NCSX Work Breakdown Structure

Stellarator Core Systems (WBS1)

Auxiliary Systems (WBS2)

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Electrical Power Systems (WBS 4)

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Project Management and Integration (WBS 8)

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NCSX Fabrication Project

Work Breakdown Structure (WBS) Dictionary

Stellarator Core Systems (WBS 1)

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Prepared by: _____
W. Reiersen, Engineering Manager

Reviewed by: _____
B. Nelson, Cognizant WBS Manager (WBS 1)

Reviewed by: _____
R. Simmons, Project Control Manager

Reviewed by: _____
M. Zarnstorff, Physics Manager

Reviewed by: _____
P. Heitzenroeder, Deputy Project Manager for Engineering

Approved by: _____
G. H. Neilson, Project Manager

NCSX WBS Dictionary
Stellarator Core Systems

WBS Element: 1	**WBS Level: 2**
WBS Title:	**Stellarator Core Systems**
Description:	NCSX operations are divided into six phases: 1. Initial Operation 2. Field Line Mapping 3. Initial Ohmic 4. Initial Auxiliary Heating 5. Confinement and Beta Push 6. Long Pulse The NCSX Fabrication 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 re-commissioning and installation of two of the neutral beamlines currently installed on the PBX-M tokamak. Unless by explicit exception, Fabrication Project are all the engineering and physics design efforts starting with the preliminary design phase (Title I) and ending with completion of the Fabrication Project, all the necessary Research and Development (R&D) to support the design effort, all component fabrication, assembly, and installation activities, and all system level commissioning and testing. Integrated systems testing of the entire NCSX device is covered in Pre-Operational and Integrated Systems Testing (WBS 92). Stellarator Core Systems include all the systems and related elements that directly provide the confining magnetic fields, the high vacuum enclosure, and the power and particle handling required for plasma formation and operation. Stellarator Core Systems include: • Plasma Facing Components (WBS 11), • Vacuum Vessel Systems (WBS 12), • TF Coils (WBS 13), • PF Coils (WBS 14), • Cryostat (WBS 15), • Machine Support Structure (WBS 16), • Modular Coils (WBS 17), • Trim Coils (WBS 18), and • LN_2 Cooling Distribution System (WBS 19).

WBS Element: 11		WBS Level: 3
WBS Title:	**Plasma Facing Components (PFCs)**	
Description:	This WBS element consists of all the in-vessel systems required to absorb the heat and particle fluxes from the plasma and to effect divertor operation for neutral recycling and density control. This WBS element also includes all the in-vessel systems that serve to protect the vacuum vessel and in-vessel components from energetic particles and heat fluxes from the plasma. Sub-elements within WBS 11 include the: • First Wall Panels and Limiters (WBS 111); • Support Ribs (WBS 112); • PFC Heating and Cooling Distribution System (WBS 113) • Divertor Plenum Baffles (WBS 114) • Divertor Plenum Pumping System (WBS 115) • PFC Local I&C (WBS 116) All local I&C within WBS 11 is included under PFC Local I&C (WBS 116). **For the NCSX Fabrication Project, local limiters will be supplied that satisfy the operational requirements for Phases 1-3 of operation.** These limiters consist of simple flat tiles attached to the vacuum vessel assembly flanges, which are located on either side of the v=1/2 symmetry planes. **For the NCSX Fabrication Project, this WBS element includes the design effort to assure that the complete assembly of PFCs required to meet the upgrade requirements can plausibly be accommodated as a future upgrade**. The design, fabrication, and installation of the complete assembly of PFCs are outside the scope of the Fabrication project.	
WBS Element: 111		**WBS Level: 4**
WBS Title:	**First Wall Panels and Limiters**	
Description:	**For the NCSX Fabrication Project, local limiters will be supplied that satisfy the operational requirements for Phases 1-3 of operation.** These limiters consist of simple flat tiles attached to the vacuum vessel assembly flanges, which are located on either side of the v=1/2 symmetry planes.	
WBS Element: 112		**WBS Level: 4**
WBS Title:	**Support Ribs**	
Description:	***Not required in NCSX Fabrication Project***	
WBS Element: 113		**WBS Level: 4**
WBS Title:	**PFC Heating and Cooling Distribution System**	
Description:	***Not required in NCSX Fabrication Project***	
WBS Element: 114		**WBS Level: 4**
WBS Title:	**Divertor Plenum Baffles**	
Description:	***Not required in NCSX Fabrication Project***	
WBS Element: 115		**WBS Level: 4**
WBS Title:	**Divertor Plenum Pumping System**	
Description:	***Not required in NCSX Fabrication Project***	
WBS Element: 116		**WBS Level: 4**
WBS Title:	**PFC Local I&C**	
Description:	This WBS element provides the local I&C required by other WBS elements included under Plasma Facing Components (WBS 11). Local I&C requirements will be	

	determined in the design of these other WBS elements. Divertor diagnostics are included under Diagnostics (WBS 3).

WBS Element: 12	**WBS Level: 3**
WBS Title:	**Vacuum Vessel Systems**
Description:	The vacuum vessel provides a vacuum boundary around the plasma chamber suitable for high vacuum conditions; structural support for all internal hardware, including the PFC Local Limiters (WBS 111) and Support Ribs (WBS 112); and access for Auxiliary Systems (WBS 2) and Diagnostics (WBS 3). This WBS element consists of all the following sub-elements: • Vacuum Vessel Assembly (WBS 121); • Vacuum Vessel Thermal Insulation (WBS 122); • Vacuum Vessel Heating and Cooling Distribution Systems (WBS 123); • Vacuum Vessel Supports (WBS 124); and • Vacuum Vessel Local I&C (WBS 125).
WBS Element: 121	**WBS Level: 4**
WBS Title:	**Vacuum Vessel Assembly**
Description:	This WBS element consists of the vacuum vessel shell, ports and extensions, blank port covers, PFC support rib interfaces, vacuum vessel support interfaces, and cooling tubes. The vessel port extensions are needed to transfer the vacuum interface flanges on the ports to an accessible location outside the modular coil structure. Each extension includes the flanges, extension tube with weld prep, and seal/bolting hardware and will come with a blank port cover. The port extensions must be welded onto the three vessel sub-assemblies after installation of the modular coils and prior to final assembly. Port stubs are provided on the vessel to permit the modular coils to slip on first, followed by welding of the port extensions. However, the port extension welding is not included in this WBS element, but is covered in WBS 7. Modification of the blank port covers to accommodate end users, e.g. Diagnostics (WBS 3), is the responsibility of the primary end user.
WBS Element: 122	**WBS Level: 4**
WBS Title:	**Vacuum Vessel Thermal Insulation**
Description:	This WBS element consists of the equipment that will provide thermal insulation between the warm vessel (293K and above) and the cold coils and structures (80K).
WBS Element: 123	**WBS Level: 4**
WBS Title:	**Vacuum Vessel Heating and Cooling Distribution Systems**
Description:	The vacuum vessel is maintained at its desired temperature (150C for bakeout, 20 to 100C for operation) by circulating a coolant through coolant tubes attached to the vacuum vessel. The Vacuum Vessel Heating and Cooling Distribution System connects the Vacuum Vessel Assembly (WBS 121) with the Vacuum Vessel and PFC Heating and Cooling System (WBS 625).
WBS Element: 124	**WBS Level: 4**
WBS Title:	**Vacuum Vessel Supports**
Description:	This WBS element consists of the equipment required to attach the Vacuum Vessel Assembly (WBS 12) to Modular Coil Winding Form/Structure (WBS 172).
WBS Element: 125	**WBS Level: 4**
WBS Title:	**Vacuum Vessel Local I&C**
Description:	This WBS element provides the local I&C required by other WBS elements included under Vacuum Vessel Systems (WBS 12). Local I&C requirements will be determined in the design of these other WBS elements.

WBS Element: 13	WBS Level: 3
WBS Title:	**Toroidal Field (TF) Coils**
Description:	This WBS element consists of the following: • TF Winding Pack (WBS 131); • TF Winding support interface hardware (WBS 132); and • TF Local I&C (WBS 133). Included in these elements are all the engineering and physics design efforts starting with the preliminary design phase (Title I) and ending at first plasma, all TF magnet component fabrication and assembly activities, and all system level commissioning and testing. At this time no R&D is anticipated for this WBS element. TF magnets and structure assembly and installation within the Test Cell and integrated systems testing of the TF magnet systems are covered in WBS Element 7 (Machine Assembly) and WBS 9 (Preparations for Operations)..
WBS Element: 131	**WBS Level: 4**
WBS Title:	**TF Winding Packs**
Description:	This WBS element consists of the manufacturing design and fabrication of the TF conductor, and the assembly of the TF winding packs. A set of toroidal field coils is included to provide flexibility in the magnetic configuration. There are 18 identical, equally spaced coils providing a 1/R field at the plasma. The windings are supported by an external structure described in WBS 162. The coils are wound from hollow copper conductor and vacuum impregnated with epoxy. They operate at the same temperature as the modular coil set, nominally 80K (cooled by LN_2). The winding packs are attached to the Coil Support Assembly (WBS 162).. At this time no R&D is anticipated for this WBS element.
WBS Element: 132	**WBS Level: 4**
WBS Title:	**TF Leads**
Description:	This WBS element consists of the manufacturing design and fabrication of the bus within the cryostat boundary up to and including interface elements for connections to power and cooling supply at the cryostat boundary. The TF coils operate at the same temperature as the modular coil set, nominally 80K (cooled by LN_2) and are connected in series. The leads consist of coaxial conductor to minimize field errors.
WBS Element: 133	**WBS Level: 4**
WBS Title:	**TF Local I&C**
Description:	This WBS element provides the local I&C required by other WBS elements included under TF Coils (WBS 13). Local I&C requirements will be determined in the design of these other WBS elements, but temperature sensors (RTDs), voltage taps, and strain gages could be included in this element.

