QPS Project Implementation

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QPS Project Advisory Committee
December 11, 2002
PPPL

ornl

UT-BATTELLE

Presentation Outline

- **Fabrication Plans**
  - How we plan to build QPS
  - R&D, primarily Modular Coils
  - Benefits of NCSX work
- **QPS Schedule**
  - Overall schedule
  - QPS schedule by major component
- **Available Infrastructure**
  - Buildings
  - Power Supplies, etc.

Fabrication Plans and Options

- All components will be built off-site, and pre-assembled to the extent possible

System	Fabrication By:
In-Vessel Components - Divertor plates, limiters	fabricated in house - material TBD
Vacuum Vessel	Commercial Tank manufacturer
Conventional Coils - TF, PF, Centerstack assy	- PF coils exist, refurbish on site - Centerstack, TF similar to NSTX, (but integration by vendor)
Modular Coils	- Winding forms by NCSX vendor - Winding, VPI, canning by Univ. TN
Structures -connecting structures, base columns	Commercial manf, same as VV if possible
Coil Services - electrical leads, cooling	Commercial leads, piping on site
Assembly, incl. mod coil field period sub-assy	Assembly on-site by ORNL craft

Modular Coil Fabrication

- **Modular Coils are very similar to NCSX, but not the same:**
  - Cast-and-machined winding form
  - Flexible cable conductor
  - "Canned" for vacuum compatibility
  - Vacuum pressure impregnated with epoxy
- **Winding forms will be manufactured by same vendor as NCSX winding forms, if possible, and procured by PPPL**
- **Winding, "canning", and VPI to be done by University of Tennessee**

We plan to build the coils at UT

- **Less costly:**
  - Lower net labor costs (direct+indirect) (~ 50%)
  - Space is available at no charge
  - More flexible arrangement with respect to contract/design changes since UT is a part of QPS project
  - Relatively close proximity to ORNL design team

- **Strengthens UT / ORNL connection, which is an upper management priority**

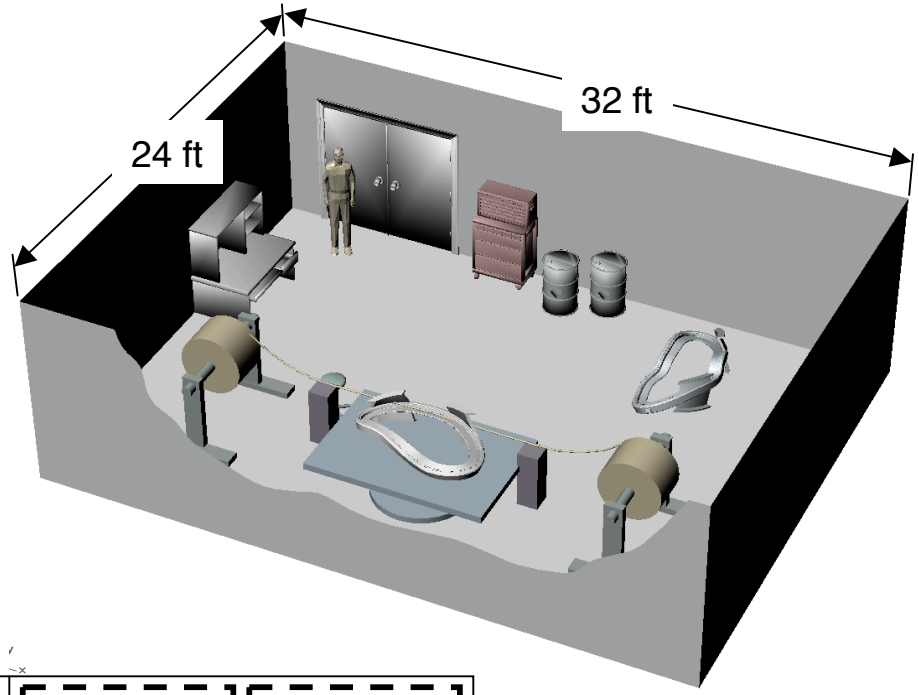
- **Provides thesis topics, fusion interest for graduate students**

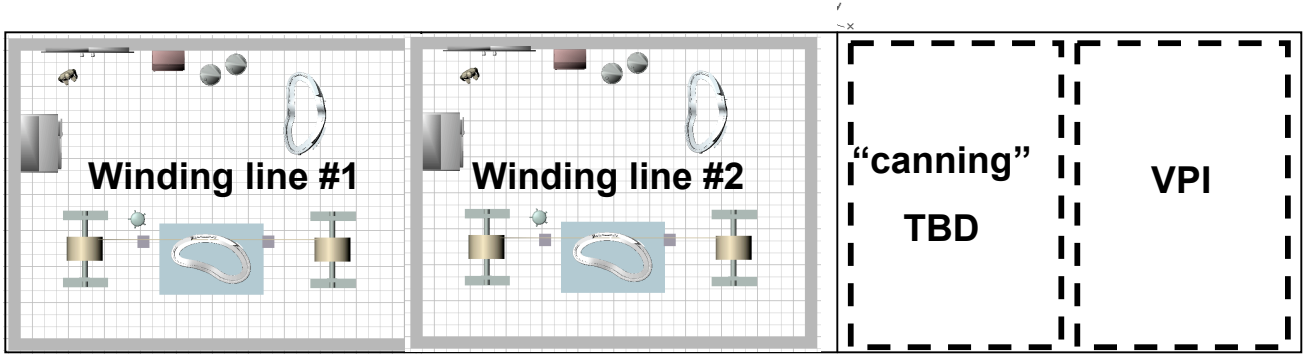
Organization for modular coil tasks at UT

- **Separate organization set up within the Mech. Engineering Department under Department Chair (Tom Shannon)**
  - **Full time engineering manager will report to Tom Shannon**
  - **Technicians hired as temporary employees by UT**
  - **Graduate students will assist where appropriate**
- **QPS design team at ORNL will be responsible for design, and assist with technical oversight, better hands on participation than at ORNL or industrial contractor**
- **Space will be prepared in the recently completed Science and Engineering Research Facility (SERF)**
  - **3 adjacent rooms envisioned, 24 x 32 ft each**
  - **Elevators, loading dock, hallways, etc. are adequate for receiving and moving modular coils**
- **All processes to be developed through R&D**

Space should accommodate two winding lines

- **Process flows from winding to “canning” to VPI**
- **Dimensional and electrical inspection occurs continuously**
- **No autoclave is needed since coils will already be vacuum-canned**





R&D will be needed for modular coils

- Integrate R&D with NCSX project
  - Modular coil winding forms will be very similar, although smaller
  - Modular coil conductor and windings will be very similar
  - Vacuum impregnation will be similar, but will not require “cocoon”
  - Continue involvement of University of Tennessee as well as potential vendors for coil winding forms
- Develop complete spec and models for prototype coil winding forms

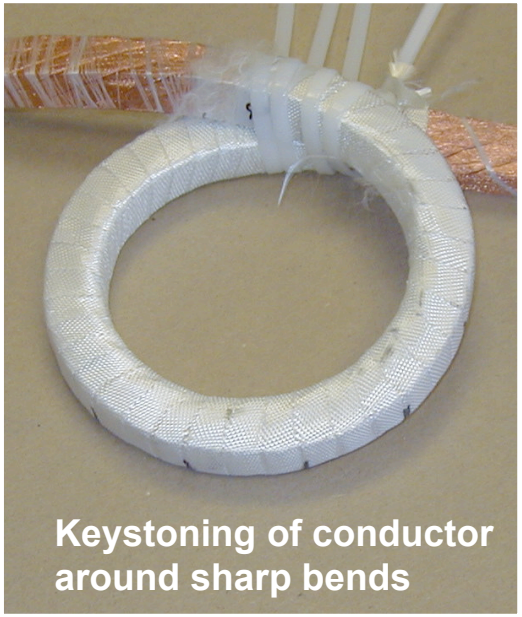
Winding form R&D

- Issues
  - Casting tolerance, repeatability
  - Machining: reach and access, tolerances, time, cost
  - Copper conducting layer

