Work Authorization Document

NSTX Upgrade Project

Control Account #:	1306	**Title:**	Inner PF Coils
WBS	1.1.8	**Title:**	Magnet Systems
Period of Performance:	01 December 2009 through 22 April 2013		
Authorized Budget:	$669	**Control Account Manager:**	Chrzanowski
Revision #:	0	**Revision Date:**	July-11

Authorized Work Description:

The inner poloidal/shaping coils subsystem consists of the new coils that will make up the poloidal field coils 1A, 1B and 1C. This WBS element includes the design, analysis, prototypes (as required), procurement activities and fabrication.

For the NSTX Upgrade three new sets of inner poloidal field coils will be installed. This WBS element include the design and procurement of the Inner poloidal field coils and supports which includes all analytical and CAD design efforts for these components. It includes the early procurement of the PF conductor and co-wound [Glass/Kapton] insulation.

Attachments:

1- A detailed Control Account schedule showing all work packages and planning packages.

2- Budgeted Cost by month.

3- Original Work Authorization Form (WAF)

4- WBS Dictionary sheet that defines the scope of work for this WBS element.

Control Account History

ECP#	Implement Date	Prior Budget	New Budget	Signature

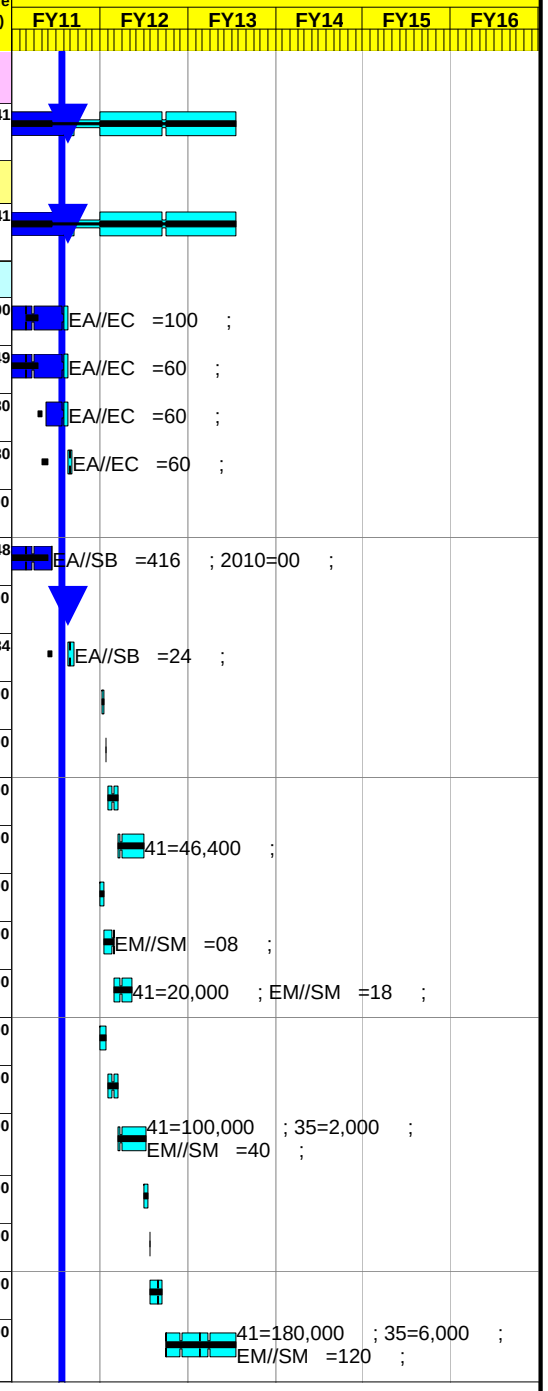
Approvals	Name	Signature	Date
NSTX-U Project Manager	R. Strykowsky		
Control Account Manager	Chrzanowski		
Functional Manager	P. Heitzenroeder		

