GA–A23345

DIII–D YEAR 2000 EXPERIMENT PLAN

by
DIII–D RESEARCH STAFF

FEBRUARY 2000

DISCLAIMER

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FOREWORD

This document presents the planned experimental activities for the DIII–D National Tokamak Facility for the calendar year 2000. This plan is part of a five-year contract between General Atomics and the Department of Energy. The Experiment Plan advances on the objectives described in the DIII–D Tokamak Long Range Plan (GA–A23344). The Experiment Plan is developed yearly by the DIII–D Research Council, reviewed by the DIII–D Program Advisory Committee, and approved by DOE. DIII–D research progress is reviewed quarterly against this plan. The 1999 plan is based on a $54.1M DIII–D program funding for FY00, with $42.3M to GA, which allows for 16 weeks of tokamak operations. Other major collaborators include PPPL ($4.49 M), LLNL ($3.4M), and ORNL ($2.49M). Funding of university collaborators are provided by DOE grants and GA subcontracts. In the event of significant budgetary, technical, or programmatic changes this plan will be revised.

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. THE 2000 DIII–D RESEARCH PLAN

The research campaign for 2000 has been organized into five research thrusts and a broader selection of experiments in four Topical Science Areas. Significant blocks of experimental time have been allocated to the research thrusts, since these activities are aimed directly at critical objectives for the DIII–D Program and for the tokamak research program generally. Additional experimental time in the topical areas maintains the breadth and scientific depth of the DIII–D Program. Below we convey the essential content of the various research thrust and topical science experiments and their goals and anticipated and hoped for results. The research described has been allocated to 55 run days out of a possible 69 run days in the 1999 campaign. Additional detailed information can be found on the Web locations:

http://fusion.gat.com/exp/
http://fusion.gat.com/exp/2000/
http://fusion.gat.com/exp/2000/thrusts.shtml
http://physics.gat.com/sched2000.asp
http://physics.gat.com/exp2000.asp

The experiment plan was put together with input and prioritization by the year 2000 Research Council. Based on the “DIII–D Five-Year Program Plan 1999–2003,” August 1998, GA–A22950, the Research Council develops a three-year plan which is annually updated. The first of these Three Year Plans was made in 1999. Progress on the research thrusts and topical areas in the 1999 experiment campaign was reviewed at the Year End Review (http://fusion.gat.com/exp/2000/review.shtml, also broadcast on the internet) September 15–16, 1999. With input from that review and considering the three-year objectives, year 2000 research thrusts were identified. A call for ideas towards those objectives was issued and approximately 200 ideas were presented at a community “Brainstorming Meeting” of October 20–22, 1999 which was broadcast on the internet. The various thrust and topical area groups prioritized, combined, and otherwise sifted these ideas. The resulting plans were presented to the Research Council December 14 and the advice of the Research Council was used to set the final allocations of run time for the year 2000 campaign.

The 2000 experiment plan, summarized in Table 1, consists of efforts in five thrust areas and four topical areas. Owing to limited run time, it was not possible to allocate time to each of the thrusts which have been identified by the Research Council over the last two years. One thrust, the Optimum Edge Thrust, was completed in 1999. Others which did not receive an explicit allocation of time in 2000 will be part of the plan in future years. Each of the nine efforts has a responsible leader and deputy leaders. A brief synopsis of progess in the various thrusts in 1999 followed by year 2000 plans is given below.

Table 1
Run Time Allocations for the 2000 Experiment Campaign

No.	Acronym	Description	69-Day Plan	Thrust Leaders
1	Edge stability	Regulate the edge bootstrap current and/or the edge pressure gradient to extend the duration of AT modes. (Analysis, diagnostic in 2000)		J. Ferron (GA) L. Lao (GA)
2	AT Scenario	Progress toward a high bootstrap fraction AT plasma demonstration	9	T. Luce (GA) M. Wade (ORNL)
3	NTM	Stabilization of neoclassical tearing modes (Some work in Stability Area)		R. La Haye (GA) C. Petty (GA)
4	RWM	Feedback stabilization of resistive wall modes	8	G. Navratil (Columbia) A. Garofalo (Columbia) M. Okabayashi (PPPL)
5	Optimum edge	Develop the basis for choosing single versus double null and the optimum triangularity of the outermost flux surface in future machine designs. (Complete)		M. Fenstermacher (LLNL) T. Osborne (GA) T. Petrie (GA)
6	High ℓ_i	Exploration of the high ℓ_i AT plasma scenario		Deferred to 2001
7	ITB	Expand the spatial extent and time duration of internal transport barriers	3	C. Greenfield (GA) E. Synakowski (PPPL) E. Doyle (UCLA)
8	AT divertor	Explore closed, pumped divertor operation toward AT application	8	M. A. Mahdavi (GA) M. Wade (ORNL)
9	EC	ECH/ECCD validation	6	R. Prater (GA) J. Lohr (GA)
		Thrust Totals	34	
		Stability Topical Area	6	E. Strait
		Confinement Topical Area	10	K. Burrell
		Boundary Topical Area	5	S. Allen
		Heating and Current Drive Topical Area	0	R. Prater
		Topical Area Sum	21	
		Percentage of Total Days	38	
		Contingency	14	
		Sum	69	

1.1. RESEARCH THRUSTS FOR 2000

1.1.1. AT Scenario, Research Thrust 2 — Preparation for an NCS AT Plasma Demonstration (Leader: T.C. Luce, Deputy: M.R. Wade)

The high q_{min} approach is the primary AT scenario being pursued by DIII–D in its long term development of the AT potential. The key to realizing this scenario in steady-state is the maintenance of a hollow current profile using ECCD to prevent resistive diffusion of the off-axis current peak. Over the next three years, the EC power on DIII–D will be increased steadily from the present system to an eight-gyrotron system. More importantly, the five newest gyrotrons will be equipped with diamond windows to enable longer (10 s) pulses. Set against this background of a steady buildup in the necessary hardware, this thrust is aimed at a first demonstration in 2001 of a non-inductive high performance AT scenario. Once such a scenario has been demonstrated, optimization of normalized and absolute performance will be carried out. Both physics understanding and direct implementation on larger devices will be key to developing confidence for a true fusion power system.

Progress toward the AT demonstration discharge was significant in 1999. Guided by previous scenario modeling, exploratory experiments to determine the limiting β at parameters suitable for the demonstration (B = 1.6 T, I = 1.2 MA) were initiated. Surprisingly, these discharges made a smooth transition into an ELMing H mode while maintaining β near the maximum value. The longest duration discharge (β_N H_{89} ~ 9 for 2 s) of this type is shown in Fig. 1. This discharge exhibits the three typical features seen in most of these high performance discharges. First, the initial rapid increase in β during the ELM-free period is terminated before the first ELM and without the catastrophic loss of performance typical of previous high performance discharges. This saturation is attributed to bursting high frequency instabilities seen on external magnetic coils which appear to be Alfvénic and driven by the NBI fast ion population. Second, the small excursions in β_N (and large ones in H_{89}) are correlated with the growth of very low frequency (<100 Hz) n = 1 magnetic perturbations identified as resistive wall modes. These set the limit on β in the quasi-steady phase. Finally, due to resistive diffusion, the current evolves to where a resistive wall mode (in this case combined with a tearing mode) grows and irreversibly ends the high performance phase. This points to the focus of this year's campaign which is current profile control and sustainment with ECCD.

