

DIII-D National Fusion Facility



The Promise of Fusion: Virtually Limitless Baseload Energy



Abundant
Fuel Source



Inherently
Safe



Zero Carbon
Emissions

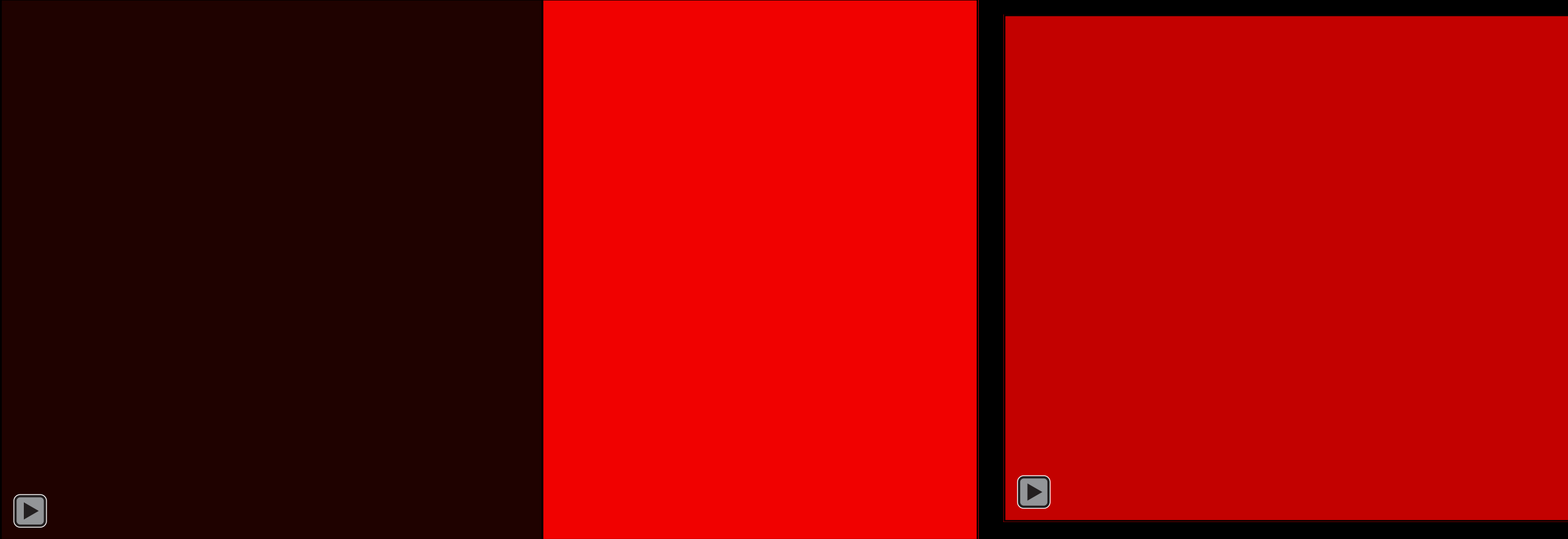
**A bathtub of seawater and two laptop batteries
contain enough fusion fuel for an individual's entire lifetime**

