

**NCSX Coil Services**

|  |  |  |
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|  | SC Project Review of NCSX, April 8-10, 2008 |  |

**P.L. Goranson**

***Work Package 161, 162, and 163***

**Coil Services System Description**



The coil services consist of the **cryogenic feeds** and **electrical leads**

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inside the cryostat, serving all of the coils, including conventional.

It includes the specification of requirements

for the coil protection system.

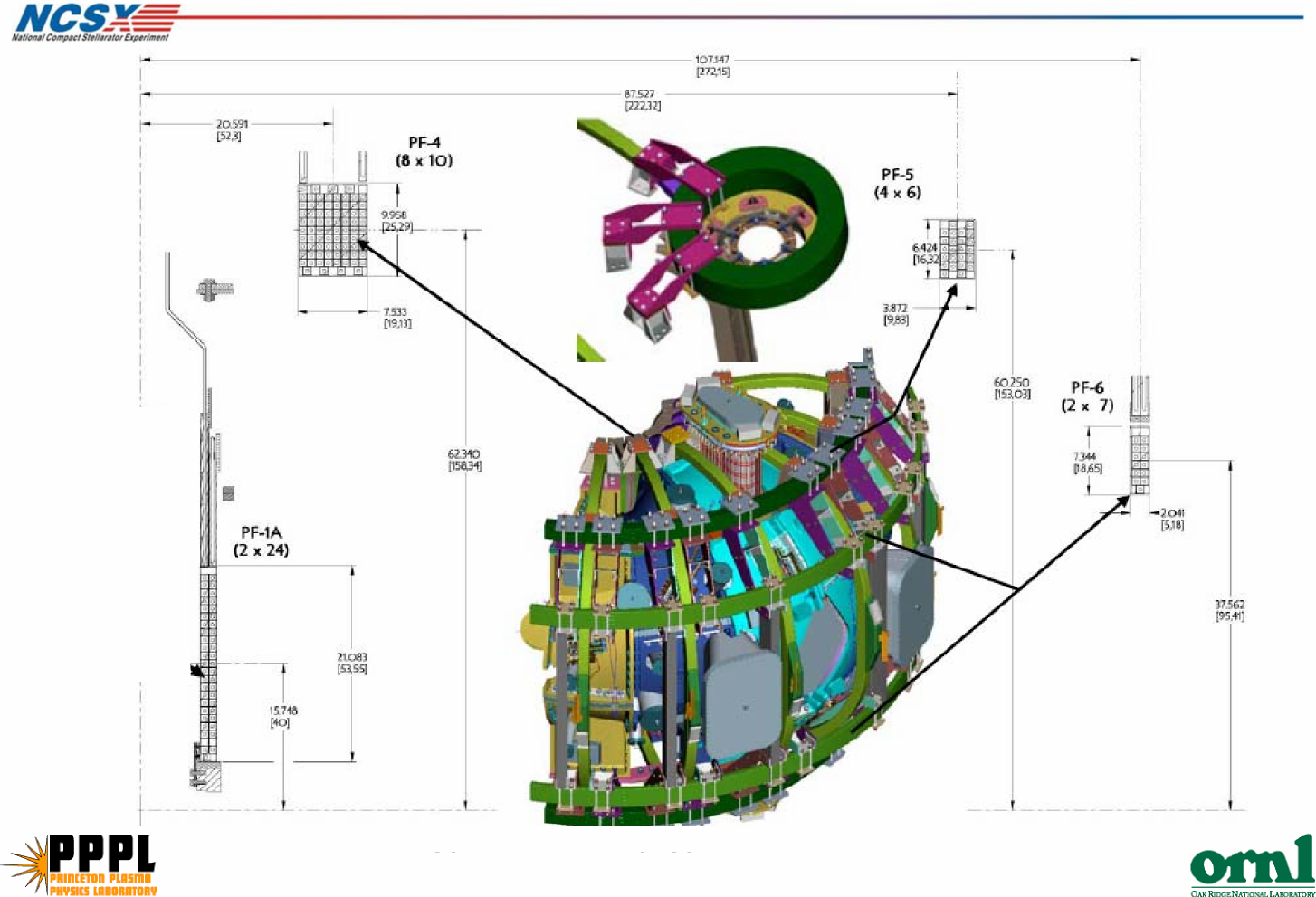
Lower-level elements include:

LN2 Distribution System (WBS 161);

Coil Electrical Leads (WBS 162); and

Coil Protection Requirements (WBS 163)

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**NCSX Coils**

**WBS 161 LN2 Distribution System**



**Description**

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This element covers the distribution of liquid nitrogen (LN2) coolant within

the cryostat. The system serves all the actively cooled coils:

TF (WBS 131)

PF (WBS 132)

Modular (WBS 14)

**Scope**

Work includes engineering design, procurement, and fabrication of

manifolds, cooling hoses, jumper hosing, valving, and associated supports.

Work in this WBS ends with delivery of components to machine assembly

operations.

**Interfaces**

I&C is procured in 1408. WBS161 includes routing and distribution of

coolant between coil input/output terminations and the supply/return

manifolds. WBS17 provides supply/return headers and hook up interfaces

in the Cryostat. Valves are included in WBS1 61.

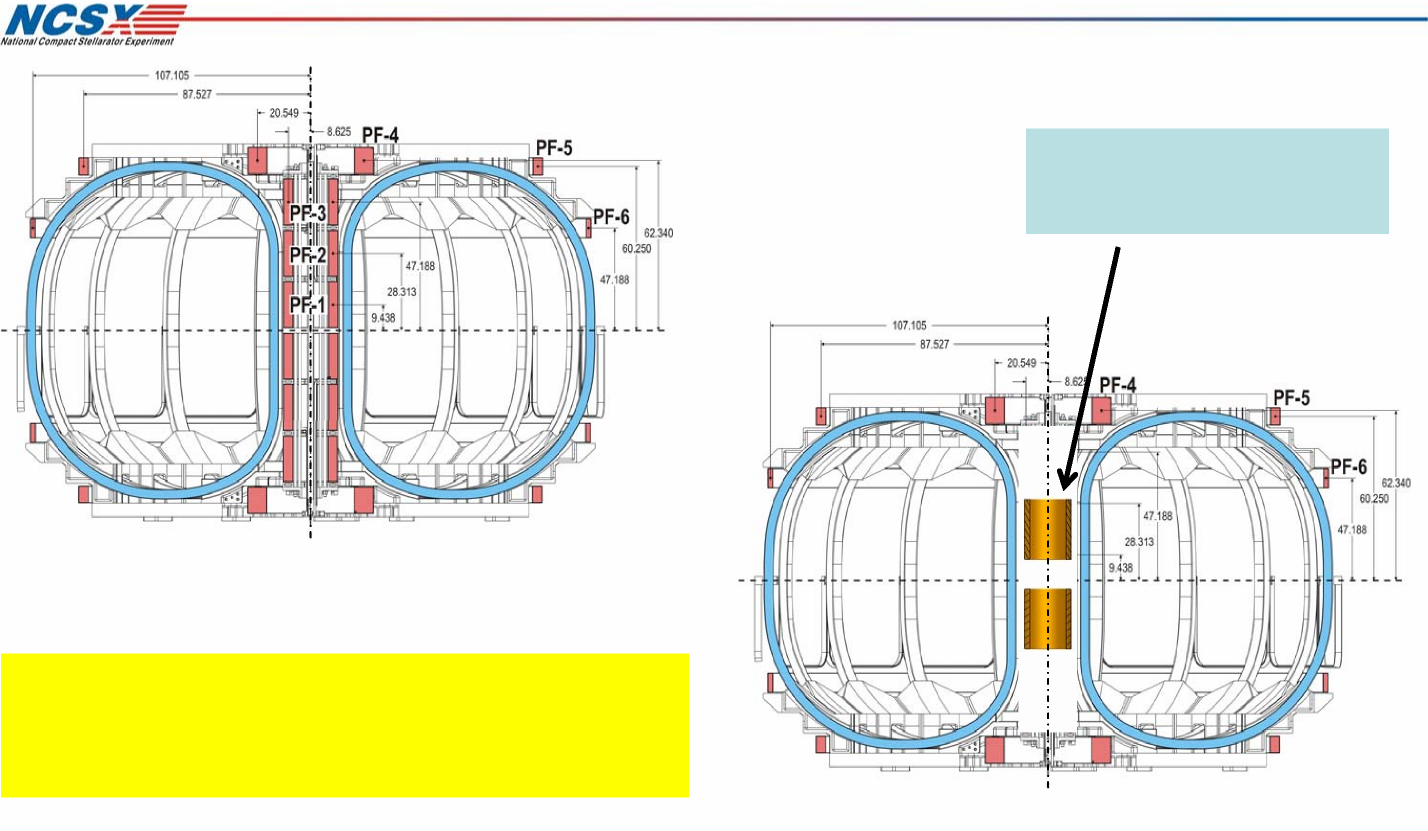
PF1a coils from

NSTX are baseline

**Baseline Configuration**

**Upgrade Configuration**

* Baseline is PF1a, PF4, PF5, and PF6 (2 each, upper and lower).
* Device can be upgraded if desired, where PF1a is replaced by PF1, PF2, PF3.



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**Central Solenoid, TF, and PF**

**Configurations**

**Modular Coil and Conventional Coil Cooling**



**Requirements**

|  |  |  |
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* Operate at 77 K with LN2.
* Operating pressure minimum 5 atmospheres absolute.
* Electric breaks in MC coil coolant lines poloidally.
* Electrical current limitation between cooling components. (bypass resistors

isolate hoses to ground)

- TF and PF hoses electrically isolated at coil terminations as

well as headers

* Provide flow balance between systems.

