Report on the Feasibility of Moving the MiniBooNE Detector/ four scenarios

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First draft 9/22/2010

Final report: 10/19/10

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EXECUTIVE SUMMARY

This report outlines some of the rough costs and conditions surrounding moving the MiniBooNE detector from its current location in the MiniBooNE detector hall to a temporary storage site 500 feet away from the MiniBooNE hall, for an unspecified duration of storage before moving it to a new detector hall in the MiniBooNE beamline.

The report is divided into four scenarios of performing the move:

1. Moving the ~950 ton detector as is
2. Moving the detector after removing only the oil
3. Moving the detector after removing the oil and the PMTs and supports, but not the cables
4. Removing everything from the detector and moving the empty steel spherical tank

Scenario 1 is clearly the most expensive move in terms of cranes and lifting fixtures. It is my opinion that scenario 1 is the only scenario that leads to an "identical" functioning detector at the new installation site. All of the other scenarios are compatible with decommissioning the detector, not to reconstituting and further running the detector in a new location. Once the oil is removed from the detector, I do not see a scenario that preserves it unchanged for future use in the existing detector. I think it would even be a technical challenge to transfer the oil from the existing detector into a new detector in a new detector hall without changing its properties (but that is not part of the scenarios described).

Scenario 2, 3 and 4 have much lower rigging costs (by a factor of 16) but complications caused by trying to preserve the oil in its current state after pumping it out of the tank.

Scenarios 3 and 4 involve significant human safety risks associated with people entering the tank to remove the PMTs and support structures.

INTRODUCTION TO THE SCENARIOS

From the Statement of Work for PO #595252, Bartoszek Engineering agrees to do the following:

"Provide descriptions and cost estimates and identify risks for removal and storage or relocation of the MiniBooNE detector under various scenarios as listed below.

All scenarios assume the top of the detector hall has been removed so that overhead access to the detector is available, and the place to which it is being moved for storage or relocation is prepared.

Assume the storage facility is located 500 feet from the present detector hall as specified by David Finley.

The storage facility is assumed to consist either of six caissons in an open field, or of a building constructed specifically for storage of the detector and any MiniBooNE equipment (such as the electronics and perhaps the phototubes and cables for those scenarios in which they are removed from the detector sphere.)

Scenario 1: The detector is to be moved as is, and with the cables attached to it.

Scenario 2: Same as Scenario 1 but with the oil removed from the detector sphere.

Scenario 3: Same as Scenario 2 but with the phototubes and their support structure removed from the detector sphere.

Scenario 4: Same as Scenario 3 but with the cables removed (meaning just the detector sphere.)"

The following sections describe each scenario in detail.

SCENARIO 1: MOVING THE DETECTOR AS IS

Description:

The MiniBooNE detector is a 40 foot diameter spherical storage tank filled with mineral oil and 1521 photomultiplier tubes (PMTs). The rough dimensions are as shown in figure 1.

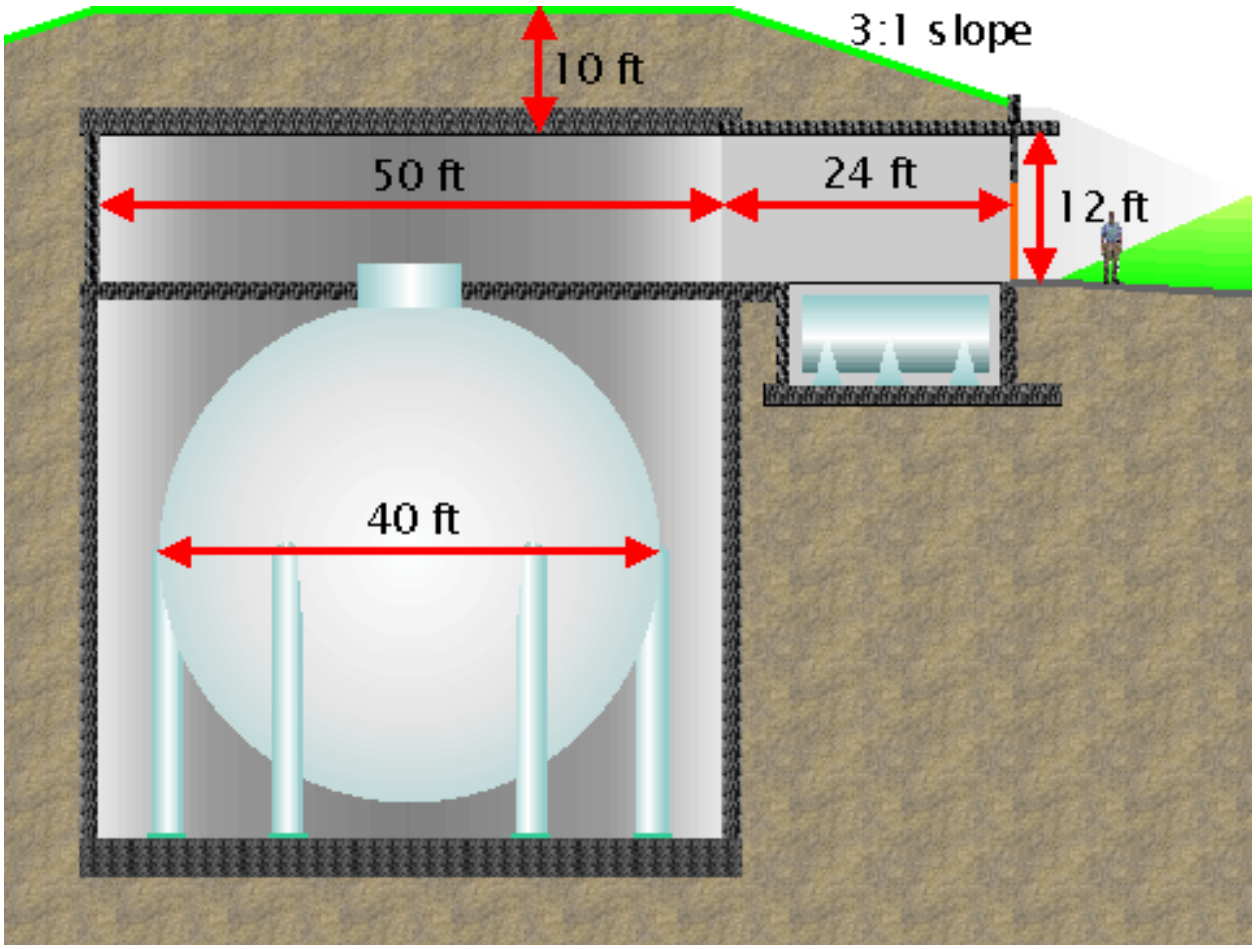

Figure 1: Cross section of the MiniBooNE tank in its hall, showing the oil overflow tank, the surface building and berm. Everything above grade level would be removed to remove the tank.