Achieving Fusion on Earth

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

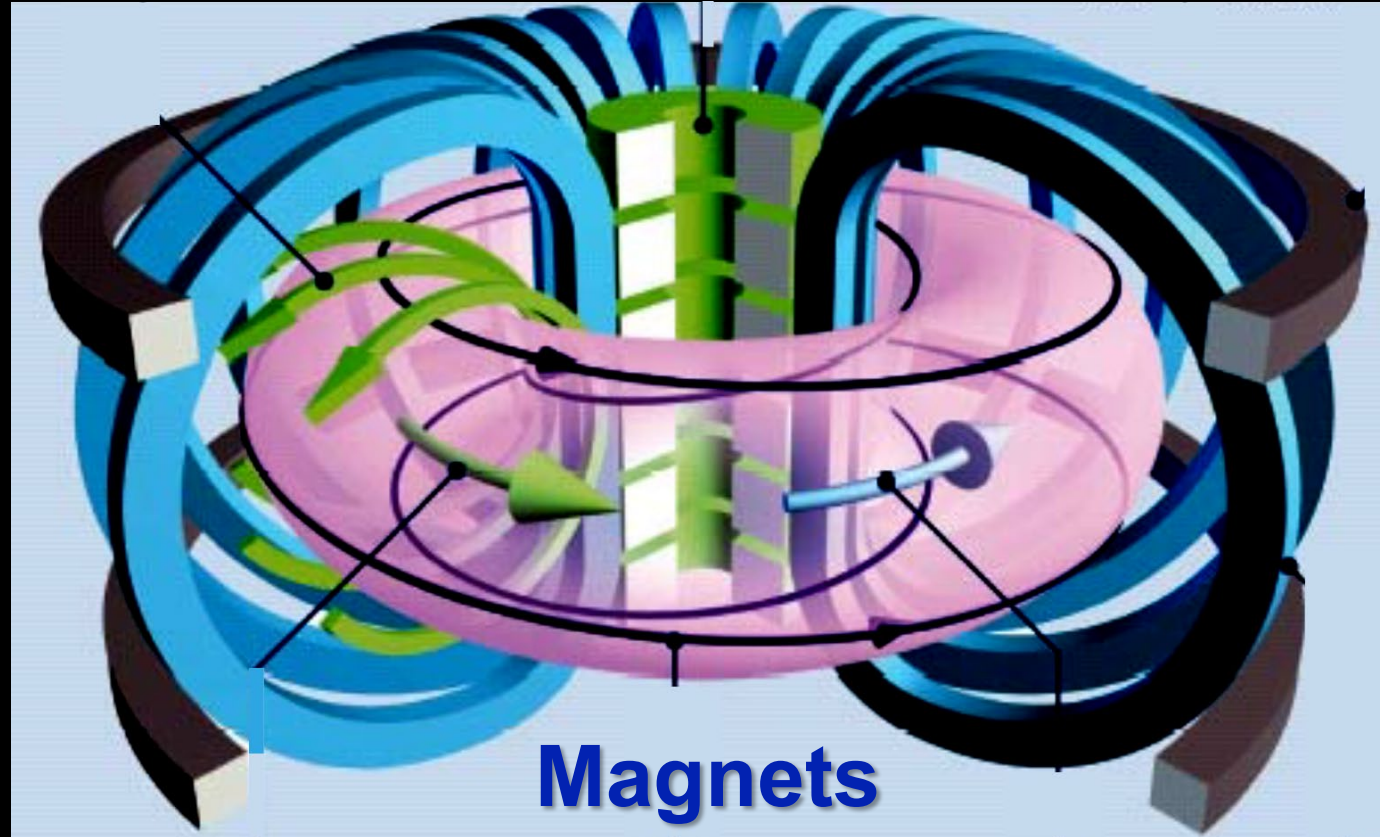
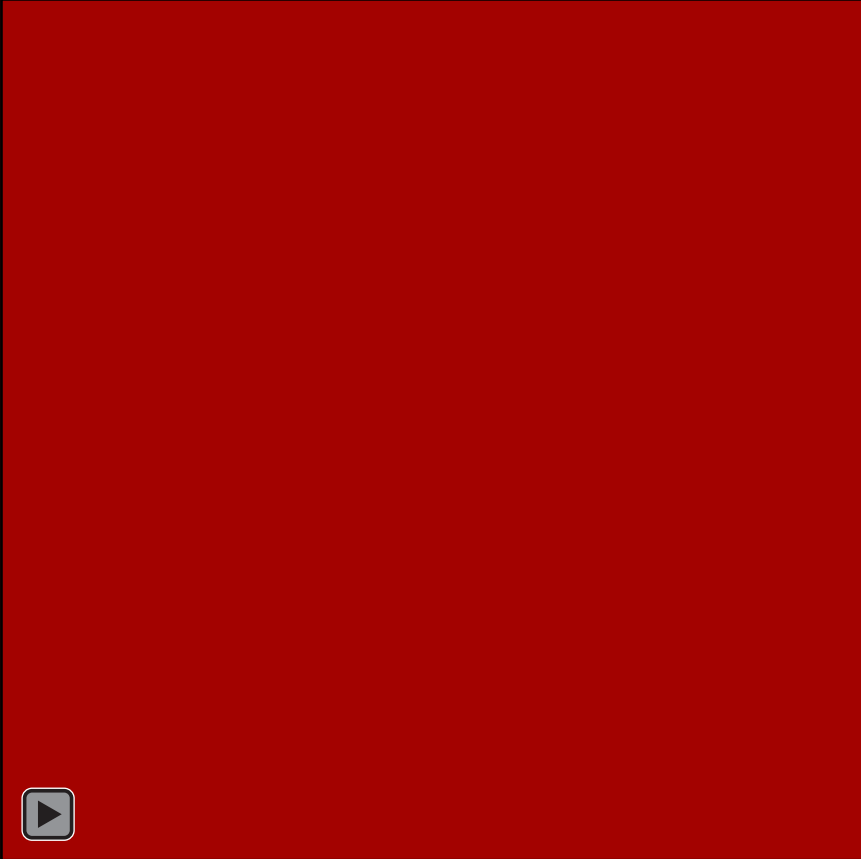


