NCSX Engineering Design Document

Metrology Needs Assessment

NCSX VVSA/MCWF Final Design Review

May 19-20, 2004

1 INTRODUCTION

Areas of the NCSX that have been identified as having measurement/metrology needs are:

- Vacuum vessel manufacture
- Modular Coil Form manufacture
- Modular Coil winding
- Test Cell Preparation
- Field Period Assembly (VV/Mod coil/PF coil)
- Machine Assembly

2 METROLOGY NEEDS

2.1 Vacuum Vessel Manufacture

The vacuum vessel shall be manufactured by welding small contoured sections to create the vacuum vessel segments. The vendor shall be responsible for the metrology required to fabricate the finished deliverable components. The vendor shall deliver a CADD model of the as-built VV geometry. The NCSX team shall be responsible the following tasks which involve metrology:

a. Vessel segment geometry inspection – measurement of the vessel shape

b. Installation of magnetic loops (external).

c. Installation of monuments to facilitate field period and machine assembly.

2.2 Modular Coil Winding Form Manufacture

The modular coil winding form shall be manufactured by casting the rough shape, followed by machining of the critical areas. The vendor shall be responsible for the metrology required to fabricate the finished deliverable components. The vendor shall deliver a CADD model of the as-built geometry. The NCSX team shall be responsible the following tasks which involve metrology:

a. Modular coil winding form geometry inspection.

b. Installation of diagnostics.

c. Installation of reference monuments.

2.3 Modular Coil Winding

NCSX team members shall wind the Modular coils at PPPL. The conductor is hand wound, held in position with clamps and epoxy impregnated to form the coil. The following tasks involve metrology:

a. Measurement/verification each turn to ensure that coil is located in the desired volume space.

b. Measurement of the completed coil.

c. Installation of monuments to facilitate Field Period Assembly.

2.4 Test Cell

NCSX will be sited in the test cell formerly used for PBX and PLT. The following tasks involve metrology:

a. Establish a global coordinate system that allows the repositioning of the metrology hardware. (Arcsecond GPS is leading candidate).

b. Install monuments on walls, floor and ceiling to allow local positioning systems (ROMER ARM and Leica Laser Tracker) to reference the global coordinate system.

2.5 Field Period assembly (FPA)

Field Period Assembly consists of the marriage of the vacuum vessel, modular coils, and TF coils. The task also includes the installation of the port nozzles. The following tasks involve metrology:

a. Assembly, with precise alignment, of three modular coils to each other.

b. Marriage of the two modular coil assemblies to the vacuum vessel.

c. Alignment/fixturing of port nozzles for welding.

d. Installation of monuments to facilitate machine assembly.

2.6 Machine Assembly

During machine assembly the 3 FPAs, and PF coils, and support structure (s) are brought together to form the NCSX device. The following tasks involve metrology:

a. Assembly, with precise alignment, of three FPAs to each other.

b. Alignment of the vacuum vessel segments, prior to welding.

c. Final alignment of conventional coils.

3 PROPOSED METROLOGICAL EQUIPMENT

Advanced metrology will be required to successfully fabricate and assemble the NCSX device. Whereas in tokamaks the symmetrical nature of their design allowed for the use simple measurement devices (lasers, levels, plum bobs, transits), the stellarator requires sophisticated, computerized measurement systems as well as metrology software.

A comprehensive suite of hardware and software is proposed that will operate as an integrated system. This system is comprised of the following:

- Hardware for measuring the orientation and global position of machine components.
- Hardware for efficiently measuring complex, contoured shapes.
- Special hardware, customized for measuring unique processes.
- Software that can operates various hardware systems simultaneously.
- Software for the post-processing of metrology data and for incorporation into as-built models/drawings.
- Individuals who are proficient in the use of the hardware and software.

3.1 Hardware

3.1.1 Arcsecond Constellation 3DI

Like GPS, Constellation 3DI uses triangulation to create a universal coordinate frame. The system employs multiple transmitters that emit “eye-safe” infrared laser signals. These signals are received by sensors, creating real-time, 3-D coordinates. Sensors can be permanently mounted onto structures, or can be incorporated into pointing devices. Sensors require line of sight to the laser transmitters.