- Plan
  - All issues addressed in detail as part of NCSX project, including copper layer, by manufacturing studies and two full scale prototype winding forms
  - QPS - specific manufacturing study for QPS coils will be conducted prior to CDR

Winding R&D

- Issues
  - Conductor insulation
  - Keystoning of conductor around sharp bends
  - Handling fixtures
  - Clamping tooling
  - In-process measurements

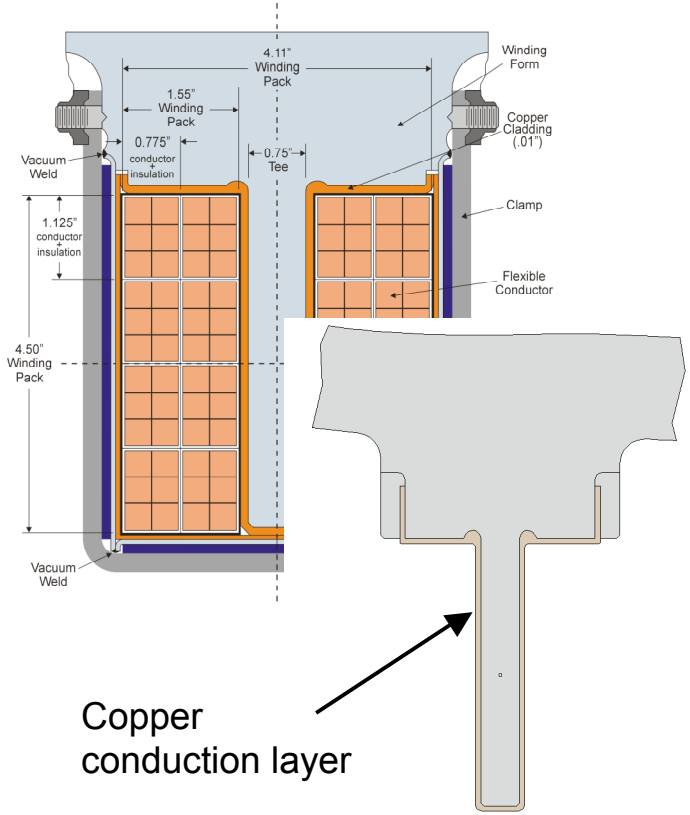


Keystoning of conductor around sharp bends

- Plan
  - All winding issues addressed in detail as part of NCSX project
  - QPS- specific fixtures and tooling will be developed in parallel / slightly after NCSX tooling is developed
  - Practice winding planned for QPS to provide experience to UT winding crew and test QPS-specific tooling and fixtures

Cooling R&D

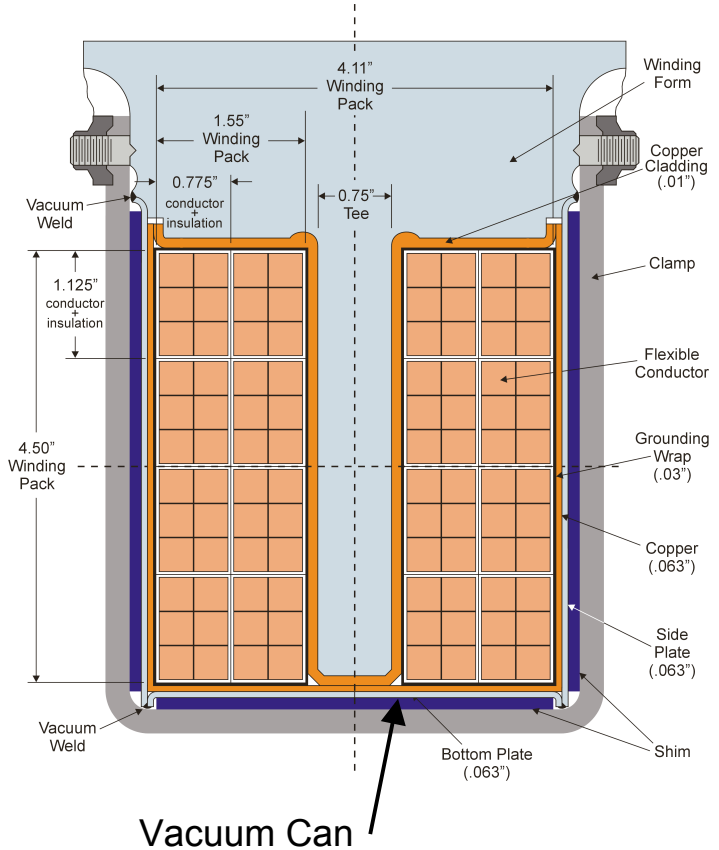
- Issues
  - Location of cooling lines
  - Thermal contact of cooling lines and copper around winding
  - Effective thermal conductivity of cable/epoxy/insulation composite, expecially 4-conductor pack



- Plan
  - Issues similar to NCSX, but details are different
  - First test article should provide initial experimental data on winding properties and cooldown and benchmark analyses
  - Test must be repeated with actual epoxy formulation and conductor

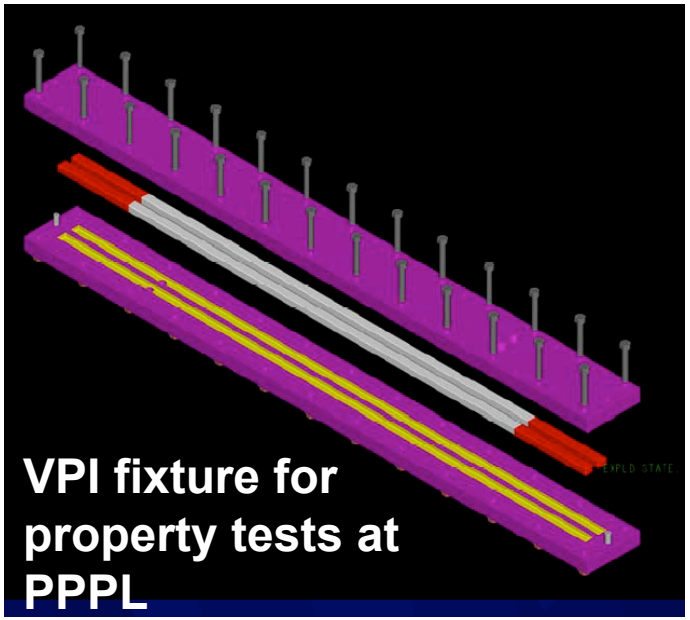
Vacuum “canning” R&D

- Issues
  - Forming of cans
  - Welding of cans w/o distortion of shape or damage to windings
  - Leak checking of cans after VPI
- Plan
  - Joint R&D with University of Tennessee:
    - Software for flat developments
    - Forming of can sides
    - Welding prep design
    - Weld process and testing



Vacuum Pressure Impregnation (VPI)

- Issues
  - Selection of epoxy
  - Setup and introduction of epoxy
  - Wicking of epoxy into interstices of cable conductor
  - Mechanical and thermal properties of cable/epoxy/insulation composite

