National Compact Stellarator (NCSX)

General Requirements Document (GRD)

NCSX-ASPEC-GRD Rev. 0

Draft F

May 1, 2002

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Record of Revisions

Revision	Date	ECP	Description of Change
Draft A	4/23/02	-	Initial Draft
Draft B	4/29/02	-	Incorporated comments from Neilson and Levine
Draft C	5/1/02	-	Incorporated comments from Neilson (revised flexibility requirements), Chrzanowski (Test Cell constraints), Johnson (table of diagnostic requirements), and Heitzenroeder (editorial improvements)
Draft D	5/2/02	-	Incorporated additional information from Levine

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1 SCOPE

1.1 Identification

This document, the National Compact Stellarator Experiment (NCSX) General Requirements Document (GRD), specifies the performance, design, documentation, and quality assurance requirements for the NCSX to be installed and operated at the Princeton Plasma Physics Laboratory (PPPL).

1.2 System Overview

The National Compact Stellarator Experiment (NCSX) will be a proof-of-principle scale facility for studying the physics of compact stellarators, an innovative fusion confinement concept. The facility will include the stellarator device and support systems. It will be constructed at the Princeton Plasma Physics Laboratory.

1.3 Document Overview

The GRD is a system specification. It is to be used as the basis for developing all lower level (subsystem and equipment) technical specifications for the NCSX Project.

1.3.1 Relationship of System to Subsystem Requirements

The specification approach being used on NCSX provides for a clear distinction between system and subsystem requirements as well as between performance requirements and design constraints.

Performance requirements state what functions a system has to perform and how well that function has to be performed. Design constraints, on the other hand, are a set of limiting or boundary requirements that must be adhered to while allocating requirements or designing the system. They are drawn from externally imposed sources (e.g., statutory regulations, DOE Orders, and PPPL ES&H Directives) as well as from internally imposed sources as a result of prior decisions which limit subsequent design alternatives.

Within the system specification, Section 3.2.2 defines the performance requirements that apply to the system as a whole. Section 3.7 defines the allocation of the system performance requirements to specific subsystems. The remainder of Section 3 of the specification is generally considered to consist of design constraints. As a rule, design constraints are not allocated to subsystems within Section 3.7. However, subsystem specific constraints may be interspersed with the system level design constraints if they are considered significant enough for inclusion within the system specification.

Within subsystem development specification, the subsystem performance requirements contained in Section 3.2.2 are generally drawn from the applicable subsystem allocations within Section 3.7 of the system specification. Additional performance requirements at the subsystem level may also be included for completeness. Similar to the system specification, Section 3.7 of the subsystem specification will contain performance requirements allocated to specific components or configuration items of the subsystem. Design constraints for the subsystem will consist of derived system level constraints and other applicable constraints.

1.3.2 Incomplete Requirements

Within this document, the term “to be determined” **(TBD)** applied to a missing or incomplete requirement infers that additional effort (analysis, trade studies, etc.) is required before the requirement can be completed.

2 APPLICABLE DOCUMENTS

The following documents of the exact issue shown form a part of this specification to the extent specified herein. In the event of a conflict, the contents of this specification shall be considered a superceding requirement.

2.1 Government Documents

2.2 PPPL Documents

2.3 NCSX Documents

[1] NCSX Initial Experimental Plan (NCSX-PLAN-EXP)

[2] NCSX Work Breakdown Structure (WBS) Dictionaries (NCSX-WBS-wbs#) where wbs# is the WBS identifier

[3] NCSX Vacuum Materials List (to be provided)

[4] NCSX Structural and Cryogenic Design Criteria Document (to be provided)

[5] NCSX Grounding Specification for Personnel and Equipment Safety (to be provided)

[6] NCSX Test and Evaluation Plan (to be provided)

[7] NCSX RAM Plan (to be provided)

2.4 Other Documents

3 SYSTEM REQUIREMENTS

3.1 System Definition

3.1.1 General Description

The mission of the NCSX research is to investigate the effects of three-dimensional plasma shaping, of internally- and externally-generated sources of rotational transform, and of quasi-axisymmetry on the stability and confinement of toroidal plasmas.

The NCSX device is a medium-scale (R=1.4 m), low aspect ratio (A~4) modular torsatron. It features modular coils, toroidal field (TF) coils, and poloidal field (PF) coils for plasma shaping and control. It also has a vacuum-tight vessel internal to the coils.

The NCSX facility will be sited at C-Site at the Princeton Plasma Physics Laboratory (PPPL). Some subsystems will be located at D-Site at PPPL. The stellarator will be situated in the former PBX-M/PLT test cell. This test cell will hereafter be referred to as the NCSX test cell.

3.1.2 Fabrication Project Scope

This specification provides requirements for all phases of NCSX operation. These requirements will be addressed within the NCSX Fabrication Project or as future upgrades.

The NCSX Fabrication Project shall include all equipment required at the start of operations (first plasma), including the support subsystems (central I&C and utility systems) required to support that equipment.

In addition, the NCSX Fabrication Project shall include the re-commissioning, installation, and subsystem testing of two of the beamlines formerly installed on the PBX-M tokamak.

For equipment not in the Fabrication Project but required as a future upgrade, sufficient effort must be made to assure that the equipment can be plausibly accommodated as a future upgrade. The cost of any additional effort required shall also be included in the Fabrication Project.

3.1.3 System Elements

All work required to execute the Project has been identified in the NCSX Project Work Breakdown Structure (WBS) Dictionary [2]. A listing of Level 2 (1-digit) WBS elements is provided in Table 3-1.

Table 3-1 Level II Work Breakdown Structure

WBS	
1	Stellarator Core Systems
2	Auxiliary Systems
3	Diagnostic Systems
4	Electrical Power Systems
5	Central Instrumentation and Control Systems
6	Site and Facilities
7	Machine Assembly
8	Project Oversight and Support
9	Preparations for Operations

3.1.4 System Functions

The top-level system functions for NCSX are detailed in Figure 3-1. This functional flow provides the foundation for the scope of the requirements within Section 3.2 of this specification.