Details of the tank:

- Full the tank weighs ~944 tons (round up to 950 tons)
  - 884 tons of mineral oil
  - 50.6 ton steel tank empty (no PMTs or supports)
  - 7.5 tons of PMTs and support structure
  - 1.6 tons of cables to the PMTs

- 40 foot diameter
- Supported on 6 legs, each 28.75” OD
- 553 inches from floor to top of “top hat” on tank
- 1521 8" PMTs on a support structure

I contacted Deep South Rigging to find out the details of lifting and moving the detector. I spoke to Thad Lentz on 9/13/10. Deep South builds 1000 ton cranes. There are only a few companies in the US with the capability to move this load. Thad gave some details of the rigging process. I have added some details based on the needs of the detector.

- 20 days to set up the crane next to the detector pit.
- A "couple of hours" to raise the detector from the pit to the surface and put it on a transporter.
- The transporter is 25 feet wide and would be able to use a hard packed gravel road of that width that would have to be constructed at FNAL. The cost of the road is not included in this report.
- An 8 hour shift would probably be needed to complete the move to the temporary site.
- Thad proposed that the tank would need to have a steel "grillage" frame assembled around the bases of the six legs. This frame would have vertical columns near the legs that would connect to a similar lifting frame above the tank. A conceptual design for such a lifting frame is shown in this report, but the cost is not included in the costs shown for rigging the full detector. See the discussion under Risks.
- Once the transporter reaches the temporary storage site there would be support pillars (Thad referred to them as "cans",) placed over the caissons at the site that would line up with hard points on the grillage frame. The transporter has hydraulic capability to change its elevation. The transporter would lower the detector and grillage frame onto the cans, then lower itself enough to be pulled out from under the detector.
- Thad did not think synthetic slings of >170 ton capacity each wrapped around the connection between the legs and sphere would be a sufficient and practical way to lift the full tank.
- The tank will need a temperature control system. See the discussion under Risks.
- The tank will need a temporary dry nitrogen system to maintain the dry nitrogen coverage inside the top hat of the tank. See the discussion under Risks
- Secondary containment of the oil during the lift and transport might need to be built in as part of the lifting fixture. This will complicate and make the lifting fixture more expensive.

- An engineering study and soil testing will be needed to assess the risk of the weight of the crane and detector on collapsing the wall of the detector hall. The cost of the testing and study is not included here.

Contact information for Deep South Crane and Rigging:

Thad Lentz
Deep South Crane and Rigging
15324 Airline Highway
Baton Rouge, Louisiana 70817
Tel. (225) 753-4371
Fax (225) 751-7700
http://www.deepsouthcrane.com/

Cost:

Based on the phone conversation with Thad Lentz from Deep South Rigging, the cost to bring a 1000 ton crane to Fermilab, set it up and transport the detector to its temporary location is approximately $4 million. This would get the detector only to its temporary storage location. A similar cost would be required to move the detector to a new location at a future time.

Cost of the gravel road: unknown

Cost of the lifting fixture and secondary containment: unknown

Cost of the tank temperature control system: unknown

Cost of the temporary dry nitrogen supply to the top of the tank: unknown

Cost of the engineering study and soil testing: unknown

Risks:

This scenario in my opinion has the highest probability of preserving the characteristics of the detector as it is right now. As long as the temperature of the oil in the tank can be maintained at its present temperature, and exposure to oxygen avoided, the risk of changes to the characteristics of the oil is minimal.

In this scenario, the oil acts as a cushion for all of the PMTs. The inertia of the full detector protects the PMTs from accelerations that might be harmful to them or their internal components. None of the following scenarios share this characteristic.

The setup of the 1000 ton crane may or may not happen in parallel with the removal of the roof of the detector hall. Weather will be a major factor and the reason that a system will be needed to maintain and control the temperature of the tank, as the tank will be exposed to the full range of temperatures of the outside environment. The oil must not be allowed to cool to the point where it becomes cloudy. Because the tank will be detached from the oil over-flow reservoir, the oil must also not be allowed to warm significantly or it will expand in volume and over-flow the tank.

The system I imagine involves an insulated blanket with heaters and thermocouples wired into it to maintain a constant temperature. If the move happens in the summer time, the insulating blanket will need a highly reflective outer cover to reflect sunlight.

The blanket would also need to be water-tight because of the high probability of rain (or snow) during a month-long exposure to the weather.

The oil has been under a cover of dry nitrogen since it was pumped into the tank and cannot be exposed to oxygen. One liter per minute of dry nitrogen has been flowing into the tank since 2001. A constant supply of dry nitrogen will be needed for the area below the lid of the tank and above the level of the oil. The amount of nitrogen needed varies with the amount of time the detector will be in storage. Provision for N_2 tank replacement and monitoring of nitrogen level will be necessary.

The purpose of the grillage lifting frame is several-fold. It prevents any change to the tank shape by lifting the legs from near where they are attached to the floor. It also avoids the problem of picking the detector from lifting points that are below the center of mass of the tank. The frame needs to be rigid enough that the tank is not allowed to move with respect to the frame as the crane is lifting the frame from its top structure (thus making the CG of the lift below the pick points). (Any relative motion between the tank and lifting frame could lead to oil sloshing or instability of the lift.) To assemble the grillage around the base of the detector, the stairway which is the only access to the floor of the detector hall currently, will have to be disassembled and removed. This creates new risks as an alternate method of man access to the floor of the detector hall will be needed. Depending on the nature of the new access, confined space rules may need to be applied to the floor of the hall.

A concept sketch of the grillage frame is shown in figures 2 and 3. Not shown are the columns adjacent to each leg and the upper frame that the crane hook connects to. The sketch shows that even very large beams may be lowered between the cylindrical concrete walls of the hall and the tank. The beams shown would probably need to be connected to each other by radial spoke beams underneath the tank. Height between the floor and the tank is limited to around 32 inches near the center of the bottom of the tank.

If beams such as the W40 x 268, or any beam close to it in the AISC table, are required these beams are not domestically produced. The grayed out section of the beam tables in the AISC Manual of Steel Construction represents beams that can only be procured overseas. I used beams of this size back in the mid '90s for an experiment at the Bates Laboratory. Those beams had to be shipped from Belgium. Beams like these will have to be procured well in advance to avoid schedule delays in the project.

The design of the lifting/grillage frame is an equivalent effort to designing a 5 story building, but the loads to be lifted are much higher than in any building of that size. It will have to be designed by structural engineers and satisfy both the AISC Code and the ANSI/ASME B30.20 Below-the-hook Lifting Devices Code.