Achieving Fusion on Earth



Field coils make a donut-shaped magnetic bottle

Achieving Fusion on Earth

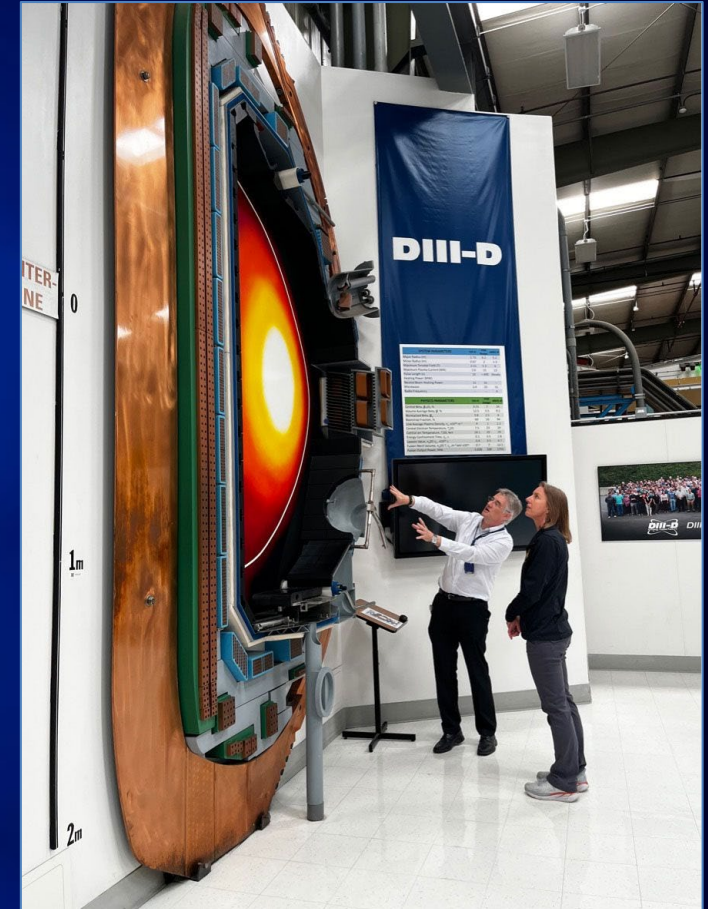


Field coils make a donut-shaped magnetic bottle

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

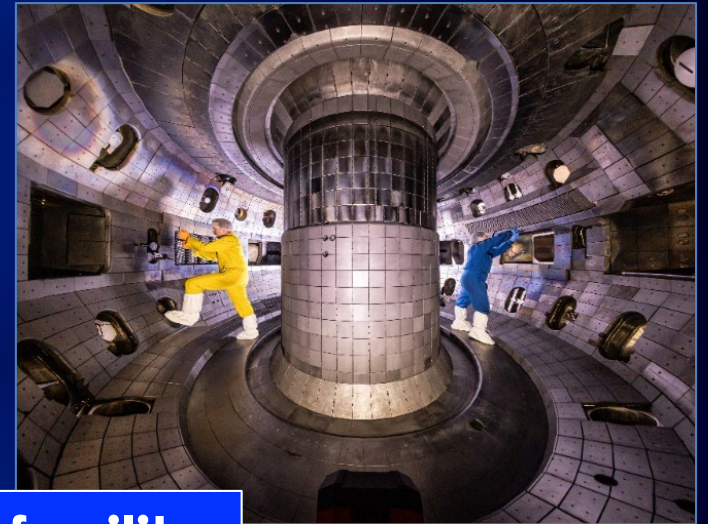
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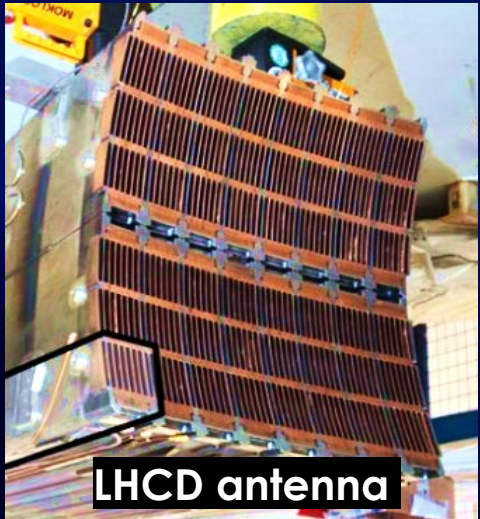
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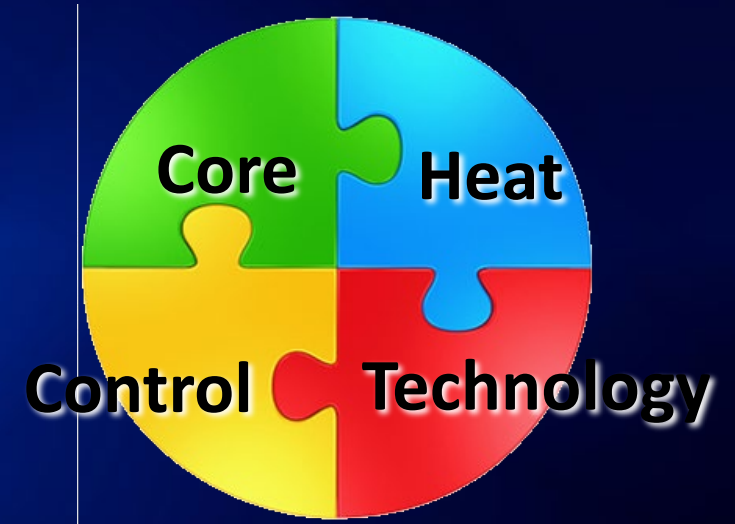
The nation's premier fusion research facility

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

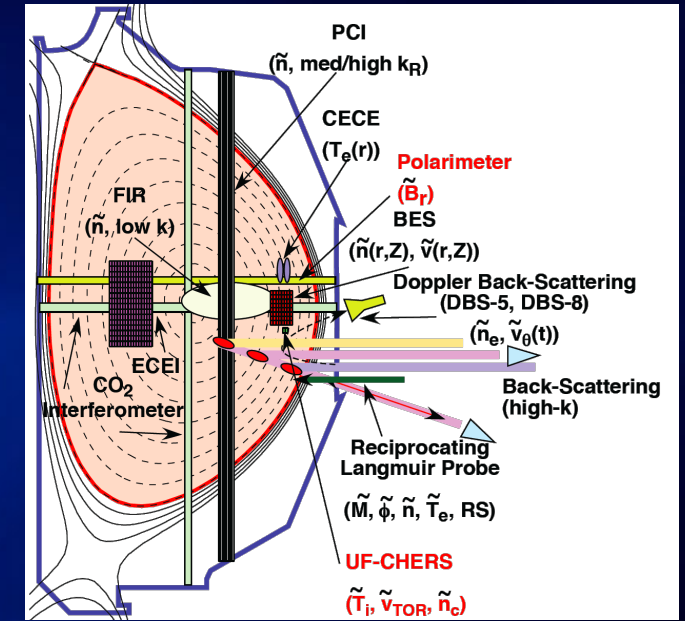
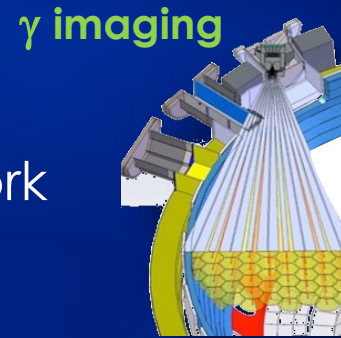