This system is proposed for the establishment of a global coordinate system and for the alignment and positioning of large structures. It shall be used for the alignment of modular coils to each other during the FPA task, and for machine assembly. It will also be employed during operations, as subsystems are added to the NCSX device. The Constellation 3DI is accurate to approximately 0.005 inch.

3.1.2 ROMER CMM Measuring Arm/Laser Scanner

The ROMER arm is a measurement system, which employs a jointed, articulating arm, and measures in either local or global coordinates. It is limited in reach, however by using fixed monuments; the device can be repositioned while maintaining alignment to a known reference. The device can be used with various contacting pointer tips or with a laser scanner attachment which allows for non-contact collection of data at a rate of over 20,000 points per second.

The ROMER arm shall be used to perform QC inspections of deliverables (vacuum vessel, modular coil winding forms, flanges, etc). It shall be used for verification that the modular coil conductor is in the proper location as it is wound onto the coil form. It shall also be used to locate the mounting points for smaller components (i.e., magnetic loop diagnostics) onto the NCSX device. The ROMER arm is accurate to 0.001 inch as a pointing device and to 0.004" with the laser scanner head.

A new twelve-foot arm with laser scanning head has been procured for NCSX metrology needs.

3.1.3 Leica Laser Tracker

The laser tracker is a laser interferometer based measuring system. It employs reflectors that are mounted (or held against) any location to make measurements. The laser tracker is a highly accurate and precise system, capable of measuring to an accuracy of 0.0002 inch. The laser tracker requires unbroken line of site from the laser base to the measured location, which often limits its functionality in congested spaces.

The laser tracker will see limited use for field period and machine assembly. It will be employed where ultrahigh accuracy is required. Since it can be used as a "pointing device", it will be used simultaneously, and in conjunction with the ROMER arm and Constellation 3DI to locate critical points in the NCSX test cell.

PPPL already possesses a Leica Laser tracker.

3.1.4 Mechanical Measurement Fixtures

As part of the modular coil winding R&D, we have developed a simple, hand-operated mechanical measurement device. The tool is intended to allow the members of the coil winding team to rapidly and accurately measure the location of the conductor as it is being laid on to the coil form. The device is bolted onto the edge of the winding form tee and is aligned perpendicular to the winding surfaces. Measurements are taken, ensuring that the conductor is located within the acceptable tolerance. The device is being used in the fabrication of prototype coils and will be refined as a result of the process.

3.2 Software

3.2.1 Spatial Analyzer

Spatial Analyzer (SA) is a metrology 3D graphical software platform that can simultaneously communicate to virtually any number and type of dimensional measurement systems. It provides simple common interfaces for each of the technologies. SA's graphical environment allows the user to download the CAD model and then make all the measurements and perform the analysis on the shop floor. With the SA system, the various metrology systems, which typically operate under unique proprietary software, can be integrated in to one single operator interface. Since SA can run multiple metrology hardware simultaneously, a volume space can be created where local measurements (taken by the Romer arm or Leica Tracker) can be instantly referenced to the global coordinate system (created by the Constellation 3DI).

This software is scheduled to be procured in the fourth quarter of FY '94.

4 APPLICATION MATRIX

Table 1 indicates which tool is capable of performing the tasks outlined earlier. In the case where multiple devices can perform certain tasks, the preferred (or optimal) device has the asterisk.

Table 1 Application matrix

	2.1			2.2			2.3			2.4		2.5				2.6		
Activity	**a**	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**a**	**b**	**c**	**d**	**a**	**b**	**c**
3DI										**x***	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
ROMER (solo)	**x**	**x**	**x**	**x**	**x**	**x**	**x**		**x**									
Laser tracker											**x**							
ROMER(with laser scanner)	**x***		**x***	**x***		**x***	**x**	**x**	**x***									
Mechanical tool							**x***											
SA	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**