GA–A27328

DIII–D YEAR 2012 EXPERIMENT PLAN

by
DIII–D RESEARCH TEAM

JUNE 2012

GENERAL ATOMICS

DISCLAIMER

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Work supported by
the U.S. Department of Energy
under Cooperative Agreement No. DE-FC02-04ER54698

GENERAL ATOMICS PROJECT 30200
JUNE 2012

FOREWORD

This document presents the planned experimental activities for the DIII-D National Fusion Facility for the fiscal year 2012. This plan is part of a five-year cooperative agreement between General Atomics and the Department of Energy. The Experiment Plan advances on the objectives described in the DIII-D National Fusion Program Five-Year Plan 2009–2013 (GA-A25889). The Experiment Plan is developed yearly by the DIII-D Research Council and approved by DOE. DIII-D research progress is reviewed quarterly against this plan. The 2012 plan is for 13 weeks of tokamak physics research operations.

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1. SYNOPSIS OF THE 2012 DIII-D RESEARCH PLAN

1.1. INTRODUCTION

The 2012 Experiment Plan covers 13 weeks of tokamak physics research operations. The 2012 campaign follows on a very successful experimental campaign carried out in 2011. The 2011 campaign consisted of 14 run weeks. Experiments in 2011 exploited the new capabilities added during the 2010–2011 Long Torus Opening II (LTO II), including: 1) reorientation of the 150-degree neutral beam line to allow for vertical displacement of the beam line so as to provide up to 5 MW of neutral beam power directed away from the magnetic axis (i.e. off-axis injection); 2) modification of the Thomson scattering system with the addition of more channels viewing the plasma edge to allow for very high spatial resolution at the plasma edge. In addition, improvements were made during the year to the pellet injection hardware to provide for up to 60 Hz pellet pacing of Edge localized modes (ELMs).

The 13-week program plan for 2012 provides adequate experimental time for DIII-D to: (a) enable the success of ITER by providing physics solutions to key physics issues (highest DIII-D priority); (b) continue its leadership role in development of a physics basis for steady-state operation in ITER and beyond; (c) to advance the fundamental understanding of fusion plasmas along a broad front.

1.2. 2011 and 2012 ITPA EXPERIMENTS

During the 2011 campaign, many experiments were conducted in support of physics areas identified by the International Tokamak Physics Activity (ITPA) working groups (Table I). These experiments continue to support long-term physics needs of ITER (Table II) in the 2012 experimental campaign.

Table I
DIII-D Conducted a Number of Experiments in 2011 in Support of the ITPA

ID No.	ITPA Title	DIII-D Experiment
TC-7	Ion temperature gradient (ITG)/trapped electron mode (TEM) transport dependence on T_i/T_e, q profile and rotation in L-mode plasmas	Investigate critical gradients and stiffness in ion and electron channels, with rotation
PEP-19	Basic mechanisms of edge transport with resonant magnetic perturbations in toroidal plasma confinement devices	Several experiments in the edge localized mode (ELM) control: 3-D field induced transport task force
PEP-23	Quantification of the requirements for ELM suppression by magnetic perturbations from internal coils	Several experiments in the ELM control: 3-D field induced transport task force
PEP-24	Minimum pellet size for ELM pacing	ELM pacing by pellets
PEP-25	Inter-machine comparison of ELM control by magnetic field perturbations from midplane resonant magnetic perturbation (RMP) coils	Several experiments in the ELM control: 3-D field induced transport task force
PEP-34	Non-resonant magnetic field driven QH-mode	QH-mode with C-coil alone, I&C coils
PEP-35	Compatibility of ELM control for ITER and ITER-like pellet core fueling	Compatibility of fueling with ELM pacing
DSOL-20	Transient divertor re-attachment	Detachment and flows
DSOL-24	Disruption heat loads	Rapid shutdown with massive impurity injection
MDC-1	Disruption mitigation by massive gas jets	Rapid shutdown with massive impurity injection
MDC-2	Joint experiments on resistive wall mode physics	Resistive wall mode (RWM) physics including rotation
MDC-8	Current drive prevention/stabilization of neoclassical tearing modes (NTMs)	NTM control: develop mirror steering algorithms for NTM control
MDC-14	Rotation effects on neoclassical tearing modes	Effect on NTMs by rotation
MDC-16	Runaway electron generation, confinement, and loss	Several experiments in the runaway electron dissipation and control task force
MDC-17	Active disruption avoidance	Disruption avoidance by electron cyclotron heating (ECH)
EP-2	Fast ion losses and redistribution from localized Alfvén eigenmodes (AEs)	Off-axis neutral beam injection (NBI) effect on AEs
EP-3	Fast ion transport by small scale turbulence	Effect of microturbulence on off-axis neutral beam current drive (NBCD) and fast ion confinement
IOS-3.2	Define access conditions to get to steady-state scenario	ITER baseline scenario with dominant electron heating
IOS-4.1	Access conditions for hybrid with ITER-relevant restrictions	High q_{min}>2 with off-axis NBI
IOS-5.2	Maintaining ion cyclotron resonance heating (ICRH) coupling in expected ITER regime	Fast wave coupling and assessment
DIAG-2	Environmental tests on first mirrors	Dimes erosion studies

