200 kton Water Cherenkov Detector Liner

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ANT11

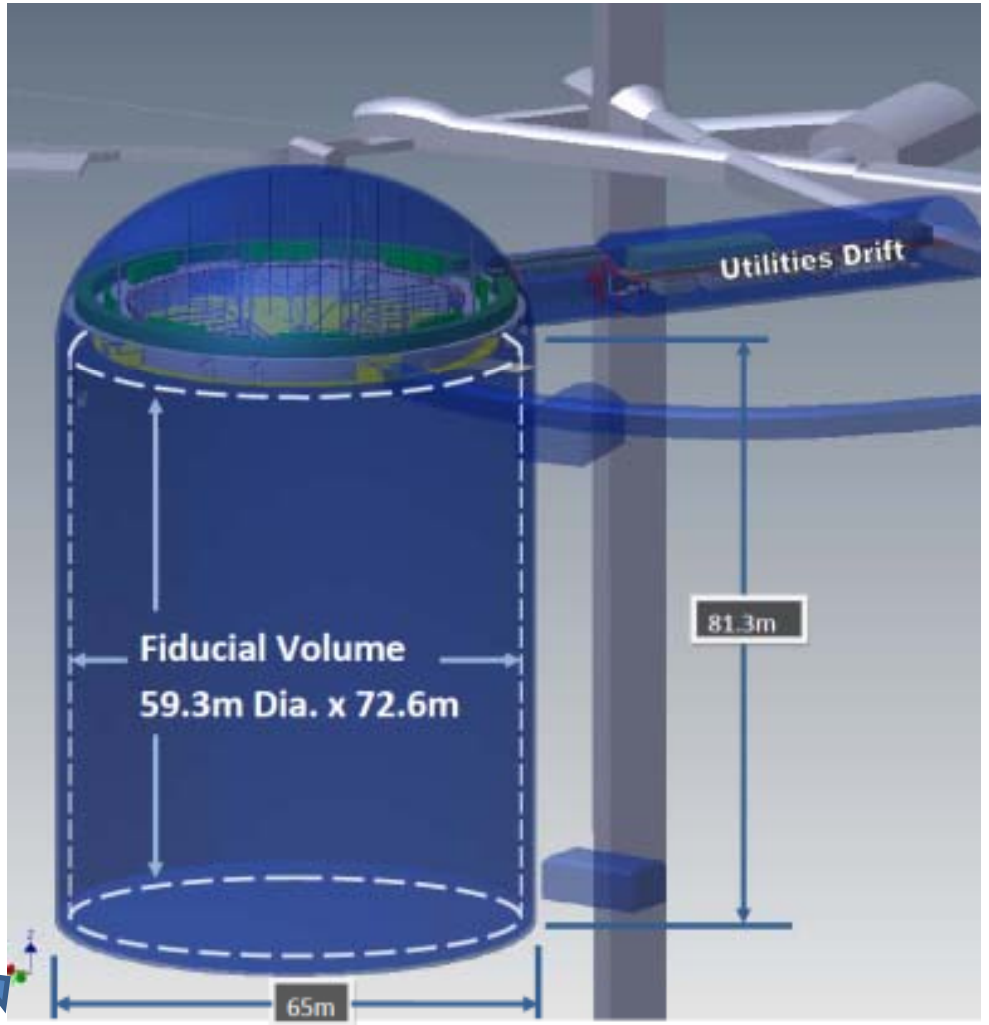
11 October, 2011

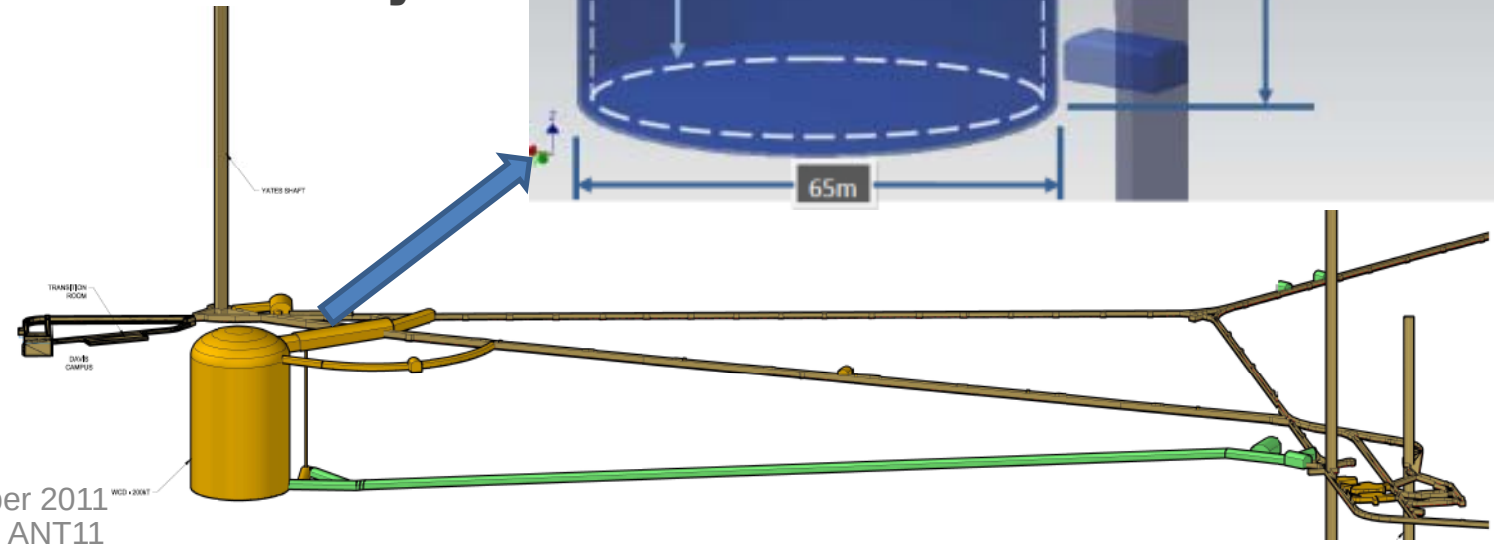
Outline

- **Water containment for 200 kton**
- **Reasons and background for choices**
- **Interface to other subsystems**
- **What have we learned from firms**
- **Material considerations**

200 kton cavern

- **Located at 4850 ft level**
- **One cavern only near Yates Shaft**
- **Remove rock at bottom (5117 ft level) to Ross Shaft**
- **Access for detector work at 4850 only**



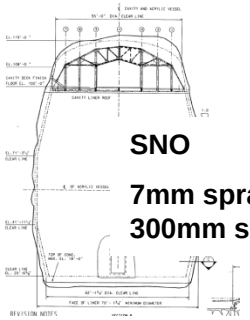


Definition

- **Vessel is the structural components to resist water load and support detector components**
- **Liner is the water proofing and leak collection components**