NSTX Upgrade Project

Activity ID	Activity Description	Work Days	BASELINE START	Forecast Start	BASELINE FINISH	Forecast Finish	Schedule Slip (Days)	Total Float	Budgeted Cost	PPCT	Earned value cost (BCWP)	Planned value cost (BCWS)
Subtotal		844	01DEC09A	01DEC09A	22APR13	22APR13	0	90	668,383.28		152,390.20	175,215.41

Job: 1306 - Inner PF Coils-CHRZANOWSKI

Activity ID	Activity Description	Work Days	BASELINE START	Forecast Start	BASELINE FINISH	Forecast Finish	Schedule Slip (Days)	Total Float	Budgeted Cost	PPCT	Earned value cost (BCWP)	Planned value cost (BCWS)
Subtotal		844	01DEC09A	01DEC09A	22APR13	22APR13	0	90	668,383.28		152,390.20	175,215.41
1306-1010	Complete Inner PF Coil Analysis	155*	01DEC10*	04OCT10A	12JAN11	18MAY11	-90	132	15,308.00	70	10,715.60	15,308.00
1306-1020	PF Lead & Flag Analysis	200*	30JUL10A	30JUL10A	12JAN11	18MAY11	-90	132	9,358.25	85	8,260.72	9,718.49
1306-1030	Fatigue Assessment & DCPS	63*	13JAN11	21FEB11A	02FEB11	18MAY11	-75	132	9,184.80	50	4,592.40	9,184.80
1306-1040	Calculation Write/Check/File	15	03FEB11	19MAY11	23FEB11	09JUN11	-75	132	9,184.80		0.00	9,184.80
1306-1040A	Modeling for Inner PF	63*	03MAY10A	03MAY10A	31AUG10A	31AUG10A	0		0.00	100	0.00	0.00
1306-1050	Compl CAD Detail and Assembly Dwgs for Inner PF	136*	23AUG10A	23AUG10A	28FEB11	11MAR11A	-9		51,115.51	100	51,055.48	51,055.48
1306-1055	Inner PF Bundle - Peer review	0				18MAY11*	0	126	0.00		0.00	0.00
1306-1060	Prepare for FDR	21*	01MAR11	19MAY11	14MAR11	17JUN11	-68	126	2,997.84		0.00	2,997.84
1306-2010	Generate SOW for Inner PF Conductor	10	10OCT11*	10OCT11*	21OCT11	21OCT11	0	156	0.00		0.00	0.00
1306-2020	Prep Spec for Inner PF Conductor	5	24OCT11	24OCT11	28OCT11	28OCT11	0	156	0.00		0.00	0.00
1306-2030	Bid/Award - Inner PF Conductor	30	31OCT11	31OCT11	13DEC11	13DEC11	0	156	0.00		0.00	0.00
1306-2050	Fab & Deliver Inner PF Conductor	70	14DEC11	14DEC11	28MAR12	28MAR12	0	156	59,856.00		0.00	0.00
1306-3010	Prep Req for Kapton/Glass Insulation	10	03OCT11*	03OCT11*	14OCT11	14OCT11	0	186	0.00		0.00	0.00
1306-3020	Bid/Award Kapton/Glass Insulation	30	17OCT11	17OCT11	29NOV11	29NOV11	0	186	1,380.64		0.00	0.00
1306-3030	Fab & Deliver Kapton/Glass Insulation	50	30NOV11	30NOV11	15FEB12	15FEB12	0	186	28,906.44		0.00	0.00
1306-4010	Prep SOW for SS Supp for PF1A/B Coils	20	03OCT11*	03OCT11*	28OCT11	28OCT11	0	146	0.00		0.00	0.00
1306-4020	Bid/Award SS Supp for PF1A/B	30	31OCT11	31OCT11	13DEC11	13DEC11	0	146	0.00		0.00	0.00
1306-4030	Fab & Deliver SS Supp for PF1A/B	80	14DEC11	14DEC11	11APR12	11APR12	0	146	138,483.20		0.00	0.00
1306-5010	Generate SOW & Spec for Inner PF Coil Fab	15	02APR12*	02APR12*	20APR12	20APR12	0	104	0.00		0.00	0.00
1306-5020	Prep Req for Inner PF Fabrication	5	23APR12	23APR12	27APR12	27APR12	0	104	0.00		0.00	0.00
1306-5030	Bid/Award Inner PF Fabrication	30	30APR12	30APR12	11JUN12	11JUN12	0	104	0.00		0.00	0.00
1306-5050	Fab & Deliver Inner PF Coils	200	02JUL12*	02JUL12*	22APR13	22APR13	0	90	264,841.80		0.00	0.00



