National Compact Stellarator Experiment

NCSX

TEST AND EVALUATION PLAN

NCSX-PLAN-TEP-00

Draft D

May 2004

Prepared by: _____

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RECORD OF REVISIONS

Revision	Date	Originator	Description of Change
1		Gentile	Modify to include "Low Power Physics Testing" & Cryostat

1 PURPOSE AND SCOPE

The purpose of this Test and Evaluation Plan (TEP) is to identify those tasks, documents, actions, reviews required to start up NCSX in a safe, efficient, and compliant manner in accordance with PPPL policies, directives, procedures and DOE orders. It is expected that many of the items required to successfully start up NCSX would occur in parallel with NCSX construction. These tasks include development of NCSX specific procedures and documents including the development of pre-operational test procedures (PTPs) and configuration of existing C-Site and D-Site subsystems to support experimental operations.

Upon completion of construction, a Facility Start Up Integrated Systems Test Procedure will be executed to establish the readiness of the facility for First Plasma and subsequent experimental operations. This plan provides an overview of the Facility Start Up Integrated Systems Testing Program, the approval process to proceed to First Plasma, and cost and schedule estimates for accomplishing that program.

2 DEFINITIONS

2.1 END OF CONSTRUCTION

End of construction is defined as that physical condition when the NCSX device and facility are assembled. Appropriate sub-systems are available to support low power physics testing (as defined in section 2.3), the hardwired interlock system (HIS) and hardwired control system (HCS) are configured and available to support safe startup activities.

2.2 START UP

Start up is defined as that condition where the NCSX (Start Up) Test Director has assumed control of NCSX from the NCSX Construction Manager and has configured the device for low power physics testing and integrated systems testing as part of the initial facility start up. Such configuration should include access control in accordance with subsystem safing procedures.

2.3 LOW POWER PHYSICS TESTING

NCSX will undergo a series of low power (combined field) physics tests for machine characterization and to ensure the proper alignment of field coils prior to the installation of the NCSX cryostat. These tests will be limited to $\leq$ 10 % of the rated field coil operating current. No attempt will be made to produce plasmas during this low power physics testing phase.

Prior to the start of NCSX low power physics tests the PPPL Activity Certification Committee (ACC) will conduct a comprehensive review of the device to ensure the safety of personnel and the machine during the low power physics testing phase. Upon successful completion of the ACC review a recommendation will be made to the PPPL Environmental Safety & Health (ES&H) Executive Safety Board for the issuance of a limited safety certificate to support NCSX low power testing.

2.4 ISSUANCE OF A FIRST PLASMA / OPERATIONS SAFETY CERTIFICATE

The issuance of a First Plasma / Operations Safety Certificate by the PPPL ES&H Executive Safety Board should be secured at the completion of; low power physics testing, completed installation of the cryostat, and successful completion of the NCSX Operational Readiness Assessment (ORA). Upon issuance of a First Plasma / Operations Safety Certificate, and with concurrence with the NCSX Project Manager, the device can be configured for normal power operations in accordance with the successful conclusion of the startup ISTP for the purpose of producing a first plasma and subsequent plasma operations.

3 RELATED DOCUMENTS

This TEP draws on the documents listed below. Documents referenced are the latest issues of the:

NCSX Facility Start Up Integrated Systems Test Procedure (to be provided)

- NCSX Safety Assessment Document (to be provided)

PPPL ESHD-5008, "Environmental, Safety, and Health Manual"

NCSX Systems Engineering Management Plan (NCSX-PLAN-SEMP)

4 NCSX SUBSYSTEMS

Table 4-1 provides the listing of the NCSX subsystems that are required for First Plasma and assumed to be available and properly configured for operation before the start of the Facility Start Up Integrated Systems Test Procedure (ISTP).

