



United States
Burning Plasma Organization

Welcome to IIS2022

11th ITER International School
ITER Plasma Scenarios and Control

IIS

Charles M. Greenfield
UC San Diego
July 25, 2022



Welcome!



I would like to personally welcome you

- To the United States!
- To San Diego!
- To UCSD (now) and General Atomics (tonight)!
- To the 2022 ITER International School!

*Many of you traveled a long way to be here
and I hope the week is enjoyable and
educational for all!*

Purpose of the ITER International School



The ITER International School (IIS) is organized regularly with the goal of giving young scientists and engineers a taste of the stimulating, multi-disciplinary and challenging field that is nuclear fusion.

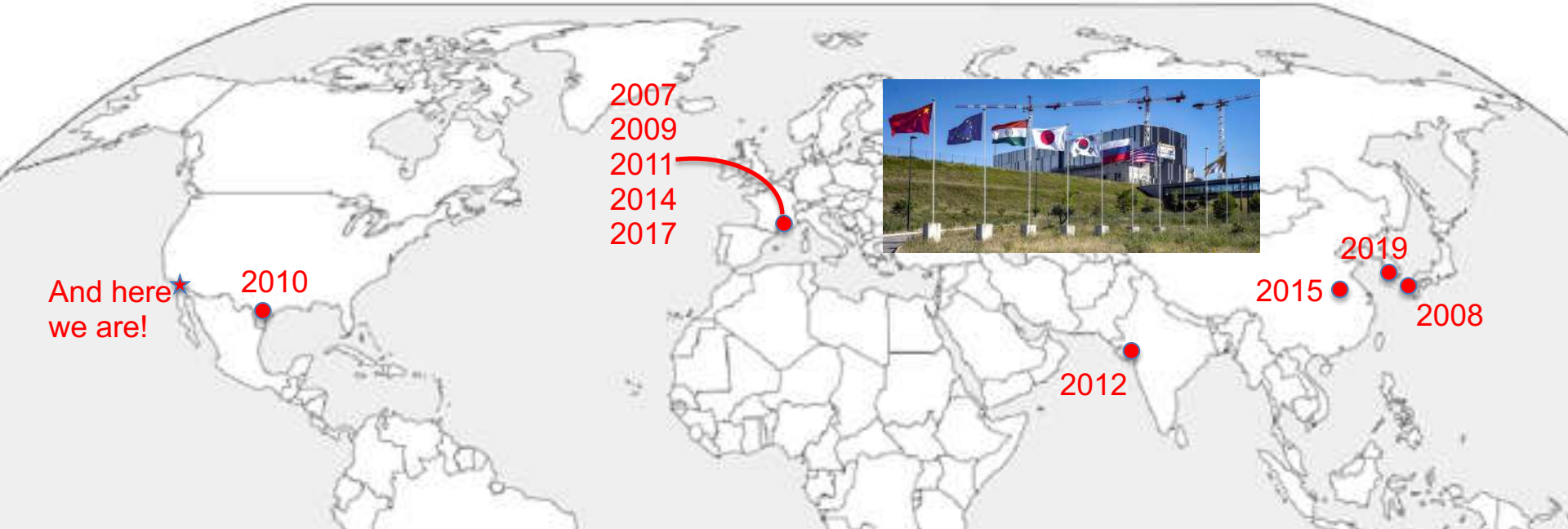
Organized for five days around a specific theme, the School offers lectures by leading specialists from research organizations within the ITER Members and from the ITER Organization, stimulating discussion sessions, and the opportunity for students to publicize their own research through poster presentations.

Because of COVID-19, it has been 3 years since we had been able to meet this way... we're all very happy to be back!

COVID-19 is still with us, so we ask all of you to take reasonable precautions during this week



The IIS alternates between Aix-Marseille University and sites in ITER Member countries



The 11th IIS marks the first time a non-EU Member has hosted twice!