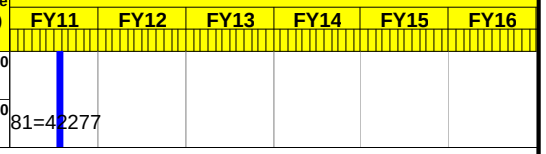
Data Date 30APR11
Run Date 20MAY11 10:51

1105

NSTX UPGRADES
RESOURCE LOADED SCHEDULE
CD-2 Schedule
April 2011

Early Bar
Progress Bar
Critical Activity

Activity ID	Activity Description	Work Days	BASELINE START	Forecast Start	BASELINE FINISH	Forecast Finish	Schedule Slip (Days)	Total Float	Budgeted Cost	PPCT	Earned value cost (BCWP)	Planned value cost (BCWS)
FY101306	FY10 Actual Cost	100	01DEC09A	01DEC09A	30APR10A	30APR10A	0		57,253.00	100	57,253.00	57,253.00
FY101306A	FY10 Actual Cost	110	03MAY10A	03MAY10A	30SEP10A	30SEP10A	0		20,513.00	100	20,513.00	20,513.00



1306 Inner PF Coils (Chrzanowski)	START	28FEB2009	31MAR2009	30APR2009	31MAY2009	30JUN2009	31JUL2009	31AUG2009	30SEP2009	31OCT2009	30NOV2009	31DEC2009
BCWS	0	0	0	0	0	0	0	0	0	0	0	10
CUM BCWS	0	0	0	0	0	0	0	0	0	0	0	10
BCWP	0	0	0	0	0	0	0	0	0	0	0	0
CUM BCWP	0	0	0	0	0	0	0	0	0	0	0	0
ACWP	0	0	0	0	0	0	0	0	0	0	0	0
CUM ACWP	0	0	0	0	0	0	0	0	0	0	0	0
CV	0	0	0	0	0	0	0	0	0	0	0	0
SV	.	.	.	.	.	.	.	.	.	.	.	-10.
CPI	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SPI	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

1306 Inner PF Coils (Chrzanowski)	31JAN2010	28FEB2010	31MAR2010	30APR2010	31MAY2010	30JUN2010	31JUL2010	31AUG2010	30SEP2010	31OCT2010	30NOV2010	31DEC2010
BCWS	11	11	13	12	4	4	4	9	14	10	10	19
CUM BCWS	21	32	45	57	61	65	70	78	92	103	113	131
BCWP	0	0	0	0	0	0	0	0	0	0	0	146
CUM BCWP	0	0	0	0	0	0	0	0	0	0	0	146
ACWP	0	0	0	0	0	0	0	0	0	0	0	126
CUM ACWP	0	0	0	0	0	0	0	0	0	0	0	126
CV	0	0	0	0	0	0	0	0	0	0	0	20
SV	-21.	-32.	-45.	-57.	-61.	-65.	-70.	-78.	-92.	-103.	-113.	15.
CPI	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.16
SPI	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.11

1306 Inner PF Coils (Chrzanowski)		31JAN2011	28FEB2011	31MAR2011	30APR2011	31MAY2011	30JUN2011	31JUL2011	31AUG2011	30SEP2011	31OCT2011	30NOV2011	31DEC2011
	BCWS	22	19	3	0	0	0	0	0	0	0	1	43
	CUM BCWS	153	172	175	175	175	175	175	175	175	175	177	219
	BCWP	3	2	6	-4	0	0	0	0	0	0	0	0
	CUM BCWP	148	150	156	152	152	152	152	152	152	152	152	152
	ACWP	4	5	27	22	0	0	0	0	0	0	0	0
	CUM ACWP	130	135	161	183	183	183	183	183	183	183	183	183
	CV	19	16	-5	-31	-31	-31	-31	-31	-31	-31	-31	-31
	SV	-5.	-22.	-19.	-23.	-23.	-23.	-23.	-23.	-23.	-23.	-25.	-67.
	CPI	1.14	1.12	.97	.83	.83	.83	.83	.83	.83	.83	.83	.83
	SPI	0.97	0.87	0.89	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.86	0.69

