NCSX Fabrication Project
Work Breakdown Structure (WBS) Dictionary
Stellarator Core Systems (WBS 1)
NCSX-WBS1-01
Revision 2

March 30, 2004

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NCSX WBS Dictionary
Stellarator Core Systems (WBS 1)
Record of Revisions

Revision	Date	Author	Description
0	9/8/2003	Simmons	Initial issue
1	2/12/2004	Simmons	Updated WBS dictionary to delete technical requirements and reflect CD-2 milestone scope.
2	3/30/2004	Simmons	Updated to correct references to partial installation of cryostat in WBS 1 Summary and WBS 172.

NCSX WBS Dictionary
Stellarator Core Systems (WBS 1)

WBS Element: 1	WBS Level: 2
WBS Title:	**Stellarator Core Systems**
Description:	The stellarator core is an assembly of four magnet systems that surround a highly shaped plasma and vacuum chamber. The coils provide the magnetic field required for plasma shaping and position control, inductive current drive, and error field correction. The vacuum vessel and plasma facing components are designed to produce a high vacuum plasma environment with access for heating, pumping, diagnostics, and maintenance. All of the NCSX coil sets are cryo-resistive and operate at liquid nitrogen temperatures, so the entire system is surrounded by a cryostat. WBS elements included in the Stellarator Core Systems are the: • In-Vessel Components (WBS 11); • Vacuum Vessel Systems (WBS 12); • Conventional Coils (WBS 13); • Modular Coils (WBS 14); • Coil Support Structures (WBS 15); • Coil Services (WBS 16); • Cryostat and Base Support Structure (WBS 17); • Field Period Assembly (WBS 18); and • Stellarator Core Management and Integration (WBS 19). The NCSX Fabrication Project includes all equipment required through the completion of the Field Line Mapping Phase of operation. For the majority of the stellarator core systems WBS elements, the final configuration will be provided by first plasma. Exception to this general rule are the upgraded in-vessel components. Unless by explicit exception, the Fabrication Project includes 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. The NCSX Fabrication Project also includes the necessary design and R&D efforts to ensure that upgrade requirements can plausibly be accommodated in the future. Integrated systems testing of the entire NCSX device is covered in and Integrated Systems Testing (WBS 85).

Work Breakdown Structure (WBS) Dictionary
Stellarator Core Systems (WBS 1)

WBS Element: 11	**WBS Level: 3**
WBS Title:	**In-Vessel Components**
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: • Limiters (WBS 111); • Internal Liner (WBS 112); • Internal Trim Coils (WBS 113); and • In-Vessel Component Local I&C (WBS 114). The PFCs inside the vessel will be introduced in stages after initial operation. The first phase will include a simple set of limiter tiles at the three v=1/2 symmetry planes which correspond to the vessel field joints. Later upgrades will provide a contoured liner, constructed of molded carbon fiber composite (CFC) panels mounted on a frame of poloidal rings. For the NCSX Fabrication Project, only the preliminary design of local limiters and any associated limiter local I&C systems that will be supplied later to satisfy the operational requirements for Phases 1-2 of operation. In addition, the NCSX Fabrication Project includes the necessary design and interface identification effort to assure that the complete assembly of in-vessel components required to meet the upgrade requirements can plausibly be accommodated as a future upgrade. However, the detailed design, fabrication, and installation of these upgrades are outside the scope of the Fabrication Project.
WBS Element: 111	**WBS Level: 4**
WBS Title:	**Limiters**
Description:	Only the preliminary design of local limiters is supplied as part of the NCSX Fabrication Project. These limiters consist of simple flat tiles mounted near the vacuum vessel assembly joints, which are located on either side of the v=1/2 symmetry planes.
WBS Element: 112	**WBS Level: 4**
WBS Title:	**Internal Liner**
Description:	***Not required in NCSX Fabrication Project, but interfaces between this system and other systems must be identified, defined, and, if necessary, provided on the other systems. Internal liners will be added as a future upgrade.*** *The upgrade concept is a contoured liner, most likely constructed of molded carbon fiber composite (CFC) panels mounted on a frame of poloidal, gas-cooled ribs. When the full complement of panels is installed, they will shield the entire interior surface of the vessel. It is compatible with staged implementation, such that the support structure and the panels can be installed during later operation.*
WBS Element: 113	**WBS Level: 4**
WBS Title:	**Internal Trim Coils**
Description:	***Not required in NCSX Fabrication Project, but interfaces between this system and other systems must be identified, defined, and, if necessary, provided on the other systems. Internal trim coils will be added as a future upgrade.*** *Internal trim coils inside the vacuum vessel will be added as necessary to provide for higher order (m=5,6) field error correction. It is anticipated that these will be conventionally wound coils in a windowpane configuration.*

