One Career in Physics

By
Dr. Christina Back
Vice President
Nuclear Technologies and Materials

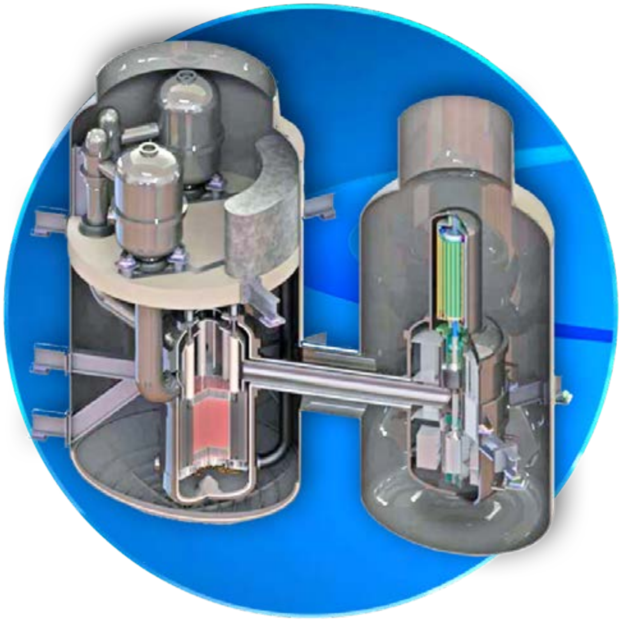
Presented to
Yale Physics Professional Development

27 April 2017

Planning a Career ?

Here's what got me interested

Here's what I am doing

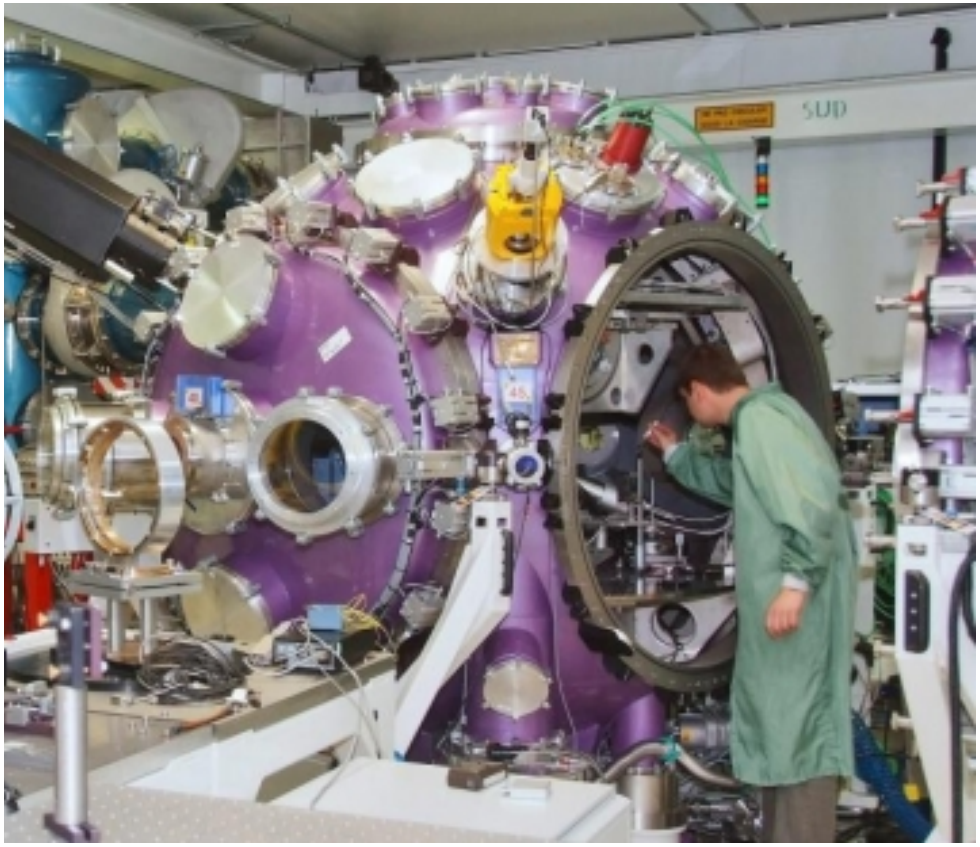


Professional Background

- **1984: Yale, B.S.**
- **1989: Univ. of Florida, Ph.D. plasma physics**
- **1992: Ecole Polytechnique, France**
  Post-doc
- **2005: Lawrence Livermore National Lab**
  Physicist
- **2009: General Atomics - Fusion**
  Program leader HED
- **2014: General Atomics – Fission**
  Division director
  Vice president

