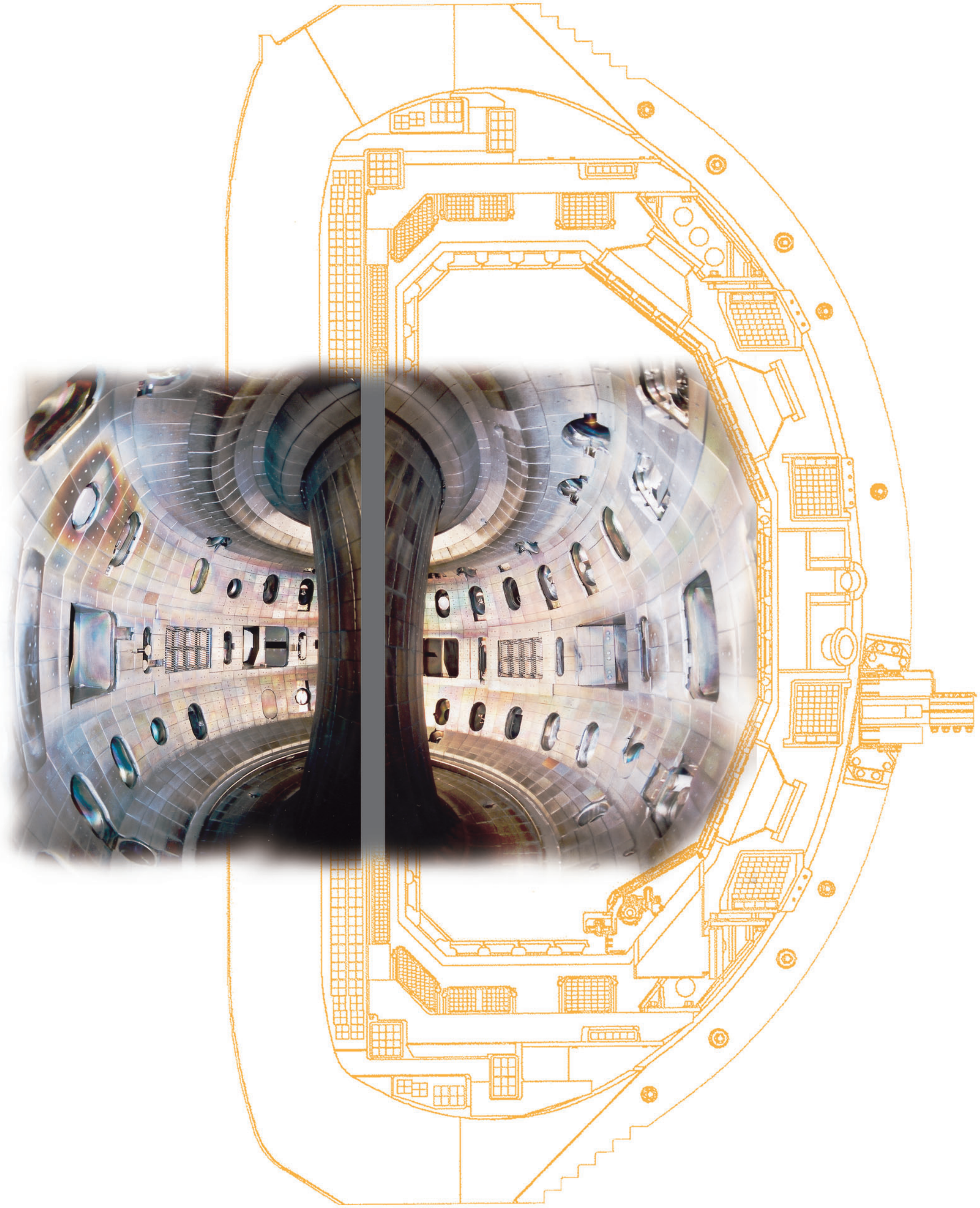

DIII–D National Fusion Program

Presented at
Office of Fusion Energy Science
FY04 Budget Planning Meeting
Washington, DC

March 12–13, 2002

DIII–D
NATIONAL FUSION FACILITY
SAN DIEGO

DIII–D NATIONAL PROGRAM OVERVIEW

by
R.D. Stambaugh

Presented at
Office of Fusion Energy Sciences
FY04 Budget Planning Meeting
Washington, DC

March 13, 2002

DIII–D
NATIONAL FUSION FACILITY
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GENERAL ATOMICS

079–02/RDS/wj

DIII–D INTERNATIONAL RESEARCH TEAM

U.S. Labs

ANL
INEL
LANL
LLNL
ORNL
PNL
PPPL
SNL

Japan

JAERI
  JT–60U
  JFT-2M
NIFS
  LHD
Tsukuba U.

European Community

Cadarache (France)
Culham (England)
Forshungzentrum — Julich
Frascati (Italy)
FOM (Holland)
IPP (Garching)
Joint European Torus
Lausanne (Switzerland)

Russia

Ioffe
Keldysh
Kurchatov
Moscow State
Troitsk

U.S. Universities

Alaska
Cal Tech
Columbia
Georgia Tech
Hampton
Lehigh
Maryland
MIT
RPI
Texas
UCI
UCLA
UCSD
Washington
Wisconsin

Other International

ASIPP (China)
CCFM (Canada)
Chalmers U. (Sweden)
CREATE (Italy)
Helsinki U. (Finland)
KAIST (Korea)
KBSI (Korea)
SWIP (China)
U. Alberta (Canada)
U. Toronto (Canada)
U. Wales (Wales)

Industry

CompX
CPI
Creare
FAR Tech
Gycom
Intelligent Optical Sys.
IR&T
Tech-X
Thermacore
TSI Research

DIII–D NATIONAL FUSION FACILITY SAN DIEGO

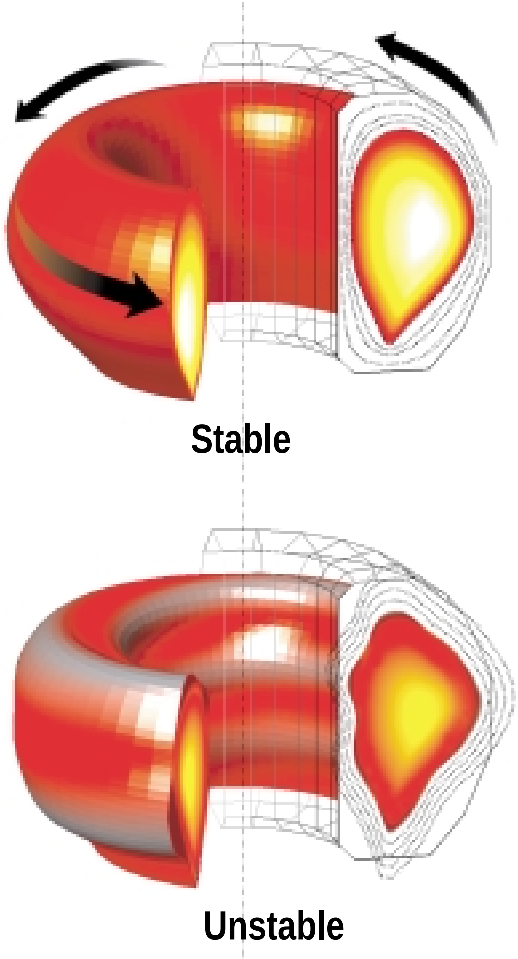
079–02/TST/wj

THE DIII–D PROGRAM EXCELS IN PROPOSED MANAGEMENT CRITERIA

- Quality
  - State-of-the-art work
  - At forefront of scientific and technologic knowledge on an international level
- Relevance
  - Work fulfills agency mission
  - Stack up against FESAC/IPPA objectives
- Performance
  - Identifiable results
  - Achieving deliverables