- **Need innovative solutions for each element**
- **Vital to test techniques together**
 - Tokamak provides the first testbed *whatever your favorite concept is*
 - *Measurement is key in resolving viability & projectability*

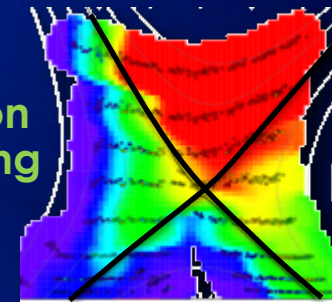


World Leading Measurement Set at DIII-D Assesses New Technologies

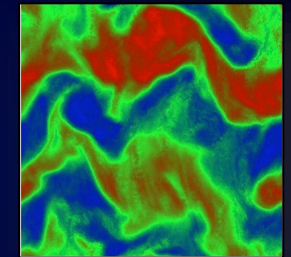
- **Comprehensive measurement capability**
 - Over 80 systems measure every property
- **Understanding precisely how new techniques work**
 - That they do work... how to make them work
 - And how they interact with other systems
- **Multiple theory groups engaged to validate state of art simulation codes**
 - Understand how technology and plasma behave → project to power plants!



2D
Thomson
scattering

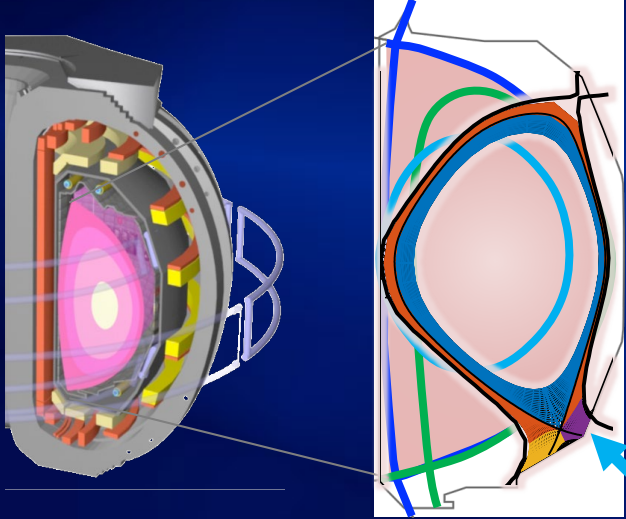


Turbulence
Diagnostics



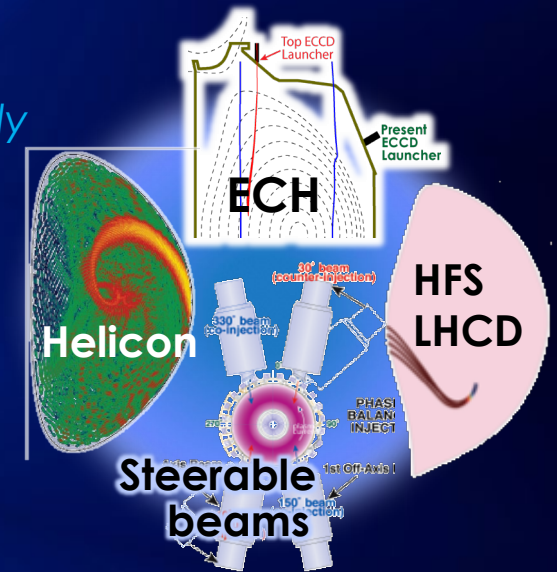
Understanding behavior is key to projecting solutions

