

NCSX Project Work Breakdown Structure (WBS) Dictionary
Stellarator Core Systems (WBS 1)
NCSX-WBS-01-04
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**Work Breakdown Structure (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.
3	11/8/2004	Simmons	Revised WBS 121, 123, 187, 191, and 192
4	7/2/2007	Simmons	Updated WBS to Reflect Scope for 2007 Rebaseline

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

WBS Element: 1		WBS Level: 2
WBS Title:	Stellarator Core Systems	
Description:	<p>The basic stellarator core is an assembly of magnet systems that surround a highly shaped plasma and vacuum chamber. All of the NCSX coil sets are cryo-resistive and operate at liquid nitrogen temperatures, so the entire system is surrounded by a cryostat.</p> <p>The scope of Stellarator Core Systems is to provide components and sub-assemblies of the stellarator core. It includes Field Period Assembly, the assembly of the modular coils, toroidal field coils, vacuum vessel, and coil support structures into three field period sub-assemblies. The poloidal field coils, trim coils, coil services, cryostat, base support structures, and field period sub-assemblies are fabricated within this WBS and assembled as part of Machine Assembly (WBS 7)</p> <p>WBS elements included in the Stellarator Core Systems are the:</p> <ul style="list-style-type: none"> • In-Vessel Components (WBS 11); • Vacuum Vessel Systems (WBS 12); • Conventional Coils and Structures (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). <p>Typical Stellarator Core Systems work scope includes engineering design, R&D to support the design and fabrication efforts, component fabrication, sub-assembly, and all component and sub-assembly level testing.</p> <p>MIE Project Scope: Defined in lower-level WBS elements.</p>	

WBS Element: 11		WBS Level: 3
WBS Title:	In-Vessel Components	
Description:	<p>This WBS element consists of in-vessel systems required to absorb heat and particle fluxes from the plasma, control neutral recycling and density, and protect the vacuum vessel from heat and particle fluxes from the plasma and neutral beams. It also includes internal trim coils. Sub-elements within WBS 11 include the:</p> <ul style="list-style-type: none"> • Limiters (WBS 111); • Internal Liner (WBS 112); • Internal Trim Coils (WBS 113); and • In-Vessel Component Local I&C (WBS 114). <p>MIE Project scope: None. All of this is future work, outside the scope of the MIE project.</p>	

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WBS Element: 12		WBS Level: 3
WBS Title:	Vacuum Vessel Systems	
Description:	<p>The scope of this WBS is the fabrication of parts which, when assembled as part of field period assembly (WBS 18):, comprise the completed vacuum vessel system. The vacuum vessel provides a vacuum boundary around the plasma 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 highly shaped, three-period structure which approximately conforms to the plasma.</p> <p>Scope consists of:</p> <ul style="list-style-type: none"> • Three vacuum vessel sub-assemblies, each consisting of a 120-degree shell sector, spacer, and associated ports. • Heating and cooling hoses, with attachment hardware. • Heating and cooling manifolds. • Cryostat interface flanges. • Heater tapes. • Supports. • Thermocouples and other instrumentation. • Thermal insulation. <p>Work includes engineering design, R&D in support of design and fabrication, component procurement, and fabrication. Work in this WBS ends with the delivery of components to assembly operations. Lower level WBS elements collapsed into the Level 3 element for the 2007 Rebaseline since majority of work already completed.</p>	

WBS Element: 13		WBS Level: 3
WBS Title:	Conventional Coil Systems	
Description:	<p>The conventional coil systems scope includes the fabrication of two planar coil systems, the toroidal field (TF) coils and poloidal field (PF) coils. It also includes external (to the vacuum vessel) trim coils for control of low-order helical field harmonics. This WBS element consists of the following:</p> <ul style="list-style-type: none"> • TF Coils (WBS 131); • PF Coils (WBS 132); • External Trim Coils (WBS 133); • Conventional Coils Local I&C (WBS 134); and • Central Solenoid Support Structure (WBS 135). <p>Work includes engineering design, R&D in support of design and fabrication, component procurement, fabrication, and sub-assembly. Work in this WBS ends with the delivery of instrumented coils and coil structures to assembly operations. All work is within the scope of the MIE project, except as noted in lower-level WBS elements.</p>	