THE DIII–D PROGRAM PRODUCED OUTSTANDING RESULTS IN 2001

- 2001 APS Excellence in Plasma Physics Prize awarded to Keith Burrell (GA), Rich Groebner (GA), Ed Doyle (UCLA), Ed Synakowski (PPPL — TFTR work) for their work on the physics of turbulence stabilization by sheared E×B flows



- Spinning plasma improves prospects for fusion energy
  — Washington Post, Physics Today, New Scientist, San Diego Union-Tribune
- Major element of disruption issue resolved
- Validated microwave current drive theory
- Suppressed major plasma instability with microwaves
- Achieved full operation of a new microwave source
- Completed scheduled 17 run weeks despite California power crisis
- Achieved advanced performance modes attractive for burning plasma experiments

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DIII–D RESEARCH HIGHLIGHTS

- Demonstrated sustained rotational stabilization of the ideal kink mode above the ideal free-boundary kink mode limit, by means of a new method to symmetrize the external magnetic field
- Validated the improvement in off-axis current drive efficiency with increasing electron beta in accordance with detailed theory and Fokker-planck modeling
- Demonstrated, for the first time, feedback-controlled positioning of electron cyclotron current drive for neoclassical tearing mode suppression, leading to improved plasma beta
- Demonstrated controlled plasma termination with high-pressure noble gas injection suppresses runaway electrons, reduces halo currents and reduces disruptive heat loads
- Demonstrated that turbulence radial correlation length scales with the toroidal ion gyroradius, not the poloidal gyroradius, consistent with gyrokinetic simulation results
- Continued progress in steady-state advanced tokamak target scenarios with error field, resistive wall mode, and density control resulting in $\beta_N H_{89P} > 10$ for 4 energy confinement times
- Showed strong experimental evidence that the neutral penetration controls the width of the H-mode density pedestal, in agreement with simple models

DIII–D RESEARCH HIGHLIGHTS (Continued)

- Documented enhanced radial plasma flow by intermittent convective transport across the plasma separatrix , accounting for half of the total cross field particle and energy transport
- Developed discharges with very high bootstrap fraction and with full noninductive sustainment of the plasma current
- In collaboration with international partners, showed the neoclassical tearing mode threshold scaled with non-dimensional physics parameters independent of system size, and provided the first demonstration of neoclassical tearing mode avoidance by non-resonant magnetic perturbations
- Demonstrated a strong reduction in plasma transport with increasing vertical plasma elongation
- Showed edge pedestal plasmas in DIII-D and Alcator C-Mod with the same non-dimensional parameters have similar profiles and microstability properties
- Created long pulse core barriers in QDB discharges with barrier duration over 3.5 s or 25 energy confinement times, and high performance QDB discharges were created with $\beta_N H_{89P} \geq 7$ for up to 10 energy confinement times
- Progress on understanding the scaling of ELM energy loss with plasma parameters, and important issue for divertor heat and particle handling in future tokamaks

DIII–D PROGRAM ADVISORY COMMITTEE (DAC) REPORT
(December 5–7, 2001)

- Charged to take a preliminary look at our next Five Year Mission (FY2004–2008)

  "We recommend three major thrusts

  - Advanced tokamak (AT) science: … the overarching mission of the DIII–D program"
  - Transport physics: …. DIII–D is well positioned to remain at the center of this grand challenge for many years"
  - Plasma macrostability: DIII–D is a world leader in physics analysis and stabilization of resistive wall modes (RWM), as well as a major participant in the physics and stabilization of neoclassical tearing modes"

- Charged to take a detailed look at our LONG-TERM STABILITY RESEARCH

  "The stability studies on DIII–D are first-rate, clearly at the world forefront. The plans are sensible and far-reaching. The PAC has no major suggestions for change."

MEMBERS OF THE PAC 2002

Prof. Richard Fitzpatrick, Institute for Fusion Studies, University of Texas at Austin

Dr. Xavier Garbet, DRFC/SCFCP, CEA Cadarache

Dr. Richard Hawryluk, Princeton Plasma Physics Laboratory

Dr. Chris Hegna,* University of Wisconsin

Prof. Sergei Krasheninnikov, Fusion Energy Research Program, University of California, San Diego

Dr. John Lindl, Lawrence Livermore National Laboratory

Dr. Kathryn McCarthy, INEL, Fusion Safety Program, Bechtel B&W Idaho, LLC

Dr. Jonathan Menard, Princeton Plasma Physics Laboratory

Dr. Hiro Ninomiya, Japan Atomic Energy Research Institute

Prof. Ronald Parker, Plasma Science and Fusion Center, Massachusetts Institute of Technology

Dr. Martin Peng, Oak Ridge National Laboratory

Dr. Stewart Prager, University of Wisconsin (Chair)

Dr. Ed Synakowski, Princeton Plasma Physics Laboratory

Dr. Michael Watkins, EFDA-JET Close Support Unit, Culham Science Center

Dr. Steven Wolfe, Plasma Science and Fusion Center, Massachusetts Institute of Technology

Prof. Hartmut Zohm, Max-Planck-Institüt für Plasmaphysik

*Substitute for an absentee member.

THE DIII–D PROGRAM EDUCATES NEW FUSION RESEARCHERS

- **Currently nine postdoctoral fellows from**
  - Columbia, LLNL, MIT, ORISE, UCSD, and UCLA
- **Six graduate students from**
  - Chalmers U., Georgia Tech, U. Padova, U. Wisconsin, UC Irvine
- **Eight undergraduate students**
- **DIII–D users — 355**
  - GA — 91
  - Collaborators — 264

TIGHT FY02 BUDGET SUPPORTS LIMITED EXPERIMENT TIME (14 Weeks) AND CONTINUED PROGRESS ON KEY RESEARCH TOOLS

- Assessing theory-based directions for control of plasma energy confinement
- Controlling plasma instabilities with microwaves
- Containing plasma instabilities with metal walls
- Completing the 6 MW microwave power system
- Installing control coils to enable our FY01 discovery (spinning plasma) to be followed up in FY03