1306 Inner PF Coils (Chrzanowski)		31JAN2012	29FEB2012	31MAR2012	30APR2012	31MAY2012	30JUN2012	31JUL2012	31AUG2012	30SEP2012	31OCT2012	30NOV2012	31DEC2012
	BCWS	64	56	51	13	0	0	27	28	25	29	28	27
	CUM BCWS	284	340	391	404	404	404	431	459	484	513	541	567
	BCWP	0	0	0	0	0	0	0	0	0	0	0	0
	CUM BCWP	152	152	152	152	152	152	152	152	152	152	152	152
	ACWP	0	0	0	0	0	0	0	0	0	0	0	0
	CUM ACWP	183	183	183	183	183	183	183	183	183	183	183	183
	CV	-31	-31	-31	-31	-31	-31	-31	-31	-31	-31	-31	-31
	SV	-131.	-187.	-238.	-251.	-251.	-251.	-279.	-307.	-332.	-361.	-389.	-415.
	CPI	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83
	SPI	0.54	0.45	0.39	0.38	0.38	0.38	0.35	0.33	0.31	0.3	0.28	0.27

1306 Inner PF Coils (Chrzanowski)		31JAN2013	28FEB2013	31MAR2013	30APR2013	31MAY2013	30JUN2013	31JUL2013	31AUG2013	30SEP2013	31OCT2013	30NOV2013	31DEC2013
	BCWS	29	25	27	20	0	0	0	0	0	0	0	0
	CUM BCWS	596	622	648	669	669	669	669	669	669	669	669	669
	BCWP	0	0	0	0	0	0	0	0	0	0	0	0
	CUM BCWP	152	152	152	152	152	152	152	152	152	152	152	152
	ACWP	0	0	0	0	0	0	0	0	0	0	0	0
	CUM ACWP	183	183	183	183	183	183	183	183	183	183	183	183
	CV	-31	-31	-31	-31	-31	-31	-31	-31	-31	-31	-31	-31
	SV	-444.	-469.	-496.	-516.	-516.	-516.	-516.	-516.	-516.	-516.	-516.	-516.
	CPI	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83
	SPI	0.26	0.24	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23

Annex I – WBS Dictionary

This Work Breakdown Structure (WBS) organizes and defines the scope of the NSTX Upgrade using the WBS as established by the original NSTX project and modified to accommodate the NSTX Upgrade.

WBS L1	L2	L3	Description
1			**NSTX UPGRADE PROJECT**
	1.1		**Torus Systems**
		1.1.0	Project Integrated Model
		1.1.1	Plasma Facing Components
		1.1.2	Vacuum Vessel and Support Structure
		1.1.3	Magnet Systems
	1.2		**Plasma Heating and Current Drive Systems**
		1.2.1	High Harmonic Fast Wave (HHFW)
		1.2.2	Coaxial Helicity Injection (CHI) Current Drive
		1.2.3	Electron Cyclotron Heating (ECH)
		1.2.4	Neutral Beam Injection (NBI)
	1.3		**Auxiliary Systems**
		1.3.1	Vacuum Pumping System
		1.3.2	Coolant Systems
		1.3.3	Bakeout Heating System
		1.3.4	Gas Delivery System
		1.3.5	Glow Discharge Cleaning System
	1.4		**Plasma Diagnostics**
		1.4.1	Plasma Diagnostics
	1.5		**Power Systems**
		1.5.1	AC Power Systems
		1.5.2	AC/DC Converters
		1.5.3	DC Systems
		1.5.4	Control and Protection System
		1.5.5	General Power Systems and Integration
	1.6		**Central Instrumentation and Controls (I&C)**
		1.6.1	Control System
		1.6.2	Data Acquisition System
	1.7		**Project Support & Integration**
		1.7.1	Project Management and Integration
		1.7.2	Project Physics
		1.7.3	Integrated Systems Tests
	1.8		**Site Preparation and Assembly**
		1.8.1	Site Preparation
		1.8.2	Torus Assembly and Construction

and TF bundle assembly. A single vendor will fabricate both components. {Ohmic Heating Solenoid (Job 1305)}

