

DIII-D National Fusion Facility



The Promise of Fusion: Virtually Limitless Baseload Energy



Abundant
Fuel Source



Inherently
Safe



Zero Carbon
Emissions

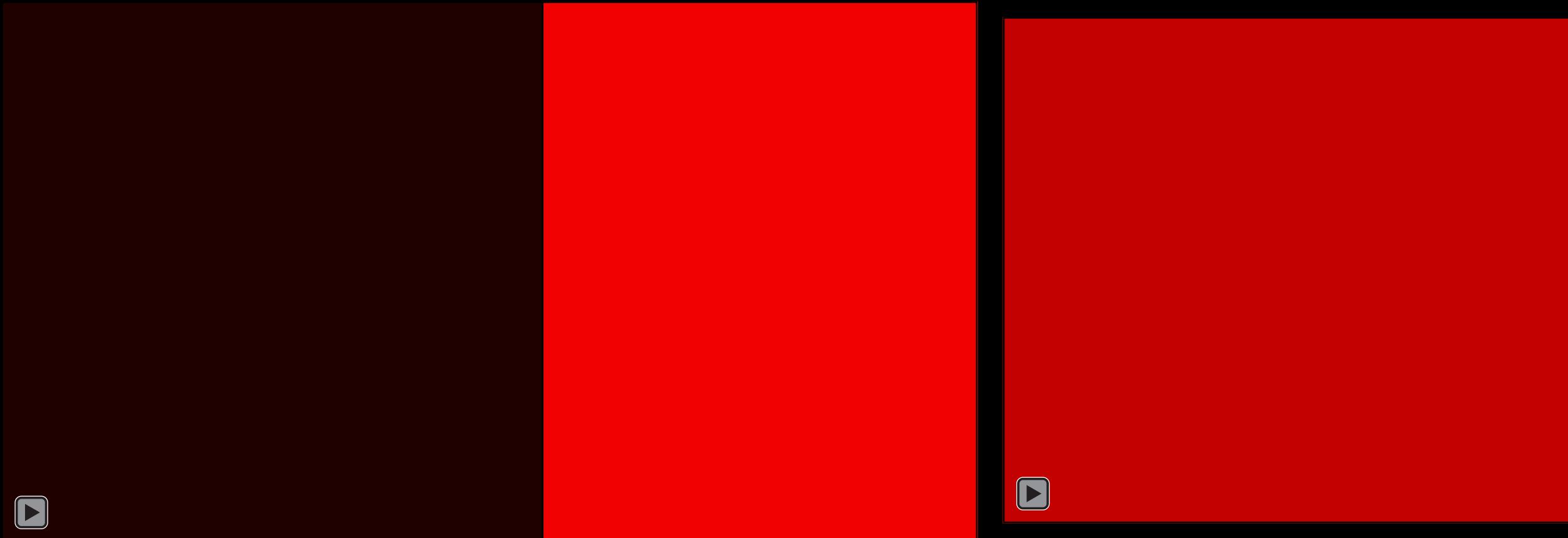
**A bathtub of seawater and two laptop batteries
contain enough fusion fuel for an individual's entire lifetime**

Achieving Fusion on Earth

*Sun holds a big ball of
hot gas together ‘plasma’
with gravity...*

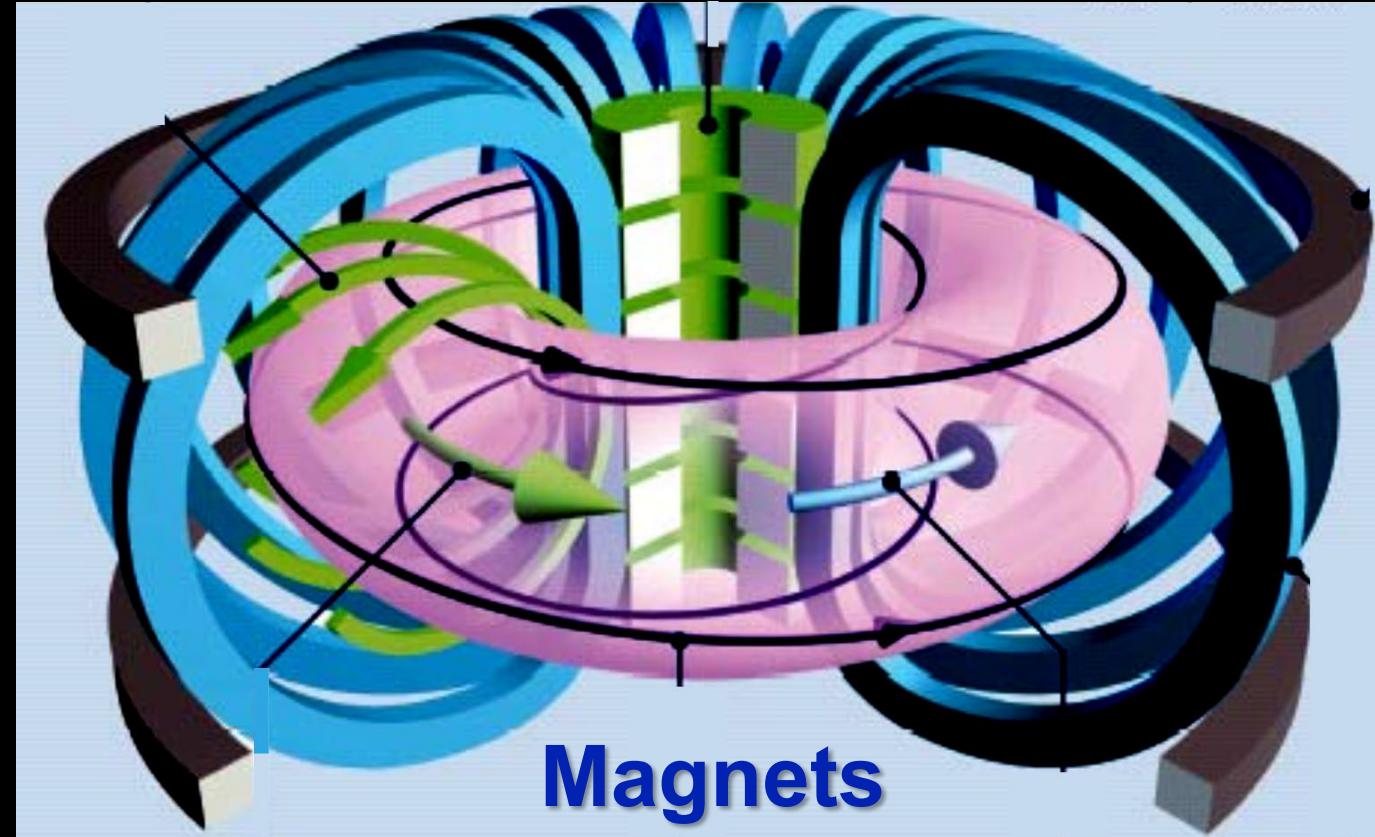
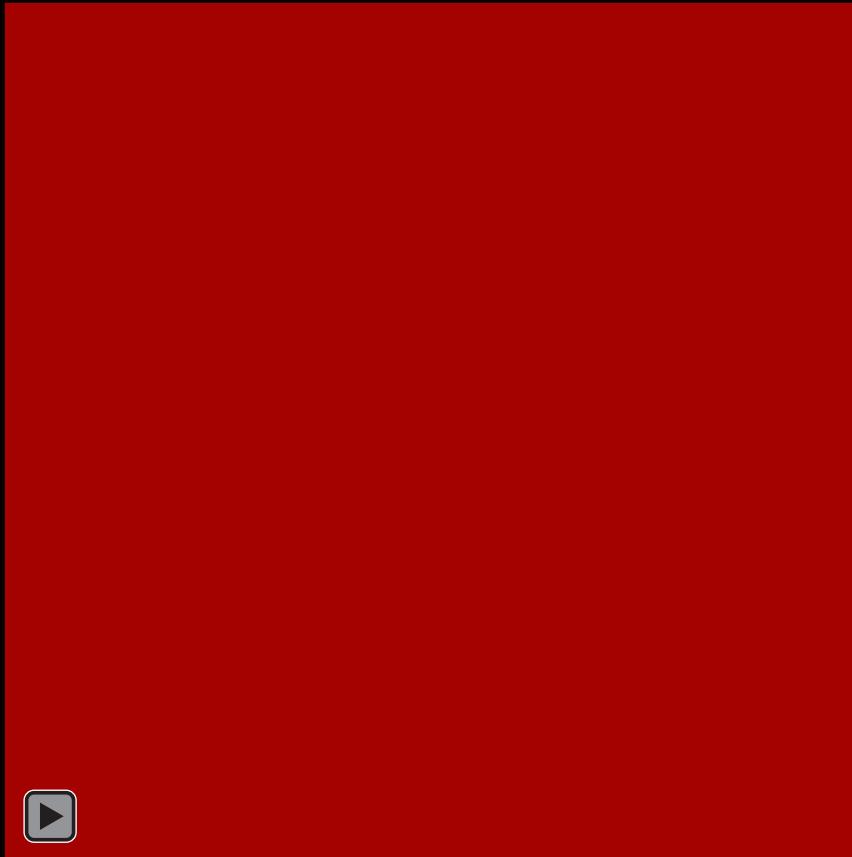