Table II
Many Experiments Planned During 2012
Will Support the ITPA

ID No.	ITPA Title	DIII-D Experiment
TC-15	Dependence of momentum and particle pinch on collisionality	Dependence of H-mode particle transport on collisionality and beam sources
TC-19	Characteristics of I-mode plasmas	Exploration of I-mode operating space in DIII-D
PEP-19	Basic mechanisms of edge transport with resonant magnetic perturbations in toroidal plasma confinement devices	Several experiments in the ELM control: 3-D field induced transport task force
PEP-23	Quantification of the requirements for ELM suppression by magnetic perturbations from off mid-plane coils	Several experiments in the ELM control: 3-D field induced transport task force
PEP-26	Critical edge parameters for achieving L-H transition	Turbulence and flow physics behind the L-H transition power threshold
PEP-27	Pedestal profile evolution following L-H/H-L transition	Pedestal evolution studies
PEP-30	ELM control by pellet pacing in ITER-like plasma conditions and consequences for plasma confinement	Tests of pellet ELM pacing
DSOL-26	Marker experiments to study material migration	DiMES material erosion
DSOL-24	Disruption heat loads	Vertical displacement event (VDE) heat load characterization
MDC-1	Disruption mitigation by massive gas jets	Rapid shutdown with massive impurity injection
MDC-2	Joint experiments on resistive wall mode physics	RWM physics model development
MDC-8	Current drive prevention/stabilization of NTMs	Real time mirror steering of electron cyclotron current drive (ECCD) for NTM suppression
MDC-16	Runaway electron generation, confinement, and loss	Several experiments in the runaway electron dissipation and control task force
MDC-17	Active disruption avoidance	Disruption avoidance by ECH
EP-2	Fast ion losses and redistribution from localized AEs	Off-axis NBI effect on AEs
EP-6	Fast-ion losses and associated heat load from edge perturbations (ELMs and RMPs)	Effect of 3-D fields on fast-ion confinement
IOS-3.2	Define access conditions to get to steady-state scenario	Several experiments in the high $q_{\min}$ area
IOS-4.1	Access conditions for advanced inductive scenario with ITER-relevant restrictions	ITER baseline scenario with dominant electron heating
IOS-5.2	Maintaining ICRH coupling in expected ITER regime	Fast wave coupling and assessment
DIAG-2	Environmental tests on first mirrors	Dimes erosion studies

1.3. 2012 MILESTONES

The 2012 experimental plan supports three DOE Milestones: Nos. 179–181. One of these milestones (181) is in support of the Fusion Energy Science (FES) Joint Research Target. Milestone 178 was based on research carried out in FY2011, though the report was submitted in FY12.

Milestone 178: ***Explore relationship between ELM suppression and increased turbulence and particle transport due to 3D field effects*** **(Completed December 2011).**

Investigate observed connections between applied 3-D magnetic fields, density decrease, edge turbulence, and edge transport as related to RMP-mediated ELM suppression. Examine and analyze relevant data and conduct new experiments, as needed, using external 3-D fields to vary the edge pressure gradient while using profile and fluctuation diagnostics to measure changes in ELM behavior, $E \times B$ flows, density and temperature gradients, stability, turbulence characteristics and flows, and fluctuation-driven edge transport. Compare measured effects with models for plasma response to 3-D fields and changes to transport.

Milestone 179: ***Evaluate off-axis neutral beam injection for high q_{min} steady-state scenarios*** **(September 2012)**

On DIII-D, discharges with high-normalized β and high noninductive current fraction (~95%) have been maintained for nearly a current profile redistribution time. Such plasmas have $q_{\mathrm{min}}>1.5$, which aids in the achievement of a high bootstrap current fraction. Modeling suggests that moving neutral beam injection off-axis (from ρ~0 to ρ~0.5) improves the access to and ability to sustain discharges with elevated q_{min} in the range 1.5–2.5 with potentially higher bootstrap current fractions. In this case, the off-axis power deposition may broaden the pressure profile and increase the β_N stability limit. We will report on experiments aimed at showing that off-axis neutral beam injection in high q_{min} discharges improves the ability to obtain sustained, fully noninductive, high bootstrap fraction operation.

Milestone 180: ***Assess alternate techniques for ELM control*** **(September 2012)**

Reliable alternative techniques for ELM control that do not require complex internal coils would be of great benefit to ITER and to magnetic fusion energy development. The ITER IO has request that experimental programs around the world examine all known techniques for ELM control that would not require magnetic coils with the vacuum vessel. Experiment will be performed to evaluate pellet ELM pacing and QH-mode operation, looking toward the development of a strong physics and operational basis for confident extrapolation to ITER. We will evaluate the operating parameter regime for low torque QH-mode and compare with peeling-ballooning and ideal MHD theory. We will evaluate the scaling of ELM frequency and ELM size with pellet injection frequency, evaluate the dependence of ELM pacing on injection location [high field side (HFS), low field side (LFS), X-point] and compare with 3-D MHD ELM triggering models.

Milestone 181: ***Core transport model validation*** **(September 2012). Supports FY2012 FES Joint Research Target (September, 2012).**

Understanding and predicting turbulence-driven thermal transport in present and future fusion experiments is a grand challenge of plasma physics. To this end, turbulence diagnostics and computer simulations and models are undergoing intense development to improve our ability to measure and predict plasma profiles and turbulence properties related to both ion and electron thermal transport. In parallel with diagnostic improvements, development of synthetic diagnostics for state-of-the-art turbulence simulations allows direct comparison with measurement. Experiments will utilize these multi-scale, multi-field turbulence and flow measurements and synthetic diagnostics to rigorously test and validate turbulence simulations. In addition, we will report on tests of transport models using comparison with measured plasma profiles and fluxes. The turbulence focus will be on obtaining and comparing radial profiles of key turbulence characteristics (e.g. nT cross phase, local n response to local grad T_e, radial correlation lengths, intermediate-kn response to local flows, etc.) to simulation results. These measurements and comparisons will be made over a range of plasma parametric states (e.g. plasma shape, confinement regimes, heating profiles, etc.) that are themselves chosen for their importance to the understanding of present and future plasmas.