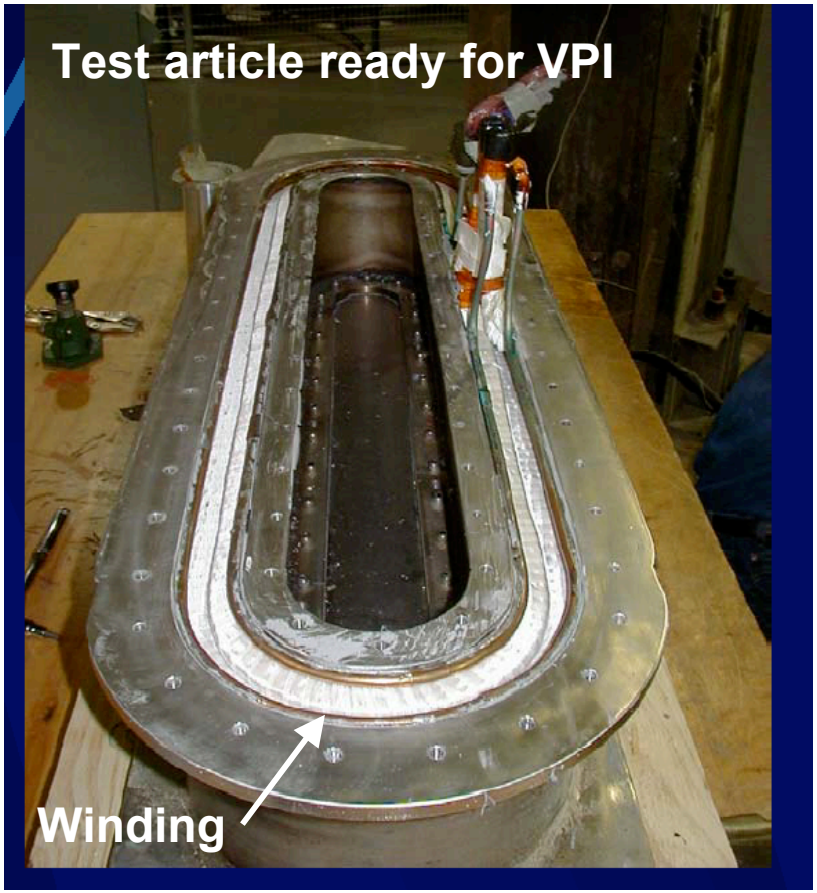


- Plan
  - All VPI issues addressed in detail as part of NCSX project
  - QPS may use cyanate ester formulation instead of CTD-101 epoxy for higher temperature properties (will require new mech. and thermal tests)
  - VPI equipment is available from BWXT in Lynchburg VA after Aug, 2003
  - Practice coil with racetrack shape wound at UT, VPI on Dec 11

First R&D test for coil winding and VPI

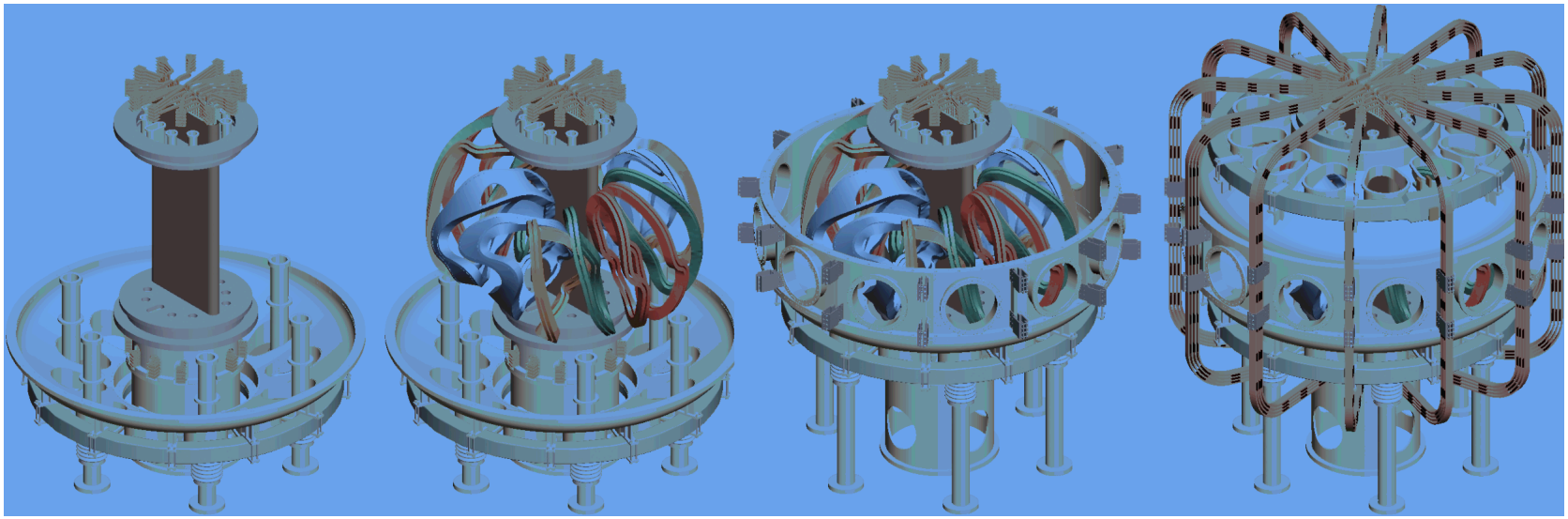
Provides test article for VPI, mechanical, electrical, and thermal testing

- Coil wound with 18 turns of prototypical cable conductor using prototypical insulation scheme
- Copper chill plates installed on either side of winding
- VPI by PPPL on Dec 11



Assembly of modular coil set

- Completed coils shipped to ORNL from UT
- Coils will be pre-assembled in field periods at ORNL



Install centerstack with dome and coils on base

Assemble modular coil field period sub-assemblies with structure around centerstack

Add vessel spool piece & upper dome with PF coils

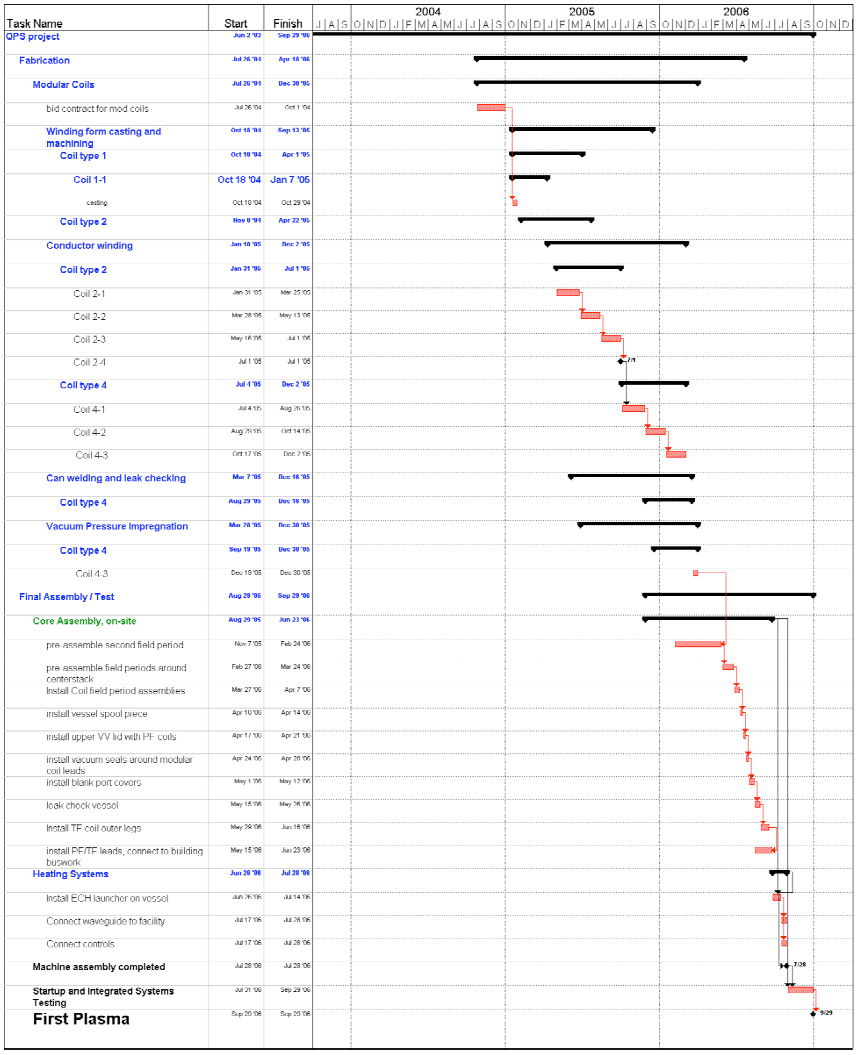
Move domes to final position, leak check vessel, & install TF coils