Table 4-1 NCSX Subsystems Needed for Facility Start Up ISTP

WBS	Name
WBS 12	Vacuum Vessel Systems
WBS 13	Conventional Coil Systems
WBS 14	Modular Coil Systems
WBS 15	Coil Support Structure Systems
WBS 16	Coil Services
WBS 172	Base Support Structure Systems
WBS 211	Gas Fueling Systems
WBS 22	Torus Vacuum Pumping Systems
WBS 25	Neutral Beam Heating Systems
WBS 26	Electron Cyclotron Heating Systems
WBS 4	Power Systems
WBS 5	Central I&C Systems
WBS 61	Water Cooling Systems
WBS 62	Cryogenic Systems
WBS 63	Utility Systems
WBS 64	Helium Bakeout System
WBS 66	Test Cell HVAC
WBS 67	Test Cell Fire Protection

5 DOCUMENTS AND PROCEDURES

Table 5-1 provides a listing of the PPPL and NCSX documents and procedures anticipated to be needed to support the Facility Start Up ISTP.

Table 5-1 Documents and Procedures Needed for Facility Start Up ISTP

Name	Identifier
Safety Documents	
NCSX Safety Assessment Document (SAD)	TBD
PPPL Environmental, Safety, and Health Manual	ESHD-5008
PPPL Engineering Procedures	
NEPA Review System	ENG-014
Control of Hazardous Energy Sources via Lockout Tagout of Energy Isolation Devices	ENG-016
PPPL Technical Procedures for Experimental Facilities	ENG-030
PPPL Work Planning Procedure	ENG-032

PPPL Engineering Design Verification	ENG-033
NCSX System Engineering Procedures	
NCSX Configuration Control Procedures	NCSX-PROC-002
NCSX Interface Control Procedures	NCSX-PROC-003
NCSX Work Planning Procedures	NCSX-PROC-004
PPPL Operating Procedures	
Control of Workplace Cleanliness Around D-Site Experimental Area	OP-AD-24D
Control Of Temporary Modifications	OP-AD-31D
Conduct of Operations	OP-AD-39
Control of Equipment and System Status (Chain of Command)	OP-AD-56
MG Reactor Kirk Key Test	OP-KK-24
MG CO2 Kirk Key Test	OP-KK-27
NCSX SLD Kirk Key Test	OP-KK-28
D-Site MG Operation in support of NCSX	OP-MG-07
Energy Conversion Systems (ECS) High Power Conversion systems (HCS) Input/Output Interface Testing	OP-PC-44
ECS Interlock and Level 1 Display Testing	OP-PC-45
SDS Pre-operational Testing	OP-PC-46
ECS Critical Interlocks	OP-PC-48
ECS Ground Fault Testing	OP-PC-49
Rectifier Settings	OP-PC-735
FCPC Daily Start up/Shutdown Procedure	OP-ECS-245
Pumpdown of a NB Enclosure	OP-NB-64
Cooldown of a NB Enclosure	OP-NB-66
NB Long Pulse Operation Source Accel Start up & Daily Operations Using Local Control	OP-NB-79
Preparations of NB Areas and Equipment for Daily Operations	OP-NB-97
Start up/operations of the 1070W Helium Refrigerator	OP-NB-229
Beamline Liquid Helium Operations	OP-NB-230
Start up and Shutdown of the Beamline Water Systems	OP-NB-710
NCSX Operating Procedures	
Preparations of Experimental Areas for Machine Operations	TBD
Testing the NCSX (High Power Interlock System (HIS) with Areas Safe for Access	TBD
Testing the NCSX Emergency Stop System	TBD
Safety Lockout Device (SLD) Test Procedure	TBD
Hot Access Requirements	TBD
Operation of the NCSX Access System	TDB
Testing of the Hot Access and HIS Systems with SLD Pressurized	TBD

