitization, control room mods, inspection techniques, passive safety features, etc.)

GAIN Initiative: Simultaneous Achievement of Three Strategic Goals

STRATEGIC GOALS



GAIN: Connecting nuclear innovators to DOE laboratory capabilities and RD&D programs



– GAIN –

Industry and investor access to DOE capabilities and expertise

2016 NE Voucher recipients	Proposal	Partner Facility
Creare LLC Hanover, NH	Investigation of Materials for Continuous Casting of Metallic Nuclear Fuel	Idaho National Laboratory
Columbia Basin Consulting Group, LLC Kennewick, WA	Lead-Bismuth Small Modular Reactor (SMR) Licensing Development	Pacific Northwest National Laboratory
Terrestrial Energy USA Ltd. New York, NY	Verification of Molten-Salt Properties at High Temperatures	Argonne National Laboratory
Transatomic Power Corporation Cambridge, MA	Optimization and Assessment of the Neutronics and Fuel Cycle Performance of the Transatomic Power Molten Salt Reactor Design	Oak Ridge National Laboratory
Ceramic Tubular Products Rockville, MD	Robust Silicon Carbide Cladding for LWR Application - Corrosion and Irradiation Proof Test of Low Cost Innovations in MIT Research Reactor	Massachusetts Institute of Technology
Oklo Inc. Sunnyvale, CA	Legacy Metal Fuel Data Exploration for Commercial Scale-Up	Argonne National Laboratory/Idaho National Laboratory
CompRex, LLC De Pere, WI	High Efficiency Heat Exchanger for High Temperature and High Pressure Applications	Argonne National Laboratory
BgtL LLC Laramie, WY	High efficiency and low cost thermal energy storage system	Argonne National Laboratory

GAIN NE Voucher Recipient	Title	Partner Facility
AMS Corp. Knoxville, TN	Radiation Aging of Nuclear Power Plant Components	ORNL
Columbia Basin Consulting Group LLC Kennewick, WA	Methodology for Meeting Containment System Principal Design Criteria for Heavy Metal Fast Reactor Systems	PNNL
DYNAC Systems LLC Del Mar, CA	Dynamic Natural Convection System	INL
Elysium Industries Clifton Park, NY	Synthesis of Molten Chloride Salt Fast Reactor Fuel Salt from Spent Nuclear Fuel	INL / ANL
Fauske & Associates LLC Burr Ridge, IL	Development of an Integrated Mechanistic Source Term Assessment Capability for Lead- and Sodium- Cooled Fast Reactors	ANL
GSE Systems Inc. Sykesville, MD	Human Factors Engineering for the Move to Digital Control Systems – Improved Strategies for Operations	INL
Kairos Power LLC Oakland, CA	NEAMS [Nuclear Energy Advanced Modeling and Simulation] Thermal-Fluids Test Stand for Fluoride- Salt-Cooled, High-Temperature Reactor Development	ANL / INL
MicroNuclear LLC Franklin, TN	Development of the Microscale Nuclear Battery Reactor System	INL
Muons Inc. Batavia, IL	Conversion of Light Water Reactor Spent Nuclear fuel to Fluoride Salt Fuel	ORNL
NuVision Engineering, Inc. Pittsburgh, PA	Evaluation of Power Fluidic Pumping Technology for Molten Salt Reactor Applications	ORNL
Oklo Inc. Sunnyvale, CA	Risk-Informed Mechanistic Source Term Calculations for a Compact Fast Reactor	SNL/ANL
SMR Inventec LLC Camden, NJ	Small Modular Reactor-160 Primary Flow Stability	ORNL
Terrestrial Energy USA Ltd. New York, NY	IMSR® [Integral Molten Salt Reactor] Fuel Salt Property Confirmation: Thermal conductivity and Viscosity	ANL
Transatomic Power Corporation Cambridge, MA	Fuel Salt Characterization	ANL



FY 2017 NE Vouchers:

- 41 Letters of Intent
- 32 Voucher requests submitted
- 25 separate small businesses
- 9 “returnees”
- 16 new businesses compared to the 2016 pilot
- ~\$4.2M awarded to 14 small businesses

GAIN TECHNOLOGY WORKING GROUPS (TWG)

Molten Salt Reactor

Duke Energy	Charlotte, North Carolina
Elysium Industries	Boston, Massachusetts
Exelon Corporation	Chicago, Illinois
Flibe Energy, Inc.	Huntsville, Alabama
Southern Company	Birmingham, Alabama
TerraPower, LLC	Bellevue, Washington
Terrestrial Energy USA Ltd.	New York, New York
ThorCon USA	Stevenson, Washington
Transatomic Power Corporation	Cambridge, Massachusetts

High Temperature Gas Reactor

AREVA NP, Inc.	Lynchburg, Virginia
BWX Technologies, Inc.	Lynchburg, Virginia
Duke Energy	Charlotte, North Carolina
Kairos Power	Oakland, California
StarCore Nuclear	Montreal, Canada
X-Energy, LLC	Greenbelt, Maryland