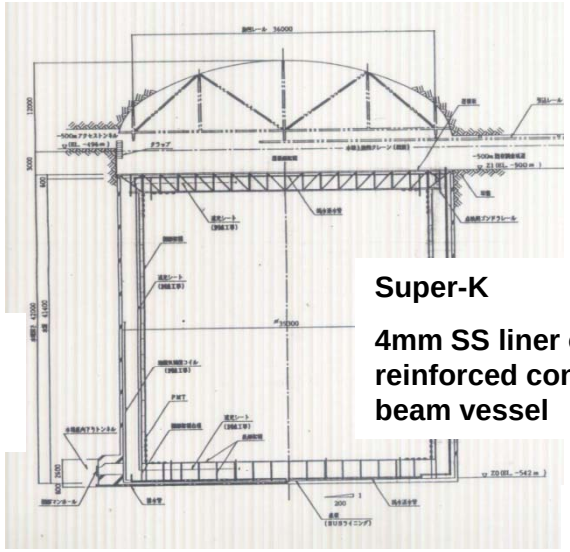
Both are needed and integrated

Size Comparison and Liners



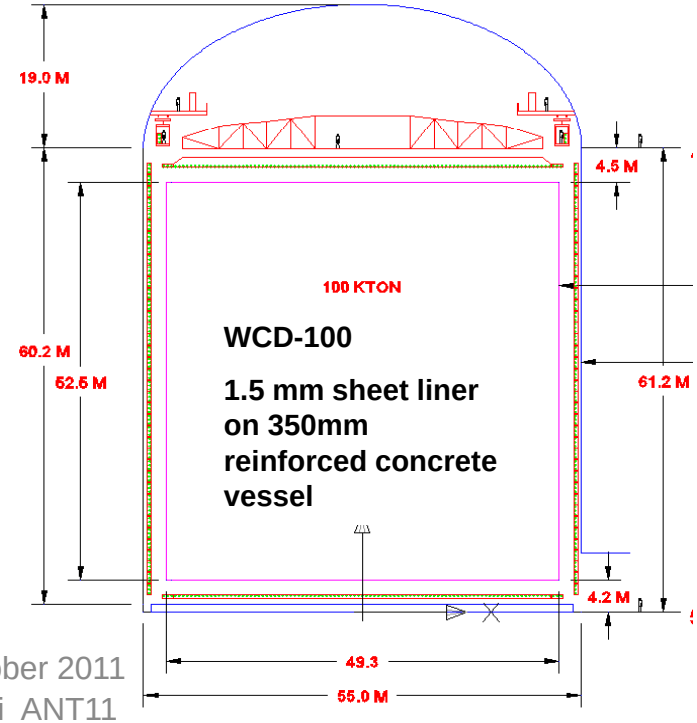
SNO

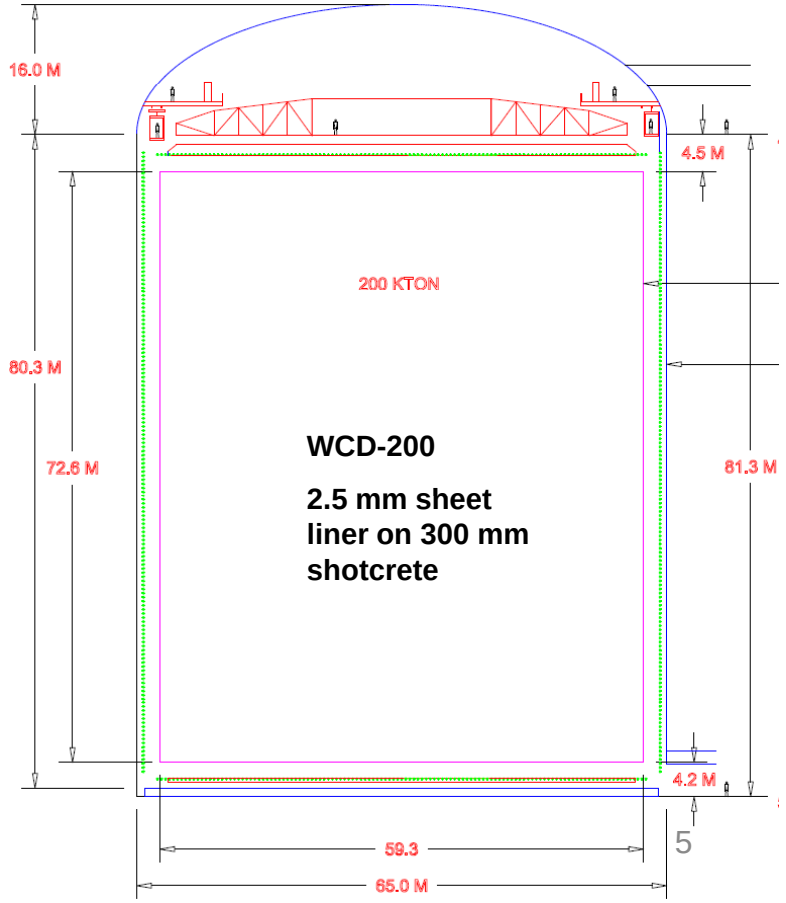
7mm sprayed liner on 300mm shotcrete



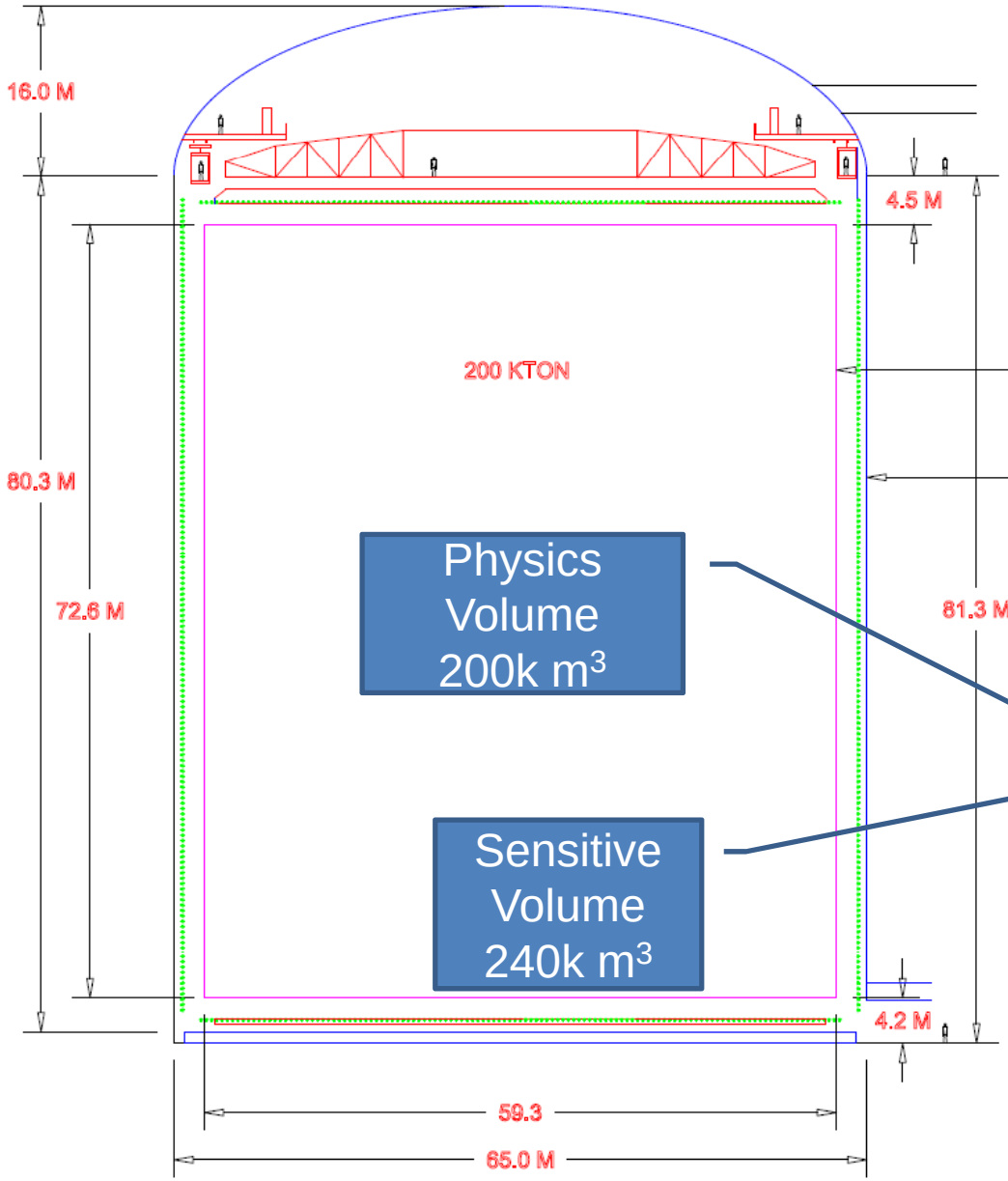
Super-K

4mm SS liner on 350mm reinforced concrete and H-beam vessel





200 kton Parameters



Total PMTs		29000
Area covered by 1 PMT	m^2	0.74
Distance between PMTs	m	0.86
PMTs on wall		20470
PMTs on Floor		4265
PMTs on Deck		4265
Number of cells across deck & floor diameter		73
Number of cells to traverse the height of wall		89
Number of cells around perimeter of wall		230
Fiducial diameter	m	59.30
Fiducial Height	m	72.60
Dia of cylinder at PMT equator	m	63.30
Height of cylinder at PMT equator	m	76.60
Water diameter	m	65.00
Water height	m	79.50
Total water volume	m^3	263805
Wetted Surface	m^2	19552
Surface to volume ratio	m^{-1}	0.074

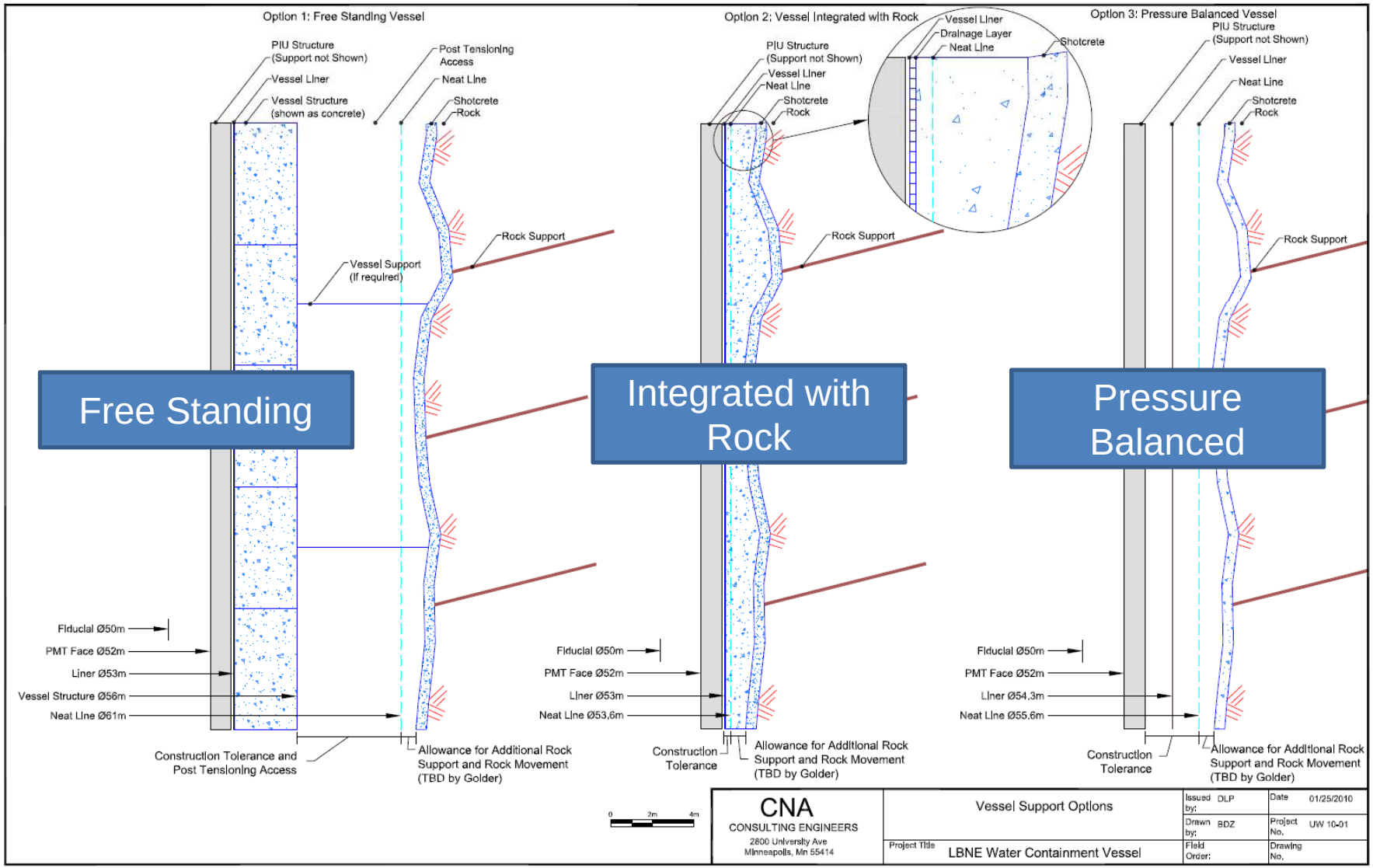
General Scope of Liner

- **Scope of responsibility:**
  - **On wall is from neat line to water**
  - **On floor is from slab to water**
  - **Interface and sealing to deck**
  - **Interface to PMT supports**
- **Extent of supply:**
  - **Full design of liner**
  - **Recommendation of materials (selection is LBNE responsibility)**
  - **Construction and installation of liner**
  - **QA and leak check**
  - **Installation of magnetic compensation coils**