NCSX Training Matrix	TBD
NCSX Operations Guide for Start up and Shutdown	TBD
High Power Pulsing (HPP) Daily Operations	TBD
Changing the Trip Control Settings of the Rochester Instrument Systems (RIS) Protective Circuit for the NCSX Field Coils	TBD
ACP & PDP Trip Control Settings	TBD
Start up, Operation, and Shutdown of the NCSX Bakeout System	TBD
Verification of Interlock Readiness for Operation of the NB Injection System	TBD
Preparation for NCSX Pumpdown	TBD
Helium Bakeout System Operations Procedure	TBD
Daily Hi-Pot Test of the NCSX Vacuum Vessel	TBD
Neutral Beam Kirk Interlock Testing	TBD
Leak Checking of NCSX	TBD
Cryostat Operation	TBD
Pre-Operational Test Procedures (PTPs)[1]	
Coil Energization Tests	TBD
Pre-Op Testing of the NB Power Systems	TBD
HiPot Test of NCSX Coil Sys from SDS in FCPC	TBD
NCSX De-Ionized Water/System Testing	TBD
NCSX Coil System Preoperational Tests	TBD
ECS to NCSX Machine Coil Link Installation	TBD
ECS Continuity, Resistance, Inductance, & Meggar	TBD
Halmar (DCCT) & Shunt System Pre-Op Testing	TBD
RIS Tests	TBD
Analog Coil Protection (ACP) Tests	TBD
PSRTC Simulation Tests	TBD
PSRTC I/O Tests	TBD
Pulse Duration Period Timer Tests	TBD
FCPC Dummy Load Tests	TBD
ECS HiPot Tests	TBD
Cryostat	TBD

[1] Preparation and implementation of Pre-Operational Test Procedures (PTPs) are the responsibly of the individual WBS elements, and is outside scope of the Integrated Systems Test Program.

6 ELEMENTS OF THE FACILITY START UP ISTP

The Facility Start Up Integrated Systems Test Procedure (ISTP) will be executed to establish the readiness of the device and facility for First Plasma and subsequent experimental operations. The ISTP is expected to include the following steps. Section 6.1, 6.3, 6.4, 6.5 are required to be in place for Low Power Physics Testing.

FACILITY PREPARATIONS

Machine area scrubs complete

Work permits reviewed and closed out as appropriate.

Installation procedure run copies reviewed and closed out as appropriate.

Status of temporary modifications to NCSX operating equipment reviewed.

Bus/coil/power systems walk down complete.

ECS SLD, HIS, HCS interlock testing complete (OP-PC-48).

MG system kirk interlock testing complete.

ECS/SLD system kirk interlock testing complete (OP-KK-028).

Testing of the Hardwired Interlock System (HIS) with areas safe for access complete.

Safety Lockout Device (SLD) testing complete.

Emergency Stop system testing complete.

Testing of the Hot Access and HIS systems with SLD pressurized complete.

VACUUM VESSEL PUMPDOWN AND TESTING

Preliminary vacuum vessel high-pots successfully completed.

Preparations for NCSX pump down complete.

Vacuum vessel pump down complete.

Leak checking of Vacuum Vessel successfully completed in preparation for bakeout.

6.3 WATER SYSTEMS TESTING

Water systems testing complete.

6.4 ENERGY CONVERSION SYSTEMS TESTING

Transrex rectifier settings checked (OP-PC-735).

- SDS pre-operational testing complete (OP-PC-46).
- ECS HCS input/output interface testing complete (OP-PC-44).

ECS interlock and level #1 display testing complete (OP-PC-45).

Halmar (DCCT) and shunt systems PTPs complete (PTP-ECS-30).

ECS continuity, resistance, inductance, and meggar measurements complete (PTP-ECS-29).

ECS ground fault detector testing complete (OP-PC-49).

ECS high pot testing complete (PTP-ECS-45).

PSRTC simulation and I/O testing complete (PTP-ECS-34/35).

Dummy load testing complete (PTP-ECS-39).

RIS testing complete (PTP-ECS-32).

ACP testing complete as appropriate (PTP-ECS-33).

PDP testing complete (PTP-ECS-43).

6.5 PREPARATIONS FOR COIL ENERGIZATION

NCSX prepared for operations per the daily start-up procedure.

