EXPLORATORY CONCEPTS

OFFICE OF FUSION ENERGY SCIENCES

FY 2004 BUDGET PLANNING MEETING
GAITHERSBURG, MD
MARCH 12-13, 2002

PRESENTED BY
BICK HOOPER

LAWRENCE LIVERMORE NATIONAL LABORATORY

What is covered in this talk

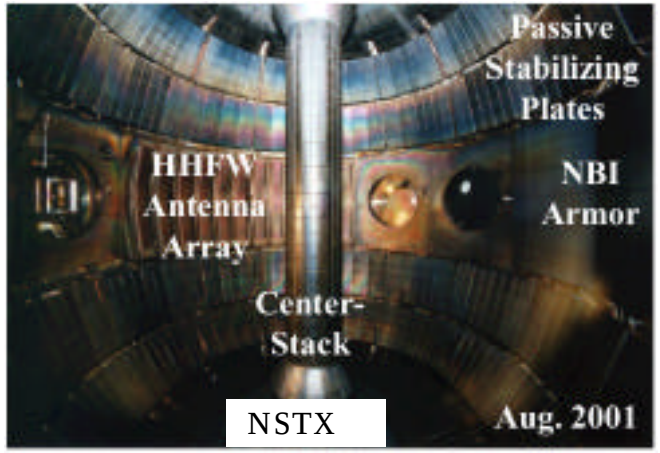
All of the EC experiments *except*

- **Those associated with the RFP (Stewart Prager)**
- **Stellarators (Jim Lyon)**

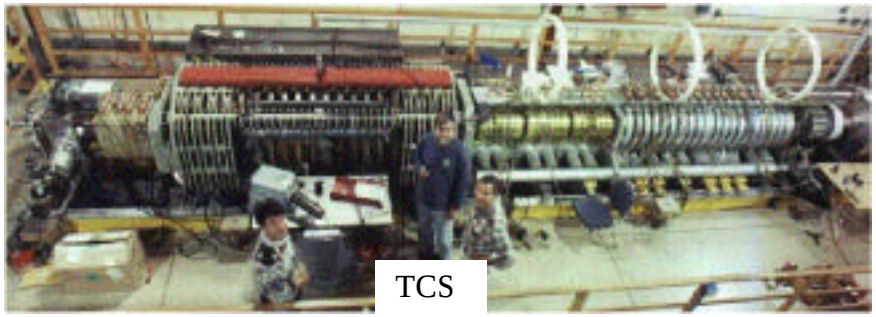
An overview of the impacts of budget reductions and increments

Individual “pages” on each experiment, providing more detail

Summary



NSTX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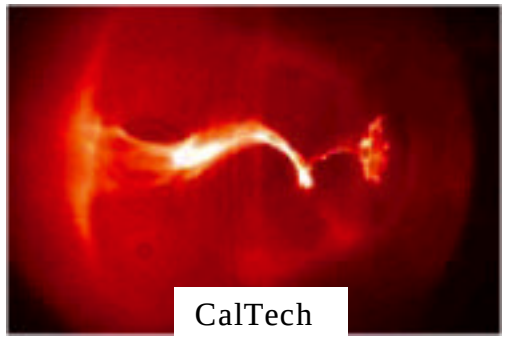
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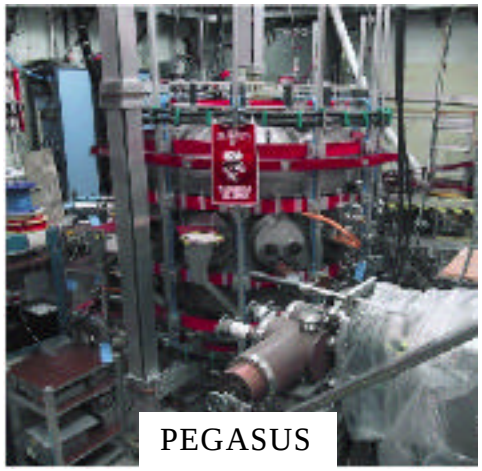
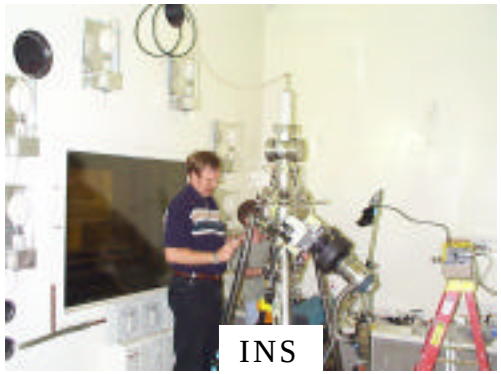

PEGASUS

ICC2002

U. Maryland, January 22-24, 2002

https://wormhole.ucllnl.org/ICC2002/

110 Registered participants
105 talks and posters
Skunkworks for "far-out" ideas
Breakout sessions for Snowmass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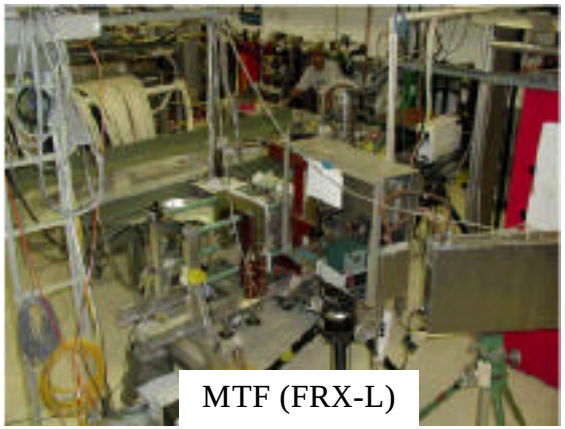
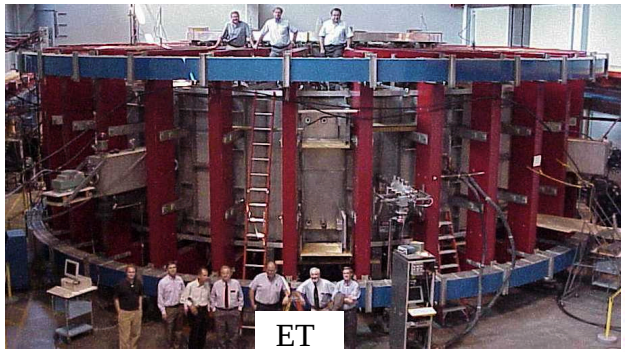
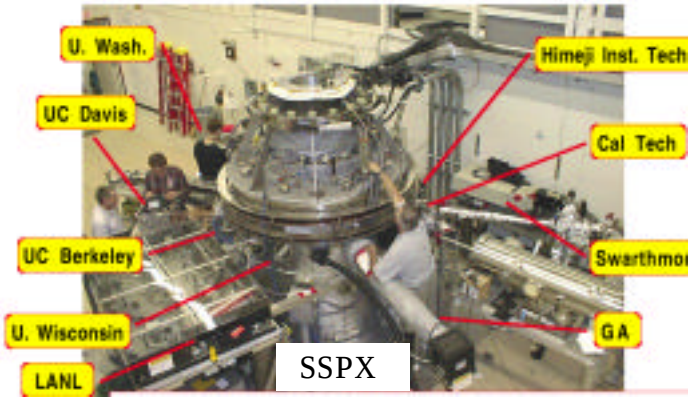