Achieving Fusion on Earth



Field coils make a donut-shaped magnetic bottle

Achieving Fusion on Earth



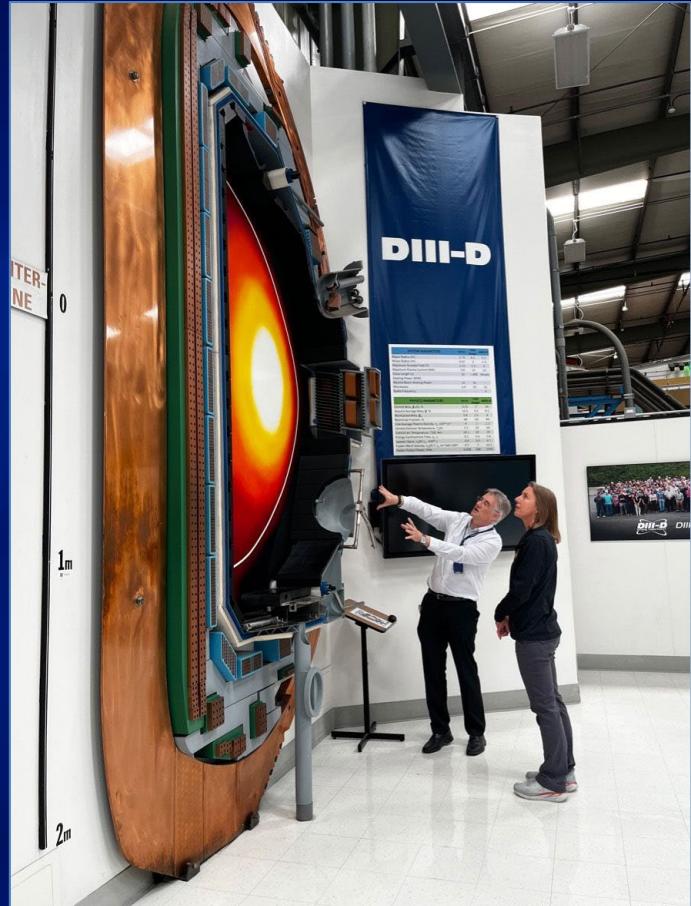
Field coils make a donut-shaped magnetic bottle

Overview of the DIII-D National Fusion Facility

U.S. Department of Energy, Office of Science

- **Our Mission is to Support the Commercialization of Fusion Energy**
 - Solve key science and technology challenges
 - Test new configurations and techniques

- **User Facility Model**
 - Open to all and free to use
 - 700+ participants across with academia, national laboratories and fusion industry
 - Significant international demand
 - Proprietary research options available



DIII-D exists to serve the national energy mission

Overview of the DIII-D National Fusion Facility

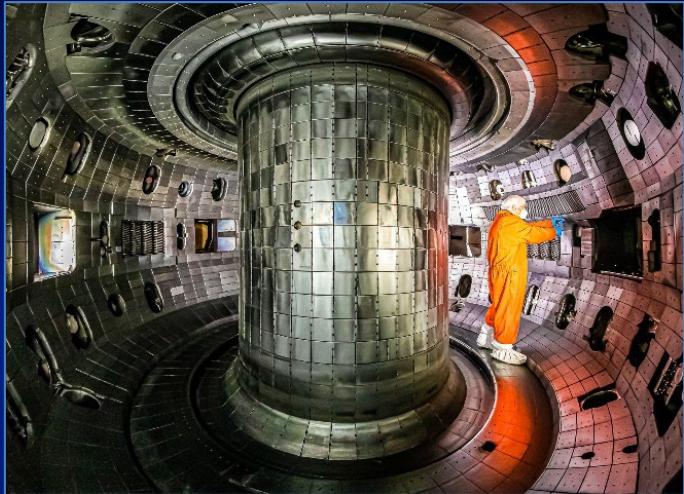
U.S. Department of Energy, Office of Science

