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Mechanical Upgrades and Maintenance of Stand 4 to Support HiLumi Magnet Testing –

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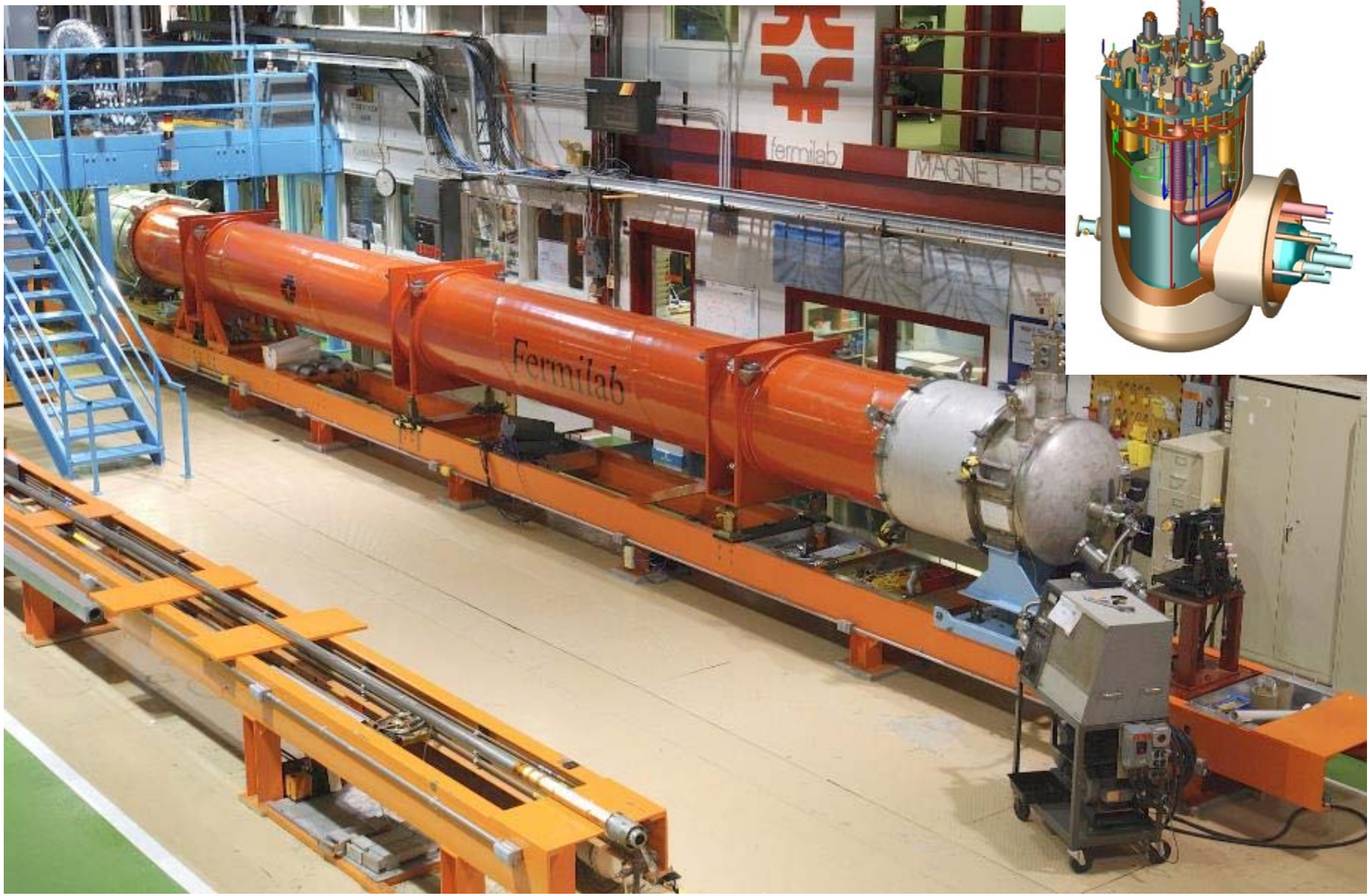
Conceptual Design Review

25 April 2016

Outline: Test Stand 4 Mech. Upgrades for HiLumi Quads

- Mechanical upgrades of the Test Stand to achieve the "full" compliment of Cold Mass Test Requirements (17.8 kA and 150 mm bore)
- Other upgrade options with reduced scope
- Risks considered for these Conceptual Designs
- Estimated Cost and Schedule for each of these scope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Options

- **Option #4 – "full" scope of the Requirements Specification**
  - Add 20 kA power capability
  - Build Warm Finger and Probe optimized for 150 mm aperture
  - Integrate a FERRET style Probe for magnetic measurements
  - Perform full aperture Magnetic Measurements and SSW at 1.9K
- **Option #3 – Baseline; use existing capabilities and test a 1.9K**
  - Use existing 15 kA Power Leads
  - Develop a FERRET style Probe (for magnetic measurements)
  - Use existing IRQ Warm Finger (need to make an extension)
  - Integrate a FERRET style Probe for magnetic measurements
- **Option #2 – Cold alignment only**
  - Cooldown to either LN2, 4.5K LHe, or 1.9K LHe temperature
  - Perform cold alignment measurement of the two cold masses
  - Use existing IRQ Warm Finger (need to make an extension)

Option 4 – Mechanical Changes

- Option 4 tasks include:
  - Purchase and Install 20 kA power leads and 1000 MCM water-cooled flex leads
  - Design and fabricate a Warm Finger Assembly optimized for the 150 mm bore
  - Disassemble the Feed Box to replace power leads, modify lambda plate plugs for power leads, baffles, expansion joints, etc.
  - Disassemble Return End, machine larger opening, and fabricate and install larger port and flange; re-assemble
  - Develop supports at the re-useable cryostat to test stand interface
  - Develop the adapter/interface box to align existing feedbox piping to the piping on the magnet cold mass
  - Adapt Return End Piping to match piping on the cold mass (return end)
  - Refurbish the magnetic measurement drive systems (probe rotation and translation, drive shaft support electronics, etc.).