MTF (FRX-L)


ET



SSPX

ICC2002

- **Outstanding scientific work presented by the Innovative Confinement Concepts experiments**
- **“High energy” meeting of > 100 enthusiasts with many new ideas**
- **Welcome opportunity for OFES personnel to meet with the people, science, and ideas in the ICC community**

However

- **Incremental funding of existing experiments, to be discussed below, would provide significant leverage to produce scientific results**
- **There are many new and innovative ideas which are worthy of funding**

The dilemma: Balance expanded support to ongoing experiments and support of new ideas

When and how do we best determine when an experiment should be considered complete, releasing funds for other concepts?

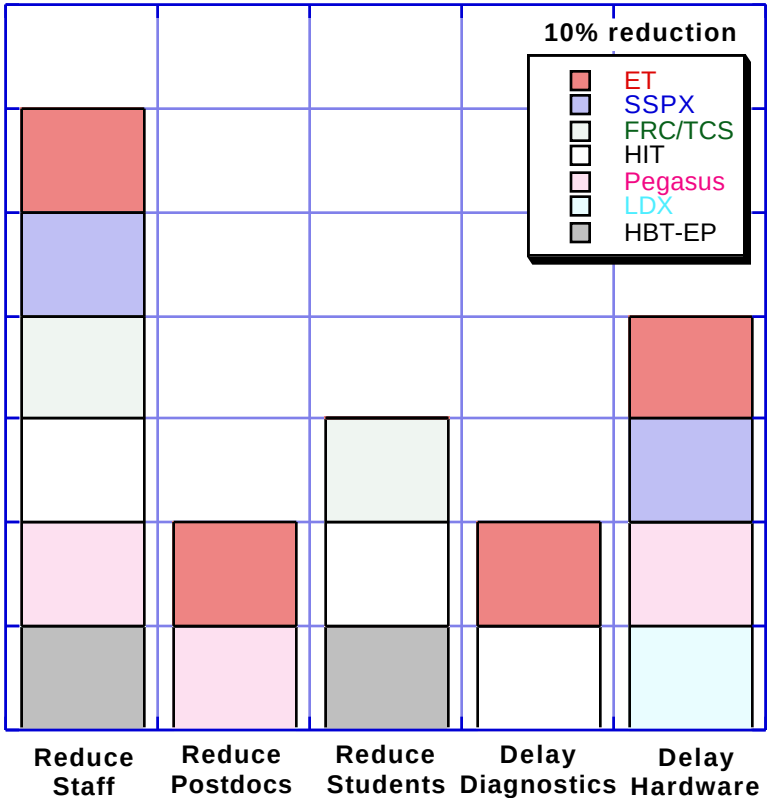
Impact of 10% reduction on several “large” EC experiments

- **Summarized are the areas in which a 10% reduction would be handled**

  See charts for individual experiments for more details for these and other ECs.

- **Smaller experiments typically will reduce operating time if cut 10%**

- **Several PIs state that facility costs are approximately fixed — thus the effect of a reduction is often in *manpower or diagnostics*, reducing scientific productivity**

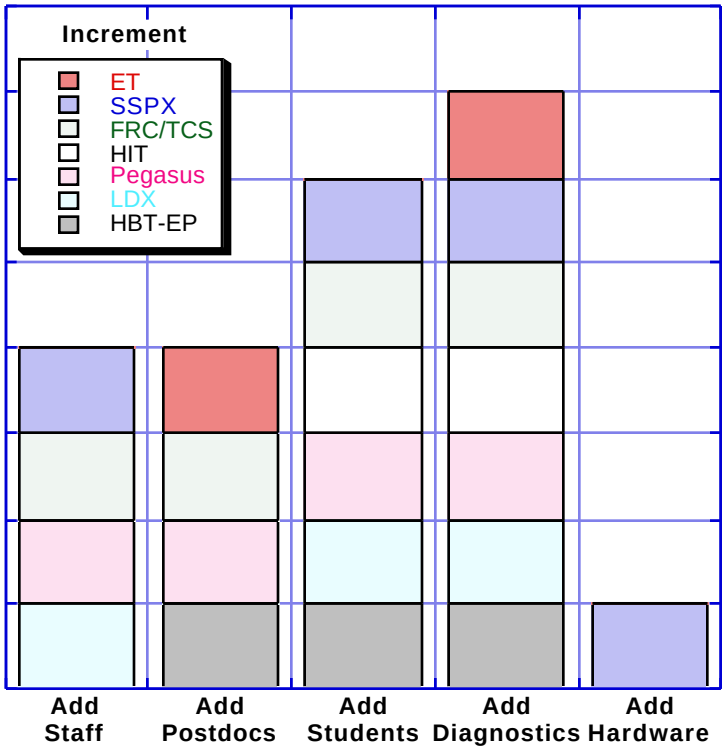


Impact of 10% - 20% increments on several “large” EC experiments

- **Summarized are the areas in which increments of 10% - 20% would be applied**

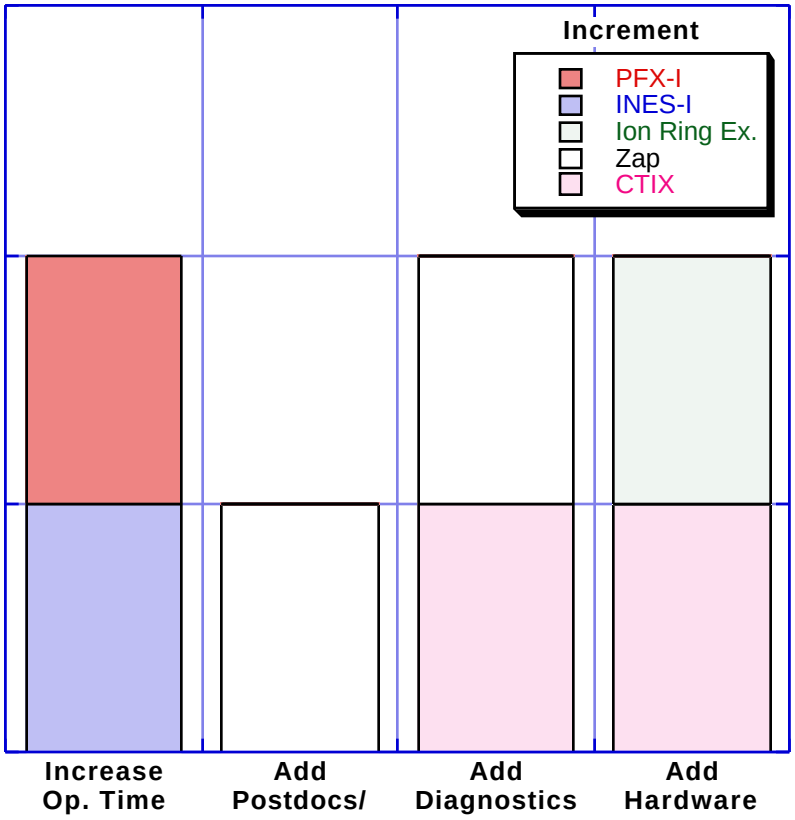
  See charts for individual experiments for more details for these and other ECs