- **Quick Facts about DIII-D**

- Largest magnetic fusion machine in the U.S.
- Largest fusion research team in the U.S.
- Most comprehensive set of measurements
- Most flexibility and control
- New capabilities added every year

- **Unique Platform**

- Rapidly prototype fusion technologies
- Power plant design and operation



Overview of the DIII-D National Fusion Facility

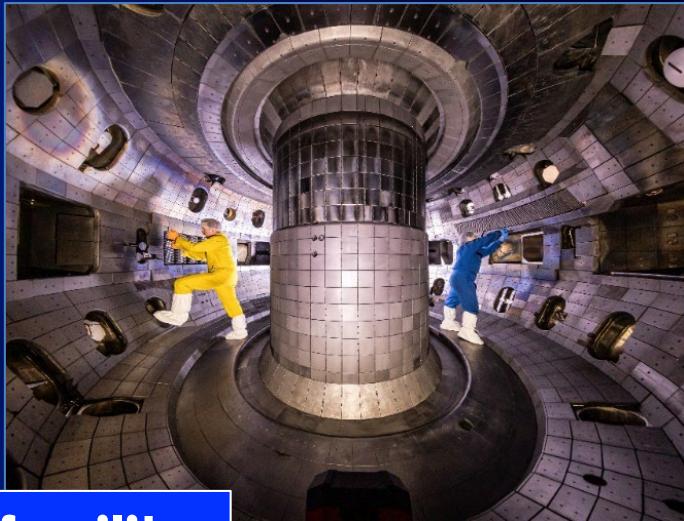
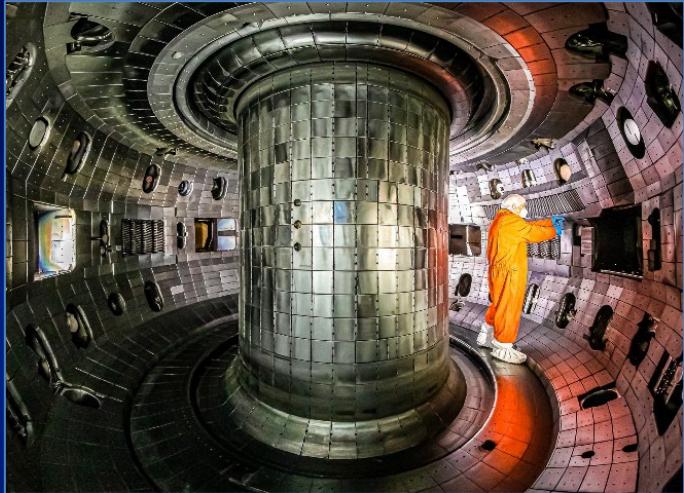
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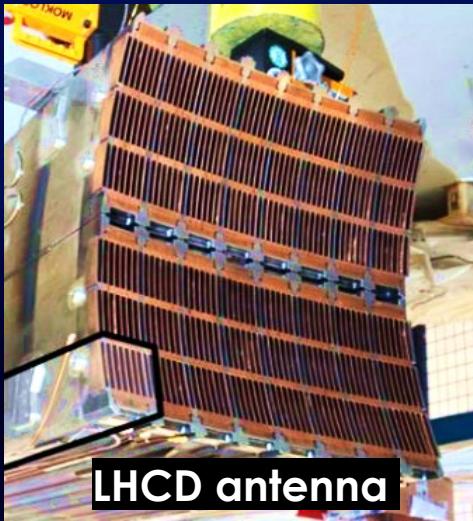
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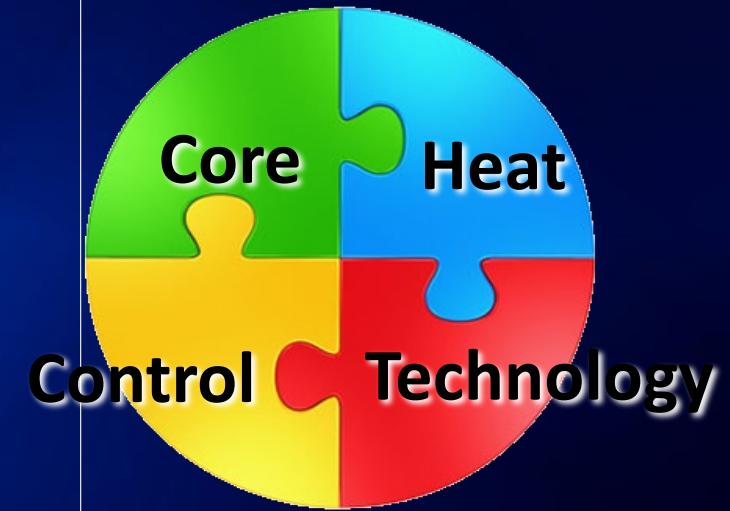
The nation's premier fusion research facility

Vital to Test New Fusion Technologies in the Plasma Environment

- **Each part interacts with and poses constraints on the others**
 - Technology \leftrightarrow Fusion core
 - Heat \leftrightarrow Technology
 - Control actuators \leftrightarrow Fusion core & technology



- **Need innovative solutions for each element**
- **Vital to test techniques together**
 - *Tokamak provides the first testbed whatever your favorite concept is*
 - *Measurement is key in resolving viability & projectability*