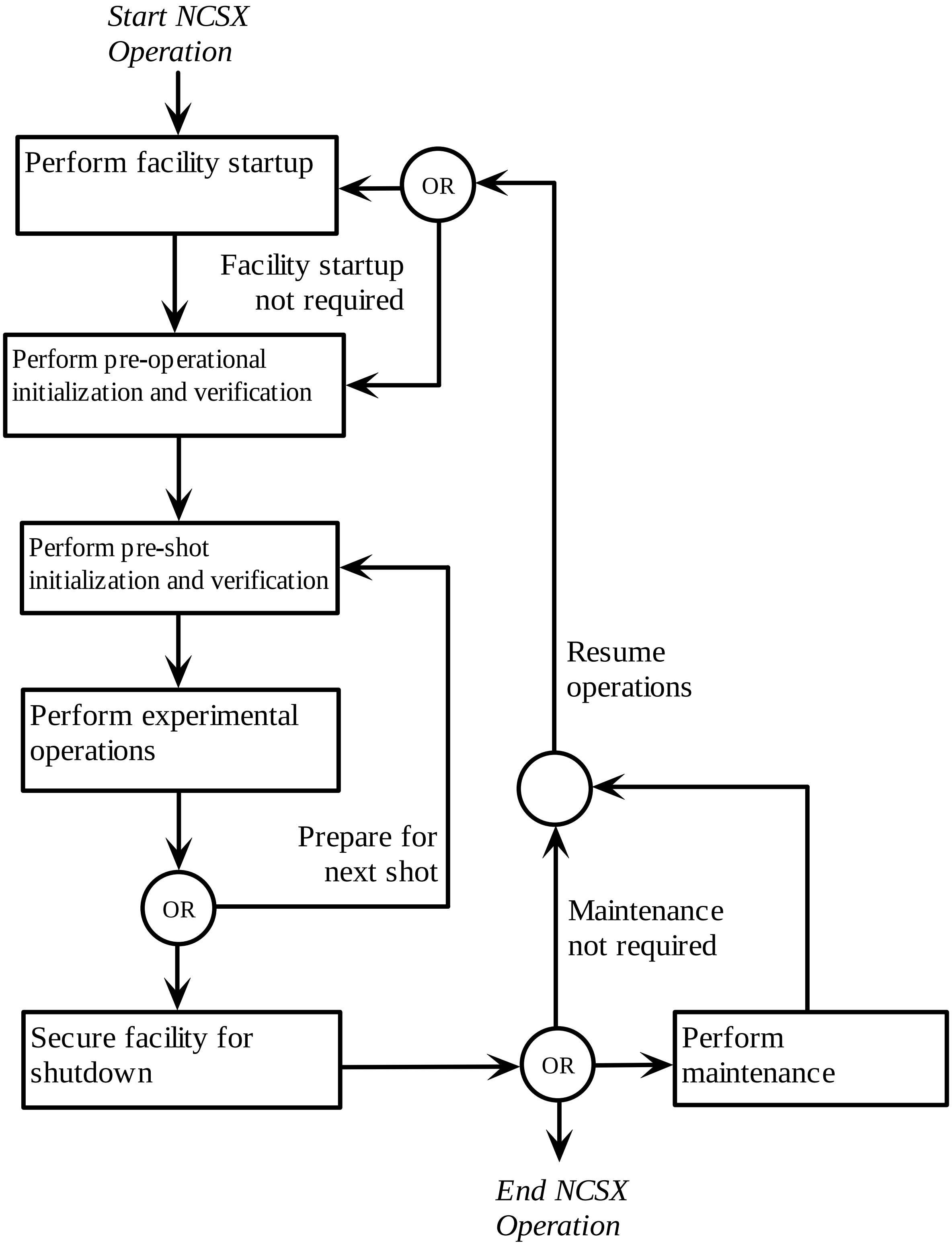

Figure 3-1 NCSX System Functional Flow Diagram

3.2 Characteristics

3.2.1 Performance Characteristics

3.2.1.1 Facility Startup

Background

Facility startup includes all activities related to the startup of the NCSX systems that are not included under pre-operation or pre-shot initialization and verification. Facility startup activities would be performed infrequently and would generally include those activities required prior to the start of a run period (typically, a month) following extended shutdowns and maintenance periods. Facility startup includes the monitoring of facility equipment operation.

Requirement

The system shall provide the capability to perform a controlled startup of the facility, and verify that the facility systems are functioning correctly.

3.2.1.1.1 Coil Cool-down

Background

Prior to experimental operations, the cryo-resistive coils must be cooled down from room temperature to a pre-shot operating temperature of 80K. The coils are located in a dry nitrogen environment that is provided by the cryostat, which surrounds the magnets. In order to gain access to the interior of cryostat, the coils must be warmed up from operating temperature to room temperature. The anticipated operational plans are expected to result in up to less than 150 cool-down and warm-up cycles between room temperature and operating temperature.

3.2.1.1.1.1 Coil Cool-down Timeline

The cryo-resistive coils (TF, PF, and modular coils) shall be capable of being cooled down from room temperature (293K) to their operating temperature (80K) within 96 hours.

3.2.1.1.1.2 Cool-down and Warm-up Cycles

The design of the cryo-resistive coils shall allow for at least 150 cool-down and warm-up cycles between room temperature and operating temperature.

3.2.1.1.2 Vacuum Requirements

3.2.1.1.2.1 Base Pressure

The device and facility shall produce high vacuum conditions with a base pressure of less than or equal to $2\text{x}10^{-8}$ torr at 293K.

3.2.1.1.2.2 Pumping Speed

The device and facility shall be equipped with the four PBX-M 1500 l/s turbo-molecular pumps (or equivalent), configured to provide a total net pumping speed at the torus of at least 2600 l/s, which is equal to or greater than that achieved on PBX-M.

3.2.1.2 Pre-operational Initialization and Verification

Background

Pre-operational initialization and verification activities would generally cover those activities required prior to the start of an operating day following an overnight or weekend shutdown that are not included under pre-shot initialization and verification.

Requirement

The system shall make experimental systems ready for the start of operations, and verify that experimental systems are functioning correctly.

3.2.1.2.1 Plasma Chamber Conditioning

3.2.1.2.1.1 Bakeout

Background

The temperature of the vacuum vessel shell will be elevated to a nominal bakeout temperature of 150ºC by circulating high temperature gas in tubes attached to the vacuum vessel shell and ports. Initially, there will be only a few, discrete limiters installed in the vacuum vessel for ohmic operation. However, later in the program, a carbon-based liner will be installed inside the vacuum vessel with a surface area that is a substantial part of the vacuum vessel surface area to absorb the high heat loads and to protect the vacuum vessel and internal components. The temperature of the carbon-based liner will be elevated to a nominal bakeout temperature of 350ºC by circulating high temperature gas in tubes attached to the liner assembly.

3.2.1.2.1.1.1 Vacuum Vessel Bakeout Temperatures

During bakeout, the temperature of the vacuum vessel shell and ports shall be maintained within ±25ºC of the nominal 150ºC bakeout temperature.

3.2.1.2.1.1.2 Carbon-based Plasma Facing Components (PFCs) Bakeout Temperatures

During bakeout, the temperature of the carbon-based PFCs (to be installed as a future upgrade) shall be maintained within ±25ºC of the nominal 350ºC bakeout temperature. (The 350ºC bakeout capability is an upgrade.)

3.2.1.2.1.1.3 Bakeout Timelines

a) The vacuum vessel and all components internal to the vacuum vessel shall be capable of being raised to their bakeout temperatures within 24 hours and maintained at that temperature indefinitely.

b) Following bakeout, the vacuum vessel and all components internal to the vacuum vessel shall be capable of being returned to their pre-shot operating temperatures within 24 hours.

c) The cryo-resistive coils shall be capable of being returned to their pre-shot operating temperatures within the 24 hours following completion of bakeout.

3.2.1.2.1.2 Glow Discharge Cleaning (GDC) During Bakeout

a) The facility shall provide a glow discharge cleaning (GDC) capability with DC glow for indefinite periods of time with the vacuum vessel and all components internal to the vacuum vessel at their nominal bakeout temperatures.

b) The facility shall be capable of using any of the following gases for GDC: hydrogen, deuterium, and helium.

3.2.1.2.1.3 Boronization

The facility shall provide (as a future upgrade) the capability for boronization for all surfaces with line-of-sight to the plasma.