ITER International School previous incarnations



1	2007	Aix-en-Provence, France	Turbulent transport in fusion plasmas
2	2008	Fukuoka, Japan	Magnetic confinement
3	2009	Aix-en-Provence, France	Plasma-surface interactions
4	2010	Austin, Texas, USA	Magnetohydrodynamics and Plasma Control in Magnetic Fusion Devices
5	2011	Aix-en-Provence, France	Energetic Particles
6	2012	Ahmedabad, India	Radio frequency heating
7	2014	Aix-en-Provence, France	High-performance computing in fusion science
8	2015	Hefei, China	Transport and pedestal physics in tokamaks
9	2017	Aix-en-Provence, France	Physics of disruptions and control
10	2019	Daejon, Korea	The Physics and Technology of Power Flux Handling in Tokamaks
11	2020	Aix-en-Provence, France	The Impact and Consequences of Energetic Particles on Fusion Plasmas

The 2020 ITER International School on "The Impact and Consequences of Energetic Particles in Fusion Plasmas" has been postponed to summer 2023 due to the coronavirus. (The exact date will be announced in autumn 2022.) The host (Aix-Marseille University) and the venue (Aix-en-Provence, France) are unchanged.

Why was there a waiting list for this school?



- **After two years of lockdowns we really did not know what kind of turnout to expect**
- **Typical IIS attendance has been about 135 people**
- **My big worry when making the arrangements for this meeting was that there would be too few people!**
 - The capacity of this room is 200 people

We were very surprised to have to turn people away... there are 200 students, lecturers, and other attendees registered for IIS2022!

We're also gratified by the level of interest and enthusiasm in IIS2022

Organization of the 2022 ITER International School



- **The US Burning Plasma Organization, along with the ITER Organization, the University of California at San Diego, and General Atomics, are hosting the 11th ITER International School (IIS) on the topic of “ITER Plasma Scenarios and Control” at UC San Diego**
- **An excellent scientific program has been assembled by Peter de Vries (ITER Organization), David Humphreys (General Atomics), and Chris Holcomb (Lawrence Livermore National Laboratory) with input from an international Scientific Advisory Committee**
- **Local arrangements were made by Miriam Holtzman (UCSD), Cynthia Meeves (UCSD), Caroline Oliva (General Atomics), Dmitri Orlov (UCSD) and myself**
 - Please thank Miriam and Cynthia if you see them around this week!
(you will)

The US Burning Plasma Organization



- **The USBPO is a community organization, formed in 2005 with the mission to “advance the scientific understanding of burning plasmas and ensure the greatest benefit from a burning plasma experiment by coordinating relevant U.S. fusion research with broad community participation.”**
- **Most USBPO activities have been tied to ITER**
 - Coordination of US input to the ITER design review
 - US representation on ITER STAC and the ITPA Coordinating Committee
 - Discussion of modes of collaboration within the greater ITER research program
- **Also takes a role in communicating burning plasma research information to the community via webinars, etc.**
- **Currently, some USBPO activities have been on hiatus while many members participate in a DOE workshop discussing a US ITER Research Program**
- **Full membership in the USBPO is open to all US fusion researchers, and associate (non-voting) membership is open to our international colleagues**

<https://www.burningplasma.org>

The agenda includes lectures by experts in scenarios and control and sessions for students to present their work in poster form