PF Coil pair 4,   
5, or 6

1-6

2 1

1 2

4

1

48

5 6 7 45 46 47

1 2 3 4

TF Coils

1 2 34561 2

**Supply Header**

One side of a Modular Coil shown

Poloidal break

Insulated jumper

**PF (4, 5, 6)**

**TF**

**PF1**

**MC**

**Outer**

**Inner**

**Return Header**

PF Coil pair

TF Coils

2 1 2 14

1

1 2 3 4 56 745464748

Spares

1-14

PF pair

MC hook up 1-48

**Return Header**

Flow balance

**Dual supply and return manifolds**

- **Individual controls are not required, a single valve in MC return balances both manifolds**

- **Valve and monitoring is outside cryostat where it is accessible** - **Individual circuits are passively (self) balanced**

**Costs reflect design in**

**Cooling System Diagram shown below**

plg 3/20/08

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Cryostat Boundary

PF Coil pair 1, 2, or3

MC hook up 1-48

Spares

1-14

**Field Period Supply Header**

1 2

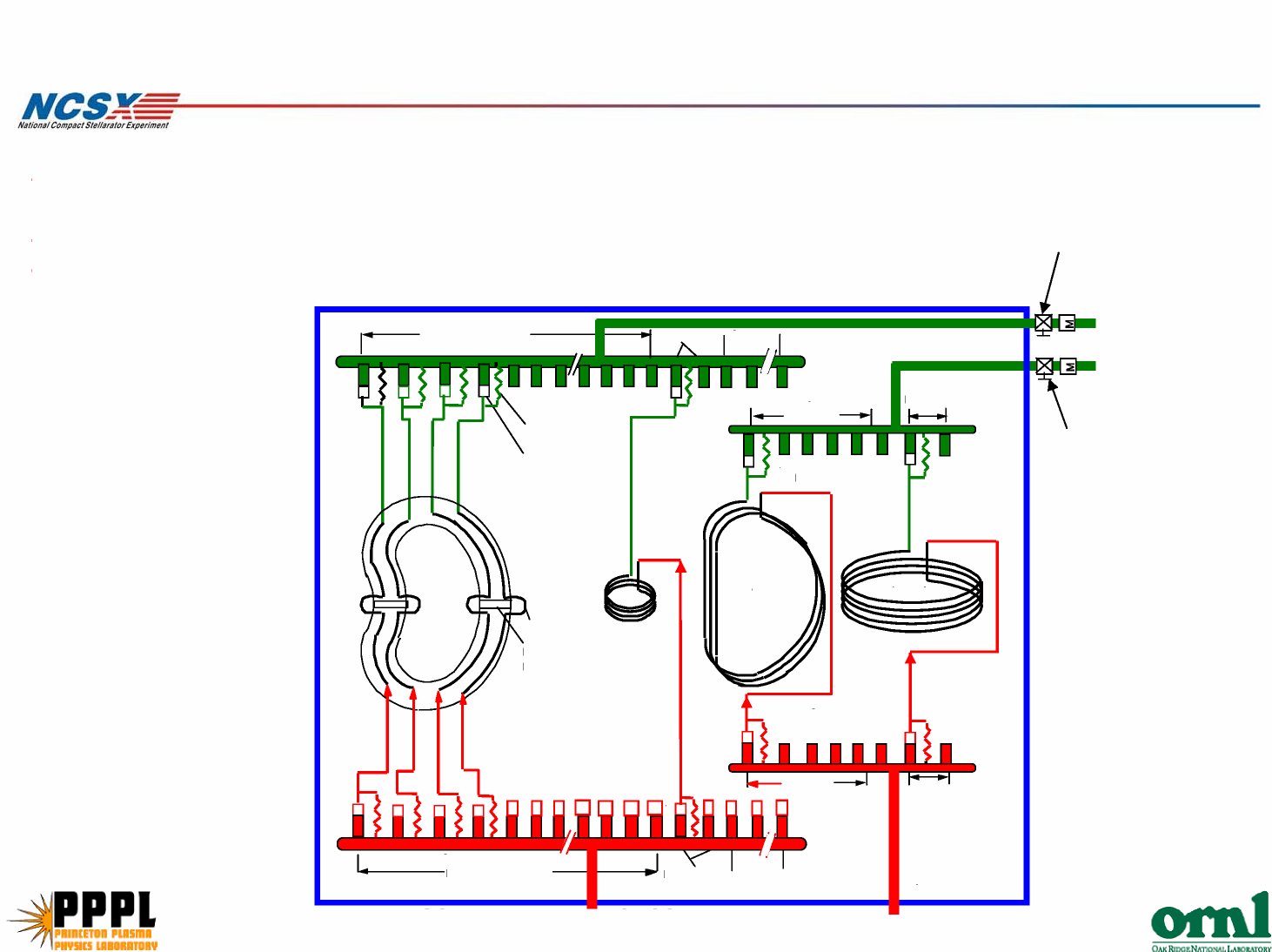
23456

Resistor

G-10 Insulator

Flow volume

1-6



**Flow distribution**



PF1A is used in CD4, replace by PF1, PF2, and PF3 in future operation.

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Pressure drops fall in two well defined groups.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **ID  (in)** | **Length of  tracing  (ft)** | **Length of  hose  (ft)** | **Minimum  flow required  (gpm)** | **Actual flow  (gpm)** | **Pressure  drop  (atmos)** |
| **MC** | 0.18 | 4 | 18 | 1.1 | 1.2 | **2.42** |
| **PF1** | 0.354 | 304 | 24 | 1.1 | 1.1 | **2.42** |
| **PF2** | 0.354 | 304 | 24 | 1.1 | 1.1 | **2.42** |
| **PF3** | 0.354 | 304 | 24 | 1.1 | 1.1 | **2.42** |
| **PF1A** | 0.354 | 178 | 24 | 1.1 | 1.2 | **2.42** |
| **spares** |  |  |  | 0.5 | 0.5 | **2.42** |
| **PF4** | 0.354 | 861 | 21 | 1.1 | 1.4 | **4.51** |
| **PF5** | 0.354 | 1100 | 21 | 1.1 | 1.2 | **4.51** |
| **PF6** | 0.354 | 786 | 18 | 1.1 | 1.4 | **4.51** |
| **TF** | 0.312 | 355 | 18 | 1.6 | 1.6 | **4.51** |