Joint Facility Research Target. Conduct experiments and analysis on major fusion facilities leading toward improved understanding of core transport and enhanced capability to predict core temperature and density profiles. In FY 2012, FES will assess the level of agreement between predictions from theoretical and computational transport models and the available experimental measurements of core profiles, fluxes and fluctuations. The research is expected to exploit the diagnostic capabilities of the facilities (Alcator C-Mod, DIII-D, NSTX) along with their abilities to run in both unique and overlapping regimes. The work will emphasize simultaneous comparison of model predictions with experimental energy, particle and impurity transport levels and fluctuations in various regimes, including those regimes with significant excitation of electron modes. Along with new experiments, work will include analysis of relevant previously collected data and collaboration among the research teams. The results achieved will be used to improve confidence in transport models used for extrapolations to planned ITER operation.

1.4. 2012 TASK FORCE AND WORKING GROUPS AND GOALS

The research campaign for 2012 is organized into the three physics groups making up the Experimental Science Division, with one additional task force coordinated independently of that management structure (Fig. 1). This follows a re-organization of the Experimental Science Division in February 2012. Previously, the Experimental Science Division consisted of six physics groups. The FY12 experiments carried out in 2011 during the October-December, 2011 run period were performed under this old organizational structure (see General Atomics Report GA-A27050, the "FY11 Experimental Plan" for the groups and their descriptions). Moving forward, the experimental plan for the remainder of the FY12 campaign described in this document will refer to the new organization with the new Physics groups. There is also a category for the Torkil Jensen Award. The Torkil Jensen Award, up to one day of experimental run time per proposal, was established prior to the 2009 campaign to encourage submission of proposals for experiments that are focused on new research topics with the potential for exploring transformational physics using very innovative techniques.

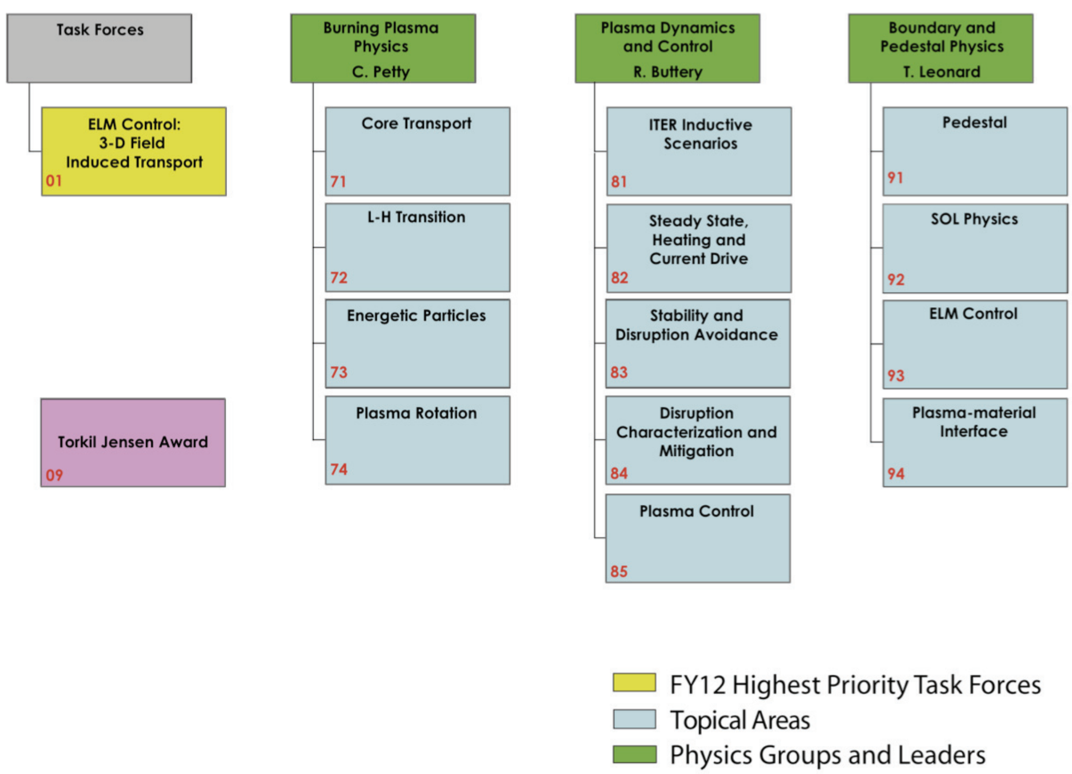

Fig. 1. The 2012 Experimental Campaign is organized into one task force, the Torkil Jensen Award category, and 13 research areas within the three main physics research areas of the Experimental Science Division.

The three main physics research areas consist of sub-sets of research areas, shown in blue, within which experiments are prepared and executed. The plans and goals for the task force and the various science areas in 2012 are detailed in the following sections.