3.2.1.2.1.4 Lithiumization

The facility shall provide (as a future upgrade) the ability to apply lithium coatings, either via Li pellets or spray, or other techniques.

3.2.1.3 Pre-shot Initialization and Verification

Background

Pre-shot initialization and verification activities cover those activities required prior to the start of each shot (plasma discharge).

Requirement

The system shall make experimental systems ready for the start of a shot (plasma discharge) and verify that the experimental systems are functioning correctly prior to the initiation of a shot.

3.2.1.3.1 GDC Between Shots

The facility shall provide the capability to perform GDC between shots with the vacuum vessel and all components internal to the vacuum vessel at their nominal pre-shot operating temperatures.

3.2.1.3.2 Pre-Shot Temperature

Interior vacuum vessel surfaces and all in-vessel components shall be maintained at a nominal pre-shot temperature of 25±5ºC without ratcheting.

3.2.1.4 Experimental Operations

3.2.1.4.1 Field Error Requirements

The toroidal flux in island regions due to fabrication errors, magnetic materials, or eddy currents shall not exceed 10% of the total toroidal flux in the plasma.

3.2.1.4.2 Electrical (Eddy Current) Requirements

Background

There are three fundamental reasons for establishing electrical (eddy current) requirements: plasma control, plasma stabilization, and field errors. The plasma will be initiated inductively on closed magnetic surfaces. The PF coils will apply the inductive voltage for plasma initiation and current drive. The toroidal resistance of the surrounding structures must be sufficiently high in order for the voltage to penetrate to the plasma chamber. Limitations on time constants for poloidal currents in the surrounding structures are also required to allow the fields from the TF and modular coils to penetrate.

The second reason is related to stabilizing external kink modes. The presence of a close-fitting conducting shell can stabilize external kink modes. The longest time constant of close-fitting conducting shells (like the vacuum vessel) should be short enough to preclude kink mode stabilization.

The third reason is related to field errors and their effect on surface quality in the plasma. Eddy currents can give rise to field errors that in turn, can create unacceptably large islands or destroy the outer surfaces of the plasma.

Requirements

a) The longest time constant of the vacuum vessel and in-vessel structures must be less than 10 ms.

b) All other structures in the stellarator core shall include electrical breaks to avoid having a toroidally continuous current path.

c) The longest time constant in electrically conducting structures outside the vacuum vessel shall be less than 20 ms.

d) Eddy currents in conducting structures surrounding the plasma shall not give rise to unacceptable field errors.

e) Stellarator symmetry shall be preserved in the design of the vacuum vessel, in-vessel structures, and electrically conducting structures outside the vacuum vessel in the stellarator core.

3.2.1.4.3 Plasma Magnetic Field Requirements

3.2.1.4.3.1 Coordinate System

Figure 3-2 illustrates the right-handed coordinate system used for the stellarator and test cell on NCSX. The Z-axis of the coordinate system is vertical. The major axis of the stellarator is coincident with the Z-axis. The following conventions are followed:

- A positive toroidal (plasma) current or a positive toroidal field point in the ϕ-direction (counter-clockwise viewed from above).
- A positive vertical field points in the Z-direction (upward).
- A positive poloidal current (TF or modular coil current in the inner leg) flows in the Z-direction and provides a positive toroidal field.
- Positive radial fields and currents are in the R-direction, radially outward from the Z-axis, the major axis of the stellarator.

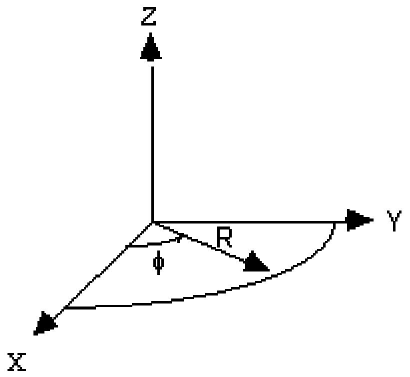

Figure 3-2 NCSX Coordinate System

3.2.1.4.3.2 Toroidal Field/Plasma Current Directionality

a) The facility shall be configured for the standard toroidal field direction to be negative.

b) The facility shall be configured for the standard poloidal field direction to be positive, corresponding to a positive toroidal (plasma) current.

c) The facility shall have the capability to be reconfigured to operate with both the toroidal and poloidal magnetic fields simultaneously flipped from their standard directions.

3.2.1.4.3.3 Reference Scenarios

Background

NCSX is designed to be a flexible, experimental test bed. To ensure adequate dynamic flexibility, a series of reference scenarios has been established. TF, PF, and modular coil systems and the vacuum vessel will be designed to meet the requirements of all the reference scenarios. Electrical power systems shall be designed and initially configured to meet the requirements of the Initial Ohmic Scenario and shall be capable of being upgraded to meet the requirements of all other reference scenarios.

The NCSX Project will provide coil current waveforms required for each reference scenario in technical data files.

3.2.1.4.3.3.1 Reference Scenario Definition

3.2.1.4.3.3.1.1 Initial Ohmic Scenario

The Initial Ohmic Scenario is characterized by:

- Ramping the coils to their pre-initiation values at a field on axis (R=1.4m) of 1.5T. The vacuum iota shall be above 0.5 in the outer half of the plasma.
- Holding the coils at pre-initiation values for 100ms
- Inductively initiating the plasma and ramping the plasma current to its maximum value of 154kA at a rate of 1.6MA/s
- Relaxing the plasma at constant current for 300ms

3.2.1.4.3.3.1.2 1.7T Ohmic Scenario

The 1.7T Ohmic Scenario is characterized by:

- Ramping the coils to their pre-initiation values at a field on axis (R=1.4m) of 1.7T. The vacuum iota shall be above 0.5 in the outer half of the plasma.
- Holding the coils at pre-initiation values for 100ms
- Inductively initiating the plasma and ramping the plasma current to its maximum value of 175kA at a rate of 3MA/s
- Relaxing the plasma at constant current for 300ms

3.2.1.4.3.3.1.3 1.7T High Beta Scenario

The 1.7T High Beta Scenario is characterized by:

- Ramping the coils to their pre-initiation values at a field on axis (R=1.4m) of 1.7T. The vacuum iota shall be above 0.5 in the outer half of the plasma.
- Holding the coils at pre-initiation values for 100ms
- Inductively initiating the plasma and ramping the plasma current to its maximum value of 175kA at a rate of 3MA/s
- Heating the plasma at constant current to a beta greater than 4% in 100ms
- Relaxing the plasma at constant current and beta for 200ms

3.2.1.4.3.3.1.4 2T High Beta Scenario

The 2T High Beta Scenario is characterized by:

- Ramping the coils to their pre-initiation values at a field on axis (R=1.4m) of 2T
- Holding the coils at pre-initiation values for 50ms
- Inductively initiating the plasma and ramping the plasma current to its maximum value of 205kA at a rate of 3MA/s
- Heating the plasma to a beta greater than 4% in 100ms

3.2.1.4.3.3.1.5 350kA Ohmic Scenario

The 350kA Ohmic Scenario is characterized by:

- Ramping the coils to their pre-initiation values at a field on axis (R=1.4m) of 1.8T
- Holding the coils at pre-initiation values for 100ms
- Inductively initiating the plasma and ramping the plasma current to its maximum value of 350kA at a rate of 3MA/s
- Relaxing the plasma at constant current for 300ms

3.2.1.4.3.3.2 Reference Scenario Requirements

TF, PF, and modular coil systems and the vacuum vessel will be designed to meet the requirements of all the reference scenarios.