WBS Element: 14	WBS Level: 3
WBS Title:	**Poloidal Field (PF) Coils**
Description:	The poloidal field (PF) magnets produce the poloidal magnetic field within the FIRE device. This WBS element consists of the following: • PF – Central Solenoid Coils (PF 1&2) (WBS141); • PF 3 Windings (WBS 142); • PF 4 Windings (WBS 143); • PF 5 Windings (WBS 144); • PF 6 Windings (WBS 145); • PF Leads (WBS 146); and • PF Local I&C (WBS 147) Included in these elements are all the engineering and physics design efforts starting with the preliminary design phase (Title I) and ending at first plasma, all PF coil component fabrication and assembly activities, all system level commissioning and

	testing and the local I&C that is integral with the PF coils. At this time no R&D is anticipated for this WBS element. PF coils and structure assembly and installation within the Test Cell and integrated systems testing of the PF coil systems are covered in WBS Element 7 (Machine Assembly) and WBS 9 (Preparations for Operations).
WBS Element: 141	**WBS Level: 4**
WBS Title:	**PF OH Solenoid Coils (PF 1 & 2)**
Description:	This WBS element covers design and fabrication of the PF 1 & 2 central solenoid coil pairs. These coils and PF 3 provide for inductive current drive and plasma shape and position control. Coil pairs are symmetric about the horizontal midplane. The coils are of conventional construction, wound from hollow copper conductor and vacuum impregnated with epoxy. The PF coils operate at the same temperature as the modular and TF coil sets, nominally 80K (cooled by LN_2). The coils are clamped together with vertical tie rods (WBS 163) and connected to the external TF structure (WBS 162). This WBS element consists of preliminary and detailed design, manufacturing design and fabrication of the PF center stack coils.
WBS Element: 142	**WBS Level: 4**
WBS Title:	**PF 3 Windings**
Description:	This WBS element covers design and fabrication of the PF 3 centerstack coil pair. These coils and the central solenoid coils (PF 1 & 2) provide for inductive current drive and plasma shape and position control. Coil pairs are symmetric about the horizontal midplane. The coils are of conventional construction, wound from hollow copper conductor and vacuum impregnated with epoxy. The PF coils operate at the same temperature as the modular and TF coil sets, nominally 80K (cooled by LN_2). The coils are clamped together with vertical tie rods (WBS 163) and connected to the external TF structure (WBS 162). This WBS element consists of preliminary and detailed design, manufacturing design and fabrication of the PF center stack coils.
WBS Element: 143	**WBS Level: 4**
WBS Title:	**PF 4 Windings**
Description:	This WBS element covers design and fabrication of the PF 4 mid ring coil pair. Coil pairs are symmetric about the horizontal midplane. The coils are of conventional construction, wound from hollow copper conductor and vacuum impregnated with epoxy. The PF coils operate at the same temperature as the modular and TF coil sets, nominally 80K (cooled by LN_2). The coils are supported via adjustable clamps to the external TF coil structure (WBS 162). The coils are designed to be self-supporting for radial loads. Vertical loads will be transmitted through the adjustable clamps to the external TF structure.
WBS Element: 144	**WBS Level: 4**
WBS Title:	**PF 5 Windings**
Description:	This WBS element covers design and fabrication of the PF 5 outer ring coil pair. Coil pairs are symmetric about the horizontal midplane. The coils are of conventional construction, wound from hollow copper conductor and vacuum impregnated with epoxy. The PF coils operate at the same temperature as the modular and TF coil sets, nominally 80K (cooled by LN_2). The coils are supported via adjustable clamps to the external TF coil structure (WBS 162). The coils are designed to be self-supporting for radial loads. Vertical loads will be transmitted through the adjustable clamps to the external TF structure.

WBS Element: 145	WBS Level: 4
WBS Title:	**PF 6 Windings**
Description:	This WBS element covers design and fabrication of the PF 6 outer ring coil pair. Coil pairs are symmetric about the horizontal midplane. The coils are of conventional construction, wound from hollow copper conductor and vacuum impregnated with epoxy. The PF coils operate at the same temperature as the modular and TF coil sets, nominally 80K (cooled by LN_2). The coils are supported via adjustable clamps to the external TF coil structure (WBS 162). The coils are designed to be self-supporting for radial loads. Vertical loads will be transmitted through the adjustable clamps to the external TF structure.
WBS Element: 146	**WBS Level: 4**
WBS Title:	**PF Leads**
Description:	This WBS element consists of the manufacturing design and fabrication of the bus, manifolds, and cooling pipes within the cryostat boundary up to and including interface elements for connections to power and cooling supply at the cryostat boundary. This element covers leads and cooling interfaces for all the PF coils. The leads consist of coaxial conductor to minimize field errors. Upper and lower PF coils in a given pair are connected in series, and PF1 and PF2 coils are connected in series. Thus, there are five independent electrical circuits. The PF coils operate at the same temperature as the modular and TF coil sets, nominally 80K (cooled by LN_2).
WBS Element: 147	**WBS Level: 4**
WBS Title:	**PF Local I&C**
Description:	This WBS element provides the local I&C required by other WBS elements included under PF Coils (WBS 14). Local I&C requirements will be determined in the design of these other WBS elements, but temperature sensors (RTDs), voltage taps, and strain gages could be included in this element.

WBS Element: 15	WBS Level: 3
WBS Title:	**Cryostat**
Description:	This WBS element consists of all the following: • Cryostat Shell and Structure (WBS 151); • Cryostat Thermal Insulation (WBS 152); • Vacuum Vessel/Cryostat Boots (WBS 153); • Cryostat Temperature Control/Heaters (WBS 154); and • Cryostat Local I&C (WBS 155) The cryostat encloses the NCSX device to provide a suitable thermal environment for the magnets. This WBS element includes the cryostat shell & structure, the wall insulation for the cryostat shell & structure, attachments for the structural support of internal components, and the required electrical, cooling and mechanical penetrations. Provisions shall be established to maintain thermal and electrical isolation, , local I&C, and appropriate interface control with the other WBS elements. Included in these elements are the necessary engineering and physics design efforts starting with the preliminary design phase (Title I) and ending at first plasma, all cryostat component fabrication and assembly activities, and all system level commissioning and testing. At this time, no R&D is anticipated for this WBS element. Cryostat assembly and installation within the Test Cell and integrated systems testing of the cryostat systems are covered in WBS Element 7 (Machine Assembly) and WBS 9 (Preparations for Operations).

WBS Element: 151		WBS Level: 4
WBS Title:	**Cryostat Shell and Structure**	
Description:	A cryostat is provided for thermal isolation. The cryostat must also seal the coil space from the outside air to prevent condensation on the cold surfaces and to provide a means for circulating dry nitrogen inside the cryostat. . The baseline concept consists of a simple fiberglass frame and panel design covered with urethane insulation. The frame consists of a molded fiberglass frame mounted to the TF coil external support structures. Fiberglass panels are attached to the frame to form a surface for the urethane. This WBS covers the frame and panels. This WBS element consists of the effort to design, fabricate, and pre-assemble/disassemble the cryostat shell & structure before assembly on the tokamak structure.	
WBS Element: 152		**WBS Level: 4**
WBS Title:	**Cryostat Thermal Insulation**	
Description:	This WBS element consists of the effort to specify and provide the cryostat thermal insulation that forms the thermal barrier between the magnets and the ambient temperature test cell. The insulation does not serve any radiation shielding or structural support functions. Urethane is sprayed on the cryostat panel assembly using a commercial process typically used for large stationary cryogenic tanks. The exterior surface of the urethane is then sprayed with a butyl rubber coating for an additional gas seal and to provide a durable surface.	
WBS Element: 153		**WBS Level: 4**
WBS Title:	**Vacuum Vessel/Cryostat Boots**	
Description:	The cryostat must seal the coil space from the outside air to prevent condensation on the cold surfaces and provide a means for circulating dry nitrogen inside the cryostat to cool down and maintain the temperature of the interior structures. A flexible silicone rubber boot is used to provide a seal between the cryostat and the penetration openings. These boots are commercially available. This WBS element consists of the effort to design, specify, and provide the boots and the interfaces between the boots and cryostat and boots and vacuum vessel.	
WBS Element: 154		**WBS Level: 4**
WBS Title:	**Cryostat Temperature Control/Heating Systems**	
Description:	The urethane insulation is probably not sufficient to prevent condensation on the outside of the cryostat. For this reason, heaters will be used to control the outside surface temperature and prevent condensation. This estimate provides an allotment to purchase standard heaters and controls. This WBS element consists of the effort to design, specify and fabricate the cryostat temperature control/heating system components.	
WBS Element: 155		**WBS Level: 4**
WBS Title:	**Cryostat Local I&C and Sensors**	
Description:	This WBS element consists of the effort to design, specify, and fabricate, the cryostat local I&C systems and sensors.. Installation within the test cell will be covered under WBS Element 7 (Machine assembly).	

WBS Element: 16	WBS Level: 3
WBS Title:	**Support Structure**
Description:	This WBS element consists of all the following: • Machine Base Assembly and Gravity Supports (WBS 161); • TF Coil Support Assembly (WBS 162); and • PF Coil Supports (WBS 163) The support structures provide the overall supporting mechanism between tokamak components as well as support to the test cell floor. At this time, no R&D is anticipated for this WBS element. Assembly and installation of these support structures within the Test Cell is covered in WBS Element 7 (Machine Assembly)..
WBS Element: 161	**WBS Level: 4**
WBS Title:	**Machine Base Assembly & Gravity Supports**
Description:	This WBS element consists of the design and fabrication of the machine base assembly. The machine base assembly consists of the base column assemblies, interconnecting beams and column base hardware. The base columns are tall enough to provide headroom under the machine and are mounted to provide a means of accommodating thermal movement. The columns will provide a long conduction path for reducing heat leakage to the machine. The interconnecting beams provide support for rails that allow individual field periods to be retracted 18 inches radially to provide sufficient clearance between the modular coils for assembly and disassembly of the field periods. Radial slide assemblies are installed on top of the support base to interface with the TF coil structure and modular coil field period subassemblies and to provide a means of assembling the machine in three field periods. The slide assemblies also provide a set of horizontal interface planes for the radial support plates. Each of three assemblies includes a horizontal alignment plate, two radial slide assemblies, four interface brackets to the radial support plates, and assorted shims and hardware.
WBS Element: 162	**WBS Level: 4**
WBS Title:	**Coil Support Assembly**
Description:	This WBS element consists of the design and fabrication of the external TF coil support structure. The external structure supports both the TF and PF coils and is tied to the modular coil structure. Tie rods and spacers will connect the center stack coils, (PF 1, 2, and 3) to each other, while support plates and crown assemblies will tie the centerstack to the external TF structure. Adjustable brackets will provide the interface between the external TF structure and the PF ring coils to accurately align the coils with respect to the modular coils and TF coils. Since large ring coils are often out-of-round, these brackets will also serve to bring the coils into an acceptably round shape.
WBS Element: 163	**WBS Level: 4**
WBS Title:	**Support Structure Local I&C**
Description:	This WBS element consists of the design and procurement of the local I&C sensors for the machine support structure..