Work Breakdown Structure (WBS) Dictionary
Stellarator Core Systems (WBS 1)

WBS Element: 114	**WBS Level: 4**
WBS Title:	**In-Vessel Component local I&C**
Description:	This WBS element provides the local I&C required by other WBS elements included under In-vessel Components (WBS 11). Local I&C requirements will be determined in the design of these other WBS elements. The scope of the NCSX Fabrication Project includes the only the preliminary design of local I&C components necessary to support the local limiters installed as part of the NCSX Fabrication Project. ***Additional local I&C systems will be added as necessary to support upgrades to other in-vessel components.***

Work Breakdown Structure (WBS) Dictionary
Stellarator Core Systems (WBS 1)

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 and access for Auxiliary Systems (WBS 2) and Diagnostics (WBS 3). The vacuum vessel is nestled inside the coil set and is highly shaped, three-period vessel, which means the geometry repeats every 120º. Stellarator symmetry also causes the geometry to be mirrored every 60º so that the top and bottom sections of the first (0º to 60º) segment can be flipped over and serve as the corresponding sections of the adjacent (60º to 120º) segment. The vessel will be constructed in full field periods and joined together at welded joints. Numerous ports are provided for heating, diagnostics, and maintenance access. Several port sizes and shapes are used to best utilize the limited access between modular coils. 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 in-house and supplier R&D, vacuum vessel component procurement and fabrication, on-site assembly activities, and all system level commissioning and testing. 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). Pre-assembly of the field periods is covered in Field Period Assembly (WBS 18). Final assembly is covered in Test Cell Preparation and Machine Assembly (WBS 7). Integrated system testing is covered in Integrated Systems Testing (WBS 85).
WBS Element: 121	**WBS Level: 4**
WBS Title:	**Vacuum Vessel Assembly**
Description:	This WBS element consists of the design, R&D, procurement, fabrication, and assembly of the vacuum vessel shell, ports and extensions, blank port covers, PFC support rib interfaces, vacuum vessel support interfaces, and cooling tubes. This WBS element consist of the following further subdivision of tasks: • The design and in-house R&D of the vacuum vessel shell and other vacuum vessel assembly elements (WBS 1211); • Procurement and Fabrication of the prototype and production vacuum vessel assembly (WBS 1212); and • On-site assembly of the vacuum vessel sectors (WBS 1213).

Work Breakdown Structure (WBS) Dictionary
Stellarator Core Systems (WBS 1)

WBS Element: 1211	WBS Level: 5
WBS Title:	**Vacuum Vessel Design and In-House R&D**
Description:	This WBS element consists of the design of the vacuum vessel assembly and any in-house (e.g., vacuum vessel joint weld tests, etc.) necessary to finalize the prototype and production vacuum vessel segments.
WBS Element: 1212	**WBS Level: 5**
WBS Title:	**Vacuum Vessel Procurement and Fabrication**
Description:	This WBS element consists of everything in the vacuum vessel assembly that is part of the vacuum vessel prototype and production vessel procurement packages, and includes the vacuum vessel shell, ports and extensions, blank port covers, PFC support rib interfaces, and vacuum vessel support interfaces. This WBS element also contains the laboratory procurement follow activities, including preparation of the necessary procurement package documentation (e.g., CSPEC, SOW, drawings, models, etc.) and technical assessments of supplier submittals.
WBS Element: 1213	**WBS Level: 5**
WBS Title:	**Vacuum Vessel On-Site Assembly**
Description:	This WBS element consists of the activities performed on site to complete the assembly of the vacuum vessel, and includes port extension welding (described in WBS 121) during field period sub-assembly and cooling tube installation on each of the three vessel segments. Because the majority of the magnetic diagnostic sensors are located exterior to the vacuum vessel and become trapped once the core machine is assembled, installation of the magnetic diagnostics will be accomplished as part of the vacuum vessel on-site assembly. 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 port extensions. Port extension welding performed prior to field period or final assembly is in this WBS element. Port extension welding performed during field period assembly is part of WBS 18. Port extension welding performed during final assembly (in the NCSX Test Cell) is part of 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 (350C for bakeout, nominally 25C for normal 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 Helium Bakeout System (WBS 64).