Ecole Polytechnique – Fusion

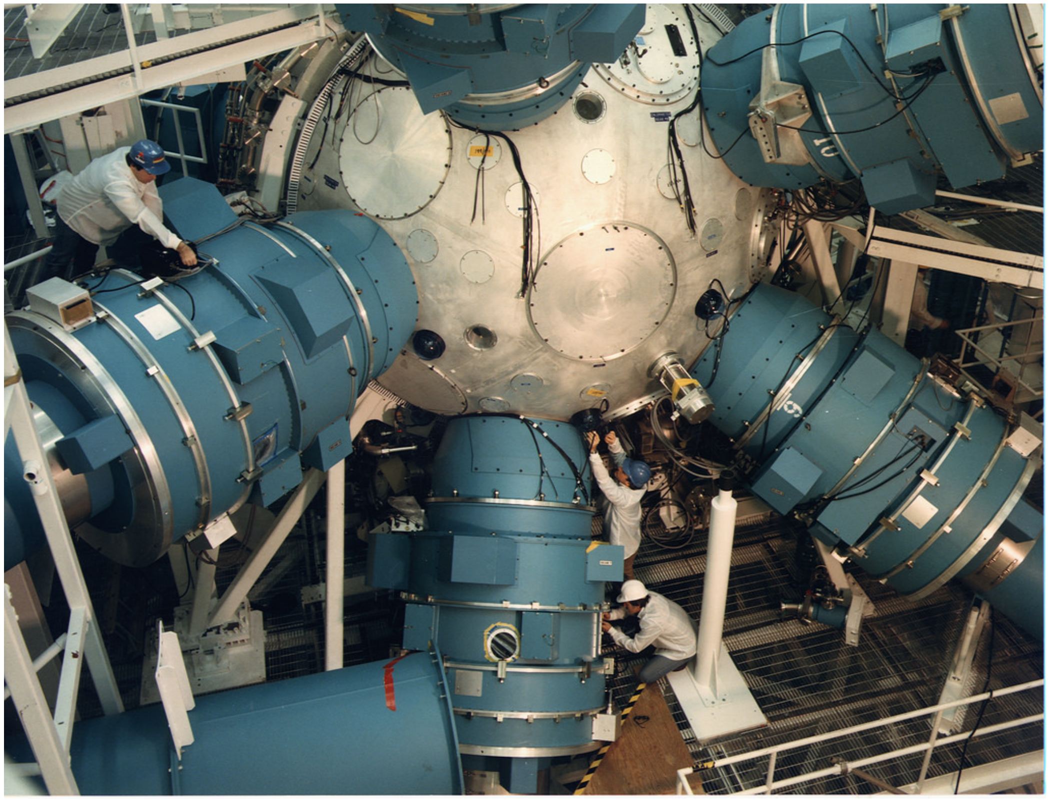
- **Attache de recherche – ”post-doc”**
- **Contributions**
  - R&D on laser-produced plasmas
  - Development of spectoscopic diagnostics
  - Plasma characterization for x-ray lasers



- **Career satisfaction**
  - Doing my own experiments
  - Working in a new environment

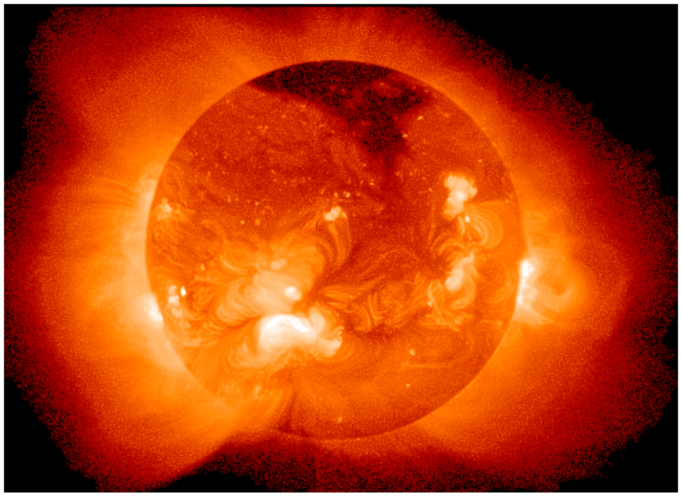
LLNL - Fusion

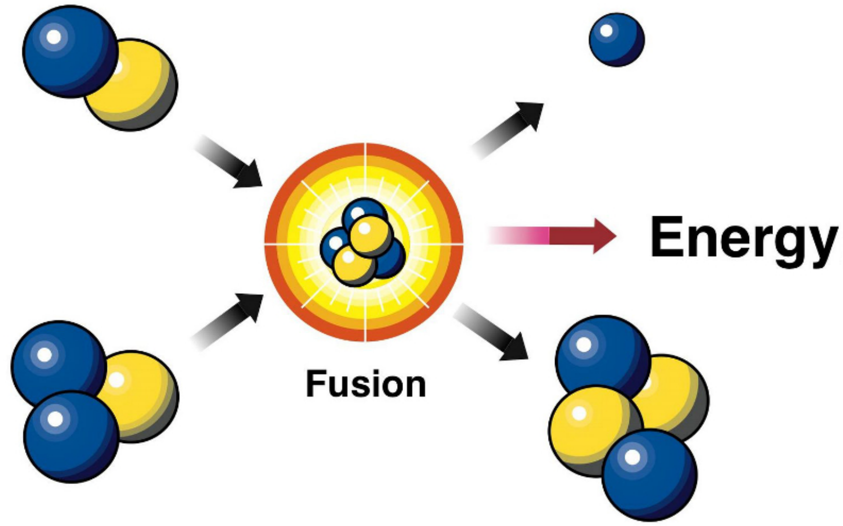
- **Experimental physicist**
- **Contributions**
  - Research papers
    - High-energy density plasmas research, Radiation transport, X-ray sources
    - Fusion – hohlraums
  - X-ray diagnostics
  - Stockpile stewardship
- **Career satisfaction**
  - Experimental work on high-powered lasers
  - APS Fellow 2004



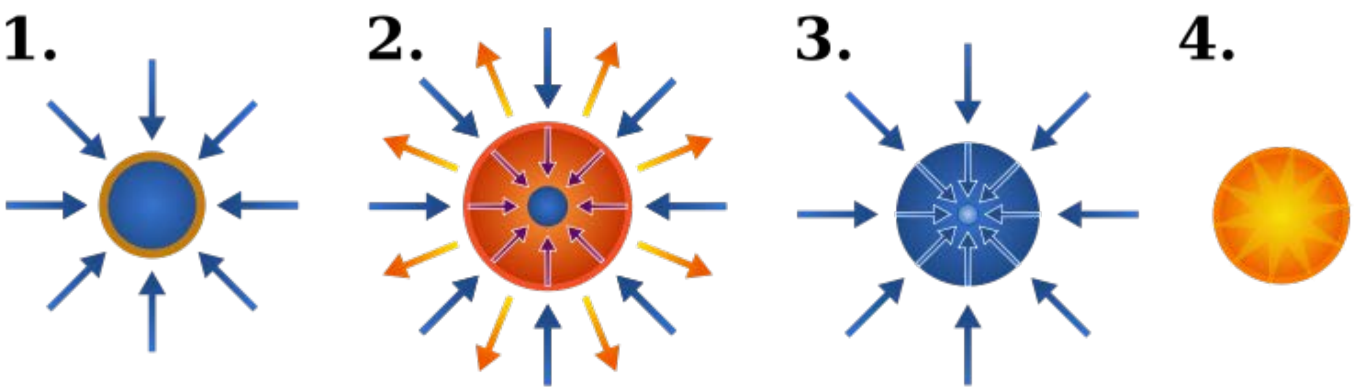
Fusion Energy is Making Energy Like the Sun