Note: The items in blue are required for all cold test options

Option 4: Modifications to the Existing Feedbox Assembly

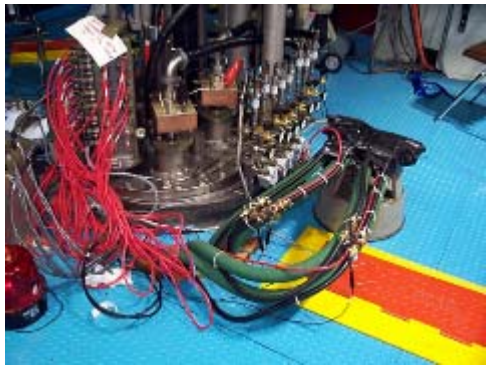
For the existing Feedbox insert, assume modification and re-install of some components vs. make new. Will modify:

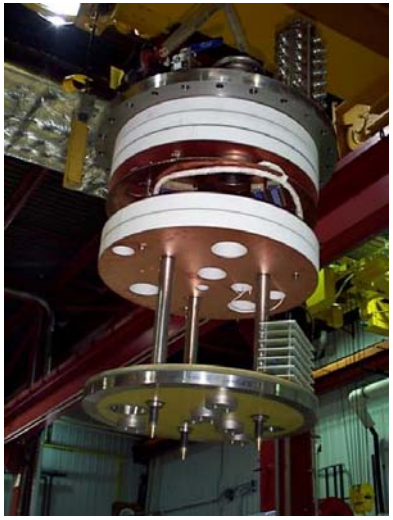
- 80K thermal shield, Cu clad G-10, and Rohacell® baffles
- Power lead Flag
- Lambda plate plugs and expansion joints with HiLumi conductor

— Design and fabricate vacuum sleeve around power leads

— Reconfigure piping to mate up with those on the adapter box/cold mass

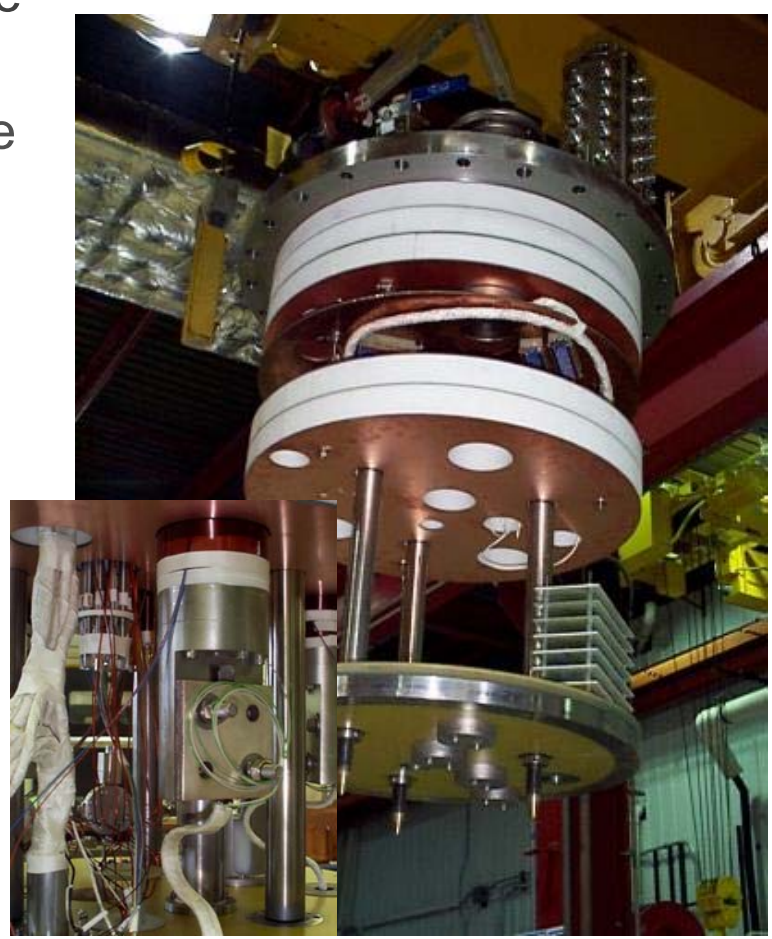
— Reassemble and re-certify (vacuum, cryogenics, instrumentation, power)





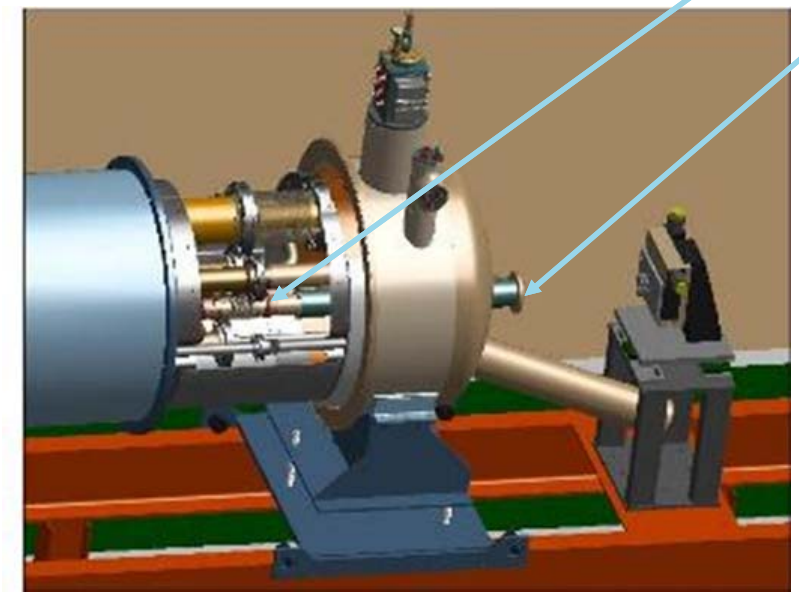
Option 4: Upgraded Feedbox

- *Assumption*: New Code Stamped Top Plate
- Two (2) 20 kA power Leads (hopefully with the minimum desired hipot standoff voltage listed in the Requirements Specification
- Expansion joints from cable rated for > 20 kA
- Larger insulating vacuum sleeves around PLs
- Upgraded water cooled Flex leads (MCM)
- Provisions for CLIQ
  - Existing vapor cooled Corrector leads being evaluated as possible option for CLIQ powering; if new leads are needed, these will use the existing penetration in the Lambda Plate
- Re-assemble and test



Option 4: Return End Can

Provides a “turnaround” for the cryogenics



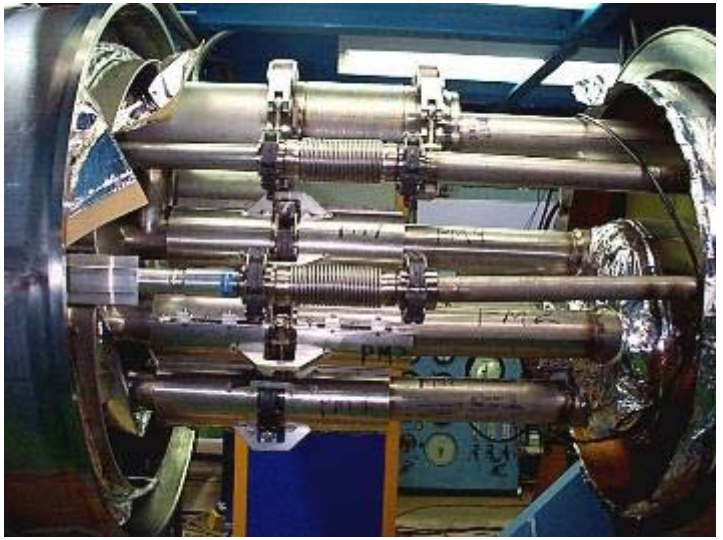
Return End Can

- Disassemble End Can
- Adapt/re-route existing piping to match up with cold mass piping
- Machine larger opening and flange for HiLumi WF pass through
- Weld Pipe stub and flange assembly for WF interface/vacuum seal
- Re-assemble