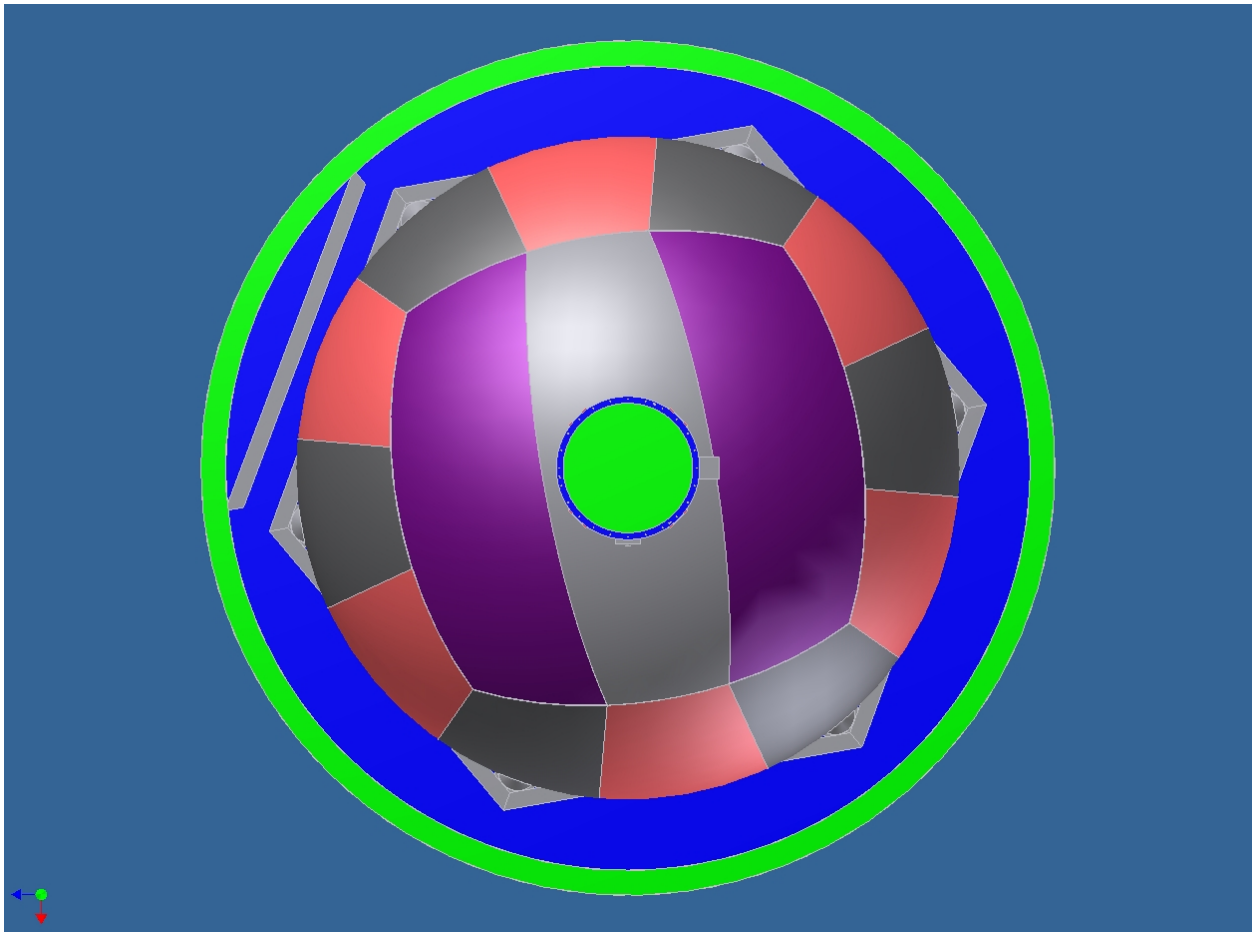

Figure 2: Top view of the Detector hall with the roof removed showing the lowering of beams for the grillage frame. The beams were approximately sized to be W40 x 268 and there is sufficient room around the tank to lower the beams in once the stairway has been removed. Longer beams that cross underneath the tank would have to be brought in sections and pieced together on the floor of the hall. See the text for more discussion.

Currently, the MiniBooNE detector hall is the secondary containment for the detector. FNAL ES&H will have to be consulted to determine the need to provide secondary containment for the oil during the move. This could require that the lifting fixture have additional features sufficient to catch and hold some or all of the oil in the event of a catastrophic leak from the sphere. Assembling a leak tight basin around the bottom of the detector will be a labor intensive, expensive and difficult activity, probably requiring welding to seal the basin. It could be the equivalent of building a cylindrical flat bottom tank around the spherical tank.

The soil around the detector will have to be tested and an engineering study will have to be done to determine whether the weight of the crane plus detector poses any risk of collapse to the walls of the detector hall.

This scenario is the most expensive in rigging costs, but has no need of alternate storage of the oil.

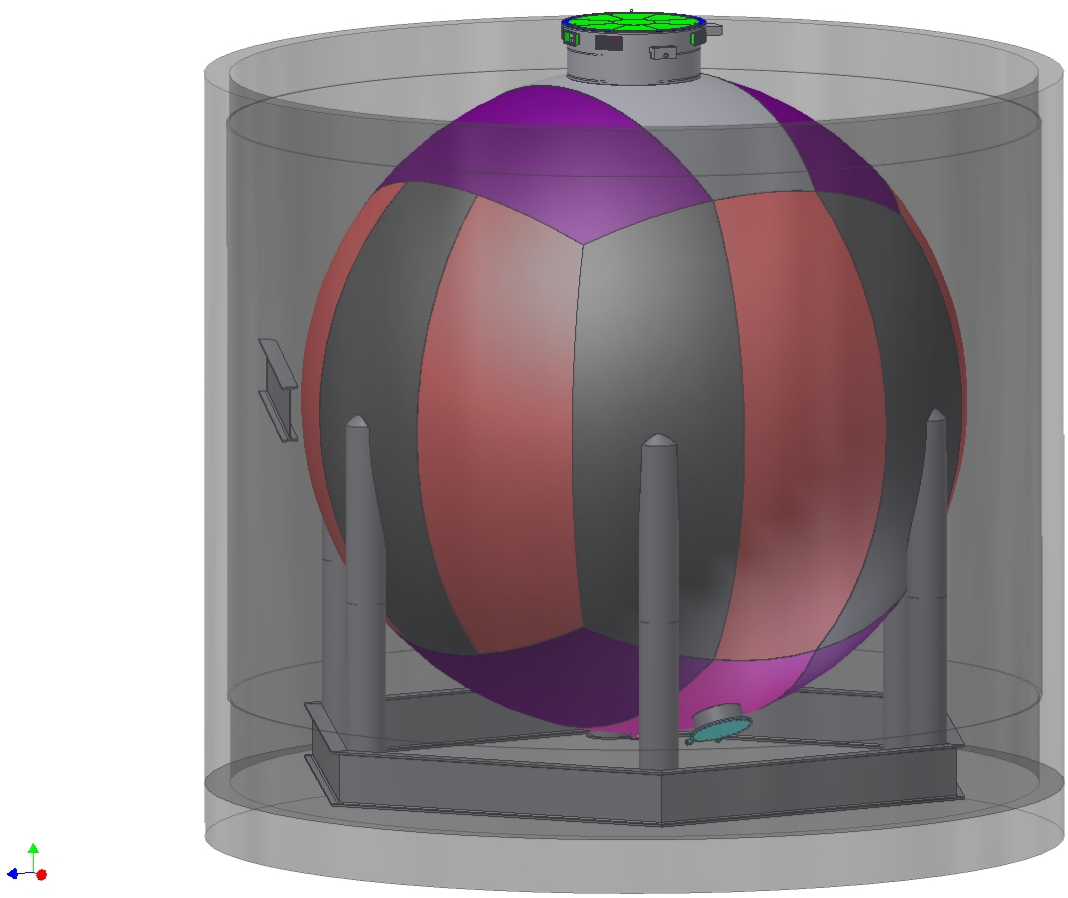

Figure 3: Conceptual sketch of the grillage frame assembled around the legs in the detector hall. There is an additional beam to show that it can be lowered past the equator of the tank without interfering with the wall of the hall. The wall of the detector hall is rendered transparent here. A similar frame would be assembled above the tank and the two frames would be connected by columns. The hook of the crane would attach to the upper frame. Gussets and reinforcements are not shown.