WBS Element: 17	WBS Level: 3
WBS Title:	**Modular Coils**
Description:	This WBS element consists of all the following: • Windings and Coil Assembly (WBS 171); • Winding Form/Structure (WBS 172); • Modular Coil Leads (WBS 173); and • Modular Coils Cooling System (WBS 174). This WBS element consists of the design and fabrication of the modular coil components, including supporting R&D necessary for the design and fabrication of these components. Modular coil assembly and installation within the Test Cell and

	integrated systems testing of the cryostat systems are covered in WBS Element 7 (Machine Assembly) and WBS 9 (Preparations for Operations).	
WBS Element: 171		**WBS Level: 4**
WBS Title:	**Modular Coil Windings and Coil Assembly**	
Description:	This WBS element consists of the design and fabrication of the modular coil windings and coil assembly. The modular coil set consists of three field periods with 6 coils per period, for a total of 18 coils. Due to symmetry, only three different coil shapes are needed to make up the complete coil set. Within the modular coil envelope is a 19 mm thick web that supports two multi-turn winding packs. The design concept uses flexible, copper cable conductor that has been compacted into a rectangular cross-section and wrapped with kapton and glass tape insulation. The conductor is wound in a double pancake on each side of the structural web. Chill plates consisting of copper sheet with cooling tubes for liquid nitrogen coolant are provided on either side of the winding packs. After winding is complete, the final geometry is verified and the assembly is vacuum pressure impregnated with epoxy to complete the insulation system. The epoxy fills the voids within the cable conductor so the winding pack becomes a monolithic copper-glass-epoxy composite. Auxiliary clamping brackets are then installed. This element includes the conductor, insulation, winding, epoxy impregnation, clamp brackets, inspection and electrical testing.	
WBS Element: 172		**WBS Level: 4**
WBS Title:	**Modular Coil Winding Form/Structure**	
Description:	This WBS element consists of the design and fabrication of the modular coil winding form/structure. There are three different coil types and three different winding forms that are repeated for a total of 18 winding forms. Each winding form is fabricated as a casting. Due to the complexity of the shape, the pattern geometry is assumed to require at least two iterations by a pattern maker. After stress relieving the castings in a fixture, all structural interface features are machined. After the coils are wound , the winding forms are bolted together, to form a complete modular coil shell structure. Assembly of the individual coil subassemblies is part of WBS 7 (Machine Assembly)	
WBS Element: 173		**WBS Level: 4**
WBS Title:	**Modular Coil Leads**	
Description:	This WBS element consists of the design and fabrication of the modular coil leads. The coils are connected electrically in 3 circuits in groups of 6. Each circuit is independently powered to provide maximum flexibility. A crossover between layers occurs at the outside of each coil and the leads extend from the plasma side of the winding pack in a coaxial arrangement to the interconnecting bus. he interconnecting bus consists of coaxial cables from the coils to the boundary of the cryostat.	
WBS Element: 174		**WBS Level: 4**
WBS Title:	**Modular Coil Local I&C**	
Description:	This WBS element consists of the design and fabrication of the modular coil local I&C components. The modular coil set requires several types of sensors at each coil. The initial design assumes 2 strain gages, 4 RTDs, and 2 voltage taps per coil.	

NCSX WBS Dictionary
Stellarator Core Systems

WBS Element: 18	WBS Level: 3
WBS Title:	**Trim Coils**
Description:	This WBS element consists of all the following: • External Trim Coil Assemblies (WBS 181); • Internal Trim Coil Windings (WBS 182); • Trim Coil Leads (WBS 183); and • Trim Coil Local I&C (WBS 184). The internal and external trim coils mitigate field errors in the NCSX device. This WBS element consists of the design and fabrication of the modular trim coils No R&D is anticipated for the design and fabrication of these components. Trim coil assembly and installation within the Test Cell and integrated systems testing of the cryostat systems are covered in WBS Element 7 (Machine Assembly) and WBS 9 (Preparations for Operations).
WBS Element: 181	**WBS Level: 4**
WBS Title:	**External Trim Coil Assemblies**
Description:	This WBS element consists of the design and fabrication of the external trim coil assemblies, referred to as external field error correction coils. These are provided on the top, bottom and outside perimeter of the coil support structure to reduce 1-1, 2-1, 3-1, and 3-2 resonant errors that may result from manufacturing or assembly errors in the modular coil geometry. These coils are wound from conventional, hollow copper conductor and vacuum pressure impregnated with epoxy. They are supported by the External Coil Support Structure described in section 2.1.3, and operate at liquid nitrogen temperatures. Each coil must be independently powered to provide the flexibility needed for correcting field errors. These coils will be mechanically installed by first plasma, but will not be electrically connected or tested until later.
WBS Element: 182	**WBS Level: 4**
WBS Title:	**Internal Trim Coil Winding Assemblies**
Description:	This WBS element consists of the design and fabrication of the internal trim/field correction coil winding assemblies. This second set of coils may be provided sometime during the operation of NCSX to mitigate, in particular the errors on m=5 and m=6 resonant surfaces. The coils are configured in a saddle geometry and are located inside the vacuum vessel on the inboard and outboard regions of the v=0 (bean-shaped) plasma cross-section. The coils should require no more than 10 kA-turns per coil. To provide this, five turns are envisaged in a 5 cm x 1 cm winding pack. Since the coils are located in the vacuum vessel, they must be vacuum tight (canned). High temperature electrical insulation will be required. The present concept for the coils is to provide a formed and embossed stainless steel panel into which the four saddle coils would be wound, with a second panel seam welded over the coils to provide the vacuum closure. Special tooling will be required to provide an accurate, contoured shape. The completed panels can be fully supported by the vacuum vessel on the inboard side, but must be cantilevered from the top and bottom on the outboard side. .
WBS Element: 183	**WBS Level: 4**
WBS Title:	**Trim Coil Leads**
Description:	This WBS element consists of the design and fabrication of the trim coil leads. A set of coaxial leads will be provided fromeach of the external trim coils.. This element includes the coaxial leads with end connections..
WBS Element: 184	**WBS Level: 4**
WBS Title:	**Trim Coil Local I&C**
Description:	This WBS element consists of the design and fabrication of the trim coil local I&C components. The trim coils will be fitted with RTDs and strain gages.

NCSX WBS Dictionary
Stellarator Core Systems

WBS Element: 19		**WBS Level: 3**
WBS Title:	**LN_2 Cooling Distribution System**	
Description:	This WBS element consists of all the effort to distribute LN2 cooling within the cryostat between the Stellarator Core Cryogenic Cooling System (WBS 633) and the components that are cooling with LN2, e.g., the TF, PF, and modular coils. This WBS element consists of the design and fabrication of the manifolds (WBS 191), cooling pipes (WBS 192), and associated I&C (WBS 193) between the LN_2-cooled components within WBS 1 (e.g., the TF, PF, and modular coils) and the Stellarator Core Cryogenic Cooling System (WBS 633) at the cryostat boundary.	
WBS Element: 191		**WBS Level: 4**
WBS Title:	**LN_2 Cooling Distribution System Manifolds and piping**	
Description:	This WBS element consists of the design and fabrication of the manifolds and piping to distribute LN_2 to components within WBS 1 (e.g., the TF, PF, and modular coils) and the Stellarator Core Cryogenic Cooling System (WBS 633) at the cryostat boundary.	
WBS Element: 192		**WBS Level: 4**
WBS Title:	**LN_2 Cooling Distribution System Flow control**	
Description:	This WBS element consists of the design and procurement of the valves and other devices controlling the flow of LN_2 to components within WBS 1 (e.g., the TF, PF, and modular coils) and the Stellarator Core Cryogenic Cooling System (WBS 633) at the cryostat boundary.	
WBS Element: 193		**WBS Level: 4**
WBS Title:	**LN_2 Cooling Distribution System Local I&C**	
Description:	This WBS element consists of the design and procurement of the local I&C sensors monitoring the distribution of LN2 to the LN2 cooled components within the cryostat boundary.	

NCSX Fabrication Project

Work Breakdown Structure (WBS) Dictionary

Auxiliary Systems (WBS 2)

-DRAFT-

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Prepared by: _____
W. Reiersen, Engineering Manager

Reviewed by: _____
H. Kugel, Cognizant WBS Manager (WBS 2)

Reviewed by: _____
M. Zarnstorff, Physics Manager

Approved by: _____
G. H. Neilson, Project Manager

NCSX WBS Dictionary
Auxiliary Systems

WBS Element: 2	WBS Level: 2
WBS Title:	**Auxiliary Systems**
Description:	NCSX operations are divided into six phases: 1. Initial Operation 2. Field Line Mapping 3. Initial Ohmic 4. Initial Auxiliary Heating 5. Confinement and Beta Push 6. Long Pulse The NCSX Fabrication Project includes all Auxiliary System capabilities required through the Initial Ohmic Phase of operation (that is, Phases 1, 2, and 3). Included in the Fabrication Project are all the engineering and physics design efforts starting with the preliminary design phase (Title I) and ending with completion of the Fabrication Project, all the necessary Research and Development (R&D) to support the design effort, all component fabrication, assembly, and installation activities, and all system level commissioning and testing. Integrated systems testing of the entire NCSX device is covered in Pre-Operational and Integrated Systems Testing (WBS 92). In addition, the NCSX Fabrication Project includes the recommissioning, installation, and subsystem testing of two of the beamlines previously installed on the PBX-M tokamak. (Integrated systems testing of the beamlines will occur during Operations and is outside the scope of the Fabrication Project.) All equipment in the Fabrication Project will be installed prior to first plasma (that is, the start of Phase 1 – Initial Operation). Auxiliary Systems include all the systems and related elements that directly provide fueling, vacuum pumping, and heating to the plasma and plasma chamber. Auxiliary Systems include: • Fueling Systems (WBS 21) • Vacuum Pumping Systems (WBS 22) • Wall Conditioning Systems (WBS 23) • ICH System (WBS 24) • Neutral Beam Heating Systems (WBS 25)

WBS Element: 21	WBS Level: 3
WBS Title:	**Fueling Systems**
Description:	This WBS element consists of all the effort and systems to provide operational gas and pellet injection fueling systems for the NCSX device. The existing PBX-M legacy systems will be used for both systems.
WBS Element: 211	**WBS Level: 4**
WBS Title:	**Gas Fueling Systems**
Description:	This WBS element consists of the effort to provide gas fueling systems. This WBS element consists of the repair and maintenance needed to bring the existing PBX-M legacy system to operational status in the NCSX facility. The legacy PBX-M Fuel Gas System includes the Hydrogen Gas Purification System.

WBS Element: 212	WBS Level: 4
WBS Title:	**Pellet Injection Fueling Systems**
Description:	This WBS elements consists of the design effort to assure that a pellet injection fueling system can be accommodated on NCSX as a future upgrade and includes identifying where the pellet injector will go, its space requirements, and the placement of guide tubes inside the vessel for pellet injection.

WBS Element: 22	WBS Level: 3
WBS Title:	**Torus Vacuum Pumping System**
Description:	The Torus Vacuum Pumping System (WBS 22) will re-use the legacy torus vacuum pumping system from the PBX-M device. The total effort will be to recommission, upgrade (as necessary), install, and test the existing systems, making them fully operational in the NCSX facility. The legacy PBX-M torus vacuum pumping system consists of: • Four (4) Leybold Heraeus TMP 1500 turbo-molecular pumps • Four (4) Model 1398 belt driven backing pumps • One (1) Kinney KT 500 belt driven roughing pump A new Residual Gas Analyzer (RGA) will be provided. In addition, the legacy Pumping System controls will be replaced with a PLC based system. The Torus Vacuum Pumping System (WBS 22) will be connected to Utility Systems (WBS 64) for venting to the outside environment.