WBS Element: 1.1.3.3.3 **WBS Level: 5**
WBS Title: Inner Poloidal Field Coils
Definition: The inner poloidal/shaping coils subsystem consists of the new coils that will make up the poloidal field coils 1A, 1B and 1C. This WBS element includes the design, analysis, prototypes (as required), procurement activities and fabrication.

For the NSTX Upgrade three new sets of inner poloidal field coils will be installed. This WBS element include the design and procurement of the Inner poloidal field coils and supports which includes all analytical and CAD design efforts for these components. It includes the early procurement of the PF conductor and co-wound [Glass/Kapton] insulation. {Inner Poloidal Field Coils (Job 1306)}

WBS Element: 1.1.3.3.4 **WBS Level: 5**
WBS Title: Center Stack Casing and Assembly
Definition: This WBS element includes the design and fabrication of the Center Stack casing and ceramic break assembly for the upgraded Center Stack as well as the assembly of the new Center Stack.

The Center Stack Casing effort includes analysis and CAD design for the casing components; the procurement of the Inconel tubing, forgings, bellows and organ pipes; the fabrication of Center Stack support legs; the procurement/fabrication of a new ceramic break assembly; the in-house assembly of the casing components; and mounting of the PF1A and PF1B structure/coils to the casing.
{CS Casing (Job 1307)}

The Center Stack Assembly effort involves all activities associated with the assembly of the Center Stack and includes design modifications and upgrade of the coil assembly stand; procedures for assembling the Center Stack and for installation; assembly of the Center Stack components including the OH/TF coil supports, mounting of the surface diagnostics and thermal blanket, inconel casing and inner PF coils and setup and tear down of the Center Stack assembly area.
{Center Stack Assembly (Job 1302)}

WBS Element: 1.1.3.4 **WBS Level: 4**
WBS Title: Coil Bus Runs
Definition: This WBS element includes the design and fabrication of the coil bus runs/supports between the NSTX coils and the FCPC cable terminations located in the NSTX test cell.
{Coil Bus Runs (Job 5501)}

Work Approval Form (WAF)

Cost Center: 9417
Job Number: 1306
Job Title: Inner Poloidal Field Coils
Job Manager: James H. Chrzanowski

Description:

Includes the design and procurement of the Inner poloidal field coils and supports [PF1A and PF1B]. Includes all analytical & CAD design efforts for these components. Includes the early procurement of the PF conductor and Co-wound [Glass/Kapton] insulation. Also includes the procurement of the PF support mandrels that the PF1A and 1B coils will be wound onto plus the fabrication of (3) sets of new inner PF coils (PF1A, 1B and 1C)

Schedule:

Refer to the Primavera Data-Base

Approvals:

James H Chrzanowski 7/20/10
Job Manager

8/3/10
Project Manager

8/3/10
Engineering Department Head

Cost Center	Work Package	Job #	Activity Name	Responsible Cog Engr	Duration (Weeks)	Start Date	EAEM1 mhrs (Chrzan.)	EAEM2 mhrs Myatt	EAEM mhrs (general)	EASB2 mhrs (Morris)	EMSM1 mhrs (Meighan)	M&S K$	OS k$	Travel k$	Stkrm. k$	Subtotal M&S k$	Basis of Estimate	Category	Contingency %
9417	1***	1306		Chrzanowski			See Job 1300												
			Final Design Activities													$0.0			
			Complete Inner PF coil analysis			24-Jun-10		100								$0.0		2	20%
			PF lead & flag analysis			24-Jun-10		60								$0.0		2	20%
			Fatigue assessment & DCPS			24-Jun-10		60								$0.0		2	20%
			Calculation write/Check/File			24-Jun-10		60										2	20%
			Complete Cad detail and assembly drawings of Inner PF coils & supports			24-Jun-10				416						$0.0		2	20%
			Prepare for FDR		2	11-Mar-11				24						$0.0		2	10%
			Purchase & Fabrication													$0.0			
			Procure Conductor																
			Generate SOW for conductor		2	27-May-11												2	10%
			Prep requisition & submit to procurement		1	10-Jun-11												2	10%
			Bid & award conductor order [220%]		5	17-Jun-11												2	10%
			Manufacture Copper conductor [extrusion]		14	22-Jul-11							$46.4			$46.4		3	25%
			Procure Kapton/glass co-wound Insulation																
			Prep requisition & submit to procurement [insulation]		1	26-Aug-11					8							2	10%
			Procure Kapton/glass co-wound insulation		10	2-Sep-11					18	$20.0				$20.0		6	20%
			Coil Fabrication- 6 coils																
			Procure Stainless steel supt for PF1A & PF1B coils		16	29-Jul-11					40		$100.0	$2.0		$102.0		3	25%
			Generate SOW & Manufacturing SPEC for Inner PF coils		3	23-Sep-11												2	10%
			Prep requisition & submit to procurement		1	14-Oct-11												2	10%
			Review bids and award contract		6	21-Oct-11												2	10%
			Fabricate Inner [6] Inner PF coils		40	2-Dec-11					120		$180.0	$6.0		$186.0		3	25%
							0	0				$0.0							
							0	**280**	**0**	**440**	**186**	$20.0	$326.4	$8.0	$0.0	**$354.4**			

Sept 7 2012

CATEGORIZATION CODES:

1 - National Standards
2 - Engineering Judgement/Experience
3 - Estimates/Data from External Sources (e.g., W7X, ATF, etc.)
4 - Previous PPPL/ORNL Experieince (e.g., TFTR, NSTX, PLT, etc.)
5 - Prototype Data/Test Results
6 - Catelogue Price/Vendor Quote
7 - Placed Contracts
8 - Actual experience for NCSX Work
9 - Other

Cost Center:	9417
Job Number:	1306
Job Title:	Inner Poloidal Field Coils
Job Manager:	James H. Chrzanowski

Uncertainty of the Estimate

	High	Medium	Low	Uncertainty Range (%)	Comments/Other Considerations
Design Maturity		x			
Design Complexity		X			

Residual Impacts

	Risk Description	Likelihood of Occurring	Mitigation Plan	Basis of estimate	Cost Impact Low ($K)	Cost Impact High ($K)	Schedule Impact Low (weeks)	Schedule Impact High (Weeks)
1	Poor impregnation	U	Local dry areas can be repaired. Extensive areas of poor VPI may require rewinding new coil		10	50	X	
2	Coil fails final acceptance tests	U	If coil cannot be repaired, a new coil be have to be wound		X	50	X	
3								
4								
5								

Notes:

(1) Cost impacts should NOT include standing army costs which are separately calculated from the schedule impact

(2) The schedule impacts should be entered as the min and max impacts on the critical path.
If there is no critical path impact then the schedule entries should be zero.

(3) Likelihood of occurrence should be entered consistent with our risk classification methodology, i.e.
VL= Very Likely (P>80%), L=Likely (80%>P>40%), U=Unlikley (40%>P>10%), VU=Very Unlikely (P<10%), NC=Non-credible (P<1%)

Design Maturity	Design Complexity					
	Low		Medium		High	
Low	-15%	+25%	-20%	+40%	-30%	+60%
Medium	-10%	+15%	-15%	+25%	-20%	+40%
High	-5%	+10%	-10%	+15%	-15%	+25%

Design Maturity Definition

High	Final design available. All design features/requirements well known. No further design development or evolution expected that will impact estimate.
Medium	Preliminary design available. Some additional design evolution likely. Further developments can be somewhat expected or anticipated and reflected in estimate.
Low	No better than conceptual design basis currently available. Design details, procedures, etc. still need much development and evolution of requirements beyond estimate basis is likely and expected.