Electrical power systems shall be designed and initially configured to meet the requirements of the Initial Ohmic Scenario and shall be capable of being upgraded to meet the requirements of all other reference scenarios.

3.2.1.4.3.4 Flexibility Requirements

Background

NCSX is designed to be a flexible, experimental test bed. To ensure that changes in equilibria can be accommodated, several dimensions have been identified over which changes in equilibria must be accommodated.

Flexibility requirements have been established for a toroidal field of 1.7T. Greater flexibility exists at lower field levels.

The NCSX Project will provide coil currents in technical data files required for each equilibrium at the extremes in flexibility space.

3.2.1.4.3.4.1 Quasi-axisymmetry Flexibility

The coils shall be designed and the power systems shall be upgradeable to vary quasi-symmetry by varying the effective ripple from the reference value to 10 times the reference value.

3.2.1.4.3.4.2 External Iota Flexibility

The coils shall be designed and the power systems shall be upgradeable to vary the rotational transfrom from -0.2 to +0.1, relative to the reference profile, while holding the global shear (ɩ(a)-ɩ(0)~0.2), plasma current (175kA), and toroidal field (1.7T at R=1.4m) constant.

3.2.1.4.3.4.3 Shear Flexibility

The coils shall be designed and the power systems shall be upgradeable to vary the shear by varying the global shear (equal to ɩ(a)-ɩ(0)) by -0.2 to +0.2, relative to the reference value, while holding the central iota (0.4), plasma current (175kA), toroidal field (1.7T at R=1.4m) constant.

3.2.1.4.3.4.4 Beta Limit Flexibility

The coils shall be designed and the power systems shall be upgradeable to be capable of reducing the kink stability beta limit to 1% from its reference value of ~4%.

3.2.1.4.3.5 Equilibrium Control

Feedback equilibrium control systems for radial and vertical plasma position control shall be provided (as a future upgrade).

3.2.1.4.4 Power Handling

Background

PFCs serve the following functions: [1] Provide for limiter operation [2] Provide for divertor operation including power handling, neutral recycling, and density control and [3] Protect the vacuum vessel and in-vessel components from particle and radiation heat loads from the plasma (including energetic ions) and from the shinethrough of neutral beams through the plasma.

Initially, the device will be configured with discrete limiters to handle the modest heat loads (less than 350kW) associated with initial ohmic operation. Upgrades to the PFC system will be incrementally made in response to experimental program needs to provide all of the functions above.

3.2.1.4.4.1 PFC Configuration

a) Coverage. The capability to expand the coverage by the PFCs (as a future upgrade) to 100% shall be provided.

b) Initial configuration. An array of poloidal limiters will be provided for the Initial Operation (Phase 1), Field Mapping (Phase 2), and Initial Ohmic (Phase 3) operation. They will be located on the inboard side of the v=0.5 cross section.

c) Divertor capability. The capability to accommodate a divertor (as a future upgrade) shall be provided.

d) Divertor pumping. The capability to configure the divertor (as a future upgrade) with a slot, permitting neutral particles passage into a sealed plenum that is actively pumped (with a cryopump or titanium getter pump), shall be provided.

e) Electrical biasing. The capability to electrically bias regions of the plasma boundary relative to each other and the vacuum vessel (as a future upgrade) shall be provided.

f) Armor. The capability to add armor to protect the vacuum vessel, port extensions, and in-vessel components from neutral beam shinethrough and from fast ions lost from the plasma (as future upgrades) shall be provided.

3.2.1.4.4.2 Maximum Power

a) The facility shall be designed for a maximum power of 350 kW for 0.3s for the Initial Ohmic Phase of operation.

b) The capability to accommodate (as a future upgrade) heat loads associated with up to 12MW of power for 1.2s (including 6MW of neutral beam injection) shall be provided.

3.2.1.4.5 Disruption Handling

The facility shall be designed to withstand electromagnetic forces due to major disruptions characterized by the disappearance of the plasma at with a maximum plasma current of 350 kA.

3.2.1.4.6 Plasma Heating

3.2.1.4.6.1 Neutral Beam Heating

3.2.1.4.6.1.1 Initial NB Heating Complement

Two of the four beamlines previously used on the PBX-M project will be installed as part of the NCSX Fabrication Project. One will be configured in the co-direction (the nominal direction of the plasma current) and one in the counter-direction. The tangency radius shall be inside the magnetic axis for the nominal 1.7T high beta equilibrium and located such that the beam does not intercept the inboard first wall.

3.2.1.4.6.1.2 Ultimate NB Heating Complement

a) The facility shall be designed to accommodate neutral beam heating using the four (4) beamlines previously used on PBX-M (as a future upgrade) in two possible configurations: [1] 2 co- and 2 counter-directed beamlines and [2] 3 co- and 1 counter-directed beamlines.

b) The facility shall be designed to accommodate an extended heating pulse duration of 1.2s.

3.2.1.4.6.2 Ion Cyclotron Heating (ICH)

a) The facility shall be designed to accommodate up to 6 MW of ICH (as a future upgrade) with a pulse length of 1.2s and frequency of 20-30 MHz.

b) The facility shall be designed to accommodate three launchers on the inboard side, one at each of the three v=0.5 cross-sections.

3.2.1.4.7 Plasma Fueling

3.2.1.4.7.1 Fuel Species

The facility shall be designed to be fueled with hydrogen (H) and deuterium (D).

3.2.1.4.7.2 Gas Injection

The device and facility shall have a programmable gas injection system with feedback on real-time density measurement.

3.2.1.4.7.3 Pellet Injection

a) The device and facility shall be designed to accommodate (as a future upgrade) a single pellet injector capable of repetitively injecting H or D pellets.

b) The facility shall incorporate guide tubes (as a future upgrade) to accommodate pellet launch from the inboard (high-field) side of the plasma.

3.2.1.4.8 Plasma Diagnostics

3.2.1.4.8.1 General Diagnostics Requirements

Diagnostic measurements of the plasma parameters that are: [1] critical to the research goals of NCSX and [2] necessary for plasma control and operational purposes shall be provided.

3.2.1.4.8.2 Diagnostics Implementation

a) All of the diagnostics required for Initial Operation and Field Line Mapping, as identified in Table 3-2 Diagnostic Requirements, shall be provided.

b) The facility shall be designed to accommodate the remaining diagnostics identified in (as future upgrades).