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



Negative triangularity new shape pioneered recently

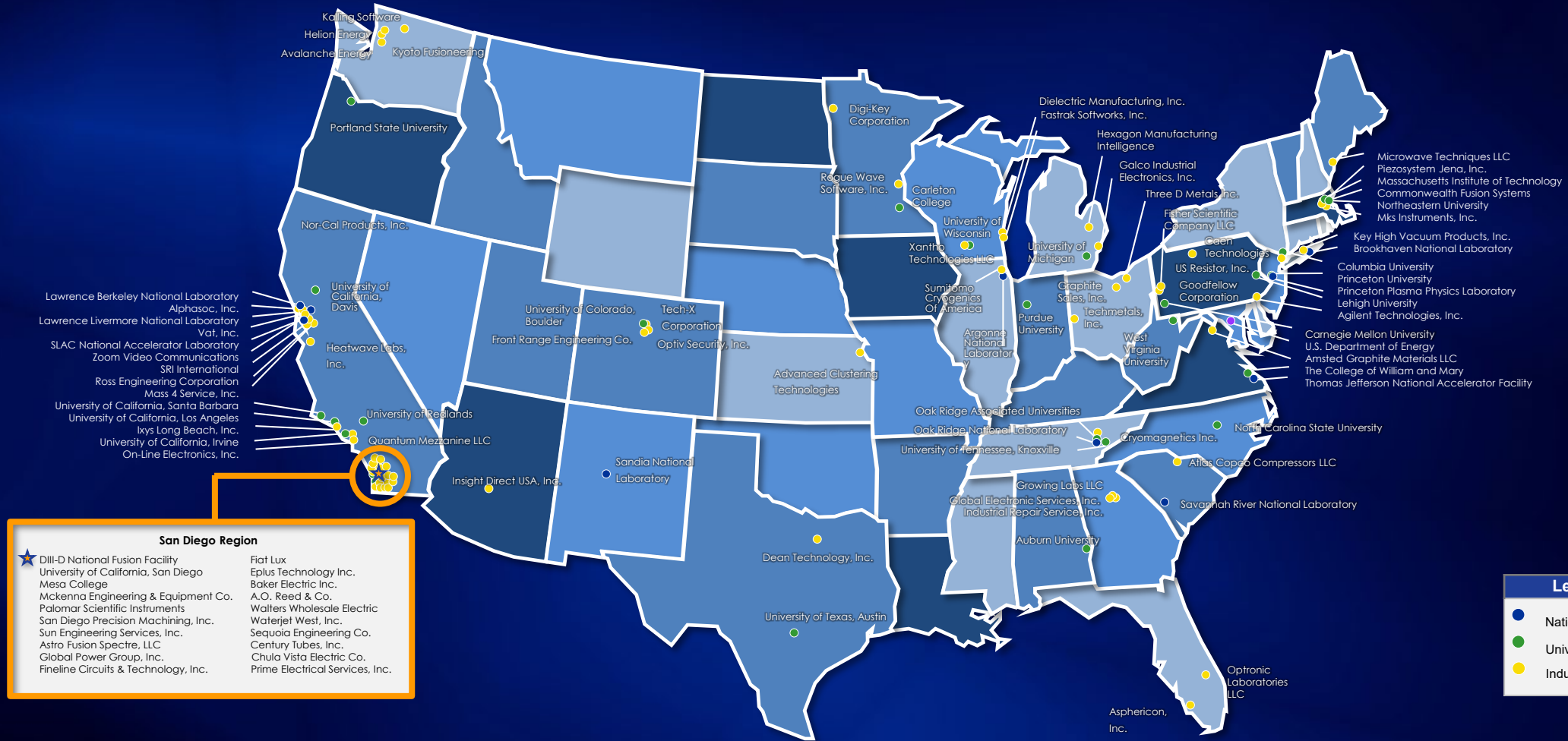
- **Flexibility to make enormous range of shapes...**
 - Develop and test many reactor concepts
- **Vary internal plasma magnetic configuration**
 - Drive heat, current & momentum where desired, independently, to electrons or ions
- **Wide range of techniques probe physics & technology**
 - Inject particles, 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

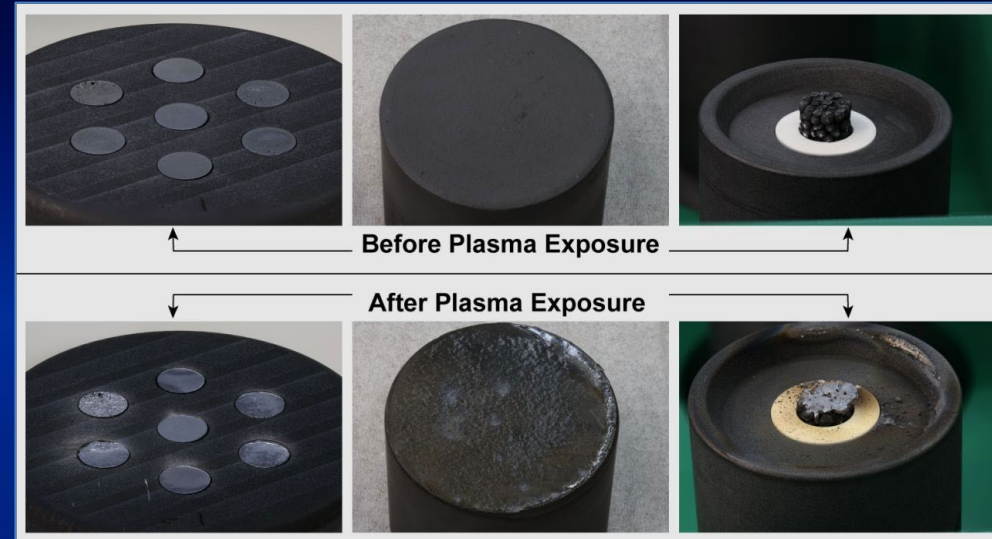
DIII-D Research is Advancing Fusion Energy