Figure 4 shows that when the detector is on the 25 foot wide transporter some of the tank legs will not be on the transporter, but are overhanging to each side. This configuration is exactly the reason why the grillage frame has to be so rigid. The frame has to support all of the legs and prevent them from deflecting, even if the legs are not receiving support from anything below them. Each leg is carrying almost 160 tons of weight. The grillage frame has to carry that load in bending without stressing the tank wall and changing its shape.

The configuration shown in figure 4 is actually the only way that the transporter hydraulics can get the detector off the transporter. When the transporter gets to the temporary storage site, the four overhanging legs are aligned with the "cans" (column supports) over the caissons that will carry the weight of the tank down to the ground. The transporter then uses its internal hydraulics to lower itself allowing the detector to sit on the cans. While the transporter is pulled out from under the detector, only four legs carry the weight of the entire detector to the ground, the ones that were outboard of the transporter. The two legs that were on the transporter are only supported by the grillage frame. Only after the transporter is removed can the

remaining two legs be supported with columns that have adjustable heights (hydraulic cylinders most likely).

The road that the transporter uses is not likely to be correctly aligned so that the sphere can be directly lifted and placed straight on the transporter. To achieve the orientation of the legs on the sphere with respect to the transporter means that the crane may have to have a swivel hook capable of rotating with a near 1000 ton load. Thad assured me that this is possible and done with their cranes.

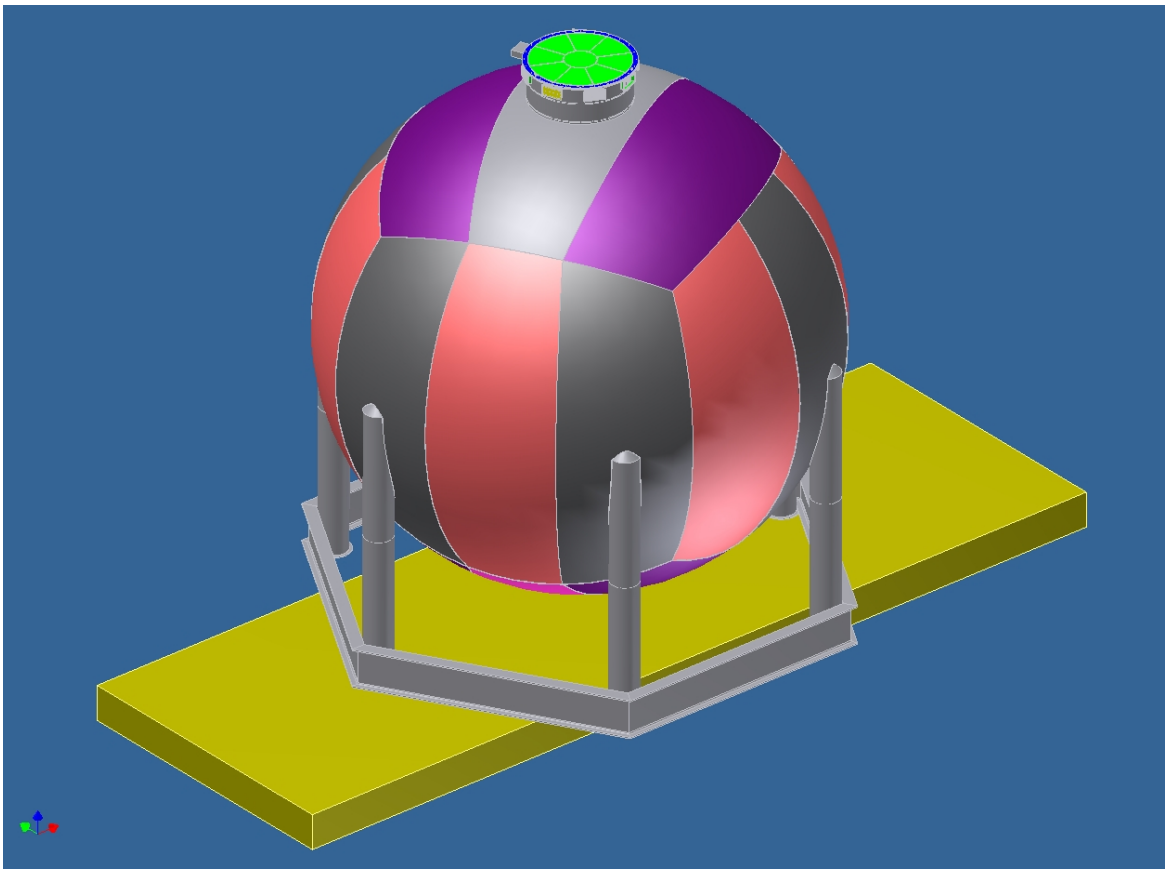

Figure 4: View of the detector on a simplified placeholder of the 25 foot wide transporter. The vertical columns and top frame are not shown here. This configuration shows that the grillage frame must be stiff enough to hold the legs as though they were still attached to the concrete floor of the detector hall to prevent the sphere from changing shape even if some of the legs are not touching a flat surface. More beams are necessary beneath the tank than just the six shown to create the required stiff platform.

Using hydraulics to pick up the load of the last two legs allows easy measurement of exactly how much load each leg is carrying. The goal is to have all six legs at the temporary storage site carrying the same loads they did in the detector hall at the same elevation they were previously with respect to one another. Hydraulics on the other cans may be useful as well for monitoring leg loads.

Once I saw how massive the grillage frame needed to be I realized the total weight of the crane pick could be well over 1000 tons. Thad assured me that Deep South Crane and Rigging can go as heavy as a 1600 ton load before they exceed the capacity of their largest crane. The six beams shown add almost 14 tons to the total

load. It is very doubtful that even a fully developed frame and secondary containment vessel would raise the pick weight close to 1600 tons.

Another risk to the detector is an accident during assembly of the grillage frame that drops one of these heavy beams on the detector.