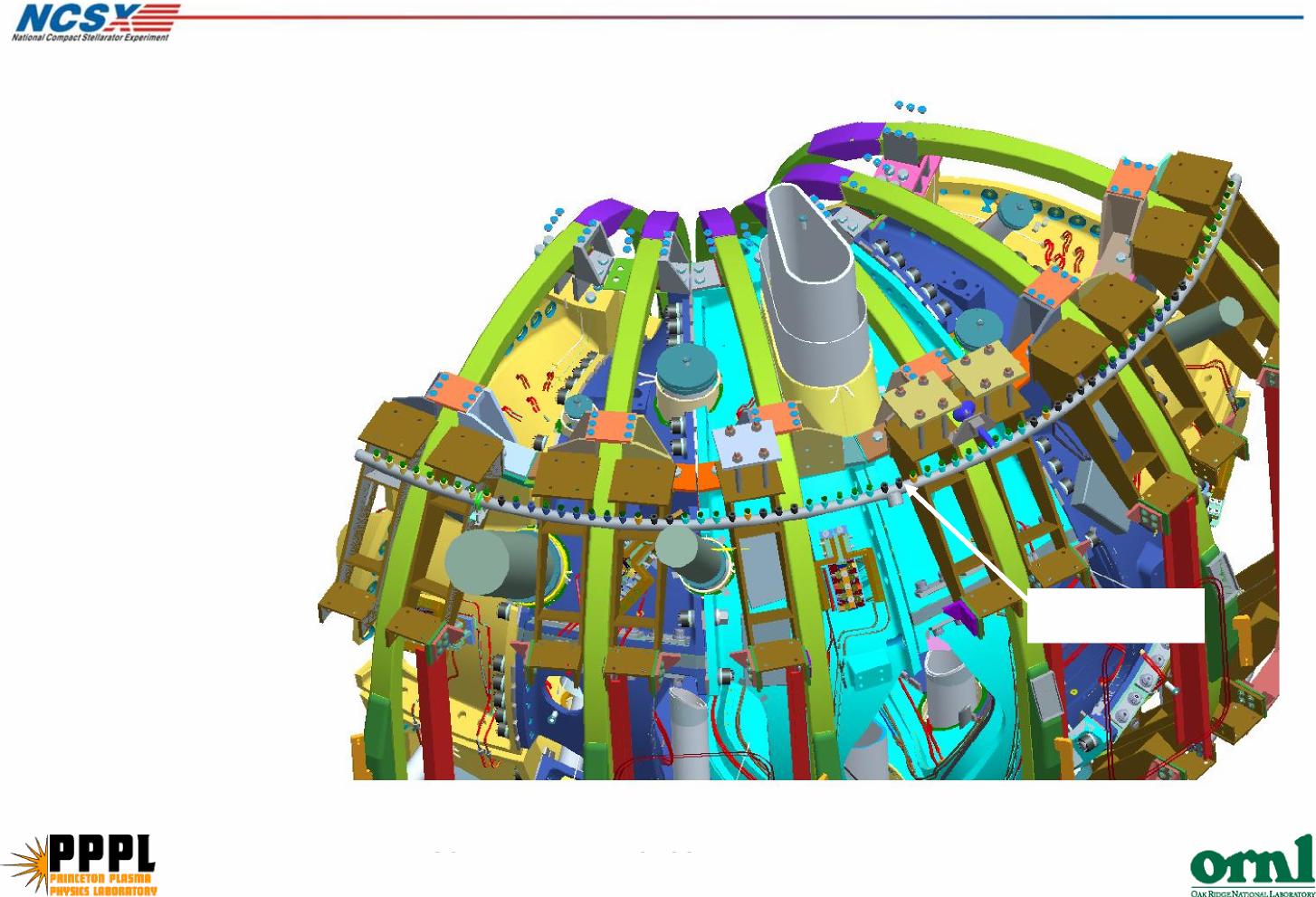
manifold

• Manifolds lie outside TF coils

- supply near bottom of VV

- return near top of VV

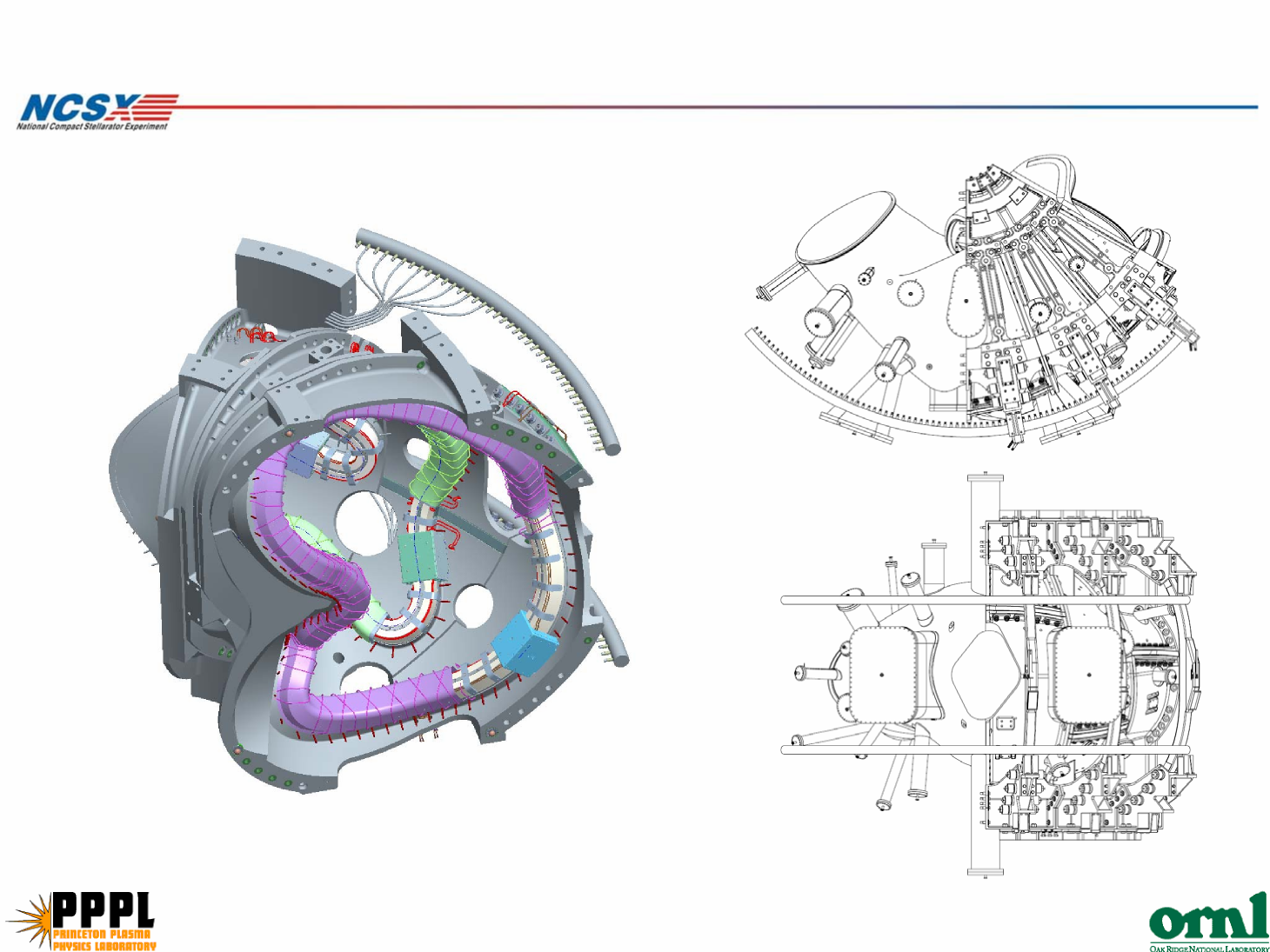
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**Typical manifold**

Transition to flex hosing at the winding form

**Manifold Jumpers**



**Resistor**

**G10 CR Male / Female coupling**

**316 SS Yor-Lok 5/16 OD tube one end and 1/4J NPT on other end**

**316 SS braided hose with 5/16 OD straight tube coupling at both ends**

**Hoses are isolated from the**

**manifolds by G10 plugs**

**- prototype will be tested**

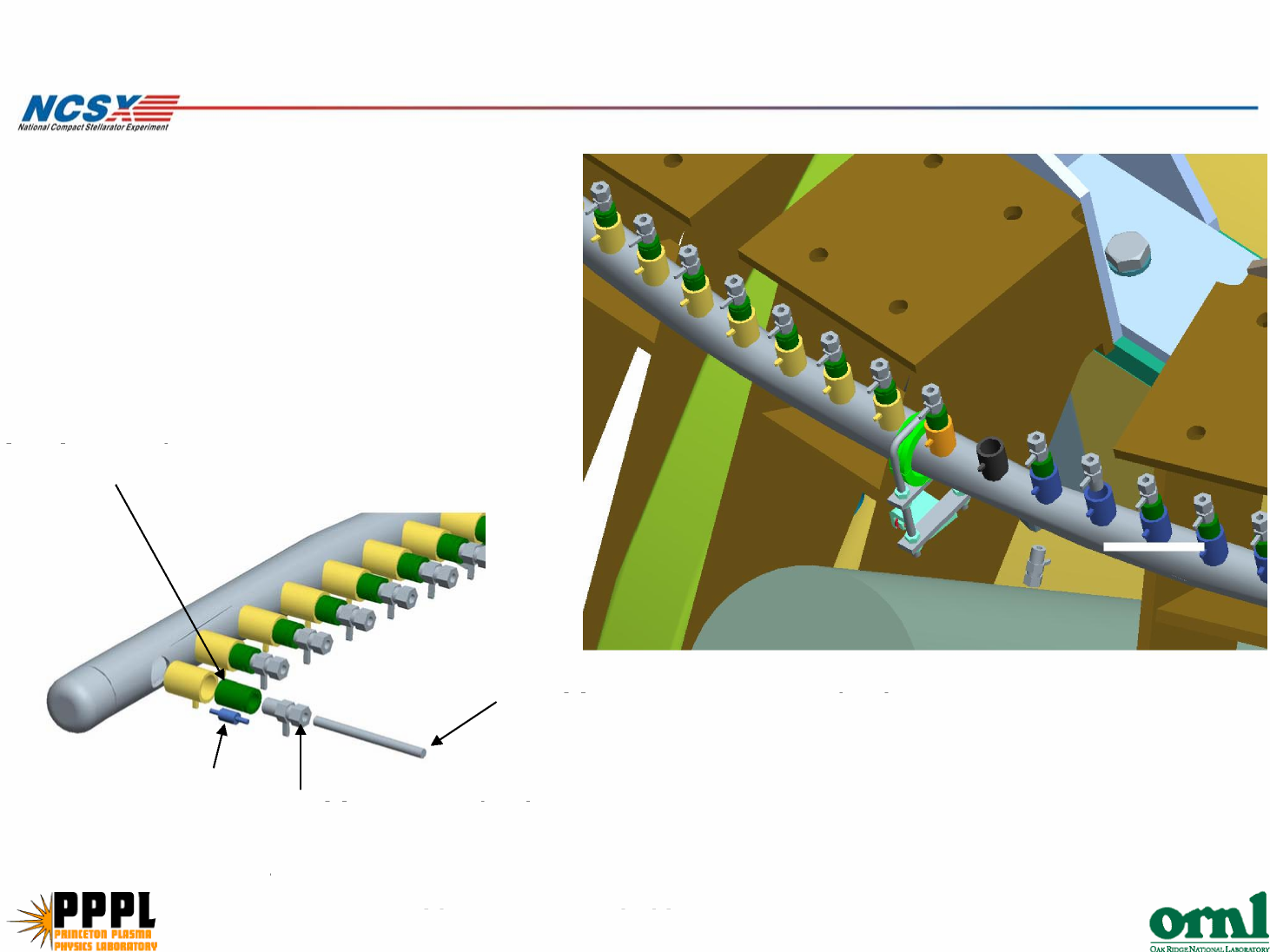
**at 77K**

-**orientation of individual**

**connections is TBD**

**Manifold hose insulators**

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**Cost Estimate Basis**



* **LN2 hoses are catalog items.**

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– **Lengths are based on ProE models.**

* **Manifold designs and prices are based on a similar design used**

**on the VV.**

– **Sizing is based on thermo hydraulics performed by**

**Engineering.**

* **Material cost is estimated on a $ per lb at current market.**
* **Supports are based on a $/length of hose.**
* **Engineering time is based on number and type of drawings for**

**each element, specifications, and the analyses anticipated.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  |  | **s i m u l**  **a t i**  **o** |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

**Description:**



**Labor**



**This effort covers all R&D, Title I, II, and III engineering for the LN2 distribution system inside the cryostat,which includes all the necessarymanifolding**

w

n

**and connections to interface with the ex-cryostatLN2 supply system. This system will be fabricated in-house by PPPL. All Title III engr associated with installation is included in WBS 7.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **p e s s u r** |  |  |  |  |  |  |  |
|  |  |  |  |
|  |  |  |  |  |  |  |