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WBS Element: 131		WBS Level: 4
WBS Title:	Toroidal Field (TF) Coils	
Description:	<p>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. Specification of TF coil protection provides limits for the coil protection system. The coils are wound from copper conductor and vacuum impregnated with epoxy. They are designed to operate at the cryogenic temperatures. The steel wedge supports are bonded to the coil by epoxy.</p> <p>MIE Project Scope: Design and fabrication of 18 TF coil assemblies consisting of D-shaped coils assembled to wedge support pieces.</p>	
WBS Element: 132		WBS Level: 4
WBS Title:	Poloidal Field Coils	
Description:	<p>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. Specification of PF coil protection limits for the coil protection system. The coils are wound from copper conductor and vacuum impregnated with epoxy. They are designed to operate at the cryogenic temperatures.</p> <p>MIE Project Scope: Design and fabrication of 3 pairs of PF ring coils, denoted PF4, PF5, and PF6. Central Solenoid will utilize existing PF-1a solenoid from NSTX.</p> <p>Future Scope: Fabrication of up to 3 pairs of new central solenoid coils.</p>	
WBS Element: 133		WBS Level: 4
WBS Title:	External Trim Coils	
Description:	<p>The external trim coil set is intended to provide low poloidal mode number ($m=2,3$) field error correction. Specification of trim coil protection limits for the coil protection system. The coils are wound from copper conductor and vacuum impregnated with epoxy. They are designed to operate at the cryogenic temperatures.</p> <p>MIE Project Scope: Design and fabrication of two pairs of local coils to be installed outside the PF coils.</p> <p>Future scope: fabrication of additional trim coils as required by the program.</p>	
WBS Element: 134		WBS Level: 4
WBS Title:	Conventional Coil Local I&C	
Description:	<p>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 thermocouples, strain gauges, RTDs, and voltage taps.</p> <p>MIE Project scope: Fabrication and installation of local instrumentation for the conventional coils.</p>	

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WBS Element: 135		WBS Level: 4
WBS Title:	Central Solenoid Support Structure	
Description:	<p>The existing PF-1a solenoid from NSTX will be utilized as the initial central solenoid for NCSX. A new support structure and associated I&C for these coils will be designed, fabricated, and installed.</p> <p>MIE Project Scope: Fabrication and installation of the support structure for existing central solenoid coils, and procurement and installation of I&C for those coils.</p>	

WBS Element: 14		WBS Level: 3
WBS Title:	Modular Coils	
Description:	<p>The modular coils consists of 18 complex-shaped coils supported on the interior surface of a toroidal shell. There are three types of coils, denoted A, B, and C, differing primarily in their shapes. The coils are wound from flexible copper cable conductor which is installed on the i.d. of a support structure called a modular coil winding form (MCWF), and vacuum impregnated with epoxy. In the finished assembly, the modular coils are arranged in three identical field periods, each containing six coils, two of each type. The coils are bolted together at mating flanges on the MCWF, using complex assembly hardware to provide structure support, insulation, and accurate coil positioning. This WBS element consists of all the following:</p> <ul style="list-style-type: none"> • Modular Coil Winding Form (WBS 141) • Modular Coil Fabrication (WBS 142); • Modular Coil Design (WBS 143) • Modular Coil Fabrication Facility (WBS 144) • Modular Coil Interfaces (WBS 145) <p>MIE Project Scope: All work is within the scope of the MIE project. Work includes engineering design, R&D in support of design and fabrication, component procurement, tooling and fixtures, fabrication, and sub-assembly. Work in this WBS ends with the delivery of 18 instrumented coils and assembly hardware to assembly operations.</p>	

