24 September 2004

To: Paul Philp
DOE Project Manager, Run IIb CDF Detector Project

From: Pat Lukens
Project Manager for the Run IIb CDF Detector Project

Subject: Run IIb CDF Detector Project August 2004 Report

Attached is the monthly report summarizing the August 2004 activities and progress for the Fermilab RunIIb CDF Detector Project. This report is available electronically at:

http://www-cdf.fnal.gov/run2b.html

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RunIIb CDF Detector Project
Progress Report No. 21
1 - 31 August 2004

I. PROJECT DESCRIPTION

The primary goal of the CDF Run IIb Detector Project is to enable the detector to exploit the physics opportunities available during Tevatron operation through 2008. The data from Run II will represent a set of detailed measurements that can be compared with the predictions of the Standard Model at the highest available collision energy. The increased size of the data sample will allow us to study the top quark by measuring the details of its production and decay mechanism. In addition, we plan precision electroweak and QCD measurements, continued searches for a variety of phenomena that are predicted to exist beyond the Standard Model framework, and to explore CP violation in the *b* quark sector. The detailed physics goals of the upgrade are described in the Technical Design Report (TDR).

The major tasks of this upgrade are:

- Upgrade the calorimeter by replacing the Central Preradiator Chamber with a device with shorter response time to allow operation in a high-luminosity environment, and adding timing information to the electromagnetic calorimeters.
- Upgrade the data acquisition and trigger systems to increase throughput needed for higher luminosity operation and efficiently trigger on the higher multiplicity events of Run IIb.

II. OVERVIEW OF PROJECT STATUS – P. Lukens

The Director's review of the project held on 20-21 July 2004 was a success. The draft report recommended that the laboratory approve the scope changes that were proposed, and this has happened. Beginning with this month's report, project status will be reported against the new baseline schedule that has been developed with for the project. Recommendations from the review committee were fairly straightforward and do not require any significant change in the way the project is conducted. Our formal response to the recommendations was presented at the Project Management Group meeting on 10 Sep.

Although not strictly within the scope of the project, the installation of a major project component, the calorimeter preshower upgrade, is now in progress. This installation will continue until the end of the current accelerator shutdown. Good progress has been made so far. Six wedges (of 48) now have new detector modules installed, and the procedure for installation appears to work well. We do not anticipate that this installation will impact accelerator operations.

III. PROJECT MILESTONE SUMMARY (as of 31 August 2004)

CDF Data Acquisition Level 1 and Level 2 Milestones
Sorted by Baseline Completion Date