**HOURS**

**Number of**

**Units Hours**

**Task ID Multiplier Unit**

**Title I an II Design**

Pro-E models (avg) 8 hrs/model 21 168 168

|  |  |  |
| --- | --- | --- |
|  | **o**  SC Project Review of NCSX, April 8-10, 2008  **f** t |  |

**i**

assy dwgs 16 hrs/dwg 24 384 384

**z**

Detail drawings 8 hrs/dwg 13 104 104

**e**

installation dwg 16 hrs/dwg 14 224 224

**d**

cooling schematic 20 hrs/dwg 1 20 20

electrical schematic 0 hrs/dwg 1 0 0

**L**

I&C schematic 20 hrs/dwg 1 20 20

stress analysis 40 hrs/calc 1 40 40

**N   
2**

thermal analysis 40 hrs/calc 1 40 40

special analysis (electromagnetics) 160 hrs/calc 0 0 0

**fab specifications** 160 hrs/spec 2 320320

**a**

preliminary and final design reviews 80 hrs/rev 2 160 160

**n**

|  |  |
| --- | --- |
| Resolve PDR Comments | 40 hrs/PDR 1 40 40  d |

meetings/reporting/presentations 10% % of tot hrs 152 152

***Subtotal Title I & II Design 1672 1672 0 0 0 0 0 0 0***

v

|  |  |
| --- | --- |
| **R&D Activities**  R&D pressure drop simulation with pressurized LN2 and valve. Design of test unit. | **a l**  ***40*** 40  **v**  **e** |

.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | 38 | 0 | 0 | 0 | 0 | 0 |
| 104 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 40 | 40 | 0 | 0 | 0 | 0 |

**Title III**

**g**

**n**

***222 0 104 0 78 40***

**i**

Disposition of deviation requests and

non-conformances 1 hrs per 38 38

As-built drawings 2 # dwgs 52 104

Procurement coordination 80

***0 0 0 0***

***Subtotal Title III Design***

**Total 1934**

**Materials and Supplies**



**Description:**

|  |  |  |
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**This effort covers procurement of materials for the LN2 distribution system by fixed price subcontract.**

**Assumptions:**

**outside engr rate = 120$ per hour**

**outside fab rate = 60$ per hour**

**outside inspection/technician rate = 80 $ per hour**

**MDL labor 80$per hour**

|  |  |
| --- | --- |
| **Purchased parts:**  **coolant line pigtails from coils to manifolds Insulating Jumper hoses**  **Manifolds for cooling lines**  **valves**  **orifices & other hardware** | **$19,800 see notes below**  **$4,320**  **$9,085**  **$9,000 see notes below $10,000** |

**Thermocouples $0 included in job 1408 for**

**R&D material and labor from below $18,000 the modular coil**

***subtotal, purchased parts* $70,205 fabrication**

**Fabrication and Assembly**

**Description:**



This effort covers all the fabrication of the LN2 system inside the cryostat including headers.

**Worksheets**

**coolant line pigtails from coils to manifolds** Average length of pigtail

Total

No. of coils

circuits per coil at header

total circuits

Total number of pigtails

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 3 ft  TF **Modular** PF1 |  | PF2 | PF3 | PF4 | PF5 | PF6 | Trim |
| 60 | 18 18 | **2** | 2 | 2 | **2** | **2** | **2** | 12 |
|  | 1 8 | **0.5** | 0.5 | 0.5 | **0.5** | **0.5** | 0.5 | 0 |
| 168 | 18 144 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 336 | supply and return per circuit |  |  |  |  |  |  |  |

**Manifolds for cooling lines**

|  |  |  |
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Assume 2 pairs of 1.5 inch manifolds for each field period, one above and one below the midplane inside the PF5 coil Each set of manifolds will have 1/3 of the required cooling connections plus 25% spare

The manifolds will connect via vertical pipes to the supply system below the cryostat

avg toroidal perimeter of field period 16 ft

avg vertical height of connection lines 9 ft

no of headers/FP 4

cost of tubing $15 per foot, 316 SSt

cost per field period $1,488

total number of coolant connections, all

headers 840

hours to weld each connection 0.5 hr per connection

shifts to form manifold tube 0.5 per manifold pair

crew size for forming 2

hours to cut vertical pipes 2 hrs per pipe

hours to weld vertical pipes to header 2 hrs per pipe

total shifts for manifolds 71

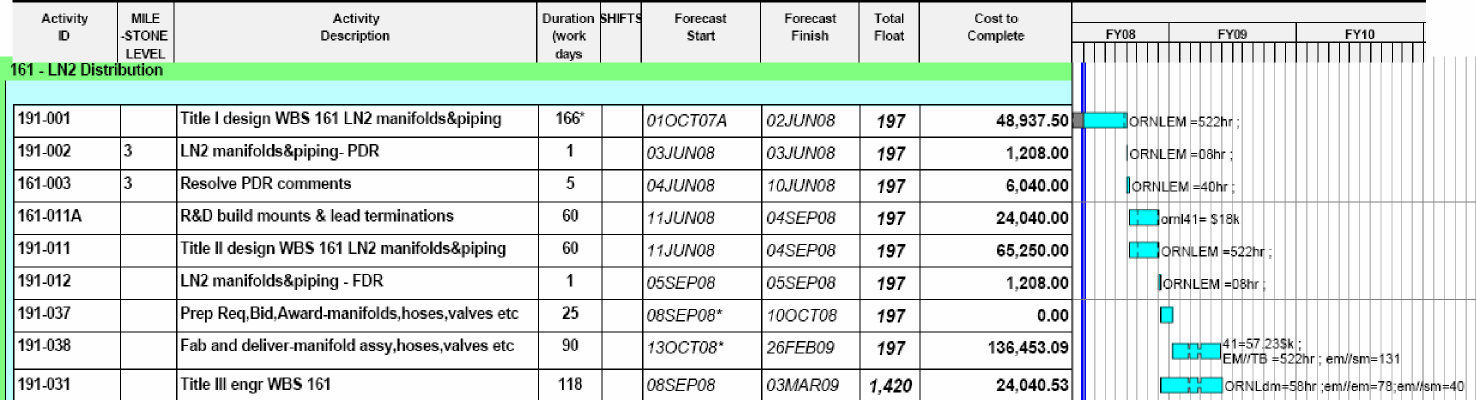
tech hours for manifolds 564 hours

technical oversight, inspection 141 hrs

**total hours for manifolds 705 hrs**

**Schedule & Staffing**

**Schedule**



|  |  |  |
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|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Staff** |  |  |  |  | **Paul** | **Sorin** | **Scott** |  |  |
|  |  |  |  |  | **Goranson Homescu** | | **Dixon** | **total** | **Total** |
|  |  |  |  |  | 40% | 100% | 100% | work hours | **WAF** |
| **Jobs** | **start** | **end** | **days** | **weeks** | hrs | hrs | hrs | available | **hours** |
| **leads(162)** | 14-Mar | 1-Feb-09 | 324 | 46.3 | 692.6 | 1351.4 |  | 2044 | 2044 |
| **headers(161)** | 1-Jan | 1-Oct-08 | 274 | 39.1 | 522.3 | 500 | 1565.7 | 2088 | 1934 |

**Cost Estimate Risks**



• LN2 Distribution System (WBS 161)

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Design is straight forward and procured items are by and large

commercially stocked. Manifolding is similar to gas system on VV,

which is complete and costs are well documented.

**Maturity – medium**

Routing and interfaces are in early design phase and design is pre

PDR. R&D required.

**Complexity – low**

**Risk Mitigation**



**Schedule Milestones**

|  |  |  |
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* **An extra full time designer was assigned to Coil Services to assure schedule is met.**
* **Hoses will be 100% leak checked at delivery to prevent delays after installation. (lesson learned from VV)**

**Design Integrity**

* **R&D at MDL will confirm functionality of G10 insulators and flow rate in corrugated hoses.**

**WBS 162 Coil Electrical Leads**



**Description**

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**This element covers the electrical leads within the cryostat, serving all the**

**coils: the TF, PF, External Trim (WBS 133), and Modular Coils.**

**Scope**

**Work includes engineering design, procurement, and fabrication of cables,**

**mounting brackets, thermal transition boxes, and associated supports. Work in**

**this WBS ends with delivery of components to machine assembly operations.**

**Interfaces**

**The WBS161 interface begins at coil terminations and ends at the cryostat**

**thermal transition/terminal box. It does not include I&C, bus work, or routing in**

**the test area.**

**Requires penetration of cryostat.**

**Share real estate used by core structural support, floor mounted utilities, bus**

**supplies, diagnostics, etc.**

**Lead Requirements**



* **Connect between bus supply in test cell and coil terminals inside**

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**cryostat.**

* **Operate nominally at 77-80 K but no active cooling is required, Cryo**

**environment is sufficient to return temperature to operating level**

**between shots.**

* **Provide Cryostat seal interface.**

– **Minimize icing**

– **Maintain positive pressure in Cryostat**

* **React internal magnetic loads.**
* **Cancel (minimize) field errors.**

**Status**



* MC design is most mature.

|  |  |  |
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* To date, most of design effort has

concentrated in this area as it is the more

challenging.

* Conventional coils will be handled in a

similar manner and use similar

components.( cable, brackets, terminations,

spacers, etc.)