WBS Element: 141		WBS Level: 4
WBS Title:	Modular Coil Winding Forms	
Description:	<p>The modular coil winding forms provide a precision guide for accurately positioning the conductor pack through winding and epoxy impregnation, and become the permanent mechanical support for the coils in the finished machine. When assembled, the eighteen winding forms form a complete toroidal shell.</p> <p>Work includes fabrication process development, materials testing, fabrication, and Title III engineering. Work in this WBS ends with the delivery of 18 winding forms to modular coil fabrication operations.</p>	

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WBS Element: 142		WBS Level: 4
WBS Title:	Modular Coil Fabrication	
Description:	<p>This element covers the fabrication of the 18 modular coils.</p> <p>Work includes fabrication process development; fabrication or procurement of parts except the modular coil winding forms; fabrication and epoxy impregnation of the winding pack; installation of parts such as instrumentation, diagnostics, and insulation blankets; and inspection, metrology, and testing of the coils. Work in this WBS ends with the delivery of 18 modular coils to assembly operations.</p>	
WBS Element: 143		WBS Level: 4
WBS Title:	Modular Coil Design	
Description:	<p>This element covers the design of the modular coil system.</p> <p>Work includes preliminary and final design, analyses and testing in support of the design, and specification of modular coil protection limits for the coil protection system.. Work in this WBS ends with the delivery of drawings, specifications, and models to fabrication and assembly operations; and documentation of coil protection limits.</p>	
WBS Element: 144		WBS Level: 4
WBS Title:	Modular Coil Fabrication Facility	
Description:	<p>This element covers the coil fabrication facility, including site preparation, fabrication of tooling, and installation of large fixtures. The supports the modular coil fabrication activities covered under WBS 142. Work in this WBS ends with the delivery and installation (as appropriate) of tooling for the modular coil fabrication facility.</p>	
WBS Element: 145		WBS Level: 4
WBS Title:	Modular Coil Interfaces	
Description:	<p>This element covers R&D in support of modular coil interface design and fabrication, and procurement of interface parts.</p> <p>Work includes analyses and testing in support of the design and fabrication; and procurement of interface parts. Work in this WBS ends with the delivery of modular coil interface parts to assembly operations.</p>	

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WBS Element: 15		WBS Level: 3
WBS Title:	Coil Support Structures	
Description:	<p>The coil support structures provide the mechanical supports connecting TF, PF ring coils (PF 4, 5, and 6), and external trim coils to the modular coil toroidal shell and the base support structure. Work includes engineering design, procurement, and fabrication of structures and associated I&C. Work in this WBS ends with the delivery of components to machine assembly operations.</p> <p>MIE Project Scope: All work is within the scope of the MIE project.</p> <p><i>Note: Previous changes to this WBS deleted lower level WBS elements.</i></p>	

WBS Element: 16		WBS Level: 3
WBS Title:	Coil Services	
Description:	<p>The coil services consist of the cryogenic feeds and electrical leads inside the cryostat, serving all of the coils. It also includes the specification of requirements for the coil protection system. Lower-level elements include:</p> <ul style="list-style-type: none"> • LN2 Distribution System (WBS 161); • Coil Electrical Leads (WBS 162); and • Coil Protection System Interfaces (WBS 163) <p>Work includes engineering design, procurement, and fabrication. Work in this WBS ends with: 1) the delivery of coil services components to machine assembly operations, and 2) the delivery of coil protection requirements to the coil protection system design activity.</p> <p>MIE Project Scope: All work is within the scope of the MIE project.</p>	

WBS Element: 161		WBS Level: 4
WBS Title:	LN₂ Distribution System	
Description:	<p>This element covers the distribution of liquid nitrogen (LN₂) coolant within the cryostat. The system serves all the coils: the TF (WBS 131), PF (WBS 132), External Trim (WBS 133), and Modular (WBS 14) Coils.</p> <p>Work includes engineering design, procurement, and fabrication of manifolds, cooling pipes, and associated supports and I&C. The WBS161 I&C interface ends at the cryostat boundary and does not cover cabling from the cryostat to the control panels, signal conditioning, power supplies, or readouts. Work in this WBS ends with the delivery of components to machine assembly operations.</p>	