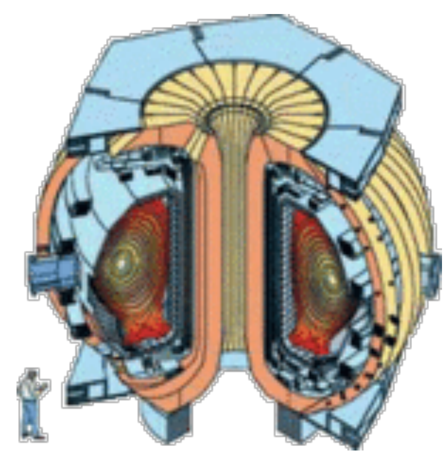
- In Nature





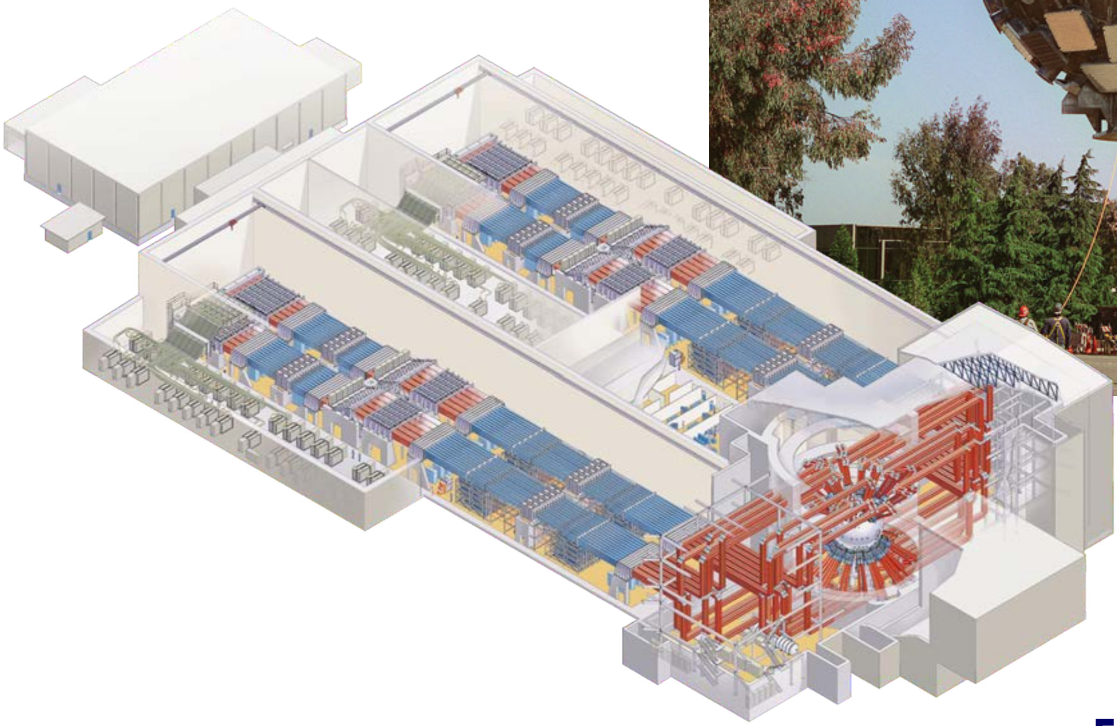
- In the Laboratory





National Ignition Facility Uses 192 Laser Beams To Compress a Capsule to Make Fusion in the Lab

NIF Building Layout is the size of 3 football stadiums



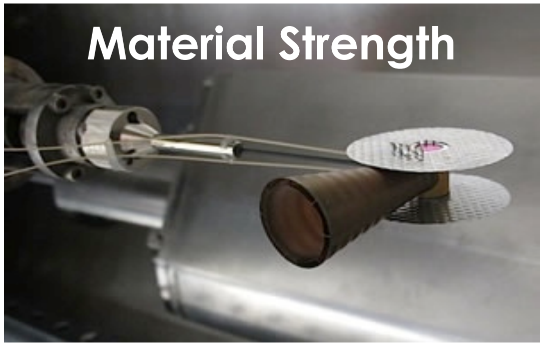
Chamber is 10 m in diameter

Fuel is deuterium and tritium atoms
Target is 1 cm long

GENERAL ATOMICS

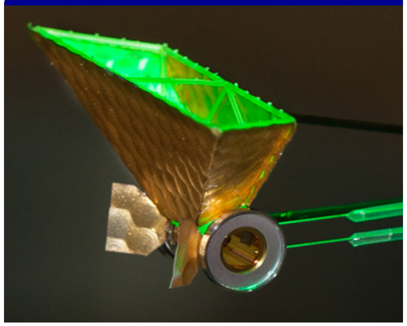
General Atomics - Fusion

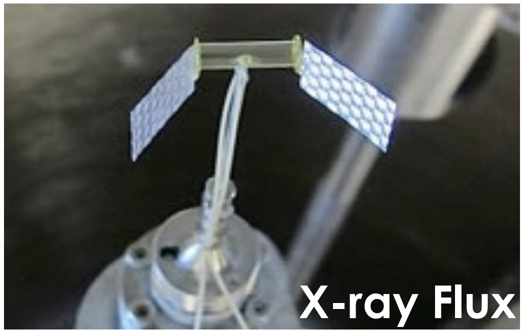
- **Program leader**
- **Contributions**
  - Established high energy density program
  - Managed budget, operations
  - Business development
    - Expansion into new R&D areas
    - Development of new "customers" (National Labs)
- **Career satisfaction**
  - Direction of group/funds
  - Responsibility for a budget
  - Growth of division