Table 3-2 Diagnostic Requirements

	research topic	essential new measurements	new diagnostics
1. Initial Operation			
	initiate plasma: exercise coil set	plasma current	plasma current Rogowskis
	Ip >25 kA	conductivity	flux loops
	checkout vacuum diagnostics	plasma position	saddle loops
	checkout magnetic diagnostics	total stored energy	B-dot probes
	initial wall conditioning		diamagnetic loop
		plasma/wall imaging	fast visible cameras
		line integrated density	1 mm interferometer
2. Field Line Mapping			
	map flux surfaces	vacuum flux surfaces	e-beam probe
	verify iota and QA	variable energy trace particles	fluorescent rod probe
			high dynamic range CCD
3. Initial Ohmic			
	initial plasma control, plasma evolution control	electron density profiles	multichord FIR interf./ polarim
	global confinement & scaling, effect of 3D shaping	electron temperature profiles	Thomson scattering
	density limit & mechanisms	radiated power profiles	core foil bolometer array
	study of Te and ne profiles.	magetic axis position	compact SXR arrays
	vertical stability	low (m,n) MHD (<100kHz)	
	current-driven kink stability	flux surface topology	
	effect of low-order rat. surf. on flux-surface topology	impurity species	visible spectrometer
	initial study of effect of trim coils, both signs	impurity concentration	abs. UV spectroscopy
	effect of contact location on plasma edge & recycling	Zeff	filtered 1D CCD camera
	initial attempts to control plasma contact location	hydrogen recycling	visible filterscopes
4. Initial Aux. Heating			
	plasma control with NB heating and CD		diagnostic neutral beam
	test of kink & balooning stability at moderate beta	ion temperature profile	toroidal CHERS
	effect of shaping on MHD stability	toroidal rotation profile	
	initial study of Alfvenic modes w/ NB ions	poloidal rotation profile	poloidal CHERS
	confinement scaling w/ iota, B, …	radial electric field	MSE polarimeter
	local transport measurements, perturb. meas.	iota profile	
	test of quasi-symmetry on confinement and transport	fast ion loss	fast ion loss probe
	density limits and control with heating	ion energy distribution	neutral particle analyser
	use of trim coils to minimize rotation damping	neutron flux	epithermal neutron detector
	blip measurements of fast ion conf. and slowing down	first wall surface temperature	compact IR cameras
	initial attempts to obtain enhance confinement regimes	high frequency MHD(<5Mhz)	high frequency Mirnov coils
	pressure effects on surface quality		fast tang. x-ray pinhole camera
	controlled study of neoclassical tearing using trim coils		enhanced x-ray tomography
	wall coatings with aux. heating	SOL tmperature and density	moveable Langmuir probe
	edge and exhaust charact. with aux. heating	neutral pressure	fast neutral pressure gauges
	attempts to control wall neutral influx	target Te, ne	plate mounted Langmuir probes
	wall biasing effects on confinement		
5. Confinement & beta push			
	stability tests at beta >~ 4%	edge/div. radiated power profile	divertor foil bolometer arrays
	detailed study of beta limit scaling	divertor recycling	divertor filtered CCD cameras
	detailed studies of beta limiting mechanisms	edge temp. and dens. prof.	fast scanning edge probe
	disruption-free operating region at high beta	divertor target surface temp.	fast IR camera
	active mapping of Alfvenic mode stability (with antenna)		divertor thermocouples
	enh. conf.: H-mode, hot ion modes, RI mode, pellets	core helium density	He CHERS system (with DNB)
	enhanced confinement, rotation effects		
	scaling of local transport and confinement	divertor impurity concentration	divertor UV spectroscopy
	turbulence studies	core density fluct. amp. & spec	fluctuation diagnostics TBD
	scaling of power or other thresholds for enh. conf.		
	ICRF wave propagation and damping (possible)		
	perturbative RF measurements of transport (possible)		
	divertor operation optimized for power handling		
	trace helium exhaust and confinement		
	scaling of power to divertor		
	control of high beta plasmas and their evolution		
6. Long Pulse			
	long pulse plasma evolution control	more detailed divertor profiles	divertor Thomson scattering
	equilibration of current profile		divertor diagnostics (TBD)
	beta limits with ~ equilibrated profiles		
	edge studies (3nd generation wall)		
	long-pulse power and particle exhaust w/ div. pumping		
	compatibility of high conf., high beta, and div. ops		

3.2.1.4.9 Instrumentation, Control, and Data Acquisition

The NCSX facility shall have an instrumentation, control, and data acquisition (central I&C) system that allows for coordination of operations and the acquisition, archiving, and display of all pertinent information.

3.2.1.4.10 Pulse Repetition Rate

The facility shall be designed for pulses to be initiated at intervals not exceeding 15 minutes when constrained by coil cool-down and 5 minutes otherwise.

3.2.1.4.11 Discharge Termination

3.2.1.4.11.1 Normal Termination

Background

Normal termination includes all system actions necessary to shutdown the plasma and associated subsystems at the conclusion of a shot in preparation for the next shot.

Requirement

The NCSX system shall provide the capability to perform a controlled shutdown of the plasma and associated subsystems at the conclusion of a shot.

3.2.1.4.11.2 Abnormal Termination

Background

Abnormal termination includes all system actions necessary to shutdown the plasma and associated subsystems when a condition occurs during experimental operations that could cause significant damage to the NCSX system or cause injury to personnel.

Requirement

The NCSX system shall provide the capability to perform a controlled shutdown of the plasma and associated subsystems if a condition occurs during experimental operation that could cause significant equipment damage or cause injury to personnel.

3.2.1.5 Facility Shutdown

Background

Facility shutdown involves the shutdown of NCSX equipment following the termination of a discharge (per Section 3.2.1.4.11) in preparation for a brief (overnight or weekend) or extended (between run periods) shutdown.

Requirement

The NCSX system shall provide the capability to perform a controlled shutdown of the facility.

3.2.1.5.1 Coil Warm-up Timeline

The cryo-resistive coils (TF, PF, and modular coils) shall be capable of being warmed up from operating temperature (80K) to room temperature (293K) within 48 hours.

3.2.1.5.2 Vacuum Vessel Venting

Provisions shall be made to vent the vacuum vessel in preparation for a vacuum opening.

3.2.2 External Interface Requirements

3.2.2.1 Shelter

NCSX will be sited at C-site at PPPL. The NCSX test cell will be the same test cell first used for the C-stellarator and subsequently used for the PLT and PBX-M tokamaks. It is assumed that the NCSX test cell, basement, and adjoining rooms utilized by the NCSX Project will be received equipped with proper:

- Shelter from the environment (roofing and walls)
- Lighting
- Environmental (temperature, humidity, and air exchange) control
- Fire suppression

3.2.2.2 Water Systems

NCSX will utilize the existing water systems at C-site, which are assumed to be fully operational. The NCSX Project will be responsible for adding cooling loops as required for NCSX subsystems.

3.2.2.3 Experimental Power

All experimental power for NCSX will be provided through the C-site experimental power systems except for the TF, PF, and modular coil power supplies that are connected to the D-site experimental power systems.

3.2.3 Physical Characteristics

3.2.3.1 Test Cell Compatibility

Background

NCSX will be sited in an existing test cell. NCSX equipment shall be designed to be within the lift capacity of the existing overhead crane, fit through the existing door, and be within existing floor loading limitations.

3.2.3.1.1 Maximum Lift

The maximum lift required to assemble, maintain, and disassemble NCSX shall not require an overhead crane capacity exceeding 30 tons.

3.2.3.1.2 Maximum Dimensions

Each assembly entering and leaving the test cell must be able to fit through a rectangular door that is 18 feet wide and 16 feet high.

