NCSX Project

Contingency Analysis

Prepared for
Princeton Plasma Physics Laboratory

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Introduction

This document describes the process and approach used to develop the cost and schedule contingency estimates included in the proposed baseline for the National Compact Stellarator Experiment (NCSX) Project. The contingency estimate is based on inputs of all key members of the project team using a structured process based on established DOE and industry methodologies. The contingency estimates are intended to reflect the inherent uncertainty associated with the current NCSX estimates-to-complete (ETC) and the currently identified project risks.

Overview of Methodology and Approach

The NCSX Project Team employed a structured process developed and implemented with the support of a consultant with extensive DOE and industry experience. The objective of this process was to assess and analyze all areas of risk and uncertainty that might affect the cost and schedule estimates for the project. Probabilistic Risk Analysis Techniques (Monte Carlo Analysis) were used to derive recommended contingency allowances that provide 90% confidence that the proposed baseline estimate will not be exceeded. (Since overall probability profiles are the result of the analysis used, alternative levels of confidence can also be identified and selected, at management discretion.)

Separate models were constructed to account for inherent uncertainty of the cost and schedule estimates as well as the potential residual impact of identified project risks. Each of these models is described in the following sections of this document.

Cost Estimate Uncertainty Model

All cost estimates have inherent uncertainty. In general, the level of such uncertainty is a direct result of the degree of design maturity and the complexity of the elements involved – in effect, how much definition exists to provide a basis for the estimates. For this reason, standard cost estimating practice describes uncertainty levels in terms of ranges around the point estimates which, in the case of NCSX, were developed by Job Managers and the Project Management team.

The NCSX Project relied on standard industry and DOE cost estimate classifications to describe the expected range of individual job estimates. In particular, a combination of design maturity and complexity was used to equate each job estimate to a particular cost estimate classification level which could then be used to assign an expected estimate range to each estimate. This process is described below.

Each job estimate was assigned a design maturity and complexity rating based on the definitions shown in Tables 1 and 2.

Table 1
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.

Table 2
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 first-of-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 Practice 18R-97, *Cost Estimate Classification System – As Applied to Engineering, Procurement, and Construction in the Process Industries*), the NCSX estimates were equated to the appropriate class of estimate based on the design maturity and complexity ratings, as shown in Table 3. The standard industry estimate ranges were then used as a basis to describe the expected range of each NCSX job estimate, using the maturity and complexity ratings shown in Table 4.

Table 3
NCSX Estimate Classification

Estimate Class	Level of Definition	Accuracy Range	NCSX Definition
5 - ROM DOE CD-0	0 - 2%	Low: -20 % to -50% High:+30% to +100%	L Maturity H Complexity
4 - Conceptual DOE CD-1	1 - 15%	Low: -15% to -30% High:+20% to +50%	MH and LM
3 - Preliminary DOE CD-2	10 - 40%	Low: -10% to -20% High:+10% to +30%	LL, MM, and HH
2 DOE CD-2 or 3	30 - 70%	Low: -5% to -15% High:+5% to +20%	ML and HM
1 - Definitive DOE CD-3	50 - 100%	Low: -3% to -10% High:+3% to +15%	H Maturity L Complexity

Table 4
NCSX Estimate Ranges

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

Table 5 summarizes the distribution of the NCSX Estimates to Complete (ETC) by WBS into the estimate accuracy groupings resulting from the approach described above and the ranges shown in Table 4.

Table 5
NCSX ETC by Estimate Accuracy Range

				Design Maturity/Complexity					
WBS	**Description**	**ETC**	**Frozen**	**HL**	**ML & HM**	**MM,LL,HH**	**MH & LM**	**LH**	**% of ETC**
	Assumed Estimate Accuracy Range			*-5 to +10%*	*-10 to +15%*	*-15 to +25%*	*-20 to +40%*	*-30 to +60%*	
12	Vacuum Vessel	1,428		220	1,208				2.31%
13	Conventional Coils	4,256		2,087	2,169				6.89%
14	Modular Coils	2,563	4	139	1,356	1,035	29		4.15%
15	Structures	1,530			1,530				2.48%
16	Coil Services	1,082		337	745				1.75%
17	Cryostat & Base Support Structure	1,500		920				580	2.43%
18	Field Period Assembly	14,407			6,777	1,323	6,307		23.31%
19	Stellarator Core Mgmt & Integr	2,250		2,250					3.64%
2	Auxiliary Systems	1,017				1,017			1.65%
3	Diagnostics	806		520	29	257			1.30%
4	Electrical Power Systems	2,719		1,637	1,082				4.40%
5	I&C Systems	2,095		65	1,301	729			3.39%
6	Facility Systems	2,422			222		633	1,567	3.92%
7	Test Cell Prep & Machine Assy	8,582		618			7,964		13.89%
8	Project Management & Integration	15,137	193	10,786		3,617	541		24.50%
	Total NCSX ETC	**61,794**	**197**	**19,579**	**16,419**	**7,978**	**15,474**	**2,147**	**100.00%**
		100%	0%	32%	27%	13%	25%	3%	

The ranges shown in Table 4 were used with the job manager's point estimate to describe a probability profile for each estimate as an input to a Monte Carlo analysis using Crystal Ball® and Microsoft Excel software. Each job estimate was treated as an independent variable (except for a few job estimates which were correlated to each other) with cost outcomes described as a triangular distribution where the base or point estimate is the most likely value, the low end of the range is the minimum value, and the high end of the range is the 80% confidence level value (there is a 20% chance the actual costs could exceed this upper end value).

In addition to the ranges around each job estimate used for the model, the uncertainty model also includes a factor for overall estimate uncertainty. This is to account for estimate errors and omissions or other uncertainties not captured within the scope of an individual job estimate. For the NCSX estimate uncertainty model this was assumed to add no cost for the most likely case. At the low end of the range a 1% reduction was assumed; and in the maximum case (with no chance of overrun) a 3% adder was assumed. These values were modeled using a triangular distribution in the Monte Carlo model.

Appendix A shows each job point estimate, the rating of design maturity and complexity, and the resultant ranges used as the inputs to the Monte Carlo probabilistic analysis. Information on individual estimate probability profiles, correlation factors, etc. can be found in the Crystal Ball® Report included as Appendix G of this document (these are called “assumptions” in Crystal Ball®.)

Schedule Uncertainty Model

The inherent uncertainty of the schedule duration estimates were evaluated in a similar manner as was the cost estimate uncertainty. For the schedule, a model that focused only on critical and near critical path activities was used. Because the NCSX Project is composed of a fairly sequential series of activities, a full analysis that addresses potential alternative critical paths was not considered necessary. For each activity identified and included in this model, a duration range was established using the same maturity and complexity ratings and resultant estimate uncertainty ranges as were used for costs.

As with the cost uncertainty model, Monte Carlo analysis was used to determine the overall project schedule probability profile. Each critical path (or near critical path) activity was treated as an independent variable; however within the model the schedule and cost estimate uncertainty of individual jobs were correlated (that is, if the costs went up, the schedule duration would likely increase, and vice versa). Triangular distributions were assumed with the base duration estimate being the most likely value, the low end of the range representing the minimum duration, and the high end of the range having a 90% confidence level (higher than for costs since schedule workarounds are more often possible). In addition, the model capped or limited the durations for some activities to the extent that a second shift could be used to minimize the upper end of potential durations. When this is necessary, the model adds a cost allowance for shift supervision, support and shift differential costs.

The inputs for the schedule uncertainty model are included as Appendix B of this document.

Risk Model

In addition to the models used to assess and quantify cost and schedule estimate uncertainty, a separate model was used to assess the level of contingency needed to accommodate residual risk impacts – both to project costs or the critical path for the project. The basis for this model is the NCSX Risk Register and the estimated likelihood of occurrence of risks and risk impact estimates included therein. The process used to identify risks and to manage identified risks is described in the NCSX Risk Management Plan. The model used to estimate risk related cost and schedule contingency allowances is described below.

The Risk Model assumes each identified risk has a chance of occurring based on the “likelihood” assessments determined for each risk, as described in Table 6.

Table 6
Likelihood of Risk Occurrence

Probability of Occurrence		**Criteria**
Qualitative	**Quantitative**	
Very Unlikely	<0.1	Will not likely occur anytime in the project life cycle, or the probability of the occurrence is judged to be less than 10%.
Unlikely	>0.1 but <0.4	Unlikely to occur in the project life cycle, or the probability of the occurrence is judged to be greater than 10% but less than 40%.
Likely	>0.4 but <0.8	Will likely occur sometime during the project life cycle of the project or its facilities, or the probability of the occurrence is judged to be greater than 40% but less than 80%.
Very Likely	>0.8	Very likely to occur sometime during the project life cycle or the probability of occurrence is judged to be 80% or greater.

Within the Monte Carlo analysis model, each likelihood description (likely, unlikely, etc,) is represented by a uniform probability profile (e.g., if "likely", then there is an equal chance of from 40% to 80% of the time that risk event will occur). If an event does occur, then the estimated cost and schedule impacts will be realized. These probability profiles were used as the input variables for the Monte Carlo analysis using Crystal Ball® and Microsoft Excel software. The Risk Model inputs are shown in Appendix C of this document.