World Leading Measurement Set at DIII-D Assesses New Technologies

- **Comprehensive measurement capability**

- Over 80 systems measure every property

- **Understanding precisely how new techniques work**

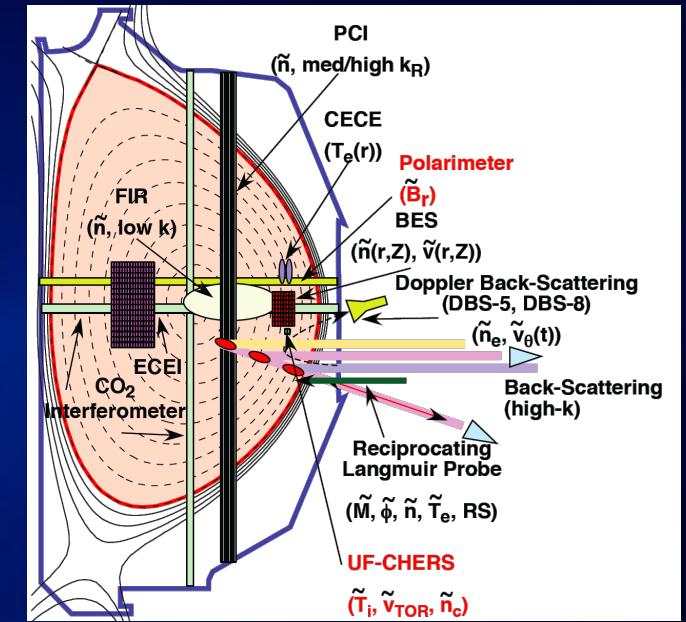
- That they do work... how to make them work
- And how they interact with other systems

- **Multiple theory groups engaged to validate state of art simulation codes**

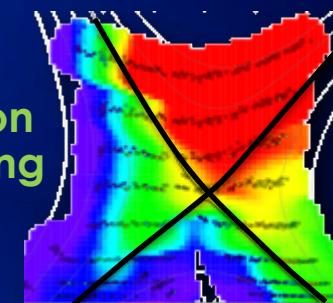
- Understand how technology and plasma behave → project to power plants!



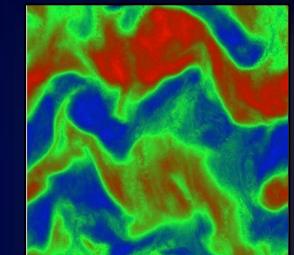
γ imaging



2D Thomson scattering

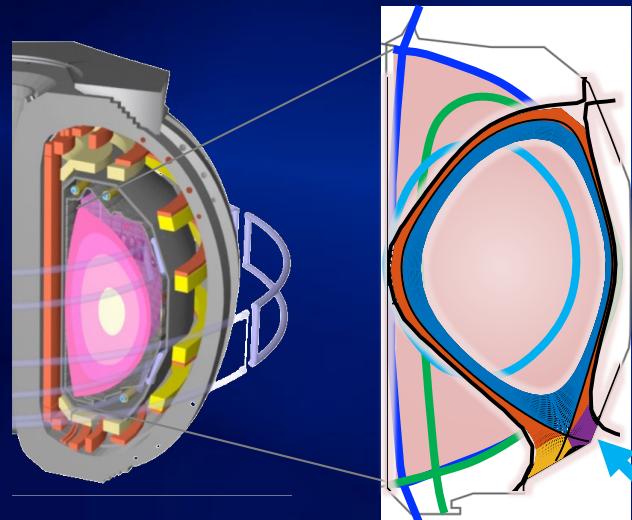


Turbulence Diagnostics

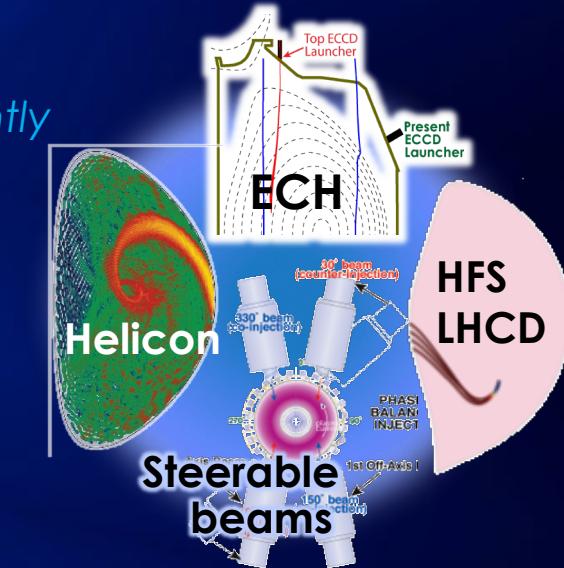


Understanding behavior is key to projecting solutions

DIII-D is a Highly Flexible Plasma Research Facility To Develop Solutions for Future Reactors



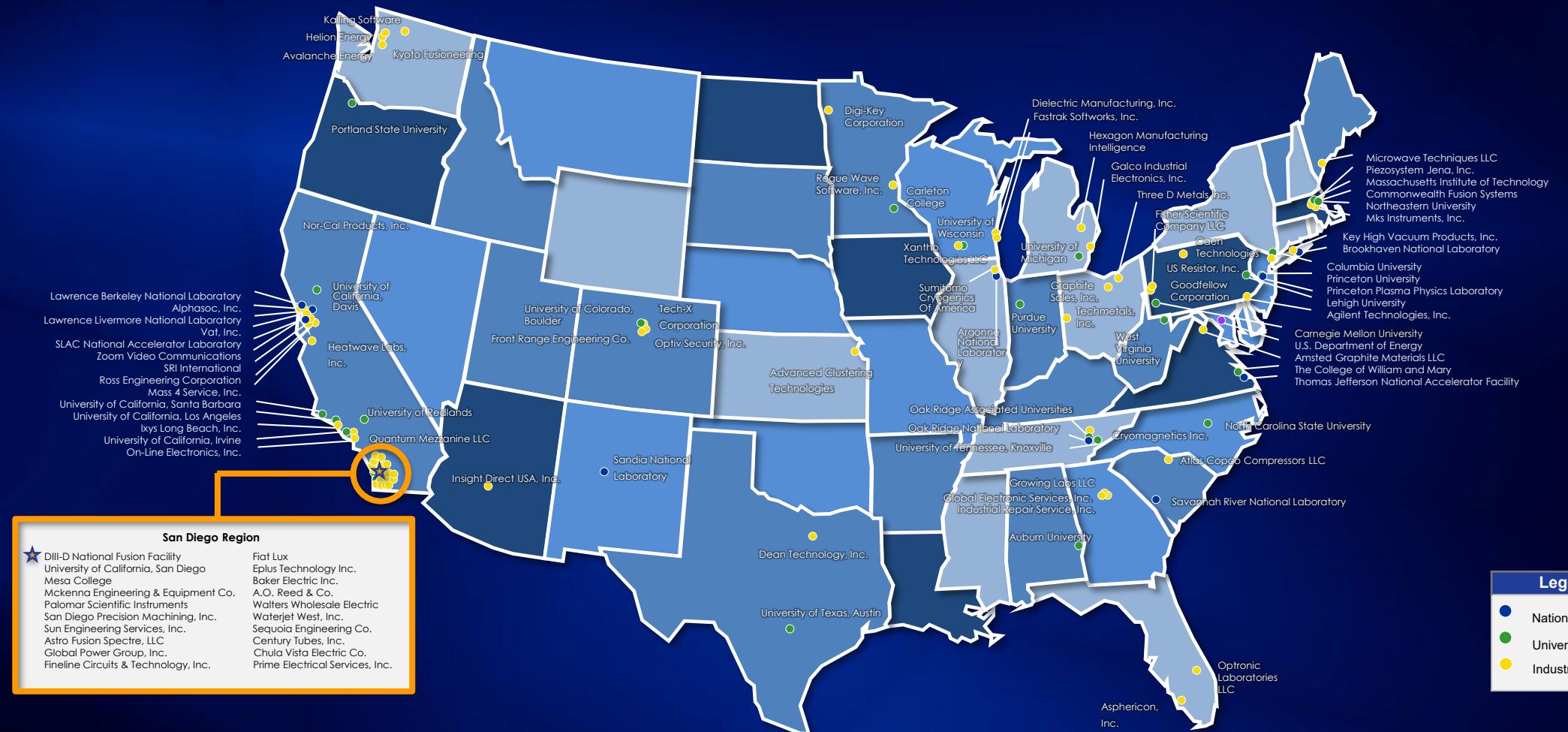
- **Flexibility to make enormous range of shapes...**
 - Develop and test many reactor concepts
- **Vary internal plasma magnetic configuration**
 - Drive heat, current & momentum where desired, independently, to electrons or ions
- **Negative triangularity new shape pioneered recently**
- **Wide range of techniques probe physics & technology**
 - Inject particles, gas, impurities. Test materials. Apply 3D fields
- **Advanced control system**
 - Robust platform to explore new approaches