Analysis of the internal loop voltage in this type of discharge indicates that about 75% of the plasma current is supplied non-inductively, of which calculations indicate 50% may be attributed to bootstrap current. The analysis shows (consistent with the original scenario modeling) that the edge current is consistent with being entirely bootstrap current, the central current is overdriven by the NBI, and the remaining Ohmic

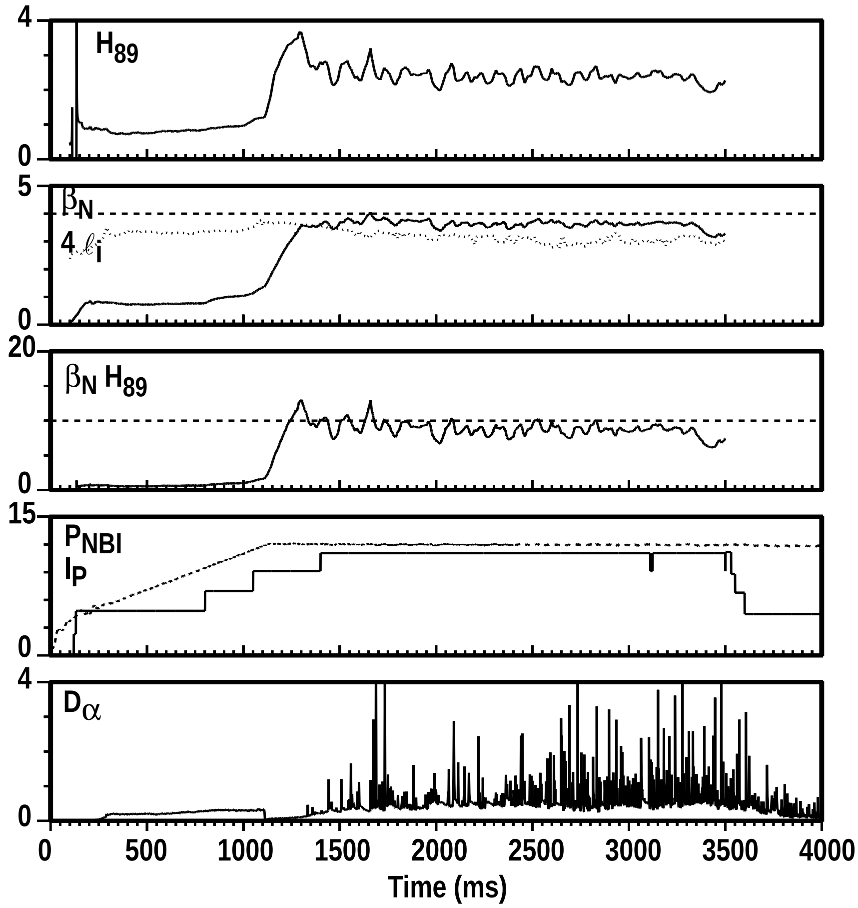

Fig. 1. $\beta_N H_{89}$ ~ 9 sustained for ~16 τ_E.

current is at the half radius. This implies that replacement of some of the NB power with off-axis ECCD should lead to a fully non-inductive current sustainment.

In order to achieve the goal of a demonstration discharge in 2001, three key tools must be commissioned and successfully applied in 2000. The new private flux cryopump is the newest part of the comprehensive particle control system required for a successful integrated scenario. The density must be held in the range of 50%–75% of the natural H–mode density for a effective current drive. The new ECCD systems are clearly an essential component of the scenario. Separate thrusts (#8 and #9) are responsible for the commissioning of these two systems. Application of these tools will occur at the earliest possible opportunity. The third tool is real-time control through the plasma control system. In addition to the significant shape control issues, algorithms will be implemented this year for β control for instability avoidance and q profile calculations for current profile control.

In 2001, the demonstration of non-inductive high performance will be the centerpiece of the plan. More gyrotrons for ECCD will be commissioned, which should allow optimization experiments involving current profile control, and higher absolute performance. In this time frame, it may also be possible to begin extending the maximum β by means of active feedback control of the resistive wall mode.

Beginning in 2001, but with increasing attention in 2002 will be experiments focused on placing this scenario on a sound theoretical and empirical basis for extrapolating to future fusion devices. The steadily increasing ECCD, diagnostic, and control capabilities should allow a window of high performance operation in contrast to the existence demonstration of 2001.

1.1.2. NTM, Research Thrust 3 — Validate Neoclassical Tearing Model and Begin Stabilization With ECCD (Leader: R. J. La Haye; Co-Leader: C.C. Petty)

After the edge instabilities that are the subject of Thrust 1, the next largest immediate stability concern for the AT work are the neoclassical tearing modes (NTMs). These modes have been seen to limit the performance in all our approaches to AT plasmas. Even in plasmas in which q_{min} has been raised above 2, NTMs have been observed. The purpose of this thrust is to gain further physics understanding of the neoclassical tearing modes and develop means of avoiding or stabilizing them.

This thrust has five highest priority tasks: use of unmodulated ECCD to stabilize NTMs, studies of the NTM critical β versus q-profile, studies of the ρ_{i*} and S scaling of the threshold β_N, tests of the physics of the polarization threshold, and studies of classical tearing mode stability.

Two principal research lines are foreseen in a three year plan: (1) studies in H–mode with sawteeth present and (2) studies in an AT mode with raised q_{min}.

H-mode With Sawteeth

The diagnostic set now available on DIII–D, in particular the MSE diagnostic for measuring the current profile, affords a scientific opportunity not previously available to measure all the quantities involved in tearing mode theory to verify that theory. Some effort will be devoted to this basic science verification. Work in 2000 will continue on our ongoing collaboration with JET, ASDEX Upgrade, JT–60U, and Alcator C–Mod on the scaling of NTMs. Tests of the physics of the polarization threshold will be made in DIII–D to confirm the theory or suggest any additional theoretical work needed. An active attempt will be made to modify the width of the 3/2 mode with ECCD. This work will lead to efforts in 2001 toward preventing their <u>onset</u> with ECCD. In the year 2002, we will be able to use two separate ECCD systems for suppressing the 3/2 and 2/1 modes simultaneously.

AT-mode Line

In 2000, we will continue to establish the critical β_N as a function of (q_0, q_{min}) for 5/2 or 3/1 modes. We will hope to continue to find that the NTM problem becomes less severe with higher q_{min}. We will also begin to study the variation of the q profile that can be achieved with ECCD so as to avoid NTMs. In the year 2001, we expect to have enough long pulse ECCD power to maintain a more stable q profile. In the year 2002, we will also seek to control the q profile and suppress the 5/2 and/or 3/1 modes by two ECCD systems.