WBS Element: 23	WBS Level: 3
WBS Title:	**Wall Conditioning Systems**
Description:	This WBS element consists of the effort and systems to provide wall conditioning and impurity control. Included are the Glow Discharge Cleaning (WBS 231), Boronization Systems (WBS 232) and Lithiumization Systems (WBS 233).
WBS Element: 231	**WBS Level: 4**
WBS Title:	**Glow Discharge Cleaning System**
Description:	This WBS element consists of the effort to provide a glow discharge cleaning (GDC) system for use on NCSX. The WBS element will consist of one fixed wall anode and one dual biased pre-ionization filament unit. These will be installed in each of the 3 NCSX Sectors.
WBS Element: 232	**WBS Level: 4**
WBS Title:	**Boronization System**
Description:	This WBS element consists of the design effort to assure that a boronization system can be accommodated on NCSX as a future upgrade. Trimethylboron (TMB) Boronization uses the regular torus Gas Injection, GDC, and Vacuum Pumping Systems. The work required to implement TMB boronization involves installing suitable pressure sensors and interlocking the TMB injection to the GDC current in the PLC.
WBS Element: 233	**WBS Level: 4**
WBS Title:	**Lithiumization System**
Description:	The capability for lithiumization, either by pellet injection, spray, or other techniques, is required as a future upgrade. This WBS element consists of the design effort to assure that lithiumization can be accommodated as a future upgrade. No R&D and prototyping; fabrication; and assembly, installation, and testing is required for WBS 233.

NCSX WBS Dictionary
Auxiliary Systems

WBS Element: 24	WBS Level: 3
WBS Title:	**ICH System**
Description:	The addition of up to 6MW of ICH is required as a future upgrade. This WBS element consists of the design effort to assure that this can indeed be accommodated as future upgrade. The design effort shall include developing a design concept, locating the equipment, and defining space requirements. No R&D and prototyping; fabrication; and assembly, installation, and testing is required for WBS 24.

WBS Element: 25	WBS Level: 3
WBS Title:	**Neutral Beam Injection System**
Description:	The NCSX Fabrication Project includes the recommissioning, installation in the NCSX Test Cell, and subsystem testing of two of the four the beamlines previously installed on the PBX-M tokamak. (Integrated systems testing of the beamlines will occur during Operations and is outside the scope of the Fabrication Project.)
251	**NB Systems Recommissioning**
	WBS 251 consists of all the effort required to modify and recommission two of the beams.
252	**NB Installation and Testing**
	NB Installation and Testing (WBS 252) includes all the effort to move two of the beams from where they are recommissioned, install them in the NCSX Test Cell, and perform subsystem testing.

NCSX Fabrication Project

Work Breakdown Structure (WBS) Dictionary

Diagnostic Systems (WBS 3)

-DRAFT-

April 27, 2002

Prepared by: _____

W. Reiersen, Engineering Manager

Reviewed by: _____

D. Johnson, Cognizant WBS Manager (WBS 3)

Reviewed by: _____

R. Simmons, Project Control Manager

Reviewed by: _____

M. Zarnstorff, Physics Manager

Reviewed by: _____

P. Heitzenroeder, Deputy Project Manager for Engineering

Approved by: _____

G. H. Neilson, Project Manager

NCSX WBS Dictionary
Diagnostic Systems

WBS Element: 3	**WBS Level: 2**
WBS Title:	**Diagnostic Systems**
Description:	NCSX operations are divided into six phases: 1. Initial Operation 2. Field Line Mapping 3. Initial Ohmic 4. Initial Auxiliary Heating 5. Confinement and Beta Push 6. Long Pulse The NCSX Fabrication Project includes all diagnostic equipment required through the Field Line Mapping of operation (that is, Phases 1 and 2). Included in the Fabrication Project are all the engineering and physics design efforts starting with the preliminary design phase (Title I) and ending with completion of the Fabrication Project, all the necessary Research and Development (R&D) to support the design effort, all component fabrication, assembly, and installation activities, and all system level commissioning and testing, including diagnostic alignments and calibrations. This summary-level WBS element consists of plasma diagnostic subsystems and components to provide the capability to measure the performance of the NCSX device. Diagnostic Systems (WBS 3) include: • Magnetic Diagnostics (WBS 31); • Fast Particle Diagnostics (WBS 32); • Impurity Diagnostics (WBS 33); • MHD Diagnostics (WBS 34); • Profile Diagnostics (WBS 35); • Edge and Divertor Diagnostics (WBS 36); • Turbulence Diagnostics (WBS 37); • EB Mapping Diagnostics (WBS 38); and • Diagnostics Integration (WBS 39). The measurement requirements that the diagnostics must satisfy are derived from the research program. The diagnostics for the first 2 phases are meant to satisfy the experimental needs of the research program planned for these periods.

WBS Element: 31	**WBS Level: 3**
WBS Title:	**Magnetic Diagnostics**
Description:	This WBS element consists of all the magnetic diagnostics required to accomplish the NCSX mission as defined in the General Requirements Document. This includes in-vessel and ex-vessel magnetic sensors needed to measure the equilibrium plasma position and shape, the plasma current, the plasma conductivity, and the total plasma stored energy. It also includes sensors to measure edge magnetic field variations due to internal MHD activity (Mirnov coils). For a typical group of magnetics channels, there are the sensors, sensor mounts, sensor lead cables, a vacuum electrical feedthrus (if in-vessel sensors), junction boxes near the machine, field cables, racks, rack cross-connects, interconnect rack cabling, integrators, data acquisition, AC power and isolation and grounding digitizers. WBS 3 is responsible for the sensors, sensor

	mounts, sensor leads, racks, and integrators. Other components in the above list are covered in other WBS areas. A significant modeling development is needed to optimally plan the type, number and placement of magnetic sensors, particularly those needed for plasma control. The model development is not budgeted in this WBS.

WBS Element: 32	**WBS Level: 3**
WBS Title:	**Fast Particle Diagnostics**
Description:	This WBS element consists diagnostics required for evaluation of fast particle behavior on NCSX. Fast particles include confined and escaping beam ions and fusion products, as well as escaping fast neutrals. There are no diagnostics in this area needed for Phases 1-3, before initial NBI operation. This WBS is responsible for the vacuum interface which might include shutters or valves, pumping systems for possible vacuum extensions, the mechanical support structures, the sensors, the racks, and sensor specific electronics. Other WBS units are responsible for field cabling, rack terminal blocks, rack AC power and grounding, and data acquisition hardware.

WBS Element: 33	**WBS Level: 3**
WBS Title:	**Impurity Diagnostics**
Description:	This WBS element consists of all diagnostics required for measurement of the types and concentrations of impurities in the NCSX plasmas. Since plasma performance typically degrades with increasing amounts of impurities, such diagnostics help to assess the readiness of the machine for experiments, most of which require good performance. They provide critical information supporting decisions on whether to use wall conditioning procedures, like bakeout and glow discharge cleaning, to reduce impurities. They also provide early warning on problems with the plasma facing components, with air leaks, etc. These diagnostics typically consist of a vacuum interface providing the view for an array of sightlines through the plasma, optics (in some case pinhole optics) for imaging the light, fiber optical cables, to relay the light to sensors, dispersive elements to analyze particular wavelengths, detectors and electronics to convert the light signal to a voltage, and associated data acquisition electronics and digitizers. If vacuum windows are used, shutters will be needed to prevent coating during wall conditioning procedures. This WBS is responsible for the vacuum interface, the shutters, the collection optics and associated support system, the fiber optics, the spectrometers, as well as the detectors and associated electronics and rack. Other WBS units are responsible for field cabling, rack terminal blocks, rack AC power and grounding, and data acquisition hardware.

NCSX WBS Dictionary
Diagnostic Systems

WBS Element: 34	WBS Level: 3
WBS Title:	**MHD Diagnostics**
Description:	This WBS element consists of all MHD diagnostics (excluding low frequency Mirnov coils which are part of WBS 31 which are also used for plasma control) required to characterize MHD activity, magnetic island locations and widths, and disruptions. A variety of diagnostic techniques will be used. This WBS is responsible for the vacuum interface, including windows, shutters, valves or electrical feedthrus. Responsibility also includes sensors, mounting structures and sensor cabling near the vacuum vessel. Sensor electronics and racks are also included. Other WBS units are responsible for field cabling, rack terminal blocks, rack AC power and grounding, and data acquisition hardware.

WBS Element: 35	WBS Level: 3
WBS Title:	**Profile Diagnostics**
Description:	This WBS element covers diagnostics required to provide spatial profile information at several times, typically every 5-10 msec, for electron density and electron and ion temperature, for the magnetic field direction, and for the toroidal and poloidal rotation. These kinetic profiles provide the information needed characterize and understand local transport and stability issues. A variety of diagnostic techniques will be used. This WBS is responsible for the vacuum interface, including windows, shutters, valves or electrical feedthrus. Responsibility also includes sensors, mounting structures and sensor cabling near the vacuum vessel. Sensor electronics and racks are also included. Other WBS units are responsible for field cabling, rack terminal blocks, rack AC power and grounding, and data acquisition hardware. Some of the techniques may require active probing with a laser beam or diagnostic neutral beam. These active probes are also the responsibility of this WBS.

WBS Element: 36	WBS Level: 3
WBS Title:	**Edge and Divertor Diagnostics**
Description:	This WBS element consists of diagnostics required to characterize the plasma edge and divertor regions. Quantities measured include the hydrogen recycling, the edge neutral pressure, the edge temperature and density profiles, the divertor radiated power, the divertor target temperature, and edge and divertor flows. This information is important in the understanding of edge transport and plasma wall interactions. A variety of diagnostic techniques will be used. This WBS is responsible for the vacuum interface, including windows, shutters, valves or electrical feedthrus. Responsibility also includes sensors, mounting structures and sensor cabling near the vacuum vessel. Sensor electronics and racks are also included. Other WBS units are responsible for field cabling and junction boxes, rack terminal blocks, rack AC power and grounding, and data acquisition hardware.

NCSX WBS Dictionary
Diagnostic Systems

WBS Element: 37	WBS Level: 3
WBS Title:	**Turbulence Diagnostics**
Description:	This WBS element consists of diagnostics required to measure plasma turbulence, which causes increased energy and particle transport. Turbulence phenomena in both the plasma core and edge regions can significantly influence plasma performance. Data from these diagnostics, combined with data from the kinetic profile diagnostics, will be critical in the understanding of the details of plasma loss mechanisms. This WBS is responsible for the vacuum interface, including windows, shutters, valves or electrical feedthrus. Responsibility also includes sensors, mounting structures and sensor cabling near the vacuum vessel. Sensor electronics and racks are also included. Other WBS units are responsible for field cabling and junction boxes, rack terminal blocks, rack AC power and grounding, and data acquisition hardware.