NCSX prepared for high power pulsing (HPP) operations.

Coil and bus system high pot and circuit resistance measurements from the SDS output complete.

- ECS start up and high pot of the NCSX coil systems complete.
- MG system operations resumed per OP-MG-07.

Pre-operational testing of coil systems complete.

COIL ENERGIZATION TESTING

Note that all of the activities identified in Sections 6.1 through Section 6.5 must be completed prior to the commencement of coil energization testing for first plasma. Section 6.2 is not required for Low Power Physics Testing.

Coil energization tests complete.

BAKEOUT IN PREPARATION FOR FIRST PLASMA

- Bakeout system testing complete.
- Bakeout of vacuum vessel complete.

7 APPROVAL FOR COIL ENERGIZATION AND FIRST PLASMA

The coil energization tests represent the first time the coils have been subject to design-level currents and voltages in situ and the first time there has been the potential for plasma formation with the associated radiation hazards. Special approvals are required for low power physics testing, normal coil energization testing, and First Plasma as described in section 2.0

7.1 COIL ENERGIZATION APPROVAL REQUIRMENTS

Prior to coil energization testing, a Safety Certificate for (limited) operation (as described in section 2.0 and detailed in Addendum 1) must be issued. The Safety Certificate is issued after the Activity Certification Committee (ACC) has made appropriate presentation and recommendation to the PPPL ES&H Executive Safety Board for the safe start up and operation of the device.

FIRST PLASMA APPROVAL REQUIREMENTS

The following reviews and approvals will need to occur prior to First Plasma:

SRC review and approval of NCSX SAD;

Review and approval of technical documents in Section 5 of this plan;

Operational Readiness Assessment Review (ORA)

ACC review and walk-down of NCSX and MIE subsystems;

Approval by ES&H Executive Safety Board for issuance of Safety Certificate;

Concurrence from the Test Director, NCSX Chief Operating Engineer, and ACC that all subsystem PTP's (for First Plasma) have been successfully completed; and

- Approval by the NCSX Project Manager to commence First Plasma.

The approval process is illustrated in the flow chart in Addendum 1 of this document.

8 COST AND SCHEDULE

It is estimated that it will take approximately 6.5 months from end of construction through First Plasma. This estimate is based on past experience with the start up of similar devices at PPPL, such as the National Spherical Torus Experiment (NSTX). The estimate assumes that upon transfer of NCSX from the Construction Manager to the NCSX (Start Up) Test Director, the required subsystems listed in Section 4 are available and configured for integrated systems testing. In addition, this schedule assumes that the required documents identified in Section 5 have been completed.

The cost associated with these activities is estimated to be $1,224,962. These costs include the start up staff, subsystem staff, low power physics tests, final ISTP and costs associated with preparation of required documentation leading to first plasma.

The start up staff for the 6.5-month duration should include:

1 Test Director,	0.75 FTE
1 Chief Operations Engineer (COE)	0.5 FTE
1 Project Engineer	0.5 FTE (budgeted in project)
2 Machine Technicians	0.5 FTE
1 Physicist In Charge (PIC)	0.5 FTE (budgeted in project)

The subsystem staff for the 3-month duration should include:

1 Water Systems Technician	0.5 FTE
1 AC Power Engineer	0.5 FTE
1 Computer Engineer	0.5 FTE
2 FCPC Technicians	0.5 FTE
1 MG Operator	0.5 FTE

The estimated cost for this staff is approximately $699,406 which includes low power physics testing and all startup activities leading to first plasma (without contingency).

Labor costs for preparing the documentation required for Facility Start Up were estimated by considering the documents that would have to be prepared and estimating the resource requirements to prepare each document. Table 8-1 provides a representative list of documents and the resource requirements to complete preparation of each document. Approximately 82 person-weeks are required for document preparation with an estimated cost of $458,003 (without contingency).

Thus combined cost for complete Facility Startup including First Plasma is $1,224,962 (without contingency) as detailed in Addendum 2.