<u>Summary of Results</u>
The result of the NCSX uncertainty and risk models is displayed in the figure below (the detailed probability profile of each uncertainty and risk element can be found in Appendix D). The contingency allowances needed to attain a 90% confidence that the proposed ETC will not be exceeded are summarized in Table 7. Table 8 also depicts the contingency required to achieve 80% or 95% levels of confidence. The ETC for the NCSX Project at the 90% level of confidence is approximately $85 million, including an approximate 36% contingency on the estimate to complete for the project.

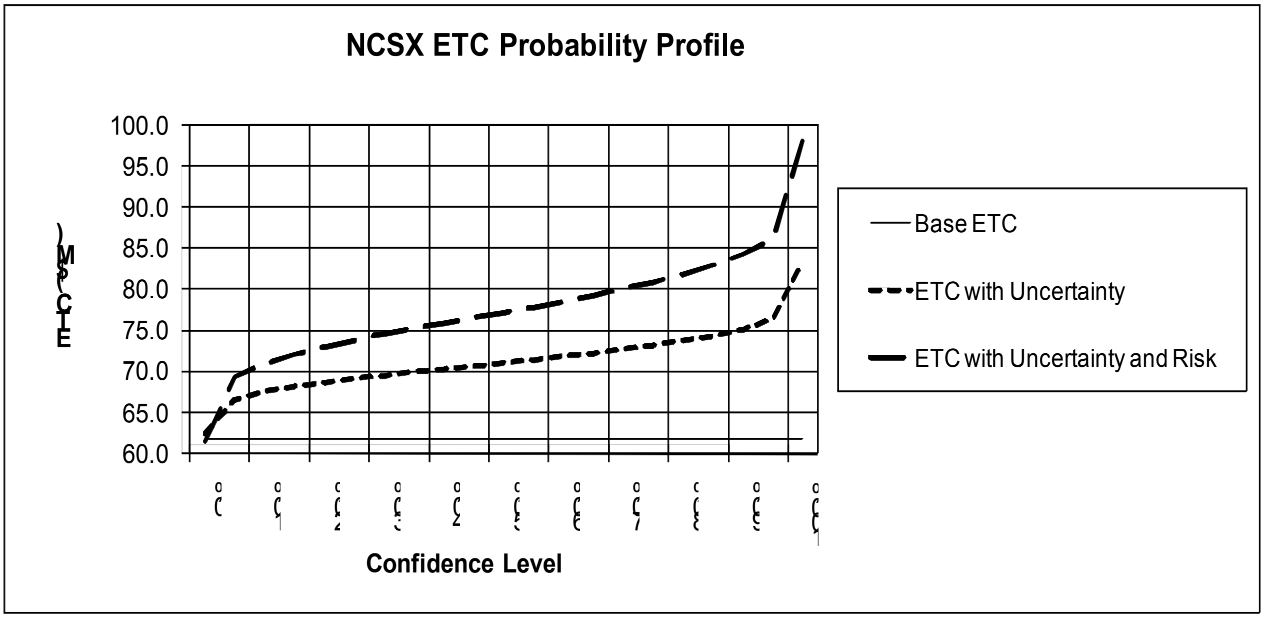

Table 7 summarizes the months of schedule contingency needed to achieve 90% confidence in the schedule end date (CD-4) as a result of both schedule estimate uncertainty (as it impacts the project critical path), and the potential residual impacts of project risk events. The schedule contingency requirements calculated by the uncertainty and risk models were adjusted downwards by assuming that the duration for the project can be reduced by working Saturdays when needed for contingent schedule impacts. Thus the overall schedule contingency was reduced by approximately 83% (6 days worked in a week as compared to the base case of 5 days of work). To the extent this reduction is made, a schedule mitigation cost adder is included to account for the added supervision and support costs needed for Saturday operations. This reduction and cost adder is depicted in Appendix D.

Table 7
Contingency Analysis Results

Base Schedule		**48.0**	months
Schedule Uncertainty Contingency at 90%		7.2	
Risk Schedule Contingency at 90%		11.8	
Total Schedule Contingency (90%)		**19.0**	**months**
Base ETC		**61,794**	
Contingency at 90% (Std Uncertainty)		9,350	15%
Cost of Schedule Uncertainty Contingency		3,780	6%
Cost of Schedule Risk Mitigation		270	0%
Total Uncertainty Contingency - 90% Confidence		13,400	22%
Risk Cost Contingency (from Risk Model) at 90%		2,840	5%
Risk Schedule Contingency (cost of stretch) - 90%		6,170	10%
Total Risk Contingency - 90% Confidence		9,010	15%
Total Cost Contingency (90%)		**22,410**	**36%**
ETC with Contingency (@90%)		***84,204***	
		$M	**$M**
	2008	0%	0.00
	2009	12%	2.69
	2010	14%	3.14
	2011	41%	9.19
	2012	33%	7.40

Also shown in Table 7 are the cost contingency allowances necessary to attain a 90% level of confidence in the Estimate to Complete for the NCSX Project. The cost contingency is comprised of the following elements:

- Standard estimate uncertainty allowance
- Cost associated with the schedule uncertainty (project costs that would be incurred as the project schedule is stretched – see Appendix E)
- Cost of Schedule Risk Mitigation representing the added costs to be incurred if and when second shift operations are needed to maintain the project schedule (or limit the amount of schedule stretch) as a result of schedule uncertainty – see Appendix E. Also included is the cost incurred for additional supervision and support when Saturdays are worked to reduce the number of weeks of schedule contingency determined as needed by the probabilistic analysis.
- Risk Contingency which includes both cost impacts and the cost that is incurred as a result of schedule impacts of risk events

Contingency by Year
Table 7 also depicts the proposed spread of contingency dollars by fiscal year. This proposed distribution of contingency allowance over the remaining project life was derived using a two step process. First, the main contributors to both estimate uncertainty and cost risk were determined using the sensitivity analysis output of the Monte Carlo simulation model. The current projected BCWS profile for each of these contributing elements were also determined and the results of the two inputs (percent contribution of each job and the spread of BCWS for each job by year) were then combined to calculate a possible spread of contingency use over time. Note that all schedule contingency related costs, which represent extension of project fixed costs, are assumed to occur at the end of the project for this analysis. These calculations are shown in Appendix F.

After this analysis was completed, there was a subjective attempt to adjust the resulting contingency spread to more accurately depict when contingency costs will in fact be needed and incurred by the project. This is necessary since it is important to maximize the level of funds available to schedule needed project activities (especially design work and placement of large procurements) as early as feasible to optimize the overall project schedule and retire risks as rapidly as possible. At the same time, it is important not to assume all contingency needs will only occur near the end of the project. The proposed spread assumed for the NCSX project (and shown in Table 7 and Appendix F) is believed to properly balance these two concerns and is based on the systematic analysis described as the first step above.

Allocation of Contingency by WBS
At the request of DOE HQ, the calculated contingency allowance was subsequently allocated to individual WBS elements. Although the contingency will not be managed in this way, this portrayal is useful for assessing to what degree the various WBS elements contribute to the uncertainty and risks for the NCSX Project. The results of this allocation are shown in Table 9.

The following methodologies were used to derive this contingency allocation:

- Uncertainty was distributed by forecasting the Monte Carlo analysis results for each WBS and determining the 90% confidence point for each WBS element.
- Schedule cost contingency was allocated to the WBS elements for which those costs will be required – the “standing army” costs associated with schedule stretch that are primarily project management related elements.
- The schedule mitigation cost was assigned to the WBS elements that would require additional shift work if the schedule uncertainty is realized.
- The risk contingency was allocated on the basis of WBS elements that may be impacted by each identified risk., again determining the 90% confidence point for each summed WBS.

After developing a detailed allocation using the above methodologies, the resulting percentages of the total calculated contingency were determined and these percentages were then applied to the total calculated contingency needed for an overall (rather than for each WBS) 90% level of confidence. The results of this calculation are shown in Table 9. Also shown in Table 9 is the percentage that this allocated contingency represents of the base ETC estimate for each WBS element.