WBS Element: 38	WBS Level: 3
WBS Title:	**Electron Beam (EB) Mapping**
Description:	This WBS element consists of all EB mapping equipment required to accomplish the NCSX mission as defined in the General Requirements. This equipment will be required in the field line mapping phase of operations (Phase 2) and thus is included in the Fabrication Project. The field line mapping hardware consists of a probe drive with an electron gun at its tip, which can be accurately positioned along a line through the nominal cross-section. The axis of the gun also needs to be adjustable for alignment with the local field. During field mapping the electron beam from the gun will intercept a fluorescent screen as it repeatedly transits the device. The light from the strike points will be imaged by a high resolution CCD camera. Careful metrology will reference screen positions to machine coordinates. Strike points will be compared to expectations of a code, which will compute the beam trajectory for given coil currents. Magnetic island structures will be investigated near reference equilibrium conditions.

WBS Element: 39	WBS Level: 3
WBS Title:	**Diagnostics Integration**
Description:	This WBS element consists of the physics support to provide diagnostic input through the detailed design phase of the machine. It also includes engineering support required to integrate the Diagnostic Systems (WBS 3) with the NCSX facility. This continues through machine assembly phase and as the baseline diagnostics are being developed. This specific element only includes the effort needed to support Diagnostic Systems (WBS 3) elements covered in the Fabrication Project Cost.

NCSX Fabrication Project

Work Breakdown Structure (WBS) Dictionary

Electrical Power Systems (WBS 4)

-DRAFT-

April 27, 2002

Prepared by: _____

W. Reiersen, Engineering Manager

Reviewed by: _____

S. Ramakrishnan, Cognizant WBS Manager (WBS 4)

Reviewed by: _____

R. Simmons, Project Control Manager

Reviewed by: _____

M. Zarnstorff, Physics Manager

Reviewed by: _____

P. Heitzenroeder, Deputy Project Manager for Engineering

Approved by: _____

G.H. Neilson, Project Manager

NCSX WBS Dictionary
Electrical Power Systems

WBS Element: 4	**WBS Level: 2**
WBS Title:	**Electrical Power Systems**
Description:	NCSX operations are divided into six phases: 1. Initial Operation 2. Field Line Mapping 3. Initial Ohmic 4. Initial Auxiliary Heating 5. Confinement and Beta Push 6. Long Pulse The NCSX Fabrication Project includes all Electrical Power System capabilities required through the Initial Ohmic Phase of operation (that is, Phases 1, 2, and 3). All equipment in the Construction Project will be installed prior to first plasma (that is, the start of Phase 1 – Initial Operation). Included in the Construction Project are all the engineering and physics design efforts starting with the preliminary design phase (Title I) and ending with completion of the Construction Project, all the necessary Research and Development (R&D) to support the design effort, all component fabrication, assembly, and installation activities, and all system level commissioning and testing. Integrated systems testing of the entire NCSX device is covered in Pre-Operational and Integrated Systems Testing (WBS 92). This summary-level WBS element consists of the electrical power systems needed by the NCSX device and facility. Electrical Power Systems (WBS 4) includes the following elements: • AC Power Systems (WBS 41) • AC/DC Convertors (WBS 42) • DC Systems (WBS 43) • Control and Protection Systems (WBS 44) • Power System Design and Integration (WBS 45) Electrical Power Systems (WBS 4) includes bus up to the interface with the subsystems, typically at the stellarator core outside the cryostat boundary. Power supplies for plasma heating systems are not included in Electrical Power Systems (WBS 4), but rather in Auxiliary Systems (WBS 2).

WBS Element: 41	**WBS Level: 3**
WBS Title:	**AC Power Systems**
Description:	This WBS element consists of the following subsystems: • Auxiliary AC Power Systems (WBS 411); and • Experimental AC Power Systems (WBS 412).

WBS Element: 411	WBS Level: 4
WBS Title:	**Auxiliary AC Power Systems**
Description:	This WBS element consists of the effort to design and reconfigure existing auxiliary AC power systems. The existing AC power infrastructure at C-site will be re-used to the maximum practical extent, except for that in the Test Cell that will be stripped. A new AC distribution system, up to and including power panels, is provided in the Test Cell. Activities associated with the reactivation of AC power systems at C-site are included. UPS systems are provided for the controllers of the cryogenic systems associated with NBI and the main NCSX coils. Grounding in the NCSX test cell is provided. This WBS element includes cabling to the racks of Diagnostics equipment. Appropriate measures shall be taken by other WBS elements to isolate the a) Vessel and b) PFCs from one another and ground. Isolation shall be tested at 5kv DC. All diagnostics components mounted on the vessel/PFC shall also be isolated at 5kV DC or float with vessel/PFC.
WBS Element: 412	**WBS Level: 4**
WBS Title:	**Experimental AC Power Systems**
Description:	This WBS element consists of the effort to design and reconfigure existing experimental AC power systems. This WBS element covers the work associated with the use of the D-site Pulsed AC Power 13.8kV distribution systems for NCSX, including reactivation of feeders not in use since TFTR along with minor changes to the lockout and E-stop interlocks which must now interface with the NCSX interlock system. The D-site Pulsed AC Power System, including the MG sets, and 13.8kV SV1/SV2 buses will be shared by NCSX and NSTX. In addition, some of the SV1/SV2 switchgear, feeders, and transformers will be shared. Other SV1/SV2 switchgear, feeders, and transformers not presently in use by NSTX and not used since TFTR operations might need to be reactivated. WBS 5 to provide interface for Lockout and E-Stop features.

WBS Element: 42	WBS Level: 3
WBS Title:	**AC/DC Convertors**
Description:	This WBS element consists of the following subsystems: • C-Site AC/DC Convertors (WBS 421); and • D-Site AC/DC Convertors (WBS 422).
WBS Element: 421	**WBS Level: 4**
WBS Title:	**C-Site AC/DC Convertors**
Description:	*No work in this area is required for the fabrication project.*
WBS Element: 422	**WBS Level: 4**
WBS Title:	**D-Site AC/DC Convertors**
Description:	This WBS element consists of the effort to design and reconfigure existing experimental D-Site AC/DC power convertors. Existing Transrex rectifiers in the FCPC building at D-site will be used to power the NCSX Modular, Poloidal Field, and Toroidal Field coils. Rectifier units not in current use for NSTX need to be reactivated and brought to an operating condition. This includes various preliminary tests such as hipot, controls check out, water system check out, trip settings, and dummy load test. Some modifications to the controls may be required to interface with the NCSX real time control system.

NCSX WBS Dictionary
Electrical Power Systems

WBS Element: 43	WBS Level: 3
WBS Title:	**DC Systems**
Description:	This WBS element consists of the following subsystems: • C-Site DC Systems (WBS 431); • D-to-C- Site DC Systems (WBS 432); and • D-Site DC Systems (WBS 433).
WBS Element: 431	**WBS Level: 4**
WBS Title:	**C-Site DC Systems**
Description:	This WBS element consists of the effort to design and reconfigure existing experimental C-Site DC systems. For the main coils (Modular, PF, TF), 1000MCM power cables coming across from D-site will be received in the existing PLT OH/EF building, and spliced to existing 1000MCM cables which connect to the Disconnect/Link area in the C-site MG basement. The existing switches and bus bar carry the current into the Test Cell. From the stubs penetrating the floor, new 1000MCM cables will be connected to the coil circuit terminals. All the components to be used for NCSX Power system which includes a) 1000 MCM cable runs b) DC Bus c) Bus stubs coming into the Test Cell shall be retained for use by WBS 4.
WBS Element: 432	**WBS Level: 4**
WBS Title:	**D-to-C-Site DC Systems**
Description:	This WBS element consists of the effort to design, fabricate, and install experimental D-to-C-Site DC Systems. A new cable run, approximately 600 feet long, will be installed from the East-West wing of the FCPC building at D-site, 2nd floor, to the C-site PLT OH/EF building. This will include 1000MCM cables, cable trays, and support system mounted above ground level.
WBS Element: 433	**WBS Level: 4**
WBS Title:	**D-Site DC Systems**
Description:	This WBS element consists of the effort to design and reconfigure (as needed) existing experimental D-Site DC systems. Reconfiguration (as needed) of the outputs of the NCSX- dedicated Transrex power supplies via new power cabling and new DC current limiting reactors. Modification of existing cabling and provision of a common tie points for the shared systems via 1000 MCM cable. Dummy load testing of NSTX systems after reconnection. Provision of isolating switches provided for opening the circuit for troubleshooting purposes at the FCPC.

WBS Element: 44	WBS Level: 3
WBS Title:	**Control and Protection Systems**
Description:	This WBS element consists of the following subsystems: • Electrical Interlocks (WBS 441); • Kirk Key Interlocks (WBS 442); • Real Time Control Systems (WBS 443); • Instrumentation Systems (WBS 444); • Coil Protection Systems (WBS 445); and • Ground Fault Monitoring System (WBS 446).
WBS Element: 441	**WBS Level: 4**
WBS Title:	**Electrical Interlock System**
Description:	This WBS element consists of the effort to design, fabricate, and install an electrical interlock system for NCSX. An electrical interlock system is designed and installed which ensures the proper configuration of the power system in accordance with the commanded state from the NCSX control room and access control systems, and which provides coordinated fast fault response of the power supplies when faults are detected. The system is implemented by Programmable Logic Controllers (PLCs) at various C-site and D-site locations interconnected through a fiber optic network. The system must be compatible with both NCSX and NSTX operations.

NCSX WBS Dictionary
Electrical Power Systems

WBS Element: 442	WBS Level: 4
WBS Title:	**Kirk Key Interlocks**
Description:	This WBS element consists of the effort to design, procure, fabricate, and install kirk key interlocks for NCSX. Mechanical kirk key interlocks are used throughout the D-site power supply system to ensure the proper sequence of manual switching operations and that equipment is in the safe state prior to accessing hazardous areas. This system must be modified (as needed) to reflect the modified power supply configuration, and must include appropriate elements from the C-site elements of the power system.
WBS Element: 443	**WBS Level: 4**
WBS Title:	**Real Time Control Systems**
Description:	This WBS element consists of the effort to develop the specification of the hardware requirements and software algorithms to be provided by WBS 5 (Central I&C) for the real time digital feedback control of the power supply system, including the high-speed digital input and output links.
WBS Element: 444	**WBS Level: 4**
WBS Title:	**Instrumentation Systems**
Description:	This WBS element consists of the effort to design, specify, procure, install, and implement current and voltage measurements for the Modular, PF, and TF coils. Current measurements are made at D-site using one precision DC Current Transducer and one optically isolated shunt per circuit. Voltage measurements are at C-site using voltage transducers from line to ground, one from each pole of each circuit to ground. Also included are signal conditioners that receive the current measurements and buffer, filter, and fan out each signal to multiple destinations.
WBS Element: 445	**WBS Level: 4**
WBS Title:	**Coil Protection Systems**
Description:	This WBS element consists of the effort to design, specify, procure, program, and implement hardware and software as required to provide 1) digital coil protection system and 2) ground fault detection system for the Modular, PF, and TF coil systems. The digital coil protection system uses the coil current measurements as input and declares a fault if electrical, thermal, or mechanical limits are exceeded. The ground fault detection system declares a fault if excessive ground current flow is detected.
WBS Element: 446	**WBS Level: 4**
WBS Title:	**Ground Fault Monitoring System**
Description:	This WBS element consists of the effort to design, specify, procure, implement a ground fault monitoring system that serves to detect the integrity of machine grounds and generate alarms in case of spurious grounds.