Feedbox and End Can Interconnect

— Serves as the Magnet/Test Stand Interface (instrumentation, power, cryogenics, and vacuum

- Provides accommodation for thermal expansion/contraction and relative misalignment
- Can be used to accommodate some of the re-routing needed to align the cold mass nozzles with the corresponding feedbox circuits
  - If additional space is required to accomplish the re-routing, then a stand alone "Adapter box" will be incorporated to accomplish this



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Interconnect - Adapter Box (for options 2 - 4)

Mech. interface from the feedbox and return end can to the cryogenic, vacuum, power, and instrumentation features on the cold mass.

- No valves are envisioned in this interface/adaptor “box”
- It is comprised of piping, (probably with provisions for thermal contraction), a nitrogen cooled thermal shield, and MLI
- If this is a separate “box” then it is likely to remain as a “permanent” extension of the feedbox after the initial setup and use

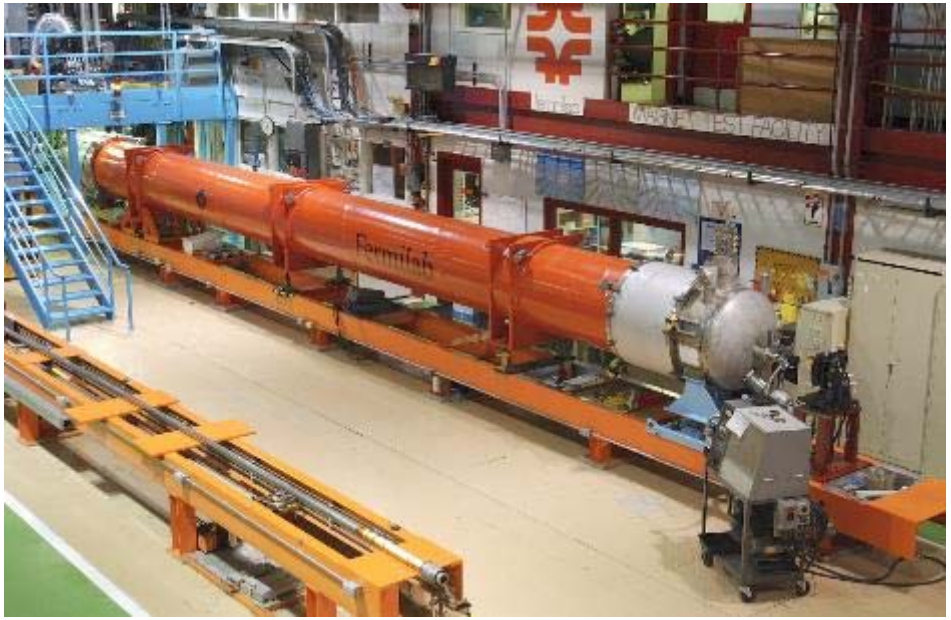
Tasks to perform are:

- Develop a Layout and Design for the Lead and Return End Interfaces
- Fabricate the Adapter/Interface Box/es
- Design and fabricate Bracing to support the Vacuum Load

Vacuum Vessel Supports on the Test Stand (same for 2 – 4)

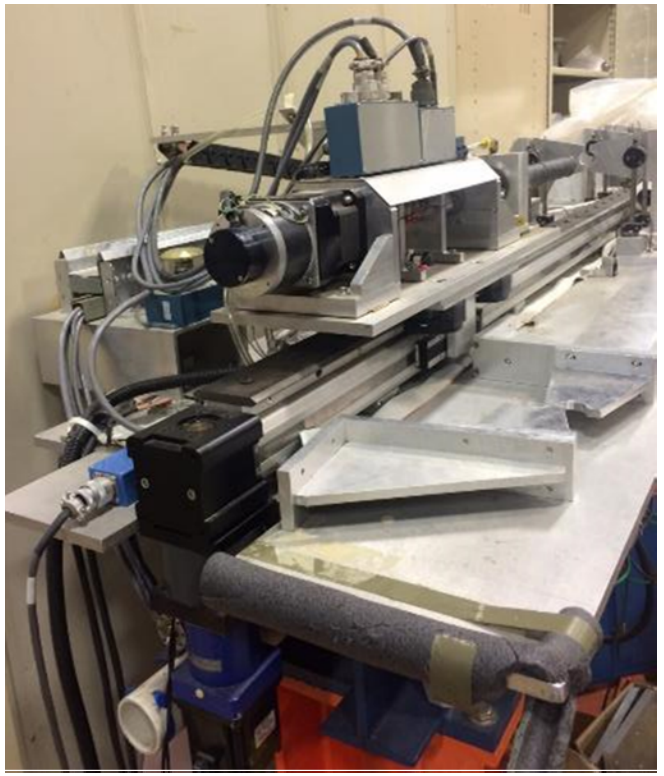
Features of the new supports will include:

- Ability to move the cryostat assembly in X,Y, and Z; and to fix the support once desired movement is achieved
- Ability to support the weight of the cold mass and cryostat assembly
- Ease of installation and removal



Option 4: Magnetic Measurements Probe and Warm Finger

- Design Warm Finger Assembly and extension
- Assemble Warm Finger
- Refurbish the Translation and Probe Drive Systems
- Refurbish the Probe Shaft Support System, and Optical Switch Electronics
- Procure/Fabricate Warm Finger and drive system Components
- Integrate new SSW system and Probe/s



Option 4: Designer Effort

- Modify Vacuum Sleeves – 1.5 wks
- Modify Baffles and test Stand Supports – 13 wks
- Adapt Interconnect Piping – 8 wks
- Adapter Box – 5 wks
- Design leak checking fixtures – 3 wks
- Design top plate – 3 wks
- Warm Finger Assembly – 4 wks

Total = 37.5 wks (0.86 FTE)

Option 4: Engineer Effort

- Design and fabricate new top plate – 4 wks
- Specify and Procure the Water-cooled flex leads – 2.5 wks
- Modify the Vacuum Sleeves around the PLs – 2 wks
- Modify the test stand supports – 4 wks
- Oversight for adaptation of interconnect piping – 5 wks
- Design and fabricate Leak Checking fixtures – 1 wk
- Adapter Box – 3 wks
- Warm Finger – 6 wks
- Oversight for the maintenance on the translation hardware for the measurement probe – 2 wks