Radiation Transport

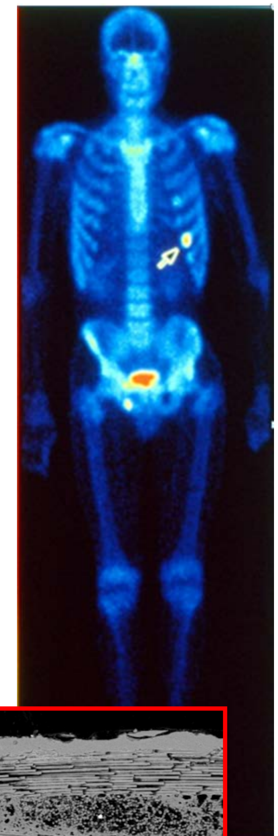
Gbar Shock



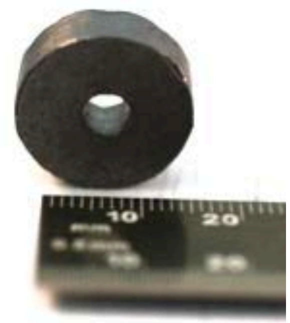


General Atomics – Fission

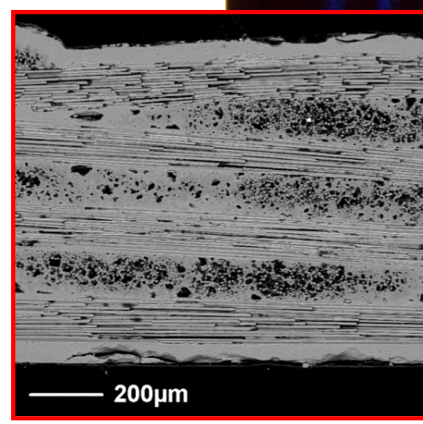
- **Project leader / Division leader / Vice President**
- **Contributions**
  - Established EM^2, Accident Tolerant Fuel
  - Revived medical isotope project
  - Revitalized division
  - Broader new business development "real" customers
  - Involved in strategy of the company
- **Career satisfaction**
  - Creating a culture of R&D and innovation
  - Growing a project/lab from zero
  - Expanding into a new field (scary !)



medical isotopes



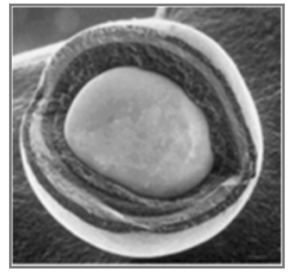
fuel pellet



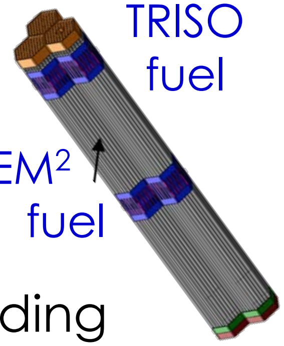
SiC-SiC composite

GA Has a Strong Commitment to Advance Nuclear Technologies and Materials

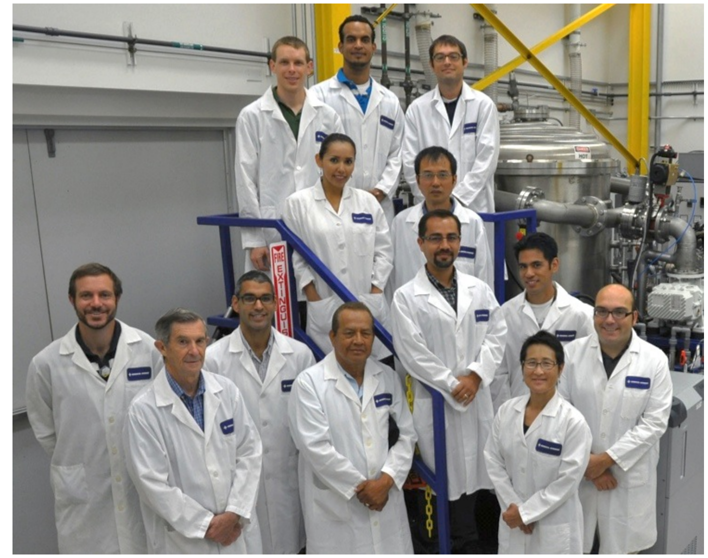
- Developing gas-cooled reactors & advanced LWR (SiC_β-SiC_β cladding)
- Substantial investment in people & equipment for fabrication
- Involvement in nuclear energy, including mining, U_3O_8 supply and UF_6 conversion