Table 8-1 Facility Start Up Documentation Requirements

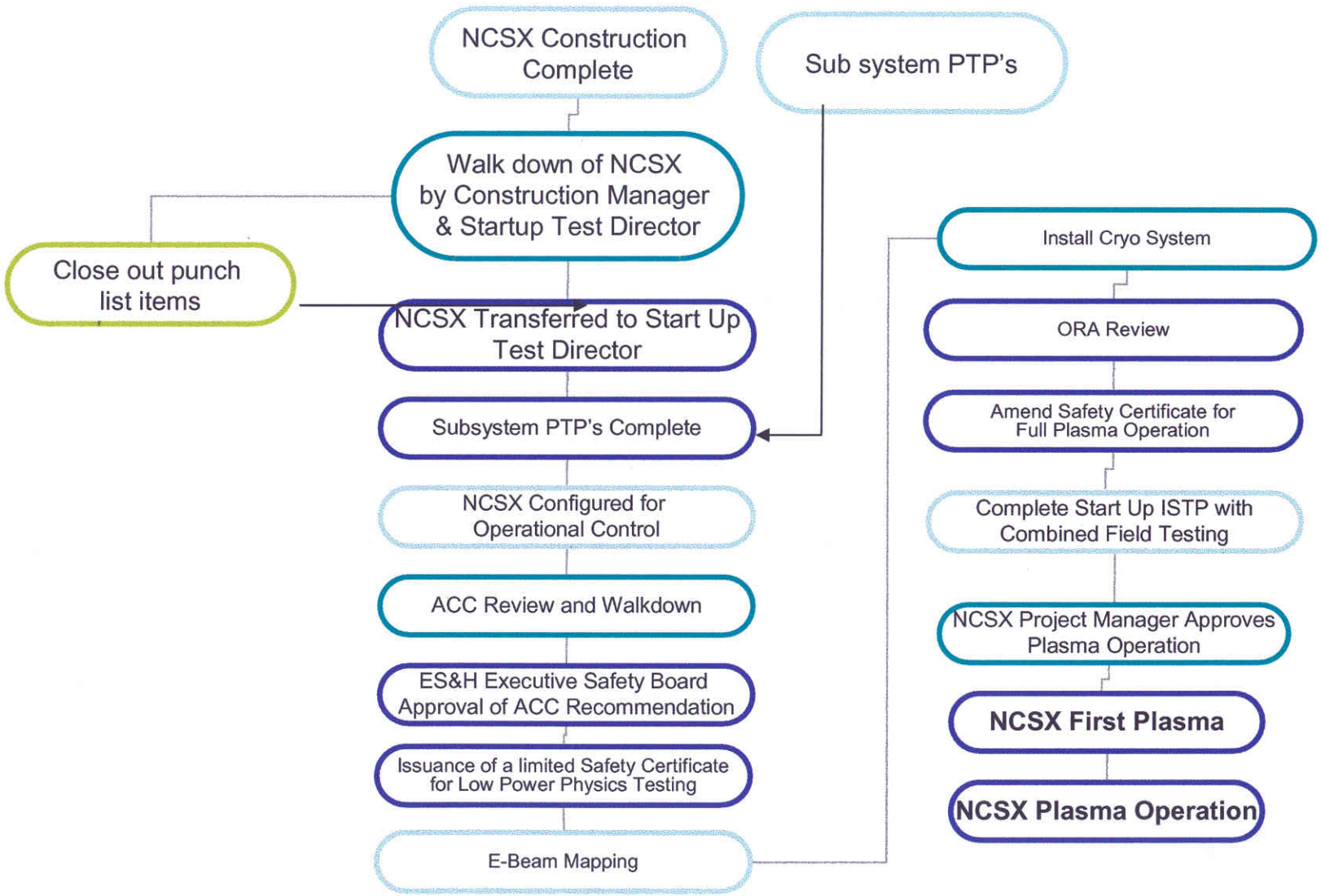
Document ID	Documents Required for NCSX Start up and Operations	Status	Person-
	*NCSX Safety Assessment Document (SAD)		8
*ESHD-5008	Environmental, Safety, and Health Manual	2	0
*ESH-014	NEPA Review System	2	0
*ESH-016	Control of Hazardous Energy Sources Via Lockout Tagout of Energy Isolation Devices	2	0
*ENG-030	PPPL Technical Procedures for Experimental Facilities	2	0
*ENG-032	PPPL Work Planning Procedure	2	0
*ENG-033	PPPL Engineering Design Verification	2	0
*NCSX-XX,	Administrative Control of Procedures	5	4
*OP-AD-39,	Conduct of Operations	6	1
*OP-AD-56,	Control of Equipment and System Status (chain of command)	6	1
*OP-AD-24,	Control of Workplace Cleanliness Around D-Site Experimental	6	1
*OP-AD-31,	D- Site Fire Watch Requirements	6	1
*OP-AD-03,	Experimental Proposals for NCSX	6	1
*OP-AD-117	Operation of the NCSX Access System	6	1
*NCSX-OP-XX,	Preparations of Experimental Areas for Machine Operations	5	3
*NCSX-OP-XX,	Operation of the NCSX TVPS	5	3
*NCSX-OP-XX,	Testing the NCSX HIS with Areas Safe for Access	5	3
NCSX-OP-XX,	GDC Operations	5	3
*NCSX-OP-XX,	Testing the NCSX Emergency Stop System	5	3
*NCSX-OP-XX,	Safety Lockout Device Test Procedure	5	2
*NCSX-OP-XX,	Hot Access Requirements	5	2

