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**UPDATED
DIII-D EXPERIMENTAL PLAN
FOR FY-1989**

by
**FUSION DIVISION STAFF
J.L. LUXON, EDITOR**

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APPROVALS

Approved:

T.C. Simonen
DIII-D Program Director
Fusion Division
General Atomics

Date

C.M. Beighley
Onsite Project Manager
Energy Research Division
DOE/SAN

Date

Erol Oktay
DIII-D Program Manager
Division of Confinement Systems
DOE/ER-55

Date

FOREWORD

This document presents the planned experimental activities for the DIII-D tokamak facility for the period FY89. This experimental plan is a revision of the plan issued in November 1988 and reflects the enhanced DIII-D response to the Transport Initiative called for by DOE given in Section 8. This new effort includes diagnostic improvements and enhancements, increased operating time and data analysis, implementation of the Advanced Divertor Program, and implementation of the pellet injector. In order to clearly communicate the changes, the changes will be presented largely as additions to the text in bold-faced type.

This plan is part of a five year contract between General Atomics and the Department of Energy. The plan will be reviewed by both organizations and approved by the DIII-D Program Director, Fusion Division, General Atomics, the Onsite Project Manager, SAN Office, DOE, and the DIII-D Program Manager, Division of Confinement Systems, Washington, D.C. It is anticipated that this document will be updated yearly, and that the progress of the DIII-D program will be reviewed quarterly against this plan. In the event of major budgetary, technical, or programmatic changes this document will be revised.

LIST OF ACRONYMS

APS	American Physical Society
a	Minor radius of plasma
B	Magnetic field
CIT	Compact Ignition Tokamak
DIII-D	Tokamak Fusion Device located at General Atomics
ECH	Electron Cyclotron Heating
ELM	Edge localized mode that limits energy storage in plasma
FY	Fiscal year
H-mode	A high regime of tokamak confinement
I	Plasma current
IAEA	International Atomic Energy Agency
IBW	Ion Bernstein Wave method of ion cyclotron heating
IBW	Ion Cyclotron Heating
ITER	International Thermonuclear Experimental Reactor
ITG	Ion Temperature Gradient
JET	Joint European Tokamak located in England
L-H Transition	Transition from L-mode to H-mode
L-mode	A low regime of tokamak confinement

NBI	Neutral beam injection
OFE	Office of Fusion Energy
O-mode	A mode of microwave propagation in which the microwave electric field is parallel to the toroidal magnetic field
q	Tokamak safety factor $q = 3$ means that a magnetic field line traverses the toroidal direction three times in one poloidal rotation.
R&D	Research and development
rf	Radio frequency
X-mode	A mode of microwave propagation in which the microwave electric field is perpendicular to the toroidal magnetic field
X-point	The location where the magnetic field is purely toroidal (no poloidal component)
β	The ratio of plasma pressure to magnetic field pressure.
Ω_H	Hydrogen ion cyclotron frequency
β_P	Beta Poloidal

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1. INTRODUCTION

This document reports the revision of the 1989 Experimental Plan for the period of July to December 1989. This revision is made because of substantial redirection by DOE in response to the transport initiative and the needs of CIT and ITER. Additional experimental time was also funded to help meet those needs. The DIII-D program that results continues to pursue our long-range goals as put forth in the 5-year plan although realization of the ultimate goals is going to take somewhat longer.

The long-range DIII-D 5 yr plan is directed ultimately at the goal of achieving good confinement at high beta in a plasma with non-inductively driven current. This is important to the design of a steady-state reactor. This program may be thought of as occurring in two phases. In the first phase of the program we are separately investigating high beta plasma confinement in inductively-driven plasmas, and non-inductive current drive. In the second phase we will combine these two elements to investigate high beta plasma confinement with non-inductive current drive.

The FY89 plan continues the first phase of the DIII-D experimental effort that contains a strong focus on beta and confinement in non-circular plasma configurations and in the divertor configuration in particular. Important work also continues in the development of rf heating systems for heating, profile control, and current drive. This research is coupled to theoretical efforts at General Atomics.

The FY89 research program outlined herein is diverse and multifaceted. However, it is also characterized by a greater synthesis of techniques toward a common goal. An example is the application of ECH for sawtooth suppression that would improve the low q confinement and allow higher β to be obtained. We believe this research program will provide a solid foundation for the continued development of the tokamak toward high beta steady-state reactor application.

The DIII-D FY89 research program will provide results that will help resolve many CIT and ITER Physics R&D issues. In addition, DIII-D confinement studies will be an important input to the newly formed National Transport Task Force.

The outline for the remainder of this plan is as follows:

Sec. 2. Summary discussion of the Experimental Plan.

3. A bar chart which summarizes the proposed Experimental Plan.
4. A summary of the research goals for FY89.
5. A tentative detail breakdown of the research plan.
6. A detail plan for major hardware tasks.

2. SUMMARY

The program proposed here is designed to support and build toward the long-term plan put forward during 1987 for the DIII-D facility. This plan has as its ultimate goal developing sufficient understanding and predictive capability to enable the demonstration of a high beta plasma with non-inductively driven toroidal current. The early stages of this plan call for the optimization of the plasma configuration for good confinement at high beta while simultaneously developing the needed rf power systems for current drive, profile control, and heating. The long-range research plan is given in Table I and in more detail in Table II together with a schedule of associated proposed milestones.

The research plan for FY89 is broken down into five subject areas: high beta, confinement, boundary physics, rf heating, and current drive. The goals of experiments in each of these areas are listed and simply stated in Section 4. Here we provide a more detailed discussion of these research plan elements.

High Beta Research

High beta studies have shown stable long-pulse high β operation up to $\beta_T = 7.4\%$ in single-null and 8% in double-null divertor plasmas. The beta limit scaling from Doublet III, $\beta_T (\%) = 3.5 I/aB$ (MA/m/T), has been shown to hold in DIII-D. Considerable progress has been made, via detailed observations and theory calculations, on identifying the cause of the first regime beta limit. A sequence of essentially pressure-driven, resistive, global modes with toroidal mode number $n = 4, 3, 2, 1$ appear as the beta limit is approached. Ultimately, the highest $\beta_N = \beta_T/(I/aB)$ is limited by a fast growing $n = 1$ mode which looks like an external kink.