- **Everyone needs *more diagnostics* to generate scientific data, together with personnel to analyze and interpret the data**



Impact of 10% - 20% increments on several “small” EC experiments

- **Summarized are the areas in which increments of 10% - 20% would be applied**
  See charts for individual experiments for more details for these and other ECs
- **Increments of 10% - 20% are typically not large enough to add new staff or postdocs**



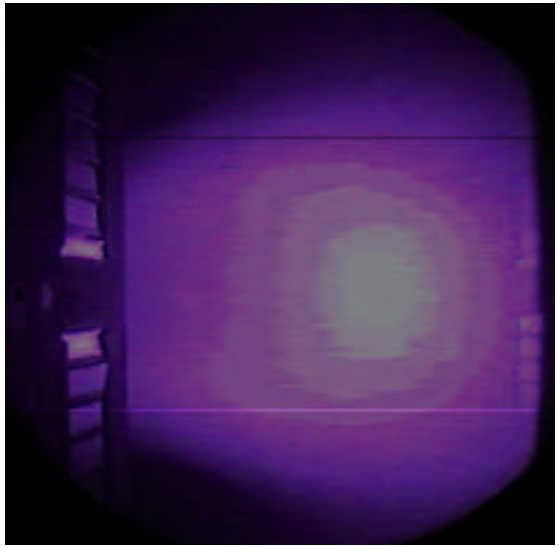
Students

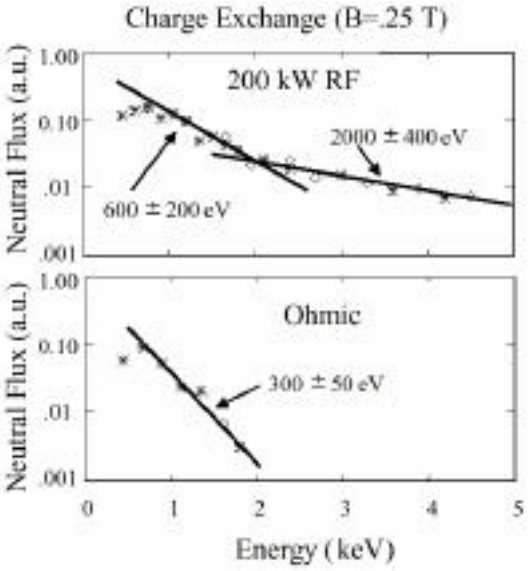
Each PI provided the number of students who worked on the experiment in the near past. (Not necessarily paid by the project.)

Postdocs	**9.5**
Graduate students	**40**
Undergraduate students	**42**

The Exploratory Concept Experiments are exciting to students and provide an outstanding introduction to science and technology

Electric Tokamak (ET)





PI: Robert Taylor, UCLA

Budget	FTE staff	– students	K$
FY02	9.5	1g/4u	1930
FY03	9.5	1pd/2g/4u	1930
FY04	9.5	1pd/2g/4u	1930

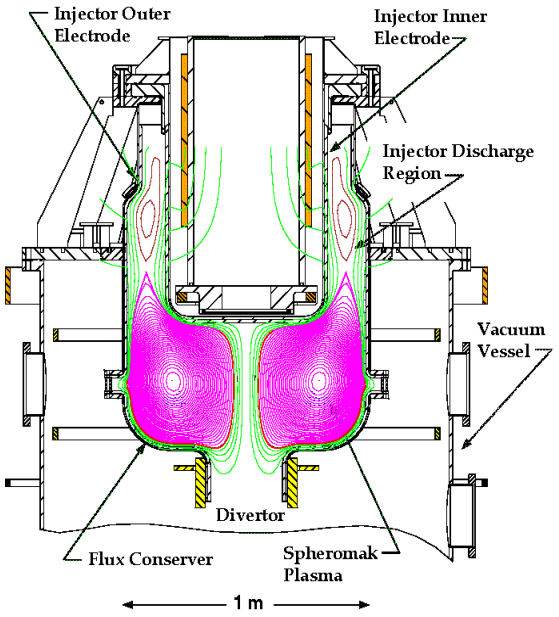
10% Reduction: FY03–No post doc, bolometry measurement and CT injection delayed; possible reduction in personnel. FY04–No post doc, soft x-ray tomography and polarimetry delayed; possible reduction in personnel.

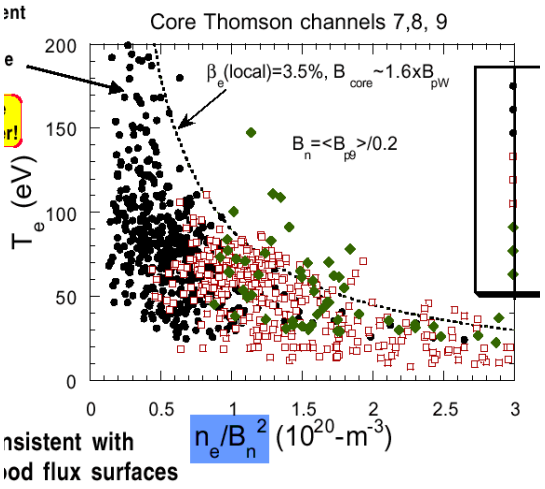
Incremental Requests (FY03) – 10% increase 200
1 or 2 post docs working on:
Integrated modeling
Installing ion beam diagnostics: plasma pot., transport, current profile measurements
RF from technology program $100K

Incremental Requests (FY04) – 10% increase 200
1 or 2 post docs to work on
RF diagnostics
Integrated modeling
VUV spectroscopy
Polarimetry

Notes:
Of the $1.93M budget, ~$1.7M goes into salaries, overhead, benefits, electricity and other fixed operating costs
Collaborators: PPPL, ORNL, Saskatchewan, UCLA, LANL, Colorado

Sustained Spheromak Physics Experiment (SSPX)





PI: David N. Hill, LLNL

Budget Year	FTE staff – students	Guidance (K$)
FY02	8.6* 1g/2u	2393
FY03	6.7 1g/0u	2462
FY04	6.7 1g/0u	2462

* includes 0.7 fte internal funding for diagnostic development

10% Reduction: Decrease manpower to 5.6 FTE + 1g/0u and reduce scope of new hardware and operations accordingly.