Status of Liner Design

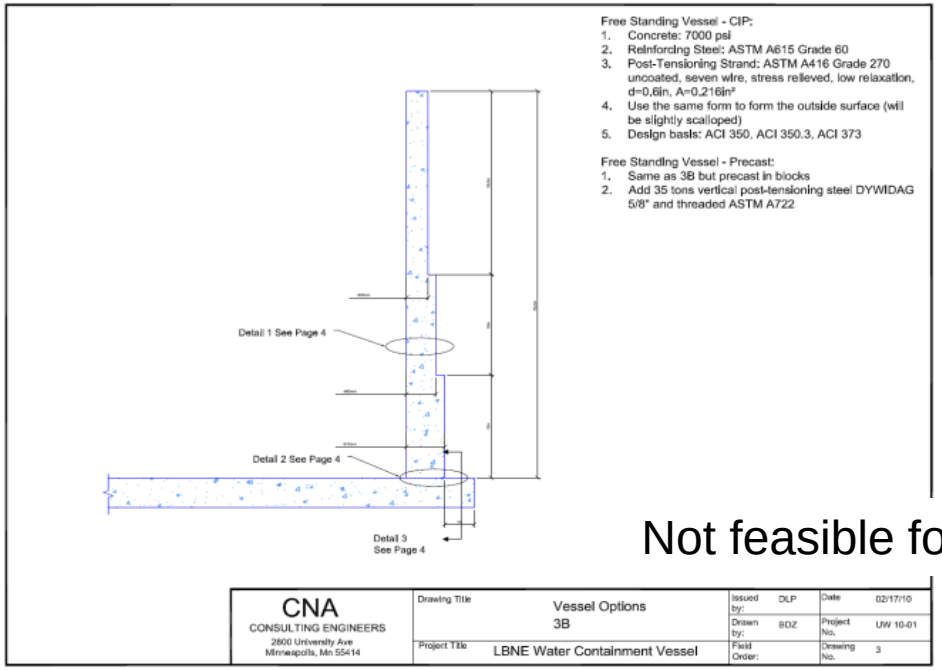
- **100 kton Conceptual Design with many options was done by CNA/HHM/SGH (DocDb 3150)**
- **100 kton was evaluated with liner on shotcrete vs liner on concrete vessel**
- **Cost and schedule estimates and peer review done**
- **200 kton cost was scaled from 100 kton**
- **200 kton was re-evaluated as part of conventional facilities contract**
- **RFI for design and construction 200kton send to companies-responses received**

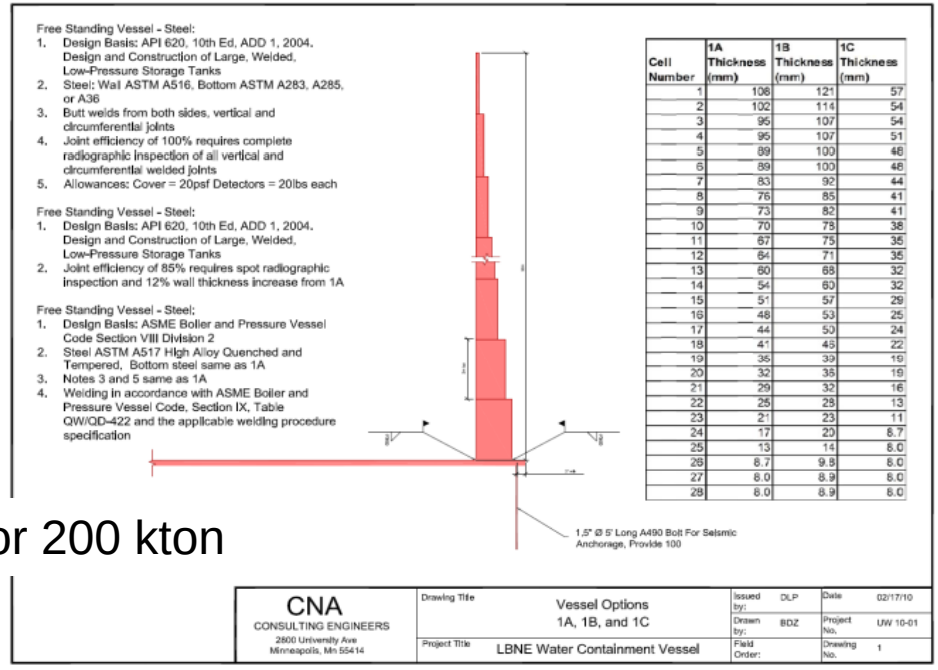
Options Studied



Free Standing Options

- Concrete option 1A
  - Less costly
  - Walls thicker
  - Can use metal or polymeric liner
- Steel Option 1B
  - Most robust but costliest
  - Can use metal or polymeric liner
  - Magnetic issues more complex



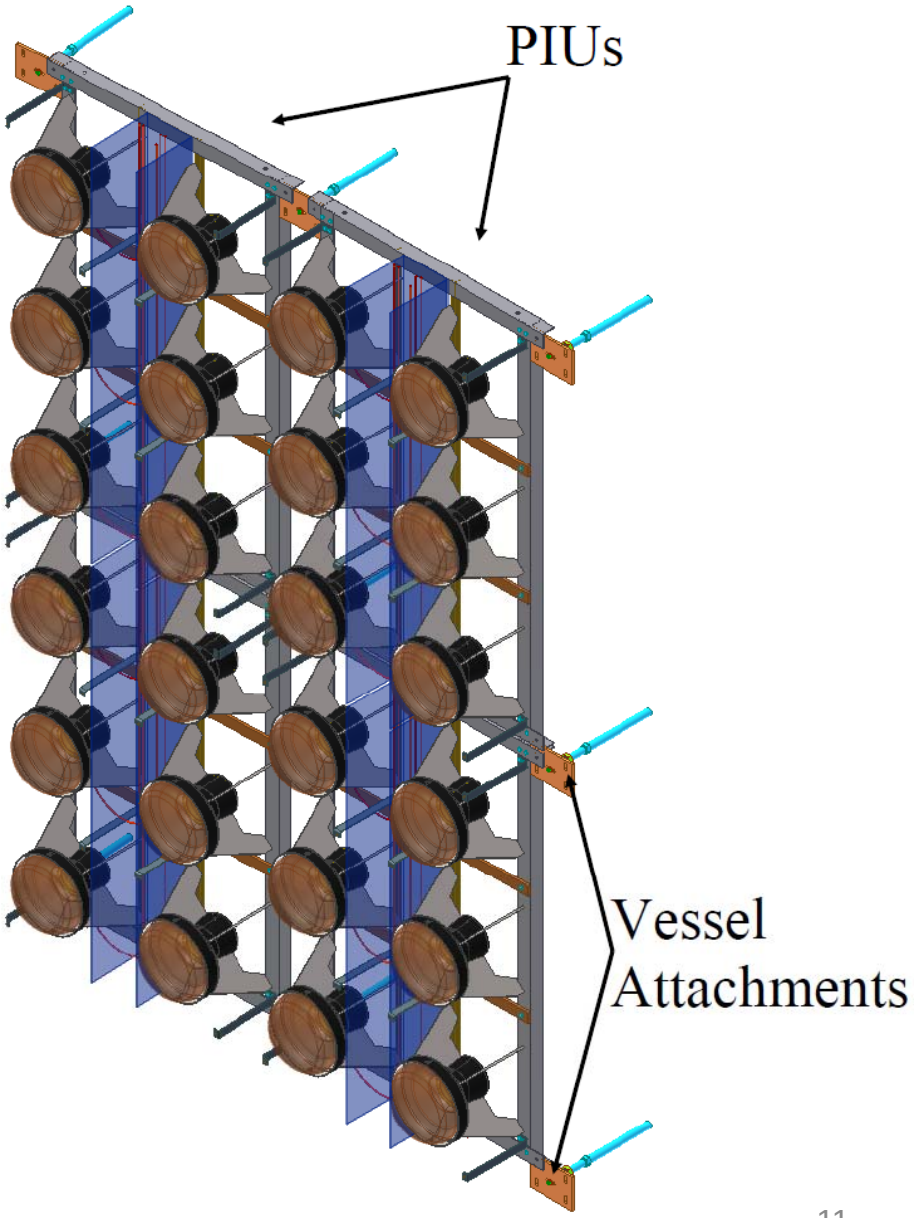


Cell Number	1A Thickness (mm)	1B Thickness (mm)	1C Thickness (mm)
1	108	121	57
2	102	114	54
3	96	107	54
4	96	107	51
5	89	100	48
6	89	100	48
7	83	92	44
8	76	85	41
9	73	82	41
10	70	78	38
11	67	75	35
12	64	71	35
13	60	68	32
14	54	60	32
15	51	57	29
16	48	53	25
17	44	50	24
18	41	45	22
19	35	39	19
20	32	35	19
21	29	32	16
22	25	28	13
23	21	23	11
24	17	20	8.7
25	13	14	8.0
26	8.7	9.8	8.0
27	8.0	8.9	8.0
28	8.0	8.9	8.0