Coils Being Installed in DIII–D

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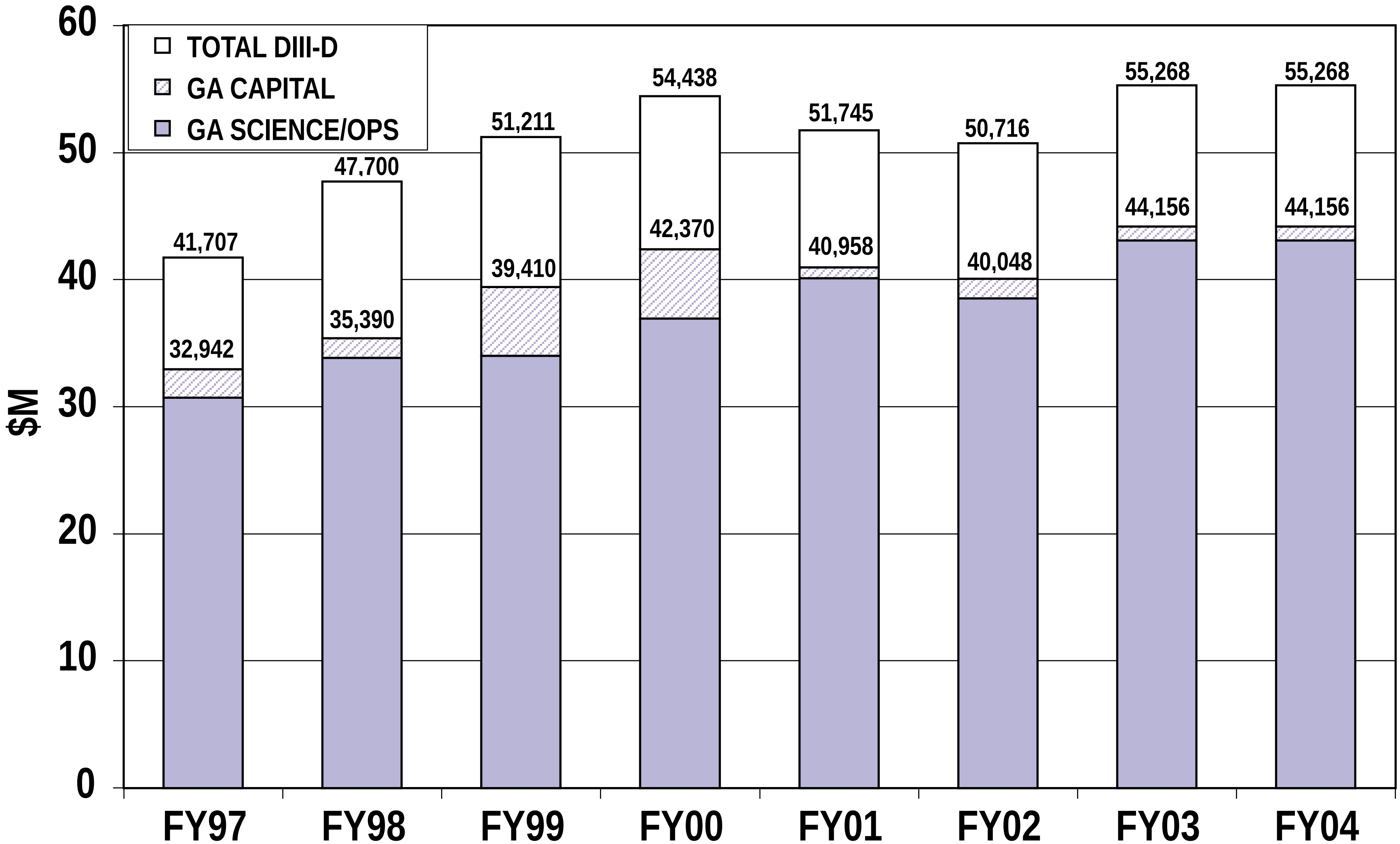
FY03 AND FY04 BUDGET INCREASES WILL ENABLE SIGNIFICANTLY INCREASED PROGRESS



DIII–D NATIONAL FUSION FACILITY SAN DIEGO

082–02/DEB/wj

FY03 AND FY04 BUDGET INCREASE ENABLES

- Run time 14 $\rightarrow$ 21 weeks
  - Increased research productivity
- Completion of RWM coil system to open up the upper half of the tokamak operating space
- Replacing 2-second Russian gyrotrons with 10-second CPI gyrotrons
  - Sustained AT performance by suppressing the main 2/1 NTM
- Support of new university turbulence diagnostics awarded in recent competition
- Resumption of fast wave operation
  - Electron heating and central q control

IMPACT OF A 10% BUDGET CUT IN THE DIII–D NATIONAL PROGRAM FOR 2004

- Basically the gains from the budget increase will be reversed and an additional $1M cut below the FY02 level will result. We would take the following actions in order

  1. No fast wave operation
  2. If university diagnostic grants are cut, then cut GA support
  3. No replacement gyrotrons
  4. Run weeks cut 14 $\rightarrow$ 12 weeks
  5. RWM coil upgrade stretched to 2005
  6. Instead of more staff — reduce staff by 4 nationally

DIII–D NATIONAL PROGRAM
INSTITUTIONAL BUDGET DISTRIBUTION FY02–04

($000)

	FY02	FY03	FY03(I)	FY04	FY04(I)
GA	$38,412	$42,249	$2,924	$41,933	$5,165
PPPL	$3,796	$4,016	$404	$4,016	$431
LLNL	$3,016	$3,087	$555	$3,087	$1,215
ORNL	$2,201	$2,328	$450	$2,328	$450
UCSD	$570	$581		$581	
U. TEXAS	$362	$384		$384	
COLUMBIA	$278	$276		$276	
SNL	$162	$160		$160	
U. WISCONSIN	$154	$152		$152	
GEORGIA TECH	$129	$128		$128	
UCLA (GA SUBCONTRACT)	$489	$453		$476	
U. Md (GA SUBCONTRACT)	$26	$26		$26	
U. IRVINE (GA SUBCONTRACT)	$87	$92		$98	
OTHER GA SUBCONTRACTS	$112	$112		$83	
GA POST DOC PROGRAM	$65	$65	$325	$65	$325
GA COLLAB. SUPPORT	$857	$1,159		$1,475	
PROGRAM TOTAL	**$50,716**	**$55,268**	**$4,658**	**$55,268**	**$7,586**