3.2.3.1.3 Maximum Floor Loading

TBD

3.2.4 System Quality Factors

3.2.4.1 Reliability, Availability, and Maintainability

Background

The overall objective is to provide a device with high operational availability, meaning that the number of plasma discharges achieved in a run period is a large percentage (greater than 75%) of the number planned. Bottoms-up reliability predictions are difficult to perform and have large uncertainties for first-of-a-kind experimental devices such as NCSX. Therefore, quantitative RAM requirements on NCSX will be few. Rather, NCSX will rather rely on sound engineering practice to assure high availability in NCSX, which has been the tried-and-true approach on similar scale fusion devices. Sound engineering practices include:

- Applying design principles that promote reliability (e.g., employing an adequate factor of safety on mechanical and electrical stresses, avoiding unnecessary complexity, using proven design approaches and well characterized materials, etc.)
- Optimizing designs for reliability and maintainability through systematic evaluation of design options,
- Performing failure modes, effects and criticality analysis (FMECAs) for RAM design improvement and verification, and
- Employing peer reviews as a mechanism to enhance the design process.

The NCSX RAM Plan [7] defines the processes that will be used by the Project to achieve a device with high availability.

Requirements

a) NCSX shall incorporate reliability and maintainability features in the design that are consistent with achieving a high (greater than 75%) operational availability.

b) Provisions for recovery shall be made for every credible failure mode.

c) The stellarator core shall be capable of being disassembled and reassembled to permit replacement of any part or machine reconfiguration that would require disassembly.

d) Assemblies that exceed two man manual lift limits shall include provisions for lifting eyes or other sling attach provisions.

3.2.4.2 Design Life

a) The facility shall have a design life of >10 years when operated per the reference scenarios defined in Section 3.2.1.4.3.3.1.

b) The facility shall be designed for the following maximum number of pulses when operated per the reference scenarios defined in Section 3.2.1.4.3.3.1 and based on the factors for fatigue life specified in the NCSX Structural and Cryogenic Design Criteria Document [4]:

- 100 per day;
- 13,000 per year; and
- 130,000 lifetime.

3.2.5 Transportability

All assemblies and components shall be transportable by commercial carrier via highway, air, sea, or railway. All system elements that are unsuitable, due to operational or functional characteristics, for normal transportation methods by highway, air, or railway shall be identified.

3.3 Design and Construction

3.3.1 Materials, Processes, and Parts

3.3.1.1 Magnetic Permeability

All materials to be used in the stellarator and peripheral equipment must have a relative magnetic permeability less than 1.02 unless otherwise authorized by the Project.

3.3.1.2 Vacuum Compatibility

a) All in-vessel metallic components shall be electro-polished.

b) All in-vessel components shall be baked and outgassed prior to installation.

c) All in-vessel materials shall be approved by the Project for vacuum compatibility [3].

3.3.1.3 Plasma Facing Surface Materials

a) Plasma facing surfaces shall be carbon-based, i.e. graphite or carbon fiber composite (CFC) material.

b) The maximum surface temperature for carbon-based PFCs shall not exceed 1200ºC.

3.3.1.4 Structural and Cryogenic Criteria

NCSX stellarator systems shall be designed in accordance with the NCSX Structural and Cryogenic Design Criteria [4].

3.3.1.5 Corrosion Prevention and Control

Materials, processes, and protective surface treatments or finishes shall be provided to ensure that equipment capability during its service life is not degraded due to corrosion. Where possible, contact between dissimilar metals shall be avoided.

3.3.2 Electromagnetic Requirements

3.3.2.1 Electrical Grounding

Electrical grounding shall be provided in accordance with the NCSX Grounding Specification for Personnel and Equipment Safety [5].

3.3.2.2 RF Shielding

TBD

3.3.3 Nameplates and Product Marking

3.3.3.1 Labels

Equipment and any parts of that equipment to be used by personnel shall be identified with appropriate labels. Labels shall indicate clearly and concisely the function and purpose of the item being labeled. Hierarchical labeling shall be used to facilitate component location on control panels. The terminology used for equipment, procedures, and training materials shall be the same for each case. Label design shall be consistent to promote simplicity and avoid clutter. The use of abbreviations and acronyms shall be minimized. Permanent labels shall be attached to the specific component or equipment in such a manner that environmental conditions or usage by personnel will not remove or destroy the label. Temporary labels shall be used only when necessary and shall not obscure other information or equipment. If a temporary label is to designate a device that is out of service, the label shall be applied so that it prevents the use of that device. Labeling shall be legible and conform to human visual capabilities and limitations in regard to physical characteristics.

3.3.4 Workmanship

During NCSX fabrication and finishing, particular attention shall be given to freedom from blemishes, defects, burrs, and sharp edges; accuracy of dimensioning radii of weld fillets; making of parts; thoroughness of cleaning; quality of brazing, welding, riveting, painting, and wiring; alignment of parts; and tightness and torquing of fasteners.

3.3.5 Interchangeability

Design tolerances shall permit parts and assemblies of the same part number to be used as replacement parts without degrading the specified performance of the parent item.

3.3.6 Environmental, Safety, and Health (ES&H) Requirements

3.3.6.1 General Safety

When utilized within its intended use and within specified environments, the safe operation, test, handling, maintenance and storage of the system hardware and software shall be provided.

3.3.6.2 Safety Hazards

The system shall not present any uncontrolled safety or health hazard to user personnel. The system shall detect abnormal operating conditions and safeguard the NCSX system and personnel.

3.3.6.2.1 Radiation Monitoring

For plasma operations (and depending on experimental plans and operational experience), fixed and/or portable gamma and neutron radiation monitors may be set up at various locations inside and outside the NCSX Test Cell. Locations for these monitors will be determined by the PPPL Health Physics organization, in conjunction with the NCSX organization.

3.3.6.2.2 Controlled Access System

A controlled access system (CAS) shall protect against inadvertent entry into the test cell when electrical, magnetic, mechanical, toxic, or radiation hazards exceed allowable limits.

3.3.6.2.3 Toxic Gases

Background

Toxic gases such as tri-methyl boron (TMB) are sometimes used to perform GDC. Potential hazards can be controlled by selecting GDC gases with reduced toxicity, minimizing the gas inventory (through the use of small storage containers and compact distribution systems), implementing controls to shut down the flow of such gases in the event that the glow discharge is extinguished, and venting the effluent from the plasma chamber in a manner that there is no risk to personnel safety.

Requirement

Safeguards shall be implemented regarding the use of toxic gases for GDC to mitigate potential safety hazards.

3.3.6.2.4 Oxygen Depletion

Background

The cryostat is filled with cold (80K), dry nitrogen gas and maintained at a pressure slightly above atmospheric to prevent moisture from leaking into the cryostat. Excessive leakage of nitrogen gas represents a possible mechanism for oxygen depletion in the vicinity of the cryostat. The air in the test cell should be constantly exchanged and oxygen levels monitored to ensure personnel safety.

Requirement

a) The air in the NCSX Test Cell shall be exchanged once per **TBD** hours when the cryostat is pressurized with dry nitrogen.

b) Oxygen levels in the vicinity of the cryostat shall be monitored to detect excessive leakage of nitrogen from the cryostat.

c) The cryostat shall be carefully air purged, monitored, and certified safe before cryostat panels are removed and personnel are allowed to enter.