WBS Element: 45	WBS Level: 3
WBS Title:	**Power System Design and Integration**
Description:	This WBS element consists of the following subsystems: • System Design and Interfaces (WBS 451); • Electrical Systems Support (WBS 452); and • System Testing/PTPs (WBS 453).
WBS Element: 451	**WBS Level: 4**
WBS Title:	**System Design and Interfaces**
Description:	This WBS element consists of the electrical system engineering and design/drafting, which includes the design and analysis of the overall electrical system, its documentation, and the conduct of design reviews.

NCSX WBS Dictionary
Electrical Power Systems

WBS Element: 452		**WBS Level: 4**
WBS Title:	**Electrical Systems Support**	
Description:	This WBS element consists of the effort to ensure overall project coordination of electrical systems by providing electrical systems support to other systems, including diagnostics, which provides the engineering, design/drafting, and installation of diagnostic cabling.	
WBS Element: 453		**WBS Level: 4**
WBS Title:	**Systems Testing (PTPs)**	
Description:	This WBS element consists of the effort to conduct all systems-related preoperational testing, including: • DC circuit hipots and impedance measurements • Electrical interlocks • Overall systems testing, including: o kirk key interlock testing, o instrumentation test & calibration, o real time control system testing, o coil protection system testing, o ground fault monitor testing, coil power supply dummy load testing, and o trim coil power supply dummy load testing.	

NCSX Construction Project

Work Breakdown Structure (WBS) Dictionary

Central I&C Systems (WBS 5)

-DRAFT-

April 27, 2002

Prepared by: _____

W. Reiersen, Engineering Manager

Reviewed by: _____

G. Oliaro, Cognizant WBS Manager (WBS 5)

Reviewed by: _____

R. Simmons, Project Control Manager

Reviewed by: _____

M. Zarnstorff, Physics Manager

Reviewed by: _____

P. Heitzenroeder, Deputy Project Manager for Engineering

Approved by: _____

G.H. Neilson, Project Manager

NCSX WBS Dictionary
Central I&C Systems

WBS Element: 5	WBS Level: 2
WBS Title:	**Central I&C Systems**
Description:	NCSX operations are divided into six phases: 1. Initial Operation 2. Field Line Mapping 3. Initial Ohmic 4. Initial Auxiliary Heating 5. Confinement and Beta Push 6. Long Pulse The NCSX Construction Project includes Central I&C capabilities required through the Initial Ohmic Phase of operation (that is, Phases 1, 2, and 3). All equipment in the Construction Project will be installed prior to first plasma (that is, the start of Phase 1 – Initial Operation). Included in the Construction Project are all the engineering and physics design efforts starting with the preliminary design phase (Title I) and ending with completion of the Construction Project, all the necessary Research and Development (R&D) to support the design effort, all component fabrication, assembly, and installation activities, and all system level commissioning and testing. Integrated systems testing of the entire NCSX device is covered in Pre-Operational and Integrated Systems Testing (WBS 92). This summary-level WBS element consists of the central instrumentation and control (I&C) systems that provide the central supervisory control and data handling systems for NCSX. These systems interface with the subsystem local I&C systems and allow for control and monitoring of NCSX experiments from the control room (local or remote) and the analysis of the results. The central I&C systems covered under this WBS elements include: • TCP/IP Infrastructure Systems (WBS 51), • Central Instrumentation and Control Systems (WBS 52), • Data Acquisition & Facility Computing Systems (WBS 53), • Facility Timing and Synchronization Systems (WBS 54), • Real Time Control Systems (WBS 55), • Central Safety Interlock Systems (WBS 56), and • Control Room Facility (WBS 57).

WBS Element: 51	WBS Level: 3
WBS Title:	**TCP/IP Infrastructure Systems**
Description:	The TCP/IP network infrastructure will provide the common backbone for all data acquisition, and I&C communications. The network will consist of three distinct networks: Physics, Engineering and Plant networks. All cable and switch infrastructure will minimally support 100Mbps Ethernet and all uplinks will be designed for 1Gigabit and possibly 10 Gigabit Ethernet. The Test Cell Ethernet infrastructure will be completely fiber optic. The primary switch hubs will be deployed in five locations: • D-Site FCPC (Power Conversion and Plasma Control); • D-Site MG; • C-Site S1 Area (RF); • C-Site NCSX Control Room (Test Cell and NBI); and • PPLCC A fiber optic infrastructure will be deployed to all primary and secondary hubs. Two fiber optic distribution panels will be located in the Test Cell on each side of the machine. A fiber optic infrastructure will also be deployed for facility timing and synchronization.

NCSX WBS Dictionary
Central I&C Systems

WBS Element: 52	WBS Level: 3
WBS Title:	**Central Instrumentation and Control Systems**
Description:	The central process control system will provide the common user interface to all engineering subsystems and high-energy processes. It will provide the synchronization between two or more operating machines at PPPL using shared power conversion resources. It will support current and historical trending, alarm logging, mimic displays, machine state archival, and process control and monitoring functions for NCSX. It will be designed using the Experimental Physics and Industrial Control System (EPICS). The following subsystems will be supported with control and display pages: • Fueling Systems; • Cryogenic Systems; • Vacuum Pumping Systems • Water Systems; • Thermocouples (NBI, Water, Coil, Vacuum Vessel); • Magnet Power Systems; • Motor Generators; • RF Heating Systems (when added as future upgrades); • Wall Conditioning Systems; and • Neutral Beam Heating Systems.

WBS Element: 53	WBS Level: 3
WBS Title:	**Data Acquisition & Facility Computing Systems**
Description:	The design of WBS 53 will use the existing MIT-developed MDSplus software for data acquisition, data archiving and display. Individual diagnostic local control and data acquisition will use standard PC architecture machines or Compact PCI chassis. Diagnostic operator interface units will be configured and deployed for initial operations. An additional facility compute server/cluster, expandable tape library, and disk storage area network (RAID 5) will be deployed for the data acquisition system. A standard Software Interface Specification to MDSplus will be designed for use at PPPL and for remote collaborators. The standard will be composed of a set of interfaces and applications, which when used, will insure a smooth integration of diagnostics into the DAS. A standard inter-processor messaging system to allow coordination of remote diagnostics and the central data acquisition system will be included in the Software Interface Specification.

WBS Element: 54	WBS Level: 3
WBS Title:	**Facility Timing and Synchronization Systems**
Description:	A new timing and synchronization technology is required for NCSX. The CAMAC based TFTR Timing System was developed in the late 70's. Typical resolution was 1ms for periods over 1 second. A requirement to use off-the-shelf or existing solutions for NCSX is highly desirable. A VME based system from BNL used on the Relativistic Heavy Ion Collider (RHIC) is being investigated. This system is being modified for use on the Spallation Neutron Source at ORNL and will provide the basis for the NCSX design. This activity will provide the engineering to convert the V102 timing modules to CPCI and PCI formats. Additional manpower to write software drivers will also be provided.

NCSX WBS Dictionary
Central I&C Systems

WBS Element: 55	WBS Level: 3
WBS Title:	**Real Time Plasma and Power Supply Control Systems**
Description:	The real time software is divided into two functions, the Power Supply Real Time Control System (PSRTC) and the Plasma Control System (PCS). The PSRTC will calculate the alpha control signal required by the power conversion firing generators. This signal is calculated using coil currents, machine state permissives, and fault conditions. The PCS can also provide inputs to the PSRTC algorithms. The PCS will use the existing user-interface/data server software system developed at General Atomics. It consists of real time "control category" routines (i.e. gas, shape, position, etc.), a waveform manager, hooks to IDL user interfaces and internal messaging and lock management software. The data acquisition system will include digitizer channels for magnetics sensors in the test cell.

WBS Element: 56	WBS Level: 3
WBS Title:	**Central Safety Interlock Systems**
Description:	The Central Safety Interlock System will provide system wide coordination of personnel and hardware interlocks. Its primary man machine interface will be EPICS. The Central Safety Interlock System will be a fail-safe, hybrid system. Mechanical components and hardwired devices will provide primary protective functions. Redundant PLC technology with redundant sensors will be used to achieve effective, safety system capabilities. Each NCSX high-energy subsystem will interface with the Central Safety Interlock System. A badge reader access control system will restrict access to the Test Cell for only authorized/trained personnel. UPS and Standby power will power critical components.

WBS Element: 57	WBS Level: 3
WBS Title:	**Control Room Facility**
Description:	This WBS element consists of the effort necessary to design and install a new NCSX control room facility. The PLT and PBX control room area is approximately 2400 sq.ft. and will not be large enough for both PPPL physicists and remote collaborators in the later phases of NCSX operation. The old DAS computer area will be used for expansion of the NCSX control room facility as required in these later phases. This WBS element will be responsible for the design and installation of the following subsystems in a new control room: • Installation of raised flooring; • Installation of workstation tables wired for network and power Installation of raised flooring; • Installation of equipment racks wired for network and power; • Expandable closed circuit TV system with PTZ cameras; • A Test Cell PA system; • Diagnostic machine microphones data included in MDSplus tree; and • Dual screen “comfort” display system.

NCSX Fabrication Project

Work Breakdown Structure (WBS) Dictionary

Site and Facilities (WBS 6)

-DRAFT-

April 27, 2002

Prepared by: _____

W. Reiersen, Engineering Manager

Reviewed by: _____

L. Dudek, Cognizant WBS Manager (WBS 6)

Reviewed by: _____

R. Simmons, Project Control Manager

Reviewed by: _____

M. Zarnstorff, Physics Manager

Reviewed by: _____

P. Heitzenroeder, Deputy Project Manager for Engineering

Approved by: _____

G.H. Neilson, Project Manager

NCSX WBS Dictionary
Site and Facilities

WBS Element: 6	WBS Level: 2
WBS Title:	**Site and Facilities**
Description:	NCSX operations are divided into six phases: 1. Initial Operation 2. Field Line Mapping 3. Initial Ohmic 4. Initial Auxiliary Heating 5. Confinement and Beta Push 6. Long Pulse The NCSX Fabrication Project includes Site and Facilities equipment required through the Initial Ohmic Phase of operation (that is, Phases 1, 2, and 3). All equipment in the Fabrication Project will be installed prior to first plasma (that is, the start of Phase 1 – Initial Operation). Included in the Fabrication Project are all the engineering and physics design efforts starting with the preliminary design phase (Title I) and ending with completion of the Fabrication Project, all the necessary Research and Development (R&D) to support the design effort, all component fabrication, assembly, and installation activities, and all system level commissioning and testing. Also included in the Fabrication Project is the removal and storage of legacy equipment from PBX-M that will be re-used on NCSX. Integrated systems testing of the entire NCSX device is covered in Pre-Operational and Integrated Systems Testing (WBS 92). This summary-level WBS element consists of the site and facilities needed to support the NCSX experimental program. The NCSX device will make maximum use of existing PPPL systems and facilities. This WBS element includes: • Facility Modifications and Test Cell Preparations (WBS 61), • Water Cooling Systems (WBS 62), • Cryogenic Systems (WBS 63), • Utility Systems (WBS 64), • Helium Bakeout System (WBS 65), and • Facility Systems Integration (WBS 66)

WBS Element: 61	WBS Level: 3
WBS Title:	**Facility Modifications and Test Cell Preparations**
Description:	This WBS element consists of the effort necessary to modify and/or refurbish existing facilities as required for the NCSX Construction Project. It includes: • Facility modifications outside the Test Cell (WBS 611); • Seismic modifications to the Test Cell walls (WBS 613).