DIII–D NATIONAL FUSION FACILITY

079–02/RDS/wj

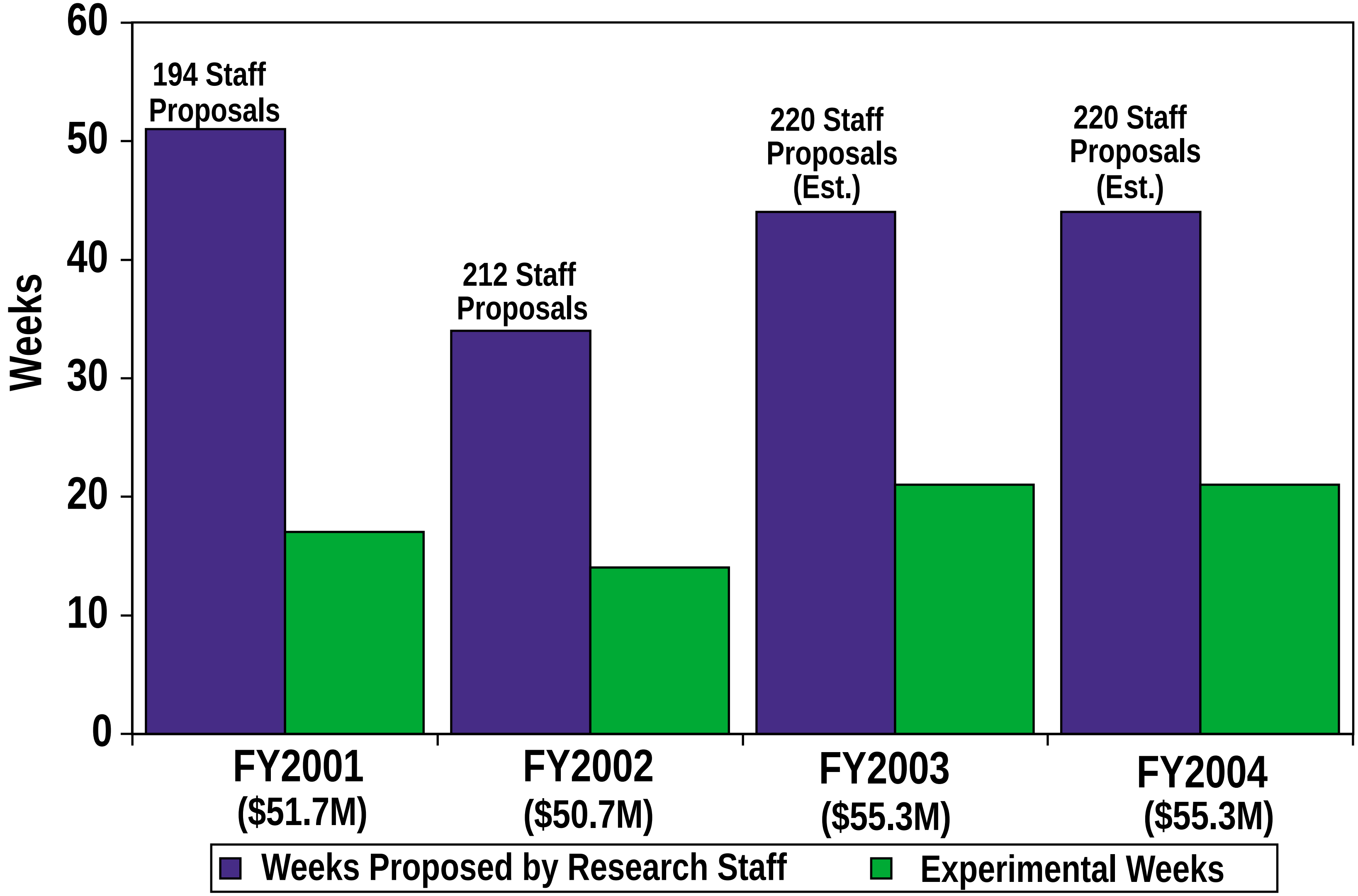
DIII–D NATIONAL PROGRAM
INSTITUTIONAL STAFFING DISTRIBUTION (FTEs)

	On-Site FY02	FY02	FY03	FY04
GA	129.8	129.8	134.2	133.0
PPPL	6.0	12.5	10.8	12.5
LLNL	11.6	14.0	13.6	13.0
ORNL	5.0	7.5	7.6	7.3
UCSD	3.0	3.5	3.5	3.2
U. TEXAS	1.0	2.5	2.5	2.5
COLUMBIA	1.0	2.0	2.0	2.0
SNL	1.0	1.0	1.0	1.0
U. WISCONSIN	1.0	1.5	1.5	1.5
GEORGIA TECH	0.5	2.0	2.0	2.0
UCLA (GA SUBCONTRACT)	4.0	5.0	5.0	5.0
U. Md (GA SUBCONTRACT)	1.0	1.2	1.2	1.2
U. IRVINE (GA SUBCONTRACT)	1.0	1.2	1.2	1.2
OTHER GA SUBCONTRACTS	—	1.0	1.0	1.0
TOTAL	165.9	184.7	187.1	186.4

DIII–D NATIONAL FUSION FACILITY

079–02/RDS/wj

FUNDING FOR THE 21 RUN WEEKS IN FY03 AND FY04 WILL ENABLE A NEEDED INCREASE IN THE NUMBER OF EXPERIMENTS RUN AND THE DEPTH OF THE INVESTIGATION IN SOME EXPERIMENTS



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082–02/RTS/rs

21 WEEKS ALLOWS INCREASED DIVERSITY AND FOCUS

#	Acronym	Description	**2002**	**2003**	**2004**
1	Edge Pedestal	Understand what determines the structure of the edge pedestal in H-mode and the edge localized modes	6	**8**	**6**
3	NTM	Advance the physics understanding of neoclassical tearing modes, including the thresholds and means of stabilization.	6	**6**	**6**
4	RWM	Advance the physics understanding of RWM stability, including the dependence on plasma rotation, wall/plasma distance, and active feedback stabilization.	8	**10**	**8**
6	High β	Exploration of the high β AT plasma scenario		**6**	**6**
8	AT Scenarios		12	**15**	**19**
		Thrust Totals	32	**45**	**45**
		Stability Topical Area	3	**6**	**7**
		Confinement Topical Area	10	**15**	**18**
		Boundary Topical Area	6	**10**	**8**
		Heating and Current Drive Topical Area	5	**9**	**7**
		Topical Area Sum	24	**40**	**40**
		Percentage of Total Days	43	**47**	**47**
		Total Allocated Days	56	**85**	**85**
		Contingency	14	**20**	**20**
		Sum	70	**105**	**105**
		Available Days	70	**105**	**105**

AN EXPANDING ADVANCED TOKAMAK OPPORTUNITY SPACE

AT Regime	Advantages	Issues
Weak negative central shear	• Least tearing trouble • Long-pulse At mode for ITER?	• Steady-state current profiles — Getting high bootstrap fraction — Current drive • Lower ultimate β_N
QH/QDB regimes	• No ELMs! • Possibility of steady-state • Double barriers separated by $\omega_{E\times B}$ zero crossing	• Peaked density profiles — Core impurity accumulation, narrow bootstrap profile, reduced stability limits • $\omega_{E\times B}$ zero crossing limits core barrier expansion • Counter NBI requirement? — Balanced NBI may be just as good
Strong negative central shear ("current hole" is extreme case)	• Stable microturbulence • Potentially highest β_N	• Obtaining large q_{min} and ITB radii • Wall stabilization • Off-axis current drive
VH–mode	• Transport barrier just in the right place for ultimate AT	• Terminations by large ELM
High internal inductance	• Good β_N without wall stabilization	• Limited bootstrap fraction

DIII–D NATIONAL FUSION FACILITY

GENERAL ATOMICS

291–01/RDS/wj

PROPOSED DIII–D FY03 AND FY04 OPERATION SCHEDULES

PROPOSED DIII-D FY2003 OPERATIONS SCHEDULE

Oct 02

S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

Nov 02

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	**H**	**H**	23
24	25	26	27	28	29	30

Dec 02

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29	30	31				

Jan 03

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19	20	21	22	23	24	25
26	27	28	29	30	31	

Feb 03

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16	17	18	19	20	21	22
23	24	25	26	27	28	

Mar 03

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16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

Apr 03

S	M	T	W	T	F	S
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20	21	22	23	24	25	26
27	28	29	30			

May 03

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25	26	27	28	29	30	31

Jun 03

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29	30					

Jul 03

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27	28	29	30	31		

Aug 03

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17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

Sep 03

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14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

Plasma physics Startup Vent

PROPOSED DIII-D FY2004 OPERATIONS SCHEDULE

Oct 03

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

Nov 03

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23	24	25	26	27	28	29
30						

Dec 03

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28	29	30	31			

Jan 04

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25	26	27	28	29	30	31

Feb 04

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15	16	17	18	19	20	21
22	23	24	25	26	27	28

Mar 04

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8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

Apr 04

			1	2	3	4
5	6	7	8	9	10	11
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19	20	21	22	23	24	25
26	27	28	29	30		

May 04

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10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