Assembly R&D

- Issues
  - Measuring of conductor position after VPI to determine winding pack current center
  - Positioning of coils to best fit location in assembly
  - Vacuum compatible electrical insulation for shims between coils
- Plan
  - All issues addressed by NCSX (except electrical insulation)
  - Joint R&D with University of Tennessee:
    - Measurement systems
    - Software for best fit algorithms
    - Materials search for ceramic insulation (ITER has process)

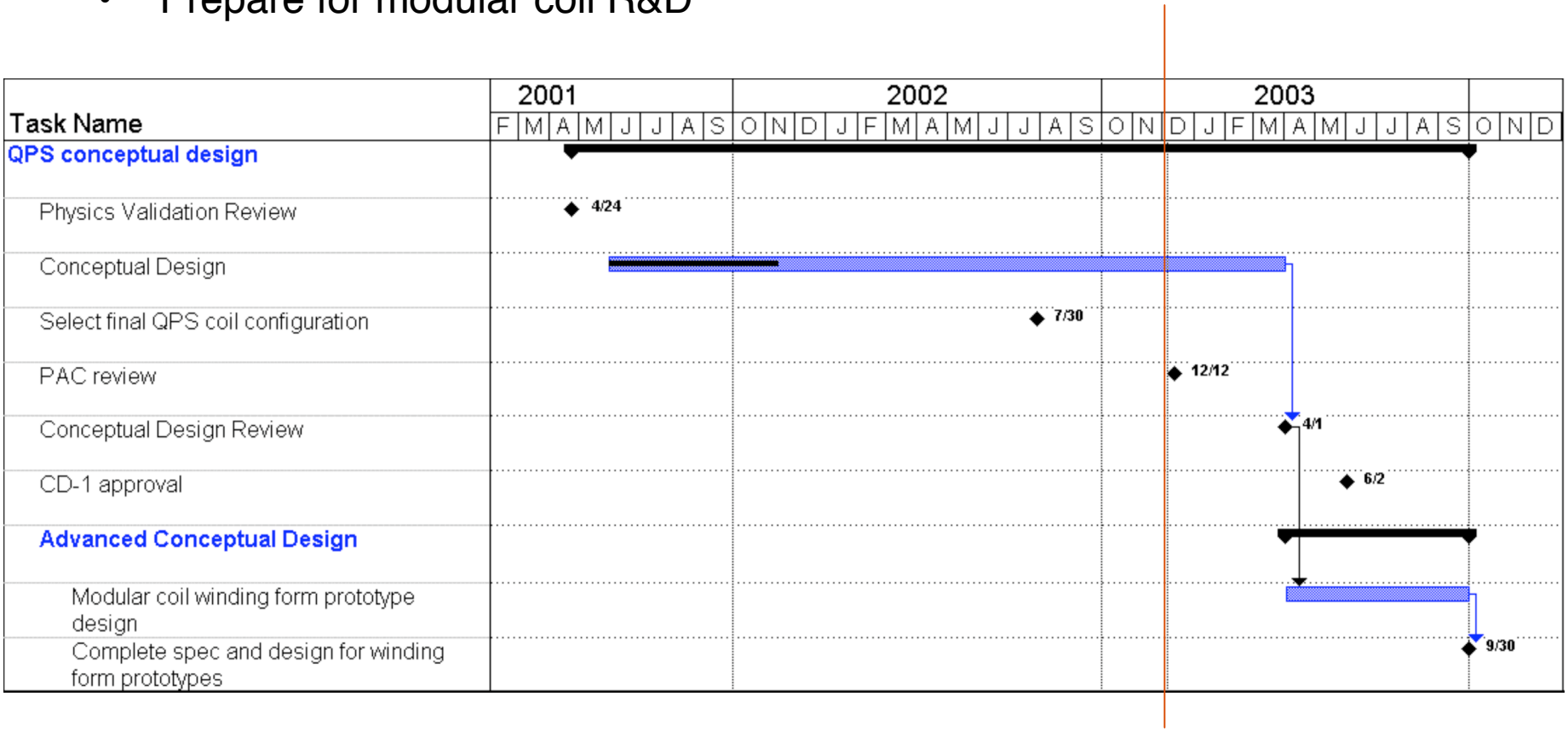
QPS Project Schedule

Task/milestone	Start	Finish
Project Start	1-Oct-03	
Mod coil R&D	1-Oct-03	24-May-05
Mod coil fab.	26-Jul-04	30-Dec-05
Vacuum Vessel	25-Oct-04	29-Jul-05
Centerstack	31-Jan-05	30-Dec-05
Machine Assy	10-Aug-05	25-Jul-06
Checkout	26-Jul-06	29-Sep-06
First Plasma		29-Sep-06



Plan prior to Project Start

- Update design and seek advice from PAC
- Update cost estimate and schedule for CDR
- Prepare for modular coil R&D



Complete conceptual design for CDR

- Modular coil set :
  - Optimize winding cross section, twist – *basically complete*
  - Develop cooling, “canning” concept for mod coils – *concept in place*
  - Configure integrated coil structure – *nearly complete*
  - Perform field/force/stress analysis – *in process*

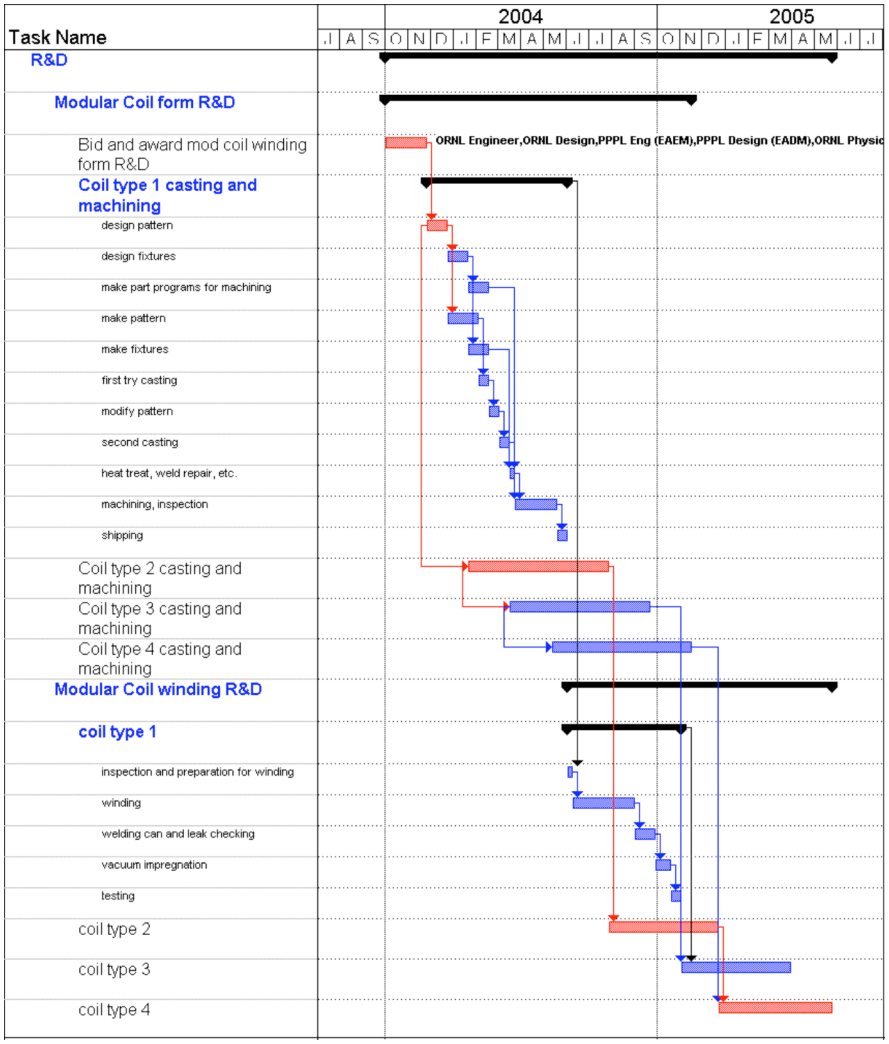
- Balance of design:
  - Refine vacuum vessel / TF coil configuration – *in process*
  - Develop vacuum pumping, bakeout, and wall conditioning scheme - *concept in place*
  - Create integrated Pro-E models of all components - *in process*
  - Perform integrated stress/deflection analysis - *in process*

