General Requirements

Note: Revised entries are shown in blue. To be revised values are shown in red. *Explanatory remarks are in italics.* ***Review issues are shown in bold red italics.***

Cost & Schedule Objectives			
Total Estimated Cost	$69M		Year of expenditure dollars
Project start date	October 1, 2002		
First plasma date	March 31, 2007		
Construction Project Scope			The NCSX Construction Project includes all equipment required through the Initial Ohmic Phase of operation (that is, Phases 1, 2, and 3). In addition, the NCSX Construction Project includes the recommissioning, installation, and testing of two of the beamlines currently installed on the PBX-M tokamak. (Phases of operation are defined in the NCSX Initial Experimental Research Plan.)
			Unless by explicit exception, all equipment in the Construction Project will be installed prior to first plasma (that is, the start of Phase 1 – Initial Operation).
			Systems must be capable of accommodating required upgrades
Siting requirements			
Location of stellarator core			NCSX shall be sited at PPPL in the former PBX/PLT Test Cell (hereafter, referred to as the NCSX Test Cell).
Test cell compatibility			Systems shall be designed to be compatible with NCSX Test Cell. Compatibility issues include maximum lift height and weight, maximum floor loading, and maximum height and width for entry into the NCSX Test Cell.
Plasma parameters			
Nominal major radius	1.4	m	*Used to relate the specified toroidal field to the total poloidal current (Ipol[MA]=5BR). Approximately equal to R(0,0) in the fixed boundary li383 plasma.*
Maximum poloidal current in modular and TF coils	14	MAT	*Corresponds to a maximum field of 2T at 1.4m (BR=2.8)*
Maximum plasma current	350	kA	(TBR)
Machine configuration requirements			
Coil systems			
General			A set of modular (torsatron) coils, PF coils, and TF coils shall be provided to support the reference scenarios and meet flexibility, field error, and polarity requirements.
Trim coils			A set of trim coils shall be provided inboard of the plasma centered on the horizontal midplane at the v=0 cross-section. These trim coils shall have the capability of correcting m=5 and m=6 field errors. (TBR if analysis indicates that one-sided coverage is inadequate.)
			The capability to incorporate additional trim coils (as a future upgrade, with m=4, 5, 6, 7) outboard of the plasma at the v=0 cross-section shall be provided.
Vacuum vessel			
General			A vacuum-tight vessel internal to the modular (torsatron) coils, PF coils, and TF coils shall be provided.
			The inner surface of the vacuum vessel shall be electro-polished.
Plasma facing components (PFCs)			

General			PFCs serve the following functions: [1] Provide for divertor operation including power handling and neutral recycling and density control [2] 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
Initial configuration			A set of poloidal rings that would serve as an array of poloidal limiters is required for initial ohmic operations.
			Areas which are expected to come in contact with the plasma shall be armored with carbon-based tiles.
Future upgrades			The capability to accommodate a divertor (as a future upgrade) shall be provided.
			Plasma facing surfaces shall be located such that long (>100m) connection lengths to the divertor and plasma shape flexibility can be provided.
			The capability to configure the divertor (as a future upgrade) with a slot, permitting neutral particles passages into a sealed plenum that is actively pumped (with a cryopump or titanium getter pump), shall be provided.
			The capability to expand the coverage by the PFCs (as a future upgrade) to 100% shall be provided.
			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.
Material			Plasma facing surfaces shall be carbon-based, i.e. graphite or carbon fiber composite (CFC) material.
Power handling			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.
Operational requirements			
Design life	10	years	When operated per the 1.7T scenario
Maximum number of pulses			When operated per the 1.7T scenario
	100		Per day
	13000		Per year
	130000		Lifetime
Maximum pulse repetition times	15	min	Pulse repetition rate for long pulse operation (when constrained by coil cooldown)
	5	min	Pulse repetition rate for short pulse operation (when not constrained by coil cooldown)
Fuel	H, D		
Shielding	None		D operation administratively limited to avoid additional biological shielding
Magnetic field polarity			
Toroidal field			The device shall be configured for the standard toroidal field direction to be negative.
Poloidal field			The device shall be configured for the standard poloidal field direction to be positive, corresponding to a positive toroidal (plasma) current.
Reconfigurability			The device shall have the capability to be reconfigured to operate with both the toroidal and poloidal magnetic fields simultaneously flipped from their standard directions.
Reference scenarios			
Initial ohmic scenario			*Same as the 1.7T ohmic scneario except with slower ramp rate (1.6 MA/s instead of 3 MA/s)*
Machine capability			The stellarator core and support systems shall be designed to support the initial ohmic scenario.

