NCSX Engineering Design Document

Design Description
Site Preparation Assembly, and Testing

NCSX CDR

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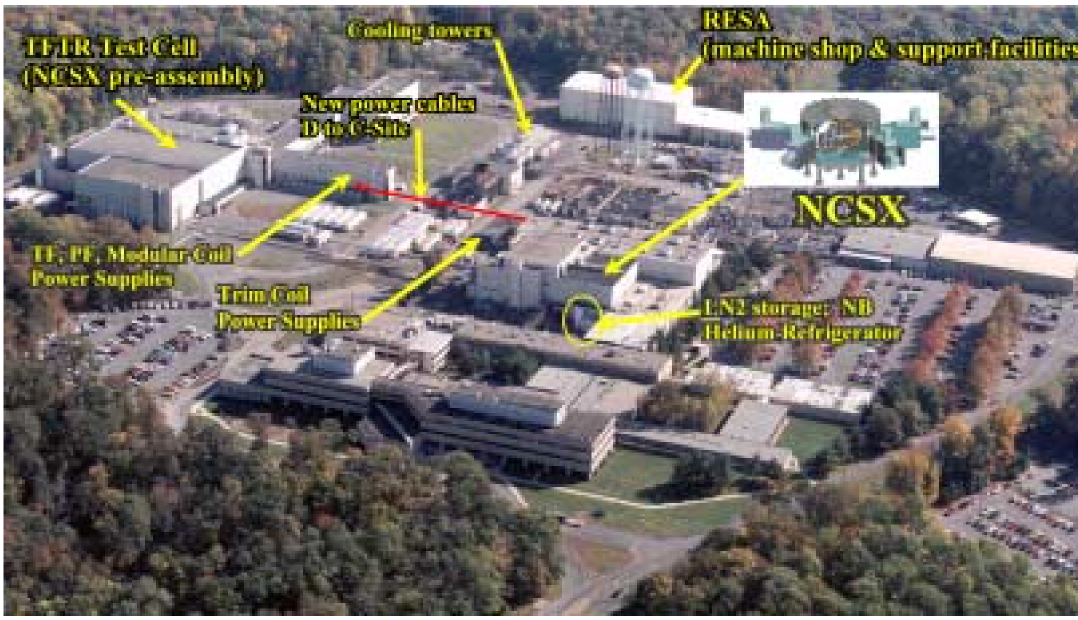
1 INTRODUCTION

NCSX will be sited at C-site at PPPL. The NCSX Test Cell will be the same Test Cell first used for the C-0Stellarator and subsequently used for the PLT and PBX tokamaks. The three field periods will be pre-assembled in the TFTR Test Cell prior to final assembly in the NCSX Test Cell. The modular coils will also be wound in the TFTR Test Cell. Figure 1-1 shows the location of the Test Cell and other facilities at PPPL that will support the fabrication and operation of NCSX.

Figure 1-1 NCSX Facility Locations



All work activities associated with the NCSX Project will be performed in accordance with Princeton Plasma Physics Laboratory (PPPL) Engineering and ES&H Procedures and Directives. A summary of these is provided below:

- <u>Integrated Safety Management (ISM).</u> All work activities will be completed using the guiding principles of ISM. This is an adopted DOE approach to doing work safely. All personnel involved will be trained to using this approach.
- <u>Job Hazard Analysis (JHA).</u> Line managers and workers will generate JHAs to identify existing or potential workplace hazards and to evaluate the risk of worker injury or illness associated with job tasks. A JHA will be generated for all work activities associated with the preparation, fabrication and assembly of the NCSX device. (Reference document ESH-014 "Job Hazard Analysis")
- <u>Engineering Work Package (EWP).</u> Engineering Work Packages (EWP) will be utilized for used for consolidation of documentation and accountability for tasks being performed in the field. An EWP is a package, which contains all pertinent documentation necessary to complete an activity. The package will contain approved RUN copies of the procedures, pertinent Job Hazard Analysis, permits, drawings etc.
- <u>Installation Procedures.</u> Procedures will be generated for the installation and removal of all major components and systems. These procedures will be generated, reviewed and approved in accordance with Engineering procedure ENG-030 "PPPL Technical Procedures for Experimental Facilities".

- Safety Procedures. All work will performed in accordance with PPPL ES&H Directives and Procedures.
- Pre-Job Briefings. A pre-job briefing will be held prior to the start of any new work activity. The purpose of the briefing will be to discuss specific work activities, responsibilities of the participants, a review of the JHA/safety issues, and to respond to all questions and concerns. The participants at these briefings should include all individuals who will be involved with the activity including lead technician, field crews, and supervisors. Representatives from construction safety, Industrial Hygiene, Health Physics and Quality Control will be included as required.
- Post-Job Briefings. A post-job briefing will be held at the conclusion of a work activity. The purpose of the briefing will be to discuss the completed work activities. It should include lessons learned including technique problems, improvements and safety related issues. The participants at these briefings should include all individuals involved with the completed activity or procedure. It should include the lead technician, field crews, and supervisors. Representatives from construction safety, Industrial Hygiene, Health Physics and Quality Control will be included as required.
- Training. Training of personnel is the key to completing the NSCX fabrication safely. Courses will offered for all personnel, instructing them in the proper use of tools and equipment; personal protective equipment (PPEs); and general laboratory policy and safety requirements.

To ensure that all field activities are conducted safely, a full time Construction Safety Representative will be utilized throughout the construction phase. Representatives from Industrial Hygiene, Health Physics, and Quality Control will provide support as required.

2 FACILITY MODIFICATIONS AND TEST CELL PREPARATIONS (WBS 61)

The Test Cell, Test Cell basement and control rooms are in the process of being cleared. These areas and the adjoining rooms to be utilized by the NCSX Project will be received equipped with the required:

- Shelter from the environment (roofing and walls)
- Lighting
- Environmental (temperature, humidity, and air exchange) control
- Fire suppression

There are a number of site preparation activities that need to be completed by the NCSX Project prior to the assembly, including facility modifications outside of the Test Cell and seismic reinforcement of the Test Cell shield walls.

2.1 Facility Modifications Outside the Test Cell (WBS 611)

There are a number of facilities outside of the NCSX Test Cell, which will be needed to support the fabrication and operation of the NCSX device, to which modifications are required. These include the:

- PBX/PLT control rooms
- D-site 2nd.floor FCPC building, and
- D-site TFTR Test Cell.

PBX/PLT Control Rooms

The former PBX/PLT Control Rooms will become the location of the new NCSX Control Room. The existing facilities are presently being cleared. Once the rooms have been cleared, the NCSX Project will refurbish the rooms, providing new lighting, ceilings and floors. Central Instrumentation and Control (WBS 5) will be responsible for the installation of new equipment in the Control Room.

D-Site Field Coil Power Conversion (FCPC) Building

The electrical power required to operate the NCSX modular, TF, and PF coil systems will originate from the FCPC building at D-site. The power will be brought over to the NCSX Test Cell from the D-site FCPC building. The second floor, which presently houses a number of offices and the Vacuum Preparation Laboratory, will be reconfigured. The laboratory will remain but the offices will be relocated. Additional modifications include the core boring of approximately (20) 6-inch diameter penetrations between the first and second floors to provide routing for the power cables along with a large weatherproofed wall penetration at the end of the FCPC building for the power cables exiting the building.

D-site Helium Bakeout System Line Extension

Pre-assembly of the three field periods will take place in the TFTR Test Cell at D-site. The facility already has sufficient floor space, lighting, power and crane capacity. However, it will be necessary to bake each of the vacuum vessel segments during assembly of the field periods. The existing NSTX Helium Bakeout System, which is located in the adjacent NSTX Test Cell, will be used for this purpose. This will require that the bakeout lines be extended approximately 100 feet to the Field Period Assembly Area in the TFTR Test Cell.

Table 2-1 Costs for Facility Modifications (WBS 611) is a summary of estimated costs for Facility Modifications Outside the Test Cell (WBS 611). The total cost is estimated to be $286K in year of expenditure dollars with an overall contingency of 14%. The schedule for implementing this work may be seen in the **Project Master Schedule**, provided as part of the Conceptual Design Report**.** Design work in preparation for these activities will be performed in FY04. The actual work will be completed in FY05.

Table 2-1 Costs for Facility Modifications (WBS 611)

Total Estimated Cost (K$)		
		611
Manufacturing Development	Labor/Other	
	M&S	
	Total	
Design (Title I & II)	Labor/Other	101
	M&S	
	Total	101
Fabrication/Assembly (incl Title III)	Labor/Other	
	M&S	59
	Total	59
Installation/test	Labor/Other	126
	M&S	
	Total	126
Grand Total		286

2.2 Seismic Modifications to the Test Cell Shield Walls (WBS 613)

Three changes will be made, as part of the NCSX Project, to the shield walls in the Test Cell:

- The shield walls will be relocated, combining the two experimental areas for PLT and PBX into a single, spacious area for NCSX;
- The height of the shield walls will be raised to reduce radiation exposure during operations; and
- The shield walls will be seismically reinforced to meet current code requirements.