WBS	Title	Baseline Comp. Date	Forecast/Actual Completion Date	Complete
1.3.2.6.3	Begin production of Level 2 Pulsar system	12 Nov 03	12 Nov 03	Yes
1.3.1.6.6	First Prototype TDC available for testing	19-Nov-03	16-Feb-04	Yes
1.3.4.4.1.4	Prototype Event Builder hardware arrives	3-Jun-04	31 Mar 04	Yes
1.3.6.1.1.7	Begin AMS Design Work	1-Sept-04	2-Aug-04	Yes
1.3.6.1.3.7	Begin Track Fitter Design	1-Sept-04	2-Aug-04	Yes
1.3.4.5.3	Production Readiness Rev - Event Builder	4-Oct-04	2-Jun-04	Yes
1.3.4.5.4.4	Arrival of the Event Builder hardware	15-Oct-04	15-Oct-04	
1.3.11.8.5.5	Begin Purchase of Pulsar Board components	20-Oct-04	20-Oct-04	
1.3.11.5.3.8	Begin Production TDC Mezzanine Card	28-Oct-04	28-Oct-04	
1.3.6.2.6.4	Begin Ampchip Production	10-Jan-05	3-Dec-04	
1.3.1.12	Beginning of TDC Production	11-Jan-05	11-Jan-05	
1.3.6.2.1.1.5	Begin AMS Mezzanine Card Production	14-Jan-05	13-Dec-04	
1.3.11.6.3.6	Installation of TDC to Finder cables Complete	18-Mar-05	31-Jan-05	
1.3.5.3.7	Arrival of 15 PCs from the vendor	23-Mar-05	23-Mar-05	
1.3.2.9	Pulsar Level 2 subproject ready for installation	1-Apr-05	1-Apr-05	
1.3.11.8.8	Begin Joint Testing with Finder Board	4-Apr-05	4-Apr-05	
1.3.11.7.5.8	Begin Production of SLAM Boards	18-Apr-05	18-Apr-05	
1.3.11.4.4.8	Begin Production TDC Fiber Transition Boards	21-Apr-05	21-Apr-05	
1.3.1.17.4	TDC Readout System Complete	6-Jun-05	6-Jun-05	
1.3.11.5.3.9	Checkout of TDC Mezzanine Cards Complete	6-Jun-05	6-Jun-05	
1.3.11.2.5.1	Begin Production XFT Finder Boards	8-Jun-05	8-Jun-05	
1.3.6.1.2.5	Hit Buffer Firmware Complete	23-Jun-05	23-Jun-05	
1.3.6.1.3.5	Track Fitter Firmware Complete	28-Jun-05	31-Mar-05	
1.3.1.13.7.10	TDC's (to populate entire COT) ready to install	27-Jul-05	27-Jul-05	
1.3.4.8	Finish Event-Builder Upgrade	28-July-05	28-July-05	
1.3.5.5.5	Arrival of 70 Level3 and 15 DAQ PCs	15-Aug-05	15-Aug-05	
1.3.5.6.5	Arrival of 140/20 PCs from the vendor	15-Aug-05	15-Aug-05	
1.3.6.1.1.5	AMS Firmware Complete	19-Aug-05	28-Feb-05	
1.3.6.3	SVT ready for installation	25-Aug-05	26-July-05	
1.3.5.8	Finish Purchase of Computers for L3 DAQ system	6-Sept-05	6-Sept-05	
1.3.11.4.4.9	Checkout of TDC Transition Boards Complete	16-Sept-05	16-Sept-05	
1.3.11.7.5.9	Checkout of SLAM Boards Complete	28-Sept-05	28-Sept-05	
1.3.11.2.5.10	Finder Board Checkout Complete	29-Sept-05	29-Sept-05	
1.3.11.10	XFT Ready for Installation at CDF	29-Sep-05	29-Sep-05	
1.3.1.13.10	TDC Production Board testing complete	30-Sep-05	30-Sep-05	
1.3.1.16	Run 2b TDC Ready for Installation	30-Sep-05	30-Sep-05	
1.3.8	Finish Run 2b Trigger DAQ project	30-Sep-05	30-Sep-05	
1.3.9	DAQ and Trigger Upgrades Ready for Installation	17-Jan-06	30-Sep-05	

CDF Calorimeter Level 1 and Level 2 Milestones
Sorted by Baseline Completion Date

WBS	Milestone	Baseline Completion Date	Forecast/Actual Completion Date	Complete
1.2.1.10.1	First phototube order placed	9-May-03	1-Apr-03	Yes
1.2.2.2.7.1	Prototype testing complete	16-May-03	28-Mar-03	Yes
1.2.2.2.7.4	ASD->TDC Cables ready for installation	16-May-03	26-Aug-03	Yes
1.2.2.2.7.2	CEM Splitters ready for installation	19-May-03	29-Jul-03	Yes
1.2.2.2.7.3	PEM Harnesses ready for installation	2-Sep-03	28-Apr-03	Yes
1.2.2.2.7.5	All EMT cables done and ready to install	2-Sep-03	26-Aug-03	Yes
1.2.2.2.7.8	VME Crate ready for installation	7-Oct-03	30-Apr-03	Yes
1.2.2.2.7.10	Upstairs components ready to install	7-Jan-04	16-Oct-03	Yes
1.2.2.2.7.11	All EM Timing components ready to install	7-Jan-04	16-Oct-03	Yes
1.2.2.2.7.6	ASD/TB ready for installation	7-Jan-04	16-Oct-03	Yes
1.2.2.2.7.7	Downstairs components ready to install	7-Jan-04	16-Oct-03	Yes
1.2.2.2.7.9	TDC boards ready for installation	7-Jan-04	16-Oct-03	Yes
1.2.1.10.3	First set of Calorimeter phototubes tested	30-Jan-04	20-Oct-03	Yes
1.2.1.10.2	1st Calorimeter WLS fiber holder finished	1-Apr-04	17-Feb-04	Yes
1.2.1.10.4	1st CPR module finished and tested	4-Jun-04	15-Mar-04	Yes
1.2.1.10.6	1st CCR module finished and tested	19-Jul-04	2-Mar-04	Yes
1.2.1.10.5	2nd set of Calorimeter phototubes tested	6-Aug-04	26-Mar-04	Yes
1.2.1.10.7	50% Calorimeter CPR Detectors Tested	14-Jan-05	30 June 04	Yes
1.2.1.10.8	50% Calorimeter CCR Detectors tested	14-Feb-05	25 Aug 04	Yes
1.2.1.10.9	Final Calorimeter CPR Detector Tested	15-Apr-05	25 Aug 04	Yes
1.2.1.10.10	Final Calorimeter CCR Detector Tested	15-Apr-05	15-Apr-05	
1.2.1.10.11	Final set of Calorimeter phototubes tested	6-May-05	6-June-04	Yes
1.2.1.10.12	End of Central Pre-shower Project	6-May-05	6-May-05	
1.2.3.5	End of Calorimeter Project: Level 2	6-May-05	6-May-05	
1.2.3.6	End of Calorimeter Project: Level 1	23-Jan-06	6-May-05	