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 Forms (WBS 141).
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:	**Conventional Coil Systems**
Description:	The conventional coil systems include all the coils required in addition to the modular coils (WBW 14) to provide the magnetic field for plasma shaping, position control, and inductive current drive. Ex-vessel trim coils are also included for low poloidal mode number (m=2,3) field error correction. This WBS element consists of the following: • TF Coils (WBS 131); • PF Coils (WBS 132); • External Trim Coils (WBS 133); and • Conventional Coils Local I&C (WBS 134). 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 coil component fabrication and assembly activities, and all system level commissioning and testing. At this time no R&D is anticipated for this WBS element. Pre-assembly of the field periods (including installation of the TF and external trim coils) is covered in Field Period Assembly (WBS 18). Final assembly (including installation of the PF coils) is covered in Test Cell Preparation and Machine Assembly (WBS 7). Integrated system testing is covered in Integrated Systems Testing (WBS 85).
WBS Element: 131	**WBS Level: 4**
WBS Title:	**TF Coils**
Description:	The set of toroidal field coils provide flexibility in the magnetic configuration. There are 18 identical, equally spaced coils providing a 1/R field at the plasma. The coils are wound from hollow copper conductor and vacuum impregnated with glass-epoxy. They operate at the same temperature as the poloidal and modular coil sets, nominally 80K (cooled by LN_2). The coils are supported by an external coil support structure (WBS 151). The coils are located at radial locations coincident with the modular coil (WBS 14) locations, both for symmetry and to avoid introducing additional obstructions to access. This WBS element consists of the manufacturing design, procurement, and fabrication of the TF conductor and assembly of the TF winding packs including interface elements for connections to power and cooling supply at the coils. Local I&C for the TF and other conventional coils is included in the Conventional Coils Local I&C (WBS 134).

Work Breakdown Structure (WBS) Dictionary
Stellarator Core Systems (WBS 1)

WBS Element: 132	WBS Level: 4
WBS Title:	**PF Coils**
Description:	The poloidal field (PF) magnets produce the poloidal magnetic field within the NCSX device. These coils provide inductive current drive and plasma shape and position control. The major components of the PF coils are the: • PF Central Solenoid Coils (WBS 1321); and the • PF Ring Coils (WBS 1322) This WBS element consists of the manufacturing design and fabrication of the PF conductor assembly of the PF winding packs including interface elements for connections to power and cooling supply at the coils, and integration of the three pairs of coils with the central solenoid structural elements.
WBS Element: 1321	**WBS Level: 5**
WBS Title:	**PF Central Solenoid Coils**
Description:	The central solenoid coil set consists of three inner solenoid pairs (PF-1, PF-2, and PF-3) and the central solenoid support structures (formerly in WBS 152). All the coils are symmetric about the horizontal midplane. The coils are wound from hollow copper conductor and vacuum impregnated with glass-epoxy. They operate at the same temperature as the toroidal and modular coil sets, nominally 80K (cooled by LN_2).
WBS Element: 1322	**WBS Level: 5**
WBS Title:	**PF Ring Coils**
Description:	The ring coil set consists of one mid-plane coil pair (PF-4) and two outer coil pairs (PF-5 & PF-6). All the coils are symmetric about the horizontal midplane. The coils are wound from hollow copper conductor and vacuum impregnated with glass-epoxy. They operate at the same temperature as the toroidal and modular coil sets, nominally 80K (cooled by LN_2). The PF ring coils are supported by the Coil Support Structure (WBS 15).
WBS Element: 133	**WBS Level: 4**
WBS Title:	**External Trim Coils**
Description:	The external trim coil set is intended to provide low poloidal mode number (m=2,3) field error correction. These will be conventionally wound coils in a windowpane configuration. They are provided at the top, bottom, and outside perimeter of the Coil Support Structure (WBS 151) primarily to reduce low poloidal mode number (m) resonant errors that may result from manufacturing or assembly errors in the modular coil geometry. This WBS element consists of the manufacturing design and fabrication of the External Trim Coils. The coils are supported by the Coil Support Structure (WBS 151).
WBS Element: 134	**WBS Level: 4**
WBS Title:	**Conventional Coil Local I&C**
Description:	This WBS element provides the manufacturing design and fabrication of the local I&C components required by the WBS elements under Conventional Coils (WBS 13). Local I&C requirements will be determined in the design of these WBS elements, and may include strain gages, RTDs, and voltage taps.