Scenario parameters			
Maximum poloidal current	10.5	MAT	
Maximum plasma current	154	kA	
Maximum pulse repetition time	15	min	
Timing			
Initiate plasma	0.1	s	Provide closed flux surfaces, initiate inductively
Ramp plasma current	0.096	s	Ramp plasma current to maximum value at 1.6MA/s
Relax plasma at constant current and toroidal field	0.3	s	Plasma current sustained by inductive current drive; poloidal current (toroidal field) at maximum value
Ramp down beta and plasma current	TBD	s	Crowbar power supplies to drive coil currents to zero
1.7T ohmic scenario			*New*
Machine capability			The stellarator core shall be designed to support the 1.7T ohmic scenario. Other systems shall be capable of accommodating the 1.7T ohmic scenario as a future upgrade.
Scenario parameters			
Maximum poloidal current	11.9	MAT	
Maximum plasma current	175	kA	
Maximum pulse repetition time	15	min	
Timing			
Initiate plasma	0.1	s	Provide closed flux surfaces, initiate inductively
Ramp plasma current	0.058	s	Ramp plasma current to maximum value at 3MA/s
Relax plasma at constant current, beta, and toroidal field	0.3	s	Plasma current sustained by bootstrap, NBI, and inductive current drive; poloidal current (toroidal field) at maximum value
Ramp down beta and plasma current	TBD	s	Crowbar power supplies to drive coil currents to zero
1.7T high beta scenario			*Formerly the high field scenario*
Machine capability			The stellarator core shall be designed to support the 1.7T high beta scenario. Other systems shall be capable of accommodating the 1.7T high beta scenario as a future upgrade.
Scenario parameters			
Maximum poloidal current	11.9	MAT	
Maximum plasma current	175	kA	
Maximum pulse repetition time	15	min	
Timing			
Initiate plasma	0.1	s	Provide closed flux surfaces, initiate inductively
Ramp plasma current	0.058	s	Ramp plasma current to maximum value at 3MA/s
Heat to maximum beta	0.1	s	Staircase NBI to heat plasma to maximum beta holding plasma current at maximum value
Relax plasma at constant current, beta, and toroidal field	0.2	s	Plasma current sustained by bootstrap, NBI, and inductive current drive; poloidal current (toroidal field) at maximum value
Ramp down beta and plasma current	TBD	s	Crowbar power supplies to drive coil currents to zero