IV. PROCUREMENT – P. Lukens

No significant procurements were placed during August 2004.

V. PROJECT HIGHLIGHTS

1.2 – Calorimeter

1.2.1 Central Preshower and Crack Detector – Steve Kuhlmann

The Central Preshower/Crack Upgrade approached completion in the month of August. All of the preshower modules necessary for installation have been assembled and tested at ANL and we are now in the process of producing spares. Production of Crack modules is 84% complete with 40 out of the required 48 modules assembled. Production of transition cards and cables is 100% complete. Optical cable production at MSU began early in August and is

approximately 25% complete. Installation began August 23, as part of the planned shutdown, and is progressing very well.

The table below shows the current production status of the CPR and CCR components:

Component	Produced	Total needed	Complete
Preshower tiles	2592	2592	100%
Preshower spliced fibers	2592	2592	100 %
Preshower fiber pigtails	192	192	100 %
Preshower modules	48	48	100 %
Crack tiles	480	480	100 %
Crack spliced fibers	480	480	100 %
Crack pigtails	48	48	100 %
Crack modules	40	48	84 %
Preshower & Crack clear fiber cables	48	192	25 %
Transition cards	96	96	100 %
PMT boxes	40	48	84 %

1.2.2 Electromagnetic Timing – Dave Toback

All EM Timing work has been completed. The components installed last year are fully functional and have established an extremely satisfactory operating history.

1.3 – Data Acquisition and Trigger

1.3.1 TDC (Time to Digital Converter) – Henry Frisch, Ting Miao

We have redesigned the card to handle 64 bit CBLT transfers to speed data acquisition time. The latest estimate is a reduction in collection time of 40% from about 500usec to, roughly, 280 usec. We are now attempting to increase the maximum number of hits to 7 instead of 4. The increased data volume will use some of the time gained by the previously quoted change. We are also redesigning the XFT seed interface to meet the new requests. We expect to require 2 different designs, one for two time bins for the existing XFT portion and a second design for the 6-seed stereo new portion. Initial designs seem to work but we are having trouble fitting these to the chips and maintaining the required timing. We will attack this problem by trading off longer logic paths for more clock cycles to achieve the required speed.

1.3.2 Level 2 – Ted Liu

The CDF Level 2 Trigger system continues to make progress on the following fronts:

- Pulsar hardware, firmware and VME software,
- PCI and CPU performance studies, and
- S-LINK data format definition for all data paths.

The table below shows the current production status of the Level 2 components:

Component	Produced	Total needed	Complete
Pulsar boards	30	30	100 %
S-Link LSC/LDC cards	20	20	100 %
S-Link PCI cards	6	6 (Ops) + 6 (Spares)	50 %
S-Link fibers	30	30	100 %
AUX cards	20	20	100 %
Hotlink mezzanine cards	20	20	100 %
Taxi mezzanine cards	30	30	100 %
Hotlink/Taxi fibers	120	120	100 %
Fiber splitters	60	60	100 %
L2 decision CPUs	4	6	67 %

The initial full-system integration and beam testing has been completed and was very successful. We have used the new Level 2 to drive the system with beam with a simplified trigger table. We have compared the decisions made with the existing system and the new system and have seen a perfect match. We have also measured the system timing at various stages and identified areas where we can make performance improvements.

At this point in time, all hardware has been installed. An Installation Readiness Review has been scheduled for September 27, 2004 and will review the remaining items necessary for final system commissioning and operation.