- **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

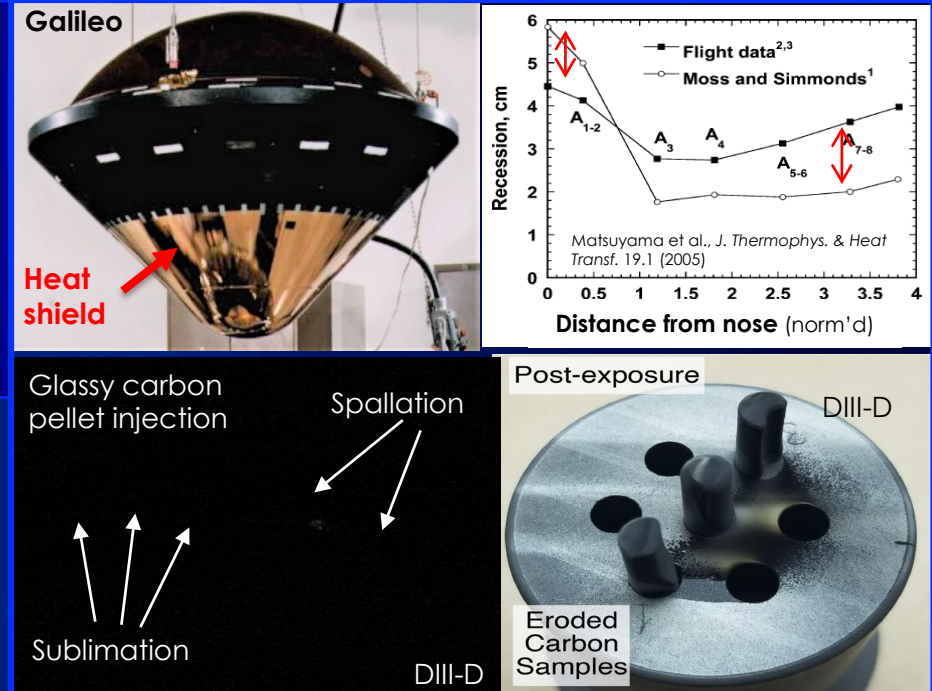
1. **Pioneered a new plasma configuration** that could make fusion more cost effective
2. **First-of-a-kind integration experiments** for the key requirements for economic fusion energy
3. **Demonstrated using AI** to eliminate plasma instabilities
4. **Tested 61 innovative materials** for fusion startups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



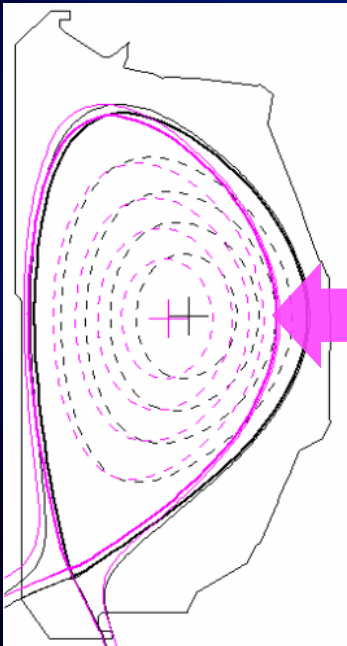
DIII-D Pioneering Transformational Solutions

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



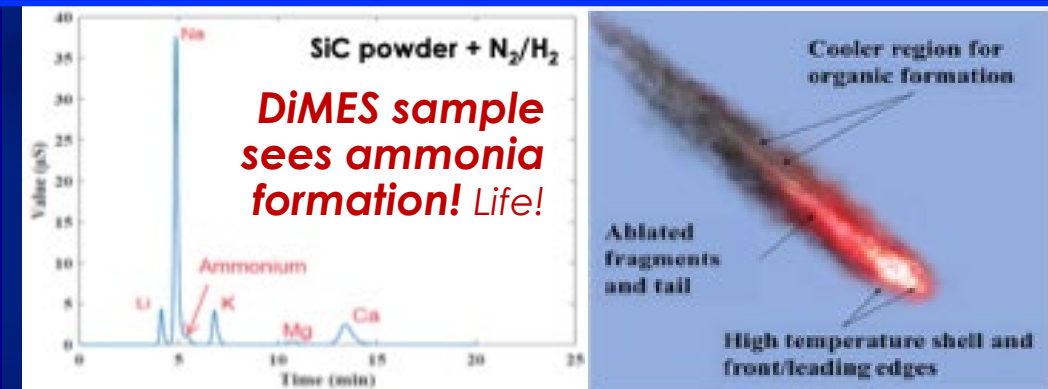
← Testing General Fusion concept
of plasma compression heating