Principal Goals for 2000

1. Test the physics of the polarization threshold for NTMs.
2. Show unmodulated ECCD shrinks NTM islands.

1.1.3. Wall Stabilization, Research Thrust 4 — Validate Model for Active Control and Optimize Control With Six-Element C–Coil (Leader: G. A. Navratil; Deputies: A.M. Garofalo, and M. Okabayashi)

The AT Program on DIII–D has shown from theory calculations that sustaining β_N greater than four requires stabilization by a nearby conducting wall. The two key elements of wall stabilization are the degree to which a conducting wall can look "superconducting" if the plasma rotates past the wall and the provision of suitable non-axisymmetric feedback to suppress the modes that grow locked to the wall. Recent theory work has suggested that even with a rotating plasma, a "resistive wall mode" can arise that is locked in position and does not rotate with the plasma. Experiments to date have provided support for both the existence of the resistive wall mode and transient evidence for the ability to operate plasmas above the no-wall beta limit as long as wall stabilization remains effective. Over the next three years, DIII–D plans to implement a set of non-axisymmetric coils to provide feedback stabilization of resistive wall modes. This thrust area has two main objectives:

1. Advance the physics understanding of resistive wall mode stability, including the dependence on plasma rotation, wall/plasma distance, and active feedback stabilization.
2. Develop sustained operation above the no-wall beta limit through passive or active stabilization of the resistive wall mode.

In 1999 significant progress was made in both the clear identification of the resistive wall mode in DIII–D high performance plasmas and the initial demonstration of active mode control using the existing C–coil set powered by three new 5000 Ampere/100 Hz amplifiers. A summary of the results of the 1999 experimental campaign for Thrust 4 is shown below:

Physics of Wall Stabilization and Plasma Rotation.

- Three AT plasmas were developed for RWM Study: SND ($\beta_N^{no-wall}$ ~ 2); DND (q_{95} ~ 4.5); DND (q_{95} ~ 5.5; record long pulse $\beta_N H$ ~ 9).
- The n=1 RWM limits the performance of low-ℓ_i AT plasmas to $\beta_N \leq 4\ \ell_i$
- Plasma rotation unable to completely suppress RWM for $\beta_N \geq 4\ \ell_i$
- Plasma toroidal rotation strongly reduced whenever detectable RWM is present ($\delta B_r \geq 1$ Gauss).
- Test of qmin dependence of rotation threshold inconclusive: unable to vary q_{min} above and below 2 at RWM onset time.
- RWM "bursting" observed in DND plasmas near $\beta_N^{no-wall}$ limit.

Initial Feedback Control Experiments (Proof-of-Principle Test).

- Radial flux leakage of n=1 mode through the vacuum vessel can be compensated by the feedback system: test of basic "Smart Shell" algorithm.
- Three feedback algorithms were tested: "Smart Shell"; "Fake Rotating Shell"; and "Mode Control".
- "Fake Rotating Shell" co-injection direction favorable for stabilization.
- Smart shell control of low density locked mode was ineffective: tearing mode not sensitive to radial flux compensation on vacuum vessel wall.
- 3-D code VALEN improved to include GATO generated n=1 RWM current distribution in the plasma model: basic tool for design of an optimal C-coil extension for mode control.
- 2-D simulation of active RWM control by A. Bondeson [MARS] and M. Chance/M. Chu [PEST-VACUUM] is in progress.

Extend Lifetime of Plasma Above the No-wall Limit.

- High β duration was extended with addition of "derivative gain" in feedback loop (both for "Smart Shell" and "Mode Control" algorithms).
- Modest improvement in high β plasma duration is consistent with VALEN predictions of control coil (C–coil) coupling to n=1 RWM.

Experimental Plans for 2000: Validate Model for Active Control and Optimize Mode Control Using the Existing Six-Element C–Coil

In the coming year we expect to significantly extend our understanding of active control using the existing C–coil set powered by three new 5000 Ampere/100 Hz amplifiers we installed and began using at the end on the 1999 experimental campaign. In addition, the saddle coil sensor array used for mode detection has been extended above and below the existing C–coil set with the addition of 24 new saddle coils providing for improved mode structure measurement and lower detection levels. Among the most important results we expect to achieve this year are:

1. Validate quantitative 3-D models now being developed for n=1 feedback control.

2. Extend the regime of improved stability with closed-loop feedback control and test a range of promising active feedback control algorithms.

3. Finalize design of upgraded external coil set for improved feedback control

Achieving these results will provide the basis for the installation and test of an upgraded C–coil system in DIII–D for mode control in 2001 and 2002. Feedback control model calculations indicate the prospect of stabilizing the RWM with an upgraded mode control coil set.in plasmas 50% to 80% above the no-wall beta limit. Successful demonstartion of theis upgraded mode control system would allow the exploration of the extremely important plasma regime approaching the ultimate AT wall stabilized beta limit of β_N in the range of 5 to 6.

1.1.4. AT Divertor, Research Thrust 8 — Explore Closed Pumped Divertor Operation Towards AT Applications (Leader: M.A. Mahdavi, Deputy: M.R. Wade)

The primary goal of the Thrust 8 is to develop density and particle control techniques for the AT plasmas, using the exiting and newly installed divertor tools. The new divertor enhancements will serve many other elements of the DIII–D program. Therefore, much of the work in this thrust will have applications to other research topics. As such, it is highly desirable to compress most of the Thrust 8 effort within the year 2000 campaign year, ahead of research topics which will utilize the new divertor capabilities.

Several years of divertor development for impurity and particle control in AT plasmas culminated with the recent successful installation of the final elements of the pumped divertor at the top half of the DIII–D vessels. The new systems consist of a cryopump at the inner-strike point, a private flux region baffle and high heat flux inner wall armor tiles. The new system combined with the outer upper cryopump and baffle system completes the package for impurity and particle control in single-null plasmas and should provide an adequate impurity and particle control tool for double-null plasmas.

Particle control requires placement of the divertor strike points accurately in prescribed positions near the cryopump pumping apertures. Furthermore, in order to regulate the plasma density at the desired value, the strike point positions have to be moved away from the pump apertures according to the density feedback command while maintaining many other plasma shape parameters fixed. What is more, introduction of the new divertor hardware into the DIII–D vessel imposed additional plasma shape constraints. Therefore, in addition to commissioning of the new divertor systems and development of impurity and particle control techniques, development of plasmas shapes for AT plasmas is integrated into the Thrust 8 activity. The Thrust 8 activities, nearly in the order that they will take place are shown as follows:

1. Develop shape control algorithms that allow precise strike-point positioning while maintaining freedom (albeit limited) in the choice of divertor geometry.

   Determine divertor configuration that provides the optimum exhaust efficiency (defined as the ratio of the exhaust rate to the particle flux incident on the divertor target) at density levels at least roughly consistent with the DIII–D AT target scenarios

   Document plasma conditions sufficiently well to allow detailed highly constrained modeling.

2. Develop a physics-based understanding of why the experimentally determined "best" divertor configuration is indeed the best through detailed modeling of the experimental data. With this knowledge, develop ideas for and test other divertor configurations with model.

3. Measure exhaust efficiency versus pumping configuration, flux expansion, and toroidal field direction.

4. Determine heat flux distribution on upper divertor at low density, and heat load and particle flux limits in best configurations.

5. Establish an ELMing H–mode scenario which can be used as a proxy for the Thrust 2 high-performance discharge and then systematically vary divertor and plasma conditions to study the effect of divertor symmetry (DRSEP scan), X–point height (rigid-body translation of shape), initial conditions on final density, and beam and carbon contributions to density.