1.4.1. TASK FORCE ON 3-D FIELD INDUCED EDGE TRANSPORT AND ELM CONTROL (Leader: R. Nazikian)

1.4.1.1. Mission. Understand the magnetic topology in the presence of 3-D fields, how the transport in the boundary of the plasma responds as a consequence of the presence of 3-D fields, how that transport leads to ELM suppression, and how to extrapolate to ITER conditions.

1.4.1.2. Importance and Urgency. ITER needs to make a design decision in the next 1–2 years regarding the inclusion of ELM control coils to mitigate and suppress ELM activity. This decision needs to be informed by a firm physics basis for the interaction of 3-D fields with plasma that extrapolates from current observations on DIII-D and AUG to ITER relevant parameters. In order to provide such a physics basis, DIII-D must undertake new experiments to fill vital gaps in the existing data and perform detailed physics analysis over a range of key plasma parameter required for extrapolation to ITER conditions.

1.4.1.3. Research Areas for 2012. This Task Force will focus on the following areas:

- Determine the magnetic topology and plasma response to the presence of externally applied non-axisymmetric fields.
- Investigate how external and internal non-axisymmetric fields change plasma transport (particle, energy and momentum).
- Explore how non-axisymmetric fields modify ELM stability.

1.4.1.4. New and/or Unique Tools.

- Combination of upper and lower internal coils (I-coils) capable of high frequency or high current operation with external error field correction coils (C-coils).
- Unique diagnostics, such as tangential soft x-ray imaging at the X-point region and above midplane magnetic probes, to measure plasma response including resonant field amplification and island formation.
- Application of state-of-the-art modeling tools such as MARS-F, PIES, M3DC1, ELITE, XGC0 and other codes to assess the plasma response to non-axisymmetric fields.

1.4.2. BURNING PLASMA PHYSICS (Leader: C. Petty)

1.4.2.1. Mission. Advance the predictive capability of critical physics phenomena in burning plasmas.

1.4.2.2. Importance and Urgency. Understanding the underlying mechanisms behind observed physical phenomena is critical for the design and operation of future devices. Validation of comprehensive physics models in the areas of transport and energetic particles will be a key focus of this group.

1.4.2.3. Research Areas for 2012. This physics area is organized into two topical groups, Energetic Particles and Transport. For planning purposes, the latter group is further divided into core transport and turbulence, plasma rotation, and the L-H transition. In addition, the integrated modeling group resides in the Burning Plasma Physics area. It is involved in general model development and serves as our liaison to other DIII-D groups that are strongly involved with model and software tool development. Members of the Burning Plasma Physics area are expected to work with the other physics areas on transport and energetic particle issues of importance.

- **Energetic Particles**. This research program strives to validate theoretical models of fast-ion instabilities, to predict their consequences in ITER, and to develop the means to control their effects. This year's group members will continue to focus on off-axis neutral beam physics, characterizing the beam parameters, investigating the effect of off-axis deposition on Alfvén eigenmode stability and mode structure, and measuring changes in fast ion confinement and current drive due to microturbulence.
- **Core Transport and Turbulence**. The long-term goal of this group is to develop a predictive understanding of transport embodied in a suite of validated transport models. This year's research plan supports the 2012 Joint Research Target and Milestone 181 on core transport model validation. Transport model validation on DIII-D is based on a primacy hierarchy that addresses physics on multiple levels to determine whether success/failure is systematic (multiple channels, a range of spatiotemporal scales) or is limited to certain areas. This group will also continue to analyze and model experiments from 2011 that tested the profile stiffness and critical gradient predictions in the TGLF code against experimental data.
- **Plasma Rotation**. Goal this year is to investigate the neoclassical theory of poloidal rotation by use of CER chords inside the magnetic axis to measure differences in toroidal rotation between the low- and high-field sides of the plasma.

- **L-H Transition**. An experiment will be done to examine the turbulence, GAM and shear flow physics near the plasma boundary to explain the density scaling of the L-H transition power threshold. A full fluctuation diagnostic set (BES, DBS and RS-probe) and a near-ITER-like plasma shape are important aspects of this experiment.

1.4.2.4. New and/or Unique Tools.

- DIII-D's uniquely comprehensive diagnostic set facilitates the detailed science studies conducted in the Burning Plasma Physics area. New diagnostics include a broadband Faraday rotation polarimeter along the midplane, fast time response photomultipliers for FILD, inboard/outboard CER chords, HF-CHERS, and a flexible 2D spatial configuration for BES.
- Unique capabilities for varying shape, heating location and heatingmix, and density. The off-axis beam and real time steerable ECH launchers are an important enhancement for heating profile flexibility.

1.4.3. DYNAMICS AND CONTROL (Leader: R. Buttery)

The priorities of this area flow from three principal goals in 2012: (i) to identify the optimization and control requirements for ITER Q=10 operation with low injected torque; (ii) to understand the role of current profile in optimizing the performance for a fusion steady state; (iii) to develop and perform basic characterization of the main candidate techniques for handling disruption events in ITER. Necessary stability and control work also flows from these objectives.

1.4.3.1. Mission. To develop viable integrated solutions for ITER, FNSF and a fusion power plant, understanding the physics basis to give confidence in extrapolation.

1.4.3.2. Importance and Urgency.

- In the coming years it is vital to anticipate the new physics conditions expected in ITER in order to develop the operational requirements and control systems needed to ensure ITER meets its main Q=10 performance.

- Fusion power plants and Fusion Nuclear Science Facilities (FNSF) require steady state regimes at higher performance levels than ITER. The approach for these facilities is to develop the design requirements for optimizing performance.