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

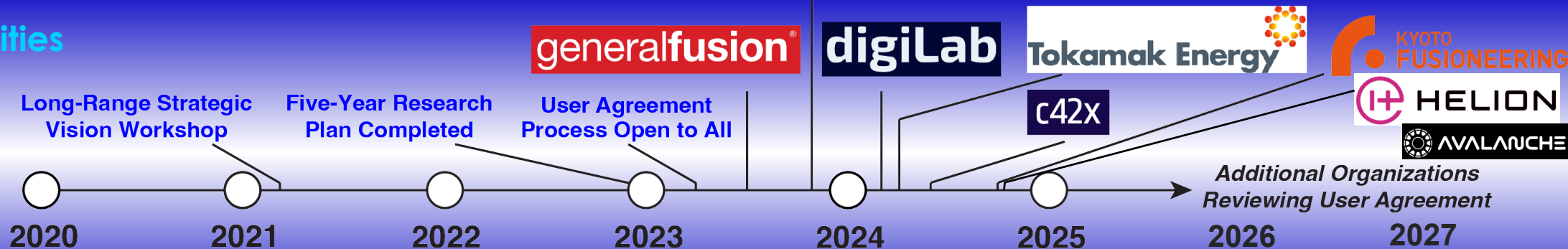
**NEXT STEP
FUSION**



Oliphant Fusion



DIII-D Activities



DOE Activities

FESAC Long Range Plan Released

White House Summit on Bold Decadal Vision

Milestone Program Awardees Announced

DOE Fusion Energy Strategy Released

18 private fusion partners with 88 users to date

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

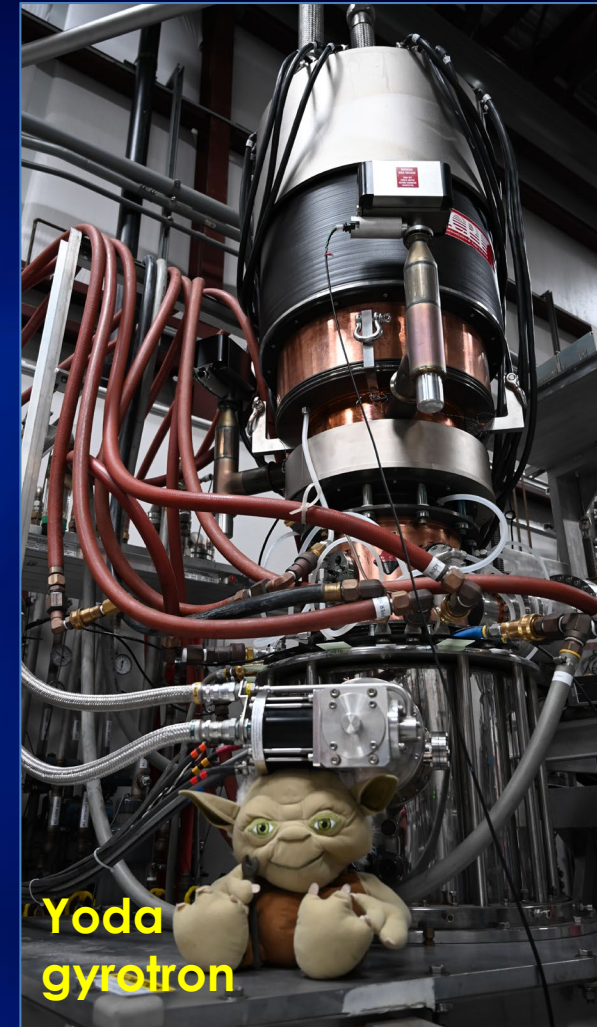
- **Pipeline for industry**
- **Early Career Opportunities**
 - ¼ of User base are students
 - 100+ grad students, 70+ postdocs
 - Dedicated PhD runtime
 - Internships & school programs
- **Construction and Operation of real working fusion facilities**



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

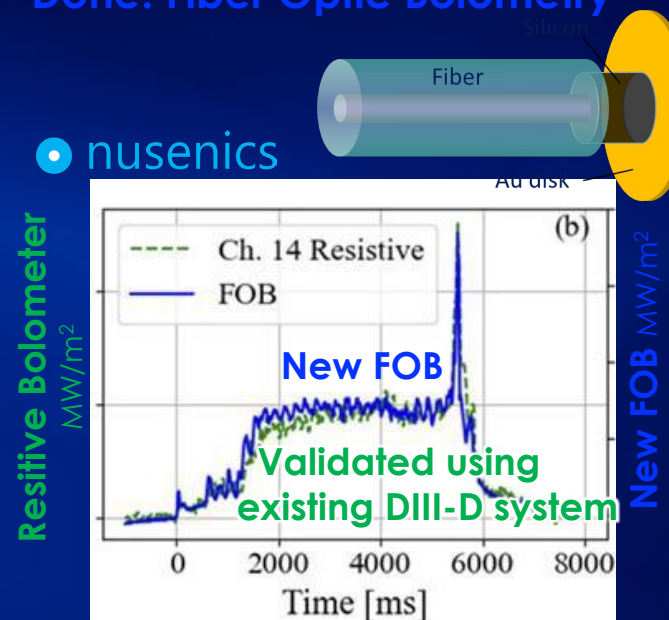
- **DIII-D pursuing many innovations**

- 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)

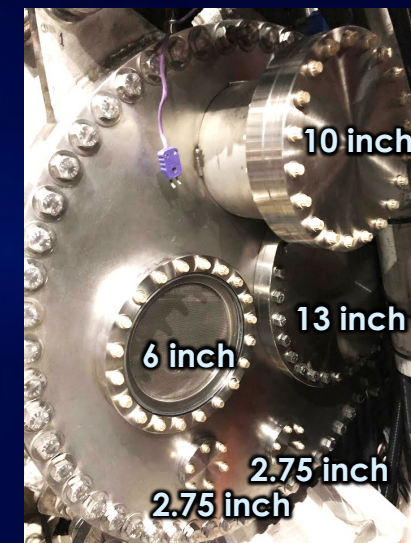
Plus many techniques through DOE measurement innovation awards