The Test Cell is presently shielded by a system of high-density concrete blocks separating the Test Cell into what were once the PBX and PLT experimental areas, as shown in Figure 2-1. These blocks will be taken down and reconfigured as shown in Figure 2-2. The new configuration will provide a more spacious experimental area, more space for unloading equipment upon entering the Test Cell area, an open hatch for crane access to the basement, and three ways of emergency egress from the Test Cell.

During the reconfiguration of the shield walls, improvements to minimize radiation exposure during deuterium operation in the control room and adjacent offices will be incorporated. Analysis done during PBX operations showed a benefit in from raising the wall one to two blocks in front of the control room and adjacent offices. In line with ALARA (As Low As Reasonably Achievable) practice, the shield wall will be raised to lower radiation levels. To minimize the cost impact, the existing inventory of shielding blocks will be incorporated into this wall extension to the maximum extent possible. Spare shielding blocks from TFTR are also available for use.

The present construction consists of both keyed interlocking block systems and unkeyed freestanding blocks. An analysis of the existing design has revealed that upgrades to the supporting structure for the shield wall will be required to meet site seismic requirements. Keyed interconnecting blocks will require the least modification. These blocks carry shear loads down to the floor and into adjacent walls, providing a relatively stiff composite structure. Long, freestanding sections of keyed wall will still require additional support. During NCSX modifications, plates and brackets will be added along the top of the wall to stiffen corner sections sufficiently to eliminate overturning seismic moments. Sections of wall farthest from the corners will partially transfer horizontal seismic loads to adjacent walls through trusses. Initial design efforts will focus on the stiffening of the walls as a freestanding system. If analysis shows these efforts are insufficient, additional supports supporting the shield walls to building steel will be added. The unkeyed, non-interconnecting shielding blocks will require more extensive modifications. These sections of wall will require that stiffening plates and bars be added along their height to provide shear elements from one block to the next. These supports will be in addition to the system of supports added to prevent overturning moments as described above.

Table 2-2 is a summary of estimated costs for Seismic Modifications to the Test Cell Shield Walls (WBS 613). The total cost is estimated to be $457K in year of expenditure dollars with an overall contingency of 14%. The schedule for implementing this work may be seen in the **Project Master Schedule**, provided as part of the Conceptual Design Report**.** Design work in preparation for these activities will be performed in FY05. The actual work will be completed early in FY06.

Table 2-2 Costs for Seismic Modifications to the Shield Walls (WBS 613)

Total Estimated Cost (K$)		
		613
Manufacturing Development	Labor/Other	
	M&S	
	Total	
Design (Title I & II)	Labor/Other	40
	M&S	
	Total	40
Fabrication/Assembly (incl Title III)	Labor/Other	
	M&S	99
	Total	99
Installation/test	Labor/Other	318
	M&S	
	Total	318
Grand Total		457

Figure 2-1 Present Shield Wall Configuration

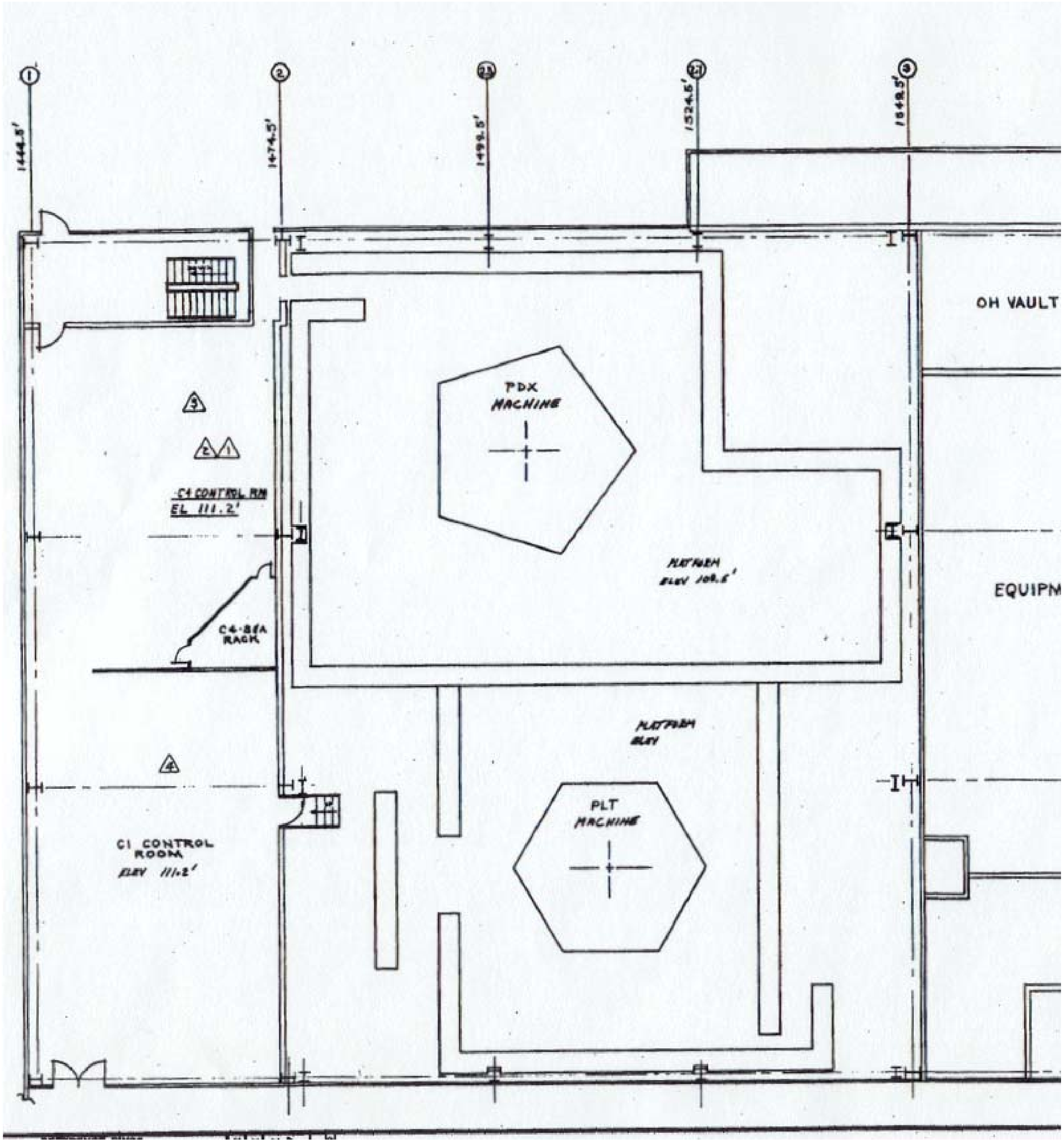
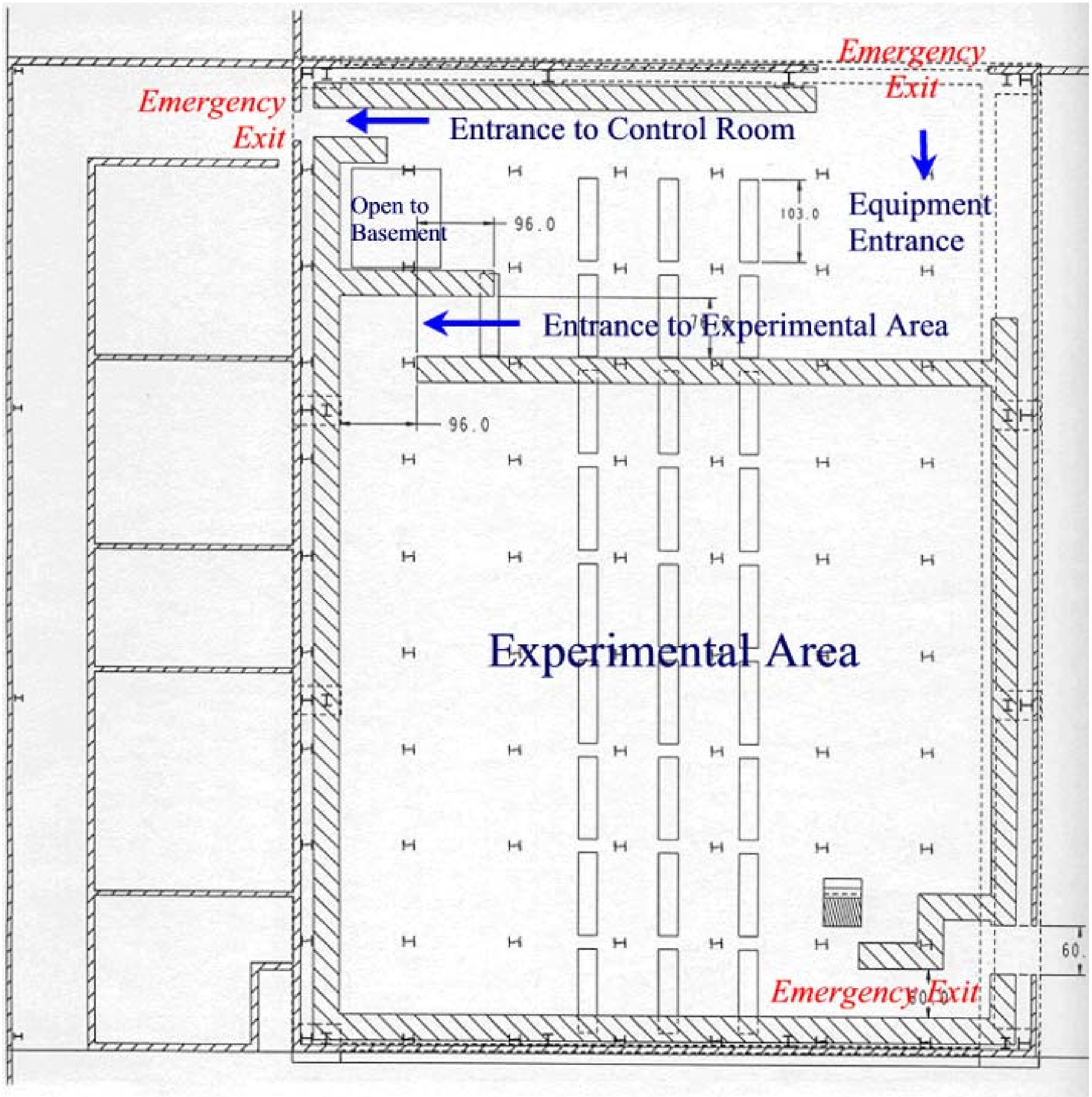