Update PVR cost estimate

- Cost estimate will take advantage of NCSX experience, but with modifications
  - Components are smaller, lower performance
  - Manufacturing study to provide cost data for winding form
  - Vacuum vessel is conventional tank
  - Winding will be performed in University facilities with University labor, supervised by UT, ORNL engineers and technicians
  - Infrastructure is separately funded

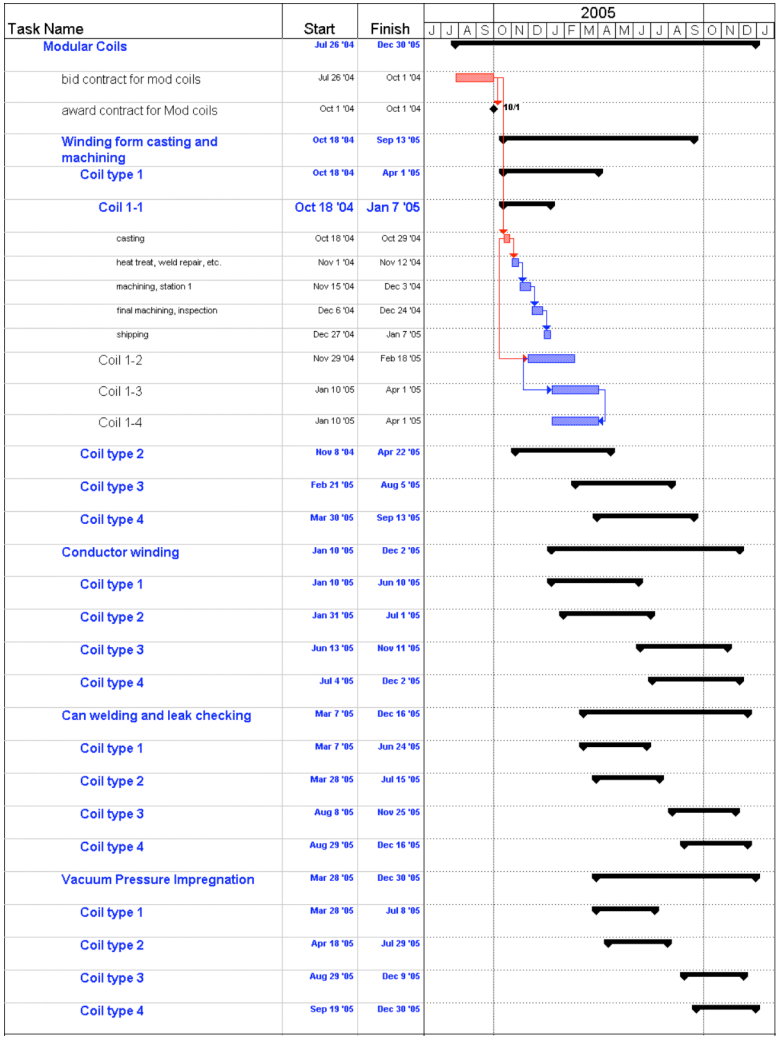
Schedule for R&D modular coils

Task/milestone	Start	Finish
Bid/Award	1-Oct-03	25-Nov-03
Casting 1	26-Nov-03	1-Jun-04
Casting 2	21-Jan-04	27-Jul-04
Casting 3	17-May-04	21-Sep-04
Casting 4	12-May-04	16-Nov-04
Coil 1 Winding/VPI	2-Jun-04	2-Nov-04
Coil 2 Winding/VPI	28-Jul-04	21-Dec-04
Coil 3 Winding/VPI	23-Nov-04	29-Mar-05
Coil 4 Winding/VPI	22-Dec-04	24-May-05



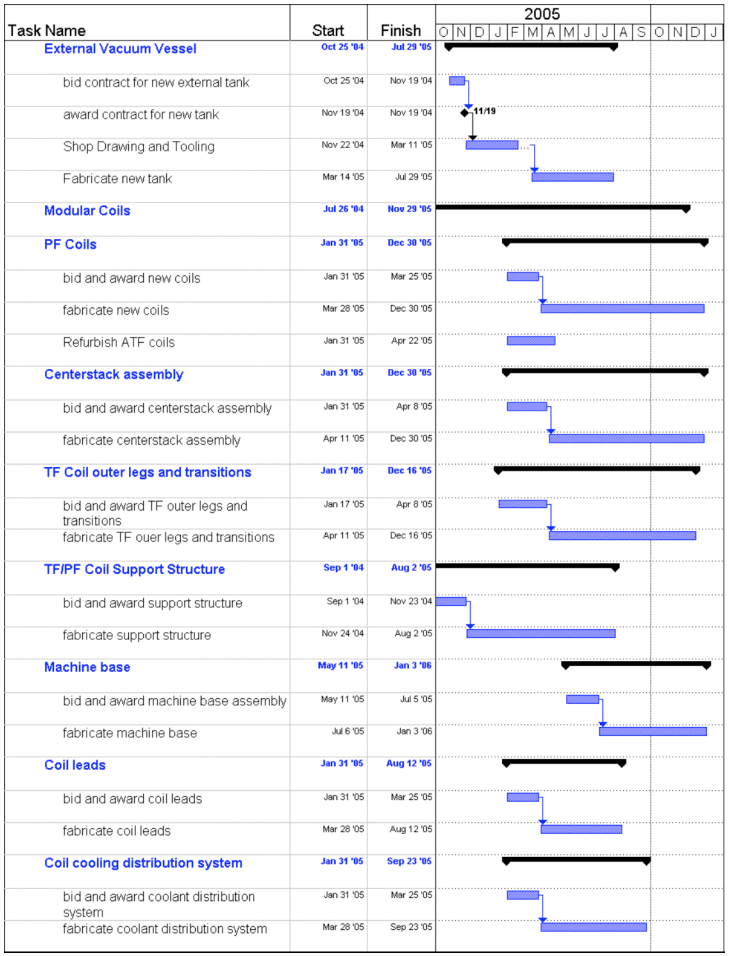
Schedule for production modular coils

Task/milestone	Start	Finish
Bid/Award	26-Jul-04	1-Oct-04
Castings, Type 1	18-Oct-04	1-Apr-05
Castings, Type 2	8-Nov-04	22-Apr-04
Castings, Type 3	25-Feb-05	5-Aug-05
Castings, Type 4	30-Mar-05	13-Sep-05
Coil 1 Winding/VPI	10-Jan-05	8-Jul-05
Coil 2 Winding/VPI	31-Jan-05	29-Jul-05
Coil 3 Winding/VPI	13-Jun-05	29-Aug-05
Coil 4 Winding/VPI	4-Jul-05	30-Dec-05