6. Use improved exhaust and gas injection capabilities and the ability to pump the inner divertor leg to study effect of induced particle flows on core carbon buildup and trace impurity exhaust at low density.

1.1.5. EC, Research Thrust 9 — Electron Cyclotron Heating Physics Commissioning (Leader: R. Prater, Deputy: J. Lohr)

The ability to apply high power electron cyclotron heating (ECH) for localized heating and current drive is a key element of the AT program on DIII–D. The function of the localized current drive is to develop and sustain the desired current profile, thereby avoiding the decay in the central safety factor which leads to sawteeth and enhanced transport. In addition to the AT program, there are numerous experiments which either benefit from ECH or depend fully upon it. These experiments include studies of the heat pinch, locally measured transport, rf-assisted startup for optimized shear, studies of plasmas with equal electron and ion temperatures, edge heating or current drive for controlling ELMs, and many others.

The objective of this work is to bring the ECH system to the condition where power from at least four gyrotrons can be applied robustly to the plasma with high power and long pulse length. At present, three of the gyrotrons are made by Gycom, and their power and pulse length is limited by the boron nitride window to 0.75 MW for 2 s. Two of the gyrotrons are made by CPI, and they have diamond windows which can operate for longer pulses, nominally 10 s at 1 MW. Power supplies for these gyrotrons are also being developed at present.

The transmission lines for the ECH power follow designs well tested in past experiments. These evacuated transmission lines have been shown to handle high power with little difficulty. Grooved mirrors are used to generate the elliptical polarizations needed to launch pure X–mode power, and a code has been tested which calculates the grooved mirror settings needed for a particular equilibrium for given angles of incidence of the rays.

New this year is the ECH launcher designed and constructed by Princeton Plasma Physics Laboratory. This launcher differs from the previous launchers in that it has mirrors which can be tilted in the toroidal direction remotely through a vacuum feed-through. (Both types of launcher may be tilted in the vertical direction.) The PPPL launcher will facilitate tests of the physics of ECCD, since n-parallel can be varied from shot-to-shot. Co-current drive as well as counter-current drive can be carried out. This important flexibility will facilitate a number of exciting experiments.

One-Year Goal

Commission the 110 GHz ECH system to demonstrate reliable high power from four-gyrotrons with pulse lengths longer than 1 s, with well characterized launching direction and polarization of the waves.

Objective: Demonstrate that the four gyrotron ECH/ECCD system is ready for routine operation for performance of experiments on DIII–D which need high power electron heating or localized current drive.

Critical Path Elements

- High power long pulse operation of at least four gyrotrons
- Power supplies to power four gyrotrons simultaneously
- Operation of two gyrotrons from a single power supply
- Efficient transmission and polarization control
- Launchers with good optical properties

Approach

Apply modulated ECH power and use wave absorption measurements, as deduced from temperature fluctuations measured by electron cyclotron emission, to determine the wave propagation properties and mode content. This approach has been well developed in past applications.

1.2. PHYSICS TOPICAL AREAS

1.2.1. Stability — (Leader: E.J. Strait)

Stability Topical Area Goals (3 Year View)

1. Advance the physics understanding of resistive wall mode stability, including the dependence on plasma rotation, wall distance, and feedback stabilization. *Develop sustained operation above the no-wall beta limit through passive or active stabilization of the resistive wall mode.*

2. Characterize the physics of edge-driven instabilities in plasmas with a large (H–mode) edge pressure gradient and associated bootstrap current.

Develop methods to avoid or reduce the impact of edge-driven instabilities through modification of the edge pressure gradient, collisionality, or shaping.

3. Advance the physics understanding of non-ideal plasma instabilities including neoclassically driven tearing modes, sawteeth, and fast ion driven instabilities. *Develop sustained high beta operation free of neoclassical tearing modes, through profile control or active stabilization.*

4. Advance the understanding of disruption physics in advanced tokamak discharges.
Develop methods of mitigating halo currents and disruption heat loads, and disruption avoidance using real-time identification of disruption boundaries.

The DIII–D Stability and Disruption Physics program addresses critical issues for both conventional and Advanced Tokamak (AT) plasmas. With recent advances in scientific understanding and technical tools, we are beginning to study plasmas compatible with steady-state operation, and to develop active means of controlling stability. Much of the fundamental stability physics involved also has wider application in other toroidal confinement devices. For experiments in 2000, resistive wall stabilization experiments (Goal #1) will be carried out under research Thrust #4, while the other goals will be addressed within the Stability topical science area.

Stabilization by a conducting wall is predicted to strongly enhance the ideal kink mode beta limit in AT plasmas with a broad pressure profile and broad, negative central shear (NCS) current density profile. However, the presence of a resistive wall is expected to destabilize a slowly growing Resistive Wall Mode (RWM). Experiments in 1999 showed that small-amplitude resistive wall modes can cause a significant slowing of plasma rotation, a potential problem for rotational stabilization of the RWM. An important goal for the coming year will be to improve our understanding of the relationship between RWM stability and plasma rotation, in comparison with recent theoretical models. Initial tests of active feedback control have been carried out using the existing C-coil, driven by three new power amplifiers provided by PPPL. These showed promising results, producing a modest extension of the duration at high beta. In 2000 we plan to continue the feedback experiments, making use of newly installed arrays of sensor loops, with the aim of validating feedback control models sufficiently to design an extension of the active coil set. The longer-term goal for the next three years is to use the additional active coils to achieve sustained operation significantly above the no-wall stability limit. Much of the physics understanding of rotation and feedback stabilization gained here should be applicable to other toroidal confinement concepts.

Experiments and modeling indicate that edge-localized modes (ELMs) are triggered by moderate-wavelength instabilities, driven in the H–mode edge pedestal by the steep pressure gradient and its associated bootstrap current. Recent experiments have succeeded in reducing ELM amplitudes by the use of discharge shaping to lower the stability limit for short-wavelength ballooning modes at the edge, thereby limiting the pressure gradient to the first regime ballooning mode limit. Preliminary experiments in DIII–D as well as other tokamaks have also shown promising results with the use of impurity radiation to reduce the edge pressure gradient and bootstrap current. These and other approaches for control of the edge will be pursued in future DIII–D experiments, toward the goal of an ELMing H–mode edge plasma compatible with an internal transport barrier (ITB). However, most experiments will be deferred until 2001, when better measurements of the edge current density should greatly aid our understanding of edge stability physics.

Neoclassically driven tearing modes (NTMs) are metastable modes, destabilized by the helically perturbed bootstrap current arising from a "seed island." DIII–D experiments in 1999 have extended the range of data for scaling of the instability threshold. A multi-machine database incorporating the DIII–D data suggests that stability may improve at large magnetic Reynolds number S, due to reduced seed island amplitudes. Experiments in 2000 will aim to test theories for the damping of the NTM, a key physics element for predicting their stability. Experiments have also shown that current profile modification can be used to avoid triggering the instability, and in the future electron cyclotron current drive (ECCD) will provide a valuable tool for q profile control to improve stability. A major emphasis of future work will be the use of localized ECCD at the mode rational surface for direct stabilization of the NTM, as predicted theoretically.