Work Breakdown Structure (WBS) Dictionary
Stellarator Core Systems (WBS 1)

WBS Element: 14	**WBS Level: 3**
WBS Title:	**Modular Coils**
Description:	The function of the modular coils s to provide the basic quasi-axisymmetric magnetic configuration for the device. 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 assembly. The coils are connected electrically with three circuits in groups of six coils, according to type. The windings can produce alternate magnetic configurations by varying the current for each coil type independently. This WBS element consists of all the following: • Winding Form (WBS 141) • Windings and Coil Assembly (WBS 142); • Modular Coils Local I&C (WBS 143); and • Modular Coil Winding Facility and Fixtures (WBS 144). This WBS element consists of the design, procurement, 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 in a field period is covered in Field Period Assembly (WBS 18). Final assembly of the field periods is covered under Test Cell Preparation and Machine Assembly (WBS 7). Integrated systems testing is covered in Integrated Systems Testing (WBS 85)
WBS Element: 141	**WBS Level: 4**
WBS Title:	**Modular Coil Winding Forms**
Description:	This WBS element consists of the design, procurement, and fabrication of the modular coil winding forms. The function of the winding forms is to provide an accurate means of positioning the conductor during the winding and vacuum-pressure impregnation (VPI) process. The winding forms are permanent structures that also provide mechanical support for the windings during coil operation. The complete assembly of winding forms is referred to as the structural shell. 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 field period. During final assembly, the field periods are bolted together to form the completed stellarator core assembly.

WBS Element: 142		WBS Level: 4
WBS Title:	**Modular Coils Windings and Assembly**	
Description:	This WBS element consists of the design, procurement, and fabrication of the modular coil windings and coil assembly. The function of the modular coil windings is to provide the basic quasi-axisymmetric magnetic configuration for the device. The windings can produce alternate magnetic configurations by varying the current for each coil type independently. Within the modular coil envelope, a thick web 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. Copper cladding consisting of copper sheet formed to the surface of the winding form and outside of winding pack (or a different arrangement to be determined during design) is provided for coil cooling. 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, integral cooling components (e.g. chill plates), epoxy impregnation, clamp brackets, inspection and electrical testing. This WBS element consist of the following further subdivision of tasks: • Design and in-house R&D activities necessary to finalize the modular coil winding and assembly components (WBS 1421); • Procurement and fabrication of modular coil winding components (WBS 1422); • Modular coil winding activities (WBS 1423); and • Modular coil testing activities (WBS 1424).	
WBS Element: 1421		**WBS Level: 5**
WBS Title:	**Modular Coil Windings and Assembly Design and R&D**	
Description:	This WBS element consists of the design and fabrication of the modular coil copper cladding for cooling the modular coil. This will include all the material and laboratory labor.	
WBS Element: 1422		**WBS Level: 5**
WBS Title:	**Modular Coil Winding Components**	
Description:	This WBS element consists of all the procured components for the modular coil windings, and includes the cable conductor, kapton and glass insulation, epoxy, coil clamps, cooling lines, lead blocks, fillers, etc.	
WBS Element: 1423		**WBS Level: 5**
WBS Title:	**Modular Coil Winding Labor**	
Description:	This WBS element consists of all the labor required to wind conductor, vacuum bag, vacuum impregnate with epoxy, connect cooling lines, and inspect the modular coils.	
WBS Element: 1424		**WBS Level: 5**
WBS Title:	**Modular Coil Testing**	
Description:	This WBS element consists of the special facilities, test labor, supervision, cryogens, and reporting required for testing individual modular coils, including electrical tests at room temperature and cryogenic temperature.	
WBS Element: 143		**WBS Level: 4**
WBS Title:	**Modular Coils 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, which	

	will include strain gages, RTDs, and voltage taps.
WBS Element: 144	**WBS Level: 4**
WBS Title:	**Modular Coil Winding Facility and Fixtures**
Description:	This WBS element consists of the design and fabrication of the autoclave chamber and fixtures that will be used in winding the modular coils. The autoclave chamber will be used for the epoxy impregnation of the NCSX modular coils..