Appendices

A. Estimate Uncertainty Ranges
B. Schedule Uncertainty Ranges
C. Risk Model Inputs
D. Probabilistic Model Results
E. Schedule Contingency Costing Bases
F. Basis for Spread of Contingency by Fiscal Year
G. Crystal Ball® Report

Table 8
Summary of Risk/Contingency Analysis Results

	90% Confidence		80% Confidence		95% Confidence	
Base Schedule	**48.0**	**months**	**48.0**	**months**	**48.0**	**months**
Schedule Uncertainty Contingency	**7.2**		**5.9**		**8.2**	
Risk Schedule Contingency	**11.8**		**10.4**		**12.9**	
Total Schedule Contingency (90%)	**19.0**	**months**	**16.3**	**months**	**21.1**	**months**
Base ETC	**61,794**		**61,794**		**61,794**	
Contingency (Std Uncertainty)	**9,350**	**15%**	**8,640**	**14%**	**9,990**	**16%**
Cost of Schedule Uncertainty Contingency	**3,780**	**6%**	**3,120**	**5%**	**4,320**	**7%**
Cost of Schedule Mitigation (incl. 2nd Shift & Saturdays)	**270**	**0%**	**230**	**0%**	**300**	**0%**
Total Uncertainty Contingency	**13,400**	**22%**	**11,990**	**19%**	**14,610**	**24%**
Risk Cost Contingency (from Risk Model)	**2,840**	**5%**	**2,550**	**4%**	**3,000**	**5%**
Risk Schedule Contingency (cost of stretch)	**6,170**	**10%**	**5,460**	**9%**	**6,770**	**11%**
Total Risk Contingency	**9,010**	**15%**	**8,010**	**13%**	**9,770**	**16%**
Total Cost Contingency	**22,410**	**36%**	**20,000**	**32%**	**24,380**	**39%**
ETC with Contingency	***84,204***		***81,794***		***86,174***	
Contingency Spread by Year		**$M**		**$M**		**$M**
2008	**0%**	**0.00**	**0%**	**0.00**	**0%**	**0.00**
2009	**12%**	**2.69**	**12%**	**2.40**	**12%**	**2.93**
2010	**14%**	**3.14**	**14%**	**2.80**	**14%**	**3.41**
2011	**41%**	**9.19**	**41%**	**8.20**	**41%**	**10.00**
2012	**33%**	**7.40**	**33%**	**6.60**	**33%**	**8.05**
		22.41		**20.00**		**24.38**

Table 9
Contingency Allocation by WBS

WBS			Allocation of Contingency Allowances (90% Confidence)					% of Cont.	Allocated Contingency	% of ETC
		ETC	Uncertainty	Schedule	Sched Mitig	Cost Risk	Total			
12	Vacuum Vessel	1,428	195			60	255	1.0%	222	16%
13	Conventional Coils	4,256	473			360	833	3.2%	725	17%
14	Modular Coils	2,563	427			30	457	1.8%	398	16%
15	Structures	1,530	288			573	861	3.3%	749	49%
16	Coil Services	1,082	165			60	225	0.9%	196	18%
17	Cryostat & Base Support Structure	1,500	498			150	648	2.5%	564	38%
18	Field Period Assembly	14,407	2,841	1,876	135	1,195	6,047	23.5%	5,262	37%
19	Stellarator Core Mgmt & Integr	2,250	232	796		0	1,028	4.0%	894	40%
2	Auxiliary Systems	1,017	270			0	270	1.0%	235	23%
3	Diagnostics	806	113			0	113	0.4%	98	12%
4	Electrical Power Systems	2,719	247			163	409	1.6%	356	13%
5	I&C Systems	2,095	306			0	306	1.2%	267	13%
6	Facility Systems	2,422	1,132			0	1,132	4.4%	985	41%
7	Test Cell Prep & Machine Assy	8,582	3,119	1,876	135	730	5,861	22.8%	5,100	59%
8	Project Management & Integration	15,137	1,763	5,401		145	7,309	28.4%	6,360	42%
	Total	61,794	12,070	9,950	270	3,465	25,755	100.0%	22,410	36%

APPENDIX A

COST ESTIMATE UNCERTAINTY RANGES

WBS2	Job	WBS4	Maturity	Complexity	ETC (ML)	Estimate Uncertainty Range	
						Low	High
12	1204 - Job: 1204 - VV Sys Procurements (nonVVSA)	122 - Thermal Insulation	H	L	220	209	242
	1204 - Job: 1204 - VV Sys Procurements (nonVVSA)	124T - Heater Tape for Port Stub	H	L			
	1204 - Job: 1204 - VV Sys Procurements (nonVVSA)	124U - T/C and Heater Tape Leads	H	L			
	1204 - Job: 1204 - VV Sys Procurements (nonVVSA)	124V - Spacer Flux Loops & Boxes	H	L			
	1204 - Job: 1204 - VV Sys Procurements (nonVVSA)	125 - VV Local I&C	H	L			
	1250 - Job: 1250 - Vacuum Vessel Fabrication**CLOS	-	FROZEN				
	1260 - Job: 1260 NB Transition Ducts- GORANSON	-	M	L	566	509	651
	1270 - Job: 1270 - Heater Control System-GORANSO	-	M	L	642	578	738
13	1302 - Job: 1302 - PF Design -KALISH	-	H	L	91	86	100
	1302 - Job: 1302 - PF Design -KALISH	RBLX - FY07 Rebaseline Exercise	FROZEN				
	1352 - Job: 1352 - PF Coil Procurement-CHRZANOW	13P - PF Coil Fabrication	H	L	1,638	1,556	1,802
	1353 - Job: 1353 - CS Structure Procurement-DAHLG	132A - CS Support Structure	H	L	358	340	394
	1354 - Job: 1354 - Trim Coil Design &Procurement-K	TRIM - Trim Coil **Updated estimate**	M	L	1,433	1,290	1,648
	1355 - Job: 1355 - WBS 13 I&C Proc and Coil Assy-C	134 - TF/PF Loacl I&C	M	L	109	98	125
	1361 - Job: 1361 - TF Fabrication-KALISH	-	FROZEN				
	1361 - Job: 1361 - TF Fabrication-KALISH	130 - TF Title III and Fabrication Oversight	H	M	153	138	176
	1361 - Job: 1361 - TF Fabrication-KALISH	13Y - TF Fabrication Contract	H	M	474	427	545
	1361 - Job: 1361 - TF Fabrication-KALISH	RBLX - FY07 Rebaseline Exercise	FROZEN				
14	1404 - Job: 1404 - MCWF R&D 1st Prod Casting**CL	-	FROZEN				
	1408 - Job: 1408 - MC Winding Supplies-CHRZANOV	-	L	L	123	105	154
	1411 - Job: 1411 - MCWF Fabr. S005242-HEITZENR	-	Closed				
	1416 - Job: 1416 - Mod Coil Type AB Fnl Dsn-WILLIA	MCDB - Clamp hardware modifications	H	L			
	1416 - Job: 1416 - Mod Coil Type AB Fnl Dsn-WILLIA	MCDC - Blanket thermal insulation	H	L			
	1416 - Job: 1416 - Mod Coil Type AB Fnl Dsn-WILLIA	MCDE - Top level assy models/drawings	H	L	10	10	11
	1416 - Job: 1416 - Mod Coil Type AB Fnl Dsn-WILLIA	MCDF - Analysis and closeout documentation	H	L	122	116	134
	1416 - Job: 1416 - Mod Coil Type AB Fnl Dsn-WILLIA	TCCO - Type C Design Closeout	H	L	7	7	8
	1421 - Job: 1421 - Mod Coil Interface Design-WILLIA	-	L	M	23	18	32
	1421 - Job: 1421 - Mod Coil Interface Design-WILLIA	142B - Outboard Interface-Bolted Joint Tests-Tension	L	M	2	2	3
	1421 - Job: 1421 - Mod Coil Interface Design-WILLIA	142C - Outboard Interface-Bolted Joint Tests-Shear	L	M			
	1421 - Job: 1421 - Mod Coil Interface Design-WILLIA	142F - Inboard Interface-AB/BC/AA	L	M	4	3	6
	1421 - Job: 1421 - Mod Coil Interface Design-WILLIA	142G - Inboard Interface-CC	L	M		Included above	
	1421 - Job: 1421 - Mod Coil Interface Design-WILLIA	142H - Weld Access test	L	M			
	1421 - Job: 1421 - Mod Coil Interface Design-WILLIA	142Z - Outboard Interface	L	M			
	1429 - Job: 1429 - MC Interface R&D-DUDEK	142D - Outboard Interface-Friction	Closed		4	FROZEN	
	1431 - Job: 1431 - Mod. Coil Interface Hardware-DUI	BLAD - Bladders	H	M	5	5	6
	1431 - Job: 1431 - Mod. Coil Interface Hardware-DUI	BUSH - Bushings	H	M	19	17	22
	1431 - Job: 1431 - Mod. Coil Interface Hardware-DUI	PUCK - Pucks	H	M	36	32	41
	1431 - Job: 1431 - Mod. Coil Interface Hardware-DUI	SHMS - Shims-Outboard	H	M	593	534	682
	1431 - Job: 1431 - Mod. Coil Interface Hardware-DUI	SHMT - Shims-Inboard	H	M	131	118	151
	1431 - Job: 1431 - Mod. Coil Interface Hardware-DUI	SHMU - Shims- C-C Joint	H	M	28	25	32
	1431 - Job: 1431 - Mod. Coil Interface Hardware-DUI	STUD - Studs Washers Nuts	H	M	143	129	164
	1431 - Job: 1431 - Mod. Coil Interface Hardware-DUI	TECH - Misc Tech Shop Support	H	M	119	107	137
	1451 - Job: 1451 - Mod Coil Winding-CHRZANOWSK	1 - Station 1 Post VPI	H	H	912	775	1,140
	1451 - Job: 1451 - Mod Coil Winding-CHRZANOWSK	1A - Station 1a/4 Casting Prep	H	H		Included above	
	1451 - Job: 1451 - Mod Coil Winding-CHRZANOWSK	2 - Station 2-Winding Instl Chill Plates Tubing Bag	H	H		Included above	
	1451 - Job: 1451 - Mod Coil Winding-CHRZANOWSK	3 - Station 3-Winding Instl Chill Plates Tubing Bag	H	H		Included above	
	1451 - Job: 1451 - Mod Coil Winding-CHRZANOWSK	5 - Station 5-VPI	H	H		Included above	
	1451 - Job: 1451 - Mod Coil Winding-CHRZANOWSK	LABR - LOE Oversight & Supervision	H	H		Included above	
	1459 - Job: 1459 - Mod Coil Fabr.Punch List-CHRZAI	PLCT - Punchlist- Coil Technicians	M	L	282	254	324
	1459 - Job: 1459 - Mod Coil Fabr.Punch List-CHRZAI	PLTS - Punchlist Tech shop/RESA	M	L		Included above	
15	1501 - Job: 1501 - Coil Structures Design-DAHLGRE	-	M	L	90	81	104
	1550 - Job: 1550 - Coil Struct. Procurement -DAHLGI	-	M	L	1,440	1,296	1,656
16	1601 - Job: 1601 - Coil Services Design-GORANSOI	161 - 161 - LN2 Distribution	H	L	306	291	337
	1601 - Job: 1601 - Coil Services Design-GORANSOI	162 - 162 - Electrical Leads	M	L	745	671	857
	1601 - Job: 1601 - Coil Services Design-GORANSOI	163 - 163 - Coil Protection System	H	L	31	29	34
	1601 - Job: 1601 - Coil Services Design-GORANSOI	RBLX - FY07 Rebaseline Exercise	H	L			
17	1701 - Job: 1701 - Cryostat Design-RAFTOPOLOUS	-	L	H	580	406	928
	1702 - Job: 1702 - Base Support Struct Design-DAHL	-	H	L	139	132	153
	1751 - Job: 1751 - Cryostat Procurement-RAFTOPOI	-	H	L	550	523	605
	1752 - Job: 1752 - Base Support Proc-DAHLGREN	172 - 172 - Base Support Structure	H	L	231	219	254
18	1802 - Job: 1802 - FP Assy Oversight&Support-VIOL	A - Oversight and Supervision	H	M	3,826	3,443	4,400
	1803 - Job: 1803/1805- FPA Tooling/Constr-BROWN/	3.00 - Station 3-Modular Coil to VVSA Assembly	M	L	250	225	288
	1803 - Job: 1803/1805- FPA Tooling/Constr-BROWN/	5.00 - Station 5-Final Field Period Assembly	M	L	203	183	233
	1803 - Job: 1803/1805- FPA Tooling/Constr-BROWN/	6.00 - 6.00-Final Machine Assembly	L	M	541	433	757
	1806 - Job: 1806 - FP Assembly specs and drawings-	-	M	M	54	46	68
	1806 - Job: 1806 - FP Assembly specs and drawings-	1.00 - 1.00-VV Prep Station	M	M	19	16	24
	1806 - Job: 1806 - FP Assembly specs and drawings-	2.00 - Station 2-Modular Coil Sub- Assembly	M	M	2	2	3
	1806 - Job: 1806 - FP Assembly specs and drawings-	3.00 - Station 3-Modular Coil to VVSA Assembly	M	M	30	26	38
	1806 - Job: 1806 - FP Assembly specs and drawings-	5.00 - Station 5-Final Field Period Assembly	M	M	114	97	143
	1806 - Job: 1806 - FP Assembly specs and drawings-	6.00 - 6.00-Final Machine Assembly	M	M	137	116	171
	1810 - Job:1810-Field Period Assy -Station 1 2 3 VIC	S0P0 - General Assy Support	H	M	1,946	1,751	2,238
	1810 - Job:1810-Field Period Assy -Station 1 2 3 VIC	S1P1 - Station 1-VV Prep (hard surface components) F	H	M	552	497	635
	1810 - Job:1810-Field Period Assy -Station 1 2 3 VIC	S1P2 - Station 1- VV Prep (hrd surf cmpntsFP#2	H	M		Included above	
	1810 - Job:1810-Field Period Assy -Station 1 2 3 VIC	S1P3 - Station 1- VV Prep (hrd surf cmpntsFP#3	H	M		Included above	
	1810 - Job:1810-Field Period Assy -Station 1 2 3 VIC	S1SP - Station 1-Spool pieces (3) (spacers)	H	M		Included above	
	1810 - Job:1810-Field Period Assy -Station 1 2 3 VIC	S2H1 - Station 2 MC subassy A1B1C1	M	H	414	331	580
	1810 - Job:1810-Field Period Assy -Station 1 2 3 VIC	S2H2 - Station 2 MC subassy A2B2C2	M	H	314	251	440
	1810 - Job:1810-Field Period Assy -Station 1 2 3 VIC	S2H3 - Station 2 MC subassy A3B3C3	M	H	317	254	444
	1810 - Job:1810-Field Period Assy -Station 1 2 3 VIC	S2H4 - Station 2 MC subassy A4B4C4	M	H	311	249	435