TRISO fuel

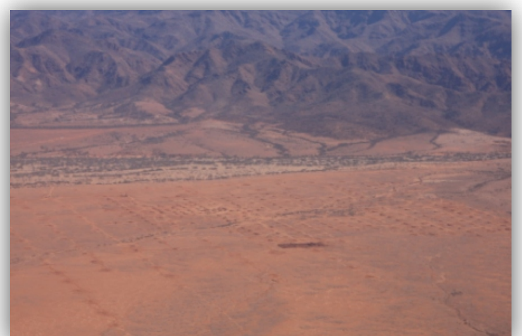


EM^2 fuel



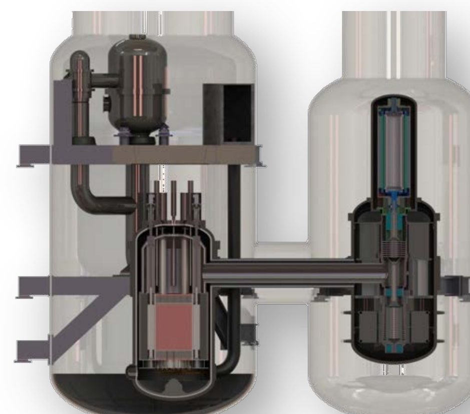
Fuel fabrication team

TRIGA Reactor



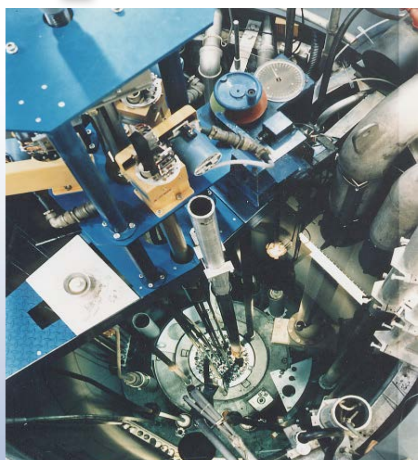
Heathgate Resources

Nuclear Fuels Corp.



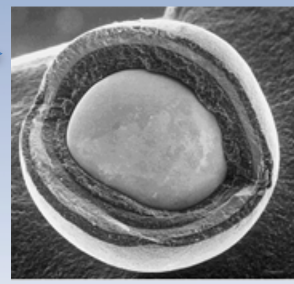
EM^2 reactor

60+ Years of Innovative Fission Research and Development



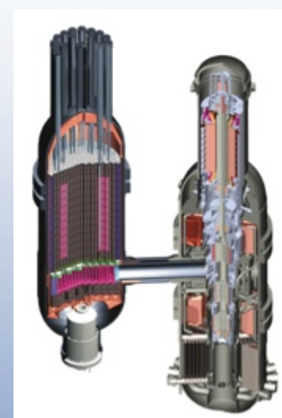
TRIGA Mark I
1958 at GA

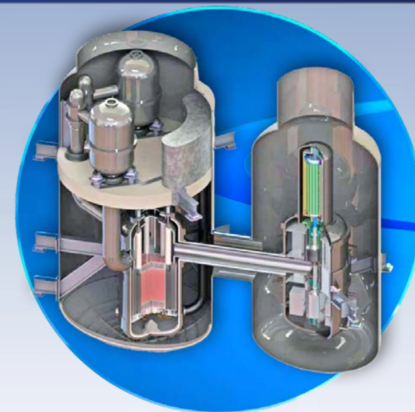
Peach Bottom 1966
He-cooled



Ft. Saint Vrain
1973
TRISO fuel

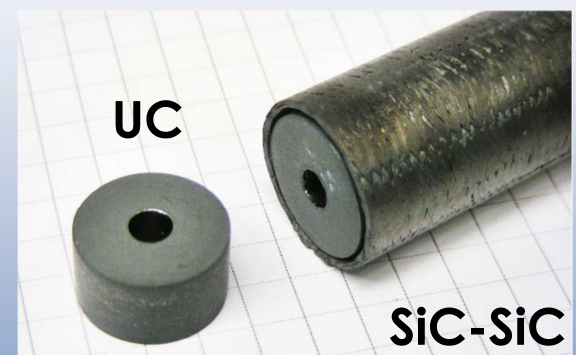
GT-MHR 1990s
Gas turbine





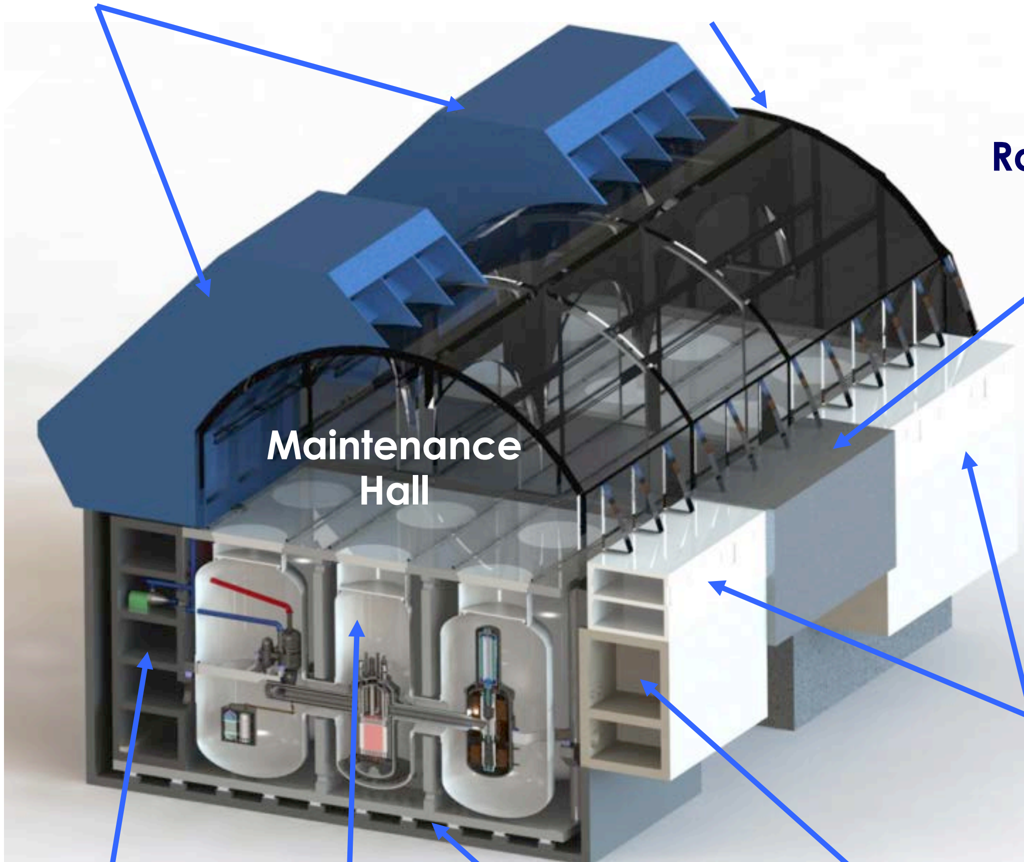
EM^2 2009
He-cooled
fast gas
reactor
concept