Total = 29.5 wks (0.67 FTE)

Option 4: Mechanical Technicians Effort

- Disconnect and remove the top plate insert – 1.5 wks
- Disassemble and re-assemble the Return End – 1 wk
- Fabricate and install upgraded power components – 9 wks
- Install auxiliary services (compressed air, LCW, etc.) – 6 wks
- Assemble the top plate – 5 wks
- Modify Vacuum Sleeves – 1 wk
- Fabricate Expansion joints – 3 wks
- Assemble Warm Finger – 8 wks
- Assist with the maintenance on the Magnetic Measurements system drives – 16 wks

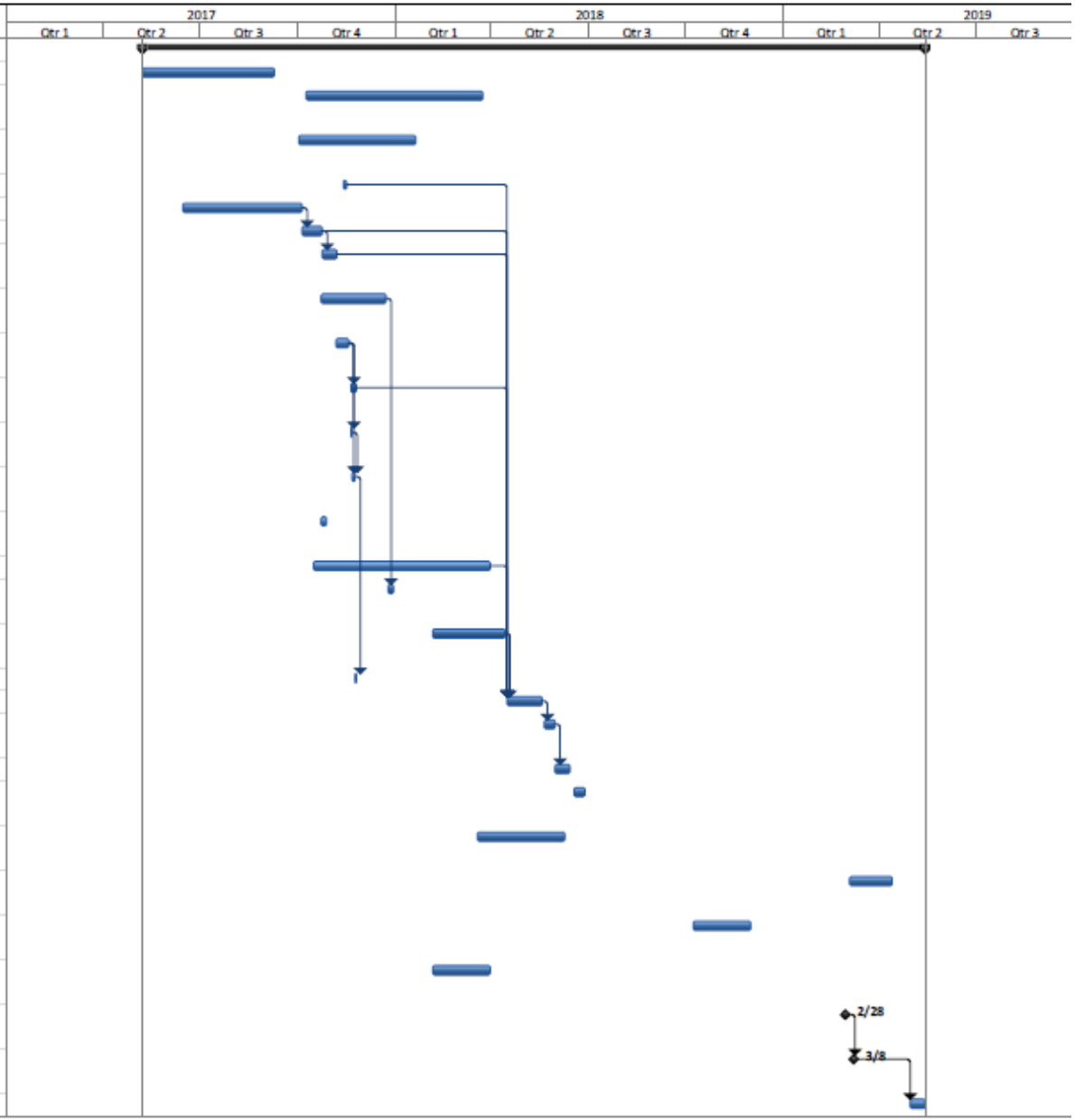
Total = 50.5 wks (1.15 FTE)

Option 4: M&S

- New Top Plate - $30K
- Flex leads - $9K
- Modify Vacuum Sleeves - $6.4K
- 20 kA vapor cooled leads - $77K
- Test Stand Supports - $10K
- Fabricate Adapter Box and Shield - $20K
- Misc. Welding (est.150 hrs.) - $12K
- Tubes for WF assembly - $7K
- Bellows, Spiders, pump-out/relief, etc. - $5K
- Replace Toothed Belt in translation system - $20K
- Service/replace components on the Measurement Table (pneumatic slides, optical switches, flexible coupling, etc. - $20K