Fiscal year 1989 efforts along this line will be in the area of detailed transport studies at the beta limit. This effort will include studying possible fast ion transport and fluctuation data from the UCLA scattering system. The first regime β limit studies will be extended to more advanced plasma shapes. This work will require substantial preparatory work on the plasma shape control system. Fiscal year 1989

Table I

INTEGRATED LONG-RANGE DIII-D PROGRAM PLAN

TABLE II
DIII-D LONG RANGE RESEARCH PLAN

CY	FY86	FY87	FY88	FY89	FY90	FY91	FY92	FY93	FY94	FY95
RESEARCH OBJECTIVES	INITIAL OPERATION	DEVELOP HIGH BETA PLASMAS WITH INDUCTIVE CURRENT DRIVE BUILD ECH & ICH SYSTEMS		OPTIMIZE BETA WITH INDUCTIVE CURRENT DRIVE DEVELOP NONINDUCTIVE CURRENT DRIVE METHODS			DEVELOP HIGHER BETA AND HIGHER NONINDUCTIVE CURRENT TOKAMAK		LONG PULSE OPERATION	
NON INDUCTIVE CURRENT DRIVE BETA GOALS		◇ 0.3 MA • 1/2% beta					◇ 0.5 MA • 1% beta		◇ 1 MA • 2%	◇ 2 MA • 5% for 10 sec
PHYSICS										
HIGH BETA (◇)	Plasma Production	High Beta Beta Limit	Double Null Shape Topology	High Elongation	Shape Profile Control	Current Drive	Moderate Current Drive		High Current Drive	
CONFINEMENT (○)	Achieve H-mode	H-mode scaling Current scaling Elm Physics	Ohmic H-mode Counter Injection Elm/ST Suppression Low q	2.5 MA Deuterium Operation Fluctuations	Edge Optimization Modulated ECH With IBW	Transport Studies Current Drive Effects	Optimize CD Profile			
BOUNDARY PHYSICS (p)	Heat Loads	Density Feedback Neutral Pressure Langmuir Probe Strike Point Sweep	Top Divertor Inside Wall Wall Conditioning Tangential H-alpha Heat Loads	Edge Optimization Divertor Erosion	Pellet Fueling Advanced Divertor	Pumping	CD Profile Effects			
RF HEATING: ECH (△)	Outside Launch Heating Elm/ST Control H-Mode			Outside Launch O-mode Inside Launch H-Mode Startup Elm/ST Control	Transport	Assist High Beta ECH with FWCD	Two Freq ECH 3 CW ECH H-Mode B Scaling	6 MW ECH	10 MW ECH	10s Pulse
RF HEATING: ICH (▽)	FW Coupling to H-Mode Connection to Theory			IBW Heating	H-Mode Profile Control	FW Heating FW H-Mode				
CURRENT DRIVE (□)		Demonstrate NBCD		HRFD Scaling Inside Launch ECCD	Modest Power FWCD		4.5 MW ICH	9 MW FWCD	High Power (ECH + FW)	10s Pulse
							3.6 MW	Modest Power (FW + ECH)		
PHYSICS MILESTONES										
		● Evaluate Confinement with NB ▲ Report on Outside Launch ECH	● Report on Divertor studies ● Report on Beta Results ● Report on Double Null ● Report on beta limit ▲ Assess Confinement	▲ Assess ECH Profile Control ■ Assess NBCD ■ Evaluate ECCD ▲ Compare Inside/Outside ECH ◆ Report on beta Double Null ○ Report tau Scaling to 2.5 MA in D ○ Report Maximum beta & tau ○ Report Fluctuation Measurements □ Report ECCD ○ Report Local Transport p Install Advanced Divertor ▽ Install Fast Wave Current Drive ○ Report ITER R & D	▽ Evaluate IBW Potential ◇ Report Profile Control of beta limits △ Operate First 110 GHz Gyrotron ○ Edge Electric Field ○ Pellet Injection ○ Report ITER R & D ○ First Multipulse Thomson ○ Correlate Fluctuation Measurements with ITG p Test Advanced Divertor □ Report FWCD Results △ Operate 4 - 110 GHz Gyrotrons ○ Report Pellet Results ◇ Assess Beta Studies with Full CD △ Report Initial 110 GHz ○ Assess Confinement with RF Profile p Report on Divertor Improvement □ Report CD Performance with 6 MW RF ◇ High Beta for 5 Sec ○ Assess Confinement with 19 MW RF ◇ Sustain 2 MA 5% beta for 10 sec					

will also contain initial efforts at affecting β limits using profile control from ECH or IBW. We also intend to try to reach higher numerical values of β_T by pushing up to the β limit in the regime $q < 3$. At present, the achieved β in this regime has been limited by the energy confinement time becoming independent of I_p for $q < 3$. Consequently, the research topics on sawtooth suppression and ELM suppression appear variously under the beta, confinement, and rf program headings. The effort to attain higher β_T will also be helped by the neutron shielding which will enable deuterium neutral beam injection into deuterium plasmas which yields higher beam power and better plasma confinement. These advantages may be crucial to achieving high beta in some of the more advanced limiter plasma shapes where H-mode is probably not available. In FY89, we also intend to mount an experiment aimed at pushing into the second stable regime.

Confinement Research

The confinement research program in FY89 has components that relate to the beta program, to producing scaling information for future machine design, and to providing basic understanding in several areas of plasma transport research. H-mode studies will continue to be emphasized. The neutron shielding will allow us to obtain the clear scaling information with deuterium neutral beam injection into deuterium plasmas, uncomplicated by isotope effects. These data will also be our contribution to a joint effort with JET to extract the size scaling of H-mode from direct comparisons of corresponding discharges in our two machines. Following up our first production of H-mode with ECH alone and even with ohmic power alone, we will continue exploring rf produced H-mode with ECH and IBW.

In more basic studies, we will seek a greater depth of understanding of interior plasma transport coefficients and processes using pulse modulation techniques and the UCLA scattering system. Because of our excellent rotation speed profile measurements derived from the charge exchange recombination diagnostic system, momentum confinement studies will come along as a by-product of scaling studies.

Boundary Physics

Boundary physics studies in FY89 will concentrate on H-mode topics and other divertor issues relevant to future machine design efforts. We perceive that the demonstration of long pulse, steady H-mode is a critical issue in future machine designs. We have already obtained a 5 second steady H-mode with good confinement characterized by grassy ELMs. We have also seen effective prevention of central impurity accumulation by ELMs in high current operation. These lines of research on long-pulse and impurity control will be continued. We will also study particle transport. An effort is underway to form a collaborative arrangement with other edge plasma specialists to provide the necessary studies of erosion/redeposition, main plasma exhaust, pumping and recycling, and helium exhaust. In this area, we note the critical role that the development of helium glow wall conditioning has played in our program this year. Work will continue on defining effective methods of divertor plasma-wall interaction for future machine designs. In FY87 and early 88, our detailed investigation of ELMs in H-mode led us to propose that ELMs are triggered by edge ballooning instabilities. In FY89, we will concentrate on the physics of the L-H transition, bringing to bear data from the UCLA scattering system and microwave reflectometer system.