NCSX WBS Dictionary
Site and Facilities

WBS Element: 611	WBS Level: 4
WBS Title:	**Facility Modifications Outside the Test Cell**
Description:	This WBS element includes the modification of facilities outside of the C-site Test Cell, which will be required for NCSX usage for either assembly or operation. The following work scope is anticipated: • 2nd floor of FCPC - Installation of twenty (20) 6-inch diameter penetrations through the FCPC floor. Installation of weatherproofed penetration through the 2nd. Floor wall of FCPC for cables running from FCPC to the new Test Cell • TFTR Test Cell - Extend the Helium Gas Bakeout System line from the NSTX Test Cell to the vacant TFTR Test Cell, to be used for baking out of vacuum vessel segments (to 150ºC) during assembly of field periods. • NCSX Control Room- Installation of new ceiling, lighting electrical panels plus new painted walls/partitions as required. Does not include the costs of a new raised floor.
WBS Element: 612	**WBS Level: 4**
WBS Title:	***Not used***
Description:	
WBS Element: 613	**WBS Level: 4**
WBS Title:	**Seismic Modifications to the Test Cell Walls**
Description:	This WBS element includes the activities associated with modifications to shield walls to be meet seismic and shielding requirements. The work scope includes: • Reconfiguring and seismically supporting shield walls to meet seismic requirements; and • Increasing the height of the shield walls on the east, west and south sides of the Test Cell as appropriate.

WBS Element: 62	WBS Level: 3
WBS Title:	**Water Cooling Systems**
Description:	This WBS element includes all the effort required to add cooling loops to the existing C-site (CS) and HVAC Water Systems as required for NCSX subsystems. This WBS element consists of the following sub-elements: • Neutral Beam Water Cooling (WBS 622) • Vacuum Pumping Water Cooling (WBS 623) • Bakeout Water Cooling (WBS 624) • Diagnostics Water Cooling (WBS 625)
WBS Element: 621	**WBS Level: 4**
WBS Title:	***Not used***
Description:	

WBS Element: 622	WBS Level: 4
WBS Title:	**Neutral Beam Water Cooling Systems**
Description:	This WBS element consists of the effort to provide cooling water capability for the neutral beams in the Fabrication Project. This job includes the design for four (4) neutral beams but the fabrication and installation for only two (2) neutral beams. Electrical connections to motorized valves are provided by the Neutral Beam WBS. Initially, this WBS will provide a 375 gpm cooling water capability for the NCSX neutral beams for day one operations. The NB Accel Rectifiers will require cooling water (they are located in the MG room). The old cooling system for the rectifiers was a closed one with it's own chiller and demineralizer. That chiller has been removed. The old cooling system will be plumbed into the CS water system to provide necessary cooling.
WBS Element: 623	**WBS Level: 4**
WBS Title:	**Vacuum Pumping Water Cooling System**
Description:	This WBS element consists of the effort to provide a cooling water loop to reject heat produced by the vacuum vessel vacuum pumping system. The system used on PBX-M will be reused where practical. The cooling loop will be connected to the HVAC water system. This WBS will Provide a small < 20 gpm cooling water loop to reject heat produced by the vacuum vessel and neutral beam vacuum pumping systems. The existing HVAC chilled water system will be used as the ultimate heat sink. This system is required to operate 24 hours/day 365 days/year.
WBS Element: 624	**WBS Level: 4**
WBS Title:	**Bakeout Water System**
Description:	The WBS element consists of the effort to provide a cooling water loop to reject waste heat from the Helium Bakeout System (WBS 65). The cooling loop will be connected to the CS cooling water system.
WBS Element: 625	**WBS Level: 4**
WBS Title:	**Diagnostic Water Cooling System**
Description:	The WBS element consists of the effort to provide a manifold around the machine which supplies de-ionized (DI) cooling water facility for the diagnostics systems. The work includes design, fabrication and installation. The cooling loop will be connected to the CS cooling water system.

WBS Element: 63	WBS Level: 3
WBS Title:	**Cryogenic Systems**
Description:	This WBS element consists of the following subsystems: • LN_2-LHe Supply System (WBS 631); • LN_2 Coil Cooling (WBS 632); and • GN_2 Cryostat Cooling System (WBS 633).
WBS Element: 631	**WBS Level: 4**
WBS Title:	**LN_2-LHe Supply System**
Description:	This WBS element consists of the effort to design and install a system to supply liquid nitrogen and liquid helium to the NCSX facility. End users include the LN_2 coil cooling supply system (WBS 632), the GN_2 cryostat cooling supply system (WBS 633), and the NB system (WBS 25). This WBS element also includes refurbishment of the existing LN_2 storage tank. This WBS will support two beamlines with provisions for a total of four beams and a pellet injector. Initially, the two beamlines will be tested using individual LHe dewars, which are not part of this work package. The facility is required to accommodate (as a future upgrade) a LHe transfer line between the helium dewar in the C-site Helium Dewar Storage Shed and the four beamlines.

WBS Element: 632	WBS Level: 4
WBS Title:	**LN_2 Coil Cooling Supply System**
Description:	This WBS element consists of the effort to provide a closed loop LN_2 system for the cooling of the modular coils (WBS 17), TF coils (WBS 13), and PF coils (WBS 14). The distribution system within the cryostat for cooling the coil systems is the responsibility of WBS 1.
WBS Element: 633	**WBS Level: 4**
WBS Title:	**GN_2 Cryostat Cooling System**
Description:	This WBS element consists of the effort to circulate GN_2 through the cryostat to provide cooling during cooldown from room temperature and also during operation. This WBS element also provides heating to bring the equipment within the cryostat up from the operating temperature of 80K back to room temperature. The cryostat cooling system is vented to the outside environment through a stack that is also part of this WBS element.

WBS Element: 64	WBS Level: 3
WBS Title:	**Utility Systems**
Description:	The WBS element only consists of the effort to provide the design, fabrication and installation of a manifold system around the NCSX stellarator for compressed air, vacuum pump venting and gaseous nitrogen. The vacuum pump venting system shall provide a system to vent the vacuum pumps in the CS basement and the diagnostic vacuum pumps in the NCSX test cell to the outside. Construction of the system shall be such that the system can be upgraded to TMB use at a later date.

WBS Element: 65	WBS Level: 3
WBS Title:	**Helium Bakeout System**
Description:	The WBS element consists of the effort to provide heating and cooling to the vacuum vessel and plasma facing components (PFCs). Prior to Initial Auxiliary Heating (Phase4), there will be only minimal coverage of the interior with carbon tiles so a 350ºC bakeout is not required for the Fabrication Project. However, accommodating a 350ºC bakeout of the PFCs is required as a future upgrade. In the Fabrication Project, the capability to maintain the temperature of the vacuum vessel and PFCs between 20ºC (the normal operating temperature) and 150ºC (for bakeout of the vacuum vessel and other metallic structures inside the vacuum vessel) will be provided. As currently envisioned, this pressurized helium gas will be circulated to effect temperature control.

WBS Element: 66	WBS Level: 3
WBS Title:	**Facility Systems Integration**
Description:	Since the facility systems will not be designed until late in the fabrication project, this WBS element provides a minimal level of effort activity to ensure that the WBS Managers remain engaged with the project developments.

NCSX Fabrication Project

Work Breakdown Structure (WBS) Dictionary

Machine Assembly (WBS 7)

-DRAFT-

April 27, 2002

Prepared by: _____

W. Reiersen, Engineering Manager

Reviewed by: _____

J. Chrzanowski, Cognizant WBS Manager (WBS 7)

Reviewed by: _____

R. Simmons, Project Control Manager

Reviewed by: _____

M. Zarnstorff, Physics Manager

Reviewed by: _____

P. Heitzenroeder, Deputy Project Manager for Engineering

Approved by: _____

G.H. Neilson, Project Manager

NCSX WBS Dictionary
Machine Assembly

WBS Element: 7	WBS Level: 2
WBS Title:	**Machine Assembly**
Description:	NCSX operations are divided into six phases: 1. Initial Operation 2. Field Line Mapping 3. Initial Ohmic 4. Initial Auxiliary Heating 5. Confinement and Beta Push 6. Long Pulse This summary-level WBS element consists of the necessary engineering and field craft labor to install the stellarator core systems, provide special machine assembly tools and equipment, and in-vessel measurement systems. Based on Davis-Bacon determinations, this may be performed by either craft labor or national laboratory labor, depending on the degree of specialization required. Acceptance of stellarator core components at PPPL and subsequent assembly, installation, and testing is covered under Machine Assembly (WBS 7) and Pre-operational and Integrated Systems Testing (WBS 92). In addition, this WBS element includes coordination and oversight of all assembly, installation, and testing activities in the TFTR test cell (where pre-assembly operations will take place) and the NCSX test cell and basement up until first plasma. The Construction Manager is responsible for this WBS element. The Construction Manager shall participate in design reviews to assure the constructability of the NCSX facility. This WBS element includes the following sub-elements: • Assembly Planning and Oversight Operations (WBS 71) • On-Site Pre-Assembly Operations (WBS 72) • Assembly Operations in the Test Cell and Basement (WBS 73) • Measurement Systems (WBS 74) • Platform Design and Fabrication (WBS 75) • Tooling Design and Fabrication (WBS 76)

NCSX WBS Dictionary
Machine Assembly

WBS Element: 71	WBS Level: 3
WBS Title:	**Assembly Planning and Oversight Operations**
Description:	This WBS element consists of the following subsystems: • Planning Activities Prior to Construction (WBS 711); and • Construction Management (WBS 712).
WBS Element: 711	**WBS Level: 4**
WBS Title:	**Planning Activities**
Description:	This WBS element includes those activities associated with planning the assembly, installation, and testing of the NCSX device. It includes the coordination between WBS elements whose activities directly involve the assembly of the NCSX components in the NCSX test cell and basement. This WBS element includes the planning and coordination activities for the pre-assembly of the stellarator core field periods in the TFTR test cell. This WBS element also includes participation in design reviews by the Construction Manager to assure the constructability of the NCSX facility.
WBS Element: 712	**WBS Level: 4**
WBS Title:	**Construction Management**
Description:	This WBS element consists of those activities associated with coordinating, managing and overseeing the construction/assembly of the NCSX device. It begins with the preparation of the test cell and concludes with the first plasma activities. Included in this element are oversight of: • All activities in the vacant TFTR test cell during the pre-assembly of the three field periods • All activities in the NCSX test cell relating to the assembly of the NCSX. This WBS element provides for a Construction Manager, plus engineering and supervisory support for all assembly activities. Coverage by Construction Safety, Health Physics, Industrial Hygiene, and Quality Control personnel will be required to support Construction Management but are not included in Fabrication Project costs.