- Total = $210K

ID	Task Name	Duration	Start	Finish
1	**Stand 4 Preparations - Option 4**	**526 days**	**Mon 5/8/17**	**Mon 5/13/19**
2	Design and Fabricate the Adapter Box	90 days	Mon 5/8/17	Fri 9/8/17
3	Design, fabricate, assemble, and test larger diameter WF assembly	120 days	Mon 10/9/17	Fri 3/23/18
4	Replace toothed belt, photo-eyes, covers on flexible coupling, translation slides	80 days	Mon 10/2/17	Fri 1/19/18
5	Disconnect existing flexible cables	3 days	Mon 11/13/17	Wed 11/15/17
6	Procure 20 kA Vapor Cooled Leads	80 days	Thu 6/15/17	Wed 10/4/17
7	Prep 20 kA Power Leads and VTaps	13 days	Thu 10/5/17	Mon 10/23/17
8	Construct and Install LTS bus section and flag	10 days	Tue 10/24/17	Mon 11/6/17
9	Specify and Procure Water-cooled Flexible Cables - 2 pairs	45 days	Mon 10/23/17	Fri 12/22/17
10	Dissassemble and Relocate External Piping and Transfer Lines	10 days	Mon 11/6/17	Fri 11/17/17
11	Disassemble, modify, and re-install baffles	5 days	Mon 11/20/17	Fri 11/24/17
12	Disconnect Lambda Plate " tie-down " rods	1 day	Mon 11/20/17	Mon 11/20/17
13	Remove the Top Plate Assembly and store on support structure	3 days	Tue 11/21/17	Thu 11/23/17
14	Disassemble and re-assemble the RE vacuum vessel	5 days	Mon 10/23/17	Fri 10/27/17
15	Design and fabricate a new top plate	120 days	Mon 10/16/17	Fri 3/30/18
16	Prep 1500 MCM cables and install at VMTF and Stand 4	5 days	Mon 12/25/17	Fri 12/29/17
17	Mofidy the Vacuum Sleeve Assembly around the power leads	50 days	Mon 2/5/18	Fri 4/13/18
18	Clean and Prep Lambda Plate surface	1 day	Fri 11/24/17	Fri 11/24/17
19	Assemble Top Plate	25 days	Mon 4/16/18	Fri 5/18/18
20	Install Top Plate Assembly and tie-down the Lambda plate	8 days	Mon 5/21/18	Wed 5/30/18
21	Perform Electrical Checkout of Stand	10 days	Thu 5/31/18	Wed 6/13/18
22	Verify performance of the lambda plate seal	8 days	Mon 6/18/18	Wed 6/27/18
23	Modify the test stand supports and install supports	60 days	Mon 3/19/18	Fri 6/8/18
24	Install Feed Box auxiliary services (air, water, etc.)	30 days	Mon 3/4/19	Fri 4/12/19
25	Adapt Interconnect piping (Feedbox to magnet)	40 days	Mon 10/8/18	Fri 11/30/18
26	Design and fabricate Leak checking fixtures	40 days	Mon 2/5/18	Fri 3/30/18
27	Receive Recommendation to operate (from Safety Panel)	0 days	Thu 2/28/19	Thu 2/28/19
28	Receive Operational Readiness Clearance (ORC)	0 days	Fri 3/8/19	Fri 3/8/19
29	Acceptance test and Commissioning	10 days	Tue 4/30/19	Mon 5/13/19



Option 4: Risks

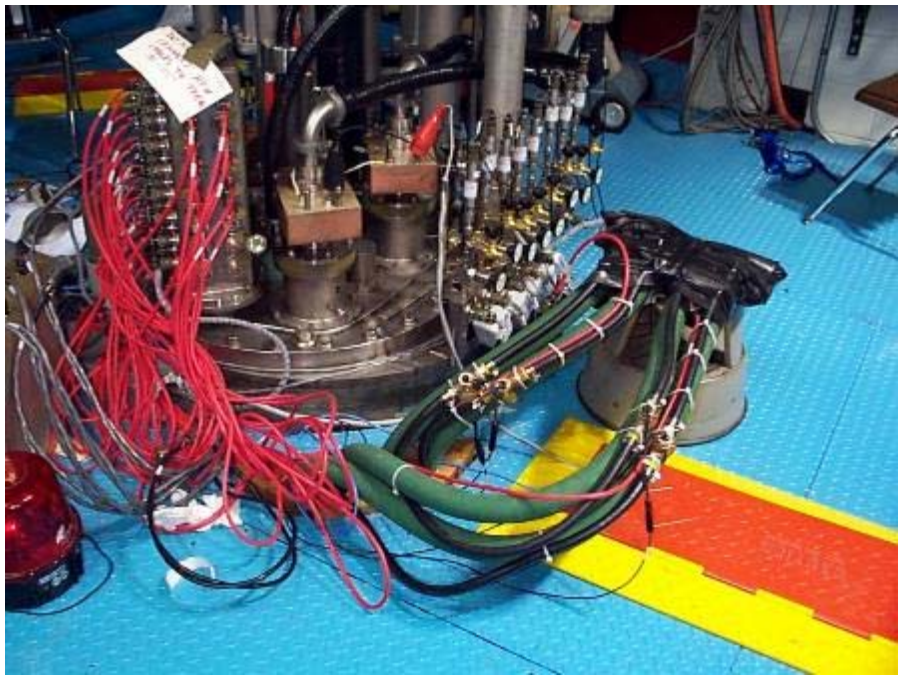
1. Low Technical risks (interface seals)
2. Unavailability of SME for some aspects of the magnetic Measurement System maintenance/refurbishment tasks (electrical, electronics, optical switches, etc.)
3. Lack of experienced personnel who are available to execute many of the specialized mechanical tasks (LTS soldering, vacuum leak checking, etc.)
4. Limited availability of qualified vendors to service some of the existing equipment (acquired in ~2000)

Option 3 – Mechanical Tasks

- Option 3 tasks include:
- Disassemble, clean, and service seals in the Feed Box
- Re-assemble and perform electrical checkout and leak check
- Extend the existing Warm Finger Assembly (this cold mass assembly is longer than IR quads; plus allowance for interface box/es)
- Develop supports at the re-useable cryostat to test stand interface
- Develop the adapter/interface box to align existing feedbox piping to the piping on the magnet cold mass
- Adapt Return End Piping to match piping on the cold mass (return end)
- Refurbish the magnetic measurement drive systems (probe rotation and translation, drive shaft support electronics, etc.)

Note: We will perform a thorough leak check and electrical checkout of the system after the assembly is reassembled

Feedbox (No Mech. Changes are required for Option 3)



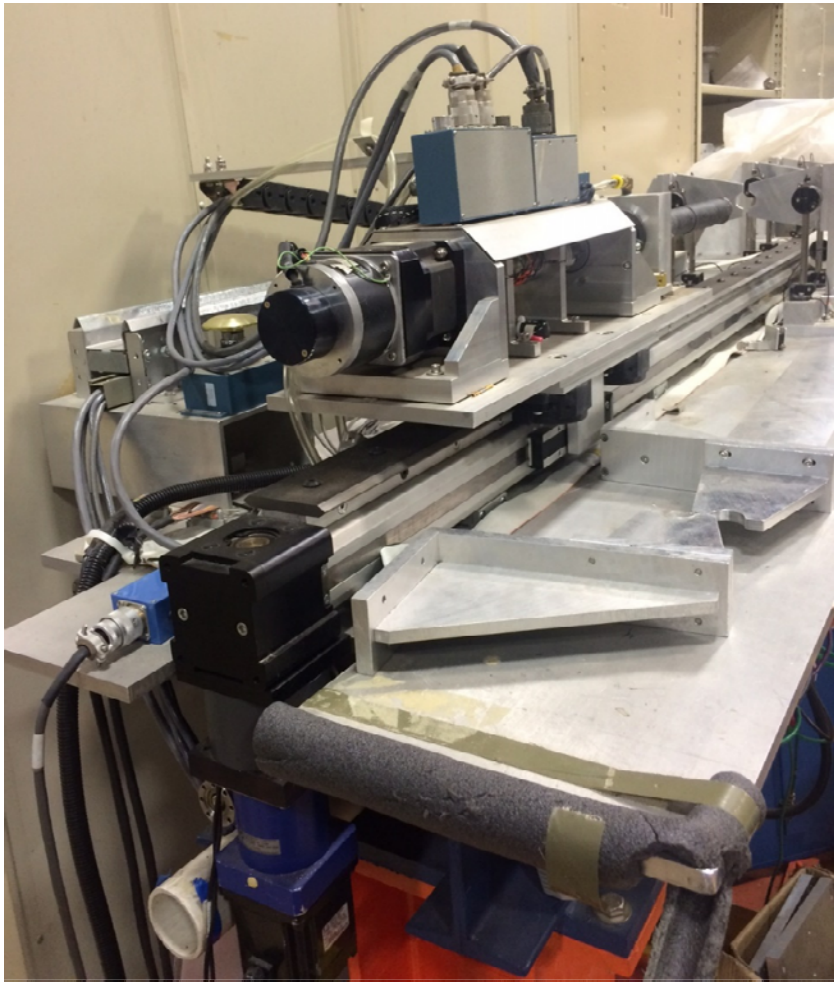
Top of Feedbox showing cryogenic, instrumentation, and power connections at the room temperature interface/s