Radiofrequency Heating

The rf heating program will have two operational components in FY89: electron cyclotron heating (ECH) and ion Bernstein wave heating (IBW). The ECH program in FY87 and 88 utilized second harmonic outside launch and studied heating, obtained H-mode, suppressed sawteeth, and suppressed ELMs. Because of the low cutoff density for the available outside launch X-mode waves, $\bar{n}_e \lesssim 2 \times 10^{13} \text{ cm}^{-3}$, this impressive list of accomplishments was performed in a density regime somewhat disjoint from other experiments, especially the high beta work which is usually done at higher density. Because of our desire to use ECH for sawtooth and ELM suppression to improve confinement at low q in the beta program, we have installed both an X-mode inside launch ECH system for which the cutoff density is about $7 \times 10^{13} \text{ cm}^{-3}$ and an O-mode outside launch system for which the cutoff density is $\lesssim 3 \times 10^{13} \text{ cm}^{-3}$. Initial experiments with the inside launch system resulted in some damaged waveguides which have been corrected and experiments are underway. The outside launch system was operational in early FY89.

The IBW research program will begin in FY89. The entire antenna and 2 MW generator system is installed and operational. We already know that IBW coupling to H-mode plasmas is less sensitive to edge conditions than fast wave coupling. Initial experiments are concentrating on basic IBW heating mechanisms. Key physics issues are linear versus non-linear absorption mechanisms and majority versus minority heating schemes. By employing the tunability of the system, varying the toroidal field, and using different harmonic resonances, great flexibility in heating location can be obtained. In particular, the IBW should be useful in pressure profile control in low B_T , high beta plasmas. This application takes on added importance since we believe the modes which prevent the attainment of the highest value of β_N are primarily pressure driven.

Current Drive Research

The current drive program in FY89 will continue to investigate neutral beam (NBI) current drive and a preliminary assessment of ECH current drive. Initial NBI current drive experiments have, in addition to driving substantial currents, shown that the second stability regime can be approached. This occurs by virtue of the relatively high plasma energy developed at modest current resulting in high β_P . Further experiments are planned to explore the second stable regime behavior. The ability of ECH to assist NBI current drive by increasing the electron temperature will be studied. Current drive using ECH alone may require re-orienting either the inside or outside launchers. This change requires hardware modifications and a vent, and it is currently being considered.

The revised plan presented here reflects particularly the increased emphasis on transport within both confinement and boundary physics research areas. These efforts include experiments to understand confinement, including fluctuation studies, detailed comparison of regimes with different confinement, detailed measurement of transport and development of functional dependencies; experiments to identify new confinement regimes, built upon combining the features of known regimes of enhanced confinement, and specific tests of existing theories. The completion of the shield wall allows extensive operation in deuterium which allows this work to be carried out largely with the more relevant deuterium isotope and, because of the enhanced confinement of deuterium the experiments can be carried out in more meaningful

regimes. The revised plan also specifically addresses the identified needs of CIT and ITER. The planned responses in these areas are summarized in Section 9. Immediate responses include operation issues, performance limits, confinement understanding and physics and technology of the plasma boundary.

3. EXPERIMENTAL PLAN

Table III summarizes the basic program elements for FY89. The updated plan consists of 26 weeks of operation rather than 22 weeks as in the earlier plan. Two machine vents in December and April were for ECH waveguide modifications, diagnostic improvements, and general maintenance. The updated plan strengthens the DIII-D transport program. This plan is responsive to CIT and ITER physics R&D needs. High beta work on plasma elongation and advanced shape were delayed.

TABLE III
UPDATED DIII-D FY89 RESEARCH PLAN (8/1/89)

[illegible]

[illegible]

4. GOALS FOR EXPERIMENTS IN 1989

This section contains a short summary of the principal goals for the experiments on DIII-D during 1989. The work is broken down into five subject areas: beta studies, confinement (and Transport) investigations, boundary physics, rf heating program, current drive studies and CIT/ITER Physics R&D. Each of these areas supports the others; accordingly, in some cases, you will find the same goal listed under two topics. The aim of most DIII-D experiments is to integrate these individual topics. A common example is confinement studies carried out at high beta with divertor discharges.

These goals have been modified in July as is shown in bold.

4.1. BETA STUDIES

The main goals in the high beta area are:

1. Develop effective control methods for more advanced plasma shapes including
  - a. Double-null divertors [completed].
  - b. Plasmas with elongation up to 2.5.
  - c. Plasmas with high triangularity and indentation [delayed].
2. Extend the beta limit studies to these more advanced plasma shapes [delayed].
3. Reach the β limit in the regime $q < 3$.
4. Explore the utility of profile control derived from ECH or IBW for increasing stability [delayed].
5. Continue second stability investigations in high poloidal beta plasmas [limited effort].
6. Study plasma transport, including fast ion transport, at high beta.

4.2. CONFINEMENT (AND TRANSPORT) INVESTIGATIONS

1. Evaluate confinement with deuterium injection into deuterium plasmas up to plasma currents of at least 2.5 MA.
2. Study H-mode produced with rf power alone (ECH and/or IBW).
3. Improve confinement at low q by stabilizing sawteeth and/or ELMs.
4. Provide information on the size scaling of H-mode (jointly with JET).
5. Perform a detailed transport study using pulse modulation techniques and scattering diagnostics.
6. Evaluate momentum confinement as a function of plasma parameters.
7. Conduct detailed confinement studies fluctuation diagnostics (e.g., current).
8. Continue enhanced confinement mode development and understanding.
9. Determine functional transport coefficient dependence including isotopes.
10. Improve and enhance transport diagnostics for profile and fluctuation measurements.
11. Initiate pellet injector to control density and radial gradient to improve transport studies.

4.3. BOUNDARY PHYSICS STUDIES

1. Demonstrate long pulse (~ 5 sec) quasi-stationary H-mode plasmas. Evaluate impurity transport properties.
2. Determine particle transport in H-mode to understand the flat to hollow density profiles and steep edge gradients.
3. Develop an understanding of the physics of the L-H transition. Identify the nature of the turbulence and fluctuations that correlate with L- versus H-mode.
4. Document divertor region heat loads, particle loads, and impurity effects as a function of X-point position and for single- and double-null divertors.
5. Continue to develop improved methods of wall conditioning.
6. Develop advanced divertor design to provide control and measurements for transport studies.

4.4. RF HEATING PROGRAM

Both electron cyclotron heating (ECH) and ion Bernstein wave heating (IBW) will be studied.

4.4.1. ECH Program

1. Verify ECH fundamental mode heating physics.
2. Attempt to produce and study H-mode with ECH alone.
3. Enhance H-mode by means of central ECH to peak up profiles or edge ECH for ELM stabilization [limited].
4. Stabilize sawteeth.
5. Assist NBI current drive [delayed].
6. Provide a preliminary test of ECH current drive.

4.4.2. IBW Program

1. Explore and document IBW heating efficiency and coupling in various regimes. Key issues are linear versus non-linear heating mechanisms and majority versus minority species heating regimes.
2. Attempt to produce H-mode with IBW alone or in combination with ECH [delayed].
3. Utilize IBW for pressure profile control in the high beta studies [delayed].