Able to rapidly pioneer new techniques & discover how they work

DIII-D Serves the Whole U.S. Fusion Ecosystem

100+ Institutions!



Leading universities, national labs & private fusion companies

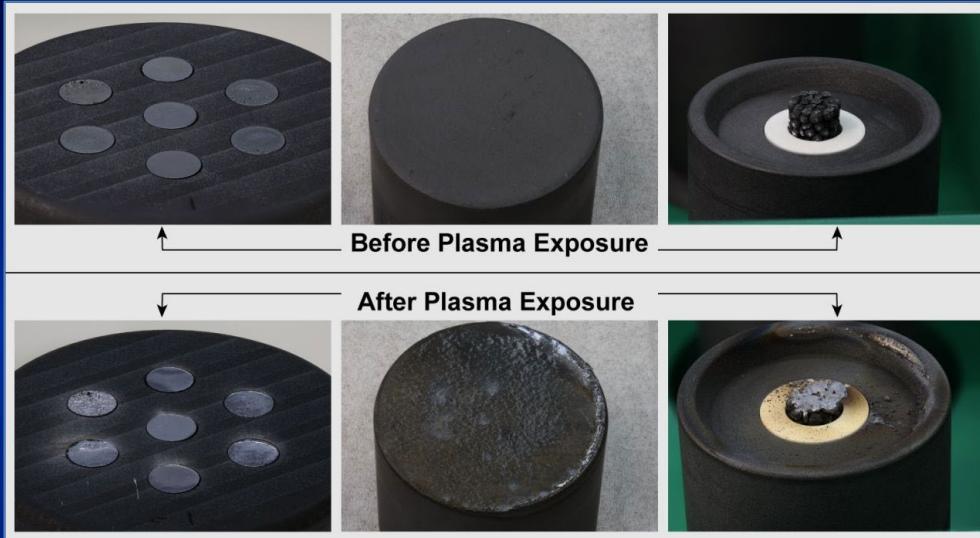
DIII-D Research is Advancing Fusion Energy

- **Focus Areas**

- Qualifying reactor materials
- Demonstrating reactor control
- Pioneering fusion technologies
- Raising performance

- **Key Activities to deliver this**

- Fusion industry support
- Fundamental science
- Artificial Intelligence & Digital Twin
- Workforce development



Recent Major Accomplishments

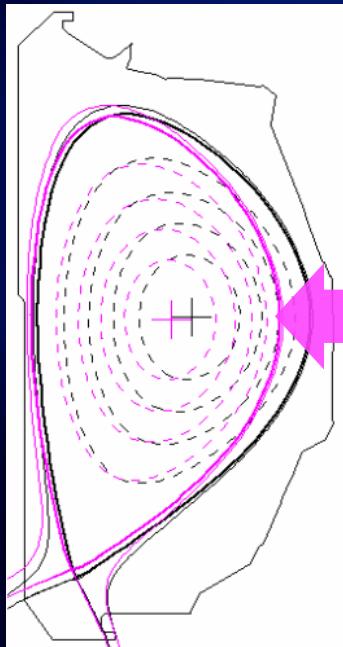
1. **Pioneered a new plasma configuration** that could make fusion more cost effective
2. **First-of-a-kind integration experiments** for the key requirements for economic fusion energy
3. **Demonstrated using AI** to eliminate plasma instabilities
4. **Tested 61 innovative materials** for fusion startups & gov partners
5. **World-first demonstration of three new high-efficiency plasma heating approaches**



DIII-D Pioneering Transformational Solutions

High heat flux tests →
spacecraft re-entry models

- >> Resolve anomalies in Galileo probe as it entered Jupiter's atmosphere
- >> Validated model for future heat shields