	Monday	Tuesday	Wednesday	Thursday	Friday
Morning	<p>Welcome <i>Charles Greenfield, General Atomics</i></p> <p>Introduction to UCSD <i>Dmitri Orlov, UC San Diego</i></p> <p>DIII-D Scenario Development and Control Research <i>Chris Holcomb, Lawrence Livermore National Laboratory</i></p> <p>Status of the ITER Project and its Scenario Development and Control <i>Peter de Vries, ITER Organization</i></p>	<p>Control Simulation <i>Wolfgang Treutterer, Max Planck Institute for Plasma Physics</i></p> <p>Magnetic Equilibrium and Instability Control <i>Gianmaria De Tommasi, University of Naples</i></p>	<p>Model Based Control <i>Egemen Kolemen, Princeton University</i></p> <p>Core Kinetic and Magnetic Control in Tokamak Reactors <i>Eugenio Schuster, Lehigh University</i></p>	<p>Integrated Operation Scenarios <i>Francesca Poli, Princeton Plasma Physics Laboratory</i></p> <p>ITER Pre-Fusion Power Operation Phase Scenarios <i>Sun-Hee Kim, ITER Organization</i></p>	<p>Alternative Tokamak Operation Scenarios <i>Yong-Su Na, Seoul National University</i></p> <p>Long-Pulse Tokamak Operations <i>Sang-Hee Hahn, Korea Institute of Fusion Energy</i></p>
Afternoon	<p>Introduction to Tokamak Operation Scenarios and Development Considerations <i>Hartmut Zohm, Max Planck Institute for Plasma Physics</i></p> <p>The Science of Control <i>Michael Walker, General Atomics</i></p>	<p>First Wall Heat Load Control, ELM and Divertor, Detachment Control <i>David Eldon, General Atomics</i></p> <p>Disruption Prevention and Avoidance <i>David Humphreys, General Atomics</i></p> <p>Poster Session I</p>	<p>Actuators and Sensors for Tokamak Control <i>George Sips, General Atomics</i></p> <p>Integration of plasma real-time control, state monitoring and event detection for reliable and routine operation of tokamaks <i>Federico Felici, Swiss Plasma Center</i></p> <p>Scenario Development Constraints (operation limits, control constraints) <i>Indranil Bandyopadhyay, ITER India</i></p>	<p>ITER Baseline Scenario (Q=10 ELMy H-mode) <i>Francesca Turco, Columbia University</i></p> <p>Preparation and Execution of JET Deuterium-Tritium Campaign <i>Joëlle Mailloux, UKAEA</i></p> <p>Poster Session II</p>	<p>Best Poster Prize Closing Ceremony</p>
Evening	<p>Early dinner served to all participants</p> <p>Tours of DIII-D at 5:45PM and 7:15PM (for those who registered)</p>	<p>School Dinner sponsored by General Atomics</p>	<p>Perhaps the most important part of any school: Discussion sessions are interspersed throughout the program</p>		

About the main sessions



- **A detailed agenda is posted at <https://iis2022.burningplasma.org/agenda>**
- **The lecture slides will be posted on the school website this week**
 - For now they will all be accessible only to registered attendees
 - As we receive permission from the lecturers they will be made publicly available... eventually moving to the IIS archive at <https://www.iter.org/education/iis>
- **Please participate in the discussion sessions!**
- ***Lunch will be served to all participants outside the auditorium each day***

A general background knowledge of tokamaks and plasma physics is assumed, so the school will quickly dive into the topics of scenario development and control