4.5. CURRENT DRIVE STUDIES

1. Assess (preliminary) ECH current drive.
2. Assist NBI current drive with ECH [delayed].
3. Investigate second stability behavior in current drive plasmas [limited].

4.6. CIT/ITER PHYSICS R&D

1. Integrate results of above research into CIT/ITER physics programs.

2. **Develop theoretical models of plasma disruptions and compare with DIII-D data.**
3. **Conduct experiments to evaluate possible low voltage plasma startup.**

5. DETAIL RESEARCH PLAN

Table IV(a) on the following page gives the original Experimental Plan by experimental task. That schedule called for two weeks of operation followed by two non-operating weeks for a total of 22 weeks. The schedule gives the allotted time in days for the month noted.

Table IV(b) presents the revised and extended plan for the remainder of the year, based on 26 weeks operation.

The plan for the remainder of 1989 is summarized Table IV(b). Unfortunately the individual entries differ substantially from the earlier 1989 Experimental Plan [see Table IV(a)] because of specific items planned in response to the increased emphasis on transport and the needs of CIT and ITER, as well as more detailed understanding of the needs within the program elements.

The major change in emphasis is the increased emphasis on transport under both the confinement and boundary physics headings and refocusing in other areas to meet program needs. The rf programs emphasis for both IBW and ECH is directed at the physics understanding of these systems. The beta work will concentrate on the role of plasma elongation which was delayed from earlier in the year due to emphasis on transport studies. The added transport tasks are supported by the four additional weeks of running time that has been provided.

TABLE IV(a)
ORIGINAL FY 1989 PLANNED EXPERIMENT TASK RUN DAYS

	CY 88			CY 89								
	O	N	D	J	F	M	A	M	J	J	A	S
EXPERIMENTS												
Run days (110)	10	10	10	2	10	10	5	10	10	10	12	11
Meetings*		I, A									A	
Torus Vents		ECH										
HARDWARE AVAILABILITY												
SHIELDING												
ECH, outside launch O-mode												
inside launch X-mode												
IBW System												
OPERATIONAL ISSUES (10)												
Vertical Control (b/a<3)		2										
Triangularity Control			1		1							
Indentation Control			1		1							
High Current Development					1		1					
Improved Low I _p Control					1							
Pulse Length Extension	1											
HIGH BETA STUDIES (25)												
Double-Null Divertor		2			2							
High Elongation			2			2					2	
High Triangularity							2					2
Indentation								2				
Transport Study									2			
IBW Profile Control											2	2
ECH ELM Suppression							1					
Second Stability										2		
CONFINEMENT STUDIES (25)												
D into D Scaling Study								4				4
Size Scaling of H-mode (JET)								2				
ECH H-Mode						1						
IBW H-Mode			2							2		
Sawtooth Stabilization	2					2						
Scattering Data						2						1
Modulated Transport						2		1				
BOUNDARY PHYSICS STUDIES (16)												
Long Pulse H-Mode	1								1	2		
Particle Transport											2	
Impurity Transport										2		
Fluctuation Study							1			2		
X-Point Scans											2	
Wall Conditioning Assessment				2								
ECH STUDIES (Basic) (6)												
Outside Launch Heating O-Mode	2											
Inside Launch Heating X-Mode					4							
IBW STUDIES (Basic) (18)												
Central Heating (3/2 ΩH)	2	2							1			
Edge Heating (3/2 ΩH)		2	2						1			2
Off-Axis Heating (5/2 ΩH)	2	2									2	
CURRENT DRIVE STUDIES (10)												
ECH Alone									2			
ECH Assisting NBI									1			
NBI Alone								1			1	
Second Stability Attempt			2						2		1	

*Meetings: I = IAEA; A = APS.

TABLE IV(b)
 UPDATED FY 1989 DIII-D PLANNED EXPERIMENT TASK RUN DAYS

Experiments	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Run Days	5	15	12	16	6	14	16	10	7	10
Meetings									APS	
NEUTRAL BEAM POWER (MW)	12	.	.	.	.	.	16	.	.	.
ECH POWER (MW)			1.8	.	.	.	.	.	.	.
IBW POWER (MW)	2	.	.	.	.	.	.	.	.	.
NEUTRON SHIELDING FACTOR	10	30	30	100	.	.	.	.	.	.
OPERATIONAL ISSUES										
ECH preionization				1	1					
Locked mode studies		.		1				1		
Density limit studies		1	1							
High elongation development				2		2				
Pulsed discharge cleaning	2									
Develop carbonization									2	
Density control using glow		1	1							
Routine SND, 2.5 MA plasma			2							
Develop 3.0 MA d-n divertor								1		
High performance plasmas					1			1		
CONFINEMENT PHYSICS										
Current, power and density scan			1			2		2		
Size scaling with JET		2								
Ohmic H-mode					1					
Super H-mode development				2	1		2			2
Low q confinement studies						1		2		
L-mode density scan (Waltz)				1		1				
Vary ion heating profile (fluc.)				1						
Isotope effect investigations				2						
Modulated transport studies							2			
Neoclassical comparison at high I_p			2							
L-mode vs H-mode χ comparison				1						
Dependence on vertical elongation								1		
Fast electron transport										
Transport and fluctuation studies						2	2			
Counter-injection with D-beams							2			
Error fields										1
Ion temperature gradient modes										1
Electron drift wave										2

TABLE IV(b) (Continued)

Experiments Run Days Meetings	Mar 5	Apr 15	May 12	Jun 16	Jul 6	Aug 14	Sep 16	Oct 10	Nov 7 APS	Dec 10
BOUNDARY PHYSICS										
Power and particle exhaust										
Long pulse H-mode; impurity behavior				1			2	1		
X-point sweeping										
T _e and T _i changes at L to H trans										
L to H edge rotation change in counterinjection							2			
Low density limit of H-mode										
Fluctuation changes at L to H trans				2		1		2		
Limiter H-mode		2						2		2
ELM stabilization studies						1				
Test of Hinton-Staebler theory										
H-mode studies with ECH				2	1		2			
H-mode with IBW										
Advanced divertor tech. tests										
HIGH BETA WORK										
Profile control and $n = 4,3,2,1$ modes (ECH)		2					1	2		
Beta limits and sawteeth			1							
Test Troyon vs shape and elongation								1		2
Beta limits at high temp. and field			1	1		2	1	1		
Second stability experiments							2			
ECH										
Fundamental heating studies			3							
Sawtooth suppression			1						1	
High temperature with NBI						2			2	
IBW										
Search for IBW heating		2		2		2	1		4	
Document IBW heating										
CURRENT DRIVE										
ECH current drive			1		1					
Alfvén instability experiment		2					1			
NBI current drive							1			
ECH enhanced NBI drive							1	1		

6. DETAIL HARDWARE PLAN

This section contains the master schedule of all milestones currently agreed and the schedules for specific hardware tasks. Table V is the master schedule used by General Atomics to monitor work on DIII-D.