Disassemble, clean, and service seals

Feedbox access port for magnetic measurements device insertion

Magnetic Measurements System (for Option 3)

- Disassemble existing Warm Finger
- Design and fabricate an extension to the existing Warm Finger Assembly
- Assemble and leak check Warm Finger
- Refurbish the Translation and Probe Drive Systems
- Refurbish the Probe Shaft Support System, and Optical Switch Electronics
- Integrate new SSW system and Probe/s



Option 3: Designer Effort

- Design and fabricate an extension of the existing IRQ Warm Finger Assembly - 3 wks
- Reconfigure Feed and Return Box piping to align with pipes for similar service on the cold mass assembly – 10 wks
- Design magnet-to-test stand support – 12 wks
- Leak Checking fixtures – 3 wks
- Adapter Box/es – 5 wks

- Total = 33 wks (0.75 FTE)

Option 3: Mechanical Engineer Effort

- Design and fabricate an extension of the existing IRQ Warm Finger Assembly – 1 wk
- Oversight to reconfigure Feed and Return Box piping to align with pipes for similar service on the cold mass assembly – 5 wks
- Adapter Box – 3 wks
- Design and fabricate leak checking fixtures – 1 wk
- Design and fabricate magnet-to-test stand supports – 4 wks
- Inspect and/or perform maintenance (clean, leak check, etc.) on mechanical components in the Feed and Return Box – 1 wk
- Oversight for the maintenance on the translation hardware for the measurement probe – 2 wks

Total = 17 wks (0.39 FTE)

Option 3: Mechanical Technician Effort

- Disassemble and re-assemble top plate insert – 3 wks
- Fabricate an extension of the existing IRQ WF Assembly – 2 wks
- Remove, inspect, clean, and re-install power components – 4 wks
- Reconfigure Feed and Return End piping to align with pipes for similar service on the cold mass assembly – 4 wks
- Inspect and/or perform maintenance (clean, leak check, etc.) on mechanical components in the Feed and Return End – 2.0 wks
- Assist with the maintenance on the Magnetic Measurements system drives – 16 wks

Total = 31 wks (0.71 FTE)

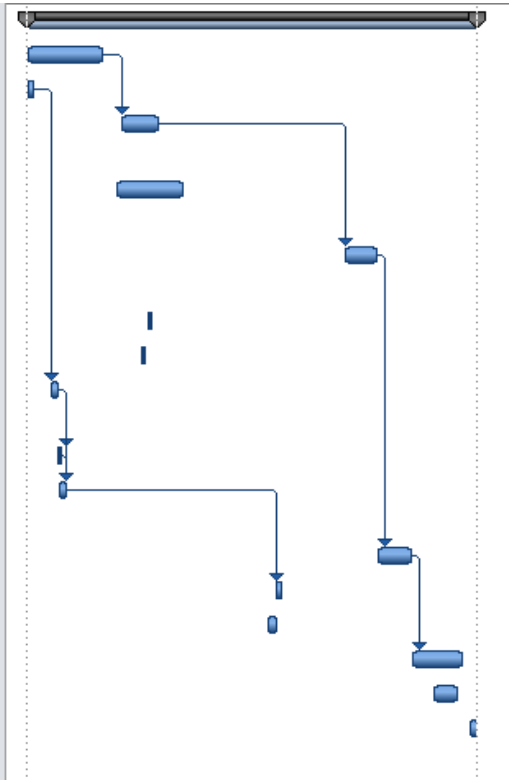
Option 3: M&S Estimate

- Modify the Test Stand Supports – $6.4K
- Fabricate leak Checking Fixtures – $6.4K
- Fabricate the Adapter Box/es – $20K
- Refurbish Measurement Table – 20 $K
- Spares for Measurement Table – 15 $K
- Fabricate WF extension – $1.6K
- Misc. Materials – $10K

- Total = ~$79K

Option 3: Schedule

		Stand 4 Preparations - Option 3	526 days	Mon 5/8/17	Mon 5/13/19	
2		Design and Fabricate the Adapter Box/es	90 days	Mon 5/8/17	Fri 9/8/17	
3		Disassemble the Test Stand	10 days	Mon 5/8/17	Fri 5/19/17	
4		Design, fabricate, assemble, and test the extension to the WF assembly	45 days	Mon 10/9/17	Fri 12/8/17	2
5		Replace toothed belt, photo-eyes, covers on flexible coupling, translation slides	80 days	Mon 10/2/17	Fri 1/19/18	
6		Adapt Interconnect piping (Feedbox and Return End to magnet)	40 days	Mon 10/8/18	Fri 11/30/18	4
7		Clean and Prep Lambda Plate surface	1 day	Fri 11/24/17	Fri 11/24/17	
8		Disconnect existing flexible cables	3 days	Mon 11/13/17	Wed 11/15/17	
9		Disassemble Clean and re-assemble the top plate Insert components	10 days	Thu 6/15/17	Wed 6/28/17	3
10		Clean and Prep Lambda Plate surface	1 day	Thu 6/29/17	Thu 6/29/17	9
11		Install Top Plate Assembly and tie-down the Lambda plate	8 days	Fri 6/30/17	Tue 7/11/17	9,10
12		Design and fabricate Leak checking fixtures	40 days	Mon 12/3/18	Fri 1/25/19	6
13		Verify performance of the lambda plate seal	8 days	Mon 6/18/18	Wed 6/27/18	11
14		Perform Electrical Checkout of Stand	10 days	Wed 6/6/18	Tue 6/19/18	
15		Modify the test stand supports and install supports	60 days	Mon 1/28/19	Fri 4/19/19	12
16		Install Feed Box auxilliary services (air, water, etc.)	30 days	Mon 3/4/19	Fri 4/12/19	
17		Acceptance test and Commissioning	10 days	Tue 4/30/19	Mon 5/13/19	



Option 3: Risks

- None

Option 2 – Mechanical Tasks (mostly the same as option 3)

- Option 2 tasks include:
  - —Disassemble, clean, and service seals in the Feed Box
  - —Re-assemble and perform electrical checkout and leak check
  - —Extend the existing Warm Finger Assembly (this cold mass assembly is longer than IR quads; plus allowance for interface box/es)
  - —Develop supports at the re-useable cryostat to test stand interface
  - —Develop the adapter/interface box to align existing feedbox piping to the piping on the magnet cold mass
  - —Adapt Return End Piping to match piping on the cold mass (return end)
  - —Refurbish the magnetic measurement drive systems (probe rotation and translation, drive shaft support electronics, etc.)