Figure 2-2 Proposed Shield Wall Configuration for NCSX



3 MACHINE ASSEMBLY (WBS 7)

Machine Assembly (WBS 7) 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. It includes acceptance of stellarator core components at PPPL and subsequent assembly and installation. This WBS element also 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.

Machine Assembly (WBS 7) has the following sub-elements:

- Assembly Planning and Oversight Operations (WBS 71)
- On-Site Pre-Assembly Operations (WBS 72)
- Test Cell & Basement Assembly Operations (WBS 73)
- Measurement Systems (WBS 74)
- Platform Design and Fabrication (WBS 75)
- Tooling Design & Fabrication (WBS 76)

3.1 Assembly Planning and Oversight Operations (WBS 71)

A Construction Manager (CM) will be appointed by the NCSX Project whose responsibility it will be to plan and oversee all activities related with the assembly of the NCSX Facility. This will include activities in the NCSX Test Cell and Test Cell Basement plus the pre-assembly activities in the TFTR Test Cell. The CM will be responsible for developing a plan for assembling the machine components and will provide integration between WBS elements involving assembly issues. The CM will also participate in all design reviews to ensure constructability of the NCSX facility.

The CM's responsibilities will also include those activities associated with the assembly of the three individual field periods, which will occur in the TFTR Test Cell. The Engineering and Technical Infrastructure Department will provide additional support during the Title III activities. This will include as required design/analysis support, a lift engineer for critical lifts, and field supervision.

Integrated Safety Management (ISM) will be the keystone for the planning and performance of all field activities. Safety will be the primary concern throughout performance of the Title III activities. To ensure that all field activities are conducted safely, a full time Construction Safety Representative will be utilized throughout the construction phase. Representatives from Industrial Hygiene, Health Physics, and Quality Control will provide support as required

All construction/assembly activities will require peer reviews in accordance with PPPL Engineering procedures. A Job Hazard Analysis (JHA) plus approved procedures will be required for all assembly activities. The type of activity will determine the degree of procedure detail. Additional requirements will include pre- and post-job briefings for all individuals involved with a specific activity plus adequate training of personnel. This includes not only training for general laboratory requirements, but also for use of personnel protective equipment (PPE's) and equipment operation.

Table 3-1 is a summary of estimated costs for Assembly Planning and Oversight Operations (WBS 71). The total cost is estimated to be $1521K in year of expenditure dollars with an overall contingency of 10%. The schedule for implementing this work may be seen in the **Project Master Schedule**, provided as part of the Conceptual Design Report**.** This work will commence at the start of Title II design (October, 2002) and continue until First Plasma (March, 2007).

Table 3-1 Assembly Planning and Oversight Operations (WBS 71) Costs

Total Estimated Cost (K$)				
				71 Total
		711	712	
Manufacturing Development	Labor/Other			
	M&S			
	Total			
Design (Title I & II)	Labor/Other	246		246
	M&S			
	Total	246		246
Fabrication/Assembly (incl Title III)	Labor/Other			
	M&S			
	Total			
Installation/test	Labor/Other		1275	1275
	M&S			
	Total		1275	1275
Grand Total		246	1275	1521

3.2 On-Site Pre-Assembly Operations (WBS 72)

The three field periods will be pre-assembled as individual units, and then transported to the NCSX Test Cell for final machine assembly. The present plan is to utilize the TFTR Test Cell at D-site for assembling the three field periods. The TFTR Test Cell was selected because of its large open floor space, crane capacity, abundant electrical power, good lighting, and ventilation control. Adequate floor space is required for assembly of several field periods in parallel. The Test Cell's close proximity to the NSTX device allows use of the NSTX Helium Gas Bakeout system, which will be used for baking individual vacuum vessel segments on each field period.

The components comprising a field period will be delivered to the assembly area for receipt inspection. The toroidal field (TF) and modular coils will be visually inspected and electrically tested as part of the acceptance program. The vacuum vessel will be delivered in three sections, one section for each field period, with port extensions that will be welded to the vacuum vessel at a later time.

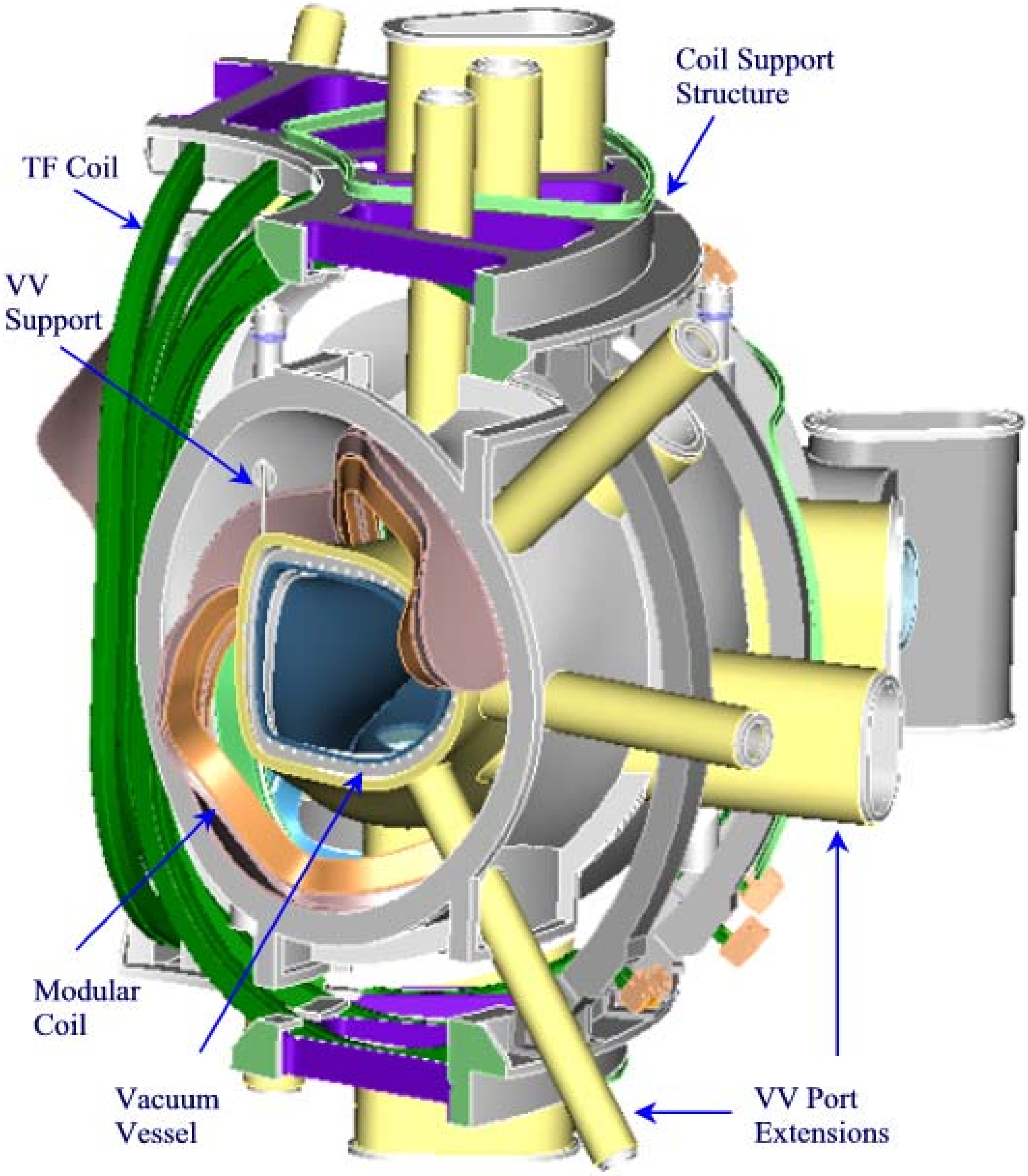
Each field period is comprised of one-third of the vacuum vessel, one-third of the coil support structure, six modular coils; and six TF coils. There are three types of modular coils. They are referred to as the banana-section, mid-section and bullet-section coil types.