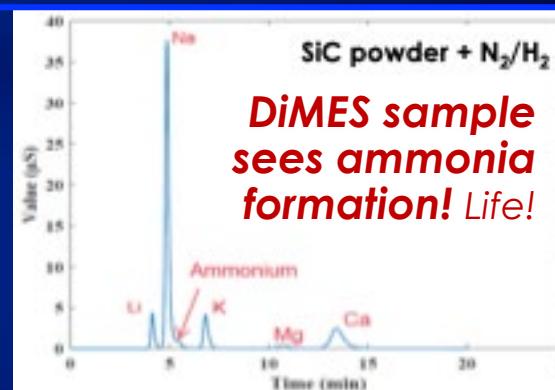
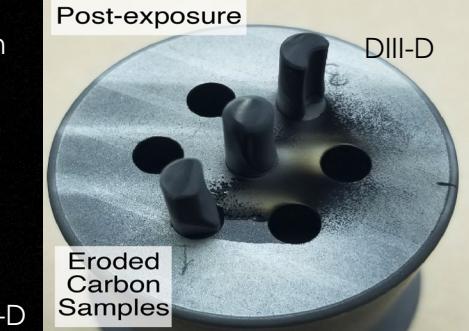
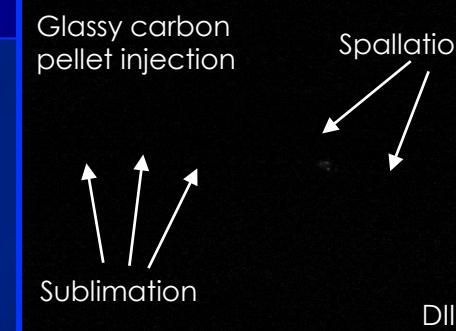
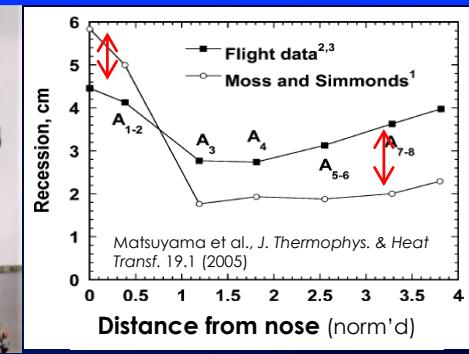


← Testing General Fusion concept of plasma compression heating

Compression heating

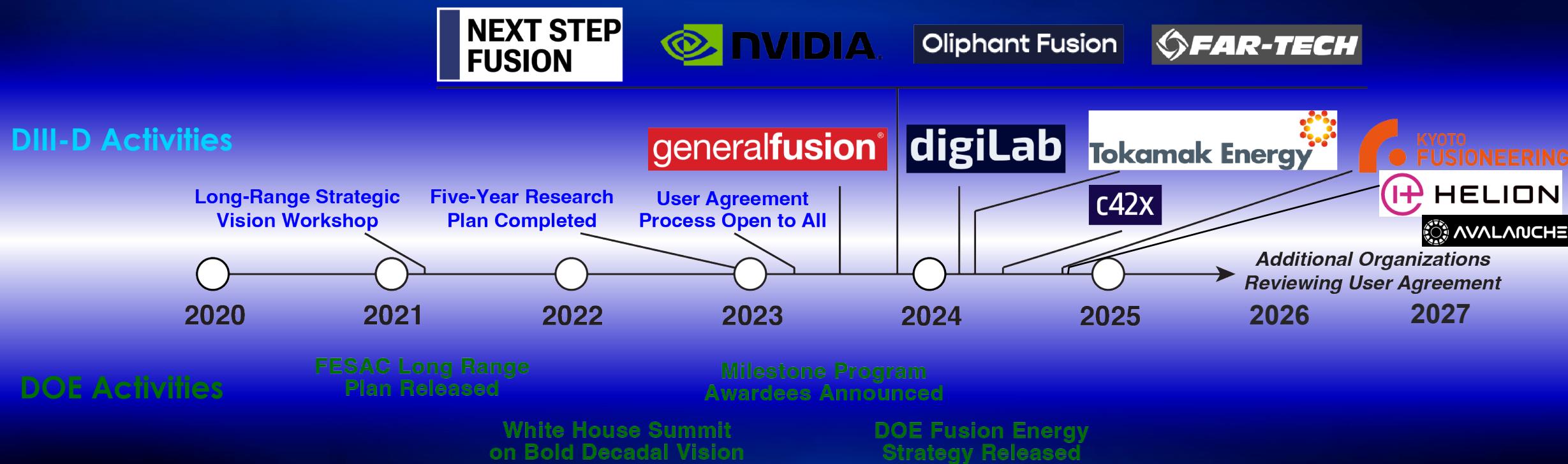
Use DiMES facility explores → organic molecule formation

- >> Understand building blocks of life!



DIII-D Developed a Low Barrier to Entry for Industry Partners

- Non-proprietary User Agreement provides free access to the DIII-D Research Program in a process that can be completed in a single day
- Strong initial uptake leading to continued growth in industry participation



18 private fusion partners with 88 users to date

DIII-D Training the Next Generation of Fusion Scientists & Engineers

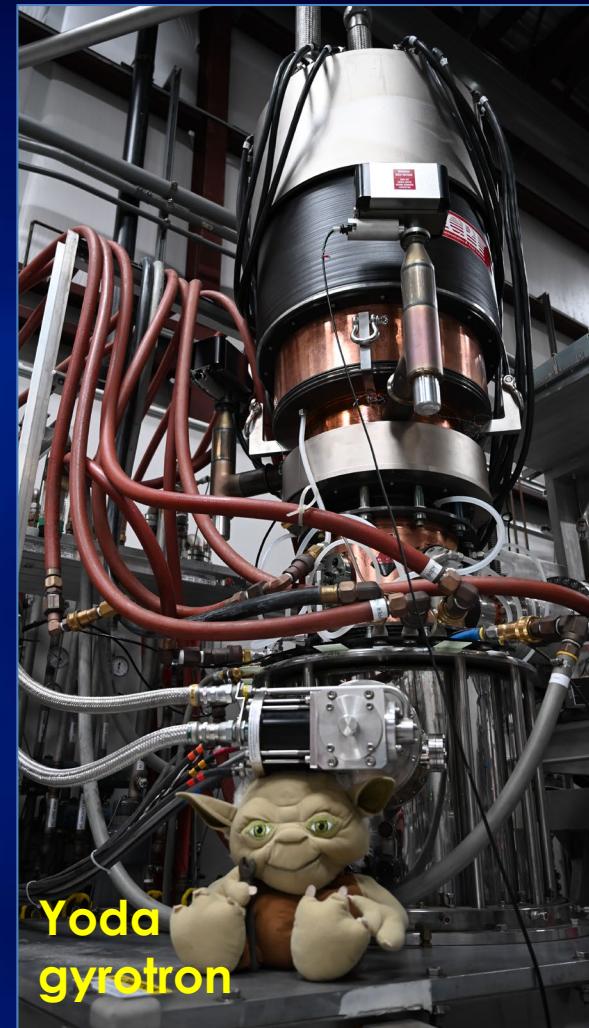
- **Pipeline for industry**
- **Early Career Opportunities**
 - ¼ of User base are students
 - 100+ grad students, 70+ postdocs
 - Dedicated PhD runtime
 - Internships & school programs
- **Construction and Operation of real working fusion facilities**



Come and learn with us!