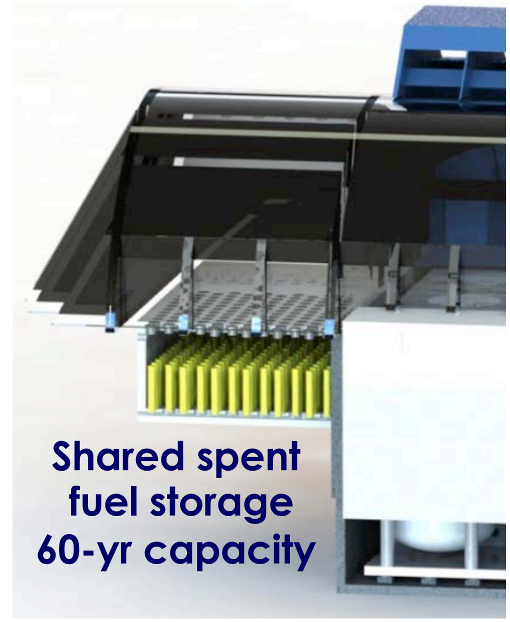
Technologies address 4-core challenges:
- Safe
- Less waste
- Competitive cost
- Non-proliferation

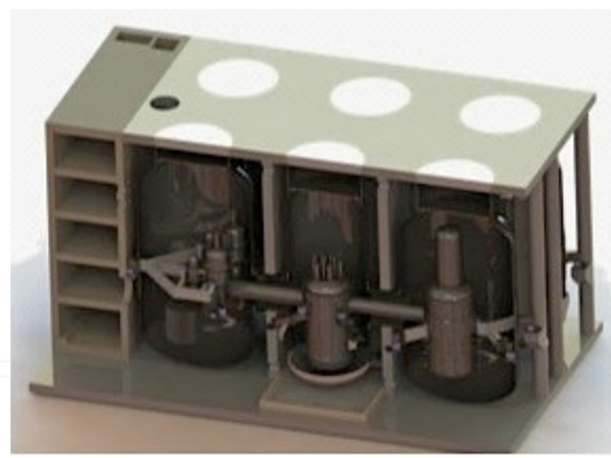


GENERAL ATOMICS

General Atomics Is Developing the Energy Multiplier Module, a Gas-Cooled Reactor



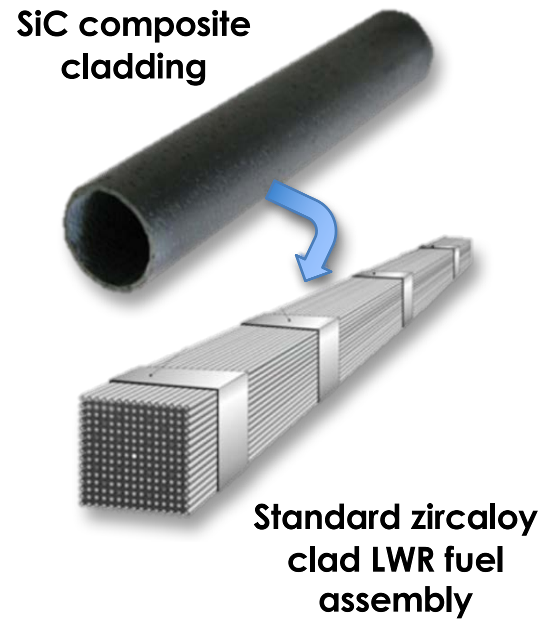




Installation module with 2 reactor systems on a seismic isolation platform

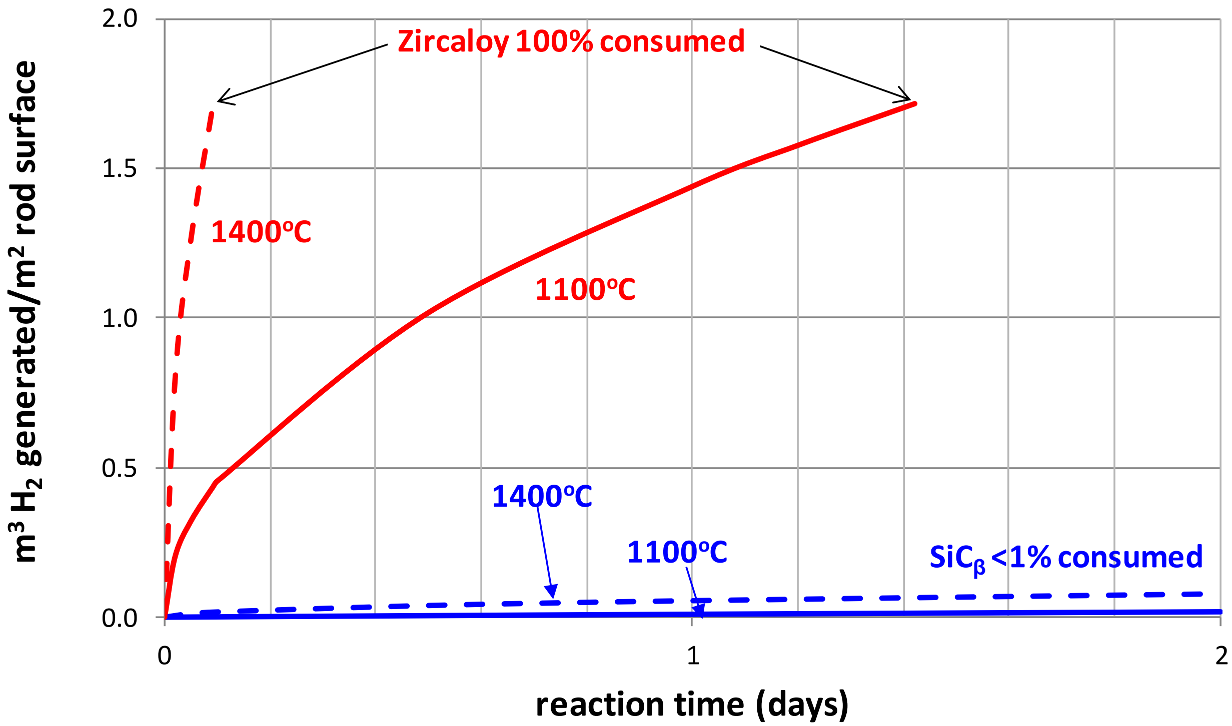
Because of Fukushima, the Nuclear Industry Is Seeking Safer Alternatives