Table V(b) is the revised master schedule for the remainder of the calendar year. The run weeks shown for the remainder of FY89 reflect 26 weeks of operations. The weeks have been organized to reflect the timing of other external events such as the APS and Fusion Engineering Meeting. Extensive operation is planned for the remainder of the calendar year to provide the detailed studies outlined earlier in this document.

TABLE V(a)

MASTER SCHEDULE

ACN 8800X
13266

ITEM	DESCRIPTION	TASK LEADER	DCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
			CPS	DPS	CPS	DPS	DPS	DPS	DPS	DPS	DPS	DPS	DPS	DPS
1.0	OPERATIONAL WEEKS (22 WKS)(TENTATIVE)	N/A												
2.0	VESSEL VENT (TENTATIVE)	N/A												
3.0	CONFERENCES	N/A												
4.0	MILESTONES													
5.0	36.0 BEGIN EXPERIMENTS USING 1.4 MW ECH POWER	PRATER												
5.0	31.0 COMPLETE RADIATION SHIELDING ROOF	VENKATESH												
5.0	30.0 INITIATE ICH IAW EXPERIMENTS	MATHEW												
5.0	33.0 REPT THE PHYSICAL MECHANISM OF THE BETA LIMIT	STANDAUGH												
5.0	47.0 COMPARE INSIDE & OUTSIDE LAUNCH HEATING	PRATER												
5.0	37.0 REPT ON PRELIM ASSESSMENT OF ECH PROFILE CONT'L PRATER													
5.0	51.0 ASSESS CONFINEMENT NOT CURRENT DRIVE DISCHARGES	STANDAUGH												
5.0	52.0 COMPLETE RADIATION SHIELDING WALLS	VENKATESH												
5.0	48.0 EVALUATE ECH CURRENT DRIVE EFFICIENCY	PRATER												
5.0	49.0 REPT DEFERENCE OF BETA LIMIT ON PLASMA SHAPE	STANDAUGH												
5.0	58.0 EVAL CURRENT & PWR IN @ AT HIGH PLASMA CURRENTS	STANDAUGH												
5.0	55.0 REPT ON THE OPTIMAL PLASMA CONFIGURATION	STANDAUGH												
5.0	HARDWARE DEVELOPMENT	N/A												
5.0	MECHANICAL ENGINEERING TASKS	ANDERSON												
5.1	DEVICE UPGRADES	CALLIS												
5.1.1	SHIELDING (ROOF)	VENKATESH												
5.1.2	SHIELDING (WALLS)	VENKATESH												
5.1.3	OUTER WALL TILES (ISVH)	SMITH												
5.1.4	LIMITER HEAD REPAIR (ISVH)	ANDERSON												
5.1.5	CATV COMPRESSOR UPGRADE	LANGHORN												
5.1.6	PELLET INJECTOR	TBO												
5.1.7	BIAS DIVERTOR (ISVH)	SCHAEFER												
5.1.8	1MW ANTENNA UPGRADE (ISVH)	MATHEW/HHELPS												
5.1.9	SANDIA TILE INSTALLATION (ISVH)	SMITH												
5.2	DIAGNOSTIC SYSTEMS	STANDAUGH												
5.2.1	DUAL RANGE SPECT	BROOKS												
5.2.2	CURRENT PROFILE	POLLITER												
5.2.3	CENTERPOST IN CAMERA SYSTEM	FETIMIE												

LEDEND
CRITICAL PATH =
COMPLETED MILESTONES =
PROGRESS OF ACTIVITY =
INSIDE VESSEL WORK =
DIRTY VENT =
CLEAN VENT =
POSSIBLE RESCHEDULE SEP 0-11
FALL DATES SHOWN REFLECT PRELIMS
NOT AVAILABLE BY 1/25/87 =

PROCURE & FAB

DESIGN

CONCEPTUAL DESIGN

DESIGN

CONCEPTUAL DESIGN

DESIGN

PROCURE & FAB

Original Master Schedule - Table V(a)

MASTER SCHEDULE

[illegible][illegible]

1999		2000		2001		2002		2003		2004		2005		2006		2007		2008		2009		2010		2011		2012		2013		2014		2015		2016		2017		2018		2019		2020		2021		2022		2023		2024		2025		2026		2027		2028		2029		2030		2031		2032		2033		2034		2035		2036		2037		2038		2039		2040		2041		2042		2043		2044		2045		2046		2047		2048		2049		2050		2051		2052		2053		2054		2055		2056		2057		2058		2059		2060		2061		2062		2063		2064		2065		2066		2067		2068		2069		2070		2071		2072		2073		2074		2075		2076		2077		2078		2079		2080		2081		2082		2083		2084		2085		2086		2087		2088		2089		2090		2091		2092		2093		2094		2095		2096		2097		2098		2099		2100																																																																																								
7	14	21	28	4	11	18	25	2	9	16	23	30	6	13	20	27	3	10	17	24	31	7	14	21	28	5	12	19	26	8	15	22	29	1	8	15	22	29	6	13	20	27	3	10	17	24	31	9	16	23	30	1	8	15	22	29	7	14	21	28	4	11	18	25	2	9	16	23	30	10	17	24	31	8	15	22	29	5	12	19	26	3	10	17	24	31	11	18	25	1	8	15	22	29	9	16	23	30	6	13	20	27	4	11	18	25	2	9	16	23	30	12	19	26	3	10	17	24	31	10	17	24	31	8	15	22	29	7	14	21	28	5	12	19	26	3	10	17	24	31	13	20	27	1	8	15	22	29	11	18	25	2	9	16	23	30	14	21	28	5	12	19	26	3	10	17	24	31	15	22	29	1	8	15	22	29	13	20	27	4	11	18	25	2	9	16	23	30	16	23	30	1	8	15	22	29	14	21	28	5	12	19	26	3	10	17	24	31	17	24	31	1	8	15	22	29	15	22	29	7	14	21	28	5	12	19	26	3	10	17	24	31	18	25	1	8	15	22	29	16	23	30	6	13	20	27	6	13	20	27	4	11	18	25	2	9	16	23	30	19	26	3	10	17	24	31	19	26	3	10	17	24	31	17	24	31	1	8	15	22	29	18	25	2	9	16	23	30	20	2

Updated Master Schedule -- Table V(b)