Jun 04

	1	2	3	4	5	6
7	8	9	10	11	12	13
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21	22	23	24	25	26	27
28	29	30				

Jul 04

			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

Aug 04

				1	2	3
4	5	6	7	8	9	10
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18	19	20	21	22	23	24
25	26	27	28	29	30	31

Sep 04

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10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

Plasma physics Startup Vent

DIII–D
NATIONAL FUSION FACILITY
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IMPROVING FY03 BUDGET WILL STRENGTHEN PREPARATION FOR THE PLANNED FY04 FUSION PROGRAM ASSESSMENT

- **FY03 research milestones**
  - Investigating how plasma gets from the core plasma to the vacuum chamber wall
  - Moving toward combining high plasma performance with effective power and particle exhaust
  - Exploring a new mode for steady-state advanced tokamak operation
  - Proving the role of self-driven plasma current in instabilities at the plasma edge
  - Exploring plasmas beyond the frontier of conventional stability limits

IMPROVING FY03 BUDGET WILL STRENGTHEN PREPARATION FOR THE PLANNED FY04 FUSION PROGRAM ASSESSMENT

- **FY04 research milestones (proposed)**
  - Maintaining high performance by controlling plasma instabilities with microwaves
  - Examining the role of particle flux on the structure of the edge transport barrier
  - Evaluating the physics basis for steady-state advanced tokamak operation
  - Assessing the operating space for tolerable edge localized modes in a next-step tokamak
  - Demonstrating the effectiveness of non-axisymmetric control coils inside the vacuum vessel for feedback stabilization of plasma instabilities near the vessel wall

RESEARCH ACCOMPLISHMENTS ANTICIPATED IN FY03

DIII–D is a very broad program and as is clear from the list of FY01 research accomplishments the DIII–D Program can be expected to produce a long list of research advances in FY03 and FY04. The milestones for the DIII–D Program certainly give goals for future years. We list a few principal research goals we expect to accomplish in FY03

- **Wall stabilization —** We expect late in the FY03 campaign to have the full 18 coil feedback system working on DIII–D. This system holds the promise of enabling plasmas to reach the full ideal MHD beta limit in the presence of an effective conducting wall. This will open up for exploration the upper half of the tokamak operating space. In this first year, most of the effort will be expended commissioning the system and beginning the feedback optimization, with expectations of some initial experiments exploiting the expected higher beta capability.
- **Neoclassical tearing stabilization —** Research will benefit from routine availability of 6 gyrotrons. We anticipate that 6 gyrotrons will enable suppression of the most important tearing mode instability, the 2/1 NTM. Suppression of the 2/1 NTM, together with effective wall stabilization application, is expected to enable higher performance to be reached in our longest duration (6 s) Advanced Tokamak plasmas. These plasmas in DIII–D already hold the worldwide record for highest normalized stability and confinement performance for durations more than a current diffusion time and this record should be increased.
- **Edge pedestal —** Research using the lithium beam diagnostic should provide proof of the role of the self-driven edge bootstrap current in the stability of the plasma edge. This will essentially complete a comprehensive physics understanding of the main edge localized instabilities and enable physics based prediction to future burning plasma devices.

RESEARCH ACCOMPLISHMENTS ANTICIPATED IN FY04

- **Wall stabilization —** The full 18 coil wall stabilization system will have had its shakedown operation in FY03 and should be ready for research to demonstrate values of normalized beta well above the no-wall limit. Some further effort will likely be required to optimize the feedback. We anticipate showing long duration sustainment of normalized beta values well in excess of what is presently relied upon to design future devices. This research work should establish the feasibility of wall stabilization to significantly increase the performance potential of the tokamak
- **Advanced tokamak scenario —** Work based on the negative central shear regime will have available as tools the wall stabilization system, the upper divertor pumping system, and the 6 gyrotron system for both current profile control and neoclassical tearing mode suppression. We plan in addition to have additional electron heating from the fast wave system to boost the EC current drive efficiency. Demonstration of high performance modes will be limited to 2 s because 4 of the 6 gyrotrons can only pulse that long. The two second discharge duration should be adequate to illustrate that discharges that are in principle steady-state can be sustained for times long compared to the confinement time and therefore meet the five year FESAC goal
- **Quiescent Double Barrier Regime —** It should be possible in FY04 to make some definitive statements about the prospects of the QDB regime as a steady-state Advanced Tokamak mode. Current profile control experiments in this mode should have been done in FY03 or certainly in FY04. We also expect progress by this time on understanding the physics of the Quiescent H–mode edge. The edge plasma in this mode is ideal from a burning plasma experiment viewpoint

DIII–D ADVANCED TOKAMAK FACILITY CAPABILITIES PLAN

DRAFT 3/4/02

Milestones: ◆ Summer Workshop (2002) · Next Five Year Period ◆ (2003) · FESAC Assessment ◆ (2004)

CY	2001	2002	2003	2004	2005	2006	2007	2008
Operation Periods	17	14	21	21	21	21	21	21

H&CD

EC
- ▲ 4 Gyrotrons
- ▲ 2 Launchers
- △ 6 Gyrotrons
- △ 3 Launchers
- □ 8 Gyrotrons (6 LP)
- □ 9.0 MW Long Pulse
- □ 4 Steerable Launchers

FW
- □ Resume Operation (3 of 6 MW)
- □ 6 MW Operation

NBI
- □ Counter Beam Line(s)
- □ Divertor DNB

RWM Stabilization
- ▲ Internal Sensors
- △ 12 Internal Coils
- △ Power Supplies

Fueling Divertor
- □ Lower Pumping
- □ Reactor Fueling
- □ Double Null
- □ Ergodization

Long Pulse
- 138 kV Substation □
- □ PF Cables
- □ TF Diodes
- □ TF Belt Bus

Diagnostics
- △ Edge j (r)
- △ CER Upgrade
- △ Zonal Flows
- △ High k, ETG
- □ Fast Ions
- □ Turbulence Imaging
- □ Momentum Transport
- □ Magnetic Fluctuation
- □ Fast Ion MHD
- □ Particle Transport
- □ Divertor Flows
- □ Main Chamber

▲ = Completed
△ = Will be done under guidance budgets
□ = Budget availability TBD