I asked Thad to provide the terms of contracting a 1000 ton crane and what the potential cost and schedule risks are of canceling the crane contract. This is his reply:

> *"Typically a customer reserves a crane with a letter of intent approximately 18 months prior to the job. This letter holds the crane on a first right of refusal for 4 to 6 months. Should another job come up for the crane during your time frame, you will be given the opportunity to implement a contract promptly. Once a contract has been signed (preferably 12 months prior to job) a monetary cancelation clause will be written into the contract. The maximum cost for this crane is $1,250,000.00. (See example below.)*
>
> *EXAMPLE ONLY*
>
> *Cancellation Terms*
>
> *It is our understanding that this project is slated for October, 2013.*
>
> *In the event the project is cancelled or postponed, the following conditions and charges will apply:*
>
> *Basis of postponement / cancellation charges:*
>
> - *Minimum cancellation / postponement charge is: $500,000.00 (except as noted).*
> - *Contract mobilization commencement date is 1 September 2013 (baseline date for the purpose of calculating cancellation / postponement costs).*
> - *Cancellation / postponement charges have an effective date of 1 April 2012.*
> - *Cancellation / postponement charges increase incrementally by $1,389.00 per calendar day starting at $500,000.00 on 1 April 2012 to a maximum of $1,250,000.00 on 1 September 2013.*
> - *If project is cancelled, and Deep South is able to secure a like kind project to replace this project, then there will be no cancellation charges except for incurred costs.*
>
> *Postponement Terms*

In the event the project is postponed, the following conditions and charges will apply:

Basis of postponement charges:

- *All charges detailed above will be applicable if project postpones.*
- *Additional conditions in the event of a postponement:*
    - *Proposal pricing will remain valid for up to (12) months from contract "hook-in-air" date of 1 October 2013.*
    - *Any postponement in schedule will be subject to availability of personnel and equipment.*

Schedule Float

Deep South has agreed to provide ConocoPhillips with a limited amount of schedule float:

Basis of schedule float: (the intent of the schedule float clause is to provide COP with a "+/-" two week (cumulative)conditional window in which to begin the T/A)

From date of contract execution or 1 April 2012 up to 31 January 2013, Deep South will allow a hook-in-air date float of "+/-"(2) weeks with no financial impact to COP.

From 1 February 2013 up to 13 July 2013, Deep South will allow a hook-in-air float date of "+" (2) weeks and "–" (0) weeks with no financial impact to COP.

From 13 July 2013 until contract hook-in-air date of 1 October 2013, hook-in-air date will remain fixed and equipment will commence billable time on contract hook-in-air date."

As can be seen above, uncertainty in the schedule can lead to substantial additional costs.

SCENARIO 2: MOVE THE DETECTOR FULLY ASSEMBLED BUT EMPTY OF OIL

Description:

The tank weighs approximately 59.7 tons (60 tons rounded,) empty of oil but containing all other components.

It may be possible to weld on lifting lugs to the legs of the tank for this lift, or the use of synthetic slings around the legs may be practical in this case.

A lifting fixture between the tank and crane hook is probably still required.

A wider gravel road is still required for the transporter.

Another rigger that I contacted was Alan Sheeler of Lockwood Brothers Inc. Alan had an interesting variation on the move that deals with this scenario. His idea is to temporarily remove the oil from the vessel to make moving the tank easier (using a smaller, cheaper crane) then putting the oil back in the tank during the temporary storage period. The oil would have to be removed and stored again when the final detector hall is ready and the detector moved from the temporary to final location.

The removal and temporary storage of the oil is non-trivial as described in the risks section. Alan gave estimated costs for oil removal in an e-mail but a full analysis was not performed.

Contact information for Lockwood Brothers:

Alan H. Sheeler
Lockwood Brothers Inc.
220 Salters Creek Road
Hampton, VA 23661
Tel. (757) 722-1946
http://www.lockwoodbros.com/

Cost:

According to Thad Lentz of Deep South Crane and Rigging, the cost to move the detector to the temporary storage site without oil is in the range from $250,000 to $300,000

Cost of the below-the-hook lifting fixture: unknown

Cost of alternative storage for the oil (including temperature control and dry nitrogen coverage): unknown

Cost of the gravel road: unknown

Alan Sheeler provided the following table by email:

Using round numbers for an order of magnitude:	
Vessel modification design and implementation	$100K
Oil out	$200K
Rigging Design and creation	$100K
Crane rental (3 month min) and Rigging Crew	$500K
Oil in	$200K
Later date (to go from temp storage to final location):	
Oil out	$200K
Crane and Rigging crew	$500K
Oil in	$200K
Total Job:	$2.0 M

To compare Alan's and Thad's estimates, we need to first realize that Thad's estimate is only for the move from the original location to the temporary storage location, and that it is ambiguous on exactly what is included in the estimate. (For example, it is not clear to me whether the cost of the lifting fixture for the lighter move is included or not.) For this scenario, Thad's estimate for the move to temporary storage is $300K while Alan's is $1,100K when the oil removal is included. Thad gave no indication of the cost of the oil removal and storage.

In my opinion, Alan's estimate for the cost of removing and replacing the oil should be considered a rough guess reflecting no real work to come up with the number.

Finally, Alan thought that the cost to move the tank full of oil (Scenario 1) was potentially much higher than the Deep South estimate, but he refrained from giving an estimate for that scenario.

Risks:

The risk of collapsing the wall of the detector hall is greatly reduced in this scenario.

The size of the crane is also substantially reduced here. The size of the transporter is probably not reduced, but the weight capacity of it can be substantially less than in the first scenario.

The risk of changing the properties of the oil is non-negligible in this scenario. The oil must be pumped out of the tank and stored in a larger number of smaller containers. For example, the tank holds about 250,000 gallons of oil. This can be divided into the following numbers of containers:

Type of Storage container	Number required
Rail car, 30,000 gallons each	9
Portable tank, 21,000 gallon capacity	12
Tanker truck, 9,000 gallon capacity	28
Tanker truck, 5,500 gallon capacity	46
55 gallon drum	4,546

After a brief web search, I spoke to Ed Olson of Adler Tank Rentals, 815-530-5467. He does not stock any food-grade containers of any kind. The oil was originally transported from the rail head at FNAL to the detector site by food-grade tanker trucks. It is cheap to rent a 21,000 gallon portable tank from Adler at $40/day, but it is not stainless and may be contaminated with whatever was last stored in it. The tanks are delivered washed out, and it is the renter's responsibility to clean out the tank before returning it to Adler. I do not think these tanks are a viable option to store the oil if the intent is to return it to the detector unchanged.

I think the only storage options are food grade containers or clean stainless steel containers. I do not have information about the cost or availability of this kind of tank.

The same temperature controlled conditions for the oil are required in any scenario where the intent is to restore the detector to its original condition. No matter what the oil is stored in, its temperature must be maintained near the temperature it is at right now.

The dry nitrogen coverage is also required during temporary storage. The oil will be exposed to oxygen during removal and pumping into temporary storage. When the oil was initially pumped into the tank, it was bubbled with dry nitrogen to drive off the entrained oxygen. I do not know how such a system can be applied to temporary storage tanks.

Once the oil is removed from the tank, I do not see how it can be guaranteed to have exactly the same properties it has right now in the detector.

I do not see how scenarios 2, 3 and 4 can be reconstituted into an identical detector at the new location in the future.

The risk of damage to the PMTs is also larger in my opinion in this scenario. In Scenario 1, the detector weighs so much that it is hard to imagine "bumping" it or accelerating it fast enough to cause any differential motion of the liquid that could harm the PMTs, or by extension the photocathode arrays and other delicate components inside the PMTs. The riggers I spoke to thought that the motion of the crane and transporter in either Scenario 1 or 2 would be gentle enough to avoid damaging the PMTs, but the risk is greater in Scenario 2 than in Scenario 1.