1.3.11 XFT (eXtremely Fast Tracker) II – Richard Hughes, Brian Winer

The preproduction of the XTC-II, the hit finder for the stereo layers, has been tested and found to be stable within a nanosecond. The stereo finder boards are still undergoing schematic capture. The SLAM board schematics are complete and layout has begun. A review of the SLAM board design is scheduled for late in September. If the design is accepted, the board will be sent out for preproduction fabrication.

Sept – Stereo finder board schematics are finished and they are undergoing review. SLAM board layout neqrting completion and a review of the SLAM board was held on the 24 September in preparation for sending it out to be built (preproduction). No major problem areas were discovered and the review committee suggested minor improvements to the design. Going out in October.

1.3.4 Event Builder – Bruce Knuteson

We have received 16 of the 20 VMIC 7805 boards that have been ordered. We expect that the remaining 4 boards should arrive shortly.

Code development for the operation of the Scanner CPUs and the Event Builder Proxy has continued. We have successfully interfaced to the Hardware Database and to Run Control, using Smartsockets for the latter. We expect to be able to conduct initial tests of the SCPU and Proxy code in the real CDF DAQ system during the month of September.

1.3.6 SVT (Silicon Vertex Tracker) – Mel Shochet

AM++:
Each of the three prototype boards was assembled: the AM++ VME board, the Lamb board, and the AMchip test board. Some problems were found in fabrication, which were worked around. These will be fixed when the next boards are produced. Test stands were set up for both the standard cell chip and the LAMB. Testing commenced.

AMS/RW:
Firmware design began so that data can be fed from a Pulsar into the AM++ boards. The functionality was first partitioned among the three FPGAs. Then the needed software development tools were obtained. The "glue" and much of dataio2 firmware was written. Simulation of this code has begun.

Hit Buffer:
The distribution of functionality among the FPGAs was revisited, and it was found that the control FPGA and one of the IO FPGAs will suffice. A note with the revised Hit Buffer specifications is in preparation, and initial firmware and software simulation has begun.

Track Fitter:
The new firmware was largely completed, with both types of FPGAs fully compiled for the first time. This enabled us to determine how much memory is available for the spy buffers and FIFO in the control chip, as well as a confirmation that three fitters can fit inside one FPGA.

Pulsar Mezzanine Cards:
The requirements of all three Pulsar varieties were reviewed. We found that the simplest solution is to build two types of mezzanine cards, each a single-width board. Timing simulations started using the selected chips and the Pulsar line lengths and terminations.

VI. FINANCIAL STATUS (as of 31 August 2004)

The baseline cost of the Project is $10,375K, and consists of the costs for the scope of the Run IIb Project ($8,702K) plus the closeout costs of the silicon detector upgrade ($1,673K), which will no longer be constructed.

The table below contains current values for selected financial tracking quantities that do not appear in the standard Obligations or Cost Performance Reports.

		31 August 2004
Estimate to Completion		$9,838 K
Percent Complete		33 %

Two additional financial reports are attached and offer a more complete financial snapshot of the Project through the last day of the reporting month:

CDF RunIIb Obligations Report - This report provides a summary, at Level 2, of outstanding requisitions and purchase orders where money has been committed but for which the Project has not been invoiced. This does not include requisitions in the system which have not had a Fermilab Purchase Order number assigned as of the date of the report. A brief description of the columns included in this report is given below:

- Current Month Total Cost – The cost charged to the project for the reporting month.
- Current Month Obligation – This is the total of the obligations made against the project for the reporting month.
- Year to Date Total Cost – This is the total cost charged to the project in this fiscal year.
- Year to Date Obligations with Indirect – This is the total of the obligations made against the project for this fiscal year.
- Current Purchase Orders Open Commitment – This is the total of the open commitments against the project. It includes open commitments from the current and all prior years.
- Prior Year Total Cost - This is the total cost charged to the project in all prior fiscal years.

The total project cost is simply the sum of the Year-to-Date costs and the Prior Year costs. The total committed and spent is the Total Project Cost plus the Open Commitment value.