Breaks and lunch will be available outside the auditorium



About the poster sessions

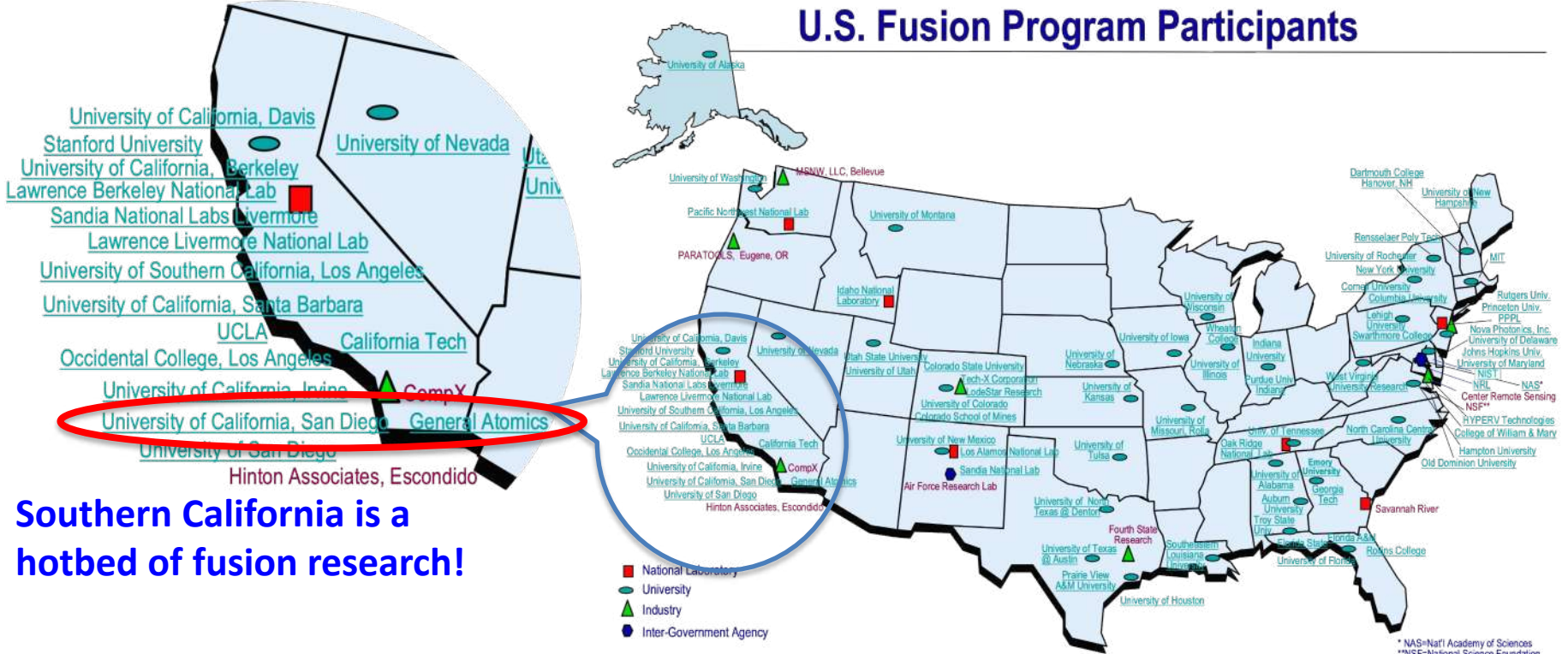
- **There are two poster sessions, on Tuesday and Thursday afternoon**
 - 111 total posters
- **There will be prizes for the best *student* posters in each session**
 - Sorry, those who registered as “other attendee” are not eligible for prizes
 - Judging will be done by the lecturers
- **The prizes will be presented at the end of the school on Friday**
 - CS coils superconductor samples
 - Coffee-table picture books of ITER construction



Fusion research is widespread in the United States



U.S. Fusion Program Participants

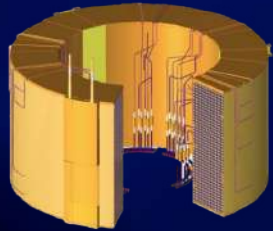


Dmitri Orlov will tell you about UCSD
I will say a little bit about General Atomics...

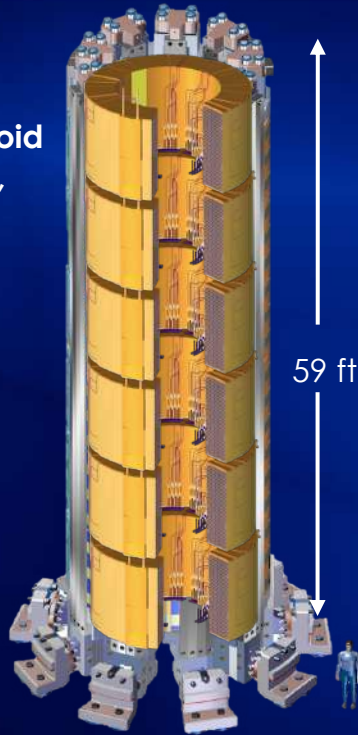
Not shown: Privately funded fusion research is a new growth industry in the US and the world