*NCSX-OP-XX,	Testing of the Hot Access and HIS Systems with SLD Pressurized	5	2
*NCSX-OP-XX,	NCSX Training Matrix	1	3
*NCSX-OP-XX,	NCSX Operations Guide for Start up and Shutdown	5	3
NCSX-OP-XX,	HPP Daily Operations	5	2
*NCSX-OP-XX,	Changing the Trip Control Settings of the RIS Protective Circuit for the NCSX Field Coils	5	2
*NCSX-OP-XX,	ACP & PDP Trip Control Settings	5	2
NCSX-OP-XX,	Start up, Operation, and Shutdown of the NCSX Bakeout System	5	3
NCSX-OP-XX	Verification of Interlock Readiness for Operation of the NB Injection System	5	3
*NCSX-OP-G-XX	Preparation for NCSX pumpdown	5	3
NCSX-OP-XX	Helium Heating and Cooling System Operations Procedure	5	3
*NCSX-OP-G-XX	Daily Hi-Pot Test of the NCSX Inner/Outer Vacuum Vessel	5	3
NCSX-OP-G-XX,	NCSX Boronization using TMB	5	4
*ISTP-NCSX-01	Coil EnergizationTests	1	4
*OP-KK-24	MG Reactor Kirk Key Test	6	3
*OP-KK-27	MG CO2 Kirk Key Test	6	1
*OP-KK-28	NCSX SLD Kirk Key Test	6	1
OP-KK-90	ICRF System 3&4 Kirk Key and Local E-Stop Test	6	2
OP-KK-266	ICRF System 5&6 Kirk Key and Local E-Stop Test	6	2
OP-KK-267	ICRF System 1 &2 Kirk Key and Local E-Stop Test	6	2
NCSX-OP-G-XX,	MPTS Personnel Safety Interlock Test Procedure	6	3
NCSX-OP-G-XX,	Neutral Beam Kirk Interlock Testing	6	2
*OP-MG-07	D-Site MG Operation in support of NCSX	6	2
OP-PC-44	ECS HCS Input/Output Interface Testing	6	2
*OP-PC-45	ECS Interlock and Level 1 Display Testing	6	2
*OP-PC-46	SDS Preoperational Testing	6	2
*OP-PC-48	ECS Critical Interlocks	6	2
*OP-PC-49	ECS Ground Fault Testing	6	2
*OP-PC-735	Rectifier Settings	6	2
*OP-ECS-245	FCPC Daily Start up/Shutdown Procedure	6	2
*NCSX-XX	Leak Checking of NCSX	5	2
OP-NB-64	Pumpdown of a NB enclosure	5	1
OP-NB-66	Cooldown of a NB enclosure	5	1
OP-NB-79	NB Long Pulse Operation Source Accel Start up & Daily Operations using local control	5	1
OP-NB-97	Preparations of NB Areas and Equipment for daily operations	5	1
OP-NB-229	Start up/operations of the 1070W helium refrigerator	5	1
OP-NB-230	Beamline liquid helium operations	5	1