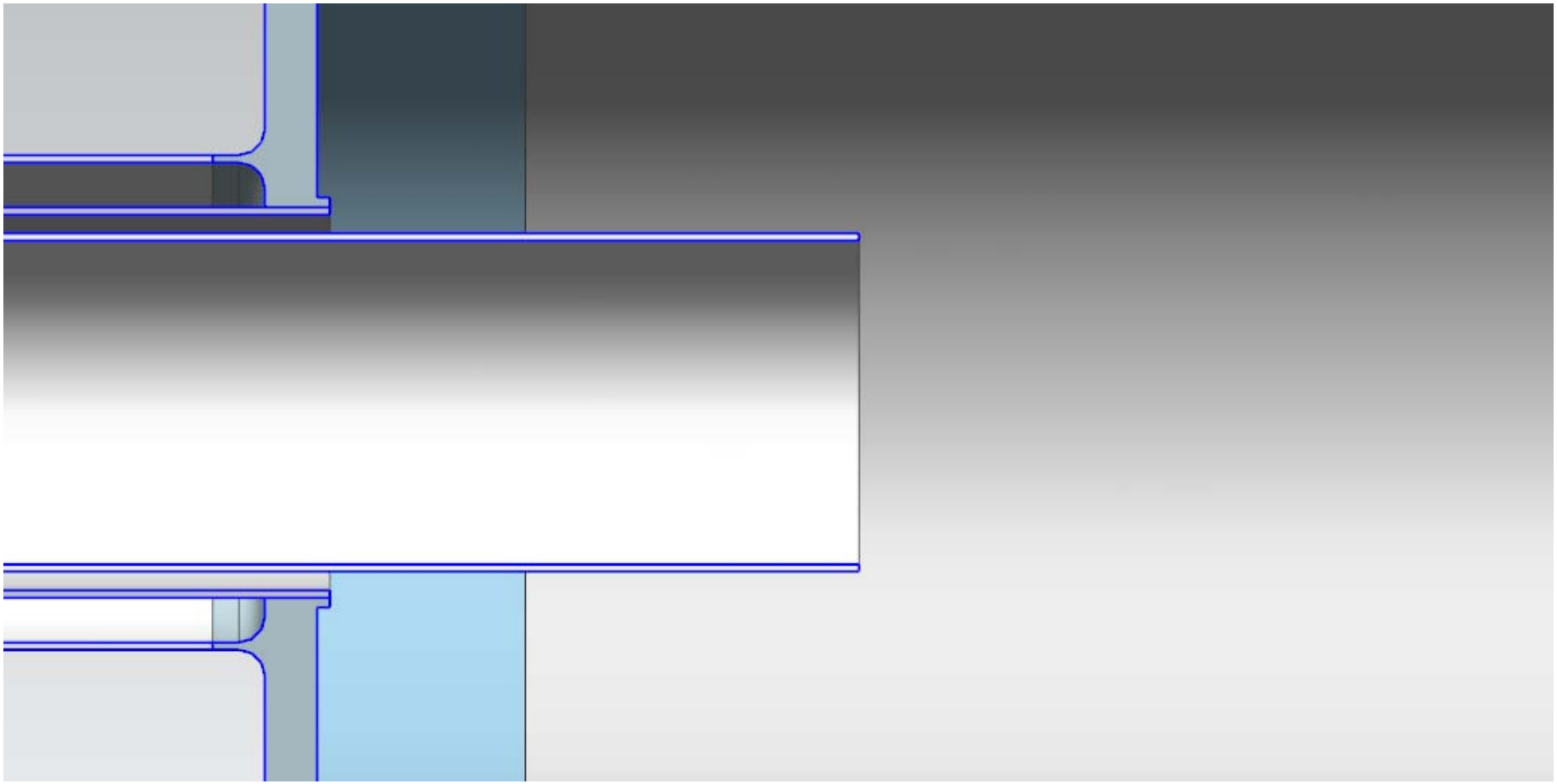
Effort and M&S Summary

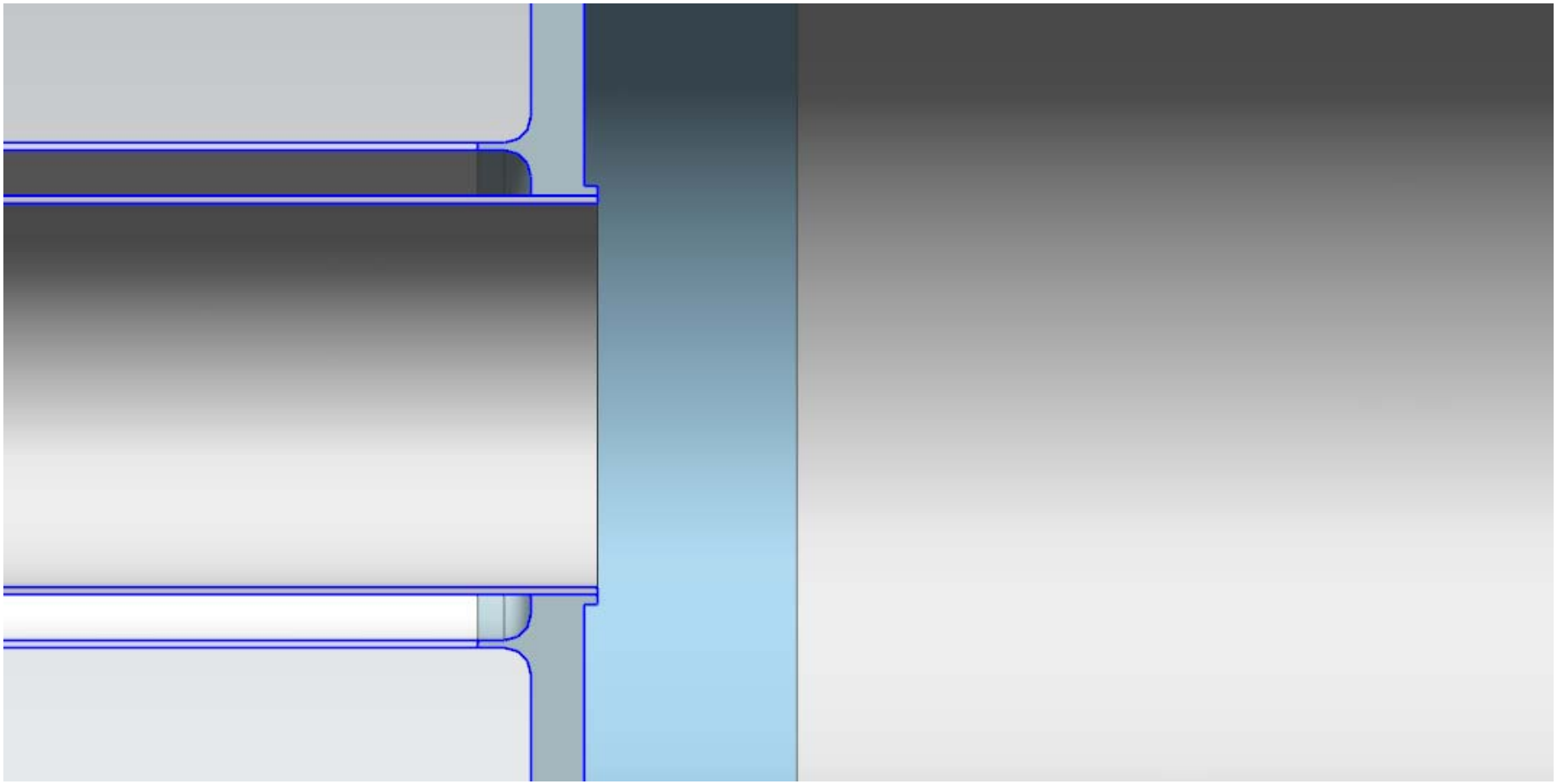
Option #	Designer (wks)	Engineer (wks)	Technician (wks)	M&S ($K)
2	33	16	30	45
3	33	16	30	79
4	37	30	52	210