Our program will continue to explore and validate basic MHD stability physics, making use of DIII–D's extensive set of diagnostics for precise, detailed measurements of the pressure and current density profiles and the internal structure of MHD modes. Investigation of the physics of the sawtooth crash will be continued, including the role of fast ions in sawtooth stabilization. Validation of resistive interchange mode theory in regions of negative magnetic shear will provide a test of basic stability physics which is also applicable to stability of stellarator plasmas. Preliminary experiments will be carried out in 2000 to measure the damping rate of stable MHD modes, using low-power signals launched from the ICRF antennas. This technique can provide valuable physics information on the driving and damping rates of kink modes, tearing modes, and fast ion-driven Alfvén eigenmodes, and has the potential to provide a warning signal for the approach to stability boundaries.

Disruptions are in principle predictable, occurring when a stability boundary is crossed, and much of the DIII–D stability program can be viewed as learning how to predict and avoid disruptions. However, some disruptions are inevitable due to unforeseen causes such as control system failure or unexpected impurity influx. The DIII–D program will continue to develop methods of mitigating the effects of disruptions using impurity pellets, hydrogenic pellets, and possibly liquid jets, as well as gas puffing. Important physics issues to be investigated in the next three years include the physics of non-axisymmetric halo currents, the role of avalanche processes in runaway electron generation, and the transport of impurity ions during disruption mitigation.

1.2.2. Confinement and Transport (Leader: K. H. Burrell)

This topical area has experiments under various headings:

In the area of **Fundamental Turbulence Studies**, we will perform an experiment investigating whether infrequent large transport events (avalanches) are an important part of the overall tokamak transport.

In the **H–mode Physics area**, two experiments are planned. First, we will investigate the relative importantance of electron versus ion heat flux in triggering the L to H transition. This experiment will also be used to provide information on the edge neutral density in L–mode and H–mode which will allow us to test a recent theory of the H–mode edge pedestal which includes neutral effects. Second, we will investigate further the effect of the ion grad B drift on the edge plasma prior to the transition. Analysis last year of two year old data showed that the edge electric field reversed sign when the direction of the toroidal field reversed. The key question to be investigated this year is whether it is the direction of the grad B drift relative to the divertor X–point which is the key parameter in this behavior. These shots will also be used for further studies of the pellet-triggered H–modes which were first investigated last year on DIII–D.

In the area of **Test of Transport Models**, an experiment will be done to demonstrate the existence of a heat pinch with outside launch, second-harmonic ECH and to determine if the heat pinch is dependent on the sign of the magnetic shear as predicted. The inward transport effect seen with the 60 GHz system remains a severe challenge to the theoretical community. One remaining mechanism could explain the observed profiles without requiring transport up the temperature gradient: the conversion of the fraction of ECH power which is not absorbed at the resonance to electron Bernstein waves at the upper hybrid layer. This mode conversion is not possible with second harmonic outside launch. The superior diagnostic set now available and the higher power densities possible with the 110 GHz ECH system could provide clear evidence of the mechanism responsible for the inward transport. Furthermore, the theoretical heat pinch model of coupled transport between Grad-J and Grad-T can be tested by comparing the non-diffusive electron transport for positive and negative shear plasmas.

A second **Test of Transport Models** experiment is planned to provide tests of turbulence simulations, tests of transport models with modulated ECH, a test of the predictive capability of turbulent transport models and a demonstration of marginal stability in the electrons (L–mode part only).

The experiment in the **Nondimensional Transport** area will investigate the changes in radial correlation length and decorrelation time as ρ_* is varied. Preliminary experiments suggested that the correlation length was proportional to ρ_* as expected from local turbulence models but that the decorrelation time varied in such a way that Bohm-like transport scaling resulted. However, the match of the other nondimensional parameters in this preliminary experiment was not good enough to produce a definitive result. A better match will be produced in the new experiment.

The **Core Transport Physics** area will have four experiments. First, we will do a more detailed investigation of the formation of regions of reduced core transport and the effect of the q profile on that formation. As part of this work, we will also use perturbative transport techniques to study the reduced energy and particle transport region. Modulated ECH will be used to investigate electron thermal transport while modulated gas injection will be used to study particle transport.

Second, we will investigate the controlled density, ELM-free H–mode that was discovered last year. This will be the first dedicated experiment in this area; previous work was done piggyback. The key for the new experiment is to utilize all the fluctuation diagnostics to determine the nature of the MHD modes at the plasma edge which provide sufficient particle transport to maintain density control without significantly degrading the edge pedestal. In addition, we plan to use pellet and neon injection both to provide perturbations for transport studies and also to attempt to trigger reduced core transport in these shots. An ELM-free, controlled density shot with reduced core transport would be of great interest to reactor designers.

Third, we will investigate further the fundamental physics of core transport reduction using impurity injection which was so successful last year. A prime goal this year is to obtain information on the electron thermal transport reduction and to attempt to correlate that with the changes seen in high-k turbulence ($k > 10\ cm^{-1}$). Indeed, by reducing the transport effects of ion temperature gradient modes to negligible levels, we are in a position to probe the fundamental physics of electron temperature gradient mode and high-κ turbulence.

Fourth, we will study the formation of core electron transport barriers using intense ECH directed to produce counter-ECCD. In experiments on DIII–D last year, ECH during the initial current ramp produced significant localized reductions in the electron thermal diffusivity. This is similar to effects seen several years ago on DIII–D with counter-FWCD and seen last year on ASDEX–U using counter-ECCD. This is contrary to results seen three years ago on DIII–D where application of ECH to a region where ion transport was reduced lead to increased ion transport. The key question here is to try to sort out what the competing effects are that have produced these disparate results.

1.2.3. Divertor/Edge Physics (Leader: S. L. Allen)

Divertor/Edge Physics Experimental Objectives for FY2000

The planned experiments, in rough order of priority, are described below. Some of the ideas were grouped by machine configuration (e.g., those with the upper divertor), and others were grouped by topic (e.g., understanding carbon transport).

A. (Configuration grouping) **— Upper Divertor Experiments at "high" density (2 days).** (Experiments that involve the upper pump that will not be done in Thrust 2, as they will focus on reducing the density).

1. Does the plasma detach at lower core density with the closed divertor, as predicted by UEDGE and observed by other machines?
2. Is the density limit reduced by the closed divertor?
3. Is the density limit reduced by the low x-point height above the floor (the dome)?
4. Characterize upper divertor with new diagnostics, both ELMing H–mode and detached plasmas (PDD) upper tangential TV camera (carbon and deuterium profiles), Langmuir probes (may require some sweeping to get good data), filterscopes (look at different lines).
5. What is the impurity enrichment with puff and pump of the upper divertor compared to the lower divertor?
6. Is a narrow divertor slot compatible with a radiative divertor?

An optimistic estimate is that these experiments will take 2–3 days, assign 2.

1. What is the effect of the ∇-B drift on the upper divertor detachment and density limits. (It is assumed that the experiments in section A above will be done with the ∇-B drift *towards* the upper divertor (opposite to that used in all but one day of Thrust 2 plans!). We would do one day with the ∇-B drift away from the upper divertor.