7. MILESTONE SCHEDULE (Research Operations)

	Task Description	Approved (Target) Date	Completed Date
37.	Correlate beta results with previous Doublet III results	3-88	3-88
38.	Compare observed beta limits with first stability regime theories	3-88	3-88
39.	Assessment of energy confinement in DIII-D	11-88	11-88
40.	Report final assessment of outside launch ECH heating	9-87	9-87
42.	Evaluate β limit of a discharge with $I/aB > 3$	6-88	3-88
43.	Evaluate β limit of a divertor discharge with $I/aB > 2.3$	3-88	3-88
44.	Report comparison of modeling of divertor neutral pressure with experimental results (with PPPL or LLNL)	12-87	12-87
45.	Initiate inside launch ECH experiment	3-88	3-88
46.	Evaluate confinement in double null divertors	7-88	7-88
47.	Compare ECH inside and outside launch heating	6-89	6-89
48.	Evaluate ECH current drive (with LLNL)	5-89	6-89
49.	Evaluate β limit of a double null divertor	6-89	6-89
50.	Initiate ICH IBW experiments	10-88	10-88
51.	Complete radiation shielding roof	9-88	10-88
52.	Complete radiation shielding walls	4-89	4-89
53.	Report on the physical mechanism of the β limit	11-88	10-88
54.	Assess stability and confinement in NBI current driven discharges	3-89	3-89
55.	Assess optimization of plasma configuration for maximum $\beta\tau$	9-89	
56.	Begin experiments using 1.4 MW generated ECH power	8-88	8-88
57.	Report on a preliminary assessment of ECH profile control	1-89	1-89

Task Description		Approved (Target) Date	Completed Date
58.	Extend current scaling, power scaling, and isotope studies to 2.5 MA and 10 MW D→D	7-89	7-89
59.	Report results of Outside Launch ECH Current Drive Experiments	(12-90)	
60.	Evaluate the potential of IBW heating for tokamaks	4-90	
61.	Evaluate the role of profile control in modifying β limits	7-90	
62.	Complete interim report on DIII-D ITER Physics R&D	(10/89)*	
63.	Submit initial report on fluctuation measurement studies (with UCLA)	(12/89)*	
64.	Submit report on results of Local Transport Studies	(3/90)*	
65.	Complete installation of Advanced Divertor (with LLNL, ORNL, SNLA, SNLL, UCLA)	(5/90)*	
66.	Complete installation of Fast Wave Current Drive Antenna (with ORNL)	(5/90)*	
67.	Complete interim report on DIII-D ITER Physics R&D	(6/90)*	
68.	Operate prototype 110 GHz gyrotron at GA	(7/90)*	
69.	Evaluate the role of edge electric fields in H-mode	(8/90)*	
70.	Evaluate confinement in H-mode with density profiles modified with pellet injection	(8/90)*	
71.	Complete interim report on DIII-D ITER Physics R&D	(10/90)*	
72.	Obtain First Data from Multipulse Thomson Scattering radial profile	(10/90)*	
73.	Correlate turbulence measurements with ITG mode theory	(12/90)*	
74.	Test particle control with the Advanced Divertor	(12/90)*	
75.	Evaluate Fast Wave Current Drive efficiency	(3/91)*	
76.	Begin DIII-D 110 GHz ECH experiments with 4 gyrotron system	(6/91)*	

*Proposed new milestones.

8. DIII-D CONFINEMENT UNDERSTANDING PROGRAM

DIII-D has a carefully developed program to improve confinement understanding. The DIII-D tokamak is well suited for experiments directed at improving confinement understanding due to its ability to obtain enhanced confinement over a wide range of parameter space relevant to next generation devices such as CIT and ITER. Our confinement program is concentrating on H-mode and edge physics where we have unique diagnostic and machine capabilities. The unique capabilities include:

- Significant plasma current (3.0 MA limiter, 2.5 MA divertor).
- Elongated plasma shape ($\kappa \leq 2.5$) and double null divertor.
- Substantial neutral beam heating: 14 MW H^o, 16 MW D^o.
- Localized rf heating for modulated transport studies: 2 MW ECH and ICH.
- H-mode operation (NBI, ECH, ohmic, limiter).
- High beta: $\beta_T \leq 8\%$, $\beta_p \leq 4.5$, $\epsilon\beta_p \leq 1.4$.
- Significant plasma parameters: $\bar{n}_e \leq 1.4 \times 10^{20} \text{ m}^{-3}$, $T_i \leq 11 \text{ keV}$, $T_e \leq 5 \text{ keV}$, $\tau_E \leq 0.34 \text{ sec}$.
- Mature profile diagnostic systems with edge profile resolution.

DIII-D experiments indicate that changes in edge plasma parameters, fluctuations, and radial electric fields are intimately connected with improved H-mode confinement. The abrupt L- to H-mode transition provides a unique opportunity for improving our understanding of H-mode physics, determining the criteria required to achieve H-mode, and predicting the subsequent confinement quality.

We summarize here specific questions we will be addressing in the DIII-D confinement program and the new diagnostics and tools we will employ.

Relation to Theory. DIII-D confinement research will be guided by theoretical work on L–H-mode physics and edge plasma effects. In the next one to two years we intend to address specific theoretical questions, such as:

- What is the role of ITG and electron drift mode turbulence in the L–H transition? Theory predicts threshold ion temperature and density gradients, fluctuation spectral characteristics, and anomalous transport coefficients, all of which we will seek to measure.
- What is the mechanism of the L–H transition? Theories identify the edge electric field as important. We will concentrate on that hypothesis.
- Do magnetic perturbations that connect magnetic surfaces play a role? Possible sources of such perturbations are resistive modes or field errors. We will use superthermal electrons to probe the structure of such perturbations.

Several steps have been taken to enhance coordination between theory and experiment. These include increased emphasis and visibility through transport seminars, formation of several small working groups including non GA participants, and the development of theoretical-driven proposals for DIII-D transport experiments. Examples of present theoretical interactions are listed in Table VI. We are encouraging more interactions to develop to address specific questions arising from our experiments.

New Diagnostics. New diagnostics will be applied to DIII-D to improve our understanding of confinement. These include:

- Improved radial resolution of ion temperature and rotation profiles to compare measurements of gradients with theories based on the ion temperature gradient mode and on the effects of radial electric fields on H-mode.