WBS Element: 72	WBS Level: 3
WBS Title:	**On-Site Pre-Assembly Operations**
Description:	This WBS element consists of the pre-assembly operations for stellarator core components that will take place in the TFTR test cell. It consists of the following sub-elements: • Preparation of the Pre-Assembly Area (WBS 721) • Receive, Inspect, and Test Coils (WBS 722) • Receive, Inspect, & Test Vacuum Vessel (WBS 724) • Assemble Field Periods (WBS 725)

WBS Element: 721	WBS Level: 4
WBS Title:	**Preparation of the Pre-Assembly Area**
Description:	The WBS element consists of the activities associated with preparing the field period pre-assembly area (the vacant TFTR test cell) for receipt of components. This includes installing assembly fixtures and tooling. Determining what radiological controls (if any) are required for working in the TFTR test cell (in the presence of the TFTR Neutral Beam boxes) is also part of this WBS element.
WBS Element: 722	**WBS Level: 4**
WBS Title:	**Receive, Inspect, and Test Coils**
Description:	The WBS element consists of the activities associated with the receipt of all coil assemblies from the suppliers. This includes receiving and unloading of new coil assemblies and performing mechanical inspections and electrical testing of delivered coil assemblies. This includes the both Toroidal Field (TF) coils and Poloidal Field (PF) coils. The present plan is to fabricate the modular coils in-house. Those inspections/testing activities will be included in the Modular Coil fabrication costs**.**
WBS Element: 723	**WBS Level: 4**
WBS Title:	***Not used***
Description:	
WBS Element: 724	**WBS Level: 4**
WBS Title:	**Receive, Inspect, and Test Vacuum Vessel**
Description:	The WBS element consists of the activities associated with receiving and inspecting the three (3) sections of NCSX vacuum vessel. This includes delivery and receiving inspections of the three (3) sections (plus port extensions) plus unloading of the vacuum vessel segments to the TFTR test cell pre-assembly area.
WBS Element: 725	**WBS Level: 4**
WBS Title:	**Assemble Field Periods**
Description:	This WBS element consists of those activities associated with the pre-assembly of the three NCSX field periods. The pre-assembly activities will occur in the vacated TFTR test cell designated as the pre-assembly area. The work scope includes: • Assembly and alignment of the TF/Modular coils with 1/3 of the vacuum vessel; • Positioning and welding port extensions onto the VV segment; • Completing bakeout of the VV segment to 150 degrees C; • Vacuum leak checking of the vessel segment and port extensions; • Transportation of each field period to the NCSX test cell for final assembly.

WBS Element: 73	WBS Level: 3
WBS Title:	**Test Cell & Basement Assembly Operations**
Description:	This WBS element consists of those activities associated with the final assembly of the stellarator core in the NCSX Test Cell and Basement. Work scope includes the following activities in order of work to be performed: • Installation and leveling of machine base plate • Installation and leveling of the machine support columns; • Installation of the machine platform. • Installation of lighting and fire detection/suppression systems under the platform • Installation of the lower cryostat floor; • Installation of the lower PF-3 & 4 coils in preliminary positions;

	• Installation of the three (3) field periods • Reinstallation of shield wall around the high bay/delivery area only • Labor support for WBS 22 for the performance of the pump down and vacuum leak test PTPs; • Placement of the lower PF-3 & 4 into their final position; • Installation of the upper PF-3 & 4 coils; • Installation of the PF-1 & PF-2 solenoid; • Installation of external Cryostat walls and ceiling; • Labor support for WBS 63 for the performance the Cryostat Systems Test PTP **This WBS element does not include:** • Installation of any of the power or bus systems (WBS 4) • Installation of the bakeout and/or cooling systems (WMS 62) • Installation of the Cryo systems (WBS 63) • Modification & seismic upgrade of the test cell shield walls (WBS 61) • Installation of diagnostic systems

WBS Element: 74	**WBS Level: 3**
WBS Title:	**Measurement Systems**
Description:	This WBS element consists of those efforts required to design, procure and fabricate fixtures & tooling to be used for position measurement of the stellarator core components. This fixturing will be used in conjunction with PPPL owned measurement systems including the FARA Mechanical Measuring arm and Leica Laser measurement devices.

WBS Element: 75	**WBS Level: 3**
WBS Title:	**NCSX Platform Design and Fabrication**
Description:	This WBS element consists of the activities associated with design and fabrication of the NCSX machine platform. This work scope encompasses the design and fabrication of a platform around the NCSX device, in support of various diagnostics and systems required for operation. It includes all platform material procurements. This WBS element also includes the design and fabrication of any "catwalks" or other structures that are logical extensions of the platform provided to facilitate assembly and maintenance within the NCSX test cell. Installation costs are included in the WBS 73 element.

WBS Element: 76	**WBS Level: 3**
WBS Title:	**Tooling Design & Fabrication**
Description:	This WBS element consists of the activities associated with the design and fabrication of tooling required to assemble the NCSX device. The work scope includes the design and fabrication of special fixtures and tooling which will be required during pre-assembly of the field periods in the vacant TFTR test cell and final assembly of the NCSX machine components in the C-site NCSX test cell. All procurements of miscellaneous items required for assembly such as safety equipment, general tools, hardware, disposable items, specific procurement of welding supplies (e.g., weld wire) and equipment required to assemble the NCSX device are included in this element.

NCSX Construction Project

Work Breakdown Structure (WBS) Dictionary

Project Management and Integration (WBS 8)

-DRAFT-

December 14, 2001

Prepared by: _____

W. Reiersen, Engineering Manager

Reviewed by: _____

R. Simmons, Cognizant WBS Manager (WBS 8)

Reviewed by: _____

M. Zarnstorff, Physics Manager

Reviewed by: _____

P. Heitzenroeder, Deputy Project Manager for Engineering

Approved by: _____

G. H. Neilson, Project Manager

WBS Element: 8	WBS Level: 2
WBS Title:	**Project Management and Integration**
Description:	This summary-level WBS element consists of all the non-hardware-related activities necessary to develop requirements and manage the NCSX Project such as project management, systems engineering, environmental and safety/QA management, and, project physics.
WBS Element: 81	**WBS Level: 3**
WBS Title:	**Project Management and Control**
Description:	This WBS element includes the overall project direction, oversight, and administrative support, including budgeting, cost control, scheduling, and procurement activities. These are in direct support of the NCSX fabrication project. In addition, PPPL collects direct allocations charged to the NCSX Project and Program. The direct allocation charges are to cover the allocated charges for the Computer Division's support and maintenance of the VAX, UNIX and CADD computer systems and desktop computer support here at PPPL and the diagnostic and rf development activities at PPPL.

WBS Element: 82	WBS Level: 3
WBS Title:	**Project Engineering**
Description:	This WBS element includes all the overall engineering management and support of the design and construction process. It includes the following activities: • Engineering requirements and interface definition; • Overall project design integration and global models; • Configuration management and control; and • Systems code studies.

WBS Element: 83	WBS Level: 3
WBS Title:	**Environmental and Safety/QA Management**
Description:	This WBS element includes all the ES&H and Quality Assurance/Quality Control support of the design and construction process. Since these activities cut across all WBS elements, the effort is defined and collected here. It includes the following activities: • Construction Safety; • Electrical Safety; • Radiation Safety; • NEPA & Safety Assessment Review & Coordination; • Industrial Hygiene & Safety; • Quality Assurance; and • Quality Control of the procurement and construction processes. These personnel are funded under the general indirect costs pool via the G&A rate rather than by direct project funds.

WBS Element: 84	WBS Level: 3
WBS Title:	**Project Physics**
Description:	This WBS element includes the project physics activities in direct support of the NCSX fabrication project. Since these activities cut across all WBS elements, the effort is defined and collected here. It includes the following activities: • Physics requirements and interface definition; • Physics models and codes to facilitate the physics design and analyses of options; and • Physics analyses of options.

NCSX Construction Project

Work Breakdown Structure (WBS) Dictionary

Preparations of Operations (WBS 9)

-DRAFT-

March 25, 2002

Prepared by: _____

W. Reiersen, Engineering Manager

Reviewed by: _____

J. Chrzanowski, Cognizant WBS Manager (WBS 9)

Reviewed by: _____

R. Simmons, Project Control Manager

Reviewed by: _____

M. Zarnstorff, Physics Manager

Reviewed by: _____

P. Heitzenroeder, Deputy Project Manager for Engineering

Approved by: _____

G. H. Neilson, Project Manager

WBS Element: 9		WBS Level: 2
WBS Title:	**Preparations for Operations**	
Description:	This summary-level WBS element consists of all the necessary preparations for operations and the integrated systems testing needed to achieve first plasma and to carryout the initial experimental program. These costs will be incurred during the latter stages of the fabrication project and include the one-time costs related to testing, startup, operator training, and commissioning of the NCSX device for first plasma. Commissioning costs for the individual subsystems are included in the subsystem scope of work. Similarly pre-operational expenses to support the experimental program after first plasma are not included. Nor is it an initial allowance for operational spares.	
WBS Element: 91		**WBS Level: 3**
WBS Title:	**Pre-Operational Planning and Operations Staff Buildup**	
Description:	In order to be prepared for operations, there is a necessary buildup and training of the operations team and the preparation of operating procedures. The work scope for this will be funded outside the fabrication project baseline.	
WBS Element: 92		**WBS Level: 3**
WBS Title:	**Pre-Operational and Integrated Systems Testing**	
Description:	The NCSX device will have to undergo a series of pre-operational and integrated systems test to demonstrate that it is ready for operation. This WBS element covers the planning, coordination, procedurization, and execution of the Integrated System Tests, which consist of: • First energization of all of the magnet coil systems • First plasma. Costs for operating and staffing the facility for these tests are included. Prior Preoperational Tests are assumed covered by the individual WBS elements.	
WBS Element: 93		**WBS Level: 3**
WBS Title:	**Operational Spares**	
Description:	The NCSX project will start operations with a minimal amount of spares that are expected to support operations. Definition of these spares and their purchase is outside the scope of the fabrication project.	