General Atomics is home to numerous fusion technology and research efforts

ITER
Central Solenoid
(6 modules,
1000 tons)



ITER CS Module



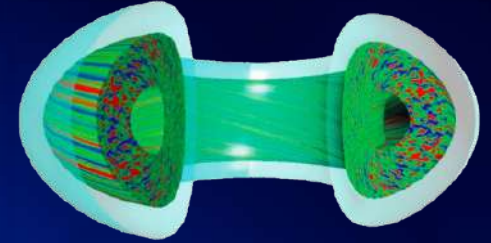
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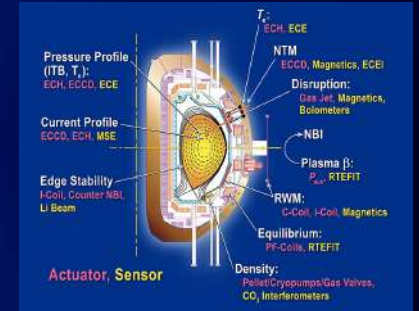
Plasma diagnostics



Fusion Technology



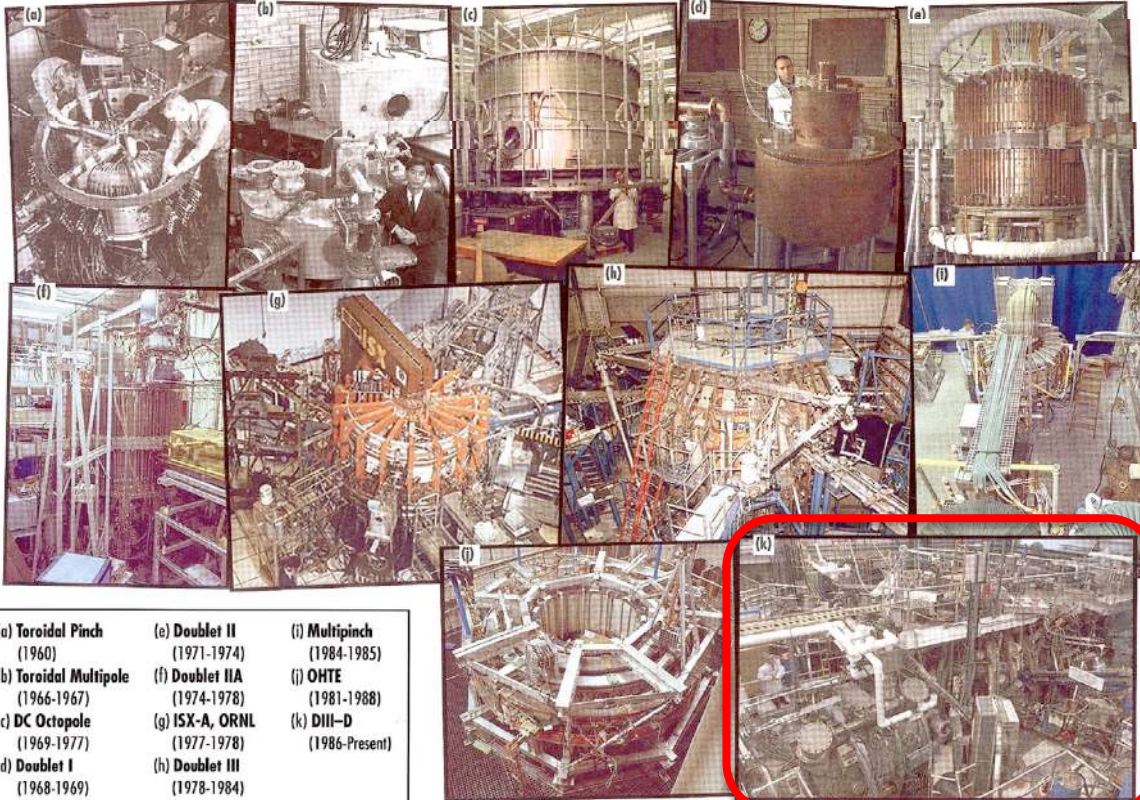
Theory and Computation



Plasma Control

General Atomics has a 60+ year history of hosting fusion research devices

FUSION RESEARCH AT GENERAL ATOMICS 1960-PRESENT



Tonight's tour



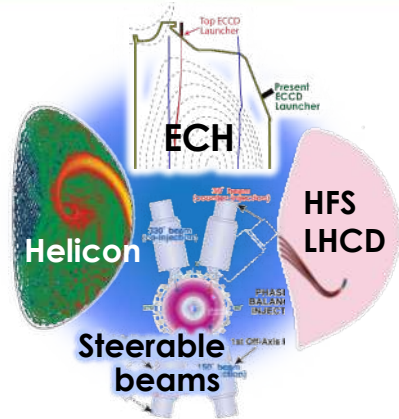
DIII-D is a Highly Flexible Plasma Research Facility Able to Explore a Wealth of Underlying Physics

Steerable heating and current drive systems

Neutral beams, microwave, high harmonic fast wave
Variable torque, localization, heating, current, electrons/ions

18 field shaping coils & 3 arrays of 3-D coils

Wide range of plasma configurations
Probe and control plasma MHD events