SCENARIO 3: MOVE THE DETECTOR AFTER REMOVING THE PMTS AND SUPPORT STRUCTURE

Description:

In this scenario the tank is first drained of oil. All of the conditions and risks of the preceding scenario about changing the properties of the oil hold for this scenario.

Once the tank is drained of oil, the man hatch on the bottom of the tank is removed and the PMTs and their support structure are removed in the reverse order in which they were assembled.

The weight of the tank without oil or PMTs is approximately 52.2 tons. (Weight of steel tank plus cables only.)

Photos are included here to show how the PMTs were installed initially.

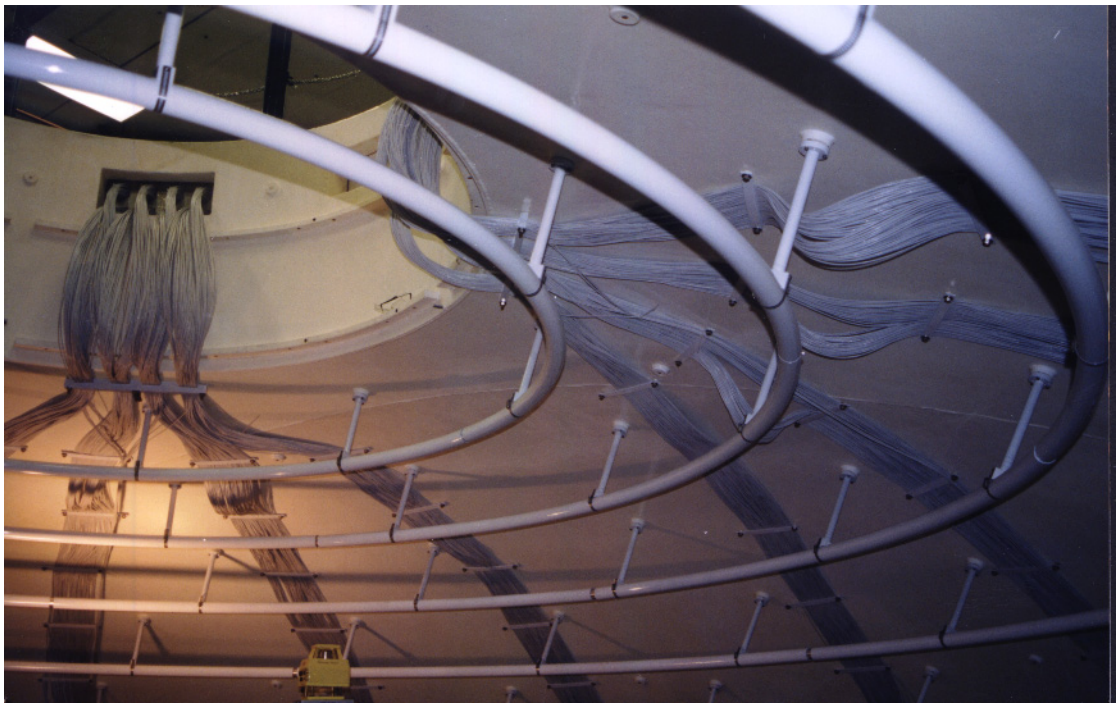

Figure 5: A view of the "Lats and Struts" near the top of the tank, the support structure that holds up the light-tight panels that separate the inner volume of the detector from the veto region. The light-tight panels (shown in the next picture,) support the inner PMTs. This picture also shows the cable bundles that run through the tank that are addressed in Scenario 4. These cables would be the only things left inside the tank in Scenario 3.

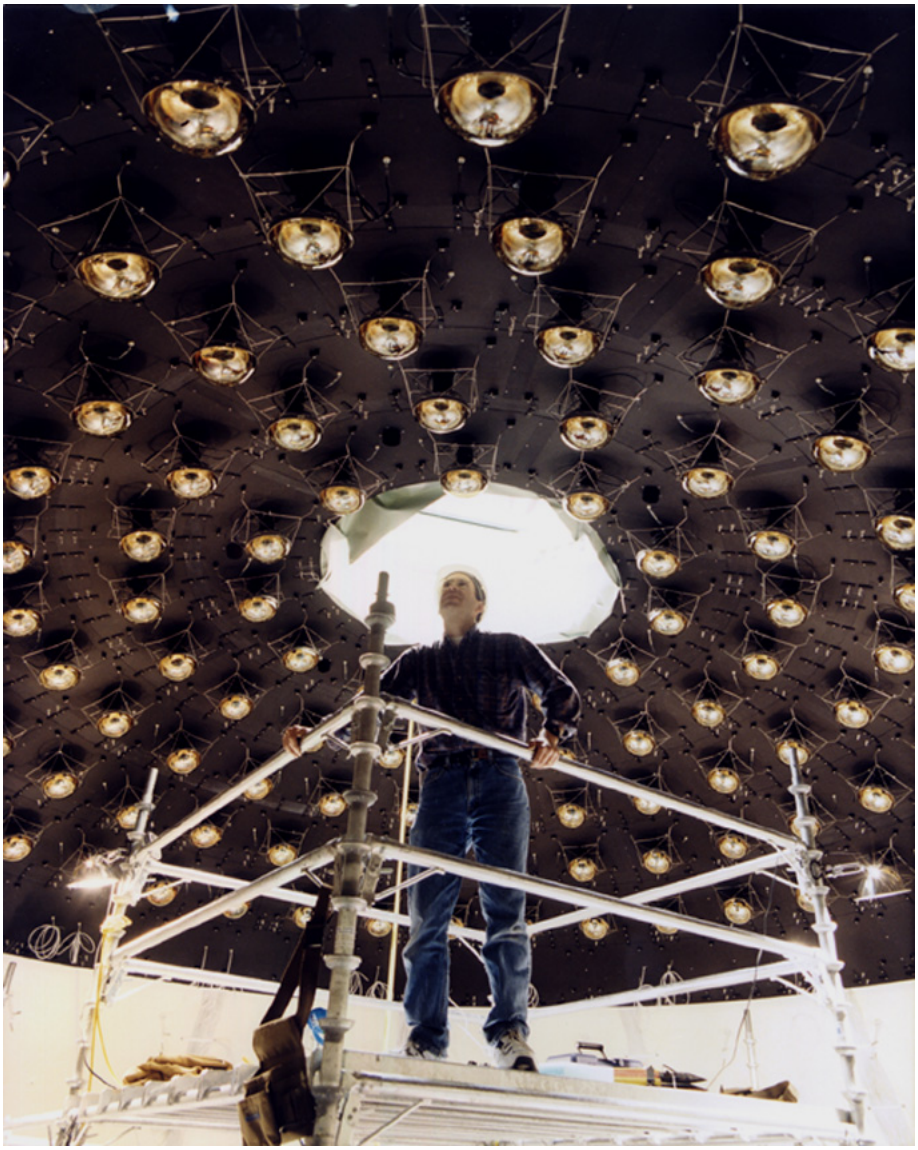

Figure 6: The inner light-tight panels are assembled at the top of the detector with the inner PMTs. This picture was taken early in the assembly of the internals of the detector. The black panels are bolted to the lats and struts shown in Figure 5. Scaffolding was erected inside the tank to assemble everything from the top down. As rows were completed, the top level of scaffolding was removed out the man hole in the bottom of the tank (shown in Figure 7.)