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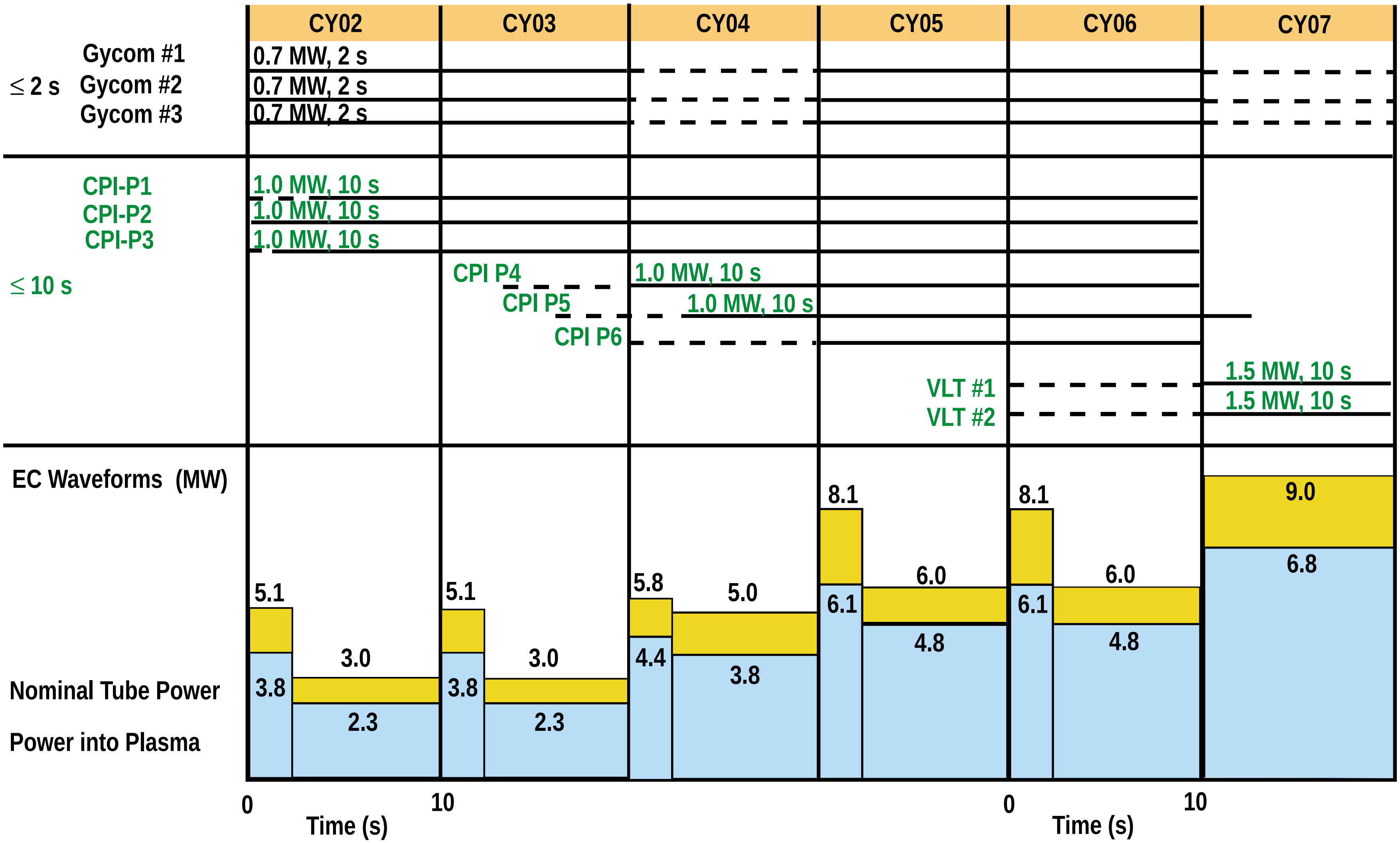
EC SYSTEM PLAN



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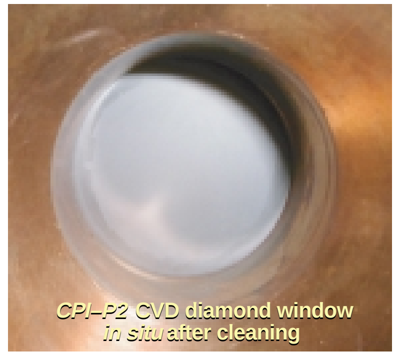
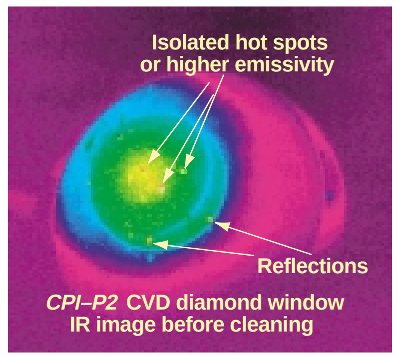
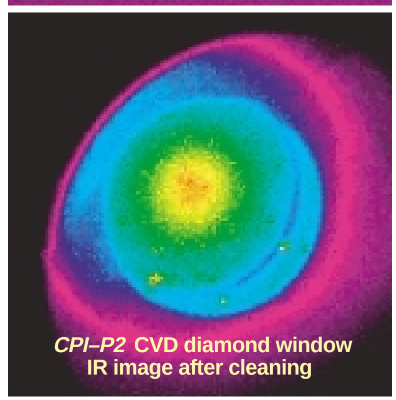
WITH THE HELP FROM THE VLT GYROTRON DEVELOPMENT PROGRAM THE CVD DIAMOND WINDOW PROBLEM WAS IDENTIFIED AND CORRECTED

- Several CVD diamond windows have failed due to contamination. Raman scattering measurements on the CPI–P2 window were made on the gyrotron, which verified the presence of graphite on the surface. “Hot spots” also were seen in the IR measurements of the window temperature during operation. The window was grit blasted with 3 micron alumina. This reduced the graphite and eliminated most of the “hot spots” from the IR measurement

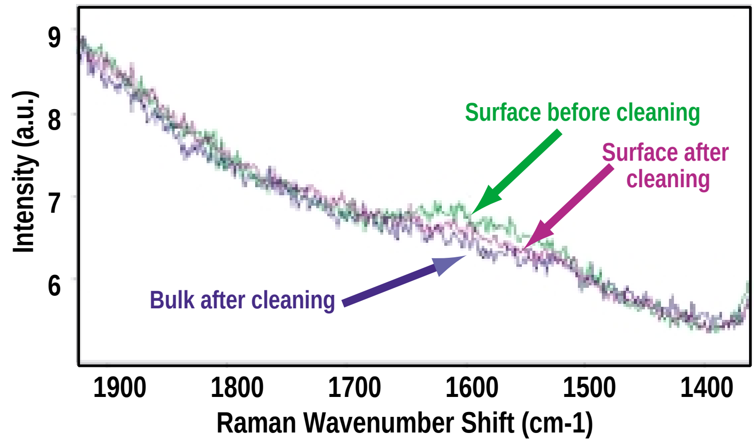

CPI–P2 CVD diamond window
In situ after cleaning



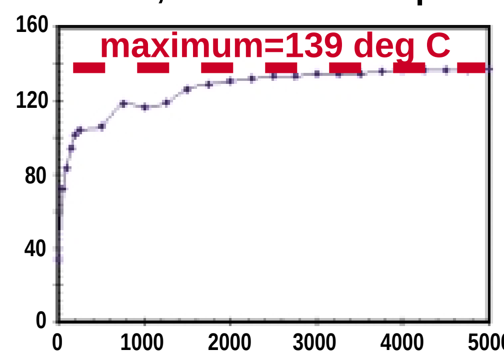
CPI–P2 CVD diamond window
IR image before cleaning


CPI–P2 CVD diamond window
IR image after cleaning

In Situ Raman Spectra of CPI–P2 Diamond Window Near Graphite Wavenumber Shift at ~1600 cm^{-1}



IR measurement of the peak diamond window temperature for a 1.0 MW, 5.0 sec CPI–P2 pulse



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DIII–D GYROTRON STATUS

Mfg/Gyrotron No.	Parameters			
	Current Status		Nominal Design	
	Power (kW)	Pulse (s)	Power (kW)	Pulse (s)
Gycom 1	750	2.0	750	2.0
Gycom 2	750	2.0	750	2.0
Gycom 3	750	2.0	750	2.0
CPI P1	550 (factory) at GA	10.0	1000	10.0
CPI P2	1000	5.0	1000	10.0
CPI P3	550 (factory) operating at GA	10.0	1000	10.0