Special tooling is required to assemble the modular coils to the vacuum vessel segment. This tooling will be needed to prevent damage to the modular coils during assembly and to assist in the alignment process. The first step will be to place the vacuum vessel segment into an assembly fixture that will position and support the vacuum vessel to allow three of the modular coils to be slid over the VV and assembled from one end. The remaining three modular coils will be then assembled from the opposite end of the vacuum vessel. It will be necessary to temporarily support the vacuum vessel inside of the modular coils until the vacuum vessel supports have been installed. Assembly of the modular coils with the vacuum vessel segments is the highest risk assembly activity. Difficulty in assembling the field periods may arise, and alignment of the magnet system may require extensive in-field work.

The TF coils and coil support structure will be pre-assembled in two 60º segments, with three TF coils per segment. Once the modular coils have been joined with the VV, the TF coil and coil support structure segments will be added to the field period assembly. Once assembled, port extensions will be welded onto each VV segment. An automatic orbital welding head will be utilized for a majority of the welds. Other welds will be performed manually.

Following the welding operation, the ports and ends of the vacuum vessel will be sealed and a vacuum leak check performed. The vacuum vessel segment will then be baked to 150ºC. Following bakeout, a vacuum leak check will again be performed to verify the integrity of the newly welded port extensions. Once leak checking has been completed, the field period will be readied for transport to the NCSX Test Cell. The assembled field period is shown in Figure 3-1.

Figure 3-1 Assembled Field Period



Multiple field periods may be in varying stages of assembly at one time. Availability of components and schedule requirements will dictate the work that is being performed. Following the completion of a field period, the unit will be loaded and secured onto a lowboy trailer. The field period will then be transported from the pre-assembly area in the TFTR Test Cell to the NCSX Test Cell C-site where it will be installed on the machine support structure.

Table 3-2 is a summary of estimated costs for On-Site Pre-Assembly Operations (WBS 72). The total cost is estimated to be $843K in year of expenditure dollars with an overall contingency of 33%. The schedule for implementing this work may be seen in the **Project Master Schedule**, provided as part of the Conceptual Design Report**.** This work will commence in the second half of FY04 with the arrival of the first modular coil and vacuum vessel segments. It is scheduled to be completed late in FY06.

Table 3-2 On-Site Pre-Assembly Operations (WBS 72) Costs

Total Estimated Cost (K$)						
						72 Total
		721	722	724	725	
Manufacturing Development	Labor/Other					
	M&S					
	Total					
Design (Title I & II)	Labor/Other					
	M&S					
	Total					
Fabrication/Assembly (incl Title III)	Labor/Other		36	46	675	758
	M&S					
	Total		36	46	675	758
Installation/test	Labor/Other	86				86
	M&S					
	Total	86				86
Grand Total		86	36	46	675	843

3.3 Test Cell & Basement Assembly Operations (WBS 73)

The NCSX machine will be located in the NCSX Test Cell at C-site. The footprint of the stellarator core in the experimental area of the Test Cell is shown in Figure 3-2. The present plan is to pre-assemble and test as many components as possible, such as the field periods, outside of the NCSX Test Cell. This will help to minimize congestion in the Test Cell and streamline the assembly schedule. This method was used quite successfully during the construction of the NSTX device. The machine components will be delivered to the NCSX Test Cell and assembled together using the overhead crane's 30-ton main hook and the 5-ton auxiliary hook.

Early in the assembly phase, the shield walls will be reconfigured and seismically supported as shown in Figure 2-2. All of the shield walls will be installed except for the area in front of the receiving area. Leaving this area open will allow larger components, such as the field periods, to be lifted with greater ease. Following installation of the shield walls, the machine support structure will be positioned, leveled, and mounted on the Test Cell floor. The final assembly sequence is illustrated in Figure 3-3, Figure 3-4, and Figure 3-5.

Once the machine support structure has been installed, the installation of the platform around the machine will begin. Three-quarters of the platform will be installed. Only the northeast section of platform will not be installed. This will facilitate installation of the field periods on the machine support structure. The early installation of the platform will allow the other WBS elements, such as Electrical Power Systems (WBS 4), Neutral Beam Injection Systems (WBS 25), Torus Vacuum Pumping System (WBS 22), Helium Bakeout System (WBS 65), Water Cooling Systems (WBS 62), and Cryogenic Systems (WBS 63), to begin installation of their equipment. In addition, lighting, fire detection, and fire suppression systems under the platform can also be installed.

Figure 3-2 Stellarator Core Positioned in Test Cell

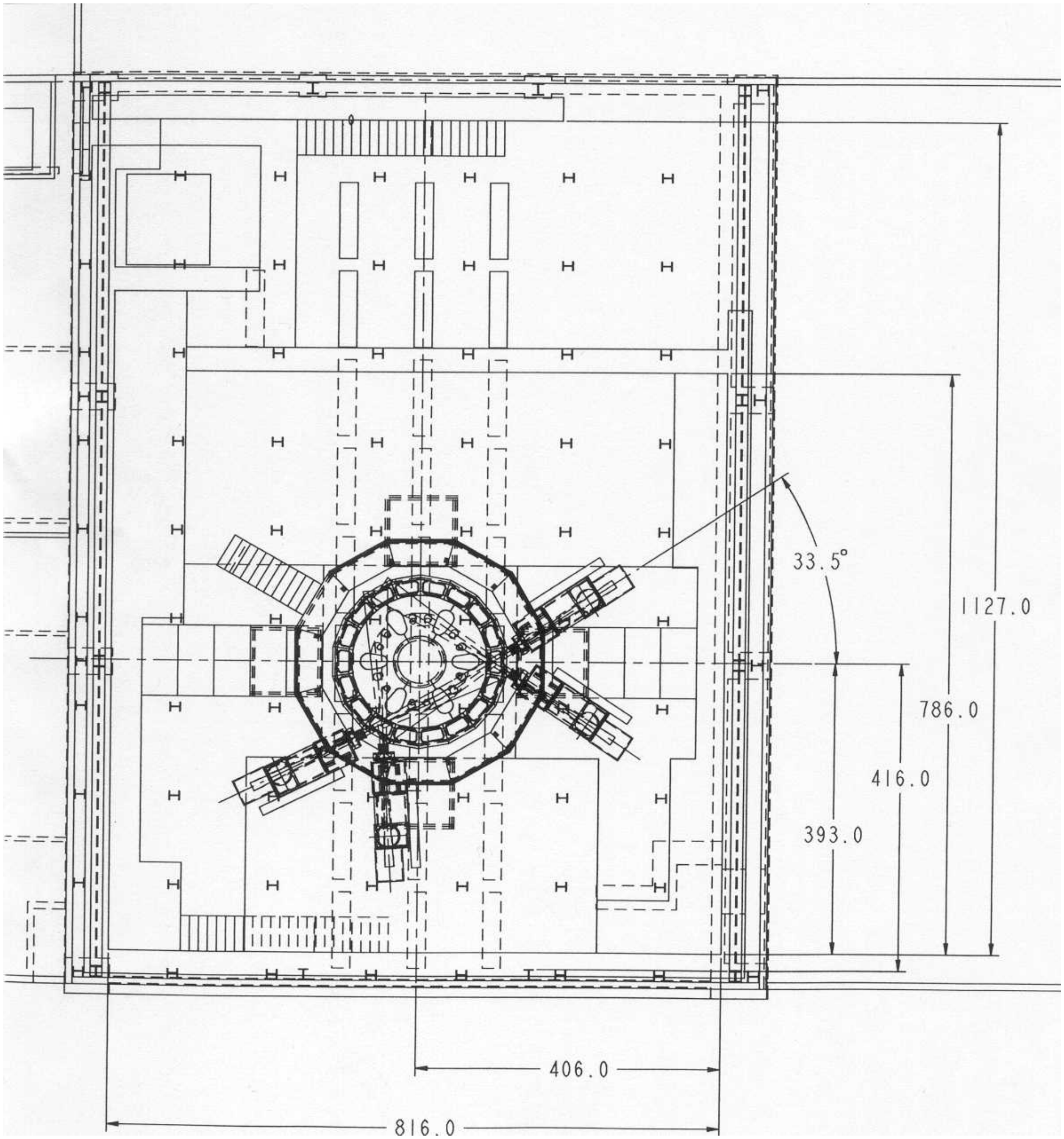


Figure 3-3 NCSX Final Assembly Sequence (1 of 3)