As shown in the photos, scaffolding will have to be brought in through the bottom man-hole and re-erected inside the tank. PMTs and structure will be removed from the bottom up.

This scenario poses two choices for the PMTs and support structure.

- Choice 1: Bag all of the components but do not attempt to clean them of oil
- Choice 2: Clean the oil off of every component and store them in clean, dry storage

The challenge with choice 1 is what to bag the parts in that will not be degraded by the mineral oil and contaminate it. This will require testing similar to the oil compatibility testing that was done during the design of the tank to determine what materials would be allowed in the tank. In spite of the compatibility of the bag material, the oil soaked parts will still be exposed to oxygen. If these parts are reinstalled in the detector without any cleaning it is not clear how the oil would not be contaminated with oxidized oil and other contaminants picked up in the disassembly. The exposed surface area and thin films of oil would guarantee that the oil surrounding the removed parts would get thoroughly oxidized. It is not known if the bubbling process that was initially used to drive out oxygen from the oil after initial delivery would work again, but it is certain that if it did work the oil would not have the same characteristics it has now for a period of months after reassembly of the detector.

The time required to store everything in this choice would presumably be less than that required in Choice 2, but the stored parts would have to be tagged and organized for safe keeping as in Choice 2.

The challenge with choice 2 is what to clean everything with that will leave the PMTs functional and not produce environmental waste. This is a major operation requiring the equivalent of a factory set-up to clean, organize and store all of the components of the detector. Choice of detergent and waste water disposal will require testing and consultation with FNAL ES&H.

Figure 7: A view of the bottom of the tank showing the man-hole and the drain line and valve. All of the scaffolding is brought into the tank through the man hole on the left of the picture.

The only difference in the disassembly process of Scenario 3 and Scenario 4 is that if Scenario 3 is chosen, the cables would not be unfastened from the inside surface of the tank.

If Scenario 4 is chosen, during the disassembly of the PMT support structure, while the scaffolding is in place, the cable ties would have to be removed and the cables allowed to dangle free.

Cost:

Extrapolating from what Thad Lentz of Deep South Crane and Rigging said for scenario 2, the cost to move the detector to the temporary storage site in Scenario 3 is also in the range from $250,000 to $300,000. The detector weight in this scenario is only 7.5 tons less than in scenario 2, an insignificant difference to cranes of this scale.

Cost of the below-the-hook lifting fixture: unknown

Cost of alternative storage for the oil (including temperature control and dry nitrogen coverage): unknown

Cost of the gravel road: unknown

Cost of bagging supplies, compatibility testing, and storage facility for Choice 1: unknown

Cost of cleaning supplies and factory set up for Choice 2: unknown

The Lockwood estimate for Scenario 2 would practically apply to Scenarios 3 and 4 as well as they are not significantly different in rigging.

Risks:

The major risk associated with scenarios 3 and 4 is to people. When the detector was first assembled, everything was clean and dry. The tank was well ventilated with fresh air.

In this scenario, when the man hole is first opened and people are reaching in to remove the first PMTs, oil will be dripping everywhere. The tank will certainly need ventilation to allow people to go inside, and the fumes extracted by the ventilation may need to be processed somehow before the air can be exhausted to the outside. I do not have the expertise to know anything about how the fumes should be dealt with.

It is possible that the extent of ventilation required may mean that Choice 1 above cannot be made if the detector is to be reassembled. The oil remaining on the parts may be too contaminated with oxygen and other materials (clothing, gloves, dirt, etc,) to allow the part to be reinstalled without first washing it off.

I do not know if the atmosphere inside the tank will be harmless with just fans blowing air through the detector. It may be that anyone inside the tank is required to wear breathing apparatus. This would have to be determined by FNAL ES&H.

As the scaffolding is reassembled inside the tank it will become coated with mineral oil as parts that are removed drip on it. The fall hazard will be significant on the scaffolding.

SCENARIO 4: MOVE THE EMPTY STEEL SPHERICAL TANK

Description:

This scenario is much like Scenario 3 with the additional work of releasing the cables from restraints on the inside wall of the tank while the PMTS and structure are being removed, and removing the cables by disassembling the flanges around the top hat of the tank. The same decisions about cleaning or not cleaning the cables and everything else as described in Scenario 3 also have to be made here.

The empty tank weighs 50.6 tons.