- Disruptions remain the most critical challenge for ITER. The required mitigation solutions have not been determined, but if insufficient, will result in damage to ITER. The US is responsible for developing the ITER disruption mitigation system by 2016.

To do so the US needs to develop a robust mitigation system for runaway electrons as well as a disruption avoidance system using preemptive control systems to minimize the frequency of disruptions.

1.4.3.3. Research Areas for 2012. This physics group is organized into the following topical areas:

- **ITER Inductive Scenarios.** This area focuses on three candidate regimes for Q=10 operation in the ITER: the Baseline, QH mode and Advance Inductive mode. The focus in 2012 is to optimize the three regimes using beam torque. In 2013–18 the DIII-D program will explore these regimes with hydrogen/helium operation, L/H access, current profile control, ELM/edge harmonic oscillation (EHO) control, active disruption avoidance, radiative divertor solutions and integration of innovative methods from this or other parts of the program.

- **Steady-State Heating and Current Drive.** This area focuses on high β_N steady-state optimization "high $\rho(q_{min})$" and the "high ℓ_i" regimes. Studies in 2012 will focus on the role of the current profile on performance. In 2013 the focus will turn to shape dependence and understanding ITER and FNSF requirements, then progressing in later years to higher β_N power plant requirements. The program will also pursue integration with edge solutions and develop necessary stability controls for passive and active stable operation. Relevant heating and current drive physics will also be explored.

- **Stability and Disruption Avoidance.** This area provides the underlying physics basis and controls necessary for operating stable scenarios. The focus in 2012 is on developing real time EC steering NTM control, improved methods of error field correction, integrated disruption response, and steady-state RWM physics limits. Later years will develop increased understanding of 3-D field interactions, progress towards routine disruption avoidance or event recovery, and if needed, resistive wall mode control.

- **Control Group** seeks to integrate advanced control science with stability and configuration control techniques to provide robust disruption free operation in ITER and future devices. In 2012, the program supports all the stability and scenario development goals, and in particular seeks to implement model based profile control. Later years will have increased focus on controlled operation near stability boundaries with robust and active disruption avoidance.

- **Disruption Characterization and Mitigation** research aims to develop sufficient mitigation tools to safely land a plasma, should a termination event be detected. FY2012 sees the beginning of an accelerated program to explore solutions for

ITER, which are needed for final design in 2016. The goal is to design candidate actuators for the thermal quench (to mitigate heat loads with sufficient symmetry, and to see if runaway suppression is possible), and (through improved control) of any resultant runaway beam in the current quench or runaway plateau phase of ITER. The is a challenging program, involving the development of new actuators and operational approaches, understanding of new physics processes and regimes, and multi-scale modeling. Subsequent to 2016, research will continue to explore the optimization of mitigation schemes and extension to FNSF.

1.4.3.4. New and/or Unique Tools for 2012.

- High power ECH/ECCD (six gyrotrons) with real time steering for off-axis current drive and stability control.
- Counter-NBI, provided by the rotated 210º beamline, allows control of applied torque decoupled from heating power, facilitating low-rotation studies.
- Off-axis NBI provided by the 150° beamline allows off-axis neutral beam current drive and broader pressure profiles.
- The pumped divertor regions facilitate particle control in plasma shapes optimized for high β and low collisionality.
- The internal I-coil and external C-coil for unique harmonic flexibility to provide/optimize simultaneous error field, NTV rotation and RWM control.
- Shattered pellets and shell pellets for thermal quench radiative heat load mitigation and runaway mitigation
- Runaway beam control developed to assess drive, sinks and mitigation of growing/mature runaway beams.

1.4.4. BOUNDARY AND PEDESTAL PHYSICS (Leader: A. Leonard)

1.4.4.1. Mission. Develop physics understanding of scrape-off layer (SOL) and divertor plasmas and edge plasma and plasma solutions (including pedestal) consistent with high fusion performance.

1.4.4.2. Importance and Urgency. Understanding the physics of the pedestal, SOL plasma, divertor plasma and plasma materials interactions is critical for the design and operation of ITER.

1.4.4.3. Research Areas for 2012. This physics group is organized into the following topical areas:

- **Pedestal**
  - **Tests of pedestal transport models.** Examine proposed mechanisms governing transport in the pedestal, including, kinetic ballooning modes (KBMs), electron temperature gradient (ETG) and Paleoclassical transport.
  - **Role of neutral fueling.** Determine the ionization source in the pedestal and the role it plays in establishing the pedestal density profile. Look for evidence of a radial pinch in pedestal particle transport.
- **Divertor and SOL Physics**
  - **Divertor detachment and plasma flows**. Test models of detachment onset and the interaction of plasma flows with attached and detached divertor plasmas. Explore configurations with potential for enhanced divertor detachment and heat flux spreading control.
  - **Thermal transport in the plasma boundary.** Develop understanding of heat transport in the SOL and divertor toward predicting SOL properties for ITER, including the role of fluctuation driven transport in the SOL. Examine SOL transport and profiles that lead to the observed scaling of divertor heat flux width.
- **ELM Control**
  - **Resonant magnetic perturbations.** Determine the physical processes that lead to ELM suppression with the application of RMP fields. This includes the plasma response to determine the actual magnetic field structure within the plasma, and the mechanism for enhanced transport that limits the pedestal profiles to below the critical ELM gradients.
  - **QH-mode.** Establish the viability of the QH-mode in ITER. The important issues include establishing QH-mode at low input torque and other reactor-relevant parameters. Determine the required velocity shear to establish QH-mode, and how non-resonant non-axisymmetric fields can establish the required velocity profile.
  - **Pellet ELM pacing.** Establish the viability of pellet ELM pacing for ITER. Demonstrate that rapid pellet injection can increase the ELM frequency by at least a factor of 10 with little degradation in plasma

confinement. Determine the minimum pellet penetration into the pedestal that still triggers an ELM. Demonstrate the compatibility of pellet ELM pacing with high field side central pellet fueling.