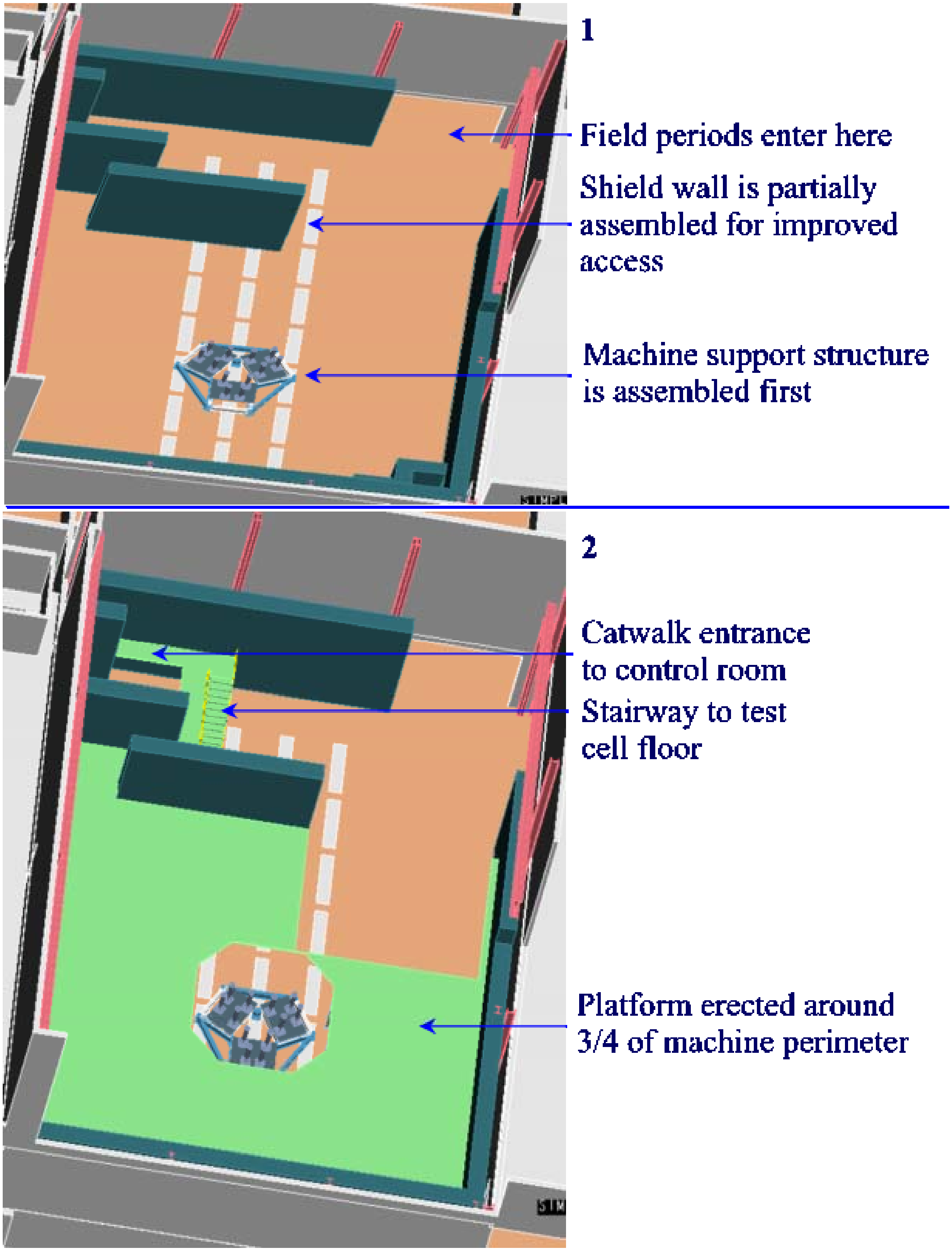
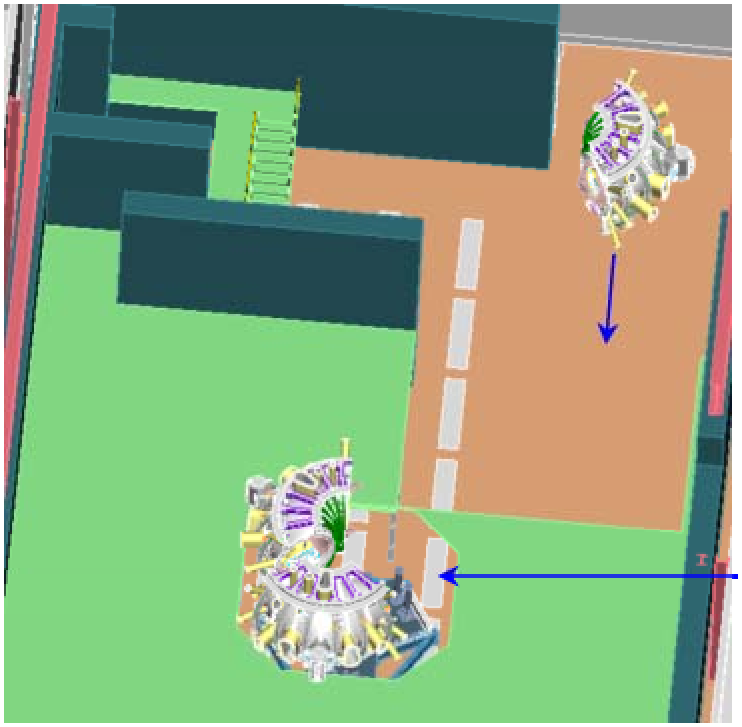


Figure 3-4 NCSX Final Assembly Sequence (2 of 3)



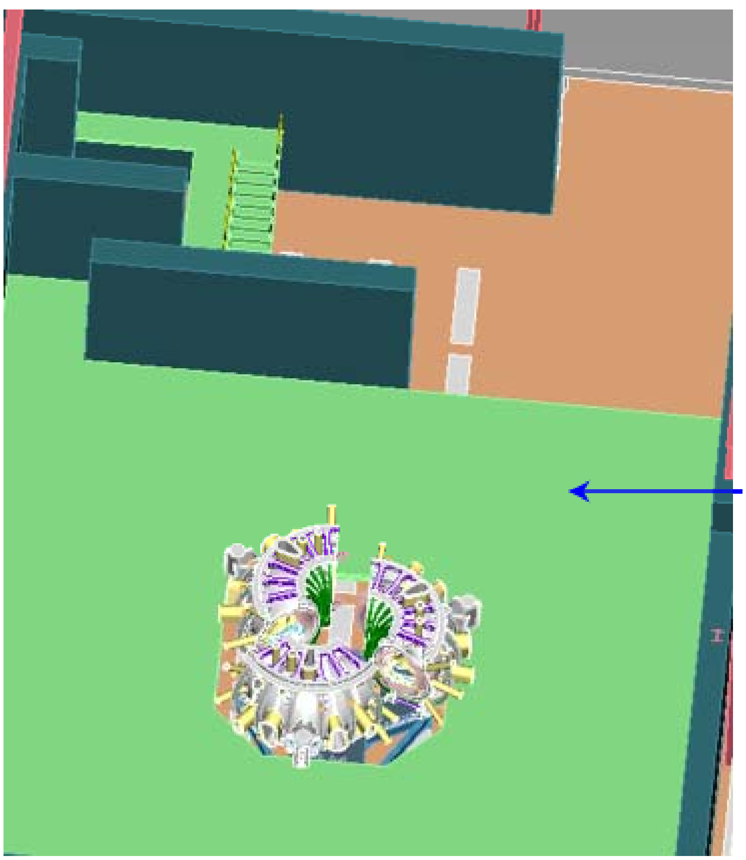
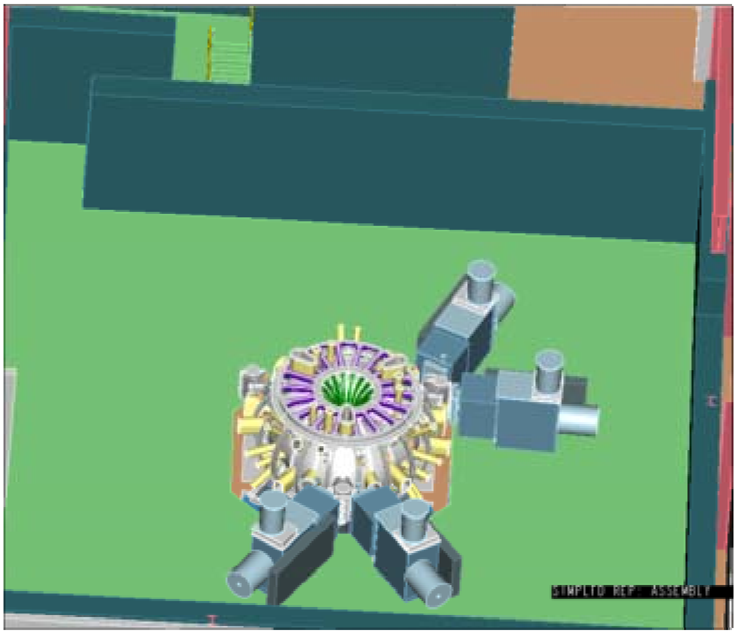