Incremental Requests (FY03)	+673 total
Scientific Personnel	124
Operating Personnel	275
Students	83
Injector Modifications	106
Diagnostics (Start diagnostic neutral beam)	85

Incremental Requests (FY04*)	+716 total
Scientific Personnel	138
Operating Personnel	281
Students	25
Diagnostics (Finish diagnostic neutral beam)	272

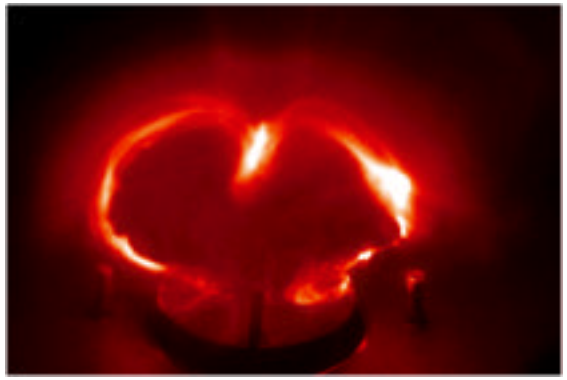
*tasks based on obtaining FY03 incremental funding

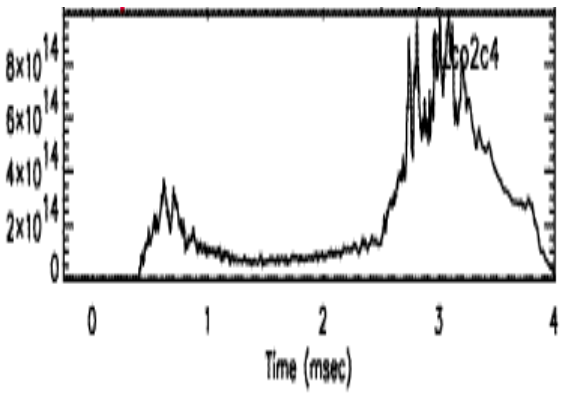
Notes:

FY02 was the first year with no LLNL funding – GSO used to retain staff (+1.5 FTE over FY02 budget steady state level).

FY02 collaborators: LANL, U. Wash, UC Davis, Caltech

Determination of Helicity Injection (CalTech)
SSPX Collaboration (LANL)





Helicity Injection — PI: Paul Bellan, CIT

Budget Year	FTE staff – students	Guidance (K$)
FY02	2pd/2g/3u	372
FY03	2pd/2g/3u	372
FY04	12pd/2g/3u	372

Notes:

Experiments are done in the laboratory at Cal Tech, and provide an interesting coupling to solar flare plasmas. In addition, a camera has been mounted on SSPX to provide information on structure in the spheromak plasma, with a grad student part-time at LLNL

SSPX Collaboration — Glen Wurden, LANL

Budget Year	FTE staff	Guidance (K$)
FY02	0.5	118
FY03	0.5	118
FY04	0.5	118

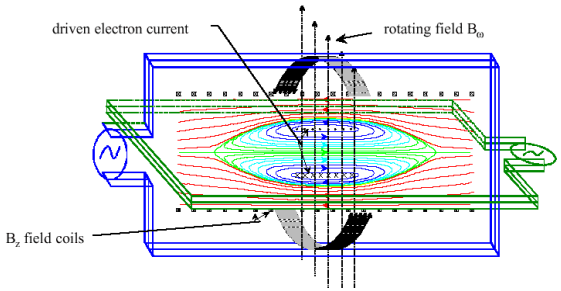
Incremental Requests (FY03, FY04)

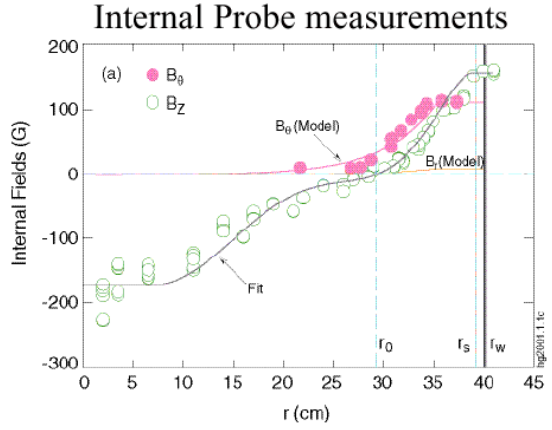
Strengthen support of SSPX	100

Notes:

LANL provided the interferometer and H-alpha diagnostics on SSPX and has conducted experiments using the H-alpha emission

Field-Reversed Configurations FRC – (LSX/mod + TCS)





PI: Alan L. Hoffman, U. Washington

Budget	FTE		K$
FY02	8.0	1pd/5g/1u	1645
FY03	8.0	1pd/5g/1u	1645
FY04	8.0	1pd/5g/1u	1680

10% Reduction: Decrease manpower to 9.5 FTE with corresponding reduction in scope

Incremental Requests (FY03)

Design of new chamber	100

Incremental Requests (FY04)

Scientific Personnel (post doc, 1 student)	120
Operating Personnel (0.5 student)	10
Diagnostics (Thomson scattering)	80
New Chamber Construction	500

Notes:

- Fixed operating costs of off-campus laboratory are a major part of the budget, increments support add. students and scientists
- Additional scientific personnel will work on the Thomson scattering diagnostic
- Students are charged as 0.5 FTE each by UW but separately listed in the table
- Grant runs to Jan. 2003
- FY02 collaborators: LANL, Swarthmore, PPPL (Belova), GA (Schaeffer), U. Washington (G. Vlases)

FRC Collaborators

Rotomak FRC/drive – Glen Wurden (LANL)

Budget Year	FTE staff – students	Guidance (K$)
FY02	0.5	180
FY03	0.5	180
FY04	0.5	180

Notes:
Supports diagnostics and the Rotomak Power Supply

Edge Physics Studies – George Vlases (U. Washington)

Budget Year	FTE staff	Guidance (K$)
FY02	0.2	69
FY03	0.2	69
FY04	0.2	69

FRC Theory — Elena V. Belova (PPPL)

FRC Theory – Elena V. Belova (PPPL)

