NCSX Fabrication Project
Work Breakdown Structure (WBS) Dictionary
Diagnostic Systems (WBS 3)
NCSX-WBS3-01
Revision 1

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Prepared by:

Bob Simmons
Digitally signed by Bob Simmons
DN: CN = Bob Simmons, C = US
Reason: I am the author of this document
Date: 2004.02.13 09:16:45 -05'00'

R. Simmons, Systems Engineering Support Manager

Reviewed by:

David Johnson
Signature Not Verified
Digitally signed by David Johnson
DN: cn=David Johnson, c=US
Date: 2004.02.27 10:42:59 -05'00'

D. Johnson, WBS 3
WBS Manager

Larry Dudek
Signature Not Verified
Digitally signed by Larry Dudek
DN: cn=Larry Dudek, c=US
Date: 2004.02.23 12:47:13 -05'00'

L. Dudek, Ancillary Systems
Project Engineer

R. Strykowsky, Project Control
Manager

Michael Zarnstorff
Signature Not Verified
Digitally signed by Michael Zarnstorff
DN: cn=Michael Zarnstorff, o=PPPL, c=US
Date: 2004.03.16 13:51:05 -05'00'

M. Zarnstorff, NCSX Physics Manager

Wayne Reiersen
Signature Not Verified
Digitally signed by Wayne Reiersen
DN: cn=Wayne Reiersen, o=PPPL, c=US
Date: 2004.03.20 08:57:56 -05'00'
Reason: I have reviewed this document
Location: PPPL

W. Reiersen, Engineering Manager

Approved by:

Hutch Neilson
Digitally signed by Hutch Neilson
DN: CN = Hutch Neilson, C = US, O = PPPL
Date: 2004.02.16 15:31:42 -05'00'

G.H. Neilson, Project Manager

NCSX WBS Dictionary
Diagnostic Systems (WBS 3)

Record of Revisions

Revision	Date	Author	Description
0	**9/8/2003**	**Simmons**	**Initial issue**
1	**1/21/04**	**Simmons**	**Updated WBS dictionary to delete technical requirements and reflect the updated CD-2 scope.**

NCSX WBS Dictionary
Diagnostic Systems (WBS 3)

WBS Element: 3	**WBS Level: 2**
WBS Title:	**Diagnostic Systems**
Description:	The diagnostic systems provide the detailed measurements of the plasma parameters that are critical to the research goals of NCSX. Each diagnostic system must be designed to satisfy specific measurement requirements that are derived from the research program. These requirements can be described in terms of the range of the plasma parameter being measured, the desired accuracy, and the spatial and temporal resolution required to permit the experimental investigation of the various research topics. These systems typically include state-of-the-art instrumentation detecting light or particles from the plasma or plasma facing components, and the supporting interface hardware that provides the required views. The diagnostic systems will be installed as needed to support the research program. The set of diagnostics that are part of the NCSX Fabrication Project are only those needed to verify that the core device has met its engineering goals. WBS 3 is responsible for the basic diagnostic system components. These include sensors, collection systems and associated support structures, sensor cables, and signal conditioning hardware and racks. There are several critical areas of diagnostic support that are the responsibility of other WBS elements. These tasks have been planned and budgeted in those WBS elements. 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. 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.

NCSX WBS Dictionary
Diagnostic Systems (WBS 3)

WBS Element: 31	WBS Level: 3
WBS Title:	**Magnetic Diagnostics**
Description:	The magnetic sensors include diamagnetic loops, flux loops, saddle loops, Rogowski coils and B-coils that will provide signals to measure the magnetic flux change in the many geometries necessary to determine the magnetic field geometry using an equilibrium reconstruction code. Because of the strong shaping in NCSX plasmas, such a magnetic reconstruction can provide important information on profiles of plasma pressure and toroidal current. 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 feed-thrus (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. For the NCSX Fabrication Project, an extensive set of ex-vessel sensors will be installed, and a few of them will be connected to field cables, integrators and digitizers. Many of these sensors are located exterior to the vacuum vessel and become trapped once the core machine is assembled and therefore are also included as part of the NCSX Fabrication Project even though they are not needed until later in the research program. 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. This WBS is responsible for the vacuum interface that 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. *There are no diagnostics in this area needed for before initial NBI operation, however the necessary design effort to define interfaces and physical interfaces is part of the NCSX Fabrication Project.*

NCSX WBS Dictionary
Diagnostic Systems (WBS 3)

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 bake-out 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. *There are no diagnostics in this area needed for before initial ohmic operation, however the necessary design effort to define interfaces and physical interfaces is part of the NCSX Fabrication Project.*

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 feed-thrus. 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. *There are no diagnostics in this area needed for before initial ohmic operation, however the necessary design effort to define interfaces and physical interfaces is part of the NCSX Fabrication Project.*

NCSX WBS Dictionary
Diagnostic Systems (WBS 3)

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 feed-thrus. 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. *There are no diagnostics in this area needed for before initial ohmic operation, however the necessary design effort to define interfaces and physical interfaces is part of the NCSX Fabrication Project.*

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. *The NCSX Fabrication Project, only one fast TV camera is planned. All other diagnostics in this category will be deferred until at least the start of ohmic operation. However, the necessary design effort to define interfaces and physical interfaces is part of the NCSX Fabrication Project.*

NCSX WBS Dictionary
Diagnostic Systems (WBS 3)

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. *There are no diagnostics in this area needed for before initial ohmic operation, however the necessary design effort to define interfaces and physical interfaces is part of the NCSX Fabrication Project.*

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 and thus is included in the NCSX 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 phosphor coated mesh. The light from the strike points will be imaged by a high resolution CCD camera. Careful metrology will reference 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 for different vacuum field configurationns. *The full set of EB mapping equipment will be provided for first plasma and EB mapping is included as part of the CD-4 completion criteria.*

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. As the design of the core machine continues, it is important to continue the integration of diagnostics into the deviceand the NCSX facility with higher levels of definition. For example, this may include: • Developing sightline concepts for the full array of planned diagnostics may point to the need for slight modifications in the diagnostic port extensions • Further definition of space needs for in-vessel sensors, and the integration of these sensors into the PFCs and associated support structures; and • Allocation of port space between diagnostics and other auxiliary systems.