WBS Element: 162		WBS Level: 4
WBS Title:	Coil Electrical Leads	
Description:	<p>This element covers the electrical leads within the cryostat, serving all the coils: the TF (WBS 131), PF (WBS 132), External Trim (WBS 133), and Modular (WBS 14) Coils.</p> <p>Work includes engineering design, procurement, and fabrication of leads and associated supports. Work in this WBS ends with the delivery of components to machine assembly operations.</p>	

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WBS Element: 163		WBS Level: 4
WBS Title:	Coil Protection System Interfaces	
Description:	<p>This WBS element consists of the development of the overall coil protection system interface logic and limitation and the design of the interfaces with WBS 4.</p> <p><i>This initial conceptual design scope has now been completed and detailed design and implementation has been transferred to WBS 4 and WBS 5. This WBS element now only contains the final design of interfaces with the coil protection systems.</i></p>	

WBS Element: 17		WBS Level: 3
WBS Title:	Cryostat and Base Support Structure	
Description:	<p>The cryostat encloses the NCSX device to provide a suitable thermal environment for the magnets. It provides thermal insulation and a tight seal to isolate the cold gaseous nitrogen atmosphere surrounding the coils and cold structure from the ambient atmosphere. It also provides a means for circulating dry nitrogen inside the cold volume to cool down and maintain the temperature of the interior structures.</p> <p>The base support system provides the gravity support for the core device (vacuum vessel and coils). During final assembly, it also provides the means to simultaneously draw the three field periods together to be joined. During operations, it also provides thermal isolation of the cold structure from the floor.</p> <p>Lower-level elements include:</p> <ul style="list-style-type: none"> • Cryostat (WBS 171); and • Base Support Structure (WBS 172). <p>Work includes engineering design, procurement, and fabrication. Work in this WBS ends with the delivery of components to machine assembly operations,</p> <p>MIE Project Scope: All work is within the scope of the MIE project.</p>	

WBS Element: 171		WBS Level: 4
WBS Title:	Cryostat	
Description:	<p>Work includes engineering design, procurement, and fabrication of the cryostat shell & structure components, insulation, attachments for the structural support of internal components, and penetrations for electrical, cooling, and mechanical support services,</p> <p>Work in this WBS includes engineering design, procurement, and fabrication. Work ends with the delivery of components to machine assembly operations.</p>	

WBS Element: 172		WBS Level: 4
WBS Title:	Base Support Structure	
Description:	<p>Work includes engineering design, procurement, and fabrication of the permanent e base support structure for the machine.</p> <p>Work in this WBS includes engineering design, procurement, and fabrication. Work ends with the delivery of components to machine assembly operations.</p>	

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WBS Element: 18		WBS Level: 3
WBS Title:	Field Period Assembly	
Description:	<p>Field Period Assembly covers the assembly of the vacuum vessel, modular coils, and toroidal field coils into three identical modules known as field periods. Each field period contains one vacuum vessel sub-assembly (120-degree shell sector, toroidal spacer, and ports), six modular coils (two each of Type A, B, and C), six toroidal field coils, and associated coil support structures. Lower-level elements include:</p> <ul style="list-style-type: none"> • FPA Management, Planning & Design (WBS 181); • FPA Area Preparation (WBS 182) – <i>Completed</i>; • Receipt, Inspection, and Testing of Conventional Coils (WBS 183)– <i>Closed, now Moved to WBS 13</i>; • Receipt, Inspection, and Testing of Vacuum Vessel Segments (WBS 184) - <i>Completed</i>; • Field Period Assembly Operations (WBS 185); • Tooling Design and Fabrication (WBS 186); and • Measurement Systems (WBS 187) – Scope limited to procurement and initial training on measurement systems -- <i>Complete</i>. <p>Work includes engineering design, R&D in support of design and fabrication, component procurement, tooling and fixtures, and assembly. Work in this WBS ends with the delivery of three field period modules to machine assembly operations.</p> <p>MIE Project Scope: All work is within the scope of the MIE project.</p>	
WBS Element: 181		WBS Level: 4
WBS Title:	FPA Management, Planning & Design	
Description:	<p>This element covers the management and planning and the design for field period assembly sequence and final machine assembly sequences and paths.</p> <p>PPPL is responsible for the overall management and planning for field period assembly and this includes preparation of FPA procedures needed for the FPA operations described in WBs 185.</p> <p>ORNL has the responsibility for the preparation of assembly specifications and drawings for the assembly of the stellarator core field periods in the TFTR Test Cell and installation into the NCSX Test Cell.</p> <ul style="list-style-type: none"> • A half period specification and assembly drawing(s) shall be prepared for the assembly of the Type A, Type B and Type C coil assemblies. • A specification and assembly drawing(s) shall be prepared for the assembly of the Type A, B, & C coil assembly to form a Field Period Assembly. • A specification and assembly drawing shall be prepared to assemble three Field Period Assemblies into the NCSX Test Cell. <p>Work in this WBS ends with the delivery of drawings, specifications, and models to field period assembly and machine operations.</p>	