- **Plasma-Material Interface**
  - **High-Z material erosion**. Measure the gross and next erosion rates for high-Z materials, Mo or W, and low-Z, Al, using the DiMES facility. Compare the results with models for gross and net erosion and develop quantitative spectroscopic methods for inferring gross erosion rates.

1.4.4.4. New and Unique Tools.

- 2-D profile of SOL and divertor carbon flow velocity using a coherence imaging diagnostic.
- Improved divertor Thomson scattering with a new higher power and higher frequency laser.
- New periscope for large area views of the vessel surface using visible and IR emission.
- Combination of upper and lower internal magnetic perturbation coils (I-coils) capable of high frequency or high current operation with external error field correction coils (C-coils).
- Unique diagnostics, such as tangential soft x-ray imaging at the X-point region and above midplane magnetic probes, to measure plasma response including resonant field amplification and island formation.
- Application of state-of-the-art modeling tools such as MARS-F, PIES, M3DC1, ELITE, XGC0 and other codes to assess the plasma response to non-axisymmetric fields.
- Flexible coils (I-coils and C-coils) to produce non-resonant fields for driving NTV plasma flows.
- New pellet injector nozzles each capable of 25 Hz operation for driving an ELM frequency of 75 Hz with three injectors.

1.5. EXPERIMENT PROGRAM DEVELOPMENT

The 2012 experimental plan was compiled based on input and prioritization provided by the 2012 DIII-D Research Council (see page vii for list of council members for 2012). The Research Council develops a research plan annually based on the “DIII-D Five-Year

Program Plan 2009–2013," January 2009, GA-A25889, with adjustments made for scientific and programmatic issues identified since that plan was written.

In January 2012, a call for experimental research proposals towards the DIII-D objectives was issued for the remainder of the FY12 experiment campaign and 394 proposals were received and discussed at a community-wide Research Opportunities Forum (ROF; http://fusion.gat.com/global/Rof2012) on February 14–16, 2012. The overall interest of the general fusion community in research on DIII-D is highlighted by the large number of submissions received from universities (149), foreign labs (21), including 12 proposals received directly from the ITER International Organization (IO) in Cadarache, France. Remote participation, using H.323 video, was used in the plenary and most of the breakout sessions to allow participation by scientists at many remote locations in the US, including Princeton Plasma Physics Laboratory, Massachusetts Institute of Technology, and Oak Ridge National Laboratory, and internationally, including JET, ASDEX-Upgrade, JAEA, MAST, TEXTOR and the ITER IO. The interest shown in the DIII-D program is partly a result of DIII-D's commitment to domestic and international collaborations as well as its participation in the ITPA process and ITER Design Review. A listing of the proposals received at the ROF can be viewed at http://fusion.gat.com/global/Rof2012.

For 2012, the working groups reviewed these proposals and gathered additional ideas in response to results from the FY11 experimental campaign and the early part of the FY12 campaign. An initial allocation of the run time was provided to the Physics Areas leaders prior to the ROF. Reprioritization of the new set of remaining proposals was done within the working groups and an overall prioritized run plan proposal was prepared in each physics area and task force. These plans were presented to the Research Council. Subsequently, the Research Council provided advice to the DIII-D Director on the relative allocation of experimental time amongst the various areas. Based on this input, the Director confirmed the initial experimental allocation that had been provided for each program area.

1.6. RUNTIME ALLOCATION

The run time allocation for 2012 is based on a 13-week experimental campaign. Three weeks (of the 13 weeks) were completed during the October through December 2011 run period. Out of the remaining 10 weeks, experimental time has been allocated for 32 run days out of a possible 50 run days, with 10 days of contingency, and 8 days of director's reserve, which includes run days for the Torkil Jensen Award. The 8 days of director's reserve will be allocated in the latter part of June after assessment of the results from the May run period and the early June experiments. Additional detailed information can be found on the web, and related links: https://diii-d.gat.com/diii-d/Exp12.

The initial run plan (Table III) reflects the DIII-D Team's commitment to support ITER Urgent Design Issues, as identified by the ITPA, US BPO, the ITER Design Review Working Groups, and the ITER STAC. The plan is highlighted by experiments in support of urgent physics issues, including research results that may have an immediate impact on the ITER design itself. Experiments where DIII-D has unique capabilities to address these issues have been given highest priority.

Table III
Run Time Allocations for the 2012 Experiment Campaign
(remaining 10 weeks: May through August 2012)

Area	Description	Plan (Days)	ITPA/IEA Experiments (Days)	Area Leaders
Task Forces				
ELM control and 3D field-induced transport	Develop sufficient physics understanding of RMP ELM suppression to extrapolate to ITER and inform ITER decisions.	4	4	**R. Nazikian**
Physics Groups				
Burning Plasma Physics	Advance basic fusion plasma science on DIII-D through test of basic theories, development of new measurement capabilities, and novel ideas	7	4	**C. Petty**
Plasma control and operations	To develop viable integrated solutions for ITER, FNSF and a fusion power plant, understanding the physics basis to give confidence in extrapolation	13	1	**R. Buttery**
Boundary and Pedestal Physics	Provide physics understanding of SOL plasma, divertor plasma and plasma materials interaction toward solutions of steady state and transient heat and particle flux issues for ITER and future high power tokamaks	8	2	**T. Leonard**
	Total allocated days	**32**	**30**	
	Director's reserve	**8**		
	Contingency	**10**		
	Available days	**50**		

1.7. DETAILED LIST OF SCHEDULED EXPERIMENTS

Table IV lists the experiments that were scheduled during the 2012 experimental campaign for the October 12 through December 2, 2011 period.