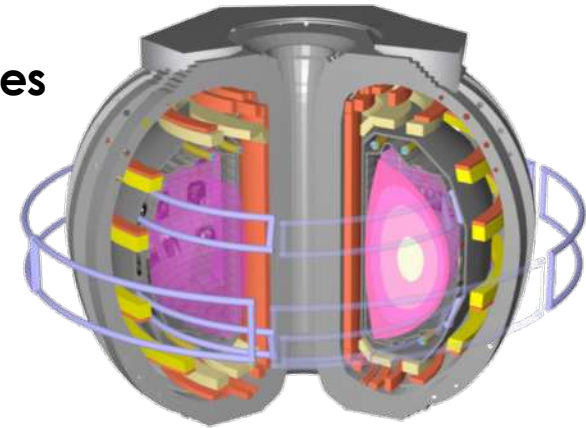


- **Perturbative materials flexibility & twin power handling zones**

Precisely study cold plasma interactions & shocks

- **High temperature bake, cryo-pumping with flexible gas and pellet injection**

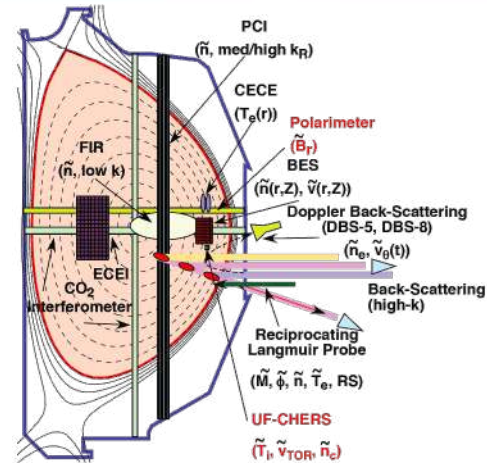
Plasma purity, density, profile control & perturbative transport



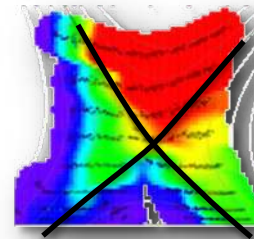
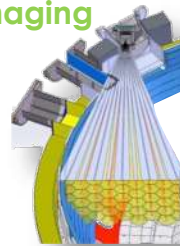
Ability to precisely design and vary plasma configuration

DIII-D has a Powerful Diagnostic Set To Test Physics Models of Behavior

- **Comprehensive diagnostics**
 - Profiles: current, rotation, T_i , T_e , n_e
 - Magnetic sensor arrays
 - Turbulence suite $k=0.1-100\text{cm}^{-1}$
 - Fast ion spectra & losses,
 - Neutrons, γ ray imaging, SXR, ICE
 - Bolometry, spectroscopy – UV, visible
 - Infra red, Langmuir probes
- **Pellet injectors:**
 - D_2 , A_r , N_e , li/B granules, shattered
- **Material sample exposure facilities**
- **Laser blow off system**