Looking Ahead – An Exciting Mission for DIII-D

- **Serving the Fusion Industry**
 - Technology solutions
 - Plasma control and optimization
 - New AI and Digital Twin techniques
- **Ongoing Improvements Support Future Power Plants & Fusion Technology**
 - Additional microwave heating →
 - Heat handling technology
 - Power plant wall materials
- **Closing the critical Science and Technology gaps for DOE roadmap & private sector**



Welcome DIII-D Family !

- **We value and appreciate your partnership**
- **We want to enable you to succeed, as a supplier or fusion innovator**
- **This event to hear your needs, meet the team, meet each other, and learn about opportunities**



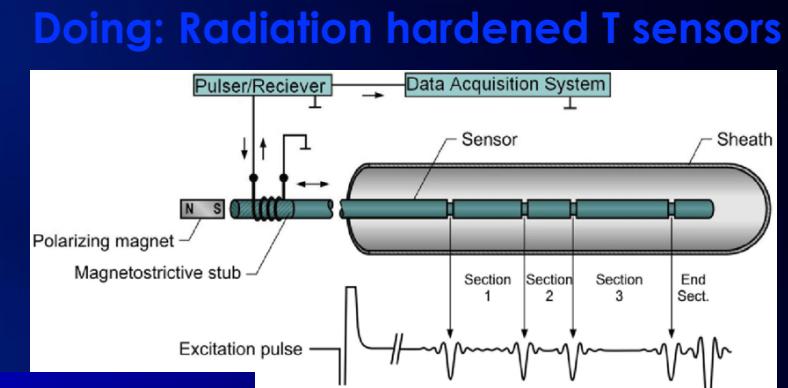
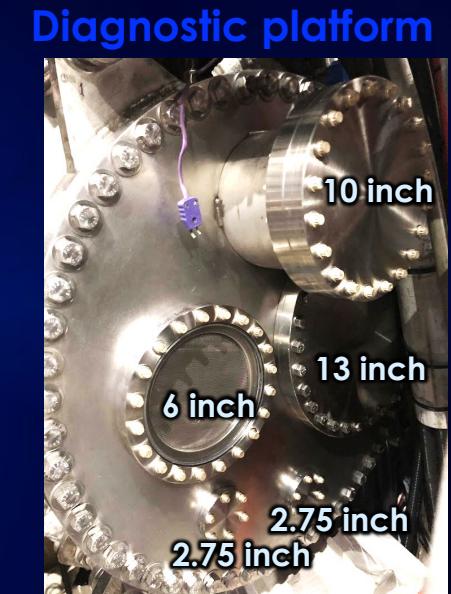
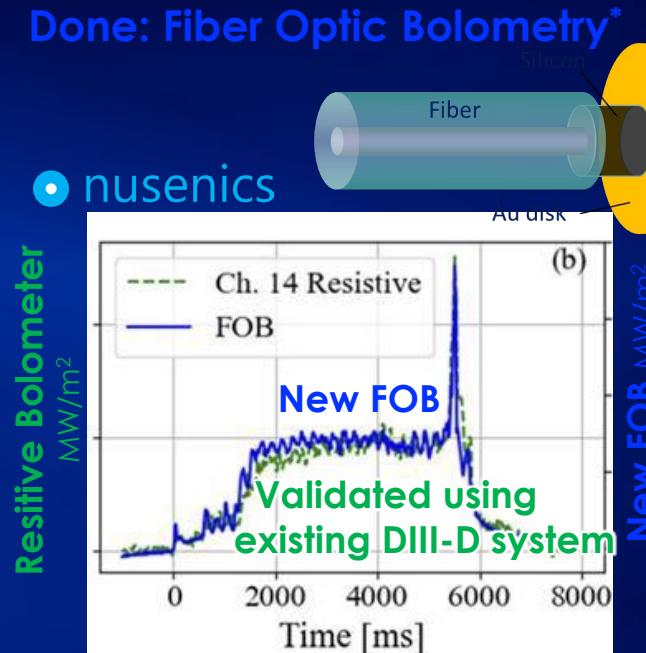
Let's go forward together – how can help?

BONUS SLIDES

DIII-D Provides a Unique Testing Ground for Fusion Diagnostics

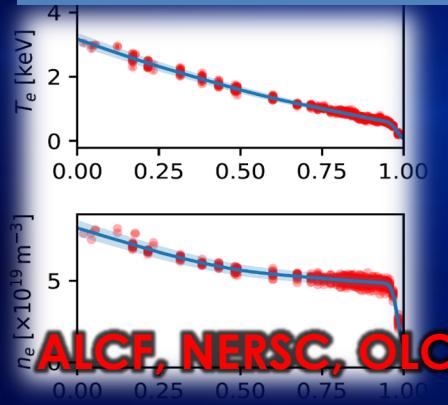
- **Fusion needs advances in diagnostics**
 - Survival of plasma & neutron fluences
 - Miniaturization & modularization
 - Reduced diagnostic set
- **DIII-D ideal proving ground**
 - Validation against proven system → in relevant plasma conditions
 - Rapid installation in many locations
- **DIII-D pursuing many innovations**
 - Innovative radiation & radiation-hardened sensors →
 - + Particle detectors (Xantho), stray EC (ITER), spin pol. fusion sensor (UCI)
 - Super-resolution synthetic diagnostics for real time control (P-U)