WBS2	Job	WBS4	Maturity	Complexity	ETC (ML)	Low	High
	1810 - Job:1810-Field Period Assy -Station 1 2 3 VIC	S2H5 - Station 2 MC subassy A5B5C5	M	H	312	250	437
	1810 - Job:1810-Field Period Assy -Station 1 2 3 VIC	S2H6 - Station 2 MC subassy A6B6C6	M	H	310	248	434
	1810 - Job:1810-Field Period Assy -Station 1 2 3 VIC	S2PM - Pre-Measuring and fitup checks	M	H	323	258	452
	1810 - Job:1810-Field Period Assy -Station 1 2 3 VIC	S2PR - Station 2 Trials & Development	M	H			
	1810 - Job:1810-Field Period Assy -Station 1 2 3 VIC	S2PX - Setup	H	H	967	822	1,209
	1810 - Job:1810-Field Period Assy -Station 1 2 3 VIC	S3P0 - Station 3 Setup/Preparations/General	M	H	188	150	263
	1810 - Job:1810-Field Period Assy -Station 1 2 3 VIC	S3P1 - Station 3-Assemble Mod Coils and VVSA-FP#1	M	H	585	468	819
	1810 - Job:1810-Field Period Assy -Station 1 2 3 VIC	S3P2 - Station 3-Assemble Mod Coils and VVSA-FP#2	M	H	408	326	571
	1810 - Job:1810-Field Period Assy -Station 1 2 3 VIC	S3P3 - Station 3-Assemble Mod Coils and VVSA-FP#3	M	H	398	318	557
	1815 - Job: 1815 - Field Period Assy -Station 5-VIOL	S4P0 - Setup/Preparations/General	L	M	294	235	412
	1815 - Job: 1815 - Field Period Assy -Station 5-VIOL	S4P1 - Station 5- Final FP Assy -FP#1 (in NCSX TC)	L	M	534	427	748
	1815 - Job: 1815 - Field Period Assy -Station 5-VIOL	S4P2 - Station 5- Final FP Assy -FP#2 (in NCSX TC)	L	M	534	427	748
	1815 - Job: 1815 - Field Period Assy -Station 5-VIOL	S4P3 - Station 5- Final FP Assy -FP#3 (in NCSX TC)	L	M	524	419	734
19	1901 - Job: 1901 - Stellarator Core Mngtt&Integr-COL	191 - 191 - Stellarator Core Management & Oversight	H	L	941	894	1,035
	1901 - Job: 1901 - Stellarator Core Mngtt&Integr-COL	192 - 192 - Stellarator Core Integr & Global Analysis	H	L	1,309	1,244	1,440
21	2101 - Job: 2101 - Fueling Systems-BLANCHARD	-	L	L	334	284	418
22	2201 - Job: 2201 - Vacuum Pumping Systems-BLAN(	-	L	L	683	581	854
31	3101 - Job: 3101 - Magnetic Diagnostics-STRATTON	124U - T/C and Heater Tape Leads	H	L	47	45	52
	3101 - Job: 3101 - Magnetic Diagnostics-STRATTON	124V - Spacer Flux Loops & Boxes	H	L	56	53	62
	3101 - Job: 3101 - Magnetic Diagnostics-STRATTON	MD2 - Modular Coil C-wound Loops	H	L	18	17	20
	3101 - Job: 3101 - Magnetic Diagnostics-STRATTON	MD3 - Rogowski Coils	H	L	180	171	198
	3101 - Job: 3101 - Magnetic Diagnostics-STRATTON	MD4 - TF and PF Co-wound Loops	H	L	46	44	51
	3101 - Job: 3101 - Magnetic Diagnostics-STRATTON	VLPB - Voltage Loops & Protective Boxes	H	L	62	59	68
36	3601 - Job: 3601 - Edge Divertor Diagnostics-STRAT	-	M	L	29	26	33
38	3801 - Job: 3801 - Electron Beam Mapping-STRATT(	-	M	M	257	218	321
39	3901 - Job: 3901 - Diagnostics sys Integration-STRA1	-	H	L	111	105	122
41	4101 - Job: 4101 - AC Power-RAMAKRISHNAN	-	FROZEN				
	4101 - Job: 4101 - AC Power-RAMAKRISHNAN	411 - 411 - Auxiliary AC Power Systems	H	L	120	114	132
	4101 - Job: 4101 - AC Power-RAMAKRISHNAN	412 - 412 - Experimental AC Power Systems	H	L	36	34	40
43	4301 - Job: 4301 - DC Systems-RAMAKRISHNAN	431 - 431 - C-Site DC Systems	H	L	577	548	635
44	4401 - Job: 4401 - Control & Protection-RAMAKRISH	441 - 441 - Electrical Interlocks	M	L	482	434	554
	4401 - Job: 4401 - Control & Protection-RAMAKRISH	442 - 442 - Kirk Key Interlocks	M	L	69	62	79
	4401 - Job: 4401 - Control & Protection-RAMAKRISH	443 - 443 - Real Time Control Systems	M	L	14	13	16
	4401 - Job: 4401 - Control & Protection-RAMAKRISH	444 - 444 - Instrument Systems	M	L	241	217	277
	4401 - Job: 4401 - Control & Protection-RAMAKRISH	445 - 445 - Coil Protection Systems	M	L	276	248	317
45	4501 - Job: 4501 - Power Sys Dsn & Integr-RAMAKR	451 - 451 - System Design & Interfaces	H	L	319	303	351
	4501 - Job: 4501 - Power Sys Dsn & Integr-RAMAKR	452 - 452 - Electrical Systems Support	H	L	199	189	219
	4501 - Job: 4501 - Power Sys Dsn & Integr-RAMAKR	453 - 453 - System Testing (PTP's)	H	L	386	367	425
51	5101 - Job: 5101 - Network and Fiber Infrastruct-SICI	-	M	L	222	200	255
52	5201 - Job: 5201 - I&C Systems-SICHTA	-	M	L	411	370	473
53	5301 - Job: 5301 - Data Acquisition-SICHTA	-	M	L	165	149	190
54	5401 - Job: 5401 - Facility Timing & Synchron.-SICHT	-	M	M	357	303	446
55	5501 - Job: 5501 - Real Time Control System-SICHT/	-	M	L	503	453	578
56	5601 - Job: 5601 - Central Safety &Interlock Sys-SIC	-	L	L	372	316	465
58	5801 - Job: 5801 - Central I&C Integr& Oversight-SIC	-	H	L	65	62	72
61	6101 - Job: 6101 - Water Systems-DUDEK	613 - 613 - Vacuum Pumping System	M	L	113	102	130
62	6201 - Job: 6201 - Cryogenic Syst-RAFTOPOLOUS	621 - 621 - LN2 -LHe Supply & LN2 coil cooling supply	L	H	803	562	1,285
	6201 - Job: 6201 - Cryogenic Syst-RAFTOPOLOUS	623 - 623 - GN2 Cryostat Cooling System	L	H	764	535	1,222
63	6301 - Job: 6301 - Utility Systems-DUDEK	-	M	L	109	98	125
64	6401 - Job: 6401 - PFC/VV Htng/Cooling(bakeout)- K	-	L	M	633	506	886
73	7301 - Job: 7301 - Platform Design & Fab-PERRY	-	H	L	212	201	233
74	7401 - Job: 7401 - TC Prep & Mach Assy Planning-PI	-	L	M	2,323	1,858	3,252
75	7501 - Job: 7501 - Construction Support Crew-PERR	S0P0 - General Assy Support	L	M	1,323	1,058	1,852
	7503 - Job: 7503 - Machine Assembly (station 6)-PEF	6S1 - 1.0 - Component Preparation	L	M	4,318	3,454	6,045
	7503 - Job: 7503 - Machine Assembly (station 6)-PEF	6S10 - 10.0 - Type-C Shim Sizing/Prep	L	M		Included above	
	7503 - Job: 7503 - Machine Assembly (station 6)-PEF	6S11 - 11.0 - Type-C Inboard Shim Installation Check	L	M		Included above	
	7503 - Job: 7503 - Machine Assembly (station 6)-PEF	6S12 - 12.0 - Install Remaining TF Coils	L	M		Included above	
	7503 - Job: 7503 - Machine Assembly (station 6)-PEF	6S13 - 13.0 - Install PF-4 Lwr & Solenoid suprt column	L	M		Included above	
	7503 - Job: 7503 - Machine Assembly (station 6)-PEF	6S14 - 14.0 - Move all Periods to installed position	L	M		Included above	
	7503 - Job: 7503 - Machine Assembly (station 6)-PEF	6S15 - 15.0 - Move VV Period to final position and Wel	L	M		Included above	
	7503 - Job: 7503 - Machine Assembly (station 6)-PEF	6S16 - 16.0 - Move TF Coils to final position	L	M		Included above	
	7503 - Job: 7503 - Machine Assembly (station 6)-PEF	6S17 - 17.0 - Install Lower PF Colis	L	M		Included above	
	7503 - Job: 7503 - Machine Assembly (station 6)-PEF	6S18 - 18.0 - Transfer Weight to Final Machine Suppor	L	M		Included above	
	7503 - Job: 7503 - Machine Assembly (station 6)-PEF	6S19 - 19.0 - Vacuum Pump System	L	M		Included above	
	7503 - Job: 7503 - Machine Assembly (station 6)-PEF	6S2 - 2.0 - Test Cell Metrology set-up/deflection test	L	M		Included above	
	7503 - Job: 7503 - Machine Assembly (station 6)-PEF	6S20 - 20.0 - MC/VVSA Annulus insulation fill	L	M		Included above	
	7503 - Job: 7503 - Machine Assembly (station 6)-PEF	6S21 - 21.0 - Instl Remaining Trim Coils & Mag struct	L	M		Included above	
	7503 - Job: 7503 - Machine Assembly (station 6)-PEF	6S22 - 22.0 - Install solenoid & Remaining PF Coils	L	M		Included above	
	7503 - Job: 7503 - Machine Assembly (station 6)-PEF	6S23 - 23.0 - Instl/Route Mag Leads to Transition Box	L	M		Included above	
	7503 - Job: 7503 - Machine Assembly (station 6)-PEF	6S24 - 24.0 - Install LN2 and I&C Services	L	M		Included above	
	7503 - Job: 7503 - Machine Assembly (station 6)-PEF	6S25 - 25.0 thru 35.0 - Cryostat NB duct & I&C Routing	L	M		Included above	
	7503 - Job: 7503 - Machine Assembly (station 6)-PEF	6S3 - 3.0 - Pre-installation set-up and test	L	M		Included above	
	7503 - Job: 7503 - Machine Assembly (station 6)-PEF	6S4 - 4.0 - FPA-1 Installation and Assembly Test	L	M		Included above	
	7503 - Job: 7503 - Machine Assembly (station 6)-PEF	6S5 - 5.0 - Spool piece installation test	L	M		Included above	
	7503 - Job: 7503 - Machine Assembly (station 6)-PEF	6S6 - 6.0 - Spool piece flange machining	L	M		Included above	
	7503 - Job: 7503 - Machine Assembly (station 6)-PEF	6S7 - 7.0 - FPA-2 Installation	L	M		Included above	
	7503 - Job: 7503 - Machine Assembly (station 6)-PEF	6S8 - 8.0 - FPA-3 Installation	L	M		Included above	
	7503 - Job: 7503 - Machine Assembly (station 6)-PEF	6S9 - 9.0 - Measure Type-C MC Flanges	L	M		Included above	
76	7601 - Job: 7601 - Tooling Design & Fabrication-PER	-	H	L	406	386	447
81	8101 - Job: 8101 - Project Management &Control-AN	-	H	L	4,156	3,948	4,572
	8101 - Job: 8101 - Project Management &Control-AN	RBLX - FY07 Rebaseline Exercise	FROZEN				