Table VI. DIII-D TRANSPORT PHYSICS COLLABORATIONS

Program	Institutions	Participants [†]	Program Elements
1. Edge Turbulence Studies	UC San Diego (Theory)	<u>Diamond</u> <u>Biglari</u> <u>Rosenbluth</u> <u>Burrell GA</u>	• Characterize edge turbulence • L- to H-mode transition • Other outside collaborators
	UC Los Angeles (Diagnostics)	Peebles Luhman Philipono <u>LeHecka*</u> <u>Doyle</u>	• Reflectometry and FIR scattering • Edge turbulence
	Advanced Divertor Program	LLNL, ORNL, SNLL, SNLA, UCLA	• Edge currents, edge probes • Divertor biasing and baffling
2. H-mode Physics	Princeton (Theory/Data Analysis)	Tang <u>Hinton GA</u> <u>Stockdale* GA</u> <u>Waltz GA</u> <u>Dominguez GA</u>	• Neoclassical transport modification by anomalous transport • Analysis of modulated ECH • ITG mode with flat density profile
	JAERI (experimental)	<u>Matsumoto</u> <u>Burrell GA</u>	• H-mode experiments
	Advanced Divertor Program	LLNL, ORNL, SNLL, SNLA, UCLA	• Density control
3. Low q Confinement	U Wisc. (Theory/Data Analysis)	Callen Cheng* <u>Schissel GA</u>	• UW has modified code for noncircular tokamak • Compare with DIII-D data
4. Transport in Elongated Plasmas	UC Berkeley (Theory/Data Analysis)	Fowler	• Students to help with transport analysis
	UCSD	Post Doc <u>Student*</u> <u>Student*</u> <u>Groeblner GA</u>	
	MIT	<u>Wolfe</u>	
5. Resistive MHD	Princeton (Modeling)	Bateman <u>Chu GA</u>	• PPPL CISLAND Code calculates satu- rated island widths for resistive modes • DIII-D EFIT equilibrium data will be used to evaluate transport
	GA Theory (Modeling)	<u>Chan GA</u>	• Combines stability codes (GATO, CART, MBC, ADJ) with transport code (ONETWO) to model DIII-D data (requires APP GA theory funding)
6. Enhanced Confinement Study and Current Profile Control	GA Theory U. Wisc. (Theory)	<u>Chan GA</u> Tataronis	• Stabilization of trapped electron mode by current profile control, drift reversal (requires APP GA theory funding) • Test Alfvén wave current drive in Phaedrus
7. Fast Ion Physics	UC Irvine (Diagnostic/Data Analysis)	Heidbrink Student*	• Energetic Ion Physics with good energy resolution charge exchange analyzer

[†] Participants located at GA are underlined; students have asterisk.

- Multipulse multi-laser Thomson scattering for L- to H-mode and edge localized mode radial profile studies as well as for time-dependent modulated (ECH, gas puff, pellets) transport evaluation of off-diagonal transport coefficients.
- Fluctuation diagnostics aimed at measuring density fluctuation spectra. Poloidal wave lengths will be determined by microwave scattering and radial correlation lengths by microwave reflectometry.

The DIII-D transport diagnostic upgrade plan is shown in Fig. 1. Other innovative proposals are developing, including spectroscopic and laser-holographic imaging of density fluctuations.

ACTIVITY	FY1989				FY1990				FY1991			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
RADIAL PROFILES												
MULTI-PULSE THOMSON												
C.E.R. UPGRADE												
MICHELSON ECE (U. MARYLAND, LLNL)												
SUPERHETERODYNE ECE (LLNL)												
BOLOMETER ARRAY REPLACEMENT												
CENTRAL THOMSON												
FLUCTUATIONS												
RADIAL CORRELATION REFLECTOMETER (UCLA)												
CARCINOTRON HETRODYNE SCATTERING (UCLA)												
PROBE CARRIAGE - FAST STROKE (SANDIA - UCLA)												
CO2 PHASE CONTRAST & IMAGING (MIT)												
TRANSPORT TOOLS												
ADVANCED DIVERTOR (LLNL, ORNL, SNLA, SNLL, UCLA)												
PELLET INJECTOR												
ECH												

Fig. 1. DIII-D transport instrument and plasma transport control tools implementation plan diagnostic. Data will be available after the designated construction periods.

New Transport Tools. In addition to new transport diagnostics, three new control tools for confinement studies will be implemented on DIII-D. These are:

- The Advanced Divertor should allow us to decouple the density and plasma current in H-mode experiments. This tool will enable us to baffle, pump, bias, as well as to measure the predicted edge current flows.
- A pellet injector will allow us to control the radial density profile for ITG mode studies, conduct modulated particle transport experiments, and explore super H-mode operation.
- The addition of 2 MW 110 GHz ECH will allow us to extend ECH H-mode studies to higher densities, explore the importance of profile control and to carry out both steady state and modulated transport studies at higher electron temperature.

9. DIII-D PROGRAM TO SUPPORT ITER AND CIT

ITER

DIII-D is in a position to provide answers to a multitude of ITER design issues. Detailed responses were developed to the request for responses to the 24 ITER R&D Physics Tasks. The tasks are summarized in Table VII, including the DIII-D responsible task leader and collaborators from outside the DIII-D program. The responses include objectives and detailed schedules for the period from now through September of 1990. These responses were reported (J. Luxon) to ITER during a meeting in Garching March 15, 1989 where the responses of the worldwide tokamak community were summarized. The response of the community was outstanding and the inputs are summarized in Table VIII. As indicated by the bold column DIII-D is expected to make the broadest contribution worldwide to ITER.

Recent DIII-D contribution to the ITER understanding base in the areas of confinement, high beta, and long pulse discharges have been particularly well received. DIII-D is viewed as a particularly valuable future contributor especially because of focus on H-mode confinement, boundary physics, long pulse discharges and current drive.

Meeting these future commitments to ITER is going to take substantial effort, resources and dedication from the DIII-D team.

TABLE VI
SUMMARY OF DIII-D CONTRIBUTIONS TO ITER

Topic		Unique	Investigator	Collaborators
DESIGN RELATED				
1. Power and helium exhaust	A	DIV H-mode	Hill	LLNL, SNL
2. Helium radial distribution	B	DIV H-mode	Miley	U. Illinois
3. Radiative edge	B	DIV H-mode	Mahdavi	LLNL
4. Divertor sweeping	B	DIV	Hill	LLNL
5. Low-Z PFC materials	A	DIV	Hill	LLNL, SNL
6. High-Z PFC materials				
7. Characterization of disruptions	B	Elongation	Taylor	PPPL
8. Disruption control	B		Taylor	
9. RF plasma formation and preheating	B	ECH	Prater	Culham
10. RF current initiation	D	ECH	Prater	
11. Inductive volt-second consumption	B		Taylor/Hogan	ORNL
12. Alpha-particle ripple losses				
13. Plasma diagnostics				
PERFORMANCE-RELATED				
14. Steady-state enhanced confinement	A	H-mode, D ₂	Gohil	ASDEX
15. Tests of theoretical transport models	A	DIV	Burrell	JET
16. Control of MHD activity	B		Strait	
17. Density limit	B	DIV	Petrie	
18. Plasma performance at high kappa	A	κ , double null	Lazarus	ORNL, Lusanne
19. Alpha particle simulations	B		Heidbrink	U.C. Irvine
20. Electron cyclotron current drive	D	ECH power	Politzer	LLNL
21. Ion Cyclotron current drive	D	ICH power	Politzer	ORNL
22. Alfvén wave instability	B		Heidbrink	U.C. Irvine
23. Advanced fueling techniques				
24. Aspect ratio scaling				

A = strong contribution; B = contribution; D = primary contribution delayed until after 1990 by hardware availability.

TABLE VII
SUMMARY OF CONTRIBUTIONS TO ITER FROM FACILITIES WORLDWIDE

The DIII-D contribution is enclosed in a heavy box.