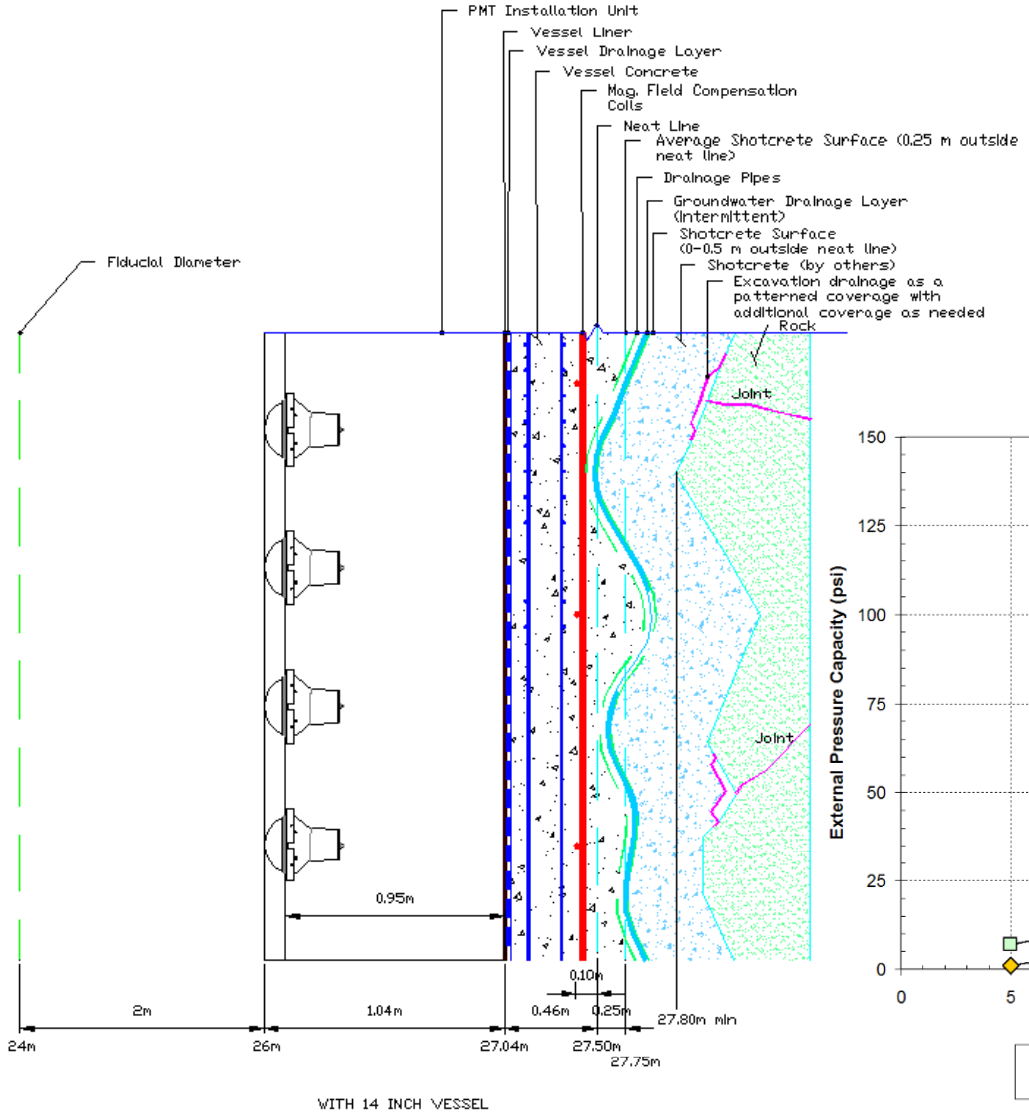
Not feasible for 200 kton

PMT Supports

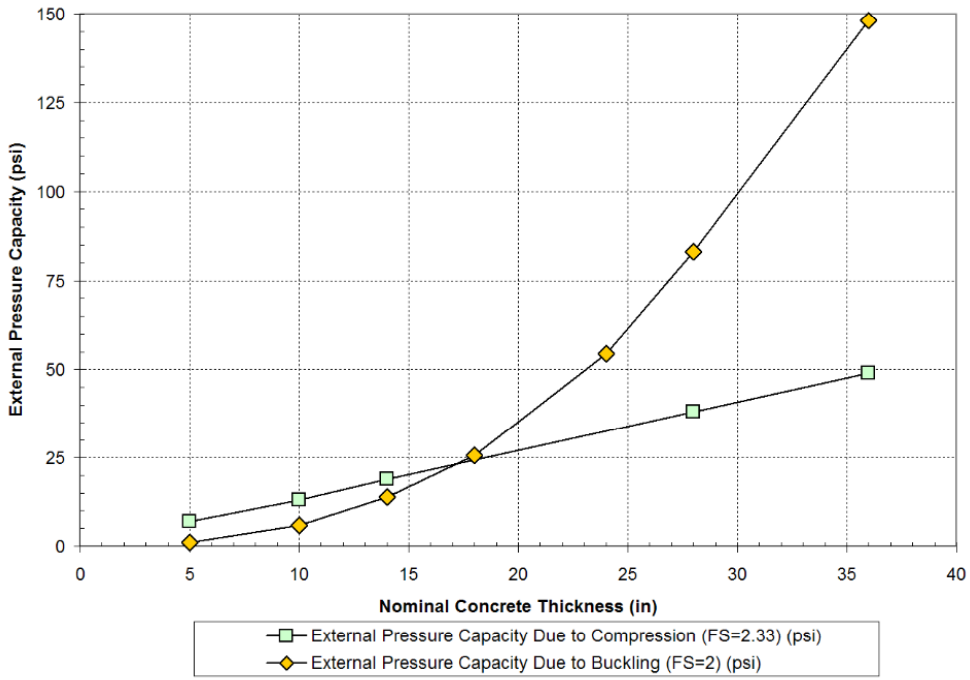
- **Strong vessel with steel or concrete allows attachment directly to wall**
- **Smooth and flat wall allows good position**
- **This was our baseline support design for a steel or concrete vessel**



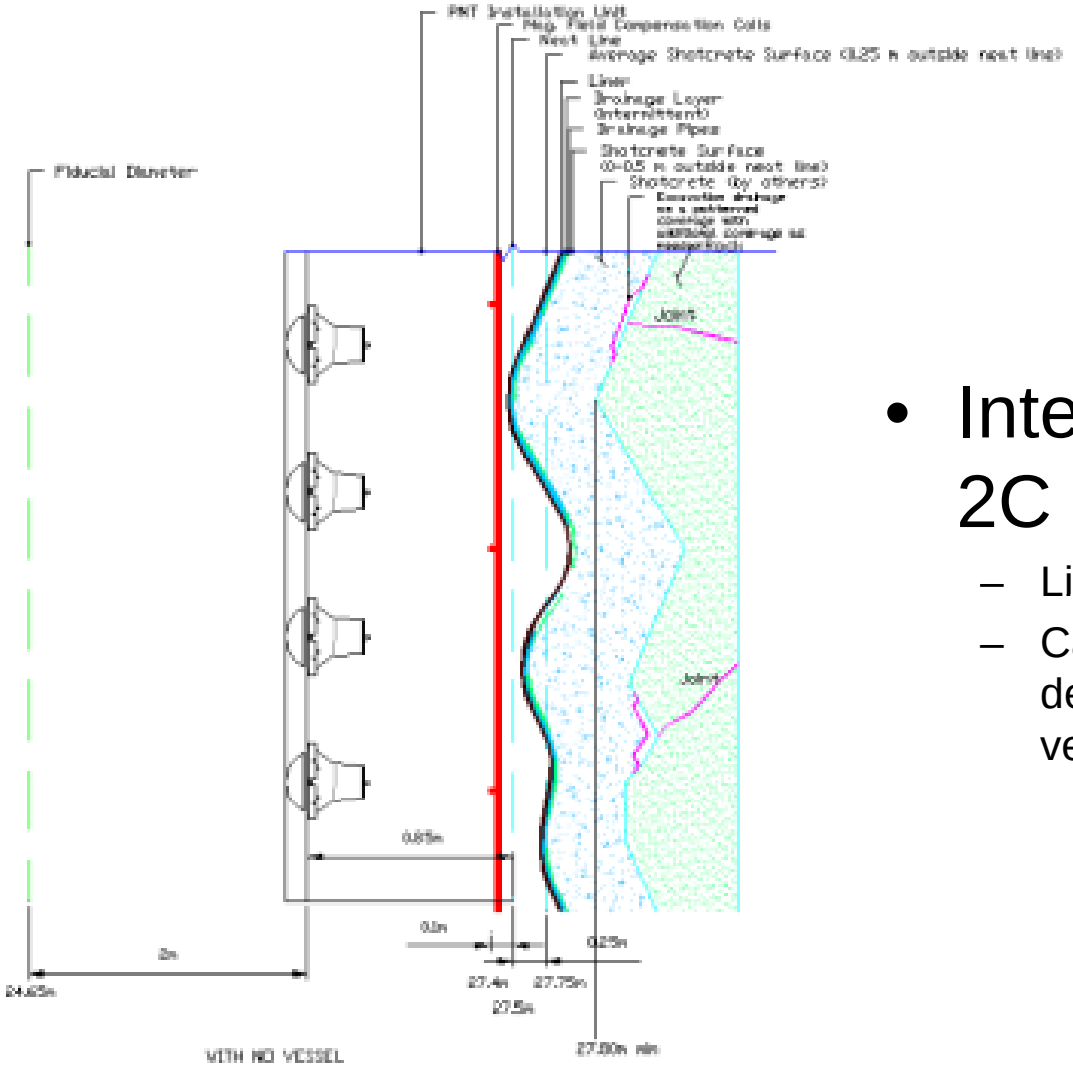
Rock Integrated Options



- Integrated option 2A
  - 35 cm reinforced concrete vessel
  - Can resist external pressure
  - Mount PMTs directly to wall