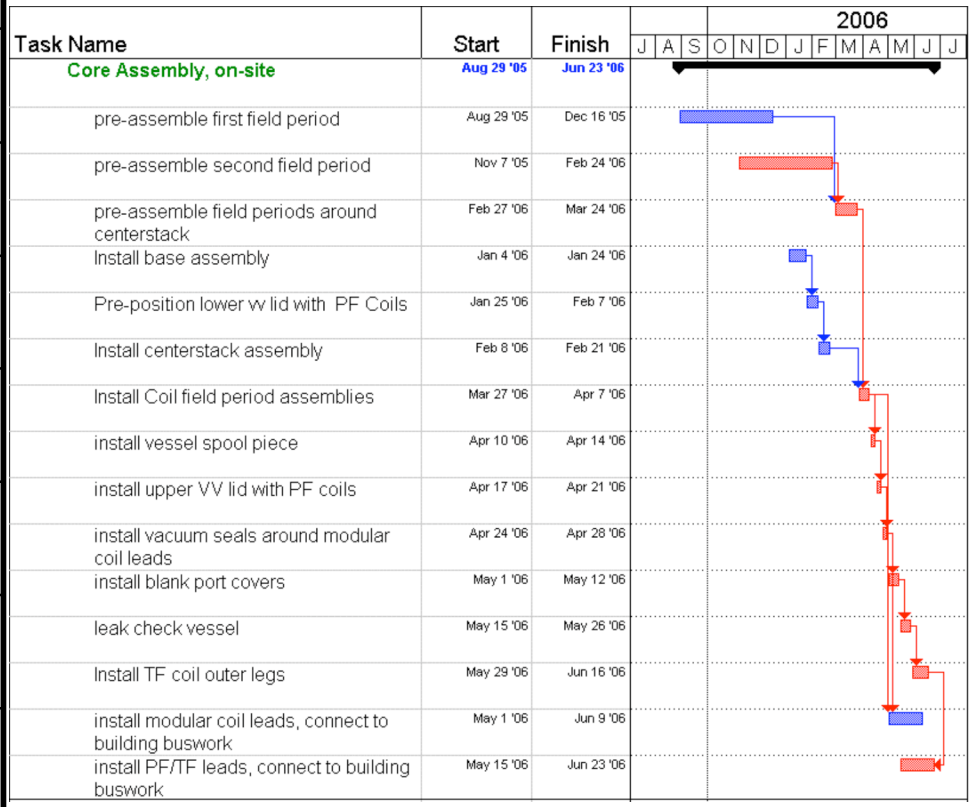
Schedule for fabrication of other components

Task/milestone	Start	Finish
Vacuum Vessel	25-Oct-04	29-Jul-05
PF Coils	31-Jan-05	30-Dec-05
Centerstack	31-Jan-05	30-Dec-05
TF Coil legs	17-Jan-05	16-Dec-05
TF PF supports	1-Sep-05	2-Aug-05
Machine Base	11-May-05	3-Jan-06
Coil Leads	31-Jan-05	12-Aug-05
Coil cooling distr.	31-Jan-05	23-Sep-05



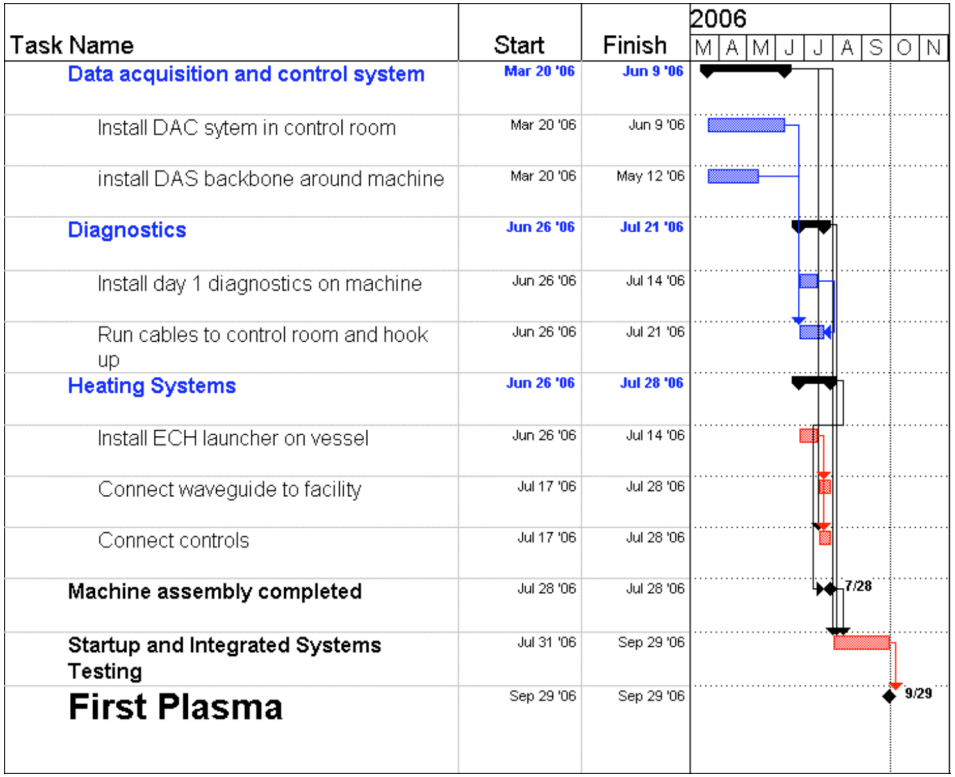
Schedule for machine core assembly

Task/milestone	Start	Finish
Pre-assemble Mod period 1	29-Aug-05	23-Jun-06
Pre-assemble Mod period 2	7-Nov-06	24-Feb-06
Base assembly	4-Jan-06	24-Jan-06
Centerstack	8-Feb-05	21-Feb-06
Final mod assy	1-Sep-05	2-Aug-05
Vacuum Vessel	25-Jan-06	25-May-06
TF Coil legs	29-May-06	16-Jun-06
Coil Leads	1-May-06	23-Jun-06