	FTE staff	Guidance (K$)
FY02	0.5	178
FY03	0.5	178
FY04	0.5	178

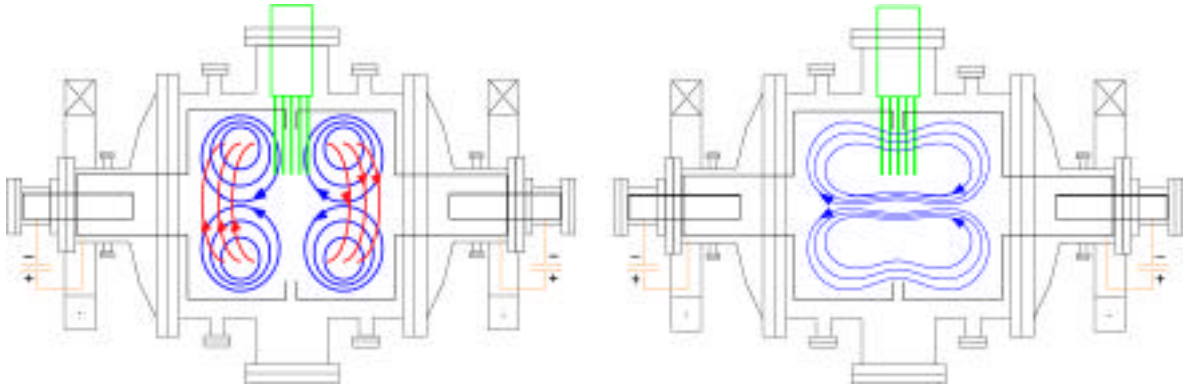
Notes:
Computational modeling studying FRC stability

FRC Rotating Magnetic Field (PPPL) – Sam Cohen (PPPL)

Budget Year	FTE staff		Guidance (K$)
FY02	0.3	4g/4u	109
FY03	0.3	4g/4u	109
FY04	0.3	4g/4u	109

Notes:
Studying effect of rotating field geometry on fieldline closure

Swarthmore Spheromak Experiment – FRC



PI: Michael Brown, Swarthmore

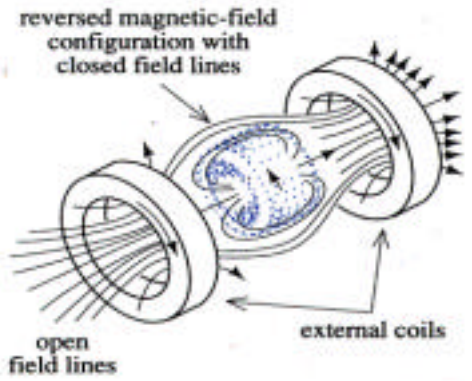
Budget	FTE (includes students)	K$
FY02	1.0	168
FY03	1.0	168
FY04	1.0	168

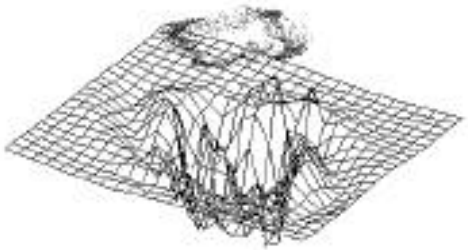
10% Reduction: Slow down scientific progress and reduce support of students

Notes:

- **Spheromaks are merged to study FRC formation**
- **Project typically supports 2-3 undergraduate students**
- **Grant runs to August 2003**
- **Collaborator: GA (Schaeffer)**

Ion Rings for Magnetic Fusion





PI: John Greenly, Cornell

Budget	FTE staff	– students	K$
FY02	3.4	1g/2u	411
FY03	3	1g/2u	411
FY04	3	1g/2u	411

10% Reduction: Work would not be completed in time to impact the next renewal proposal

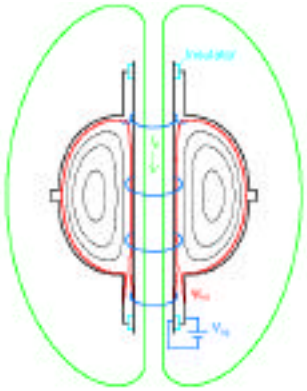
Incremental Requests (FY03)

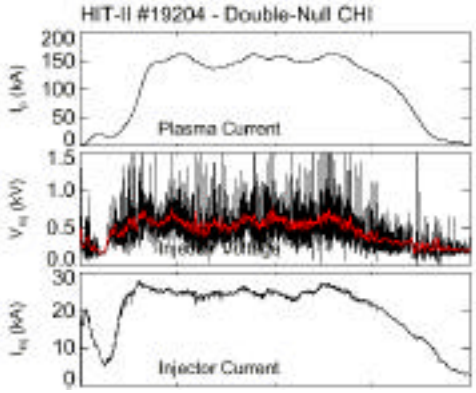
10% increase – Continue to support student without cutting staff	40
20% increase – Fabricate and bring into operation a new (demonstrated) technique for increasing ring current	80

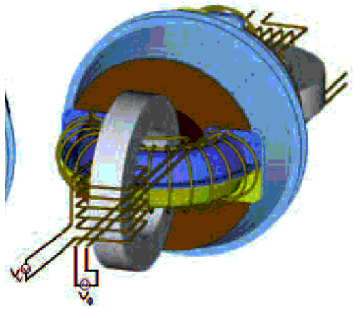
Notes:

Budget cut each of past two years, now < 85% of FY2000 funding
Grant ends January 2004

Helicity-Injected Tokamak (HIT-II) / Steady Inductive Helicity Injection (HIT-SI)







PI: Thomas R. Jarboe, U. Washington

Budget	FTE		K$
FY02	6.0	1pd/7g	908
FY03	5.5	1pd/7g	908
FY04	5.0	1pd/7g	908

10% Reduction: Lose two graduate students or one PhD scientist; progress slowed and no FIR Faraday rotation measurements

Incremental Requests (FY03 or FY04)

One student; diagnostic improvements (FIR detectors, better Thomson scattering detectors)	90
Multi-chord Faraday rotation with more detectors and manpower	180
Three-frequency FIR laser for multichord interferometry and Faraday rotation to study relaxation physics and S-scaling	270

Notes:

- Almost all costs are for manpower
- Lack of cost-of-living budget increases costs one graduate student per year or one PhD scientist every two years
- Program grant is up for renewal this year
- Proto-SI experiments start in FY02; HIT-SI in FY03 and fully operational in FY04

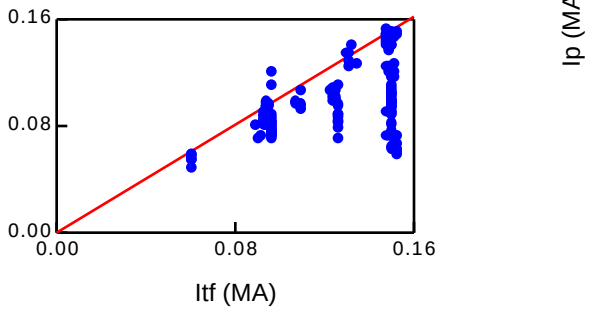
Spherical Torus – PEGASUS Toroidal Experiment

Exploring Tokamak-Spheromak Transition Region

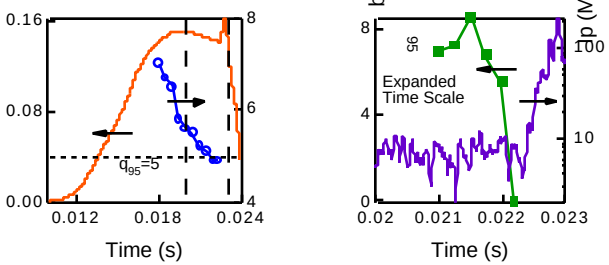
- Extensive internal diagnostics

- New PFC's
- HHFW and EBW antennae

- A=1.1-1.3, R=0.25-0.45 m, I_p=0.1-0.3 MA,B_t≤0.07 T



- Large internal n=1 modes lead to a "soft limit" in achievable plasma current



- External kink limits are raised for low l_i, low A plasmas

PI: Raymond J. Fonck, U. Wisconsin

Budget	FTE		$K - equip	$K tota
FY02 base	10.1	0.5pd/6g/10u	57	873
FY03 level	9.3	0.5pd/6g/10u	107	873
FY03 – 10%	9.3		12	786
FY04 level	9.3	0.5pd/6g/10u	85	873
FY04 – 10%	8.3		15	786

FY03 - 10%: Cut post-doc, shared tech, + equipt.
FY04 - 10%: Cut post-doc, shared tech, 3-4 undergrads, + equipt.