WBS2	Job	WBS4	Maturity	Complexity	ETC (ML)	Low	High
	8102 - Job: 8102 - NCSX MIE Management ORNL-LY	-	H	L	661	628	727
82	8202 - Job: 8202 - Engr Mgmt & Sys Eng Sprt-HEITZ	-	H	L	3,253	3,090	3,578
	8203 - Job: 8203 - Design Integration-BROWN	-	M	M	2,583	2,196	3,229
	8204 - Job: 8204 - Systems Analysis-BROOKS	-	M	M	1,034	879	1,293
	8205 - Job: 8205 - Dimensional Control Coordin-ELLI	-	M	H	541	433	757
	8210 - Job: 8210 - FY07 Rebaseling tasks	RBLX - FY07 Rebaseline Exercise	FROZEN				
	8215 - Job: 8215 Plant Design	RBLX - FY07 Rebaseline Exercise	FROZEN		193	FROZEN	
85	8501 - Job: 8501 - Integrated Systems Testing-GENT	PROC - Startup Documentation	H	L	343	326	377
	8501 - Job: 8501 - Integrated Systems Testing-GENT	SU - Start-up	H	L	450	428	495
89	8998 - Job: 8998 - Allocations-STRYKOWSKY	-	H	L	1,923	1,827	2,115
					61,794	54,041	75,490
			Estimating Process Uncertainty		-	-1%	3%
				ETC=	61,794	53,500	77,755
				Cost thru 1/31/08=	76,365	-13%	26%
				EAC=	138,159		