Assign one day. If we can somehow obtain data from Thrust 2 with ∇B away from the upper divertor, this day could be deleted.

B. (Topic grouping) **Improve understanding of carbon transport (1 day).**

1. Obtain carbon flow and carbon source data spectroscopically at high power and H–mode density (we currently have very little data in this regime, probes may not be able to take data under these conditions).

2. Do hot spots contribute significantly to the carbon inventory? Create discharges without hot spots (large gaps) and with (high power, focused on areas of the wall that are less-well aligned).

3. Is the main chamber wall a significant source of carbon? (some new diagnostic capability with filterscopes).

C. (Topic grouping) **Is pumping required for high density operation (near the Greenwald density)? (1 day).**

This is a one-day experiment to finish a topic from last year to allow a publication to go forward. Also, this will provide information on possible reasons why JT–60 and JET see degradation at high density.

1. The experiment is to examine in detail the divertor configuration required for high density operation (above the Greenwald density). We have recently realized that we think that nearly all of the high density results with good confinement have been obtained with pumping. We would like to confirm this by comparing high density shots on the same day, one set with pumping(e.g., private flux space pumping, normal pumping), and another set without pumping. A definitive result was not obtained on this topic last year in the high density experiments.

2. We would expect that we could also address some questions about pedestal parameters that were not completed last year. To our knowledge, the divertor science area is the “home” for the high density experiments.

D. (Configuration grouping) **DiMES impurity transport studies — 2 times (1/2 day) – 1 day** — plasma setup can often be done in piggyback mode, but actual data shots require that the strike point is positioned on the DiMES probe.

1. Transport of lithium. Preliminary experiments last year (1/2 day) have shown that a large amount of sputtering, erosion, and impurity transport

data can be obtained in these experiments. Introduce lithium into the plasma from the DiMES probe, and use spectroscopic diagnostics. (1/2 day)

2. Effect of impurities on sputtering rates. This experiment would introduce small amounts of impurities into the divertor to determine if the sputtering rates on the DiMES probe were affected by this. (1/2 day)

E. (Topic grouping) **Basic Divertor Physics Topics — 1 day (the group could not converge on which experiment was the highest priority, but the general feeling was that a careful comparison between experiment and theory should be done on the one-day level. However, with the alllocated time, these experiments will have to either be deferred or done in piggyback mode.)**

(NOT in order of priority) —

1. *Measurement of "sheath factor", using drsep to vary parameters*. We currently observe that the peak divertor heat flux is a very strong function of drsep close to magnetic balance, and the particle flux is a much broader function. Careful experiments (optimizing the signals on the langmuir probes and IRTV) can help us understand the "sheath" transmission factor.

2. *Measurement of fluctuations in PDD*. We have a new probe head which can be used to measure temperature fluctuations in the divertor (i.e., we can move the probe heat from the midplane to the X–point probe). Several theoretical hypothesis are being tossed around that turbulence may play an important role in PDD discharges (in addition to charge exchange in the divertor). Comparisons with the BOUT code may be possible.

3. *High time resolution measurements of ELMs* — This year, we will have several new diagnostics that will be able to measure ELM quantities in more detail. A new, high speed intensified tangential camera will be used in the divertor; this can be triggered by photodiodes (ELMs) upstream and can obtain snapshots of impurity and deuterium radiation. A new high-speed IRTV will be in use to measure the heat flux from ELMs. We will also have new probe capabilities to measure ELM properties. All these new diagnostics can be brought to bear on the study of ELMs.

F. (Topic grouping) **Does puff and pump cause a measureable plasma flow towards the divertor? Improved measurement of flow during puff and pump — 1 day requested, we will try to complete some part of these experiments in "piggyback" mode.**

1. We feel that the experiment done in 1999, which showed no evidence of plasma flow on the Mach probes during puff and pump, could be improved by a lower deuterium flow rate, and perhaps some improved spectroscopic diagnostics.

2. We are developing improved flow diagnostics, and we need discharges to test out these techniques. Specifically, we are searching for lines to pump with a laser to do fluorescence measurements in the divertor. A fiber and spectrometer have been added to the divertor Thomson scattering system. Also, R. Isler has some ideas about using high ionization states of impurities for flow measurements.

G. **X–point physics.** Last year, we found several interesting phenomena near the X–point, which will be presented in an invited PSI paper. There are several details that need to be completed. Some of these issues involve changing the potentials near the X–point by biasing — in this case, however, we would try to apply the external potential closer to the X–point

H. (Topic grouping) **C–Mod and DIII–D edge "simularity" comparison — 1 day. After discussions with the C–Mod group, it was agreed that this topic was very important, but we could not agree on exactly what experiment should be performed. These discussions will continue.**

Several divertor/SOL parameters are quite different on the two machines, including: 1) midplane pressure is high on C–Mod, low on DIII–D, 2) ionization source is believed to be primarily from the divertor on DIII–D, the main chamber is thought to be a large source on C–Mod, 3) a baffled divertor on DIII–D reduced the core ionization by about a factor of 2–3, baffles did not make large changes on C–Mod.

Exact experimental conditions are yet to be determined, but the idea is to try to obtain some overlap of conditions (particularly main chamber edge pressure) so that SOL and divertor parameters can be compared.

1.2.4. Heating and Current Drive — 3 Days Work in Thrust 9 (Leader: R. Prater)

Three-Year Goals

1. Establish predictive capability for ECCD, including dependencies on density, temperature, Z_{eff}, geometry, power density, trapping, and dc electric field. Determine the effect of H–mode and ELMs.

2. Advance the physics understanding of FWCD, including effects of frequency, $n_{||}$, competing edge losses, high harmonic cyclotron absorption on beam ions and thermal ions, rf-induced resonant ion transport, wave propagation, conservation of toroidal mode number.
3. Complete the understanding of NBCD, including the effects of fast particle modes and TAE modes.
4. Develop long pulse discharges with full noninductive current drive, including discharges with very high bootstrap fraction as a step toward transformerless operation.
5. Develop routine electron heating using the ICRF system, through fast wave and/or second harmonic hydrogen minority heating (especially at high density where beam penetration is poor.)
6. Develop minority heating for sawtooth stabilization and minority or beam ion current drive.

Prioritized List of Experiments for 2000

In the 2000 experiment campaign, the focus of effort is on ECH/ECCD, which is the first goal. New capabilities in the ECH area (tested in Thrust 9) and needs in the program for a predictive capability for ECH/ECCD drive this appraoch. The two highest priority activities in this topical area are the study of the effect of collisionality and power density on ECCD (2 days) and the study of ECCD in H–mode plasmas (1 day).