2T high beta scenario			*This is a new scenario. It is intended to push the machine to higher fields without increasing the $I^2 t$ for the modular coils above the levels in the 1.7T scenario. The higher field is afforded by [1] a reduced flattop, [2] reduced modular coil currents (iota) in vacuum (S1),and [3] shorter dwell time prior to plasma initiation.*
Machine capability			The stellarator core shall be designed to support the 2T scenario. Other systems shall be capable of accommodating the 2T scenario as a future upgrade.
Scenario parameters			
Maximum poloidal current	14	MAT	
Maximum plasma current	206	kA	
Maximum pulse repetition time	15	min	
Timing			
Initiate plasma	0.05	s	Provide closed flux surfaces, initiate inductively
Ramp plasma current	0.069	s	Ramp plasma current to maximum value at 3MA/s
Heat to maximum beta	0.1	s	Staircase NBI to heat plasma to maximum beta holding plasma current at maximum value
Ramp down beta and plasma current	TBD	s	Crowbar power supplies to drive coil currents to zero
Flexibility requirements			
			The ranges in flexibility shown below are preliminary. They will be revisited once the design and cost implications are understood.
External iota flexibility			The coils shall be designed and the power systems be upgradeable to vary the edge iota over the range from 0.44-0.85 while holding the global shear ($\iota(a)-\iota(0)$) to 0.22 at constant plasma current (174kA) and toroidal field (BR=2.37 T-m).
Internal iota flexibility			The coils shall be designed and the power systems be upgradeable to vary the iota due to the plasma current at fixed toroidal field (BR=2.37 T-m).
			The plasma current shal be capable of being varied from -350 kA to +350 kA.
Shear flexibility			The coils shall be designed and the power systems be upgradeable to vary the edge iota over the range from 0.44-0.85 while holding the central iota to 0.43 at constant plasma current (174kA) and toroidal field (BR=2.37 T-m).
Beat limit flexibility			The coils shall be designed and the power systems be upgradeable to vary the beta limit (TBR).
Quasi-symmetry flexibility			The coils shall be designed and the power systems be upgradeable to vary quasi-symmetry (TBR).
Current profile flexibility			The coils shall be designed and the power systems be upgradeable to vary the plasma current profile (TBR).
Field error requirements			
			Field errors from all sources shall not result in islands that significantly increase transport. *[Use 10% as upper bound for toroidal flux in island regions.]*
Disruption requirements			
			The device shall be designed to withstand electromagnetic forces due to major disruptions characterized by the disappearance of the plasma at with the maximum plasma current (350 kA).
Electrical (eddy current) requirements			

Eddy currents			Eddy currents in conducting structures surrounding the plasma shall not give rise to unacceptable field errors.
External kink mode stabilization			The time constant of the vacuum vessel and in-vessel structures must be less than 10 ms (TBR).
Temperature requirements			
Bakeout temperature			The vacuum vessel shall be bakeable at 150C.
			The capability to bake carbon plasma facing components at 350C (as a future upgrade) shall be provided.
Pre-shot operating temperature			The pre-shot operating temperature of the vacuum vessel shall be capable of being maintained in the range of 20C-TBD without ratcheting.
			The pre-shot operating temperature of the plasma facing components shall be capable of being maintained in the range of 20C-TBD without ratcheting (TBR).
Wall conditioning			
Glow discharge cleaning			DC glow discharge cleaning (GDC) at bakeout temperatures, for indefinite time periods, in H, D, or He
			The facility shall be designed to to perform GDC between shots.
Boronization			The capability to boronize all surfaces with line-of-sight to the plasma shall be provided.
Lithiumization			The facility shall be upgradeable to apply lithium coatings, either via Li pellets or spray, or other techniques.
Neutral beam heating			
			Studies will be undertaken in conceptual design to determine the limitations and design impacts of changing the injection angle of the neutral beams
Initial configuration			
Beamlines	1		Co-injected PBX beamlines tangent near magnetic axis
	1		Counter-injected PBX beamlines tangent near magnetic axis
Power	3	MW	Nominal power to plasma from 2 PBX beamlines
Beam energy	50	keV	Nominal beam energy in PBX beamlines
Tangency radius	TBD	m	*Inside the high beta (S3) magnetic axis w/o hitting the wall on inboard side*
Toroidal location of tangency point	TBD		
Pulse length	0.3	s	
Upgrade configuration			
Beamlines	2		Co-injected PBX beamlines tangent near magnetic axis
	2		Counter-injected PBX beamlines tangent near magnetic axis
			One of the counter-injected PBX beamlines must be reconfigurable for co-injection when the device is operated in the standard polarity.
Power	6	MW	Nominal power to plasma from 4 PBX beamlines
Beam energy	50	keV	Nominal beam energy in PBX beamlines
Tangency radius	TBD	m	*Inside the high beta (S3) magnetic axis w/o hitting the wall on inboard side*
Toroidal location of tangency point	TBD		
Pulse length	1.2	s	
RF heating			