CDF Project Obligations Report Through 31 August 2004

CDF R11b EQU - August FYO4 in $K

	Expenditure Category	Current Month Total Cost	Current Month Obligation	YTD Total Cost	YTD Obligations w/ Indirect	Current PO Open Commitment	Prior Yr Total Cost
	M&S	-3.8	29.1	298.5	-320.0	125.9	221.0
	SWF	1.1	1.1	225.3	225.3	0.0	346.1
	OH	0.3	0.0	90.1	90.1	0.0	140.2
	Total 1.1	-2.5	30.2	613.9	-4.5	125.9	707.2
	M&S	18.8	0.1	195.7	235.4	39.7	0.0
	SWF	10.5	10.5	114.3	114.3	0.0	20.6
	OH	3.5	0.0	44.2	44.2	0.0	6.3
	Total 1.2	32.8	10.6	354.2	393.9	39.7	26.9
	M&S	107.4	185.3	396.1	578.3	316.6	2.9
	SWF	30.4	30.4	143.1	143.1	0.0	0.0
	OH	25.0	0.0	75.0	75.0	0.0	0.5
	Total 1.3	162.7	215.6	614.2	796.4	316.6	3.4
	M&S	1.4	1.4	15.8	15.8	0.0	13.3
	SWF	8.4	8.4	123.1	123.1	0.0	126.7
	OH	2.8	0.0	39.4	39.4	0.0	40.1
	Total 1.4	12.7	9.9	178.3	178.3	0.0	180.1
Total Project	M&S	123.8	215.9	906.0	509.5	482.2	237.2
	SWF	50.4	50.4	605.9	605.9	0.0	493.5
	OH	31.5	0.0	248.7	248.7	0.0	187.0
Grand Total		205.7	266.3	1760.6	1364.1	482.2	917.6

Total Project Cost (Inception To Date): 2678.2

CDF Project Cost Performance Report (CPR) – This report is generated from COBRA and provides a summary of the WBS 1.2-1.4 costs of the Project down to Level 3 of the Work Breakdown Structure. The closeout for the silicon detector subproject does not have its performance tracked here. Input data originates with the status (% Complete) of the Project schedules as reported by the Level 2 managers and actual costs extracted from the Fermilab accounting system. Where possible, costs are accrued for items that have been delivered, but not yet invoiced. This is only possible for a small fraction of our cost. Financial summaries are shown for this reporting period (columns 2-6) as well as the project to date (columns 7-11). Column 12 contains our baseline BAC, and will only be changed after the formal implementation of the Change Control process. Column 13 is the projected BAC, based on the current month's schedule. A number of specialized financial terms and abbreviations used in the CPR are defined here for convenience:

ACWP – Actual Cost of Work Performed. This is the actual cost of tasks that have been completed.

BAC – Budget at Completion. The BAC is the estimated total cost of the project when completed. It is equivalent to the BCWS at completion. The baseline value of the BCWS is contained in column 12 of the Cost Performance Report.

BCWP – Budgeted Cost of Work Performed. This is the scheduled cost profile of tasks that have been completed.

BCWS – Budgeted Cost of Work Scheduled. This is the sum of the budgets for all planned work to be accomplished within a given time period.

CV – Cost Variance. $CV = BCWP - ACWP$

EAC – Estimate At Completion. This is the ACWP to date, plus the BCWS (current scheduled estimate) of remaining tasks. $EAC = (BAC\ (current) - BCWP) + ACWP$