WBS Element: 15	**WBS Level: 3**
WBS Title:	**Coil Support Structures**
Description:	The coil support structure provides the integrated support for the TF, PF Ring Coils, and External Trim Coil and interface with the machine base support structure (WBS 172). At this time, no R&D is anticipated for this WBS element. Assembly and installation of these support structures in a field period is covered in Field Period Assembly (WBS 18). Final assembly of the field periods is covered under Test Cell Preparation and Machine Assembly (WBS 7). Integrated systems testing is covered in Integrated Systems Testing (WBS 85). *Note: Former WBS 152 (CS Support Structure) has been moved to WBS 132 (PF Coils) and Former WBS 153 (Support Structure Local I&C) has been collapsed into WBS 151.*

WBS Element: 16	**WBS Level: 3**
WBS Title:	**Coil Services**
Description:	The coil services provide overall coordination of the cooling, electrical leads, and coil protection systems for the coil components within the cryostat. At this time, no R&D is anticipated for this WBS element. This WBS element consists of all the following: • LN2 Distribution System (WBS 161); • Coil Electrical Leads (WBS 162); and • Coil Protection System (WBS 163) Assembly and installation of these coil services systems in a field period is covered in Field Period Assembly (WBS 18). Final assembly of the field periods is covered under Test Cell Preparation and Machine Assembly (WBS 7). Integrated systems testing is covered in Integrated Systems Testing (WBS 85).

WBS Element: 161	**WBS Level: 4**
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 LN2 Coil Cooling Supply System Cooling System (WBS 622) and the components that are cooling with LN2, e.g., the TF (WBS 131), PF (WBS 132), External Trim (WBS 133), and Modular (WBS 14) Coils. This WBS element consists of the design and fabrication of the manifolds, cooling pipes, and associated I&C between the LN_2-cooled components within WBS 1 (e.g., the TF, PF, external trim, and modular coils) and the LN2 Coil Cooling Supply System (WBS 622) at the cryostat boundary.

WBS Element: 162	WBS Level: 4
WBS Title:	**Coil Electrical Leads**
Description:	This WBS element consists of the design and fabrication of the coil electrical leads inside the cryostat which then connect the coils to the power supply bus or cables outside the cryostat.
WBS Element: 163	**WBS Level: 4**
WBS Title:	**Coil Protection System**
Description:	This WBS element consists of the development of the overall coil protection system logic and limitation and the design and fabrication of the any coil protection system-specific sensors (e.g., temperature sensors, etc.) not specified in other WBS elements. The overall design and fabrication of the coil protection system is divided among three major WBS elements as follows: • WBS 163 – as described above; • WBS 445 (Electrical Coil Protection System) - provides the digital coil protection system and ground fault detection system for the Modular, PF, and TF coil systems and will be designed to include the trim coils as an upgrade. 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 5 – provides DC current transformer (DCCT) signal conditioners and interface with the control computer and hardwired control circuits. Provides signal transmission from C-Site to D-Site, including temperature of the coils and actual voltages across the coil. The Field Coil Power Convertors (FCPC) computer will perform real time calculation of coil impedances.

WBS Element: 17	WBS Level: 3
WBS Title:	**Cryostat and Base Support Structure**
Description:	This WBS element consists of all the following: • Cryostat (WBS 171); and • Base Support Structure (WBS 172). 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 activities, and all system level commissioning and testing. At this time, no R&D is anticipated for this WBS element. Assembly of the cryostat and base support structure is covered under Test Cell Preparation and Machine Assembly (WBS 7). Integrated systems testing is covered in Integrated Systems Testing (WBS 85)

Work Breakdown Structure (WBS) Dictionary
Stellarator Core Systems (WBS 1)

WBS Element: 171	WBS Level: 3
WBS Title:	**Cryostat**
Description:	The cryostat encloses the NCSX device to provide a suitable thermal environment for the magnets. The cryostat provides the thermal insulation for the cold coil set and structure, and must seal the coil space from the outside air to prevent condensation on the cold surfaces. The cryostat must also provide a means for circulating dry nitrogen inside the cold volume to cool down and maintain the temperature of the interior structures. This WBS element includes the efforts to design and fabricate 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.
WBS Element: 172	**WBS Level: 4**
WBS Title:	**Base Support Structure**
Description:	The base support structure provides the gravity support for the device and the integrated support for the TF and PF coils. The base support structure must also minimize the heat leak to the cold structure from the floor, must accommodate the radial thermal contraction of the cold mass, and must provide the sliding mechanism and rails to allow the three field periods to be brought together simultaneously during final assembly (or to be retracted for major modifications or repair). This WBS element consists of the design and fabrication of the base support structure. The base support structure consists of the base column assemblies, interconnecting beams and column base hardware.