ITER PHYSICS R & D PROGRAMME (up to 1990)		CONTRIBUTIONS OFFERED													08 MAR 89										
PARTNER		EC											J		SU		USA								
DEVICE		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	
DESIGN-RELATED																									
01	Power and He exhaust-----	■	-	■	■	■	-	-	-	-	-	-	■	■	-	■	-	■	■	■	-	-	?	-	01
02	He radial distribution-----	■	-	-	■	■	-	-	-	-	-	-	■	-	-	-	■	■	■	-	-	-	-	-	02
03	Radiative edge-----	-	-	■	-	■	-	-	-	-	-	-	■	-	-	-	-	■	-	■	-	-	-	-	03
04	Divertor sweeping-----	-	-	-	-	-	-	-	-	-	-	-	■	-	-	-	-	-	-	■	-	-	-	-	04
05	Low-Z PFC materials-----	■	-	■	■	-	-	-	-	-	-	-	■	-	-	-	-	-	■	-	■	-	-	-	05
06	High-Z PFC materials-----	-	-	-	-	-	-	-	-	-	-	-	■	-	-	-	-	-	-	-	-	-	-	-	06
07	Characterization of disruptions--	■	-	-	-	■	-	■	-	-	-	-	■	■	-	-	■	■	■	■	-	-	-	-	07
08	Disruption control-----	-	-	-	-	■	-	-	-	■	■	-	■	■	-	-	■	-	■	■	■	-	-	-	08
09	RF plasma formation/preheating---	-	-	-	-	■	-	-	-	-	-	-	■	■	■	-	■	■	■	■	-	-	-	-	09
10	RF current initiation-----	-	-	-	-	-	-	-	-	■	-	-	■	-	■	-	-	-	-	■	-	-	-	-	10
11	Inductive volt-second consumption	■	-	-	-	■	■	-	-	-	-	-	■	■	-	-	■	■	■	-	-	-	-	-	11
11A	RF current ramp-up assist-----	■	-	-	-	■	■	-	-	-	-	-	■	■	-	-	-	■	■	-	-	-	-	-	11A
12	Alpha particle ripple losses-----	-	-	-	-	■	-	-	-	-	-	-	-	-	-	-	-	■	-	-	-	■	-	-	12
13	Plasma diagnostics-----	-	-	-	-	-	-	-	-	-	-	-	■	-	-	-	-	■	-	-	-	-	-	-	13
PERFORMANCE-RELATED																									
14	Steady-state enhanced confinement	■	■	-	■	-	-	-	-	-	-	-	■	■	-	-	-	■	-	■	-	-	-	-	14
15	Test theoretical transport models	■	-	■	■	-	■	■	-	-	-	■	■	■	-	-	■	■	■	-	■	■	■	■	15
16	Control of MHD activity-----	■	-	-	■	■	-	-	-	■	-	-	■	■	-	-	■	■	■	■	-	-	-	-	16
17	Density limit-----	■	-	■	■	-	-	-	-	-	-	-	■	■	-	-	-	■	-	■	-	-	-	-	17
18	Plasma performance at high kappa-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	■	-	-	-	-	-	18
19	Alpha-particle simulations-----	■	-	-	-	■	-	-	-	-	-	-	-	-	-	-	-	■	-	■	-	-	-	-	19
20	Electron cyclotron current drive-	-	-	-	-	■	-	■	■	-	-	-	-	■	■	-	■	-	-	■	-	-	-	-	20
21	Ion cyclotron current drive-----	■	-	-	-	-	-	-	-	-	-	-	■	■	-	-	-	-	-	-	-	-	-	-	21
22	Alfvén wave instability-----	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	■	-	■	-	-	-	-	22
23	Advanced fuelling techniques-----	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	■	-	?	-	23
24	Scaling of plasma performance----	-	-	-	-	-	-	-	-	-	-	■	-	-	-	-	-	-	■	-	-	-	-	-	24

LEGEND	A:JET	JET	F:FTU	ENEA	K:	NFR	P:T-10	Kurchatov I.	U:ATF	ORNL
	B:TEXTOR	ERM	G:RTP	FOM	L:JT-60M	JAERI	Q:TFTR	Princeton U.	V:TEXT,APP	Texas U.
	C:TEXTOR	KFA	H:DITE	UKAEA	M:JFT-2M	JAERI	R:PBX	Princeton U.	W:TTF	Transport
	D:ASDEX	IPP	I:COMPASS	UKAEA	N:WT-3	Kyoto U.	S:DIIID	GA		task force.
	E:TORE-SupCEA	J:START	UKAEA	O:	Nagoya U.	T:MTX	LLNL			

CIT

Due to its size, shape and flexibility, DIII-D can resolve key issues associated with the design of CIT and thereby make significant and favorable budget and schedule impacts. Two specific areas have been recently identified where DIII-D research results contribute to the CIT design effort. These are low voltage plasma initiation, and divertor plate erosion studies. Plans are being laid to meet these needs with existing data and additional experiments. The need for rf-assisted breakdown data as part of the low voltage plasma initiation studies can be satisfied as part of the joint ECH experiments with Culham this summer. The erosion studies can be integrated into the ongoing studies with Sandia, LLNL, and others.

APPENDIX

TECHNICAL DIRECTION TO INCREASE TRANSPORT EMPHASIS

U.S. DEPARTMENT OF ENERGY --
SAN FRANCISCO OPERATIONS OFFICE
Energy Research Division - San Diego Site Office
P.O. Box 85608, San Diego, California 93158

June 15, 1989

Dr. T. Simonen, DIII-D Program Director
Fusion Division
General Atomics Inc.
P.O. Box 85608
San Diego, CA 92138

Subj: Technical Direction for Contract DE-AC03-89ER51114.

Ref: (1) Memo from J. Willis to N.A. Davies dtd 3/9/89, Subj: Program
Highlights - Response to the Transport Initiative - 3/3/89.

Dear Tom,

Incremental funding in the amount of \$3,000,000 is being added to the subject contract in B&R AT101014D. The purpose of this action is to enhance the utilization of DIII-D in response to the Transport Initiative (Ref (1)). Guidance for costing these funds during FY 1989 is as follows:

\$1,400,000 - for diagnostic improvements and enhancements.

1,000,000 - for increased experimental time.

400,000 - to implement the Advanced Divertor Program (ADP).

200,000 - to begin the implementation of a pellet injector for DIII-D.

The DIII-D Experimental Plan is to be updated to reflect the enhanced efforts. Also, you are requested to propose a revised set of DIII-D project milestones which reflect the shift in program emphasis toward transport studies. This material should be prepared in time for distribution at the next SAN quarterly review in July, 1989.

Very truly yours,

Clair M. Beighley

cc: Erol Oktay, ER-55
Aundra Richards, SAN-CM
Marilyn Smith, SAN-ER
James Shakiba, SAN-ER

bc: Don Gill, 01-150
Jim Luxon, 13-258
Keith Shoolbred, 13-206A