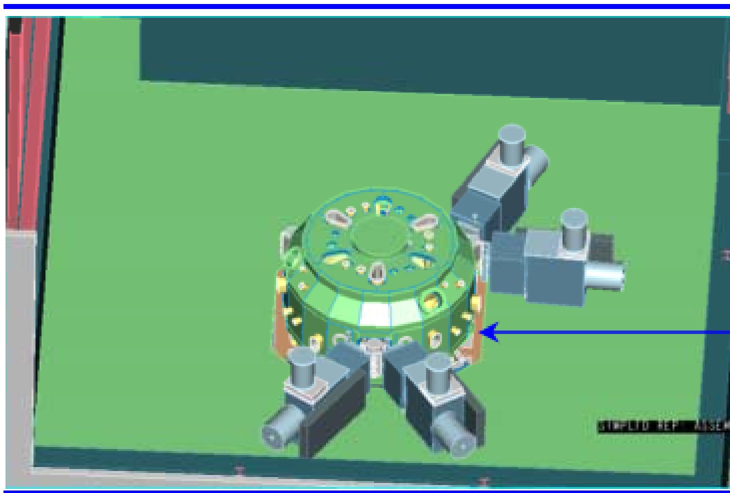
Figure 3-5 NCSX Final Assembly Sequence (3 of 3)



5

Shield wall will be completed once field period lifts are done

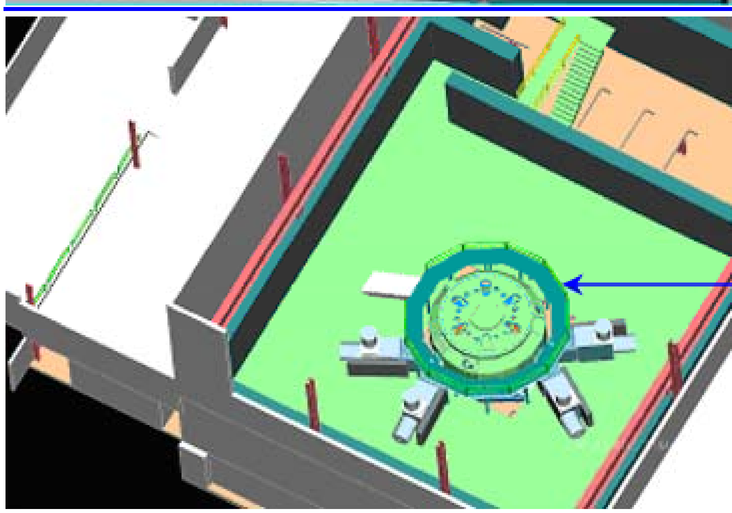
2 neutral beams will be installed once field periods are in place (4 shown)



6

PF coils will be installed once field periods are assembled

Cryostat installed after the rest of the stellarator core has been assembled



7

Upper catwalk installed outside cryostat

Prior to the delivery of the field periods, it is necessary to pre-position the lower poloidal field (PF) coils on the floor. Once in position the lower cryostat floor will be installed on top of the three field period support structures.

The field periods enter the Test Cell from the northeast corner overhead door via a lowboy trailer and will be raised into position using the 30-ton overhead crane. Each of the three field periods will be delivered and positioned on the machine support structure. The support structure was designed to allow the field periods to be moved radially together. The three field periods will be carefully slid together and the vacuum vessel segments fastened together using appropriate hardware from inside of the vacuum vessel. Special Viton "O"-rings or Helicoflex seals will be provide double, differentially pumped vacuum seals on the assembly flanges between vacuum vessel segments. Once the vacuum vessel segments are joined, the modular coils and machine support structures will be joined.

Once the last field period has been delivered to the Test Cell, the remaining sections of the machine platform will be installed to make access easier and to support auxiliary lines that will interface with the machine. The last sections of the shield wall in front of the receiving area can also be completed.

The vacuum pumping duct will then be connected to the vacuum vessel so that the Pre-Operational Test Procedure (PTP) can be performed to verify the integrity of the vacuum vessel. As part of the PTP, the vacuum vessel will be pumped down as low a vacuum as is achievable and a vacuum leak check will be performed. Once these tests have been completed, the vacuum vessel will be vented and the remaining components assembled. The beamlines can now be connected to the vacuum vessel. The lower PF coils will be raised into position. This will be followed by the installation of the PF solenoid assembly, which includes the upper and lower PF1 and PF2 coils. Once these have been secured to the coil support structure, the upper PF coils will be installed.

The next step is to install the top and side walls of the cryostat. The remaining WBS elements can now be completed including the installation of coil bus and cable runs, helium gas bakeout lines, water cooling lines, and liquid nitrogen lines. The installation of diagnostics can also be completed. The last activity is to perform the PTP for the Cryogenics System to verify that the system is functioning properly. The machine is now ready for Integrated Systems Testing.

Table 3-3 is a summary of estimated costs for Test Cell & Basement Assembly Operations (WBS 73). The total cost is estimated to be $743K in year of expenditure dollars with an overall contingency of 32%. The schedule for implementing this work may be seen in the **Project Master Schedule**, provided as part of the Conceptual Design Report**.** Final assembly activities will begin in October, 2005 and end at First Plasma in March, 2007.

Table 3-3 Test Cell & Basement Assembly Operations (WBS 73) Costs

Total Estimated Cost (K$)		
		73 Total
Manufacturing Development	Labor/Other	
	M&S	
	Total	
Design (Title I & II)	Labor/Other	
	M&S	
	Total	
Fabrication/Assembly (incl Title III)	Labor/Other	
	M&S	
	Total	
Installation/test	Labor/Other	710
	M&S	33
	Total	743
Grand Total		743

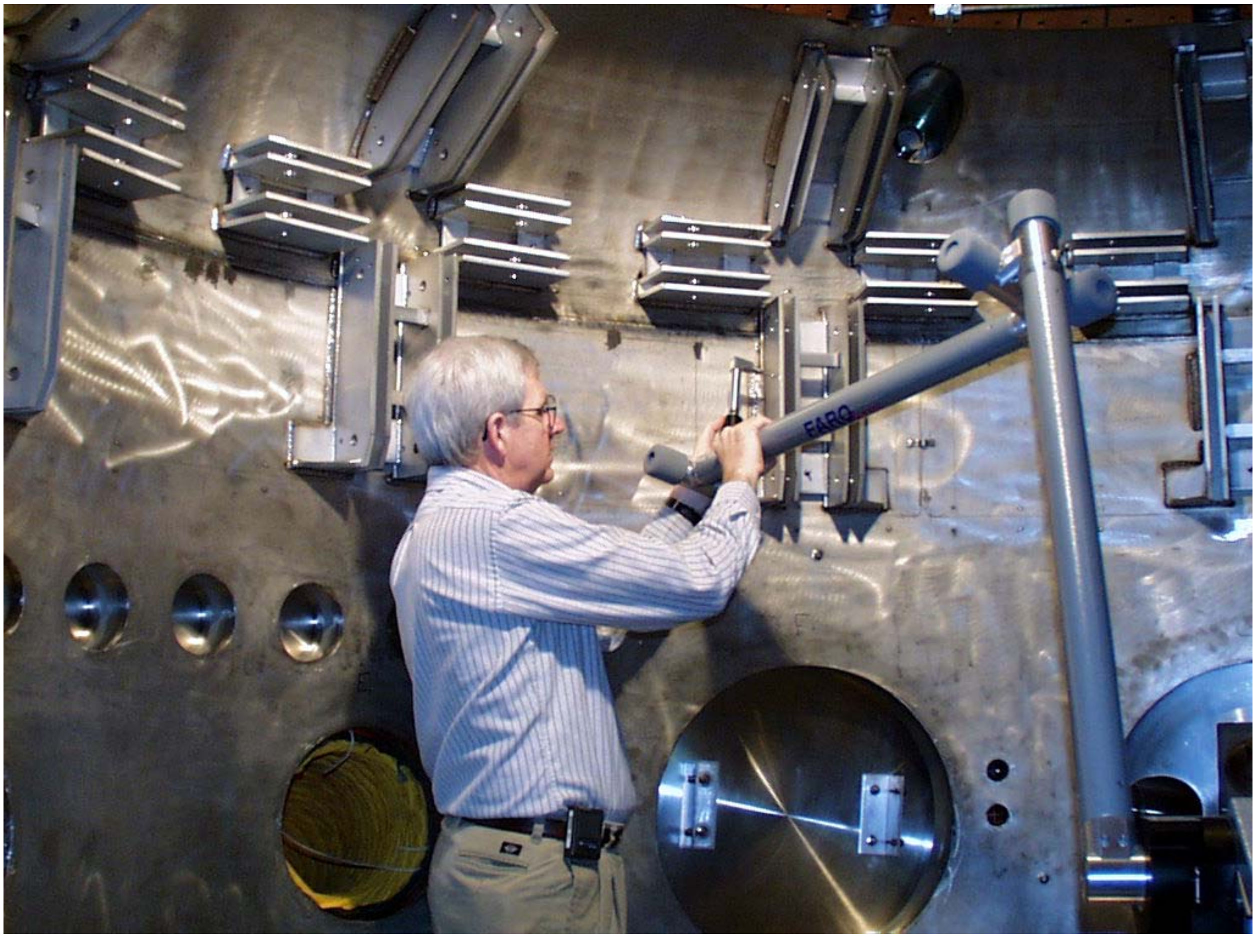
3.4 Measurement Systems (WBS 74)

The assembly of the field periods and final machine assembly will require the use of sophisticated mechanical and laser measurement systems. PPPL has a “Faro” Mechanical Measuring Arm (Figure 3-6) and a “Leica” Laser tracker (Figure 3-7). Additional fixtures will be designed and equipment procured. All of these systems will be required to accurately assemble and align the components and will be used in both the pre-assembly area (TFTR Test Cell) and the NCSX Test Cell.