Develop SiC composite cladding for LWRs and advanced reactors



- **Greatly improved safety and investment protection**
  - Prevents fuel failure during severe accidents
- **Increased power generation**
  - Enables up to 5% power uprate in existing plants
- **Increased refueling interval**
  - Increases refueling interval from 18 to 24 months
- **Higher burnup**
  - Lower fuel cost; less waste generated per kWe

SiC-SiC Composite Cladding Has Potential to Significantly Improve Light Water Reactor Safety



Eliminate hydrogen explosions

$Zr + 2H_2O \rightarrow ZrO_2 + 2H_2$

For Zircaloy, destruction by steam reaction occurs at lower temp than fuel melt

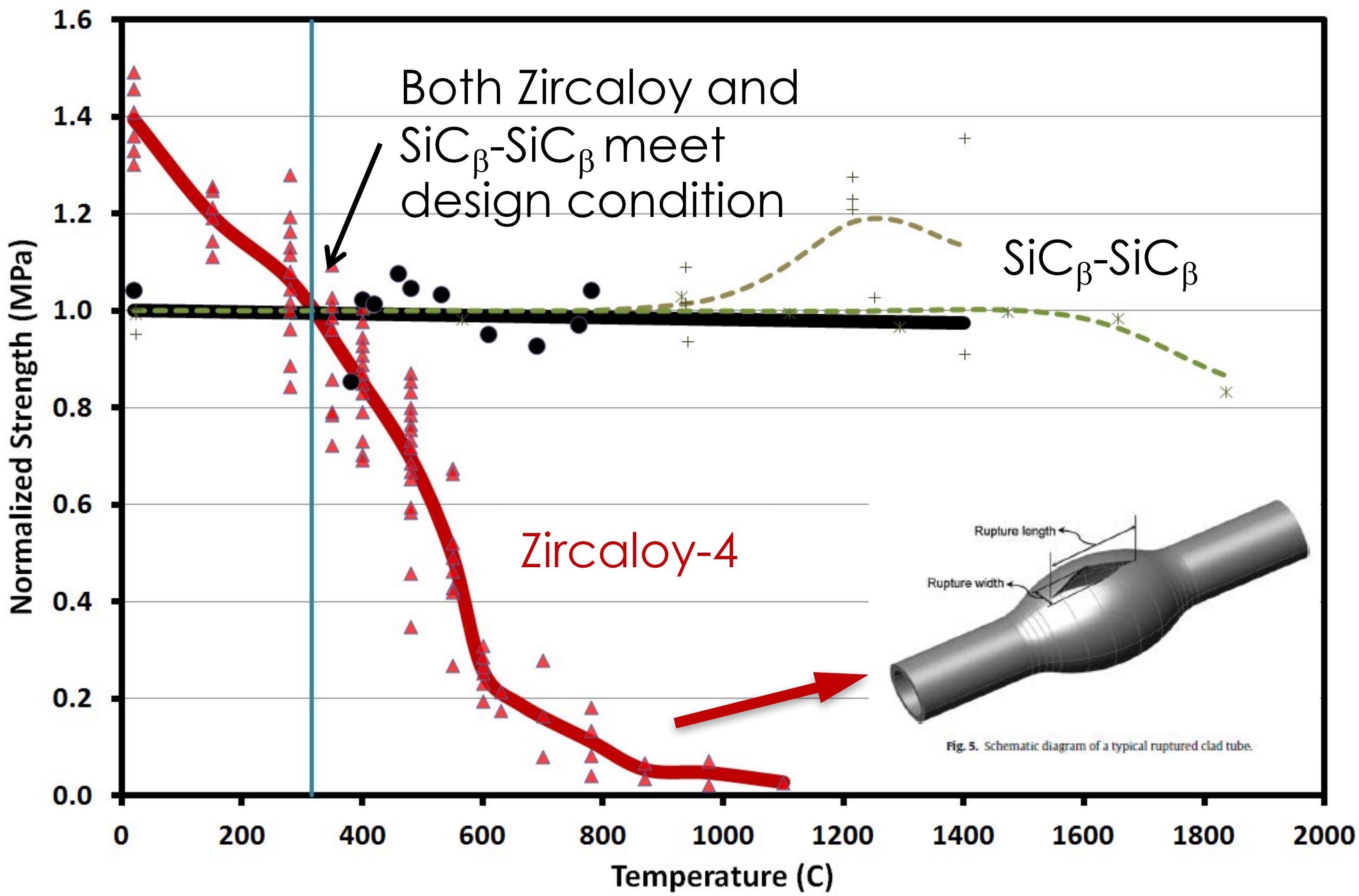
$SiC + 4H_2O \rightarrow SiO_2 + CO_2 + 4H_2$