**MC Lead Configuration**



Cable is 250 MCM

|  |  |  |
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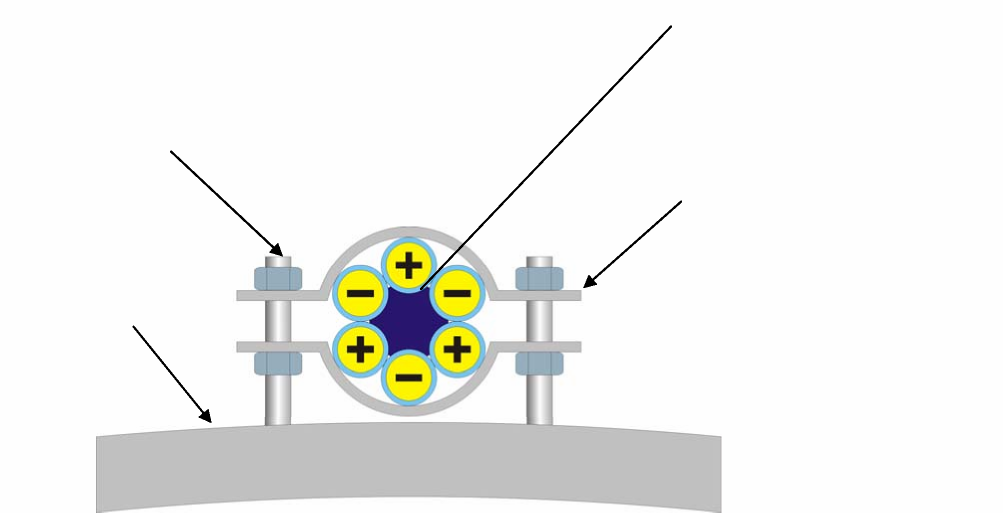
1” long spider/loom

Casting

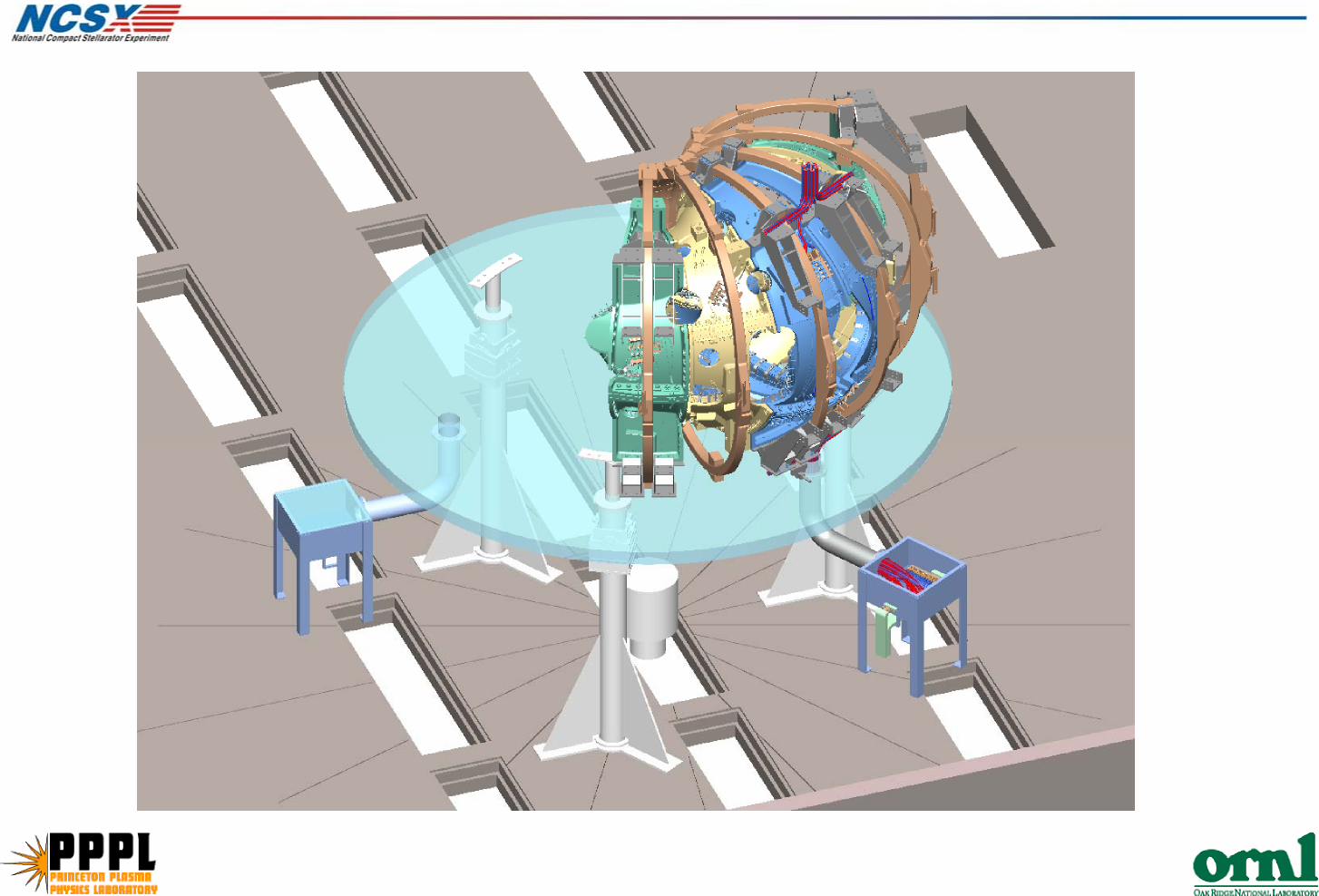
Standard

1.5” Pipe Clamp   
(1/8” thk x 1” Wide)

5/16” Stud



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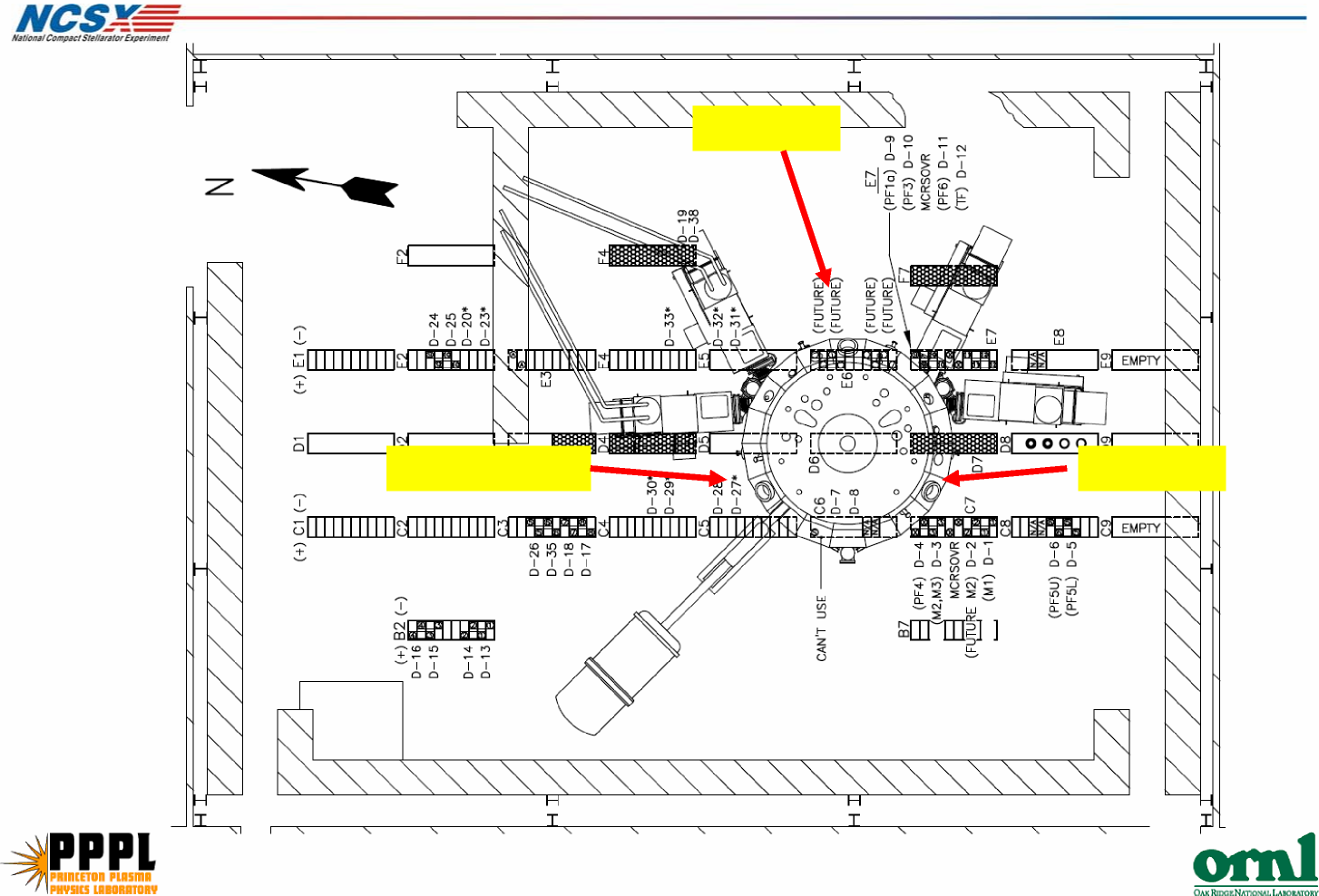