Schedule for Ancillary systems, Checkout

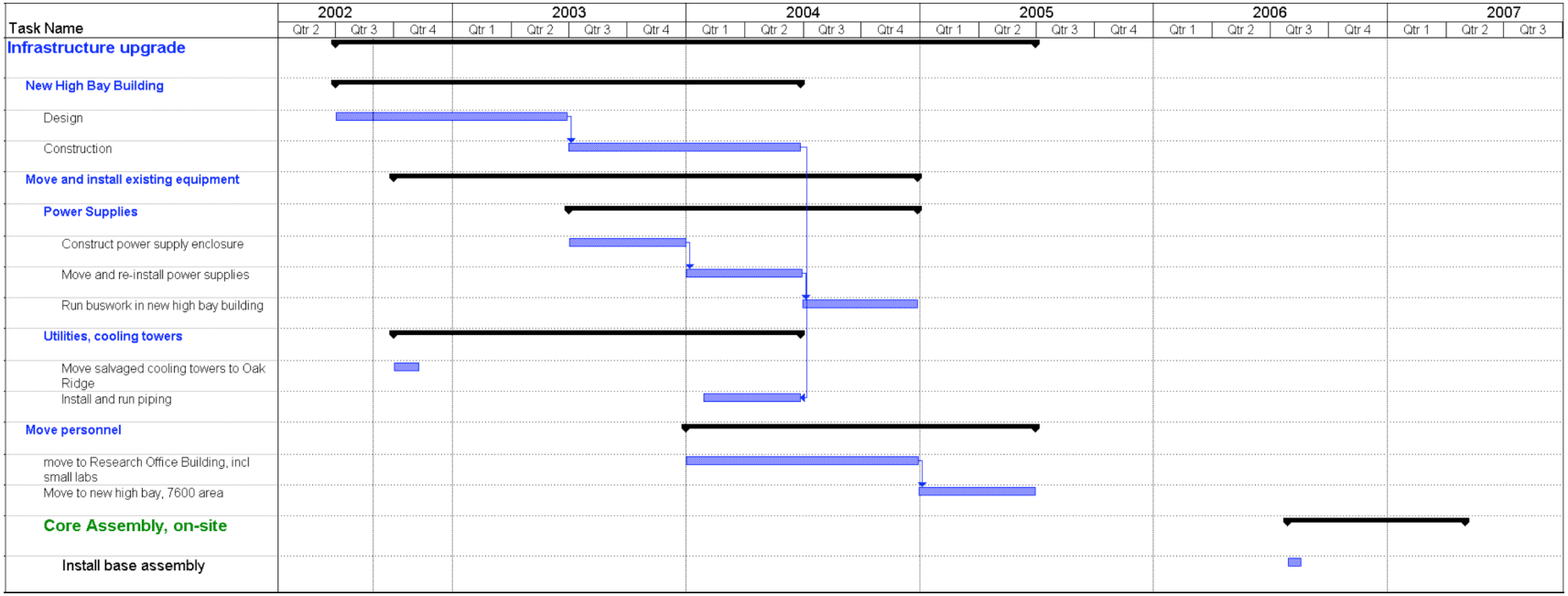
Task/milestone	Start	Finish
DAC	20-Mar-06	9-Jun-06
Diagnostics	26-Jun-06	21-Jul-06
ECH System	26-Jun-06	28-Jul-06
Startup and Integrated systems testing	31-Jul-06	29-Sep-06
First Plasma		29-Sep-06



Summary Schedule

How do Infrastructure improvements fit in?

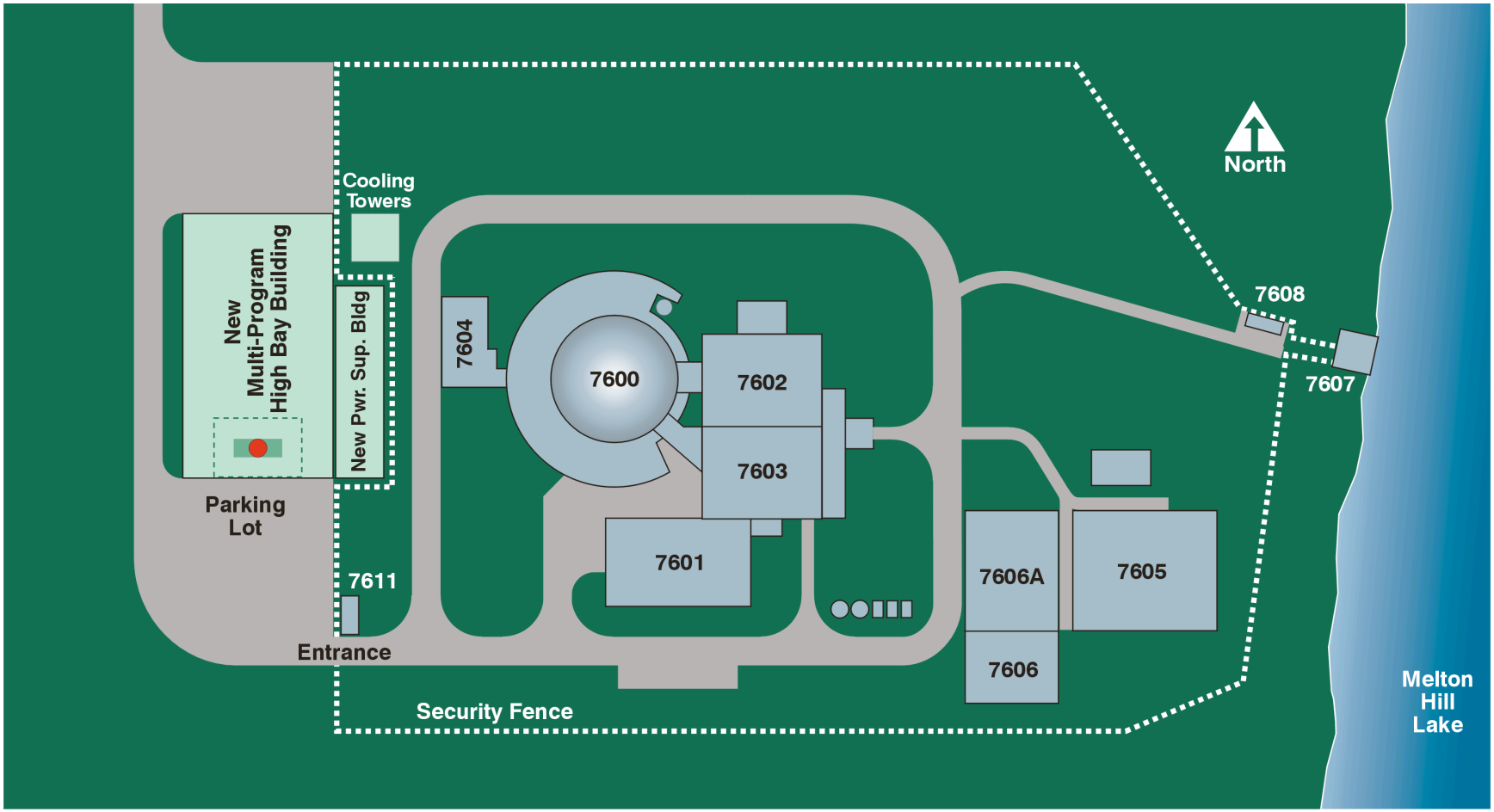
- ORNL Fusion Energy Division is moving from “Y-12” site to “X-10” site
- New buildings are planned and infrastructure will be moved
- Everything will be ready for QPS project



Infrastructure – Outside project

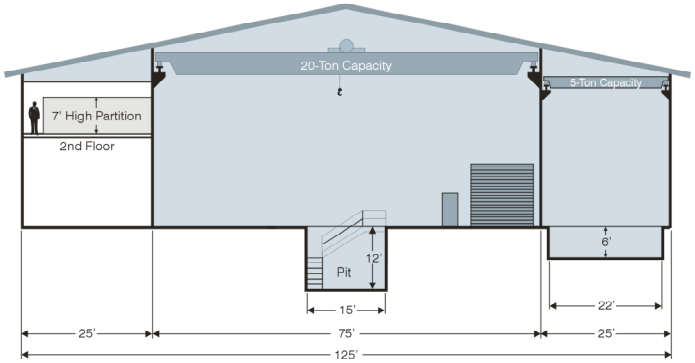
- New buildings will be built with required infrastructure
  - Magnet Power Supplies and controls
  - Buswork
  - ECH and RF Power supplies
  - Cooling system
  - Control room
  - Confinement Experimental Area
    - Machine enclosure with safety interlock system
    - Pit and foundation
- Everything will be ready for QPS project