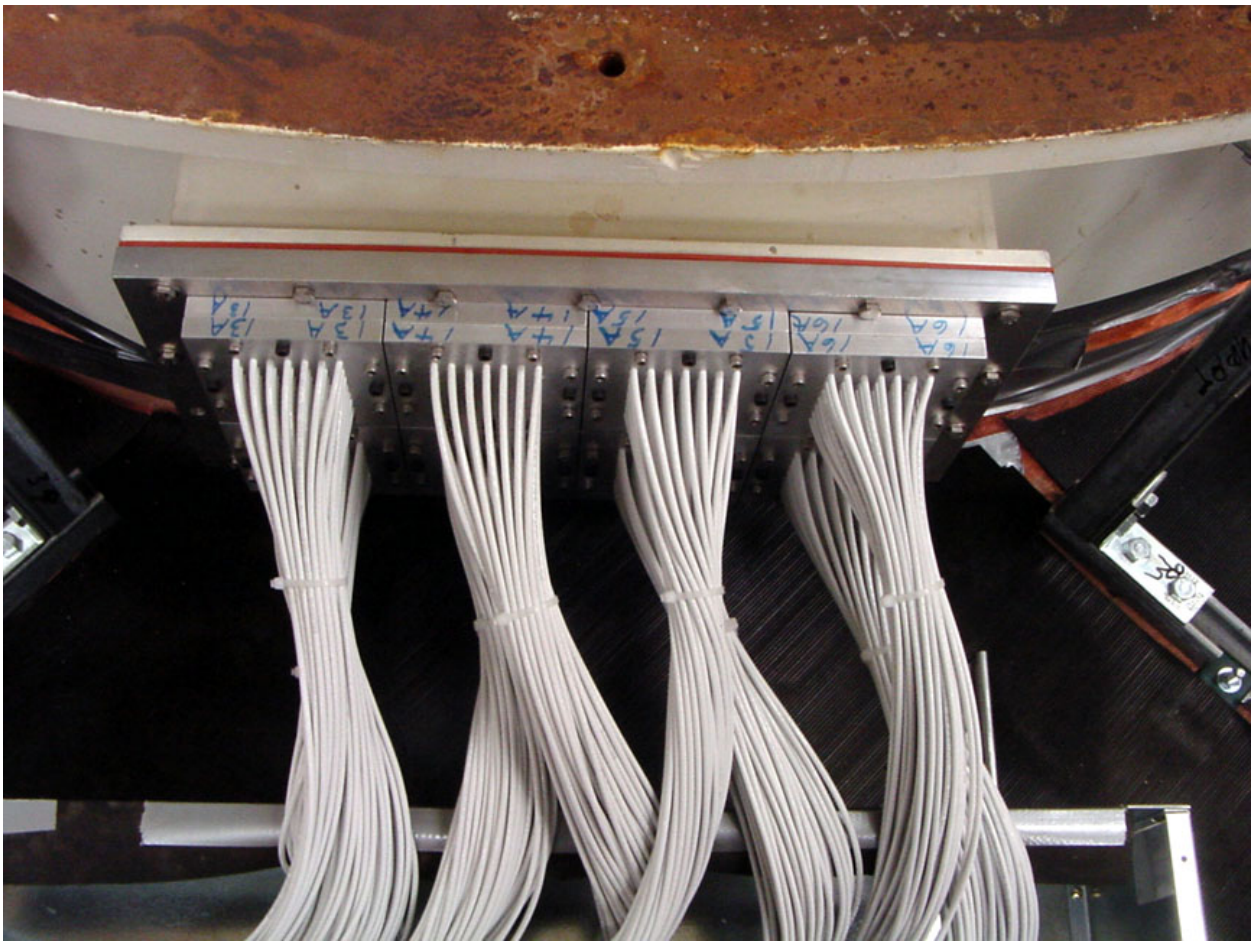

Figure 8: An outside view of the cable bundles glued to the flanges on the outside of the top hat of the tank. The cables are all the same length, but they are staggered such that cables running to the bottom PMTs of the tank are long enough to reach them, and just long enough outside the tank to reach the electronics. Cables connecting to higher PMTs inside the tank are shorter inside the tank and longer outside the tank.

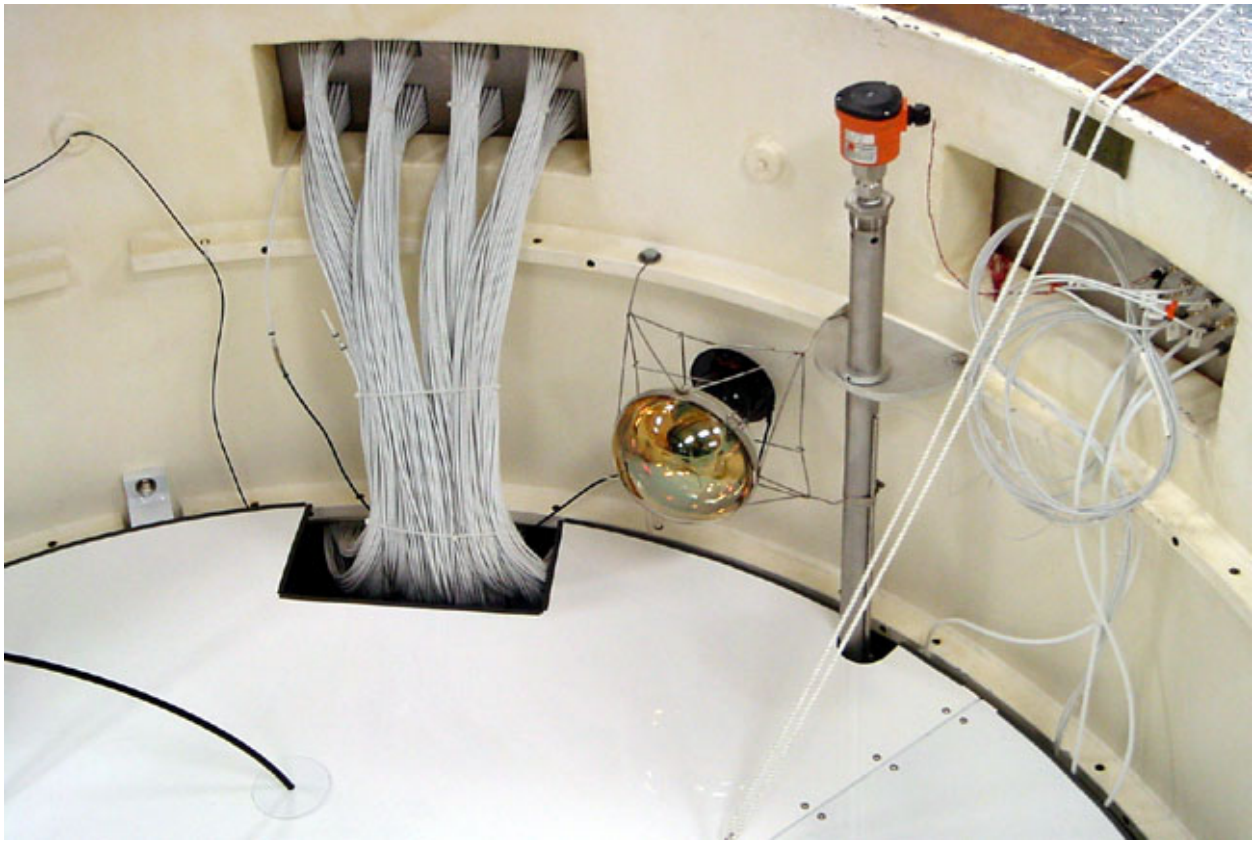

Figure 9: A view of a cable bundle inside the top hat of the tank and the 1521st PMT. In Scenario 4 everything gets removed from the tank.

Cost:

Extrapolating from what Thad Lentz of Deep South Crane and Rigging said for scenario 2, the cost to move the detector to the temporary storage site in Scenario 4 is also in the range from $250,000 to $300,000. The detector weight in this scenario is only ~9.1 tons less than in scenario 2, a difference well within the cost range given for cranes of this scale.

Cost of the below-the-hook lifting fixture: unknown

Cost of alternative storage for the oil (including temperature control and dry nitrogen coverage): unknown

Cost of the gravel road: unknown

Cost of bagging supplies, compatibility testing, and storage facility for Choice 1: unknown

Cost of cleaning supplies and factory set up for Choice 2: unknown

Cost of cable storage: unknown

Risk:

This scenario has similar risks to people from fumes in the tank to fall hazards from slippery surfaces on the scaffolding.

The additional hazard it has over scenario 3 is to the cables themselves. Removing the cables from the tank has additional risk associated with it that the cables will get damaged in handling. It is not known how well the insulation of the cables has held up after the years of immersion in mineral oil. Moving the cables may introduce cracks or insulation failures that cannot be seen by eye and would only show up with electrical testing.

This scenario looks most like a decommissioning scenario.

CONCLUSION

The four scenarios bracket the rigging costs, complexities and risks associated with moving the MiniBooNE detector to the temporary storage site.

Ultimately, the choice of how to move the detector will be based on the final disposition of the detector. If the detector will have a second life in a new detector hall elsewhere on the MiniBooNE beamline, then exquisite care needs to be taken to preserve the properties of the detector and prevent it from changing. If the detector is moved but behaves in new, unexpected and not understood ways, then the money and effort to move it and set it up will have been wasted.

If the fate of the detector is decommissioning, then the lowest cost (and safest for people) way of taking apart the detector should be selected. If decommissioning is the decision, then removing the spherical shell from the hall in one piece may not be necessary. Additional scenarios involving cutting the sphere apart and removing the pieces should be examined.