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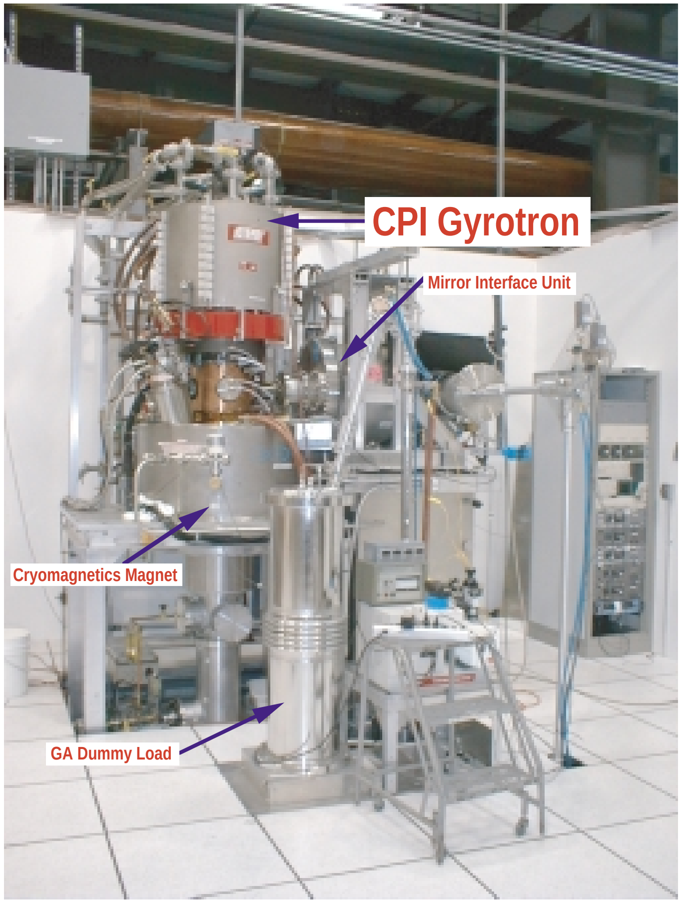
EC SYSTEM RELIABLITY HAS BECOME COMPARABLE TO THAT OF THE NEUTRAL BEAM SYSTEMS

CPI Gyrotron Installation



- New PPPL articulating launcher 1 MW 10 s

INCREMENTAL REQUEST EVOLUTION (IN PRIORITY ORDER)

	FWP 4/01	2002 Budget Set 10/01	2003 Guidance 2/02
Resistive Wall Mode 18 Coil System	Red	Green	Green
More Operating Weeks	Red: 20	Red: 14	Green: 21 !
Two Replacement Gyrotrons	Green	Red	Green
Diagnostic Initiative	Red	Red	Blue
Resume Operation of the FW System	Red	Red	Blue
ECCD Support for Systems 7 and 8	Red	Red	Red
Modernization and Refurbishments	Red	Red	Red
Ten Second Flattop at Full Field	Red	Red	Red

Green = In Base Budget Red = Incremental Blue = In Between

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INCREMENTAL REQUEST SUMMARY
(IN PRIORITY ORDER)

	FY03 ($K)	FY04 ($K)
Diagnostics	1812	2406
Resume fast wave operation	450	881
ECCD support for systems 7 and 8	—	1165
Four more operating weeks (25)	1830	1872
Increased reliability	566	415
Ten second flattop AT full field		847
	4658	7586

SUMMARY OF INCREMENTAL BUDGET REQUESTS

	FY03		FY04	
Diagnostics	**$1,812K**		**$2,406K**	
Improved Pedestal Diagnostics	GA	$449K	GA	$44K
Fast Ion Transport	GA	$194K	GA	$124K
Improved 3-D Stability Diagnostics	PPPL	$404K	GA	$183K
Fast Data Acquisition (Fluctuations)			GA	$419K
Particle Transport (Imaging)	GA	$210K	GA	$421K
Divertor CER			LLNL	$550K
Diagnostic Support	LLNL	$375K	LLNL	$475K
Post Docs	LLNL	$180K	LLNL	$190K
Resume Fast Wave Operation	**$450K**		**$881K**	
Fast Wave Support	ORNL	$450K	ORNL	$450K
Upgrade ICRF Transmitters			PPPL	$431K
EC Support Systems 7 & 8			**$1,165K**	
ECH Power Supply #3			GA	$627K
High Pressure Water Upgrade			GA	$253K
480V Substation Upgrade			GA	$237K
NB ISO Transformer Rebuild			GA	$48K
Four More Operating Weeks (25)	**$1,830K**		**$1,872K**	
Device Power	GA	$300K	GA	$300K
Operations Staff	GA	$1,205K	GA	$1,247K
Science Staff (Post Docs)	GA	$325K	GA	$325K
Increased Reliability	**$566K**		**$415K**	
New Choppers 5/Year	GA	$335K	GA	$342K
MFTF Tap Changer Rebuild	GA	$132K		
E & B Breaker Replacement	GA	$72K	GA	$73K
Meret Replacement	GA	$27K		
Ten Second Flattop At Full Field			**$847K**	
F-Coil Cable Upgrade (10 S)	GA		GA	$233K
138 kV Substation Upgrade	GA		GA	$614K
Totals	**$4,658K**		**$7,586K**	

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TURBULENCE AND TRANSPORT STUDIES ARE A CENTRAL SCIENTIFIC ISSUE TO FUSION ENERGY SCIENCES PROGRAM

- "...to fully understand micro-turbulence ... requires remote measurements of local fluctuations in density, temperature, magnetic field, and electrostatic potential...further development of diagnostic tools is needed in order to be able to make detailed comparisons with turbulence theory"

  — National Research Council, 2000

- "Temporally and spatially resolved profile measurements and new turbulence diagnostic measurements are required to accurately determine this complex transport behavior and differentiate the turbulence mechanisms responsible for the difference transport channels together with the profiles of the heating and fueling sources"

  — Integrated Program Planning Activity, 2000

NEW DIAGNOSTIC MEASUREMENTS WILL GREATLY ENHANCE SCIENTIFIC INVESTIGATION OF TURBULENCE AND TRANSPORT

— DOE Program for the development of diagnostic systems for magnetic fusion energy systems —

- **Advanced multifield, 2-D optical turbulence measurement (U. Wisconsin)**
  - Unambiguous identification of zonal flows, turbulent flux
  - Measures $\tilde{n}$, $\tilde{v}_r$, $\tilde{v}_0$ (BES)
  - Measures $\tilde{T}_i$ (CHERS)
- **Enhanced spatial resolution high-κ scattering (UCLA)**
  - Measures $\tilde{n}$, $10 \lesssim \kappa \leq 40\ cm^{-1}$, spatially localized
- **Phase contrast imaging (MIT)**
  - Measures $\tilde{n}$, $\kappa < 300\ cm^{-1}$
  - Two radial views — can be changed once/day
- **New fast ion collectors (Colorado School of Mines)**

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EXPERIMENTS PROPOSED AT 2002 RESEARCH OPPORTUNITIES FORUM THAT WOULD USE THE FW SYSTEMS IF AVAILABLE