Design Complexity Definition

Low	Work is fairly well understood -- either standard construction or repetition of activities performed in past. Little likelihood of estimate not being well understood and requirements not being well defined.
Medium	More complex work requirements that have potential to impact cost and schedule estimates. Limited experience performing similar tasks, so ability to estimate accurately is somewhat suspect
High	Extremely challenging tasks and/or requirements. Unique or firstof-a-kind assembly or work tasks. No good basis for estimating work exists so there is a high degree of estimate uncertainty.

Based on standard industry and DOE estimate classifications (Per AACEI Recommended

Cost Center:	**9417**						
Job Number:	**1306**						
Job Title:	**Inner Poloidal Field Coils**						
Job Manager:	**James H. Chrzanowski**						

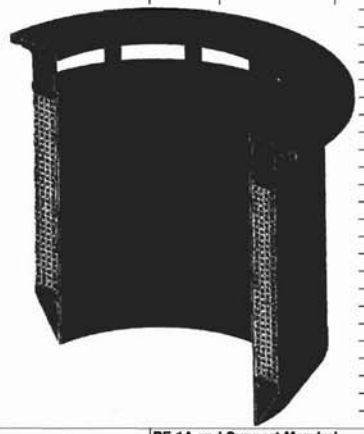
Materials and Subcontracts (M&S)	**k$**	**Basis of Estimate**
Description:		
Copper conductor	$46	4
Co-wound insulation [Kapton/glass]	$20	6
Fabricate inner PF coils	$180	6
Fabricate PF supports [mandrels- PF1A & 1B]	$100	2

CATEGORIZATION CODES:

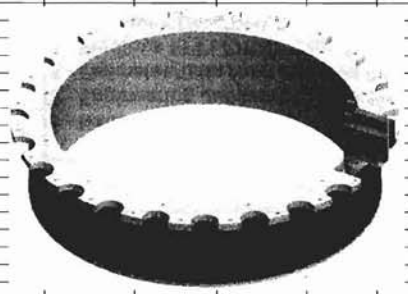
1 - National Standards
2 - Engineering Judgement/Experience
3 - Estimates/Data from External Sources (e.g., W7X, ATF, etc.)
4 - Previous PPPL/ORNL Experieince (e.g., TFTR, NSTX, PLT, etc.)
5 - Prototype Data/Test Results
6 - Catelogue Price/Vendor Quote
7 - Placed Contracts
8 - Actual experience for NCSX Work
9 - Other

TOTALS

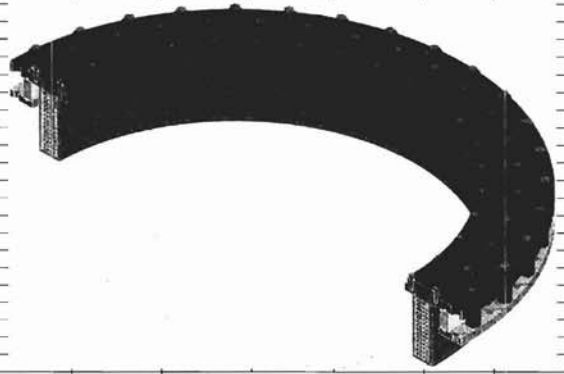
PF Conductors		width in	Height in	Hole Dia in	Hole Area in2	Area in2	Coil R in	Turn	Length/Turn in	Length/Coil in	Length/Coil ft	x 2	Wt/coil lb	x 2			
PF1a		0.551	1.100	0.205	0.1180	0.488	12.571	64	78.946	5052.5	421.0	842.1	789.2	1578.3			
PF1b		0.633	0.392	0.126	0.0024	0.246	15.763	32	98.992	3167.7	264.0	528.0	249.1	498.2			
PF1c		0.705	0.603	0.126	0.0024	0.423	21.674	20	136.113	2722.3	226.9	453.7	368.2	736.5			
															x 2.2	$7.50	
														2813.0	**6188.6**	**$46.4**	k
								PI	**3.14**								
							Density	**0.32**	**#/Cu in**								



PF-1A and Support Mandrel



PF-1B and Support mandrel



PF-1C and Ceramic Break Assembly