Done: Fiber Optic Bolometry*

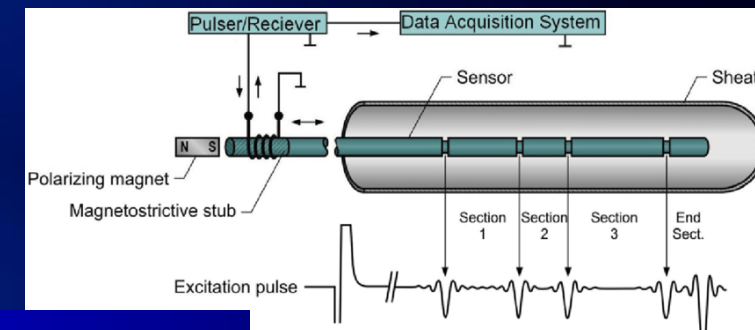
- nusenics



Diagnostic platform



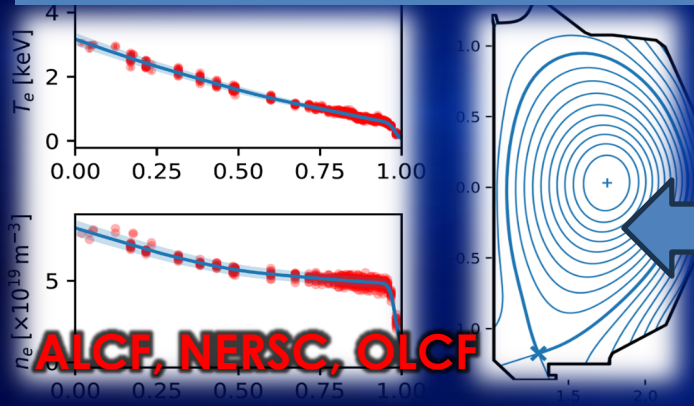
Doing: Radiation hardened T sensors



Unique & needed capabilities for all fusion concepts

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

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

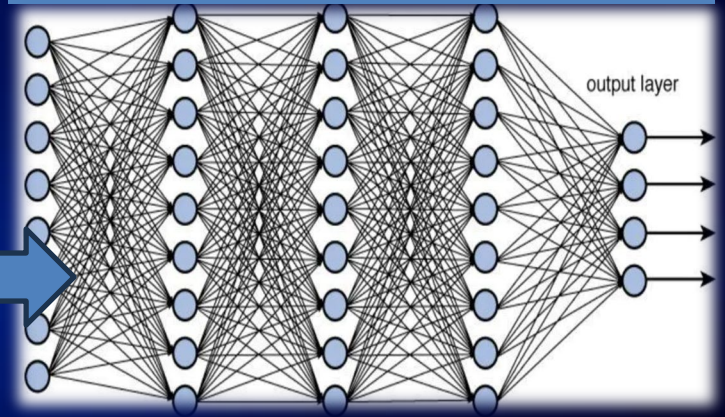


Digital & Physical Twin integrates big data, ML & supercomputing

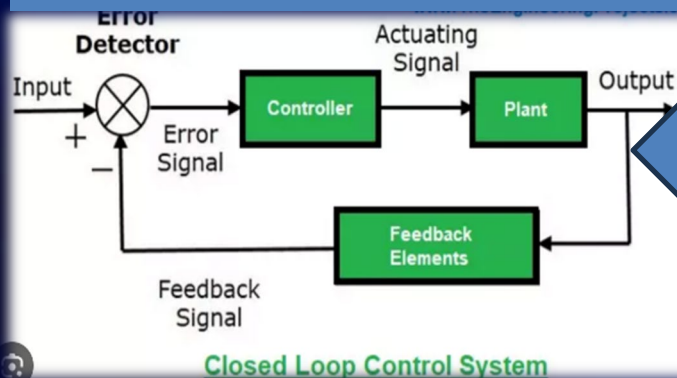


NVIDIA-GA prototypical digital twin of DIII-D

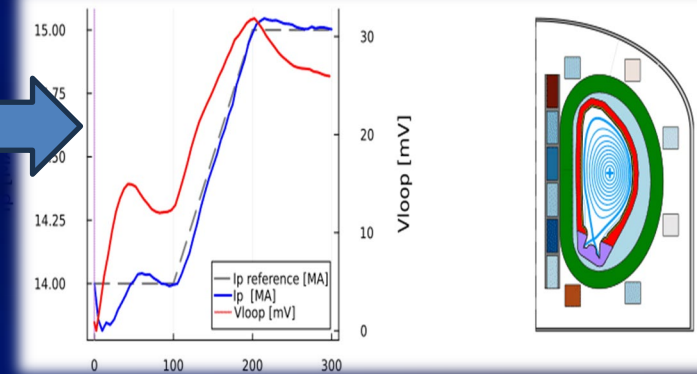
Data Platform: AI/ML at scale



Real-time Forecasting and Actuator Control



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, Pls
 - **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

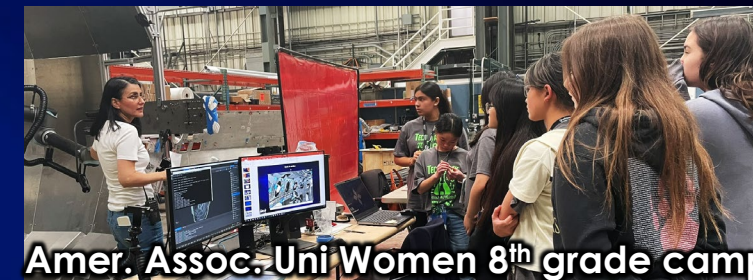


Prof. Livia Casali, Early Career Award
"Innovative Core-Edge Solutions for Tokamaks"
Co-lead DIII-D Core-Edge Task Force
Professor at UT Knoxville



A. Rosenthal
DOE Highlight
MIT PhD

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



An environment for people to grow