WBS Element: 18	WBS Level: 3
WBS Title:	**Field Period Assembly**
Description:	This WBS element consists of all the following: • Field Period Assembly Planning and Oversight (WBS 181); • TFTR Test Cell Area Preparation (WBS 182); • Receipt, Inspection, and Testing of the Conventional Coils (WBS 183); • Receipt, Inspection, and Testing of the Vacuum Vessel (WBS 184); • Field Period Assembly Activities (WBS 185); • Tooling Design and Fabrication (WBS 186); and • Measurement Systems (WBS 187) The three field periods will be pre-assembled in the TFTR Test Cell prior to final assembly in the NCSX Test Cell. This WBS element covers the assembly of filed periods in the TFTR Test Cell.
WBS Element: 181	**WBS Level: 4**
WBS Title:	**Field Period Assembly Planning and Oversight**
Description:	This WBS element includes planning for the assembly of the stellarator core field periods in the TFTR Test Cell and oversight of the area preparation.

Work Breakdown Structure (WBS) Dictionary
Stellarator Core Systems (WBS 1)

WBS Element: 182	WBS Level: 4
WBS Title:	**Field Period Assembly Area Preparation**
Description:	The WBS element consists of the activities associated with preparing the field period assembly area (the TFTR Test Cell) for receipt of components. This includes installing assembly fixtures and tooling
WBS Element: 183	**WBS Level: 4**
WBS Title:	**Receipt, Inspection, and Testing of Conventional Coils**
Description:	The WBS element consists of the activities associated with the receipt, inspection, and testing of all TF, PF, and external trim 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. The present plan is to fabricate the modular coil windings in-house. The receipt, inspection, and testing of the modular coil winding forms and conductor will be included under the Modular Coils (WBS 14).
WBS Element: 184	**WBS Level: 4**
WBS Title:	**Receipt, Inspection, and Testing of the 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: 185	**WBS Level: 4**
WBS Title:	**Assemble Field Periods**
Description:	This WBS element consists of those activities associated with the assembly of the three individual field periods in the TFTR Test Cell. The work scope includes: • Assembly and alignment of the TF/Modular coils with 1/3 of the vacuum vessel; • Installation of magnetic diagnostics, cooling tubes, and insulation onto the VV segment; • 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: 186	**WBS Level: 4**
WBS Title:	**Tooling Design & Fabrication**
Description:	This WBS element consists of the activities associated with the design and fabrication of tooling required during assembly of the field periods in the TFTR Test Cell. All procurements of miscellaneous items required for the pre-assembly of the field periods 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.

Work Breakdown Structure (WBS) Dictionary
Stellarator Core Systems (WBS 1)

WBS Element: 187	WBS Level: 4
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 during pre-assembly of the field periods in the TFTR Test Cell. This fixturing will be used in conjunction with PPPL owned measurement systems, including the FARO Mechanical Measuring arms and Leica Laser measurement devices.

WBS Element: 19	WBS Level: 3
WBS Title:	**Stellarator Core Oversight and Global Analyses**
Description:	This WBS element consists of the management, oversight, and global analyses of the design and integration of the stellarator core component, including overall stellarator core systems design, pre-assembly of the field periods, and assembly of the and design integration of the design, pre-assembly of the field periods, and assembly of the stellarator core components in the NCSX test cell. This also includes interface integration with the other non-stellarator core systems. This WBS element consists of the following: • Stellarator Core Management and Oversight (WBS 191); and • Stellarator Core Systems Global Analyses (WBS 192).
WBS Element: 191	**WBS Level: 4**
WBS Title:	**Stellarator Core Management and Integration**
Description:	This WBS element consists of the management oversight and integration of the design, pre-assembly of the field periods, and assembly of the stellarator core components in the NCSX test cell. This also includes interface integration with the other non-stellarator core systems.
WBS Element: 192	**WBS Level: 4**
WBS Title:	**Stellarator Core Systems Global Analyses**
Description:	This WBS element consists of the global analyses tasks in support of the overall stellarator core design.