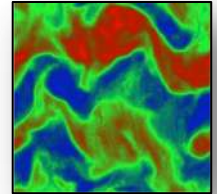


γ imaging



2D
Thomson
scattering

Turbulence
Diagnostics



Remotely observe and measure multiple plasma physics phenomena

Many of you will tour The DIII-D National Fusion Facility tonight

- **One of two US Department of Energy magnetic confinement fusion user facilities in the US**
 - Over 800 members of the DIII-D Team come from over 100 institutions throughout the world
- **Research on DIII-D covers a broad set of topics including several that help us prepare for ITER*:**
 - Scenario development
 - Plasma control
 - Transient control

** More about this from Chris Holcomb, later this morning*



What you'll see on the tour

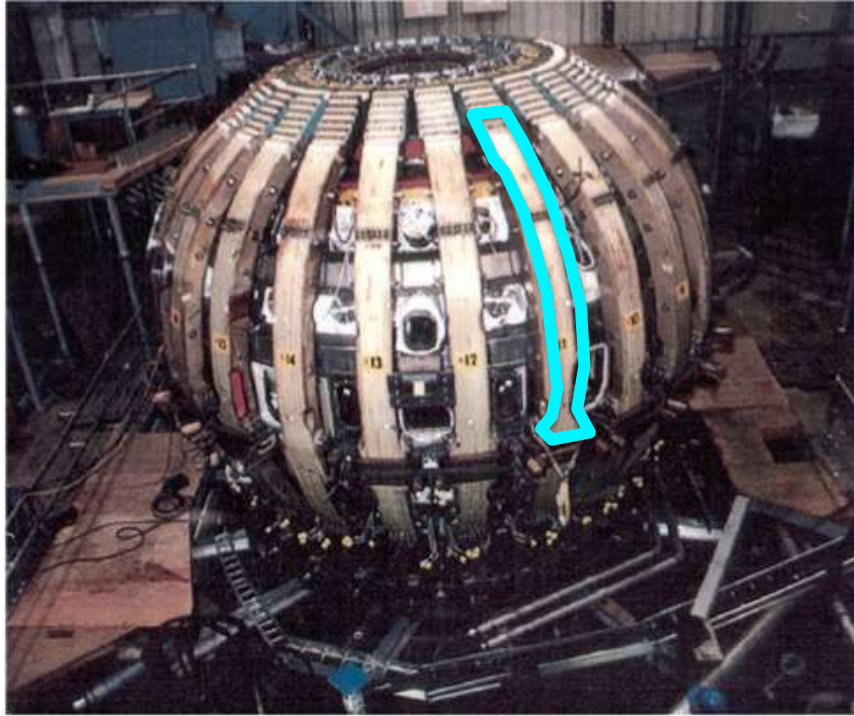
- Scale cross section and retired predecessor tokamaks
- The DIII-D Device
- ECH hall and ECH control room
- Patch panel and cryoplant
- Main control room