Incremental Requests (FY03)	$K
Radial Position PS + control system (est)	70
Retain 1/2 post-doc, shared tech	70
Second Scientist	100
Short-pulse DNB	100

Incremental Requests (FY04)	
Recover 1/2 post-doc, shared tech	70
Second scientist	100
DNB pulse extension	100
Thomson scattering components + post-doc	170
200-400 KW EBW system + post-doc (est)	150

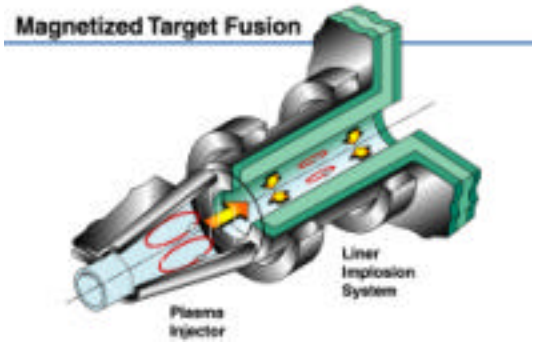
Notes:

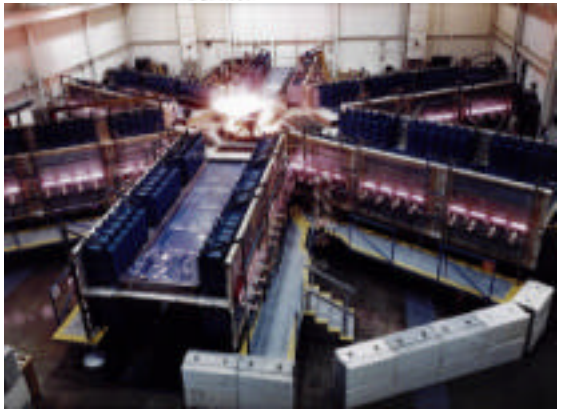
Each year: personnel, overhead, travel, + $72K operating costs.
Inflation effectively eliminates capital equipment.

Grad student = 0.5 FTE each (total = 4 -6)
Undergrad = 0.33 FTE each (total = 8 – 12)

Pos=Ext Kink Stable

Magnetized Target Fusion (MTF)





PI: Richard Siemon

Budget		FTE		K$
FY02	LANL	4.9	2pd/2g/4u	1304
FY03	LANL	5.0	2pd/2g/4u	1446
FY04	LANL	5.0	2pd/2g/4u	1446
Other labs – all years				
	AFRC	3.4		500
	LLNL	0.1		40
	GA	0.1		25

10% Reduction: Reduce number of summer students. Reduce FTE by 0.8. Slower pace

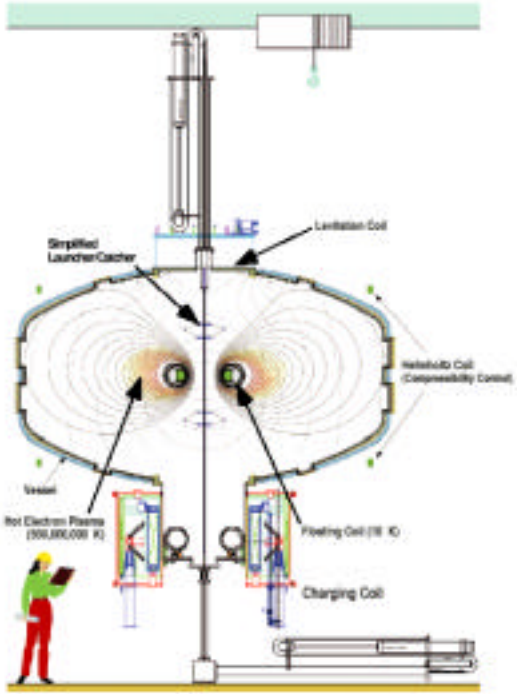
Incremental Requests – 10%

Restore funding at LLNL to $75K. Move faster on FRX-L diagnostics **200**

Notes:

- **New LANL experiment, FRX-L, operated by LANL and AFRC**
- **Stability of elongated FRC (studied in FRX-L) may be explained by D. Barnes**
- **Transport theory by D. Ryutov is encouraging for collisional high-beta regime of MTF**
- **MTF review scheduled for spring, 2003**

Levitated Dipole Experiment



A partnership of innovative plasma science with magnet technology experts: Can we achieve classical confinement at high beta?

Three SC magnets: Nb_3Sn, 1.3 MA, Floating Coil; NbTi, 4.2 MA, Charging Coil; and Bi-2223, 0.23 MA, Levitation Coil (Fusion's first high-T_C coil)
Industrial Partners: Everson Electric, Ability Engineering, American Superconductor, IGC-Advnced SC
Laboratory Partners: LBNL, BNL, PPPL, and SINTEZ (St. Petersburg, Russia)
Refereed Publications (Since 1999): 12 theory papers from community; 4 magnet tech/design papers

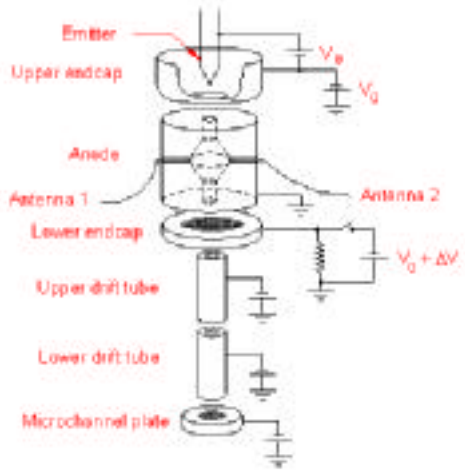
Research Plan

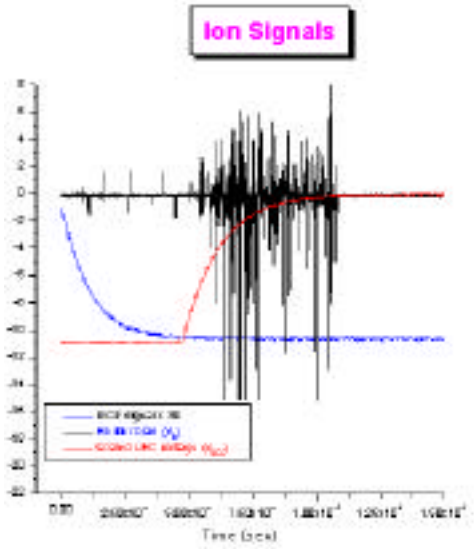
FY02: Complete fabrication of superconducting magnets
FY03: Establish reliable operation of coil systems
Initiate plasma experiments; Begin scientific studies of:
— MHD stability and Electrostatic circulation
— Pressure profile effects and pressure limits.
FY04: Study confinement at high temperature and beta;
Profile control, direct tests of compressibility, and measurement of particle and energy confinement.