3.3.6.3 Personnel Safety

The system shall meet all applicable OSHA requirements in accordance with 29CFR1910. The system shall limit personnel exposure to hazardous materials to below their OSHA permissible exposure limit (PEL).

3.3.6.4 Flammability

The use of flammable materials shall be minimized. Components containing flammable materials, fluids or gases shall be designed to minimize the possibility of leaks and spills.

3.3.6.5 Fire Suppression

A fire suppression system shall be provided for the NCSX system which meets the requirements of DOE O 420.1 and PPPL ESHD-5008.

3.3.6.6 Hazardous Materials

Radioactive and hazardous waste shall be handled in accordance with federal, state, and local standards.

3.3.6.7 Electrical Safety

Electrical apparatus and systems shall be designed so that two simultaneous failures of high voltage (>600 V) barriers or a single failure of a low voltage barrier would have to occur to endanger workers performing work processes.

3.3.6.8 Radiological Design Objectives

Deuterium (D) operation shall be administratively limited to keep personnel exposure within the radiological limits and design objectives of Table 3-3.

3.3.7 Human Engineering

Human factors technology shall be considered in the design, operation, and maintenance of the NCSX system. The criteria and requirements provided in this section are applicable to the design of the work environment and human-machine systems at NCSX facilities. These criteria shall apply to new construction and to retrofitting of existing facilities. These criteria shall be considered for upgrading existing facilities where cost-benefit or risk-tradeoff analyses indicate justification for such expenditures.

3.3.7.1 Anthropometry

Equipment that is to be used by personnel shall be designed or selected to accommodate the fifth to ninety-fifth percentile of the user population for stand-up and sit-down consoles and other work stations, for accessibility of equipment and instrumentation, for furniture and equipment layout, and for traffic flow.

3.3.7.2 Human Environments

3.3.7.2.1 Temperature and Humidity

Temperature and humidity for human environments shall be maintained within **TBD** limits.

3.3.7.2.2 Ventilation

TBD

Table 3-3 Radiological Limits and Design Objectives

			Public Exposure[1]		Occupational Exposure	
Condition		P, Probability Of Occurrence In A Year	Regulatory Limit (rem per yr)	Design Objective (rem per yr)	Regulatory Limit (rem per yr)	Design Objective (rem per yr)
Routine Operation[2]	Normal Operations	P~1	0.1 total 0.01 airborne[3] 0.004 drinking water	0.01 total	5	1
	Anticipated Events	$1>P\geq10^{-2}$	0.5 total (including normal operation)	0.05 per event		
Accidents[4]	Unlikely Events	$10^{-2}>P\geq10^{-4}$	2.5	0.5	ref[5]	ref[5]
	Extremely Unlikely Events	$10^{-4}>P\geq10^{-6}$	25	5[6]	ref[5]	ref[5]
	Incredible Events	$P<10^{-6}$	NA	NA	NA	NA

3.3.7.2.3 Lighting

Adequate light levels shall be provided.

3.3.7.2.4 Emergency Lighting

Emergency lighting systems shall be provided as required by NFPA 101. A control room emergency lighting system shall be automatically activated and immediately available for **(TBD)** hours on failure of the normal lighting system. The emergency lighting system for vital areas shall be an electrically independent system that is not degraded by failure of the normal lighting system.

3.3.7.2.5 Noise

TBD

3.3.7.2.6 Vibration

TBD

3.3.7.3 Component Arrangement

The arrangement of controls and displays on a control panel shall promote efficient use of task-related components, rapid location of any given component, and maximum operator awareness of plant conditions.

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[1] Evaluated at the PPPL site boundary.

[2] Dose equivalent to an individual from routine operations (rem per year unless otherwise indicated)

[3] Compliance with this limit is to be determined by calculating the highest effective dose equivalent to any member of the public at any off site point where there is a residence, school, business, or office.

[4] Dose equivalent to an individual from an accidental release (rem per event)

[5] See Reference 4, Section 10, Item 10.1302 for exposure limits for emergency situations.

[6] For design basis accidents (DBAs), i.e., postulated accidents or natural forces and resulting conditions for which the confinement structure, systems, components, and equipment must meet their functional goals, the design objective is 0.5 rem.

3.3.7.4 Protective Equipment

a) Personnel who work in a hazardous environment or who may be temporarily exposed to such hazards shall have convenient access to the appropriate protective equipment and garments.

b) Provisions shall be made for access, storage, and maintenance of protective equipment.

c) Personal protection equipment shall be compatible with the body sizes of personnel performing their tasks. There shall be sufficient quantity of this equipment in the proper sizes for the required number of users. There shall be provisions for an adequate supply of personal protective equipment expendables.

d) The design or selection of protective equipment shall be such that it minimizes the impairment of operational and maintenance performance.

3.3.7.5 Display Devices

TBD

3.3.7.6 System Controls

TBD

3.3.7.7 Warning and Annunciator Systems

TBD

3.3.7.8 Communications Systems

TBD

3.3.8 System Security

The system shall provide security features with the capability to protect against unauthorized access and use of the NCSX system.

3.3.9 Government Furnished Property Usage

TBD

3.4 Documentation

N/A

3.5 Logistics

3.5.1 Maintenance

The system shall be maintained using, to the extent possible, standard/common tools and existing multi-purpose test equipment. Use of new/special tools and the number of standard/common tools shall be minimized through maximum commonality of fasteners, clamps, adapters, and connectors.

3.5.2 Supply

The NCSX system shall use the existing PPPL material system.

3.5.3 Facilities

Maximum use shall be made of the existing facilities and equipment at PPPL. Modifications and new facilities shall be constructed only where existing facilities are not adequate to house, store, maintain, operate, or test NCSX equipment.

3.6 Personnel and Training

TBD

3.7 Characteristics of Subordinate Elements

Background

In this section, the performance characteristics defined in Section 3.2.1 are allocated to the subsystem level. These allocated characteristics provide the basis for defining performance characteristics in subsystem specifications.

Requirements

Allocated subsystem performance characteristics are defined in Table 3-3.

Table 3-4 Characteristics Allocation Matrix

Performance Characteristics Allocation Matrix		**WBS**					
Paragraph	**Performance Characteristics**	**1**	**2**	**3**	**4**	**5**	**6**
3.2.1.1	Facility Startup	X	X	X	X	X	X
3.2.1.1.1	Coil Cool-down						
3.2.1.1.1.1	Coil Cool-down Timeline	X					X
3.2.1.1.1.2	Cool-down and Warm-up Cycles	X					X
3.2.1.1.2	Vacuum Requirements						
3.2.1.1.2.1	Base Pressure	X	X				
3.2.1.1.2.2	Pumping Speed	X	X				
3.2.1.2	Pre-operational Initialization and Verification	X	X	X	X	X	X
3.2.1.2.1	Plasma Chamber Conditioning						
3.2.1.2.1.1	Bakeout						
3.2.1.2.1.1.1	Vacuum Vessel Bakeout Temperatures	X					X
3.2.1.2.1.1.2	Carbon-based Plasma Facing Components (PFCs) Bakeout Temperatures	X					X
3.2.1.2.1.1.3	Bakeout Timelines	X					X
3.2.1.2.1.2	Glow Discharge Cleaning (GDC) During Bakeout	X	X				
3.2.1.2.1.3	Boronization	X	X				
3.2.1.2.1.4	Lithiumization	X	X				
3.2.1.3	Pre-shot Initialization and Verification	X	X	X	X	X	X
3.2.1.3.1	GDC Between Shots	X	X				
3.2.1.3.2	Pre-Shot Temperature	X					X