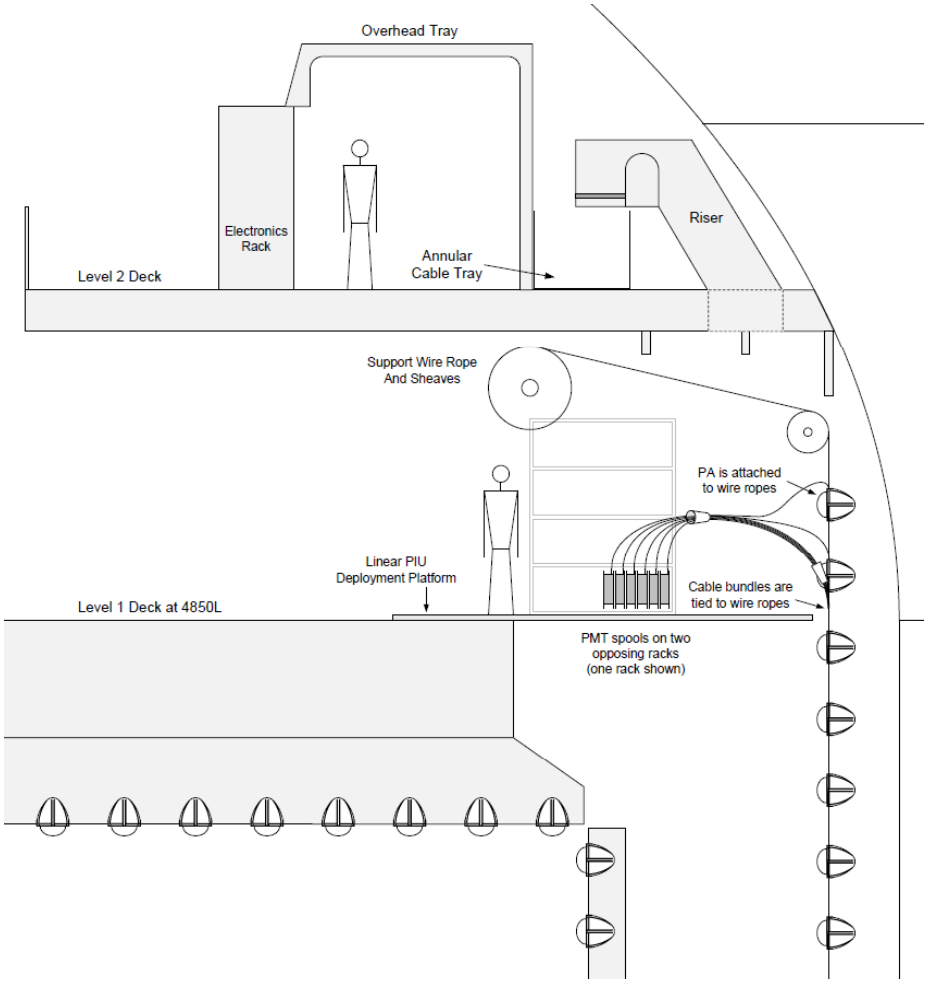


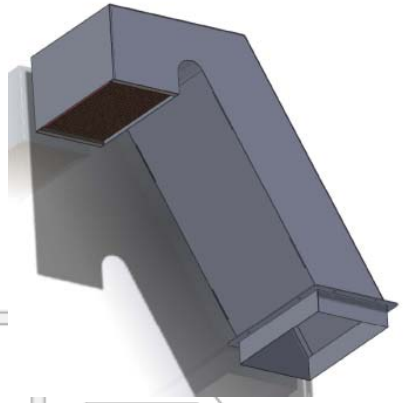
Rock Integrated Options

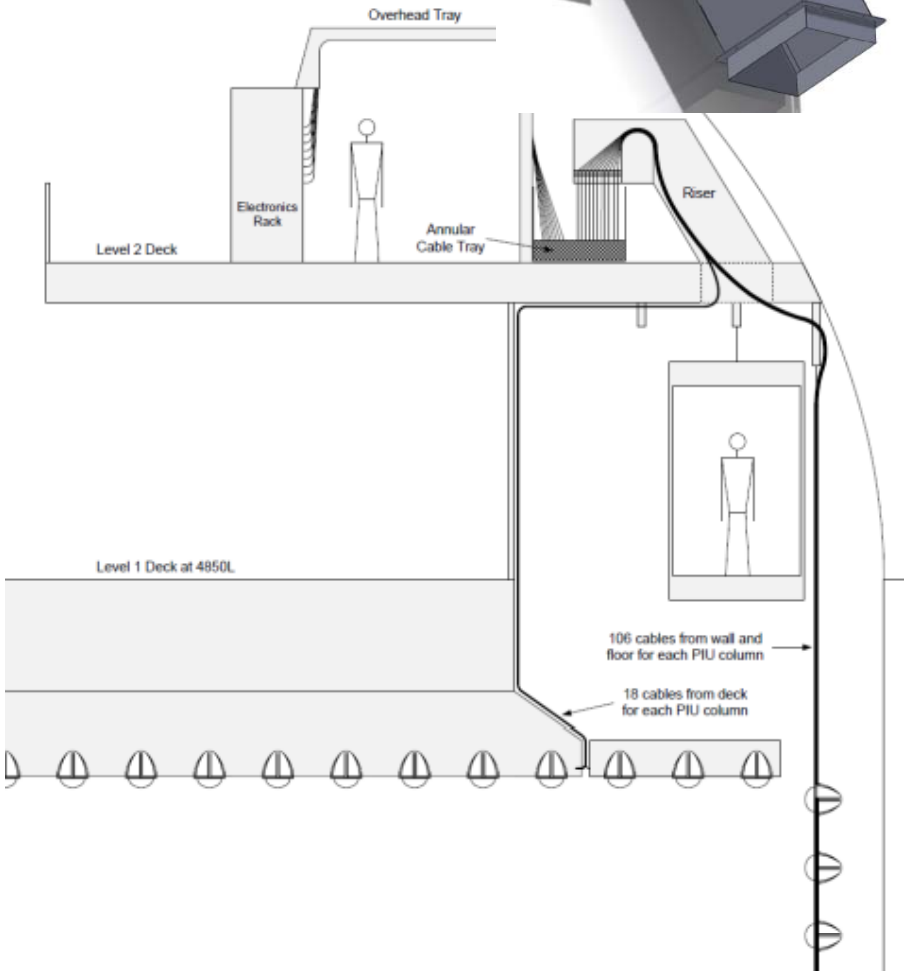


- Integrated option 2C
  - Liner directly on shotcrete
  - Cavern design team has determined rock motions are very small so this is feasible

Wall PMT Deployment

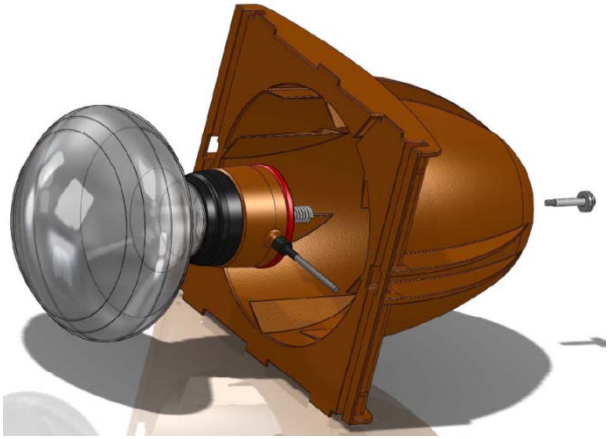


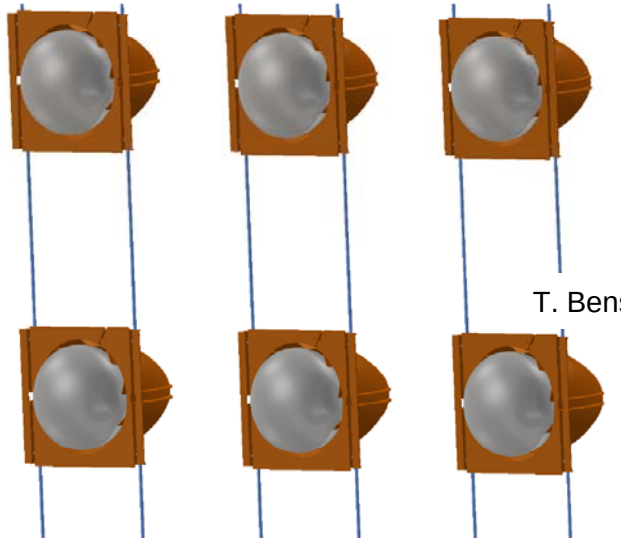




T. Benson, P. Robl, PSL

Linear PMT Supports





T. Benson, P. Robl, PSL

- **Use wire rope support for PMT assemblies**
- **All wall PMTs deployed from deck**
- **No attachments and penetrations on the wall**
- **Will require extensive testing**

Wall Liner Construction

- Concrete vessel in not base option due to cost
- Shotcrete, ground support and drainage applied to rock
- Magnetic compensation coils installed
- Additional shotcrete to smooth and cover coils
  - Probably need smoothness about 1 in 10 to15
  - One supplier says waviness should not exceed 5 cm
- Penetrations installed at appropriate time
- Detector drainage layer installed
- Sheet liner installed and welded
- Leak check

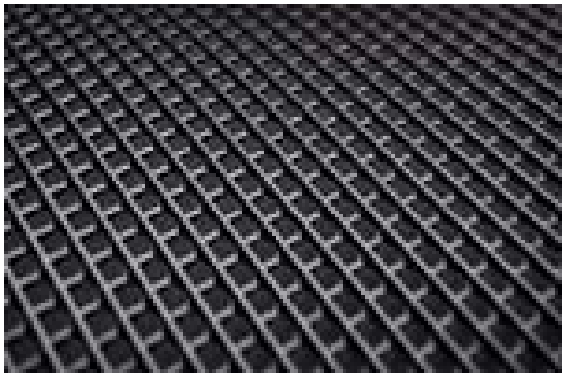
Liner Welding and Leak Check

- Liner material will come in large rolls and will be welded in place
- Fusion and extrusion weld will both be used
- Seams will have an overlap with two fusion welds, will allow for air pressure test of space between welds
- Fusion welds will mostly be used for attachment points
- Extrusion welds will be used at penetrations
- Leak checking by spark method used on liner
- Other methods may also used (vacuum box, gas, etc.)
- Conductive liner will facilitate this

Liner Material Choices

J. Youngblood, & B. Ward

- **Baseline:**
  - **Liner: 2.5 mm conductive LLDPE Geomembrane**
  - **Drainage layer: 8 mm Geocomposite (Geonet)**
- **Alternate:**
  - **Liner: 1.5 mm conductive LLDPE Geomembrane**
  - **Drainage layer: Restricted Flow GCL or none**



Gundle/SLT Environmental, Inc.