The “Faro” arm is a Silver Series, 7-axis “Convertible” configuration articulated arm with the following features:

- 12 ft. spherical working volume
- Measurements with an accuracy of +/- 0.007 inches (0.178 mm)
- Operates with Cad-based software (AutoCAD), able to graphically display and store measured data

Figure 3-6 “Faro” Measuring Arm



The "Leica" Laser Tracker (LTD500) has the following features:

- Angle resolution of 0.14 in.
- Distance resolution1.26µm
- Range of measurement
    - Horizontal +/-235 degrees
    - Vertical +/- 45 degrees
    - Distance 0-35 m (0-115 ft.)
- Absolute accuracy of a coordinate
    - Static target +/- 10 ppm (µm/m)
    - Dynamic target +/- 20-30 ppm (µm/m)
    - Measurement range 2-35 m (7-115 ft.)
    - Accuracy +/-0.05 mm (0.002 in.)

Figure 3-7 "Leica" Laser Tracker

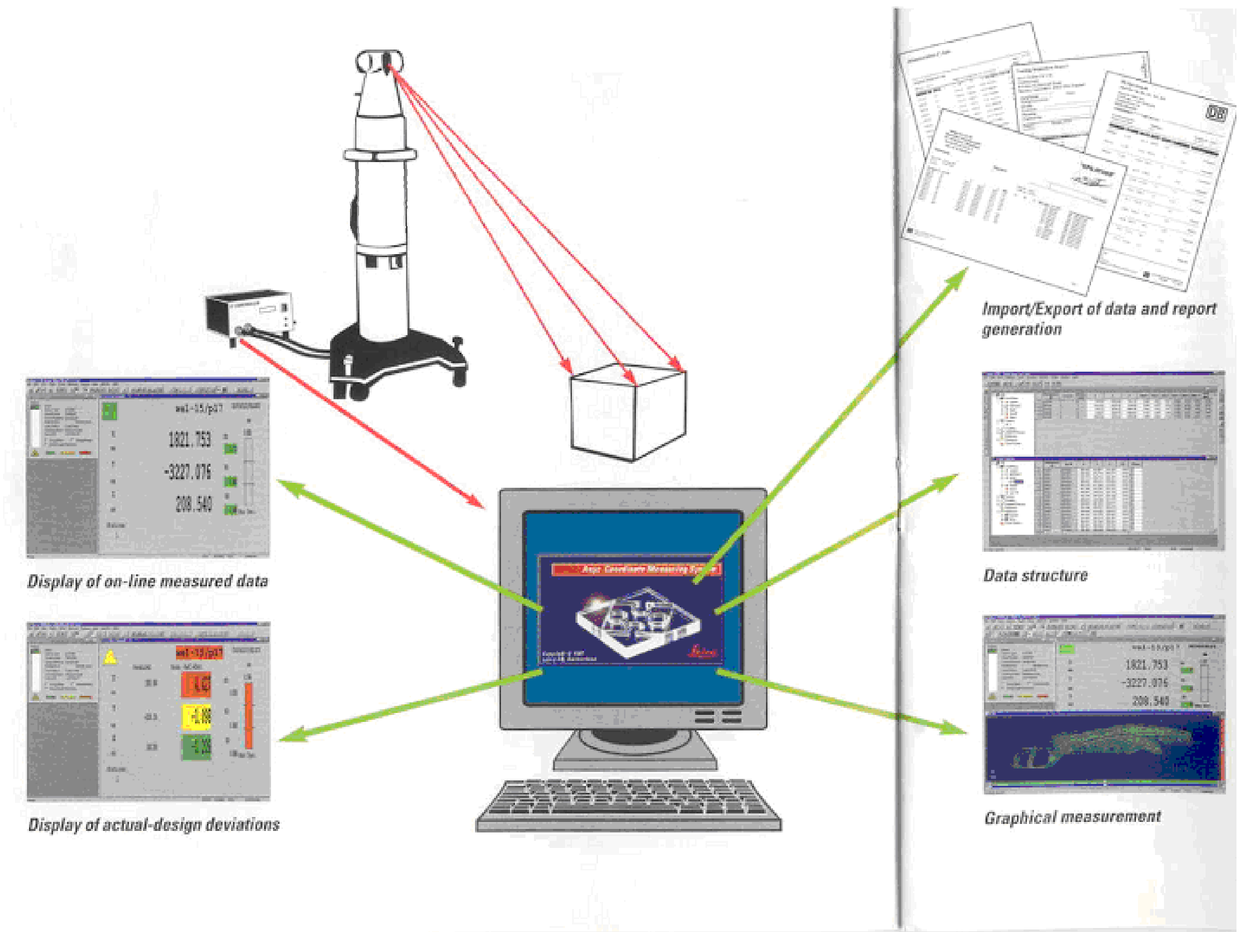


Table 3-4 is a summary of estimated costs for Measurement Systems (WBS 74). The total cost is estimated to be $149K in year of expenditure dollars with an overall contingency of 24%. The schedule for implementing this work may be seen in the **Project Master Schedule**, provided as part of the Conceptual Design Report**.** Design activities will begin in June, 2003. Procurements will be completed by October, 2004

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Table 3-4 Measurement Systems (WBS 74) Costs

Total Estimated Cost (K$)		
		74 Total
Manufacturing Development	Labor/Other	
	M&S	
	Total	
Design (Title I & II)	Labor/Other	74
	M&S	
	Total	74
Fabrication/Assembly (incl Title III)	Labor/Other	
	M&S	31
	Total	31
Installation/test	Labor/Other	44
	M&S	
	Total	44
Grand Total		149

3.5 Platform Design and Fabrication (WBS 75)

A platform will be designed for installation around the NCSX device (Figure 3-9). This will provide a good working area in support of diagnostics and improve access to the machine. The platform will be modular in design, similar to the NSTX platform, allowing for fabrication of standard parts and minimizing costs during future expansion. The framework will be constructed using aluminum structures. The joints of the frame will be electrically isolated to prevent eddy currents from developing. In addition to the platform, a catwalk will be installed (Figure 3-8) in close proximity to the machine to allow access to the upper portions of the device. The present plan is to provide a platform, which has a ceiling height of approximately 9 feet. This will allow sufficient headroom for the various WBS systems to use the platform as a structure to hang their systems. The platform will have exiting stairs from the southeast and northwest corners of the Test Cell. A 5-foot wide walkway will extend completely around the machine to the entrance of the Control Room. This will allow easy access to the machine from various locations in the Test Cell

Table 3-5 is a summary of estimated costs for Platform Design and Fabrication (WBS 75). The total cost is estimated to be $178K in year of expenditure dollars with an overall contingency of 10%. The schedule for implementing this work may be seen in the **Project Master Schedule**, provided as part of the Conceptual Design Report**.** Design activities will begin in January 2005. Procurements will be completed by May 2006.

Table 3-5 Platform Design and Fabrication (WBS 75) Costs

Total Estimated Cost (K$)		
		75 Total
Manufacturing Development	Labor/Other	
	M&S	
	Total	
Design (Title I & II)	Labor/Other	48
	M&S	
	Total	48
Fabrication/Assembly (incl Title III)	Labor/Other	
	M&S	44
	Total	44
Installation/test	Labor/Other	87
	M&S	
	Total	87
Grand Total		178