1. **Effect of collisionality and power density on ECCD.** This experiment on the effect of collisionality on ECCD will help explain the surprising results found in last year's experiments, that the decrease in the efficiency of ECCD due to electron trapping as the driven current is moved further off-axis is much weaker than theoretically expected. An understanding here is needed in order to support the application of ECCD to objectives like stabilization of neoclassical tearing modes or sustainment of off-axis plasma current for AT program purposes. (2 days)

2. **Validation of ECCD in ELMing H–Mode.** Validation of ECCD in ELMing H–mode plasmas is needed to resolve the issue of the degree of achievable power deposition localization in the presence of ELM effects on ray trajectories. Since the AT target plasmas will typically be in ELMing H–mode, an understanding of the ray propagation properties under these conditions is important. (1 day)

If contingency time becomes available, the first experiment to be added to the list is:

3. **Neutral Beam Current Drive.** NBCD is needed for realization of the AT scenarios. The actual profile of NBCD appears to be broader than predicted. Experiments are needed to clarify the mechanism by which the broadening takes place in order to increase the confidence in the models. (1 day)

4. **Transformerless Startup.** Transformerless startup is needed by low aspect ratio tokamaks since space near the centerpost is too valuable for a ohmic heating coil. Two experiments are proposed. In the first, the outer poloidal field coils are used to provide an electric field which drives the plasma current to intermediate values of current, around 150 kA. The experiment is to validate the models which have been developed and to study the transition to a magnetic configuration like that of a conventional tokamak equilibrium. (1 day) The second experiment is to apply strong electron heating from the ECH system to drive a large electron temperature gradient, which in turn generates a strong bootstrap current. Under some conditions, the bootstrap fraction may be larger than unity, and the total current increases. (1 day).

1.3. DETAILED SCHEDULE OF EXPERIMENTS

Date	Time	Exp Number	Description	Author
2/7/00	0800	2000-08-011	Shape Control Development for AT Divertor Day 1	Hyatt
2/8/00	0800	2000-22-031	Edge Er Structure and GradB effect on L->H	Carlstrom
2/9/00	0800	2000-08-012	Shape Control Development for AT Divertor Day 2	Hyatt
2/10/00	0800	2000-08-021	Quantify Upper Pump Exhaust Efficiency Day 1	Mahdavi
2/10/00	1700	2000-09-011	ECH System Conditioning - Day 1	Prater
2/12/00	0800	2000-97	Weekend	
2/14/00	0800	2000-08-022	Quantify Upper Pump Exhaust Efficiency Day 2	Mahdavi
2/15/00	0800	2000-22-051	NonDimensional Scaling of Turbulence - Day 1	McKee
2/16/00	0800	2000-08-023	Quantify Upper Pump Exhaust Efficiency Day 3	Mahdavi
2/17/00	0800	2000-23-011	Upper Divertor Experiments at High Density - Day 1	Allen
2/17/00	1700	2000-99-011	T.B.D.	
2/19/00	0800	2000-97	Weekend	
2/21/00	0800	2000-21-011	NTM Threshold and Polarization Drift	LaHaye
2/22/00	0800	2000-02-011	Re-establish 1999 High Performance Scenario	Luce
2/23/00	0800	2000-08-031	Optimize Density Control in DND Day 1	Mahdavi
2/24/00	0800	2000-98-011	Scheduled Contingency Day	
2/25/00	0800	2000-98-011	Scheduled Contingency Day	
2/26/00	0800	2000-96	Maintenance Period	
3/13/00	0800	2000-04-011	Active Control of the RWM - Day 1	Navratil
3/14/00	0800	2000-08-032	Optimize Density Control in DND Day 2	Mahdavi
3/15/00	0800	2000-04-012	Active Control of the RWM - Day 2	Navratil
3/16/00	0800	2000-08-041	Puff and Pump at Low Density	Wade
3/16/00	1700	2000-09-011	ECH System Conditioning - Day 1	Prater
3/18/00	0800	2000-97	Weekend	
3/20/00	0800	2000-23-012	Upper Divertor Experiments at High Density - Day 2	Allen
3/21/00	0800	2000-22-061	Core Barrier Formation - Day 1	Burrell
3/22/00	0800	2000-02-021	Density/Impurity Control with AT Pumping - Day 1	Wade
3/23/00	0800	2000-02-022	Density/Impurity Control with AT Pumping - Day 2	Wade
3/23/00	1700	2000-09-011	ECH System Conditioning - Day 1	Prater
3/25/00	0800	2000-97	Weekend	
3/27/00	0800	2000-04-013	Active Control of the RWM - Day 3	Navratil
3/28/00	0800	2000-23-031	Pumping Necessary for Greenwald?	West
3/29/00	0800	2000-04-014	Active Control of the RWM - Day 4	Navratil

Date	Time	Exp Number	Description	Author
3/30/00	0800	2000-21-031	Controlled Kr Radiation and ELMs	
3/30/00	1700	2000-09-011	ECH System Conditioning - Day 1	Prater
4/1/00	0800	2000-97	Weekend	
4/3/00	0800	2000-23-021	Carbon Sources and Transport - Day 1	West
4/4/00	0800	2000-22-081	RI-mode Physics	Murakami
4/5/00	0800	2000-98-011	Scheduled Contingency Day	
4/5/00	1300	2000-98-011	Scheduled Contingency Day	
4/6/00	0800	2000-98-011	Scheduled Contingency Day	
4/6/00	1300	2000-98-011	Scheduled Contingency Day	
4/7/00	0800	2000-98-011	Scheduled Contingency Day	
4/8/00	0800	2000-96	Maintenance Period	
5/1/00	0800	2000-04-021	Lower DeltaB_r Detection Threshold	Navratil
5/2/00	0800	2000-09-012	ECH System Conditioning - Day 2	Prater
5/3/00	0800	2000-04-031	RWM Physics; Rotation Effects - Day 1	Navratil
5/4/00	0800	2000-23-041	DIMES (two 1/2 days requested)	Whyte
5/4/00	1300	2000-09-012	ECH System Conditioning - Day 2	Prater
5/6/00	0800	2000-97	Weekend	
5/8/00	0800	2000-09-013	ECH System Conditioning - Day 3	Prater
5/9/00	0800	2000-04-032	RWM Physics; Rotation Effects - Day 2	Navratil
5/10/00	0800	2000-09-021	Effect of Collisionality on ECCD - Day 1	Luce
5/11/00	0800	2000-09-022	Effect of Collisionality on ECCD - Day 2	Luce
5/13/00	0800	2000-97	Weekend	
5/15/00	0800	2000-21-091	MIMO! - Request 6 X 2 hour increments	Walker
5/15/00	1300	2000-23-041	DIMES (two 1/2 days requested)	Whyte
5/16/00	0800	2000-09-031	ECCD in H-mode Petty	
5/17/00	0800	2000-02-031	Current Profile Sustainment and Control - Day 1	Luce
5/18/00	0800	2000-98-011	Scheduled Contingency Day	
5/19/00	0800	2000-98-011	Scheduled Contingency Day	
5/20/00	0800	2000-96	Maintenance Period	
6/5/00	0800	2000-21-021	Active ECCD Stabilization of NTM - Day 1	LaHaye
6/6/00	0800	2000-02-032	Current Profile Sustainment and Control - Day 2	Luce
6/7/00	0800	2000-21-022	Active ECCD Stabilization of NTM - Day 2	LaHaye
6/8/00	0800	2000-21-041	Rapid Impurity Transport in Disruption	Whyte
6/8/00	1700	2000-09-013	ECH System Conditioning - Day 3	Prater
6/10/00	0800	2000-97	Weekend	