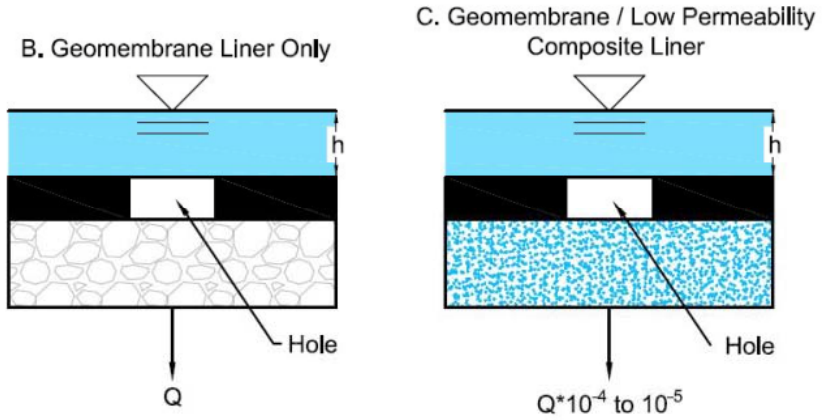
Geosynthetic Clay Liners (GCL's) are composites that combine geotextile outer layers with a core of low-permeability sodium bentonite clay.

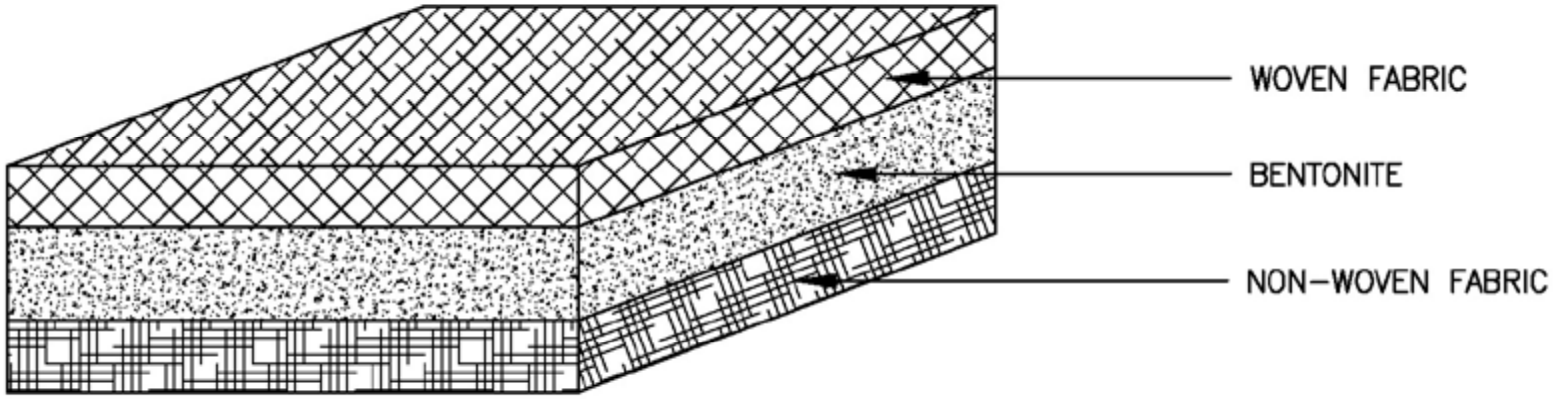
Drainage System

- **Separate drainage layers for ground water and detector leak water**
- **Separate collection, they may or may not be combined in the sump**
- **Static pressure rating and longevity must be sufficient**
- **Pressure must not build on liner when detector is empty**
- **Sedimentation in drainage layer should also be considered**

No Drainage Layer Concept And Possibly "Zero Leak"

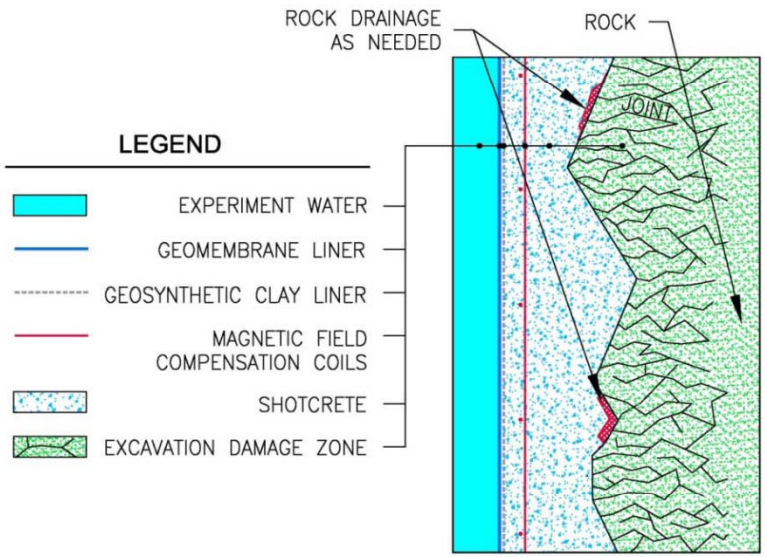
- **Minimize effects of leaks by not allowing free flow**
- **Do not collect whatever does leak**
- **Let combine with groundwater collection**



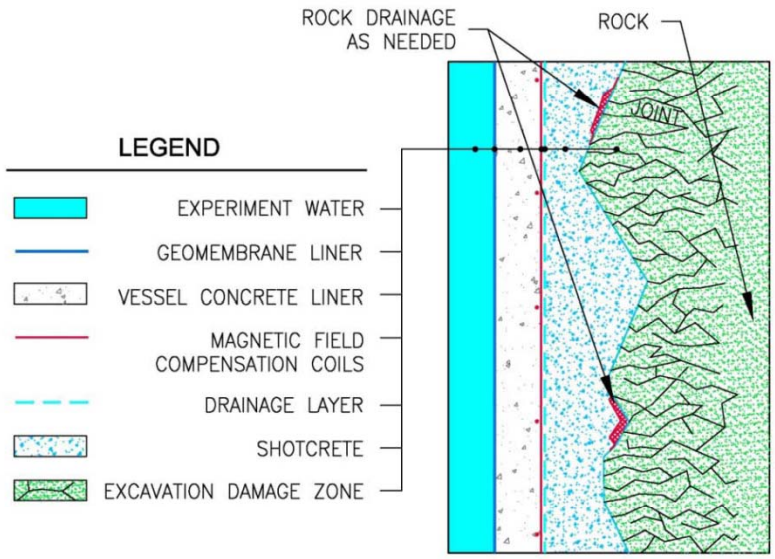


Variations on Rock Integrated Options

- Option A
  - GCL directly under liner
  - No leak collection
  - Only ground water collection



- Option B
  - Slip-formed concrete under liner
  - No leak collection
  - Concrete act like GCL (? by Farshid)



Estimating Leak Rates

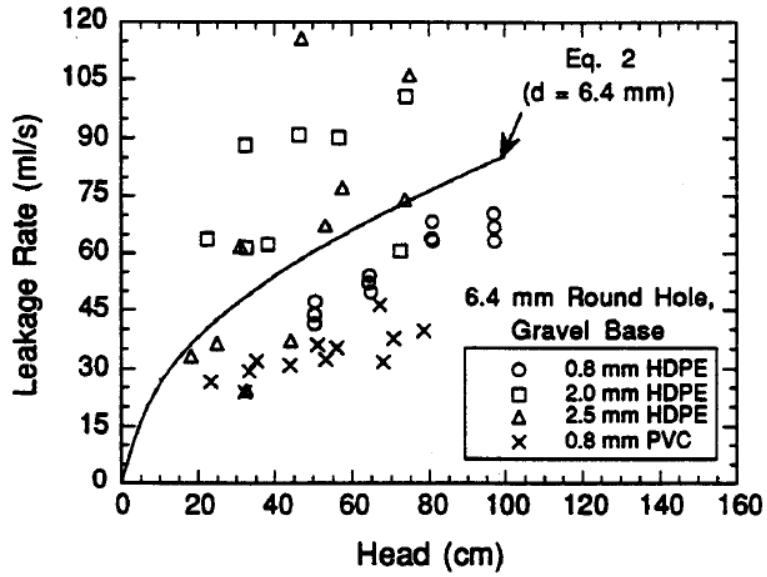
- **Leakage is, of course, dependent on size and quantities of defects**
- **Must minimize quantity of penetration**
- **5 defects per hectare is an achievable number**
- **Leak rate will be specified as a design parameter**