Schedule for both options 2 and 3 are approximately the same. The schedule for both of these options could be collapsed with a later start date as compared to option 4.

Option 2 could be further reduced (with a later start date as compared to option 3), however, for this presentation the schedule duration for both option 2 and 3 was kept the same.

Back up Slides





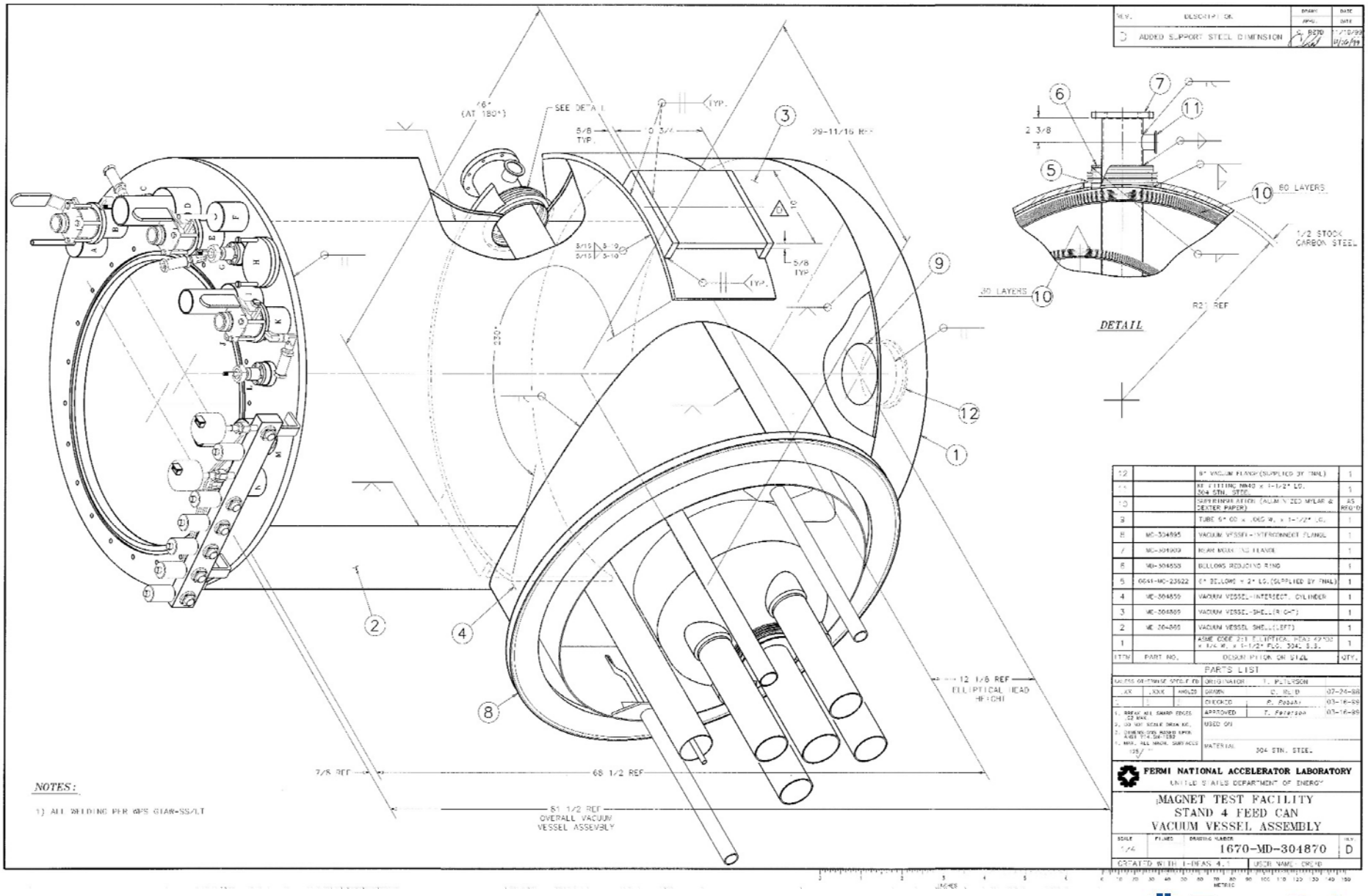
Return End

Disassemble

Machine larger opening

Fabricate and install larger port and flange

Re-assemble


DETAIL
NOTES:
1) ALL WELDING PER GPS GTAW-SS/LT
68 1/2 REF
61 1/2 REF
OVERALL VACUUM VESSEL ASSEMBLY
12 1/8 REF
ELLIPTICAL HEAD HEIGHT
60 LAYERS
1/2 STOCK CARBON STEEL
R21 REF
PARTS LIST
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
MAGNET TEST FACILITY
STAND 4 FEED CAN
VACUUM VESSEL ASSEMBLY
1670-MD-304870
304 STN. STEEL