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WBS Element: 182		WBS Level: 4
WBS Title:	FPA Area Preparation	
Description:	<p>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.</p> <p><i>This scope has now been moved to revised WBS 185 and is now closed.</i></p>	
WBS Element: 183		WBS Level: 4
WBS Title:	Receipt, Inspection, and Testing of Conventional Coils	
Description:	<p>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.</p> <p><i>This scope has now been moved to revised WBS 13 and is now closed.</i></p>	
WBS Element: 184		WBS Level: 4
WBS Title:	Receipt, Inspection, and Testing of Vacuum Vessel Segments	
Description:	<p>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.</p> <p><i>This scope is now completed and this WBS element is closed.</i></p>	
WBS Element: 185		WBS Level: 4
WBS Title:	Field Period Assembly Operations	
Description:	<p>This element covers the assembly of the three individual field periods in a series of stages:</p> <ul style="list-style-type: none"> • Stage 1: Vacuum Vessel Prep (installation of components on the surface of the vacuum vessel sectors) • Stage 2: Modular Coil Sub-assembly (assembly of modular coils into groups of three) • Stage 3: Modular Coil-to-Vacuum Vessel assembly (assembly of modular coil over the vacuum vessel sectors). • Stage 4/5: Final field period assembly (installation of port extensions, assembly of TF coils and trim coils over the modular coils, leak check, and assembly of base support connections). <p>Work includes R&D in support of assembly process development, and assembly activities. Work in this WBS ends with the delivery of three field period modules to machine assembly operations. All work is within the scope of the MIE project.</p>	

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WBS Element: 186		WBS Level: 4
WBS Title:	Tooling Design & Fabrication	
Description:	<p>This element covers the design and fabrication of the tooling and fixtures for field period assembly</p> <p>Work includes engineering design, R&D and analysis in support of the design, procurement, and fabrication. Work in this WBS ends with the delivery and installation (as appropriate) of tooling for field period assembly.</p>	
WBS Element: 187		
WBS Title:	Measurement Systems	
Description:	<p>This WBS element consists of those efforts required to design, procure and fabricate additional metrology instruments, fixtures & tooling to be used for position measurement during pre-assembly of the field periods in the TFTR Test Cell. These instruments, fixturing, and tooling will be used in conjunction with PPPL owned measurement systems, including the FARO Mechanical Measuring arms and Leica Laser measurement devices.</p> <p><i>This scope is now completed and this WBS element is closed.</i></p>	

WBS Element: 19		WBS Level: 3
WBS Title:	Stellarator Core Management and Integration	
Description:	<p>This WBS element consists of ORNL-based management and design integration activities for the stellarator core.</p> <p><i>Note: WBS 191 (ORNL Stellarator Core Management) and WBS 192 (ORNL Stellarator Core Integration) have now been collapsed into the WBS 3 level.</i></p>	