Leakage Rates from Geomembrane Liners Containing Holes

C.H. Benson
University of Wisconsi

J.M. Tinjum
University of Wisconsi

C.J. Hussin
University of Wisconsi

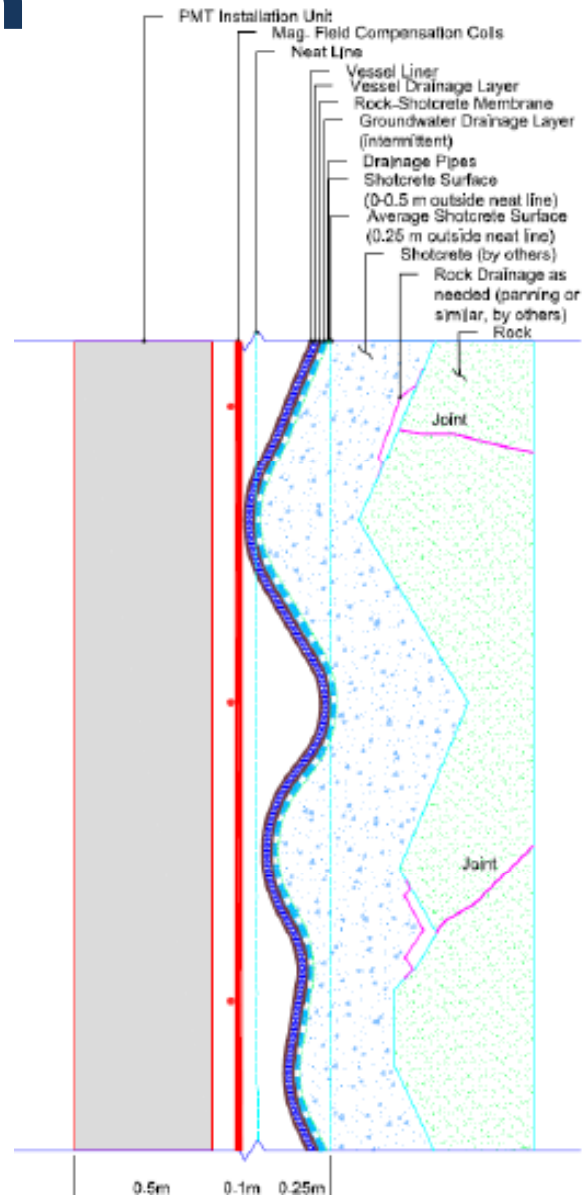


Fill rate is about $1 m^3$ per minute

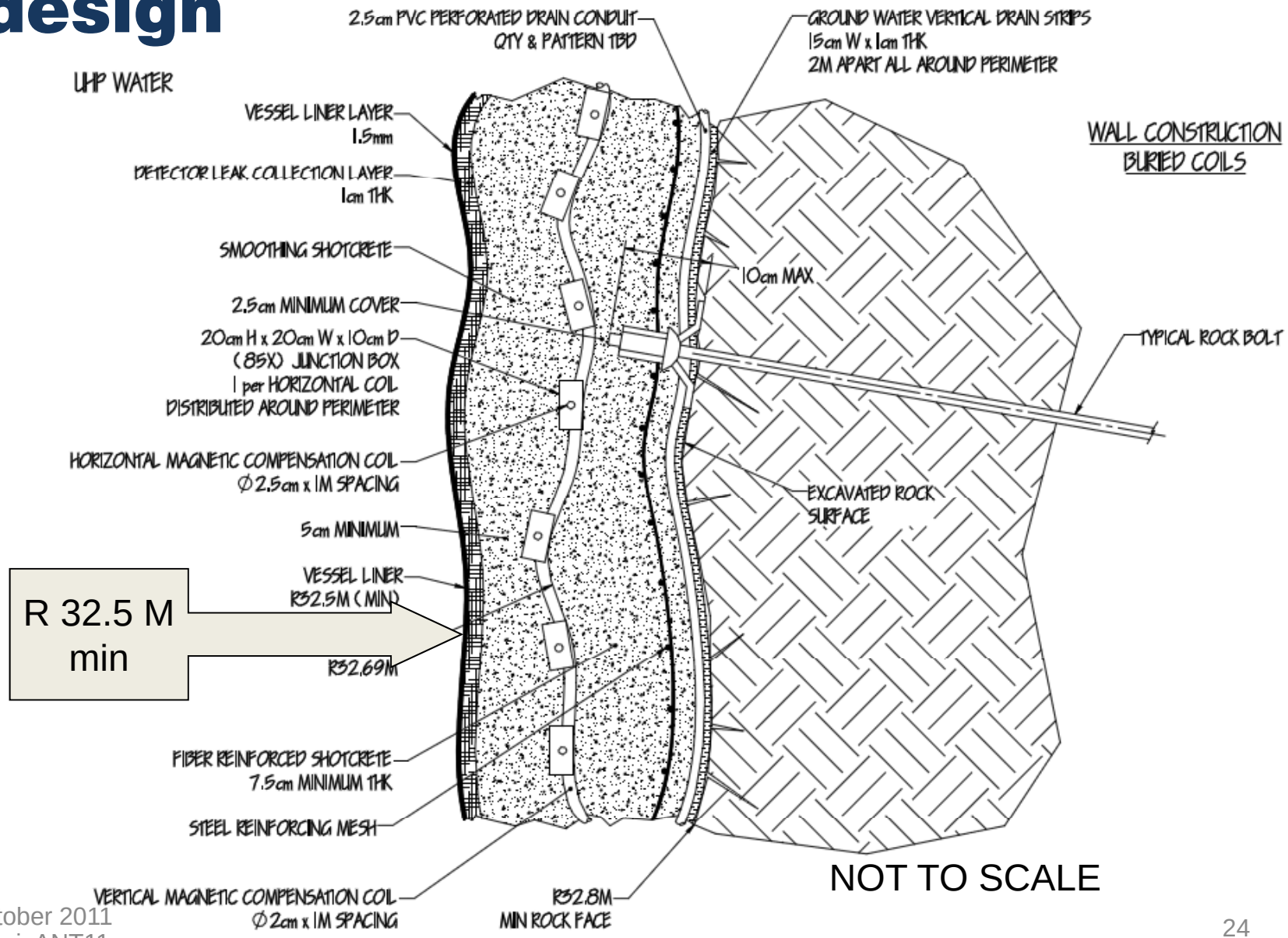
	No. of defects	Defect dia (mm)	Defect depth (m)	Leakage (m^3/day)	Level drop (m/day)	Drainage type
Median Rate	6	1	5 at 40, 1 at 80	7.4	0.002	Free flow
Median Rate	6	2	5 at 40, 1 at 80	29.8	0.009	Free flow
Maximum rate	12	1	All at bottom	19.7	0.006	Free flow
Maximum rate	12	2	All at bottom	78.7	0.024	Free flow
Best estimate	12	1	Distributed	14.1	0.004	Free flow
Best estimate	12	2	Distributed	56.3	0.017	Free flow

“Leak Free” Design

- **Leak free: It leaks but collect all leaks**
- **This design utilizes a double lined system to collect all leaks from primary liner**
- **It is used in hazardous liner applications and is a well known technology**
- **This method would be advantageous in the case we use Gd to allow for full collection and recapture**
- **Cost and schedule is the major issue with this option**