**System Layout**

MC leads

PF leads

TF & TC leads



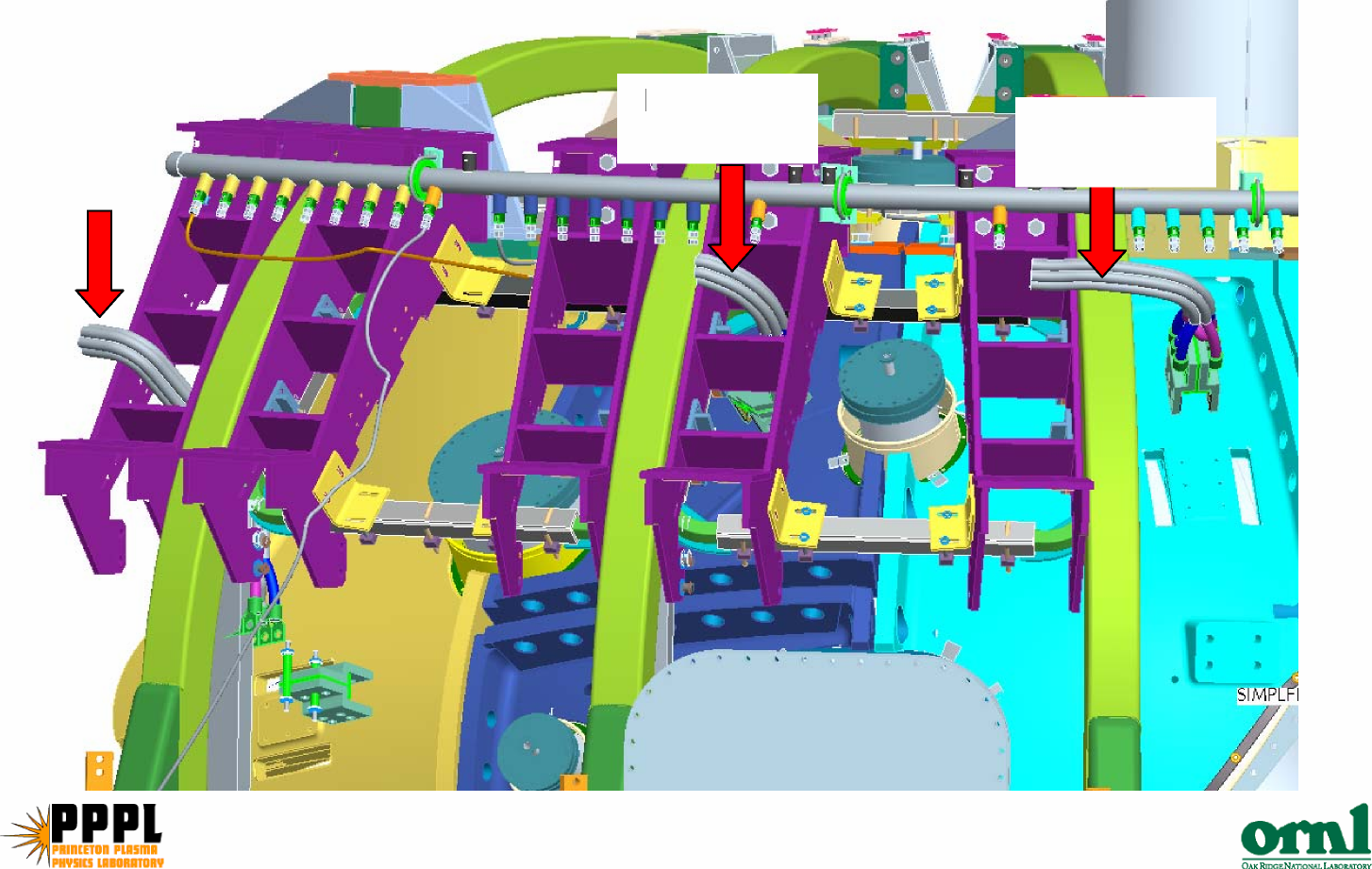
**Service routing to test cell penetrations**

**MC Lead Stub Connections**

MC A lead   
stub

MC B lead   
stub

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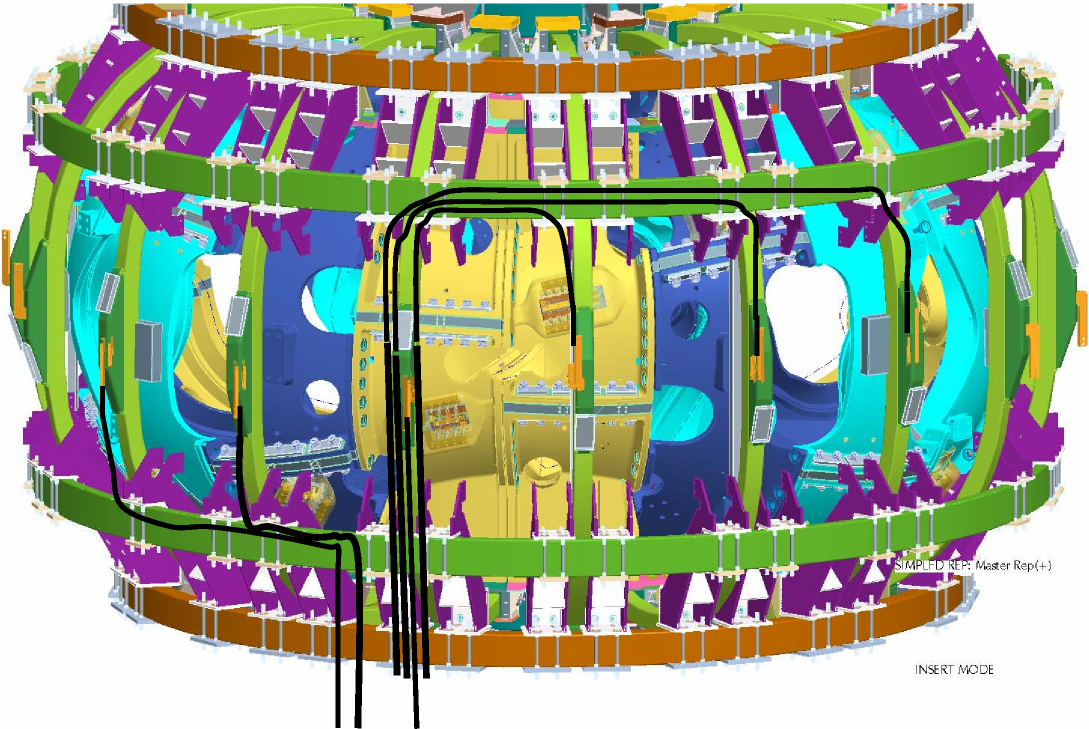
**Lead Routing**



**Services will be routed to each of the three C-C**

|  |  |  |
| --- | --- | --- |
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**interfaces.**



Hard Bus to   
power supplies

Pipe Chase

Cryostat Floor **Leads Junction Box**

(Clear cover removed)

Top View of an 8” diameter pipe chase showing the

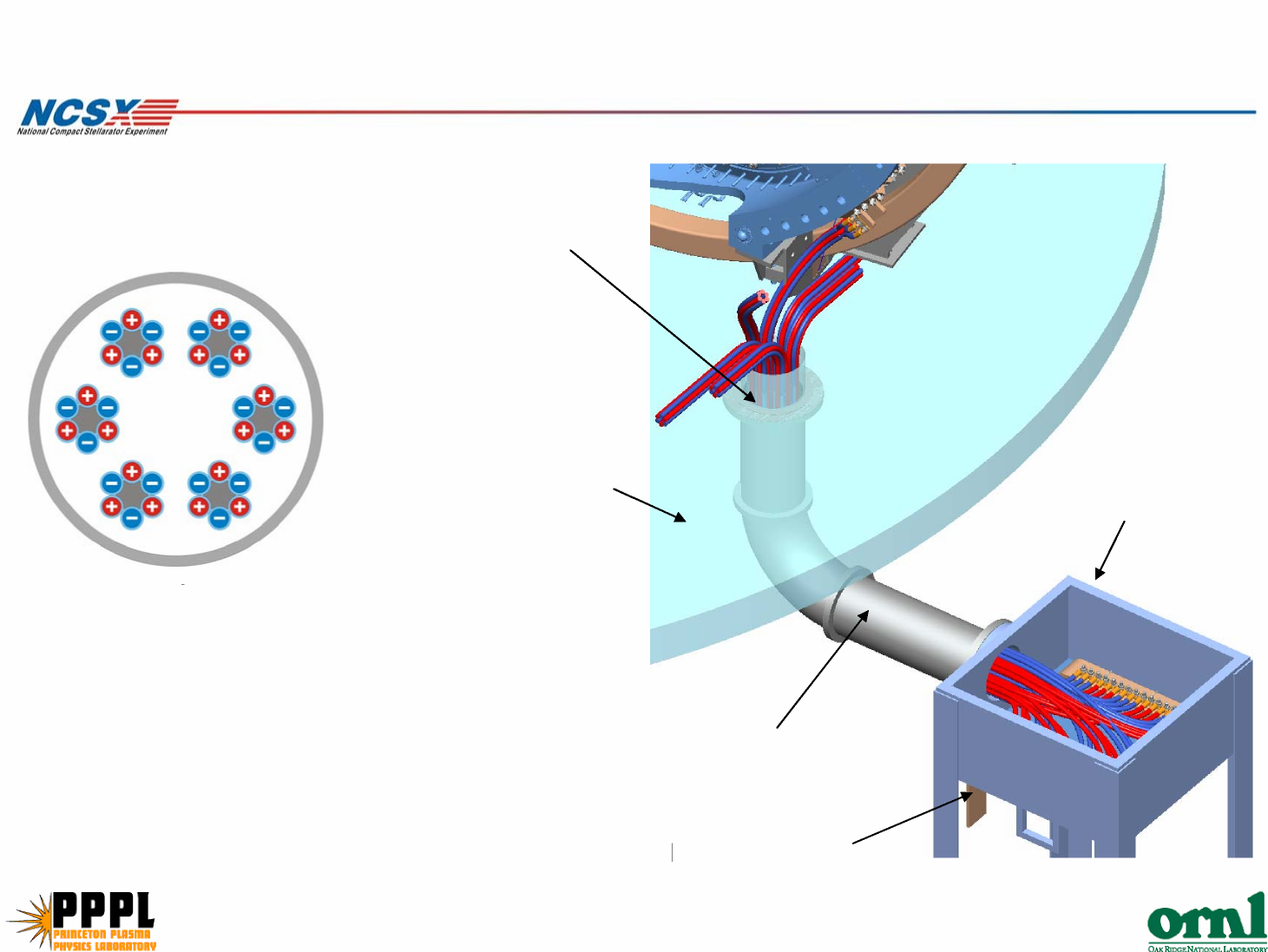
(6) modular coil leads cables from a field period