- 7 proposed experiments required the FW systems (and therefore will not be done in the 2002 run)
- 6 proposed experiments requested the FW systems in a portion of their plan; these will be recast omitting that part of the experiment
- 28 proposals did not request the FW systems, but parts of those experiments could have been done more efficiently with these systems than without
  - Most people were aware that the FW systems would likely not be available this year, and therefore assumed this in their planning
- Applications of the FW systems in these proposals
  - Raising T_e/T_i to reactor-like values; any additional electron heating is welcome for this
  - Heating without substantial torque; any additional non-NBI heating is useful for this
  - Scaling experiments with other machines that are not necessarily NBI-dominated (C–Mod, NSTX, ET)
  - “Current-hole” experiments; could profit from central counter-CD to maintain the “hole”

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FORMING FAST WAVE PLAN

- Simplify operation and increase reliability by going to fixed, high frequency operation for electron heating and current drive
  - FMIT at 60 MHz and 2 ABB at 115 MHZ

- Guidance budget committments

	FY03	FY04
GA	1.5 FTE (scientists) for OPS	1.5 FTE (scientists) for OPS
PPPL	1 FTE (engineer) for OPS	OPS support and upgrade ABB transmitters
ORNL	3/4 FTE (engineer) for OPS	3/4 FTE (engineer) for OPS

- Unresolved and/or incremental
  - Additional 2 FTE support from ORNL or PPPL
  - FY04 incremental funds (PPPL) to purchase tetrode spares

OTHER "PRESSURE POINTS" IN BUDGET

- **LLNL support of diagnostics**

	FY03 (I)	FY04 (I)
– Onsite diagnostic engineering support	$225K	$250K
– Divertor CER (Russian/MST beam)		$550K
– Post Docs (MSE operation, BOUT interface)	$180K	$180K

- **UCSD — 1/2 person support problem**

- **UCLA**

  – Base program not funded

  – ITPA International Chair of ITB Group — Doyle

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LP

EXTENSION OF THE DIII–D PULSE LENGTH TO 10 SECONDS AT FULL FIELD IS IMPORTANT

- AT scenarios presently at 1.6 T, 1.0 MA
- Higher I_p indicated direction to avoid Alfvén modes
- Maintain moderate q for AT scenarios and avoid tearing mode, hence B_T is indicated direction
- Measured current redistribution time 2 seconds at 3 keV
- Convincing demonstrations at AT scenarios

NEED IMPROVEMENTS TO VERY MINOR SYSTEMS

PF controller improvements + more thermal capacity in

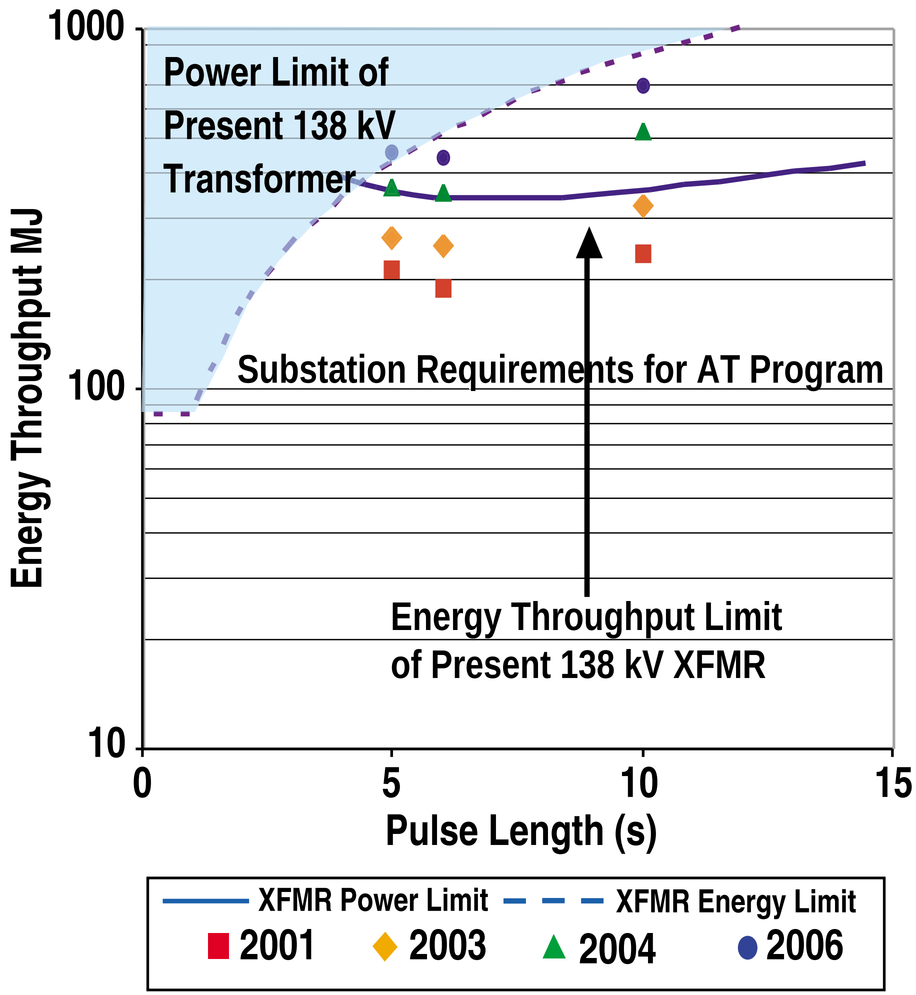
Toroidal Coil Beltbus

Toroidal Coil Freewheeling Diodes

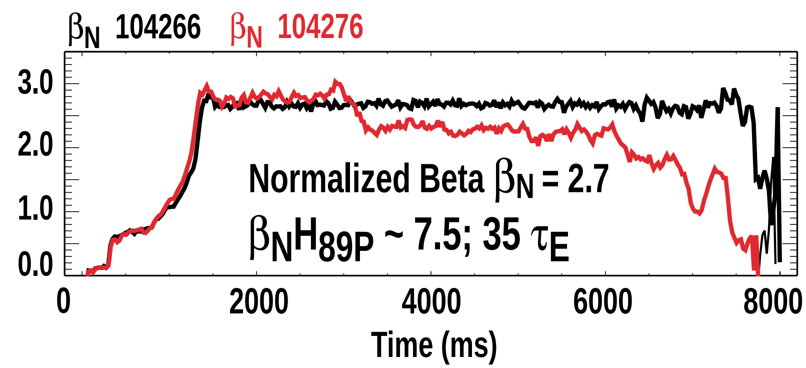
Poloidal Coil Cables

LP

138 kV SUBSTATION MUST BE EXPANDED TO SUPPORT FUTURE LONG-PULSE ADVANCED TOKAMAK NEEDS



138 kV to 12.47 kV Transformer 84 MW Peak, 350 MW Energy Throughput



Long High-Performance Discharges Trip the 138 kV Breaker

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SUMMARY

- The budget increase positions DIII–D well toward FESAC Five-Year goals
  - Wall stabilized high beta capability
  - Electron cyclotron power for tearing mode suppression
  - Advanced Tokamak physics on few τ_E time scale
  - New transport diagnostics
- More capabilities are needed toward FESAC Ten-Year goals
  - Current diffusion time scale research
    - ★ Full electron cyclotron power
    - ★ Fast wave operation
    - ★ Full field and 10-second operation
  - Major push on transport understanding leading a general advance in plasma measurement capabilities