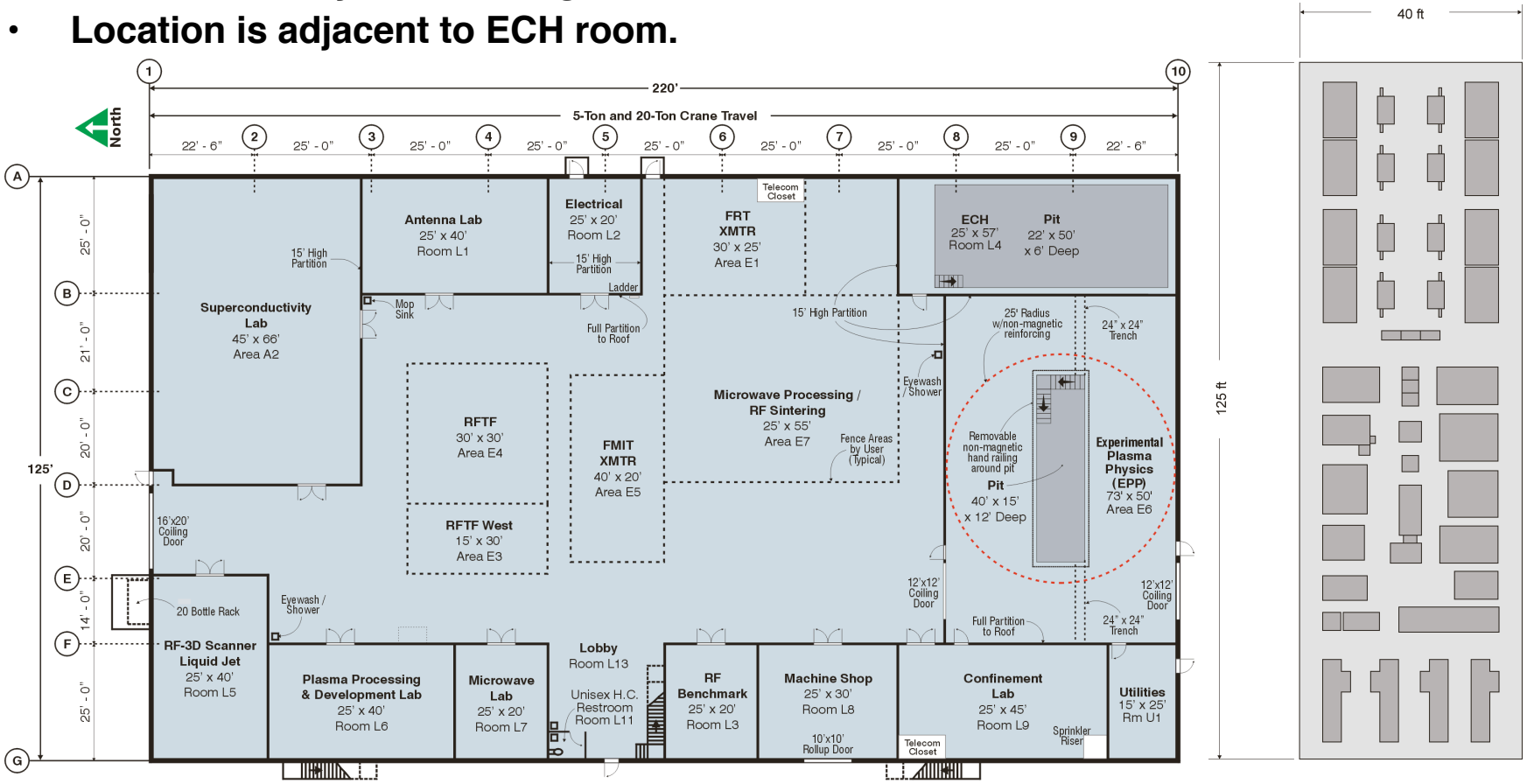
New building location at ORNL



QPS in new buildings

- QPS located in the experimental plasma physics area, over pit
- Site serviced by 20 ton bridge crane
- Location is adjacent to ECH room.





Main Level Floor Plan

Infrastructure – Power supplies match coils

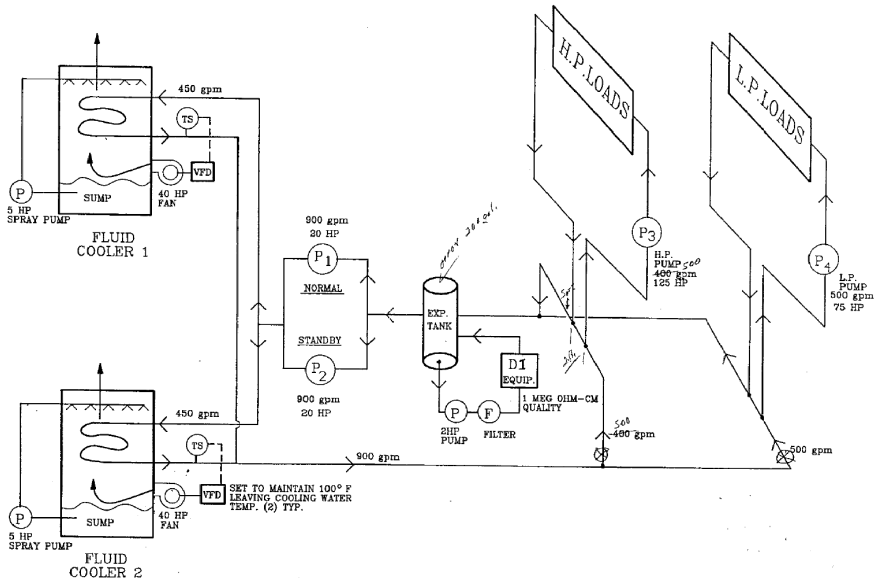
Coil Set	Power Supply
Modular Coils, 4 sets of 4 coils, 160 total turns	Existing ATF helical field power supplies, 4 each 650 V open circuit voltage, 30 kA pulsed current
OH solenoid 16 coil sections in series	Existing ATF VF coil power supply 625 V, 15kA pulsed
PBX-M OH-5 coils 1 pair	Existing ATF VF coil power supply 625 V. 15 kA pulsed rating
ATF Mid Coils 1 pair	Existing ATF VF coil power supply 625 V. 10 kA pulsed rating
TF coils 1 circuit, 48 total turns	Existing ATF helical field power supplies, 1 each 650 V open circuit voltage, 30 kA pulsed current

Infrastructure – ECH, RF Power

System	Installed Capability
ECH -	0.6 MW @ 53.2 GHz
ECH -	0.2 MW @ 56 GHz
ECH -	1.2 MW @ 28 GHz
ICRF	2 MW @ 6-20 MHz
ICRF	1.5 MW @ 40-80 MHz

Infrastructure – Cooling Water

- 8 MW system moved from CPI facility in San Diego:
  - 2 x 4 MW cooling towers
  - 900 gpm total flow in low pressure system with booster pumps for:
    - 450 gpm @ 125 psig
    - 450 gpm @ 250 psig
  - deionization/deoxygenation (DI/DO) maintains 18 MW water, 50 ppb oxygen, 5m filtration
- Total average load estimated at less than 1 MW



Summary

- **Fabrication plans in place for major components**
  - All components are “conventional” except modular coils
  - Modular coils to be wound by group at University of Tennessee
  - R&D planned for modular coils takes advantage of NCSX developments
- **Preliminary schedule developed**
  - Conceptual design in April, 2003
  - Project start in FY 2004
  - First Plasma end of FY 2006
- **Infrastructure available for assembly and operation**
  - Fusion Energy Division will move to new facility in ORNL valley
  - Power supplies, cooling water, building, etc. will be re-installed and provided as part of separate “move” project