**Leads transition thru the cryostat, to**

**room temp.**

**Modular coil Interface at Cryostat**

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**Cost Estimate Basis**



* **Cables are catalog items**

|  |  |  |
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– **Lengths are based on sketches in work sheet.**

* **Material cost of supports, spacers, and terminations is**

**estimated on either:**

**- $ per lb at current market or:**

**- $/length of cable.**

* **Engineering time is based on number and type of drawings for**

**each element, specifications, and the analyses anticipated.**

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**Total 2042**

**HOURS**

***1892***

172

40

40

40

40

24

0

0

112

0

464

320

240

400

84

8

10

8

***110***

84

8

10

8

*40* ***40***

172

40

40

40

40

24

0

0

112

0

464

320

240

400

**Hours**

***Subtotal Title III Design***

|  |  |  |  |
| --- | --- | --- | --- |
| **Title III** |  |  |  |
| vendor inspection & oversight | 8 | hrs per | 1 |
| Disposition of deviation requests and non- conformances | 0.5 | hrs/wk | 20 |
| In-House fab/assy oversight & inspection | 2 | hrs/wk | 4 |
| As-built drawings | 1 | hrs/dwg | 84 |

**R&D Activities**

R&D design time to build mounts (clamp, spider), lead terminations

***Subtotal Title I & II Design***

meetings/reporting/presentations

Resolve PDR comments

preliminary and final design reviews

Procuremnt Specifications

special analysis (electromagnetics)

thermal analysis

stress analysis

I&C schematic

electrical schematic

cooling schematic

installation dwg

Detail drawings

assy dwgs

**Title I an II Design**Pro-E models (avg)

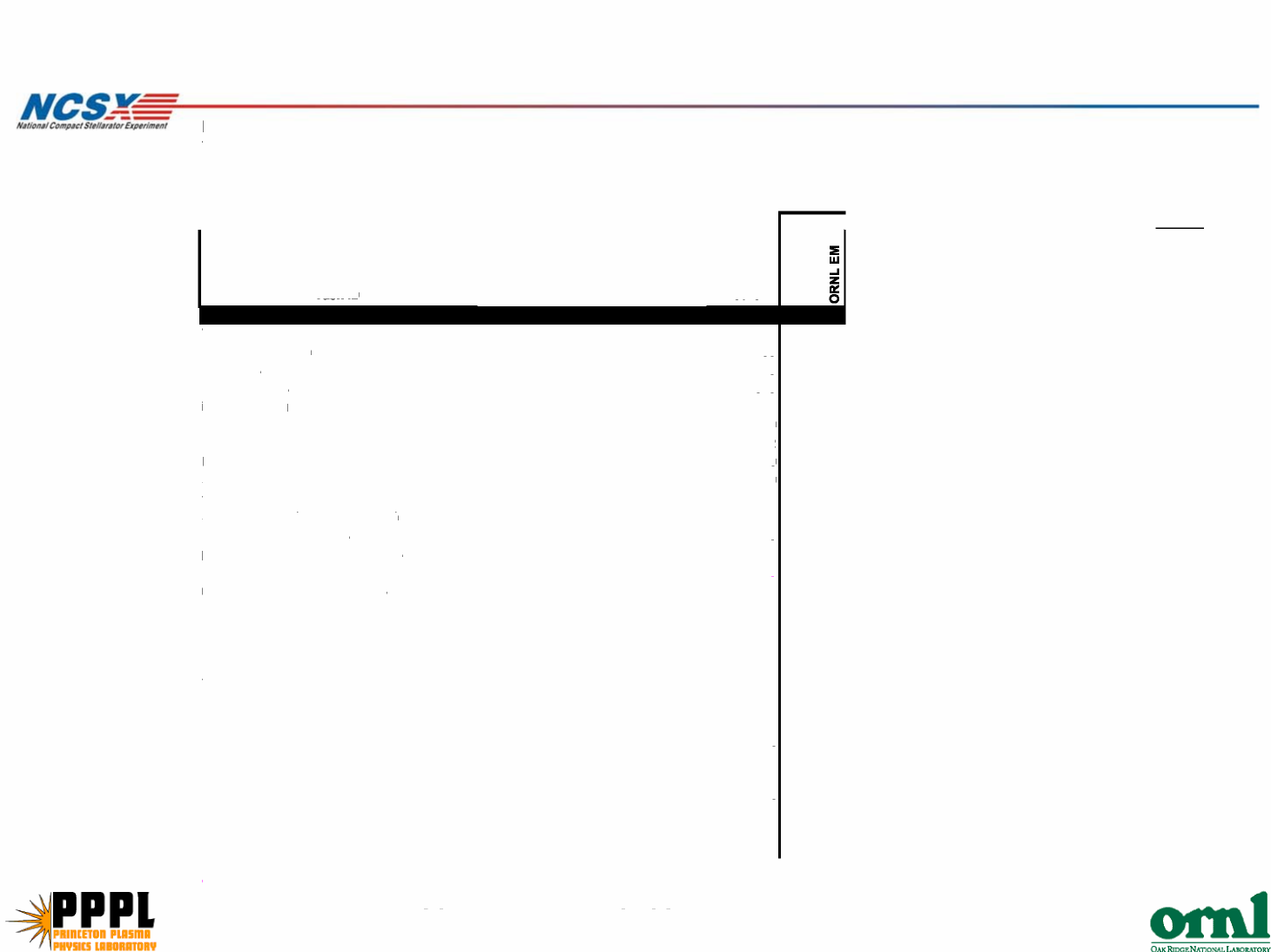
**Task ID**

|  |  |  |
| --- | --- | --- |
| **Multiplier** | **Unit** | **Number of  Units** |
|  |  |  |
| 8 | hrs/model | 50 |
| 16 | hrs/dwg | 15 |
| 8 | hrs/dwg | 40 |
| 16 | hrs/dwg | 29 |
| 0 | hrs/dwg | 1 |
| 8 | hrs/dwg | 14 |
| 8 | hrs/dwg | 0 |
| 0 | hrs/calc | 0 |
| 24 | hrs/calc | 1 |
| 40 | hrs/calc | 1 |
| 40 | hrs/spec | 1 |
| 40 | hrs/rev | 1 |
| 40 | hrs/pdr | 1 |
| 10% | % of tot hrs |  |

**This effort covers all R&D, Title I, II, and III engineering design of the coil electrical leads inside the cryostat connecting the coils to the power supply bus or cables outside the cryostat.**

**Labor**

**Description:**



**M&S**

|  |  |  |
| --- | --- | --- |
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**Description:**

This effort covers all coil leads that connect the coil terminals to the buswork at the boundary of the cryostat. **Assumptions:**

outside engr rate = 120 $ per hour

outside fab rate = 60 $ per hour

outside inspection/technician rate = 80 $ per hour

**Purchased parts:**

set of cables $32,552

misc attachment hardware $16,162 @10$/ft

thermal transition box material $0

|  |  |
| --- | --- |
| *subtotal, purchased parts* | $48,715 |

Lead bundles consist of six, 250 MCM cable with teflon sleeve. Lead ends are cooled by bleed liquid nitrogen supplied by the coil coolant header (WBS 161) Leads connect from coil terminals to buswork at bottom of machine.

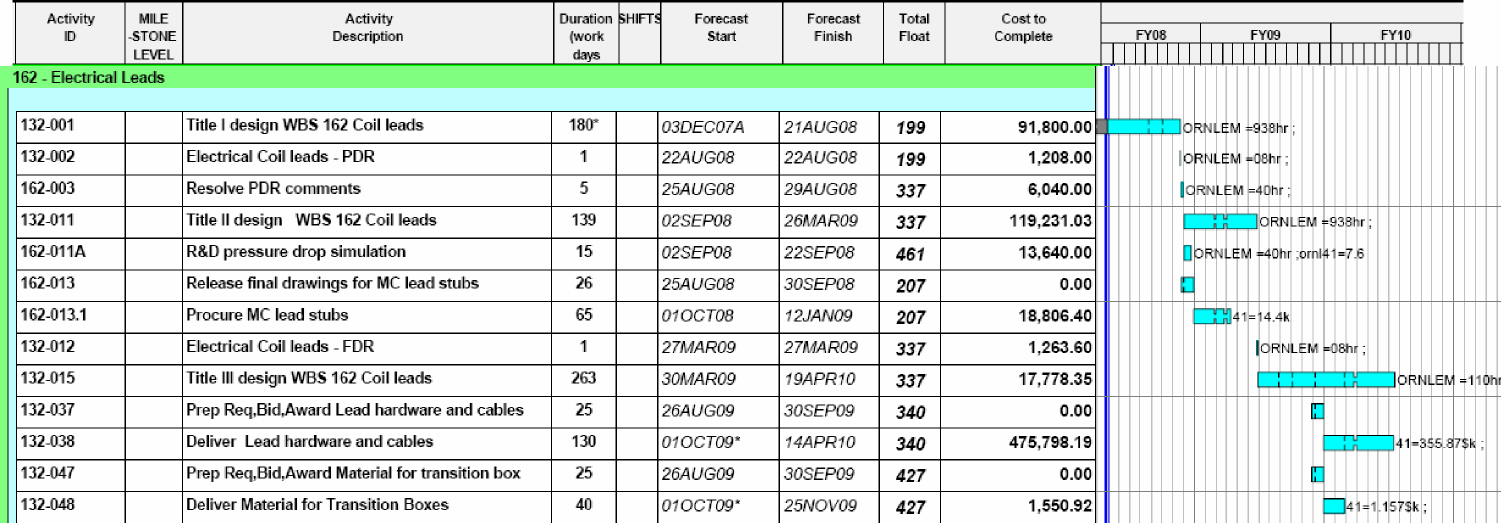
Each coil is connected separately except PF1 and PF2, which are connected in series within the central solenoid assembly