Base: $ 1.5 M **Impacts**

	FTE (Sci/Eng)	FTE (Tech)	Students	Ops/Diagnostics	+10%	-10%
FY02	4	2	3	Coil Completion; System Integration		
FY03	4 (+1 Visitor)	2	4	Base Diagnostics; Profile control w/ECRH	Install advanced Diagnost. Start Profile Control	Limited Diagnostics
FY04	5	2	5	Advanced Diagnostics; Edge Control	Install Ion 100 kW Heating; Explore higher density	Limited Diagnostics; Reduced Control Tools

Penning Fusion eXperiment – Ions (PFX-I)





PI: Martin M. Schauer, LANL

Budget	FTE	K$
FY02	1.5	425
FY03	1.5	425
FY04	1.5	450

10% Reduction: Slow progress; delay looking for POPS mode to FY05

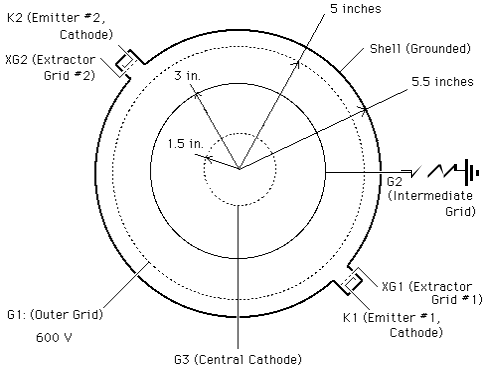
Incremental Requests (FY04)

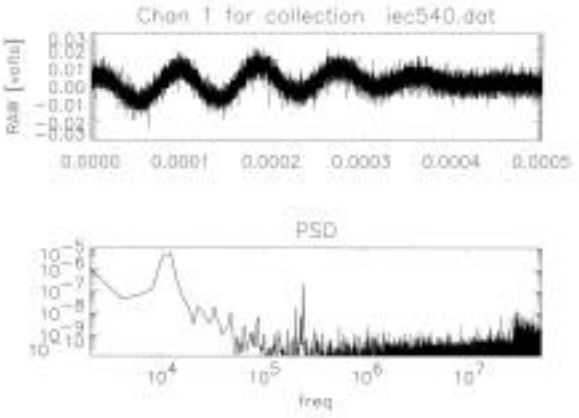
5% increase requested to cover inflation	25
Studies of POPS mode	40

Notes:

Support includes 0.5 FTE of theory (D. Barnes)

Inertial Electrostatic Confinement (INES-E)





PI: R. A. Nebel, LANL

Budget	FTE	K$
FY02	1.0	278
FY03	1.0	296
FY04	1.0	300

10% Reduction: Reduced operating time on experiment

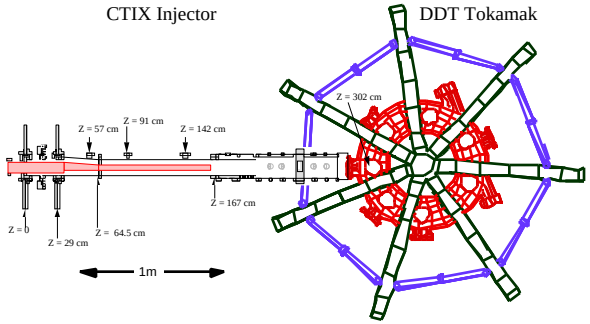
Incremental Requests (FY03 or FY04)

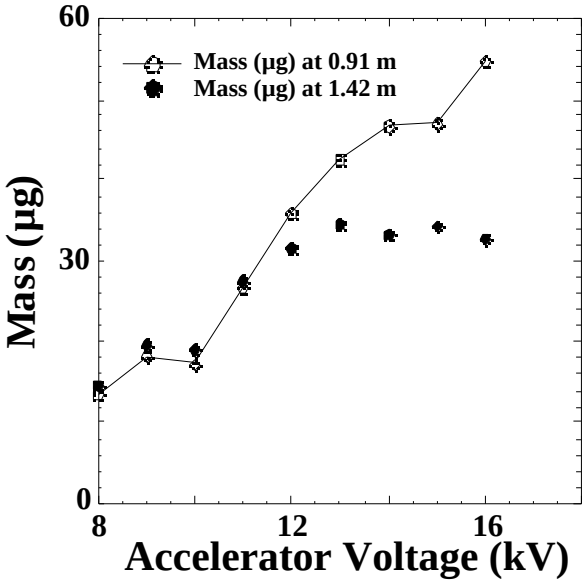
Replace previous reductions in operating time on experiment (22k reduction in fY02)	30
Complete POPs tests by end of FY03	60
Operate experiment full time, allowing full utilization of the facility	300

Notes:

- **Almost all costs are for manpower. Two people are required to operate the experiment safely**

Compact Toroid Injection Experiment (CTIX)





PI: David Hwang (UC Davis)

Budget	FTE		K$
FY02	2	2g	238
FY03	1	2g	150

10% Reduction: Cannot modify electrodes or install more efficient gas valves. Cannot complete high-current switches for polarity variation

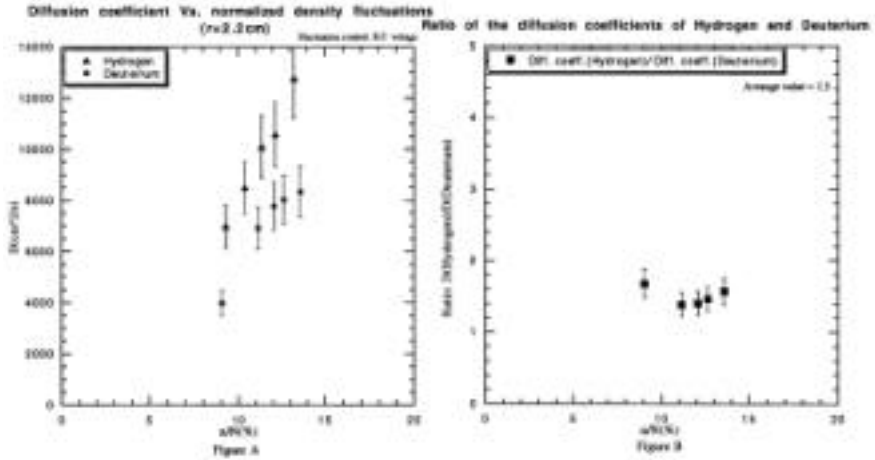
Incremental Requests (FY03)