Fast Reactor

Advanced Reactor Concepts, LLC	Chevy Chase, Maryland
Columbia Basin Consulting Group, LLC	Kennewick, Washington
Duke Energy	Charlotte, North Carolina
Elysium Industries	Boston, Massachusetts
Exelon Corporation	Chicago, Illinois
General Atomics	San Diego, California
General Electric-Hitachi	Wilmington, North Carolina
Hydromine, Inc.	New York City, New York
Oklo, Inc.	Sunnyvale, California
Southern Company	Birmingham, Alabama
TerraPower, LLC	Bellevue, Washington
Westinghouse Electric Co., LLC	Cranberry Township, Pennsylvania

Note: GAIN, DOE NTDs, EPRI and NEI participate in all of the TWG teams

TWGs Solicited for RD&D Needs

- Not all advanced reactor technologies are equally mature, and therefore have different RD&D priorities, as well as material needs

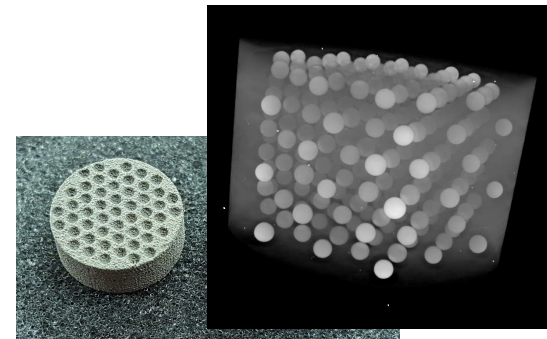
R&D

- Fuels, materials, chemistry
- T-H and safety testing
- Validation of analysis methods
- Advanced modeling & simulation tools

Other

- Vendor development for nuclear grade components
- Reserve of high-assay LEU

- Structures
 - Graphite, ferritic martensitic (HT-9),
- Fuel
 - TRISO, metal (U / U-Pu-Zr), others?
- Cladding
 - SiC composites, FeCrAl
- Components
 - Valves, grids, pipes
- Demonstration of production, characteristics, and irradiation performance all needed to bring these materials / components to market



K. Terrani (ORNL)

Where can GAIN Assist in Additive Manufacturing?

Modeling and Simulation

- *Fundamental (small and macroscale) mod-sim of key phenomena e.g., creep*
- *Materials feedback on performance (neutronics, fuel performance, CFD, chemistry, etc)*
- *Computer-based learning for process optimization & material qualification*

Expertise

- *Material science*
- *Material performance needs*
- *Process development*
- *Material qualification*
- *Licensing*
- *Codes and standards*
- *Experimental design and testing*

Unique Facilities

- *Fuel manufacturing*
- *Material production*
- *Additive manufacturing demonstration facilities*
- *Material properties and characterization*
- *Irradiation testing*
- *Post irradiation examination*

Knowledge Management & Integration
(including business vouchers, TWGs, workshops....)

– **GAIN** –

*Industry and investor access to
DOE capabilities and expertise*

Nuclear Science User Facilities Provides Access to Unique Facilities Dedicated to Material Science

- Provide irradiation (test reactor), PIE, modeling and simulation
- Co-existence and collaboration with GAIN Initiative
 - GAIN “customers” directed to NSUF as appropriate
 - Advanced nuclear industry needs communicated to NSUF
 - NSUF offers fundamental materials science capability (lower TRL) to support current and advanced reactors
- Awarded Projects on Advanced Manufacturing
 - Enhancing Irradiation Tolerance of Steels via Nanostructuring by Innovative Manufacturing Techniques
 - Irradiation Performance Testing of Specimens Produced by Commercially Available Additive Manufacturing Techniques Irradiation Testing of LWR Additively Manufactured Materials Radiation Effects on Zirconium Alloys Produced by Powder Bed Fusion Additive Manufacturing Processes
 - Additive manufacturing of thermal sensors for in-pile thermal conductivity measurement
 - Radiation Effects on Optical Fiber Sensor Fused Smart Alloy Parts with Graded Alloy Composition Manufactured by Additive Manufacturing Processes

Future Activities 2017-2018

Workshops:

- Enabling Advanced Reactors for the Market: March 8-9, 2018
- Molten Salt Reactor Workshop: October 3-4, 2018
- Gap Analysis on Standards and Codes needed for Advanced Reactors
- Follow-on modeling and simulation workshops/demonstrations: TBD
- Advanced Manufacturing: TBD

Database/catalog:

- Develop a list of historical advanced-reactor documents to support knowledge transfer; facilitate access to key documents through OSTI
- Develop and initiate the process to remove AT designation on high priority documents requested by industry

Networking:

- Create directory of advanced nuclear developers



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