ICH			
Power	6	MW	Upgrade configuration; no ICH in TPC
Pulse length	1.2	s	Upgrade configuration
Frequency range	20-30	MHz	*Mode conversion RF*
Number of launchers	3		One inboard launcher at each v=0.5 cross-section.
ECH			
			No ECH system is planned
LHH			
			No LHH system is planned
Vacuum			
Base pressure	2E-08	Torr	Base partial pressure for fuel gases (Z=2) with the system at room temperature
	5E-09	Torr	Base partial pressure for impurity gases (Z>2) with the system at room temperature
Pumping requirements			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 pumping speed at the torus of TBD. *(Should be equal to or greater than that achieved on PBX-M.)*
Vacuum compatibility			All in-vessel metallic components shall be elctro-polished.
			All in-vessel components shall be baked and outgassed prior to installation.
			All in-vessel materials shall be approved by the Project for vacuum compatibility.
Fueling			
Gas injection			
			The device and facility shall have a programmable gas injection system based on the PBX-M system with feedback on real-time density measurement.
Pellet injection			
Fueling rate			The device and facility shall be capable of being upgraded to provide a single pellet injector capable of repetititvely injecting H or D pellets.
Launch location			The device shall incorporate guide tubes to accommodate pellet launch from the inboard (high-field) side of the plasma.
External interfaces			
			External interfaces are those that exist between the NCSX project and the outside world (PPPL and beyond). The purpose of this section is to identify where those interfaces are. Lower level interface requirements will provide the technical specifications and designate responsibilities.
Electrical power			NCSX will share the D-site Transrex power supplies with NSTX for powering the modular, TF, and PF coils.
			NCSX will tie into the existing C-site AC power system for all other power requirements.
Water cooling			NCSX will tie into the C-site water cooling system for non-cryogenic heat rejection.
Record of Revisions			
	11/13/2000		Major radius changed to an even 1.7m - used to determine poloidal current
	11/17/2000		Revised table in accordance with Neilson/Zarnstorff meeting on 11/16; major changes include:
			* added 1T scenario

			* reduced heating pulse length from 4s to 1.7s
	11/30/2000		Revised table in accordance with Neilson comments received on 11/29 via e-mail (001130_requirements)
	12/8/2000		Added the Day One scenario
	1/3/2001		Revised table in accordance with Neilson guidance (12/20/2000 e-mail); major changes include:
			* added magnetic field polarity requirements
			* added flexibility requirements
			* added disruption requirement
	1/16/2001		Revised table to reflect smaller machine size and lower field
			* size scaled by 0.82
			* toroidal field scaled by 0.85
			* ramp rates increased to 3 MA/s for high/low field scenarios, 2 MA/s for Day One scenario
			* flattop at low field reduced to 1s
	7/24/2001		Revised cost and schedule objectives
			Low field scenario deleted, magnetic field in Day One scenario raised to 1.7T
			Maximum pulse repetition times explicitly added
	8/27/2001		Applied design life and number of pulses to reference high field scenario
			Added requirements for maximum poloidal current and maximum plasma current
			Added section on external interfaces
	10/5/2001		Revised first plasma data and TPC consistent with revised DOE funding profile
			Changed TPC to year of expenditure dollars, added project start data
	10/11/2001		Updated requirements to be in line with current design and thinking
			* Added siting requirement
			* Modified trim coil requirements. Outboard trim coil now an upgrade requirement.
			* Revised performance requirements for PFCs. Added upgrade requirements for a pumped divertor and expanded PFC coverage
			* Explicitly required the stellarator core to be designed for the high field scenario.
			* Replace HHFW requirements with requirements fro mode conversion RF
	11/13/2001		Updated requirements consistent with guidance from 10/17 meeting with Neilson and Zarnstorff
			* Revised definition of Construction Project scope
			* Set a maximum plasma current of 350kA
			* Added a 2T reference scenario
			* Renamed the high field scenario as the 1.7T scenario
			* Modified the Day One scenario and renamed it as the initial ohmic scenario
			* Imposed a "crowbar" condition for discharge termination
			* Added vacuum compatibility requirements
			* Deleted requirements for ECH and HHFW upgrades
			* Lowered base pressure to 2e-8