Date	Time	Exp Number	Description	Author
6/12/00	0800	2000-02-033	Current Profile Sustainment and Control - Day 3	Luce
6/13/00	0800	2000-02-051	Scale-Up to 1.6MA/2.1T and Edge Stability	Luce
6/14/00	0800	2000-04-041	Active Control of Locked Modes	Navratil
6/15/00	0800	2000-21-061	Validate Resistive Interchange Mode Theory - Day 1	
6/15/00	1700	2000-09-013	ECH System Conditioning - Day 3	Prater
6/17/00	0800	2000-97	Weekend	
6/19/00	0800	2000-22-011	Avalanches in L-Mode	Politzer
6/20/00	0800	2000-22-041	Heat Pinch Physics	Petty
6/21/00	0800	2000-22-021	Electron vs Ion Physics in H-Transition	Thomas
6/22/00	0800	2000-98-011	Scheduled Contingency Day	
6/23/00	0800	2000-98-011	Scheduled Contingency Day	
6/24/00	0800	2000-96	Maintenance Period	
7/14/00	0800	2000-99-011	T.B.D.	
7/17/00	0800	2000-07-011	Optimize Counter NBI Generated ITBs - Day 1	Greenfield
7/18/00	0800	2000-22-071	Controlled Density ELM-free H-mode	Burrell
7/19/00	0800	2000-07-012	Optimize Counter NBI Generated ITBs - Day 2	Greenfield
7/20/00	0800	2000-07-021	Neon-Puffing to Improve ITB - Day 1	Greenfield
7/21/00	0800	2000-98-011	Scheduled Contingency Day	
7/22/00	0800	2000-97	Weekend	
7/24/00	1300	2000-99-011	T.B.D.	
7/25/00	0800	2000-22-091	Test of Transport Models with Modulated ECH	DeBoo
7/26/00	0800	2000-22-101	experiment tbd	Burrell
7/27/00	0800	2000-98-011	Scheduled Contingency Day	
7/27/00	1700	2000-09-013	ECH System Conditioning - Day 3	Prater
7/29/00	0800	2000-97	Weekend	
7/31/00	0800	2000-02-041	Real-Time Beta and/or q Control	Luce
8/1/00	0800	2000-02-061	Integrated High Performance AT Demo	Luce
8/2/00	0800	2000-98-011	Scheduled Contingency Day	
8/3/00	0800	2000-98-011	Scheduled Contingency Day	
8/4/00	0800	2000-98-011	Scheduled Contingency Day	
8/5/00	0800	2000-96	Maintenance Period	

1.4. THE 2000 OPERATIONS SCHEDULE

The operations schedule is designed for efficient and safe use of the DIII–D facility. Sixteen weeks of plasma physics operations is scheduled for the calendar year 2000. The plan is to have five 3- or 4-week run periods. The operations schedule is shown in Fig. 23. Operations are carried out on either 4 or 5 days per week for 8.5 hours. Typically on four-day weeks, on one day operations are extended for 10.5 hours to allow longer experiments to reach completion.

The plan takes into consideration factors such as efficient matching of the machine run time with the availability of hardware and data analysis capabilities. Above all, the DIII–D program is carried out to keep radiation exposure to employees and to the general public. As Low As Reasonably Achievable (ALARA) and still carry out the research program.

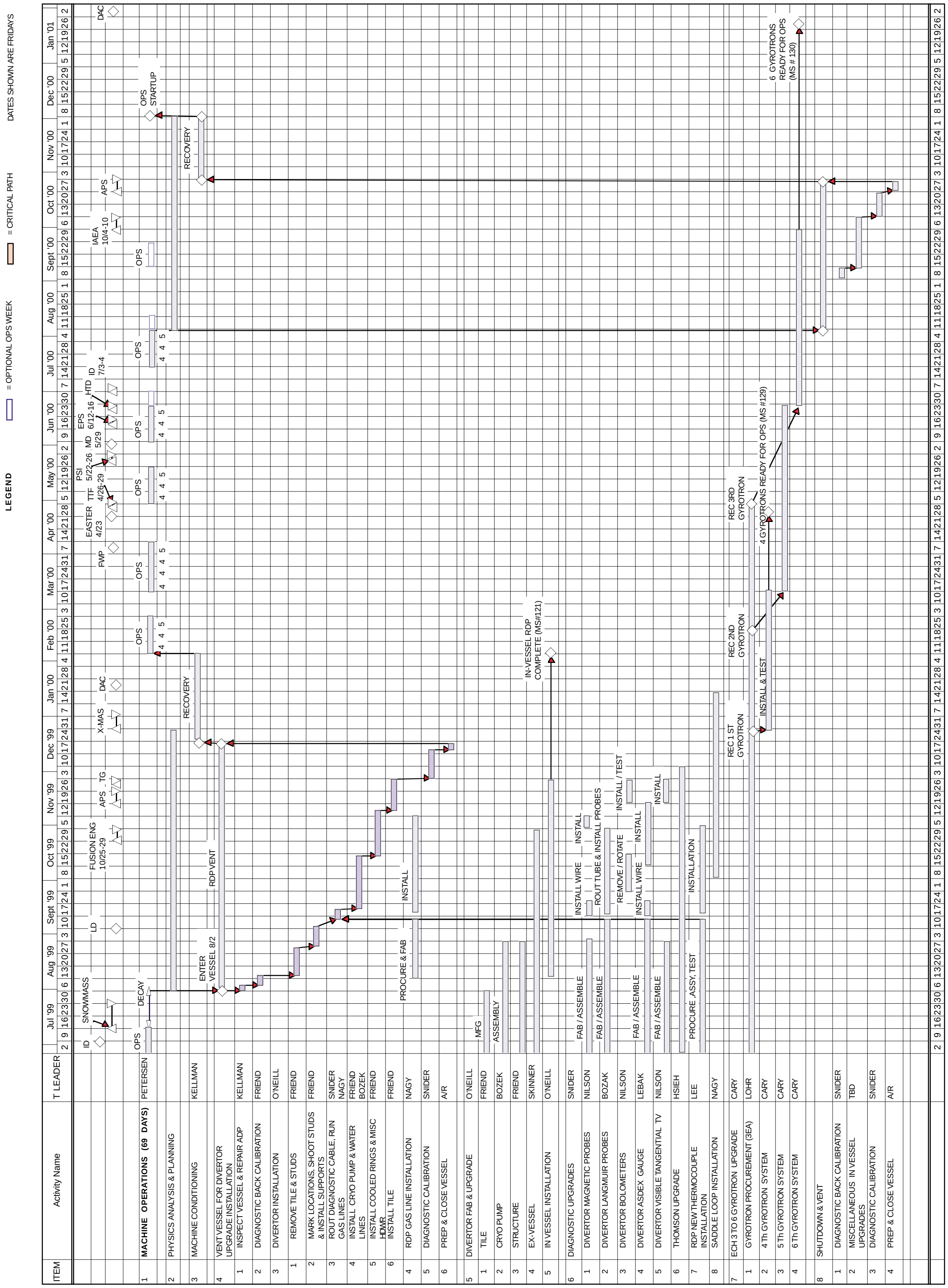

Fig. 2. DIII–D Master Schedule CY2000 16 Week Plan (With 18 Week Option).

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