APPENDIX B

SCHEDULE UNCERTAINTY RANGES

NCSX Schedule Uncertainty Model

Schedule Activity		start	finish	Base Duration (mos) on Critical Path	Estimate Uncertainty	Duration Range Low	Duration Range High	Schedule Calc	Schedule Duration	Mitigation Cost Adder	Add'l second shift available (months)
CP (within 1/2 month of CP)											
Job -1810 Field Period Assembly Stations 1,2,3	Station 2 MC Sub-assy A1/B1/C1	2/1/08	11/18/08	9.6	MH	7.7	13.4	10.9	10.9	0	
	Station 2 MC Sub-assy A3/B3/C3	11/18/08	4/13/09	4.8	MH	3.8	6.7	5.5	5.5	0	
	Station 2 MC Sub-assy A6/B6/C6	4/13/09	11/3/09	6.7	MH	5.4	9.4	7.7	7.7	0	
	Station 3 Assemble Mod Coils and VVSA FP#3	11/3/09	3/24/10	4.6	MH	3.7	6.5	5.3	4.6	42	2
Job - 1815 Field Period Assembly Station 5	Station 5 Final Assembly FP#3	3/24/10	8/11/10	4.6	LM	3.7	6.4	5.3	4.6	42	1.5
Job 7503 Final Machine Assembly (Station 6)		8/11/10	11/11/11	15.0	LM	12.0	21.0	17.2	15.7	96	1.5
Job 8501 - Integrated System Testing		11/11/11	12/13/11	1.1	HL	1.0	1.2	1.1	1.1	0	
			46.4	46.4		37.3	64.6		50.1	181.0	

Estimated Cost per month for Schedule Stretch ***525.0 thousand***

APPENDIX C

RISK MODEL INPUTS

NCSX Risk Register

No.	Affected Jobs (absorb the impacts)	Risk Description	Likelihood of Occurrence	Cost Impact ($k)	Critical Path Schedule Impact (mos)
MANAGEMENT & ORGANIZATION RISKS					
Mgmt-1		Loss or prolonged unavailability of certain key personnel from the project could substantially impact the schedule.			
a	1901	Mike Cole (ORNL) Loss of "corporate memory" of stellarator core design intent, delayed turnaround on Title III issues andproblem resolution might impact FPA schedule.	VU	$0	+0.50
b	1810 7503	Tom Brown, Art Brooks, Bob Ellis "Back office" support for FPA and final assembly becomes a chronic bottleneck, stretching out the time required to complete assembly operations	VU	$0	+2.00
c	8202	Phil Heitzenroeder (PPPL)	VU	$0	+0.50
d	8101	Ron Strykowsky	VU	$115	+0.00

NCSX Risk Register

No.	Affected Jobs (absorb the impacts)	Risk Description	Likelihood of Occurrence	Cost Impact ($k)	Critical Path Schedule Impact (mos)
e	5301 5401 5501 5601	Loss of staff with experience in specialized software delays operation of Central I&C system.	VU	$0	+0.50
f	1901 8203	Design integration effort needs to increase to manage space allocations inside the cryostat and in the test cell	VU	$300	+0.00
Mgmt-2	4501	Loss of knowledgeable staff delays operation of legacy power supplies.	VU	$0	+0.50
Mgmt-3	8101	Labor rates may be significantly lower than projected Opportunity	U	($1,000)	+1.00
Mgmt-4	8101	GPP projects not completed in time to support project needs	NC	$0	+1.00
Mgmt-5	8101	CR may delay funding to project.	U	$0	+2.00

NCSX Risk Register

No.	Affected Jobs (absorb the impacts)	Risk Description	Likelihood of Occurrence	Cost Impact ($k)	Critical Path Schedule Impact (mos)
TECHNICAL RISK - Generic Assembly Risks					
Assy-1	1810	Station 3: cost and schedule grows when Assembly Sequence Plan fully matures	VL	$240	+0.68
Assy-2	1815	Station 5: cost and schedule grows when Assembly Sequence Plan fully matures	VL	$500	+1.13
Assy-3	7503	Station 6: cost and schedule grows when Assembly Sequence Plan fully matures	VL	$650	+2.18
Assy-4	1810/ 1815 7503	Photogrammetry replaces laser tracker for some operations and saves time and money. (Opportunity)	L	($901)	(3.0)
Assy-5	1810/ 1815 7503	Assembly delayed due to metrology equipment breakdowns or anomalies.	L	$0	+1.00
Assy-6	1810 1815 7503	General purpose tooling/ lifting equipment (e.g. cranes) not available to support the schedule.	U	$0	+0.50

NCSX Risk Register

No.	Affected Jobs (absorb the impacts)	Risk Description	Likelihood of Occurrence	Cost Impact ($k)	Critical Path Schedule Impact (mos)
Assy-7	1302/1352 1354	Permeability of components outside 3m from machine to test cell walls exceed the permeability limit of mu = 1.2.	U	$200	+0.00
TECHNICAL RISKS - Station 2 Assembly					
Stat2-2	1810	Station 2: Unacceptable distortion in a field period when welding modular coil shims requiring rework and or chair installation.	**U**	$135	+1.00
Stat2-3	1810	Station 2. Unacceptable distortion in a field period when welding modular coil shims requiring complete disassembly and redesign and reassembly	**VU**	$150	+3.00
Stat2-5	1810	Station 2. Risk of loss of weld equipment or trained personnel.	NC	+ $0	+0.25
Stat2-7	1810	Station 2. Shim sets not adequate or fail - need to fabricate more shims and measure and test	U	$0	+1.00
Stat2-9	1810	Station 2 - shim bag rupture & requires replacement	VU	$200	+3.00
Stat2-10	1810	Station 2. Nose opens up while tightening outboard bolts	U	$0	+0.50
Stat2-11	1810	Station 2. Nose opens up while tightening outboard bolts. Change bolt tightening sequence is not adequate	U	$0	+1.00

NCSX Risk Register

No.	Affected Jobs (absorb the impacts)	Risk Description	Likelihood of Occurrence	Cost Impact ($k)	Critical Path Schedule Impact (mos)
Stat2-13	1810	Station 2. Modular coil damaged during assembly requiring significant rework to coil. (Complete coil re-fabrication excluded)	L	$50	+0.00

No.	Affected Jobs (absorb the impacts)	Risk Description	Likelihood of Occurrence	Cost Impact ($k)	Critical Path Schedule Impact (mos)
Stat2-14	1810	Station 2. Modular coil damage requiring coil re-fabrication.	N/A		
Stat2-15	1810 7503	Issues reported by W-7X: Loss of bolt tension with time (are we missing something in our tests?) Hot cracking of cast parts due to welding- check with dye penetrant.	VU	$30	+0.00
TECHNICAL RISKS - Station 3 Assembly					
Stat3-1	1810	Station 3: vertical weld distortion excessive. Have to take apart, modify design or procedure, re-weld.	L	$70	+1.00
Stat3-2	1810	Station 3. Problems installing coils over vacuum vessel. Trajectory following scheme does not work like the concrete block. Have to re-invent.	VU	$35	+0.50
Stat3-3	1810	Station 3. VV surface component (coolant tube, flux loop, or TC) damaged during FPA requiring significant rework. (Note: There is only 0.2" of clearance currently projected.)	VU	$20	+0.50
Stat3-4	1810	Station 3. Interferences discovered during assembly; components don't go together as planned. Assemblies have to be taken apart, components moved or re-worked, re-assembled.	U	$0	+0.50
Stat3-5	1810	Station 3. Sag distortion while MCHP are vertical in station 3	U	$25	+1.00
Stat3-6	1810	Station 3. Assembly tooling allows too much deflection and has to be redesigned.	VU	$50	+1.00
TECHNICAL RISKS - Station 5 Assembly					

No.	Affected Jobs (absorb the impacts)	Risk Description	Likelihood of Occurrence	Cost Impact ($k)	Critical Path Schedule Impact (mos)
Stat5-1	1815	Station 5: Trim coils not available when needed in field period assembly sequence. Have to implement workaround.	U	$0	+0.50
Stat5-2	1815	Station 5. TF Coils cannot be aligned	U	$0	+1.00
Stat5-3	1815	Station 5. TF coils become warped and have to be racked to restore proper geometry.	U	$60	+0.50
Stat5-5	1815	Station 5. Problems installing ports due to interferences. Have to move components or modify ports.	L	$250	+0.00
Stat5-6	1815	Station 5. Interferences discovered during assembly; components don't go together as planned. Assemblies have to be taken apart, components moved or re-worked, re-assembled.	VU	$30	+0.00
Stat5-7	1815	Station 5: Multiple vacuum leaks during initial pumpdown	L	$25	+0.00
Stat5-8	1815 7503	Station 5. Rework/replacement of high permeability components	U	$200	+0.00
Stat5-9	1815	Station 5. Field period damaged during loading, transport, or unloading from TFTR TC to NCSX TC	N/A		
TECHNICAL RISKS - Station 6 Assembly					
Stat6-2	7503	Station 6. Original base structure vendor(s) unable to deliver on schedule; not available when needed in machine assembly sequence. Have to implement workaround.	VU	$50	+0.00
Stat6-3	7503	Station 6. PF 5L & 6L not available when needed in machine assembly sequence. Have to implement workaround.	NC	$0	+0.25