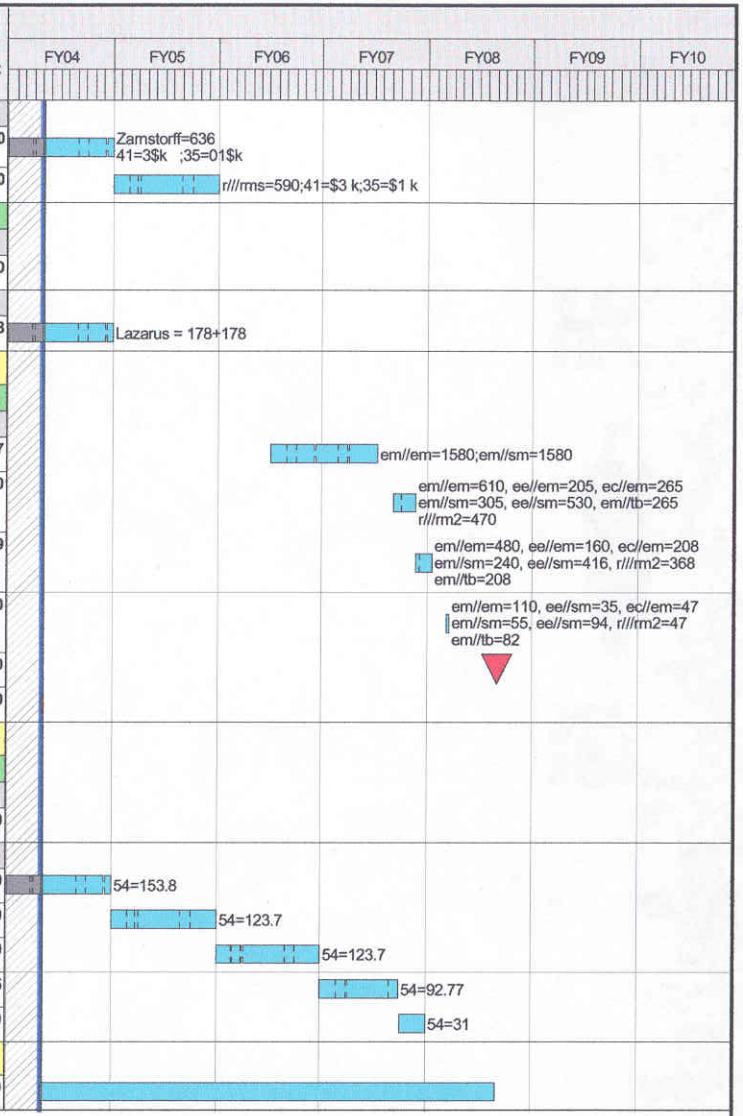
OP-NB-710	Start up and Shutdown of the beamline water systems	5	1
NCSX-PTP-XX	Preop testing of the NB Power Systems	5	4
NCSX-PTP-XX	NB Long Pulse Ion Source Start up Procedures	5	4
*NCSX-PTP-XX	HiPot of NCSX Coil Sys from SDS in FCPC	5	3
NCSX-PTP-XX	HiPot test of CHI Metal Oxide Varistors	5	3
*PTP-ECS- XX	ECS Continuity, Resistance, Inductance, & Meggar	5	2
*PTP-ECS- XX	Halmar (DCCT) & Shunt System Pre-op testing	5	2
*PTP-ECS- XX	RIS Tests	5	2
*PTP-ECS- XX	ACP Tests	5	2
*PTP-ECS- XX	PSRTC Simulation Tests	5	2
*PTP-ECS- XX	PSRTC I/O Tests	5	2
*PTP-ECS- XX	Pulse Duration Period Timer Tests	5	2
*PTP-ECS- XX	FCPC Dummy load tests	5	2
*PTP-ECS- XX	ECS HiPot Tests	5	2
PTP-NCSX-XX	NCSX ECH-PI Pre-Operations Testing	5	2
*PTP-NCSX-XX	NCSX De-Ionized Water/System Testing	5	2
*PTP-NCSX-XX	NCSX Coil System Preoperational Tests/ w Cryostst	5	4
*PTP-NCSX-XX	ECS to NCSX Machine Coil Link Installation	5	2