Plus many techniques through DOE measurement innovation awards

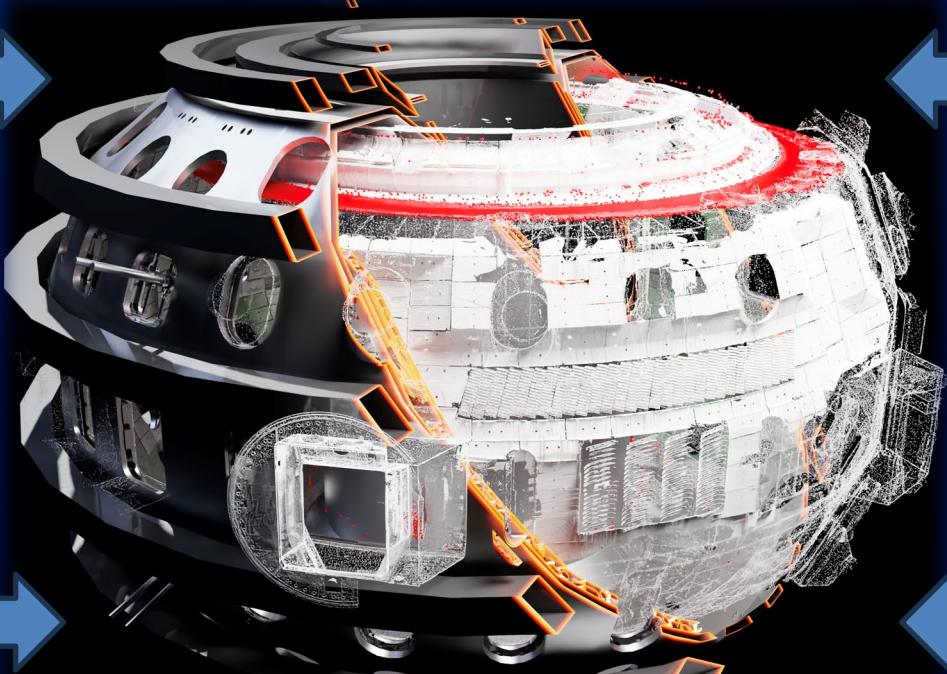


DIII-D is Pioneering Digital Technologies in Fusion with Private Sector to Lever Multiple Fusion Paths

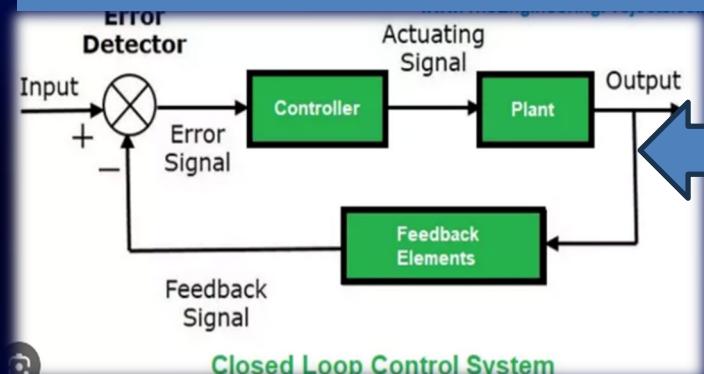
Superfacility (IRI): rapid high-fidelity analysis on demand



Digital & Physical Twin integrates big data, ML & supercomputing

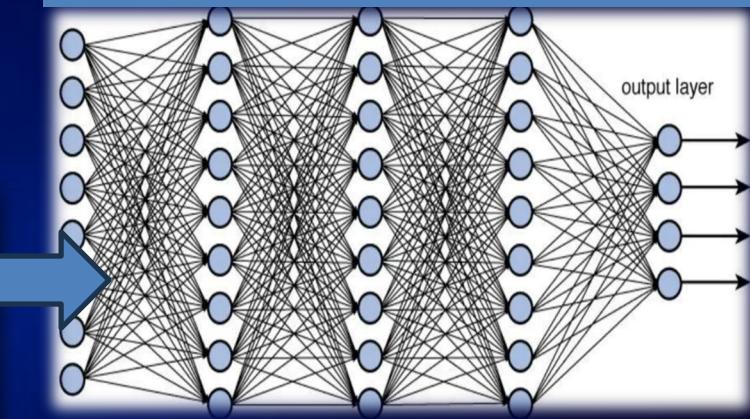


Real-time Forecasting and Actuator Control

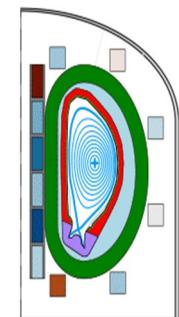
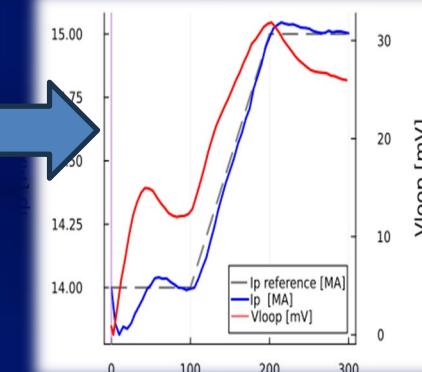


NVIDIA-GA prototypical digital twin of DIII-D

Data Platform: AI/ML at scale



FUSE: Plant and plasma simulator



DIII-D is Developing the Skills of the Fusion Workforce

- **DIII-D an early career development center**
 - **Leadership**: science, XPs, talks, papers, systems, PIs
 - **Mentorship program**, training, summer school
 - **Over 250 students, postdocs & interns** with PhD runtime & student support groups
- **Diversifying pathways**
 - **Under-represented groups**: internship programs, community college engagement, SDSU, high schools
 - **Next generation**: Local schools, girls Tech Trek, CuWiP, Young Women's STEM, Society of Women Engineers
- **Enabling workplace environment**
 - **Environment**: code of conduct, community agreements, webinars, civil treatment, bystander & meetings trainings
 - **Open opportunities** with balance monitoring, double-anonymized deconflicted XP review, access, roles committee ensures balance



Prof. Livia Casali, Early Career Award
"Innovative Core-Edge Solutions for Tokamaks"
Co-lead DIII-D Core-Edge Task Force
Professor at UT Knoxville



Shaun Haskey
Early Career Award
"Main Ion Transport and
Fueling in the Pedestal"
Leader of DIII-D NB physics



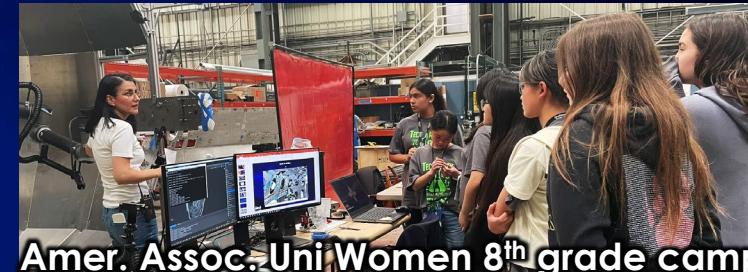
A. Rosenthal
DOE Highlight
MIT PhD



**GEM under-represented
grad interns in Ops**



Preuss high school low income first-in-family interns



Amer. Assoc. Uni Women 8th grade camp

An environment for people to grow