Performance Characteristics Allocation Matrix		**WBS**					
Paragraph	**Performance Characteristics**	**1**	**2**	**3**	**4**	**5**	**6**
3.2.1.4	Experimental Operations						
3.2.1.4.1	Field Error Requirements	X	X	X	X	X	X
3.2.1.4.2	Electrical (Eddy Current) Requirements	X					
3.2.1.4.3	Plasma Magnetic Field Requirements						
3.2.1.4.3.1	Coordinate System	X			X		
3.2.1.4.3.2	Toroidal Field/Plasma Current Directionality	X			X		
3.2.1.4.3.3	Reference Scenarios						
3.2.1.4.3.3.1	Reference Scenario Definition						
3.2.1.4.3.3.1.1	Initial Ohmic Scenario	X			X		
3.2.1.4.3.3.1.2	1.7T Ohmic Scenario	X			X		
3.2.1.4.3.3.1.3	1.7T High Beta Scenario	X			X		
3.2.1.4.3.3.1.4	2T High Beta Scenario	X			X		
3.2.1.4.3.3.1.5	350kA Ohmic Scenario	X			X		
3.2.1.4.3.3.2	Reference Scenario Requirements	X			X		
3.2.1.4.3.4	Flexibility Requirements						
3.2.1.4.3.4.1	Quasi-axisymmetry Flexibility	X			X		
3.2.1.4.3.4.2	External Iota Flexibility	X			X		
3.2.1.4.3.4.3	Internal Iota Flexibility	X			X		
3.2.1.4.3.4.4	Shear Flexibility	X			X		
3.2.1.4.3.4.5	Beta Limit Flexibility	X			X		
3.2.1.4.3.4.6	Current Profile Flexibility	X			X		
3.2.1.4.3.5	Equilibrium Control	X		X	X		
3.2.1.4.4	Power Handling						
3.2.1.4.4.1	PFC Configuration	X					
3.2.1.4.4.2	Maximum Power	X	X				X
3.2.1.4.5	Disruption Handling	X	X	X	X		
3.2.1.4.6	Plasma Heating						
3.2.1.4.6.1	Neutral Beam Heating						
3.2.1.4.6.1.1	Initial NB Heating Complement	X	X		X		X
3.2.1.4.6.1.2	Ultimate NB Heating Complement	X	X		X		X
3.2.1.4.6.2	Ion Cyclotron Heating (ICH)	X	X		X		X
3.2.1.4.7	Plasma Fueling						
3.2.1.4.7.1	Fuel Species		X				
3.2.1.4.7.2	Gas Injection		X				

Performance Characteristics Allocation Matrix		**WBS**					
Paragraph	**Performance Characteristics**	**1**	**2**	**3**	**4**	**5**	**6**
3.2.1.4.7.3	Pellet Injection	X	X				X
3.2.1.4.8	Plasma Diagnostics						
3.2.1.4.8.1	General Diagnostics Requirements			X			
3.2.1.4.8.2	Diagnostics Implementation	X		X		X	
3.2.1.4.9	Instrumentation, Control, and Data Acquisition					X	
3.2.1.4.10	Pulse Repetition Rate	X	X	X	X	X	X
3.2.1.4.11	Discharge Termination						
3.2.1.4.11.1	Normal Termination	X	X	X	X	X	X
3.2.1.4.11.2	Abnormal Termination	X	X	X	X	X	X
3.2.1.5	Facility Shutdown	X	X	X	X	X	X
3.2.1.5.1	Coil Warm-up Timeline	X					X
3.2.1.5.2	Vacuum Vessel Venting	X	X				

4 QUALITY ASSURANCE PROVISIONS

4.1 General

This section identifies the methods to be used for verification of requirements in Section 3 of this specification. General definitions of basic verification methods are outlined. System requirements will be allocated in part or total to lower-level NCSX element specifications. Verification and qualification of individual components will be conducted in accordance with individual specifications. Verification of system requirements will require additional testing in operational or near-operational environments. Detailed planning for verification of all system requirements will be documented in the NCSX Test & Evaluation Plan (TEP) [6].

4.2 Responsibility For Inspection

Unless otherwise stated, contractors are responsible for the planning and performance of all inspection requirements including test, examination, demonstration and analysis that pertain to components and subsystems under their development.

4.3 Responsibility For Conformance

All items, components and subsystems shall meet the requirements of Section 3 of this specification. The inspections set forth in this specification shall become a part of the contractors' overall quality program.

4.4 Inspection Verification Methods

Verification of qualification shall be by examination, demonstration, test or analysis. Definition of examination, demonstration, test and analysis is as follows:

a) Examination: Examination is an element of inspection consisting of investigation, without the use of special laboratory appliances, procedures or supplies and services to determine conformance to those specified requirements which can be determined by such investigations. Examination is generally non-destructive and includes but is not limited to, simple physical manipulation, gauging and measurement, visual, auditory, olfactory, tactile, gustatory and other investigations.

b) Test: Test is an element of inspection denoting the determination of the properties or elements of supplies or components thereof by technical means, including functional operation and the application of established principles and procedures. The analysis of data derived from test is an integral part of the inspection element and shall not be confused with "Analysis" below.

c) Demonstration: Demonstration is an element of inspection that, although technically a variation of test, differs from "Test" above, by directness of approach in the verification of a requirement and is accomplished without the use of elaborate instrumentation or special equipment. Thus, operation of a representative configuration item (CI) in or near its use environment would be defined as a demonstration rather than a test.

d) Analysis: Analysis is an element of inspection in the form of a study resulting in data that is intended to verify a requirement when an examination, test, or demonstration cannot feasibly be employed to verify the requirement. Such data may be a compilation or interpretation of existing data, analysis, design solutions, lower-level inspection results.

4.5 Quality Conformance

Background

This section establishes the specific evaluation criteria for verification of the system requirements in Section 3. Each Section 3 requirement is associated with a Section 0 verification method. The quality conformance matrix included in this section indicates the verification method required to verify conformance. (See sample in Table 4-1.) In general, all requirements shall be verified under operational or near-operational conditions as possible given test constraints.

Requirements

Test methods for each of the requirements in Section 3, i.e. from Section 3.2 and beyond, are identified in the Quality Conformance matrix in Table 4-1. **(Test methods TBD)**

Table 4-1 Quality Conformance Matrix

Quality Conformance Matrix		Test Method			
		Examination	Demonstration	Test	Analysis
3.2.1	Performance Characteristics				
3.2.1.1	Facility Startup				
3.2.1.1.1	Coil Cool-down				
3.2.1.1.1.1	Coil Cool-down Timeline				
3.2.1.1.1.2	Cool-down and Warm-up Cycles				
Etc.					

5 NOTES

5.1 Definitions

TBD

5.2 Acronyms

TBD