For SiC-SiC, structural failure occurs at lower temp than steam reaction

At higher temps (~1400°C) Zircaloy reaction heat exceeds decay heat

SiC-SiC Has Superior High Temperature Strength Compared to Zircaloy

- **SiC-SiC composites can hold fission gas pressure beyond 1500°C and shape beyond 2000°C**
- **Zircaloy shows ~90% drop in strength at 800°C**



SiC-SiC composites maintain mechanical properties at high temperatures

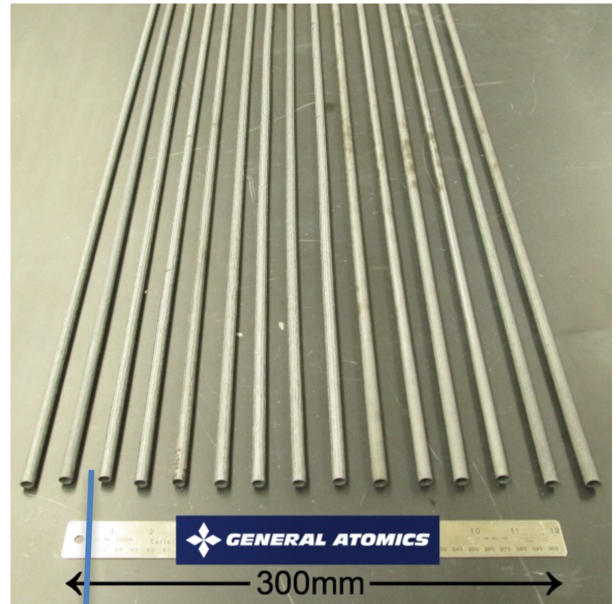
- **Strength**
- **Stiffness**
- **Toughness**

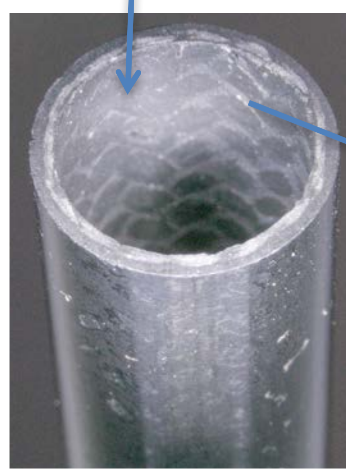
Geelhood, et al., PNNL-17700 (2008)
Gulden, J. Amer. Ceram. Soc. (1969)
Katoh, et al., J. Nuc. Mat. (2010)
Hironaka, et al., J. Nuc. Mat. (2002)
Hasegawa, et al., J. Nuc. Mat. (2000)
Snead, et al., J. Nuc. Mat. (2007)

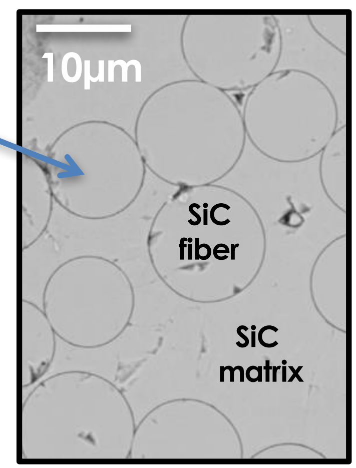
GA Is Developing SiC-SiC Composites in Support of the DOE Accident Tolerant Fuel Program

- **SiC-SiC composites offer**
  - High temperature strength
  - Superior Irradiation-resistance
  - Excellent neutronic properties
- **Benefits for LWRs**
  - Retains strength to 2000°C
  - No generation of explosive hydrogen in oxidation of metal
- **Benefits for Advanced Reactors (EM2, molten salt, advanced LWRs)**
  - High temperature operation
  - High dpa tolerance
  - Coolant compatibility
  - Extended fuel

GA SiC-SiC cladding







GA SiC joining

GENERAL ATOMICS

Reactor-based Molybdenum-99 (Mo-99) Supply System

- **Mo-99 is needed for ~ 80% of nuclear medicine diagnostic procedures**
- **GA has teamed with Nordion and Missouri University Research Reactor (MURR) to take GA solution to market**
- **GA's selective gaseous extraction process minimizes liquid waste**


Photo credit - Nordion

White House Summit on Nuclear Energy, Nov 2015

- **Panel 1: <u>Importance of Nuclear Energy to Meeting Low-Carbon</u> - John Holdren** *(Assistant to the President for Science and Technology)*
  - EPA, Old Dominion, Carnegie Institute of Science, International Scene
- **Panel 2: <u>Maintaining U.S. Leadership in Nuclear Energy</u>**
  - Westinghouse, NRC, Energy Security
- **Panel 3: <u>Unlocking the Potential of Nuclear Energy</u>**
  - DOE, INL, TerraPower, General Atomics, NuScale

THE WHITE HOUSE
WASHINGTON

Key Events In My Career

- **Went to foreign country for post doc**
  - Saw different ways of working, different values
- **Left LLNL for better opportunity**
  - Expanded my skill set
- **Sought out job offer in France**
  - Learned a lot in trying to "create the perfect job"
- **Left field of expertise**
  - Learning on the job

Important Activities

- **Network, network, network**
- **Find mentors**
- **Learn to trust yourself**
- **Stay curious and open**
- **Assess opportunities**
  - Internal
  - External – job offers
  - Volunteer - hon
  - Teaching – trial

Professional Service Can Be Very Helpful In Exploring/Expanding Options

- **American Physical Society**
  - General Councilor, various committees
- **Volunteer to promote science in the community**
- **DOE grant reviewer**
- **Conference organizing committees**
  - 2002 chair, International Conf. on Spectral Lines Shapes
- **National Research Council committee**
- **Laboratory review committees**
  - LANL, LLNL
- **National Academy of Sciences panel (Q-cleared)**

A Career Path Is Not Predictable

- **Get out of your comfort zone**
  - France
  - Moving from National Lab to Private Industry
  - Changing from fusion to fission

GENERAL ATOMICS