ETC – Estimate to Completion. $ETC = EAC - ACWP + Contingency$

Percent Complete - $\%Com = \frac{BCWP}{BAC}$

SV – Schedule Variance. $SV = BCWP - BCWS$

CDF Project
Cost Performance Report
at WBS Level 3

Cost Performance Report - Work Breakdown Structure														
Contractor: Location:					Contract Type/No:			Project Name/No: CDF RIIb Mstr Equ		Report Period: 8/1/2004 through 8/31/2004				
Quantity	Negotiated Cost		Est. Cost Authorized Unpriced Work		Tgt. Profit/ Fee %		Tgt. Price	Est Price	Share Ratio	Contract Ceiling	Estimated Contract Ceiling			
1	8,702,000		0		0	0.00	8,702,000	0		0	0			
Funding Type-CA WBS[2] WBS[3]	Current Period					Cumulative to Date					At Completion			
	Budgeted Cost		Actual Cost	Variance		Budgeted Cost		Actual Cost	Variance					
Item	Work Scheduled	Work Performed	Work Performed	Schedule	Cost	Work Scheduled	Work Performed	Work Performed	Schedule	Cost	Baseline BAC	Latest Revised BAC	BAC Delta	
EQU Equipment														
1.2 Calorimeter Upgrades														
1.2.1 Central Preshower and Crack Detectors	39,432	68,585	32,763	29,153	35,822	356,340	364,376	357,392	8,036	6,984	377,440	377,440	0	
1.2.2 Electromagnetic timing	0	0	0	0	0	35,630	35,630	23,403	0	12,227	35,630	35,630	0	
WBS[2]Totals:	39,432	68,585	32,763	29,153	35,822	391,970	400,007	380,795	8,036	19,212	413,070	413,070	0	
1.3 Run 2b DAQ and Trigger Project														
1.3.11 Revised XFTII Project	94,829	87,127	26,500	-7,702	60,627	94,829	87,127	47,800	-7,702	39,327	1,621,527	1,621,527	0	
1.3.1 Run 2b TDC Project	70,990	168,874	105,004	97,884	63,870	273,650	271,241	329,382	-2,409	-58,140	1,081,850	1,081,850	0	
1.3.2 Run 2b Level 2 Project	6,322	0	-12,754	-6,322	12,754	267,910	354,021	138,839	86,112	215,183	363,735	364,086	352	
1.3.4 Event-Builder Upgrade	75,842	34,594	43,942	-41,248	-9,348	237,066	219,901	101,593	-17,164	118,308	518,804	518,179	-624	
1.3.5 Computer for Level3 PC Farm / DAQ	0	0	0	0	0	0	85,540	0	85,540	85,540	479,403	479,403	0	
1.3.6 SVT upgrade	0	0	0	0	0	0	0	0	0	0	297,441	296,975	-467	
WBS[2]Totals:	247,983	290,595	162,700	42,611	127,904	873,455	1,017,831	617,600	144,377	448,018	4,362,760	4,362,020	-739	
1.4 Administration														
1.4.3 Construction Phase	24,593	24,702	12,658	109	12,044	474,945	475,025	358,377	80	116,649	958,867	958,867	0	
WBS[2]Totals:	24,593	24,702	12,658	109	12,044	474,945	475,025	358,377	80	116,649	958,867	958,867	0	
Funding Type-CATotals:	**312,008**	**383,881**	**208,100**	**71,873**	**175,769**	**1,740,370**	**1,892,863**	**1,356,771**	**152,493**	**583,878**	**5,734,697**	**5,733,958**	**-739**	
Sub Total	312,008	383,881	208,100	71,873	175,769	1,740,370	1,892,863	1,356,771	152,493	583,878	5,734,697	5,733,958	-739	
Management Resrv.											2,967,303	2,968,042	739	
Total	312,008	383,881	208,100	71,873	175,769	1,740,370	1,892,863	1,356,771	152,493	583,878	8,702,000	8,702,000	0	

VII. VARIANCE ANALYSIS – P. Lukens

Subproject	Schedule Variance	Cost Variance
Central Preshower and Crack	Not Significant	Not significant
Electromagnetic Timing	None	Not Significant
Run 2b TDC	Not Significant	Labor charges are higher than planned. This will be reviewed after the September production review.
Run 2b Level 2	Ahead of schedule	An error has been found in the cost accounting for labor on this task. This will be corrected in the future.
Run 2b XFTII	Not Significant	Not Significant
Event Builder	Not Significant.	No invoices yet for the single board computers. This will correct itself with time. Have not used engineering that was planned.
Computers for Level 3 and DAQ	Ahead of schedule	No invoices yet for the Level 3 computers. This will correct itself with time.
SVT Upgrade	None	None
Administration	None	Costs for support and travel have been below estimates.

VIII. BASELINE CHANGES

Change Control Request #13 was approved in August 2004. This request changed the scope, cost, and level 2 milestones for the XFT and SVT subprojects.

IX. FUNDING PROFILES

The funding profile is shown below:

	Funding Plan in Current Year $K				
	FY02	FY03	FY04	FY05	Total
DOE MIE	$ 3,460	$ 3,509	$ 1,673	$ 1,732	$ 10,375
DOE R&D	$ 1,670	$ 480			$ 2,150
Foreign Contributions	$ 39	$ 342	$ 252	$ 10	$ 643
U.S. Universities	$ 24	$ 225	$ 103	$ 26	$ 378
Total	$ 5,193	$ 4,556	$ 2,028	$ 1,768	$ 13,545