Replace old HeNe lasers in interferometers	4
Machine shop time for better valve construction	3
Fast, high-power pulse generator	3

BASIC PHYSICS OF TOKAMAK TRANSPORT AND FEEDBACK CONTROL
(COLUMBIA LINEAR MACHINE)

P.I. Amiya K. Sen, Columbia University

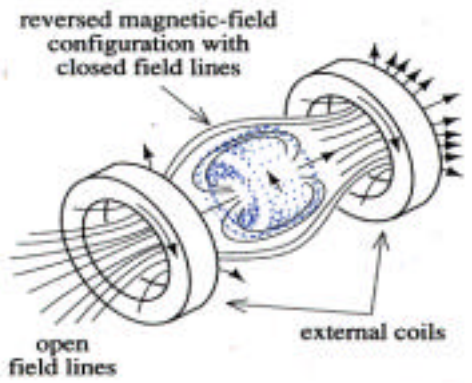
Grant NO: DE-FG02-98ER54464, Period: Jan'01 – Jan'04

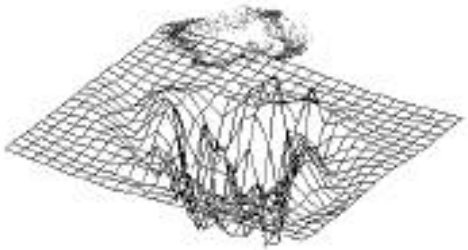


Year	2002	2003	2004
Budget	$250,000	$250,000	$250,000
Manpower	1 Faculty, 1 Post.Doc 1 Grad Student, 1 UG Student	1 Faculty, 1 Post.Doc 1 Grad Student, 1 UG Student	1 Faculty, 1 Post.Doc 1 Grad Student, 1 UG Student
Brief Plans	Conclusion of experimental study of a hybrid ITG-KH instability. Experimental study of isotope scaling of particle transport. Optimal control of multi-mode instabilities.	Experimental study of isotope scaling of thermal transport. Begin neural network control for plasma instabilities. Install new magnet coils for expansion of gyro-radius scan.	Experimental search for physics basis of isotope scaling. Bohm / gyro-Bohm scaling studies to complement the isotope scaling. Continue neural network research towards adaptive learning control.

Collaborators: (1) Dr. K. Avinash, IPR, India; (2) Dr. Ben Kadda *et al*, Univ. of Marseilles, France; (3) Prof. Scott Parker, Univ. of Colorado; (4) Prof. Wendell Horton, Univ. of Texas, Austin

Ion Rings for Magnetic Fusion





PI: John Greenly, Cornell

Budget	FTE staff	– students	K$
FY02	3.4	1g/2u	411
FY03	3	1g/2u	411
FY04	3	1g/2u	411

10% Reduction: Work would not be completed in time to impact the next renewal proposal

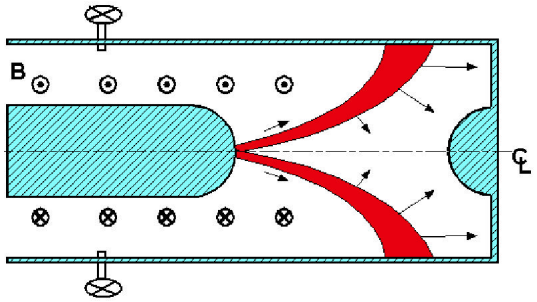
Incremental Requests (FY03)

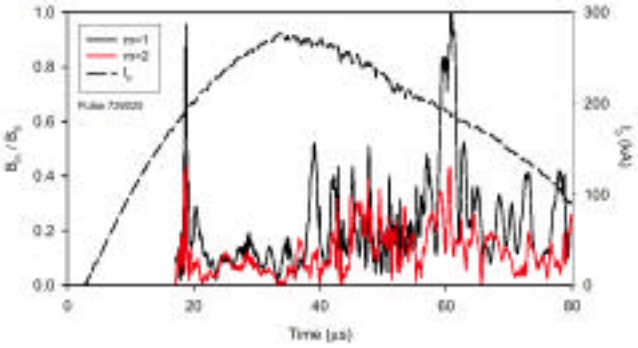
10% increase – Continue to support student without cutting staff	40
20% increase – Fabricate and bring into operation a new (demonstrated) technique for increasing ring current	80

Notes:

Budget cut to 80% of FY2000 funding
Grant ends January 2004

Flow Z-Pinch (ZaP)





PI: Uri Shumlak, U. Washington

Budget	FTE staff	– students	K$
FY02	0.7	2g/5u	288
FY03	0.7	2g/5u	288
FY04	0.7	2g/5u	288

10% Reduction: Reduce number of graduate students to one. Eliminate diagnostics that require substantial data analysis (deconvolution of plasma profile information)

Incremental Requests

Add postdoc (or graduate students) to build, install, and field Thomson scattering diag. (single point)	100
Larger vacuum system	70

Notes:

A multi-point Thomson scattering system would allow determination of equilibrium profiles through force balance. The cost would be ≈ $200K + postdoc.

Maryland Centrifugal Experiment (MCX)

Under construction

- **Magnet coils installed, braced, and aligned**
- **Magnet test complete (B_{max} = 1.8T, Mirror ratio ~ 9)**
- **Vacuum vessel installed, aligned, pumped down**

First plasma by Snowmass, 2002

PI: Adil Hassam, Rick Ellis, U. Maryland

Budget	FTE staff	– students	K$
FY02	3.3	2pd/2g/2u	386
FY03	3.3	2pd/2g/2u	386
FY04	3.3	2pd/2g/2u	386

10% Reduction: Reduce 1 graduate student, decrease faculty time by 1 month

Incremental Requests – 10% increase **40**
Hire 1/2-time technician
Expedite experimental plan

Notes:
New experiment; no data as yet

Summary

- **The Exploratory Concept Program is generally healthy — there are many exciting experiments which are starting to produce results**
- **There is a strong coupling with the education of students in the full range from undergraduate to post doctorate**
- **Facilities are in place which provide outstanding opportunities for world-class science**

However:

- **Resources are very tight, limiting diagnostics as well as staff and students to operate, take data, and analyze the data from the experiments**
- **We have also generally underestimated the length of time for an experiment to bear fruit; for a significant undertaking it is typically between 5 and 10 years**
- **Theory support, not discussed here, is very important and needs strengthening**

Thus:

- **Additional resources will have considerable scientific leverage, building on the infrastructure and programs now in place**
- **Balancing improved support while providing opportunities for new ideas will be a significant challenge for OFES and the fusion community**