Figure 3-8 Catwalk Around Top of Machine

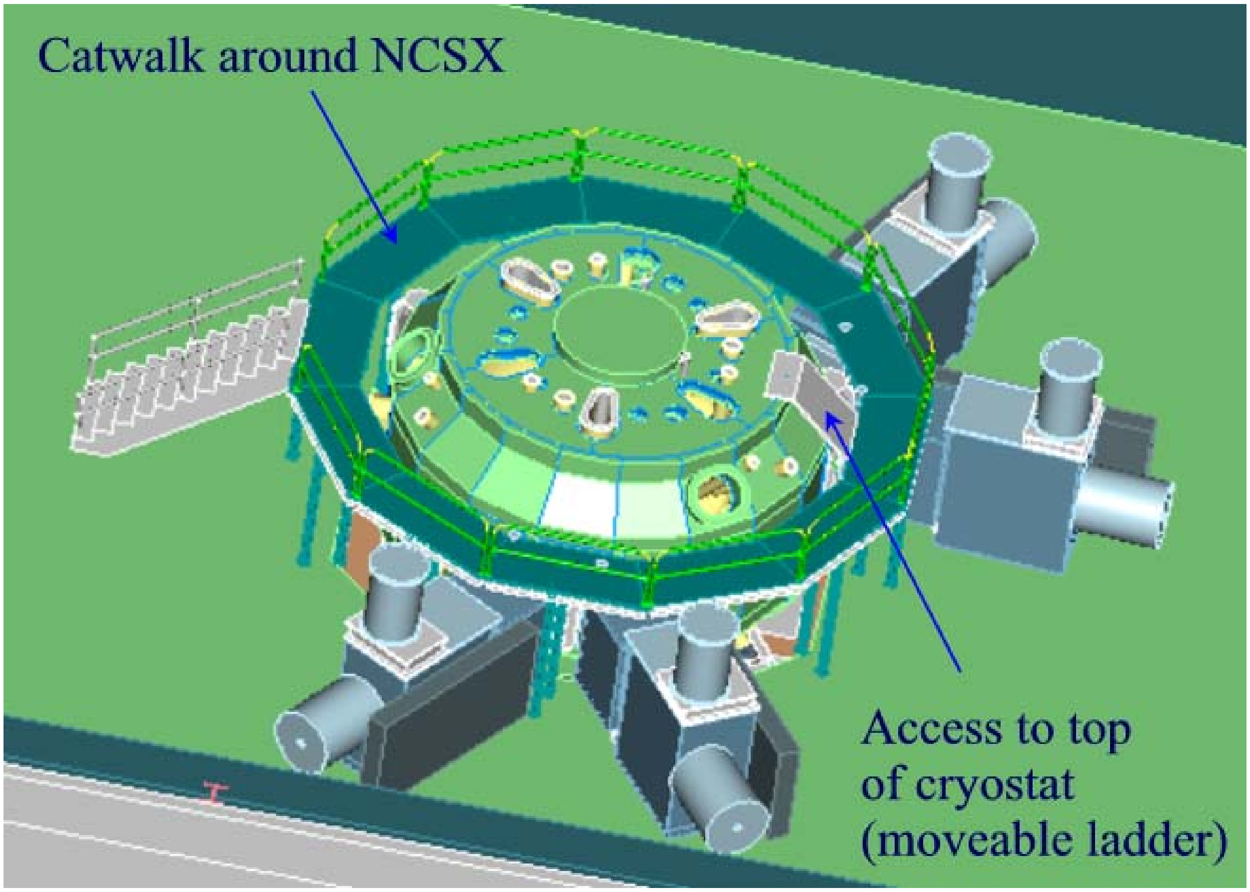

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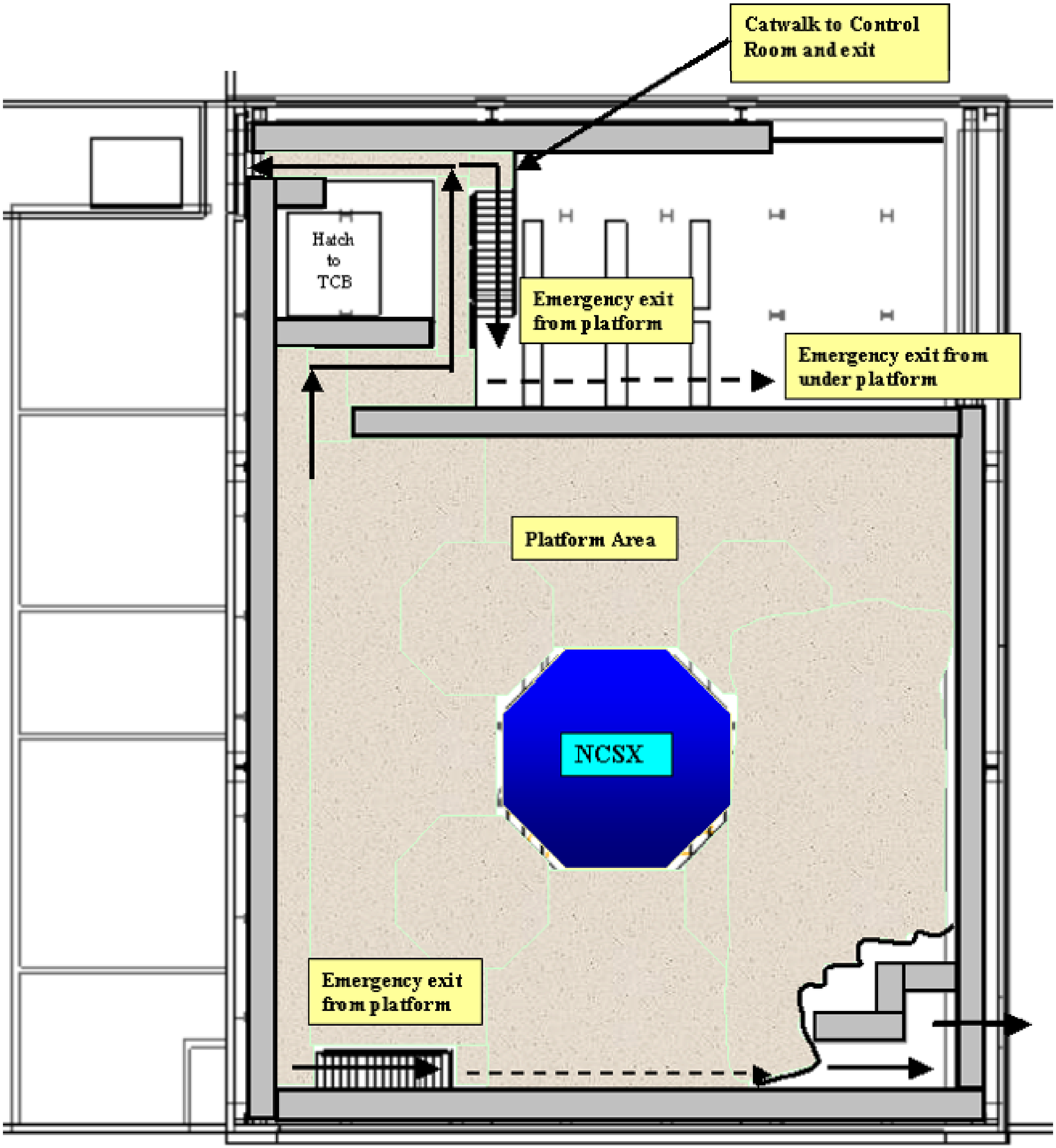
Figure 3-9 Platform Around Machine



3.6 Tooling Design & Fabrication (WBS 76)

Special tooling and fixtures will need to be designed and fabricated to support the assembly of field periods and final assembly activities. This includes:

- Fixtures for assembling the modular coils with the vacuum vessel segments
- Lifting fixtures for the modular coils, TF coils, vacuum vessel segments, and field periods
- Assembly fixture for joining TF coils and coil support structure with the field period
- Various weld fixtures
- Miscellaneous positioning and alignment fixtures and tooling

Table 3-6 is a summary of estimated costs for Tooling Design & Fabrication (WBS 76). The total cost is estimated to be $725K in year of expenditure dollars with an overall contingency of 24%. The schedule for implementing this work may be seen in the **Project Master Schedule**, provided as part of the Conceptual Design Report**.** Design activities will begin in June 2003. Procurements will be completed by First Plasma in March 2007.

Table 3-6 Tooling Design & Fabrication (WBS 76) Costs

Total Estimated Cost (K$)		
		76 Total
Manufacturing Development	Labor/Other	
	M&S	
	Total	
Design (Title I & II)	Labor/Other	158
	M&S	
	Total	158
Fabrication/Assembly (incl Title III)	Labor/Other	
	M&S	418
	Total	418
Installation/test	Labor/Other	149
	M&S	
	Total	149
Grand Total		725

4 INTEGRATED SYSTEMS TESTING (WBS 92)

This WBS element covers the planning, coordination, procedurization, and execution of the Integrated System Tests, which consist of:

- First energization (power testing) of all of the magnet coil systems, and
- First plasma.

Costs for operating and staffing the facility for these tests are included. Prior pre-operational tests are included in other WBS elements. Table 4-1 is a summary of estimated costs for Integrated Systems Testing (WBS 92). The total cost is estimated to be $462K in year of expenditure dollars with an overall contingency of 20%. The schedule for implementing this work may be seen in the **Project Master Schedule**, provided as part of the Conceptual Design Report**.** Final design of Integrated Systems Testing activities will begin in June 2006. Integrated Systems testing will be completed at First Plasma in March 2007.

Table 4-1 Integrated Systems Testing (WBS 92) Costs

Total Estimated Cost (K$)		
		92 Total
Manufacturing Development	Labor/Other	
	M&S	
	Total	
Design (Title I & II)	Labor/Other	
	M&S	
	Total	
Fabrication/Assembly (incl Title III)	Labor/Other	
	M&S	
	Total	
Installation/test	Labor/Other	462
	M&S	
	Total	462
Grand Total		462