Tokamak
cross
section

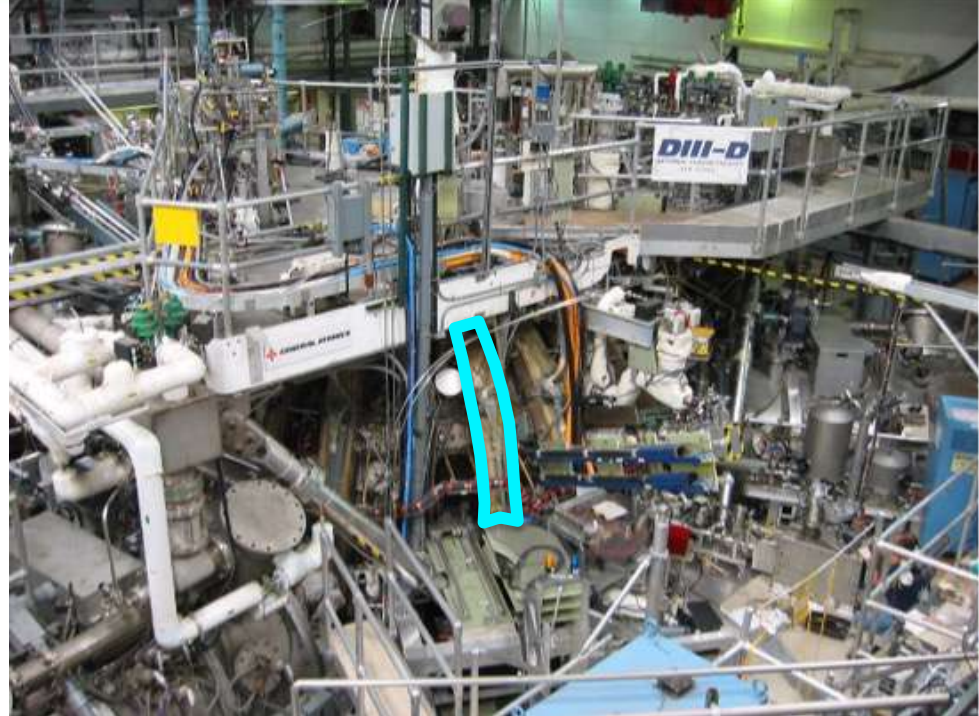
Scientific
Outreach
Coordinator



A challenge for you: Find the tokamak!



DIII-D during assembly



DIII-D today

Some tour logistics



- **The tour is limited to those who registered in advance**
- **Each of those who registered have been assigned to one of two groups:**
 - Group 1 will depart from UCSD at 5:45 PM and return at 7:45 PM
 - Group 2 will depart from UCSD at 7:15 PM and return at 9:15 PM
 - *We were not able to give everybody their preferred time*
- **Most of you are staying on campus and would otherwise miss dinner, so an early dinner will be brought HERE at 4:30 PM**
 - We know that's early, but wanted to make sure everybody has a chance to eat

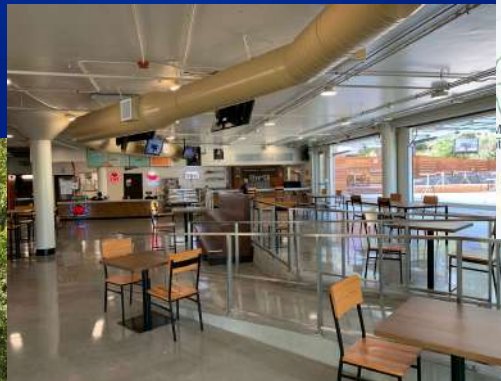
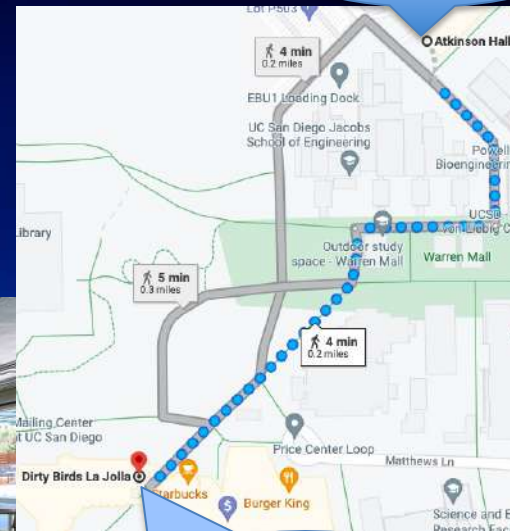
Please find your assigned tour time at <https://iis2022.burningplasma.org/tours>

Note that this is the time the buses will depart... please come a few minutes early!

General Atomics is inviting you to dinner!

You are here!

Please join us Tuesday evening following the end of the technical sessions for the IIS dinner, sponsored by General Atomics, at Dirty Birds Bar and Grill on the UCSD campus



Good things to eat and drink will be here!