NCSX Risk Register

No.	Affected Jobs (absorb the impacts)	Risk Description	Likelihood of Occurrence	Cost Impact ($k)	Critical Path Schedule Impact (mos)
Stat6-4	7503	Station 6. PF coils out of round or not flat. Supports have to be modified.	NC	$0	+0.25
Stat6-5	7503	Station 6. PF 4L, 4U, 5U, 6U not available when needed in machine assembly sequence. Have to implement workaround.	NC	$0	+0.25
Stat6-6	7503	Station 6: Trim coils not available when needed in machine assembly sequence. Have to implement workaround.	NC	$0	+0.25
Stat6-7	7503	Station 6: Leads not available when needed in machine assembly sequence. Have to implement workaround.	NC	$0	+0.25
Stat6-8	7503	Station 6. High temperature Rogowski Loop damaged during installation resulting in loss of toroidal current measurement capability	VU	$0	+0.00
Stat6-9	7503	Station 6. Interferences discovered during assembly; components don't go together as planned. Assemblies have to be taken apart, components moved or re-worked, re-assembled.	L	$50	+1.00
Stat6-10	7503	Station 6. Problems making up vacuum vessel field joint. Have to re-machine spool piece.	U	$0	+3.00
Stat6-11	7503	Station 6. Retainer and pucks do not stay on flange during assembly and moving of half field periods. Potential safety risk if individuals are under the machine.	U	$30	+1.00
Stat6-12	7503	Station 6. Problems making up C-C joint. Interferences, bolt access problems.	U	$0	+0.25
Stat6-13	7503	Station 6. Pourable insulation installation problemss; can't get what we need, don't know if it fills all the voids, leaks out all over the place; have to invent methods to ensure complete fill and seal.	U	$0	+0.25

NCSX Risk Register

No.	Affected Jobs (absorb the impacts)	Risk Description	Likelihood of Occurrence	Cost Impact ($k)	Critical Path Schedule Impact (mos)
Stat6-14	7503	Station 6. Modular coils are shorted across toroidal break between field periods causing problematic field errors	NC	$25	+0.25
Stat6-15	7503	Station 6. Assembly sled for final assembly is not adequately stiff or does not provide repeatable motion	U	$75	+0.00
Stat6-16	7503	Station 6. Vacuum leaks occur. Takes time to locate and repair.	U	$0	+0.25
Stat6-17	7503	Welding of the Vacuum Vessel pieces to the spool pieces may require the addition of thin Inconel plates to bridge gaps caused by radial and/or angular out-of-tolerance consditions of either the VV or spool pieces.	VU	$50	+4.00

No.	Affected Jobs (absorb the impacts)	Risk Description	Likelihood of Occurrence	Cost Impact ($k)	Critical Path Schedule Impact (mos)
Stat6-18	7503	Friction shims in sizes needed for C-C joint not avaialble when needed.	VU	$0	+1.50
TECHNICAL RISKS - Startup					
S/U-1	8501	Unanticipated problems with cryostat penetrations (icing, excessive condensation). May require warming up the stellarator core to effect repair with consequent impacts to critical path activities.	U	$30	+1.00
S/U-2	8501	Coil cooling system fails to cool coil structure down to cryogenic temperature	U	$0	+1.00
S/U-3	8501	Insulation on modular coil fails during initial cooldown and testing requiring in situ repair.	VU	$150	+2.00
S/U-4	8501	Insulation on modular coil fails during initial cooldown and testing requiring stellarator core disassembly	N/A		
S/U-5	7503 1352 1361 8501	Insulation on TF/PF coil fails during initial cooldown and testing requiring in situ repair	VU	$150	+2.00

NCSX Risk Register

No.	Affected Jobs (absorb the impacts)	Risk Description	Likelihood of Occurrence	Cost Impact ($k)	Critical Path Schedule Impact (mos)
S/U-6	7503 1352 1361 8501	Insulation on TF/PF coil fails during initial cooldown and testing requiring dismantling stellarator core	NC		
S/U-7	8501	Coils are hooked up with incorrect polarity	NC	$0	+0.25
S/U-8	8501	Ground faults delay coil testing.	VL	$10	+0.25
S/U-9	8501	Loop faults delay coil testing.	L	$10	+0.25
S/U-10	8501	Control System problems delay testing	L	$10	+0.25
S/U-11	8501	Loss of a key component or system delays testing - e.g., pump failure	U	$50	+0.50

NCSX Risk Register

No.	Affected Jobs (absorb the impacts)	Risk Description	Likelihood of Occurrence	Cost Impact ($k)	Critical Path Schedule Impact (mos)
S/U-12	8501	Islands detected in e-beam mapping require troubleshooting and repair; delay CD-4.	N/A		
S/U-13	8501	Loss of a key component or system delays testing - e.g., turn to turn failure	N/A		
S/U-14	3801	E-beam mapping diagnostic is not installed and ready for use during start-up. Risk is possibly complex and challenging interface of hardware borrowed from Auburn University.	VU	$50	+1.00

No.	Affected Jobs (absorb the impacts)	Risk Description	Likelihood of Occurrence	Cost Impact ($k)	Critical Path Schedule Impact (mos)
TECHNICAL RISKS - Components & Systems					
Sys-2	1352	PF vendor produces a non-compliant coil requiring fabrication of an additional coil	VU	$35	+0.00
Sys-3	1361	TF vendor produces a non-compliant coil requiring fabrication of an additional coil	VU	+ $35	+0.00
Sys-4	1451	Failure of major piece of winding equipment (e.g., motor, gear box, etc.) resulting in extended downtime in a winding station	U	$30	+0.00
Sys-5	1451	Damage or loss of modular coil during VPI or testing requiring the conductor to be stripped off and re-wound.	N/A		
Sys-8	4301	Legacy power supplies unexpectedly require modifications or additional protection as a result of failure modes analysis.	U	$50	+0.00
Sys-9	4401	Coil protection system costs grow when requirements fully mature.	U	$35	+0.00
Sys-10	1260	NB Transition duct design is vintage and revisit could result in criteria changes, i.e. diagnostic requirements, number of ports, NB alignment, further design review, etc.	U	$60	+0.00
Sys-12	1601-162	Design of cables not firmly established, satisfying field error requirements could require more costly solutions and longer lead time.	L	$60	+0.00
Sys-13	1550	Escalation of Stainless Sheet and Inconel higher than base escalation rates or due to foreign exchange rates.	VL	$495	+0.00
Sys-14	13XX 4, et al.	Escalation of Copper higher than base escalation rates or due to foreign exchange rates.	VL	$225	+0.00
Sys-16	1501 1353	Coil structure designs have to be modified after FDR to accommodate chanes in interfaces with coil services or cryostat.	L	$95	+0.00

No.	Affected Jobs (absorb the impacts)	Risk Description	Likelihood of Occurrence	Cost Impact ($k)	Critical Path Schedule Impact (mos)
Sys-17	1701	Cryostat costs grow once design matures and requirements are better understood.	U	$150	+0.00
Sys-21	1421 1431	The C-C joint may need to be re-designed if it turns out that the 2T, high beta load case is not the worst-case operating condition for the friction shims.	VU	$50	+0.00
Sys-22	1501 1353	Coil structure designs may have to be modified after FDR to accommodate fault modes.	U	$30	+0.00
TECHNICAL RISKS - Research Operations (post-CD4) => NOT PART OF MIE PROJECT					
Ops-1	8204	The operational flexibility of the machine may be limited if it turns out that the 2T, high beta load case is not the worst-case operating condition for the friction shims.	U	$50	+0.00
Ops-2	7503	Shield walls found to be inadequate. Limits operation conditions	VU	$150	+0.00

APPENDIX D

PROBABILISTIC MODEL RESULTS

Percentiles	Total ETC With Uncertainty Contingency	Risk Cost Contingency	Risk Schedule Contingency	Schedule Mitigation Cost Adder	Total Schedule Duration
0%	63,763	-980.57	-0.08	0.0	43.8
5%	66,479	615.00	4.73	26.7	46.6
10%	67,009	864.43	5.73	54.5	47.4
15%	67,370	1,054.43	6.48	78.2	47.9
20%	67,655	1,234.43	6.98	96.3	48.4
25%	67,916	1,390.00	7.48	98.4	48.8
30%	68,163	1,529.43	7.98	108.7	49.2
35%	68,383	1,644.43	8.48	118.7	49.6
40%	68,584	1,744.43	8.73	128.5	50.0
45%	68,797	1,815.00	9.23	138.2	50.3
50%	69,010	1,885.00	9.73	148.2	50.7
55%	69,219	1,959.43	9.98	158.2	51.1
60%	69,448	2,029.43	10.48	169.2	51.4
65%	69,664	2,125.00	10.98	180.7	51.9
70%	69,903	2,239.43	11.48	191.5	52.3
75%	70,153	2,384.43	11.98	198.2	52.9
80%	70,432	2,545.00	12.48	212.8	53.5
85%	70,747	2,700.00	13.23	224.8	54.2
90%	71,143	2,835.00	14.10	242.3	55.0
95%	71,781	3,000.00	15.48	271.5	56.3
100%	75,541	3,900.00	24.73	321.1	63.4