**Schedule & Staffing**



**Schedule**

|  |  |  |
| --- | --- | --- |
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**Staff**

**Paul G Sorin H Scott total Total**

40% 100% 100% work hours **WAF**

**Jobs start end days weeks** hrs hrs hrs available **hours**

|  |  |  |  |
| --- | --- | --- | --- |
| **leads(162)** |  |  | 14-Mar 1-Feb-09 324 46.3 692.6 1351.4 2044 2044 |

**Cost Estimate Risks**



Coil Electrical Leads (WBS 162)

|  |  |  |
| --- | --- | --- |
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Maturity – medium

Routing and interfacing is in early stages of design.

Design of cables is not firmly established, satisfying field

error requirements could require more costly solutions and

longer lead time.

Complexity – low

Design is straight forward and large ticket procured items

(cable and mounts) are commercially stocked.

No complications such as active cooling are required.

**Risk Mitigation**



**Schedule Milestones**

|  |  |  |
| --- | --- | --- |
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* **The Designer was assigned to Leads full time and his LN2 System**

**responsibilities reassigned.**

**- Permitted acceleration of design schedule to assure**

**critical components (coil stubs) will be procured for Station**

**5 assembly.**

* **Field error calculations are being performed up front to minimize**

**the risk that designs will have to be redone.**

**Design Integrity**

* **The terminations and clamps will be prototyped at MDL to confirm**

**their design is acceptable.**

**WBS 163 Coil Protection System**



**Description**

|  |  |  |
| --- | --- | --- |
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**This element covers the specification of coil protection requirements for the**

**coil protection system.**

**Scope**

**Work covers Title I, II, and III Engineering support for development of the**

**system, including any drawings, electrical and I&C schematics, or analyses.**

**There is no design, fabrication, or hardware included under this package.**

**The results of thermal, electrical and mechanical analysis will be used to define**

**allowable operating limits for the coils for commissioning, normal research**

**operations, and fault conditions. Appropriate diagnostics and permissive,**

**alarm, and failsafe signals to the power supply controllers and I&C systems will**

**be defined.**

20

40

0

40

0

0

0 120

0

0

0

0

0

0

meetings/reporting/presentations

preliminary and final design reviews

Procurement Specifications

special analysis (electromagnetics)

thermal analysis

stress analysis

I&C schematic

electrical schematic

cooling schematic

installation dwg

Detail drawings

assy dwgs

**Title I an II Design** Pro-E models (avg)

**Task ID**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Multiplier** | **Unit** | **Number of**  **Units Hours** | | |
|  |  |  |  |  |
| 8 | hrs/model |  | 0 | 0 |
| 24 | hrs/dwg | 120 | 0 | 0 |
| 16 | hrs/dwg |  | 0 | 0 |
| 16 | hrs/dwg |  | 0 | 0 |
| 0 | hrs/dwg |  | 0 | 0 |
| 8 | hrs/dwg |  | 0 | 0 |
| 20 | hrs/dwg | **120** | 4 | 80 |
| 0 | hrs/calc |  | 0 | 0 |
| 24 | hrs/calc |  | 0 | 0 |
| 40 | hrs/calc |  | 2 | 80 |
| 16 | hrs/spec |  | 0 | 0 |
| 40 | hrs/rev |  | 1 | 40 |
| 10% | % of tot hrs |  |  | 20 |

**This effort covers all Title I, II, and III engineering for the Coil Protection System. No hardware is anticipated for this job, only design interface with WBS 4 and 5.**

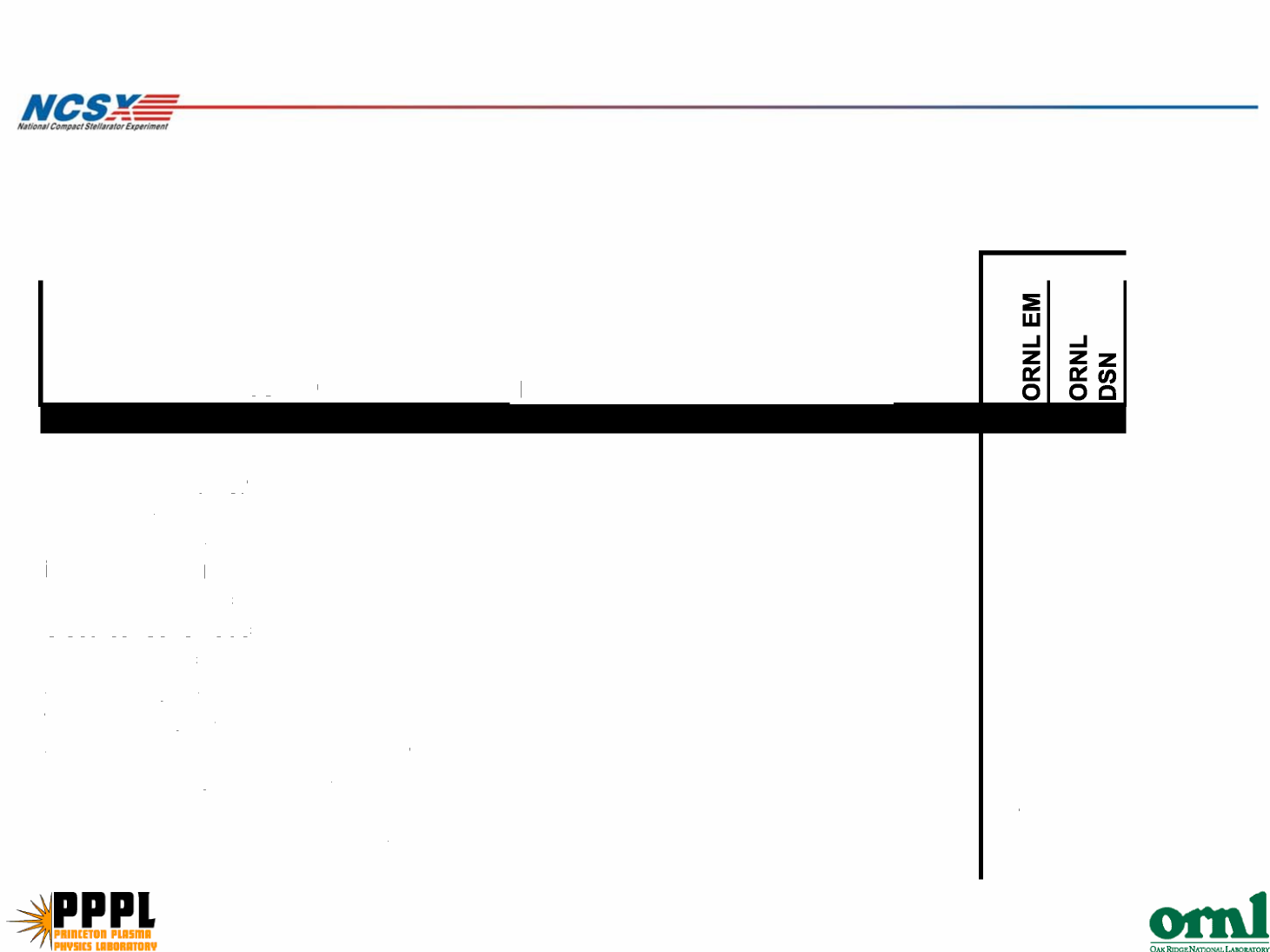
**Description:**

**Cost**

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***Subtotal Title I & II Design 220***

***100 120***

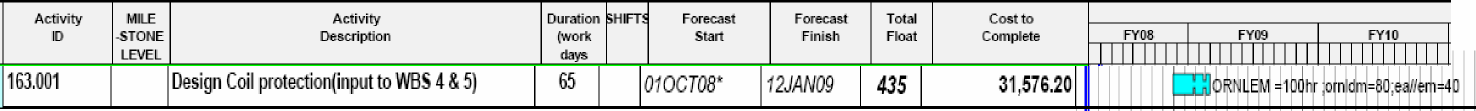


**Schedule & Staffing**



**Schedule**

|  |  |  |
| --- | --- | --- |
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**Staffing**

**Jeff Harris – 270 hours in 2009**

**Cost Estimate Risks**



Coil Protection Requirements (WBS 163)

|  |  |  |
| --- | --- | --- |
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Maturity – low

Job is at conceptual design stage. It interacts simultaneously with a

several other WBS and relies on ongoing analysis. Number of

documents is not established.

Complexity – low

Specifications may be replaced with data sheets where procured items

are available as stock items.

Many parameters are supplied from other WBS areas and are already

available.

Protocols and systems must be compatible with both initial

commissioning and full research operations.