Table IV
Detailed List of Experiments for the FY12 (Oct-Dec) Experiment Campaign

Expt	Title	Area	SL
2011-35-01	Evaluation of long-pulse stability/confinement characteristics of ITER baseline scenario	ITER demonstration discharges	G. Jackson
2011-32-01	Test blanket module (TBM) studies	Error field and TBM mockup effects	M. Schaffer
2011-01-01	n=3 RMP toroidal phase flipping to search for island structures	ELM control: 3-D field transport	M. Wade
2011-41-01	Current profile control	Integration and model-based control	M. Walker
2011-31-01	Performance extension of QH-mode with co-I_p NBI	Alternative techniques for ELM control	K. Burrell
2011-11-01	AT current profile optimization with off-axis NBI	Fully noninductive scenarios with off-axis NBI	J. Ferron
2011-14-01	RWM studies	RWM physics including rotation dependence	M. Okabayashi
2011-31-02	Pellet pacing ELM studies	Alternative techniques for ELM control	L. Baylor
2011-53-01	L-H transition trigger physics: density and q_{95} scaling mechanisms	Transport	G. Tynan
2011-61-01	Divertor geometry studies	Plasma boundary interface	T. Petrie

Table V lists the experiments that will be scheduled during the 2012 experimental campaign according to the 32 days presently allocated for the May 14 through August 31, 2012 period.

Table V
Detailed List of Experiments for the FY12 (May-Aug) Experiment Campaign

Expt	Title	Area	SL
2012-01-02	β and I-coil dependence of *n*=3 RMP ELM suppression and pedestal response	ELM control: 3-D field transport	R. Nazikian
2012-01-03	β and I-coil dependence of *n*=2 RMP ELM suppression and pedestal response	ELM control: 3-D field transport	M. Lanctot
2012-01-04	Toroidal rotation dependence of ELM suppression and pedestal structure	ELM control: 3-D field transport	W. Solomon
2012-01-05	Expand the window of ELM suppression to higher q_{95}	ELM control: 3-D field transport	J. deGrassie
2012-01-06	ELM suppression with RMP in stellarator symmetric plasmas	ELM control: 3-D field transport	E. Lazarus
2012-71-01	Commissioning of the 288 GHz R0 polarimeter	Core transport	X. Chen
2012-71-02	Dependence of H-mode particle transport on collisionality and beam sources	Core transport	T. Luce
2012-71-03	Coupling of core electron and ion transport in TEM-dominated regimes	Core transport	L. Schmitz
2012-71-04	Transport and turbulence validation in high density QH-modes	Core transport	C. Holland
2012-71-05	Edge transport shortfall in L-mode plasmas	Core transport	T. Rhodes
2012-72-01	Turbulence and flow physics behind the L-H transition power threshold	L-H transition physics	Z. Yan
2012-73-01	Effect of off-axis neutral beam on AE stability	Energetic particles	W. Heidbrink
2012-73-01	Effect of 3-D fields on fast-ion confinement	Energetic particles	M. Van Zeeland
2012-74-01	Investigate neoclassical theory of poloidal rotation	Plasma rotation	C. Chrystal
2012-81-01	ITER baseline with low rotation and electron heating	ITER inductive	G. Jackson
2012-81-02	QH mode sustained *G*~0.4 and low torque startup	ITER inductive	A. Garofalo
2012-81-03	Fast wave commissioning	ITER inductive	R. Pinsker
2012-82-01	β_N>4 with high q_{min} using off-axis NBI — Day 1	Steady-state H&CD	C. Holcomb
2012-82-02	High β, high q_{min} – Day 2	Steady-state H&CD	C. Holcomb
2012-82-03	High β, high q_{min} – Day 3	Steady-state H&CD	C. Holcomb
2012-82-04	Start high ℓ_i studies with raised I_p	Steady-state H&CD	J. Ferron
2012-83-01	Steerable mirror checkout	Stability and DA	E. Kolemen
2012-83-02	RWM physics model development	Stability and DA	J. Hanson
2012-83-03	Multi-harmonic error field control	Stability and DA	M. Lanctot
2012-83-04	Integrated soft-landing scenarios	Stability and DA	N. Eidietis
2012-83-05	Checkout PCS algorithm controls with mirrors	Stability and DA	A. Welander
2012-83-06	Feed-forward mirror sweeps for NTM suppression (a la AUG B_T sweeps)	Stability and DA	E. Kolemen

Table V
Detailed List of Experiments for the FY12 (May-Aug) Experiment Campaign (Continued)