Schedule Contingency Adjustment (work Saturdays to mitigate)

	Unmitigated	Mitigated	Mitigation Cost
80% Uncertainty	7.1	5.9	7.3
80% Risk	12.5	10.4	12.7
90% Uncertainty	8.6	7.2	8.8
90% Risk	14.1	11.8	14.4
95% Uncertainty	9.9	8.2	10.1
95% Risk	15.5	12.9	15.8

APPENDIX E

SCHEDULE CONTINGENCY COSTING BASIS

Standing army calculation

WBS	JOB	Description	Cost/yr	Cost/mo.	
18/7	1802/1810/7401/7501	Field Period Assy & Machine assy	2376	198	average of the 2 assy op
19	1901	Stellarator core management	504	42	
81	8101	PPPL Management	912	76	
81	8102	ORNL Management	312	26	
82	8202	Engineering mgt	792	66	
82	8203	Design Integration	660	55	
82	8204	Systems Analysis	132	11	
82	8205	Dimensional control	60	5	
82	8215	Plant Design	60	5	
89	8998	Allocations	492	41	
				525	

Second Shift oversight,support, cost dif

Crane support, fixture setup, misc support	1.2 fte	$17
Field Supervision	1.0 fte	$25
Metrology crews (task dependent)	n/a	$0
Metrology engineer	.5 fte	$16
Shift differntial (@ 5fte crew size)		$7
		$64

APPENDIX F

BASIS FOR SPREAD OF CONTINGENCY BY FISCAL YEAR

Major Contributors to Uncertainty Contingency

		Spread of Dollars by Year						Weighted Contingency Spread by Year					
Job	%	2008	2009	2010	2011	2012		2008	2009	2010	2011	2012	
Job 7503 Total	24.1%	0%	0%	32%	54%	14%	100.0%	0	0	0.077668541	0.129503485	0.034277045	24.1%
Estimating Process Uncertainty	8.6%	23%	27%	28%	19%	3%	100.0%	0.019659751	0.02323209	0.023839823	0.016742642	0.002857035	8.6%
7401 - Job: 7401 - TC Prep & Mach Assy Planning	6.2%	5%	7%	23%	57%	9%	100.0%	0.0028157	0.00414386	0.014051934	0.035382187	0.005312641	6.2%
* S2H1 - Station 2 MC subassy A1B1C1	4.3%	85%	15%	0%	0%	0%	5%	0.036296795	0.00651481	0	0	0	4.3%
* S2H5 - Station 2 MC subassy A5B5C5	4.2%	0%	100%	0%	0%	0%	0%	0	0.04222752	0	0	0	4.2%
* S2H3 - Station 2 MC subassy A3B3C3	4.2%	46%	54%	0%	0%	0%	100.0%	0.019471606	0.02251818	0	0	0	4.2%
8203 - Job: 8203 - Design Integration-BROWN	4.0%	9%	30%	31%	25%	5%	100.0%	0.003505875	0.0119823	0.012325099	0.010237156	0.002197015	4.0%
* S2H4 - Station 2 MC subassy A4B4C4	4.0%	0%	100%	0%	0%	0%	100.0%	0	0.04022774	0	0	0	4.0%
* S2H2 - Station 2 MC subassy A2B2C2	4.0%	79%	21%	0%	0%	0%	100.0%	0.031681725	0.00827033	0	0	0	4.0%
* S2H6 - Station 2 MC subassy A6B6C6	3.9%	0%	88%	12%	0%	0%	100.0%	0	0.03476393	0.004711595	0	0	3.9%
1802 - Job: 1802 - FP Assy Oversight&Support-VI(	3.1%	21%	40%	38%	0%	0%	100.0%	0.006691266	0.01265915	0.012100177	0	0	3.1%
* S4P3 - Station 5- Final FP Assy -FP#3 (in NCSX	2.5%	0%	0%	100%	0%	0%	100.0%	0	0	0.024879878	0	0	2.5%
* S4P2 - Station 5- Final FP Assy -FP#2 (in NCSX	2.4%	0%	0%	100%	0%	0%	100.0%	0	0	0.02411466	0	0	2.4%
* S4P1 - Station 5- Final FP Assy -FP#1 (in NCSX	2.3%	0%	63%	37%	0%	0%	100.0%	0	0.01460175	0.008399239	0	0	2.3%
* S3P1 - Station 3-Assemble Mod Coils and VVSA	2.2%	0%	100%	0%	0%	0%	100.0%	0	0.02179389	0	0	0	2.2%
7501 - Job: 7501 - Construction Support Crew-PEI	2.0%	0%	0%	27%	64%	10%	100.0%	0	0	0.005281574	0.01267878	0.001890564	2.0%
621 - 621 - LN2 -LHe Supply & LN2 coil cooling su	1.9%	7%	19%	48%	25%	0%	100.0%	0.001442034	0.00374929	0.00925305	0.004854847	0	1.9%
* S3P2 - Station 3-Assemble Mod Coils and VVSA	1.7%	0%	60%	40%	0%	0%	100.0%	0	0.01024392	0.006955747	0	0	1.7%
* S3P3 - Station 3-Assemble Mod Coils and VVSA	1.7%	0%	11%	89%	0%	0%	100.0%	0	0.00179743	0.015235398	0	0	1.7%
8101 - Job: 8101 - Project Management &Control-/	1.7%	20%	32%	28%	18%	3%	100.0%	0.003279614	0.0052966	0.004743944	0.002968999	0.000476008	1.7%
623 - 623 - GN2 Cryostat Cooling System	1.5%	2%	46%	18%	34%	0%							
Other	9.3%	23%	27%	28%	19%	3%							
	100.0%			Total Uncertainty Contingency Spread				12.5%	26.4%	24.4%	21.2%	4.7%	89.2%
				Uncertainty Contingency			***$ 9,620***	***$ 1,201***	***$ 2,540***	***$ 2,343***	***$ 2,043***	***$ 452***	$ 8,579

Major Contributors to Cost Risk Contingency		**Job(s)**	Spread of Dollars by Year						Weighted Contingency Spread by Year					
			2008	2009	2010	2011	2012		2008	2009	2010	2011	2012	
Assy-4	39.9%	1810, 1815, 7503	18%	28%	28%	20%	5%	100.0%	0.073333657	0.111979222	0.113183669	0.079700024	0.021095041	39.9%
Mgmt-3	33.0%	8101	20%	32%	28%	18%	3%	100.0%	0.064542642	0.104236764	0.093360574	0.058429747	0.009367813	33.0%
Assy-3	6.9%	7503	0%	0%	32%	54%	14%	100.0%	0	0	0.022089752	0.036832157	0.009748753	6.9%
Sys-13	4.1%	15xx	21%	79%	0%	0%	0%	100.0%	0.014362491	0.05430817	0	0	0	6.9%
Assy-2	2.9%	1815	0%	33%	67%	0%	0%	100.0%	0	0.009404761	0.019436507	0	0	2.9%
Stat5-5	2.5%	1815	0%	33%	67%	0%	0%	100.0%	0	0.008174083	0.016893105	0	0	2.5%
Assy-7	1.7%	1302, 1352, 1354	0%	10%	43%	37%	10%	100.0%	0	0.001683578	0.007281816	0.006340107	0.001678103	1.7%
Stat5-8	1.4%	1815, 7503	0%	10%	43%	37%	10%	100.0%	0	0.001395452	0.006035614	0.005255068	0.001390914	1.4%
f	1.0%	1901, 8203	12%	29%	30%	24%	5%	100.0%	0.001292209	0.002992937	0.003119793	0.002511315	0.000475172	1.0%
Other	6.6%		23%	27%	28%	19%	3%	100.0%	0.015001489	0.017727385	0.018191118	0.012775572	0.002180077	6.6%

	Total	2008	2009	2010	2011	2012
Total Risk Spread		17%	31%	30%	20%	5%
Cost Risk Contingency	***$ 2,840***	***$ 479***	***$ 886***	***$ 851***	***$ 573***	***$ 130***
Schedule Contingency all in 2012	***$ 9,950***					***$ 9,950***
		2008	2009	2010	2011	2012
Total Contingency by Year	***$ 22,410***	***$ 1,680***	***$ 3,426***	***$ 3,194***	***$ 2,616***	***$ 10,533***
		7.5%	15.3%	14.3%	11.7%	47.0%
USE		***0%***	***12%***	***14%***	***41%***	***33%***

__Rationale__: 2008 is well underway at time ETC developed, and occurrences that require the application of contingency (uncertain estimates or realized risks) will likely cause work to shift out in time and require added funding in subsequent years, thus profile moved right. For 2009, assumed average of 2008 and 2009 shown above.

APPENDIX G

CRYSTAL BALL® REPORT

(Posted Separately)