Legend: 1 - Document in development
2 - Current document satisfactory for NCSX start up and operation
3 - Document requires minor revision
4 - Document requires major revision
5 - Document needs to be developed
6 - Need a NCSX Project specific version
* - Required for First Plasma

NCSX Start Up Flow Chart



Activity ID	Activity Description	Orig Dur	Early Start	Early Finish	Total Float	PCTC	Earned value cost (BCWP)	Budgeted Cost (loaded without Conting)
840.202	Project Physics/Engr Analysis FY04	256*	01OCT03A	30SEP04	1,283	LOE	33,135.66	**99,806.20**
840.203	Project Physics/Engr Analysis FY05	255*	01OCT04*	30SEP05	1,028		0.00	**95,530.00**
Job: 8402 - Project Physics MIE ORNL-LYON								
FY03 Actual Cost								
840.301	Apr-Sept MIE Cost ORNL	152*	01APR03A	30SEP03A		100	40,980.00	**40,980.00**
840.302	Project Physics/Engr Analysis FY04	256*	01OCT03A	30SEP04	1,283	LOE	10,144.42	**30,555.48**
85 - Integrated Systems Testing								
920.001	Procedure and Document Preparation	257	03APR06*	11APR07	129		0.00	**458,003.27**
920.005	Start-up Testing	55	05JUN07	21AUG07	112		0.00	**390,743.50**
920.010	Power Testing and E-Beam Mapping	41	22AUG07	18OCT07	112		0.00	**308,663.69**
920.020	Final ISTP	10	04DEC07	17DEC07	112		0.00	**67,553.80**
730.9000	First Plasma	0		30MAY08*	0		0.00	**0.00**
920.030		1	02FEB04	02FEB04	0		0.00	**0.00**
PPPL Allocations								
Job: 8998 - Allocations								
FY03 Actual Cost								
99.03	Apr-Sept MIE Cost PPPL	128*	01APR03A	30SEP03A		100	60,670.00	**60,670.00**
99.04	PPPL Allocations FY04	256*	01OCT03A	30SEP04	1,283	LOE	88,285.51	**265,920.20**
99.05	PPPL Allocations FY05	255*	01OCT04*	30SEP05	1,028		0.00	**214,990.60**
99.06	PPPL Allocations FY06	254*	03OCT05*	29SEP06	774		0.00	**214,619.50**
99.07	PPPL Allocations FY07	190*	02OCT06*	29JUN07	519		0.00	**170,232.95**
99.07X	PPPL Allocations FY07	65*	02JUL07*	28SEP07	519		0.00	**56,885.00**
+ Contingency								
		1,106	02FEB04	30MAY08	348		0.00	**15,381,700.00**



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ECP5 Schedule
Progress Bar
Critical Activity

ECP5

NCSX Baseline (ECP5)
First Plasma May 2008

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Rev B
WBS 12-2/18; WBS 13- 2/19
WBS14- 2/20; WBS 7 -2/20