Expt	Title	Area	SL
2012-83-07	Target lock for mirror alignment of ECCD for NTM suppression	Stability and DA	A. Welander
2012-83-08	Catch and subdue with mirror alignment of ECCD and best dud detector of onset	Stability and DA	E. Kolemen
2012-84-01	Shattered pellet studies	Disruption characterization & mitigation	N. Commaux
2012-84-02	VDE heat load characterization	Disruption characterization & mitigation	D. Humphreys
2012-84-03	RE formation with new Ar pellet injector	Disruption characterization & mitigation	N. Eidietis
2012-84-04	Determine E_{crit} in stationery RE plateau	Disruption characterization & mitigation	E. Hollmann
2012-84-05	Shell pellet commssioning	Disruption characterization & mitigation	E. Hollmann
2012-91-01	Fueling to high pedestal density	Pedestal	A. Leonard
2012-91-02	Pedestal evolution	Pedestal	R. Groebner
2012-92-01	High X-point divertor geometry	Divertor and SOL physics	T. Petrie
2012-92-02	Snowflake divertor configuration initial exploration	Divertor and SOL physics	E. Kolemen
2012-92-03	SOL heat flux width dependence on power	Divertor and SOL physics	M. Makowski
2012-93-01	Develop low-torque, high normalized fusion performance QH-mode for ITER/FNSF	ELM control	A. Garofalo
2012-93-02	Experimental tests of NTV theory in counter-rotating QH-mode	ELM control	A. Garofalo
2012-93-03	Tests of pellet ELM pacing	ELM control	L. Baylor
2012-93-04	Exploration of I-mode operating space	ELM control	M. Fenstermacher
2012-94-01	DiMES material erosion	Plasma-material interface	D. Rudakov

1.8. THE 2012 OPERATIONS SCHEDULE

The operations schedule is designed for efficient and safe use of the DIII-D facility. Thirteen calendar weeks of plasma physics operations were allocated for the fiscal year 2012. Three weeks were performed during the October-December, 2011 run period and the remaining FY2012 operations are scheduled to start on May 14 and end on August 31, 2012. The operations schedule is shown in Fig. 2. The 2012 operations schedule can be viewed at https://diii-d.gat.com/diii-d/OpsSchedule12.

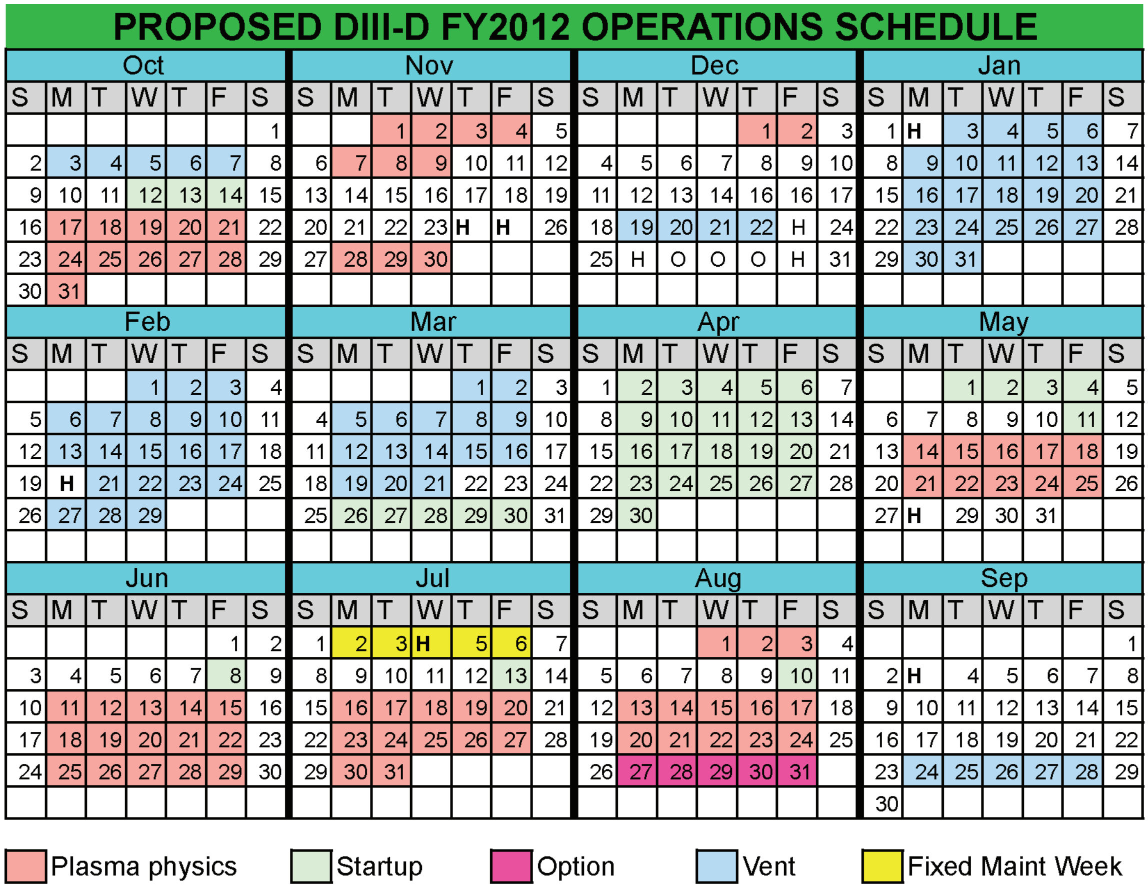

Fig. 2. DIII–D master schedule FY2012 (13-week plan).

In addition to operating the tokamak, maintenance has to be performed and new hardware is being installed to enhance DIII-D capabilities. The schedule calls for these maintenance activities to be carried out during the weeks that the tokamak is not operating.

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