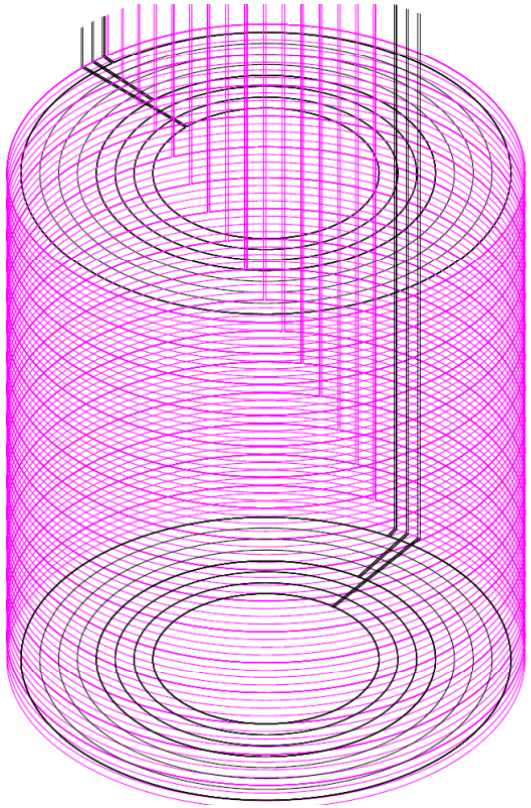


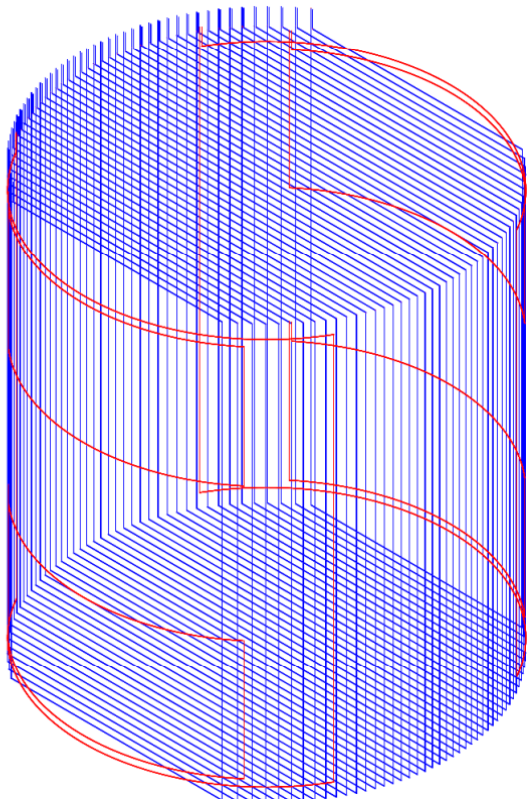
Baseline design



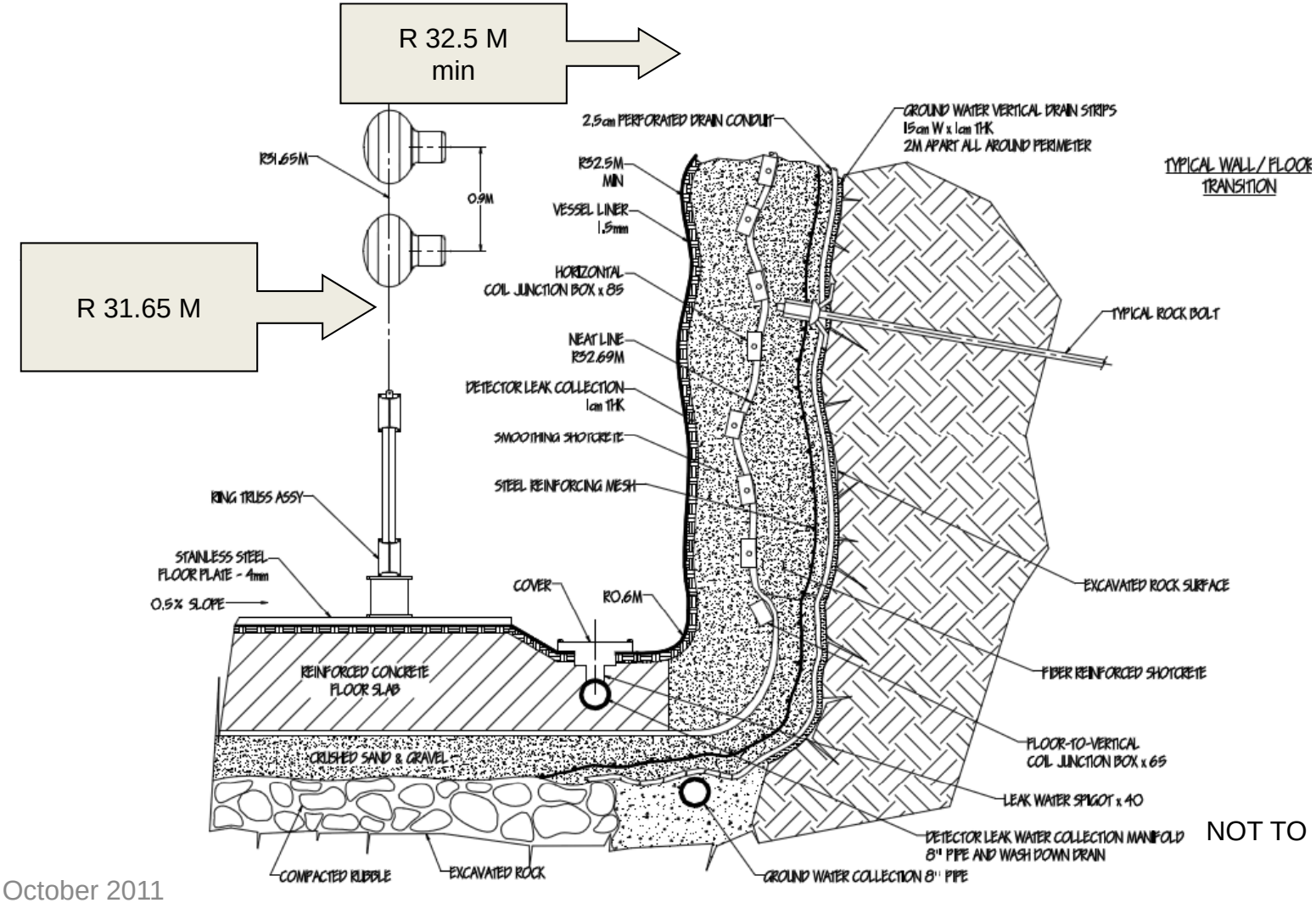
Magnetic Compensation

- **Horizontal and vertical coils**
- **Power supplies on deck**
- **Passive system also under evaluation**





Wall-Floor Interface (one possibility)



NOT TO SCALE

Liner Material Considerations

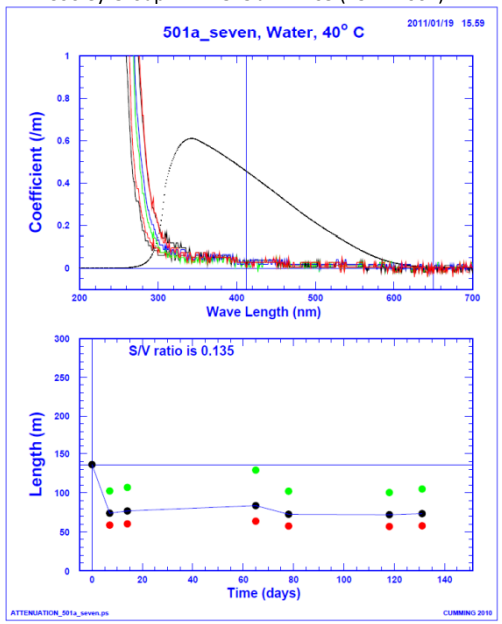
- **The material of the liner must be compatible with ultra-high purity water for up to 30 years.**
- **LBNE collaboration is responsible for test and selection of liner material from those recommended by contractor.**
- **Tests have shown that various grades of commonly used polyethylene sheet liners materials are acceptable.**
- **Tests on cold-fluid applied liners have shown that they do not perform as well and may not be acceptable.**

Liner Material Testing

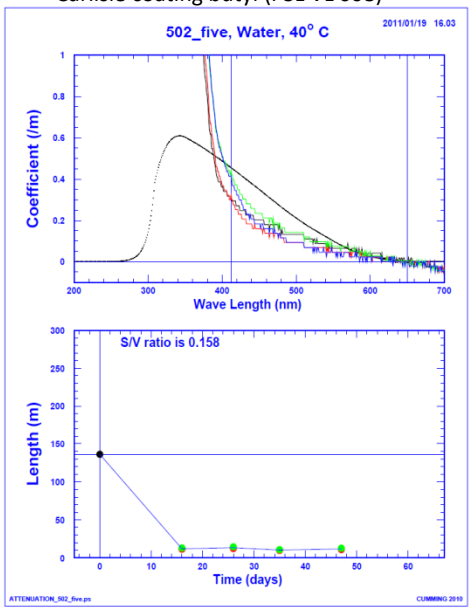
Sample Number	Material	Temp
sample499	2 Cooley Group L4090 UPW (PSL VL 003)	40
sample499a	2 Cooley Group L4090 UPW (PSL VL 003)	40
sample500	2 Cooley Group HRL-36 (PSL VL 002)	40
sample500a	2 Cooley Group HRL-36 (PSL VL 002)	40
sample501	2 Cooley Group RPP-7845 JWPW05 (PSL VL 001)	40
sample501a	2 Cooley Group RPP-7845 JWPW05 (PSL VL 001)	40
sample502	2 Carlisle coating and waterproofing sore-seal butyl (PSL VL 008)	40
sample502a	2 Carlisle coating and waterproofing sore-seal butyl (PSL VL 008)	40
sample503	Reference H2O for 499-502	40
sample503a	Reference H2O for 499-502	40
sample528	VL000 Uncoated SS316	40
sample529	VL004 Sherwin Williams Sherflex PU	40
sample530	VL005 Sherwin Williams Environment AR520	40
sample531	VL006 Sherwin Williams Dura-Plate UHS EPOXY	40
sample532	VL007A CIM Industries CIM 2000 PU	40
sample533	Reference H2O for 528-532	40
sample538	VL-009 GSE Conductive White smooth, 60mil, HDPE	40
sample538a	VL-009 GSE Conductive White smooth, 60mil, HDPE	40
sample539	VL-010 GSE Conductive Smooth, 60mil HDPE	40
sample539a	VL-010 GSE Conductive Smooth, 60mil HDPE	40
sample540	PSL VL-011 GSE HD Smooth, 60mil HDPE	40
sample540a	PSL VL-011 GSE HD Smooth, 60mil HDPE	40
sample541	PSL VL-012 GSE Ultra Flex Textured, 60mil LLDPE	40
sample541a	PSL VL-012 GSE Ultra Flex Textured, 60mil LLDPE	40
sample542	PSL VL-013 GSE HD Textured; 40mil HDPE	40
sample542a	PSL VL-013 GSE HD Textured; 40mil HDPE	40
sample543	PSL VL-014 GSE Ultra Flex Smooth, 60mil LLDPE	40
sample543a	PSL VL-014 GSE Ultra Flex Smooth, 60mil LLDPE	40
sample544	H2O Reference for 438-543	40
sample544a	H2O Reference for 438-543	40
sample547	PSL VL015 Green Plastics Virgin HDPE, 62mil	40
sample548	H2O Reference for 548	40
sample555	VL000 Uncoated SS316	RT
sample556	VL004 Sherwin Williams Sherflex PU	RT
sample557	VL005 Sherwin Williams Environment AR520	RT
sample558	VL006 Sherwin Williams Dura-Plate UHS EPOXY	RT
sample559	VL007A CIM Industries CIM 2000 PU	RT
sample560	VL-009 GSE Conductive White smooth, 60mil, HDPE	RT
sample561	VL-010 GSE Conductive Smooth, 60mil HDPE	RT
sample562	PSL VL-011 GSE HD Smooth, 60mil HDPE	RT
sample563	PSL VL-012 GSE Ultra Flex Textured, 60mil LLDPE	RT
sample564	PSL VL-013 GSE HD Textured; 40mil HDPE	RT
sample565	PSL VL-014 GSE Ultra Flex Smooth, 60mil LLDPE	RT
sample566	PSL VL015 Green Plastics Virgin HDPE, 62mil	RT
sample567	H2O Reference for sample 555-567	RT
sample572	PSL PC001 ResinLab UR3005 two-part urethane mix	40
sample573	PSL PC001 ResinLab UR3005 two-part urethane mix	RT
sample574	PSL PC002 ResinLab EP1282 two-part epoxy mix	40
sample575	PSL PC002 ResinLab EP1282 two-part epoxy mix	RT
sample576	Water Reference for 572 & 574	40
sample577	Water Reference for 573 & 575	RT

Close to 50 samples for the liner materials tested

Cooley Group RPP-7845 JWPW05 (PSL VL 001)



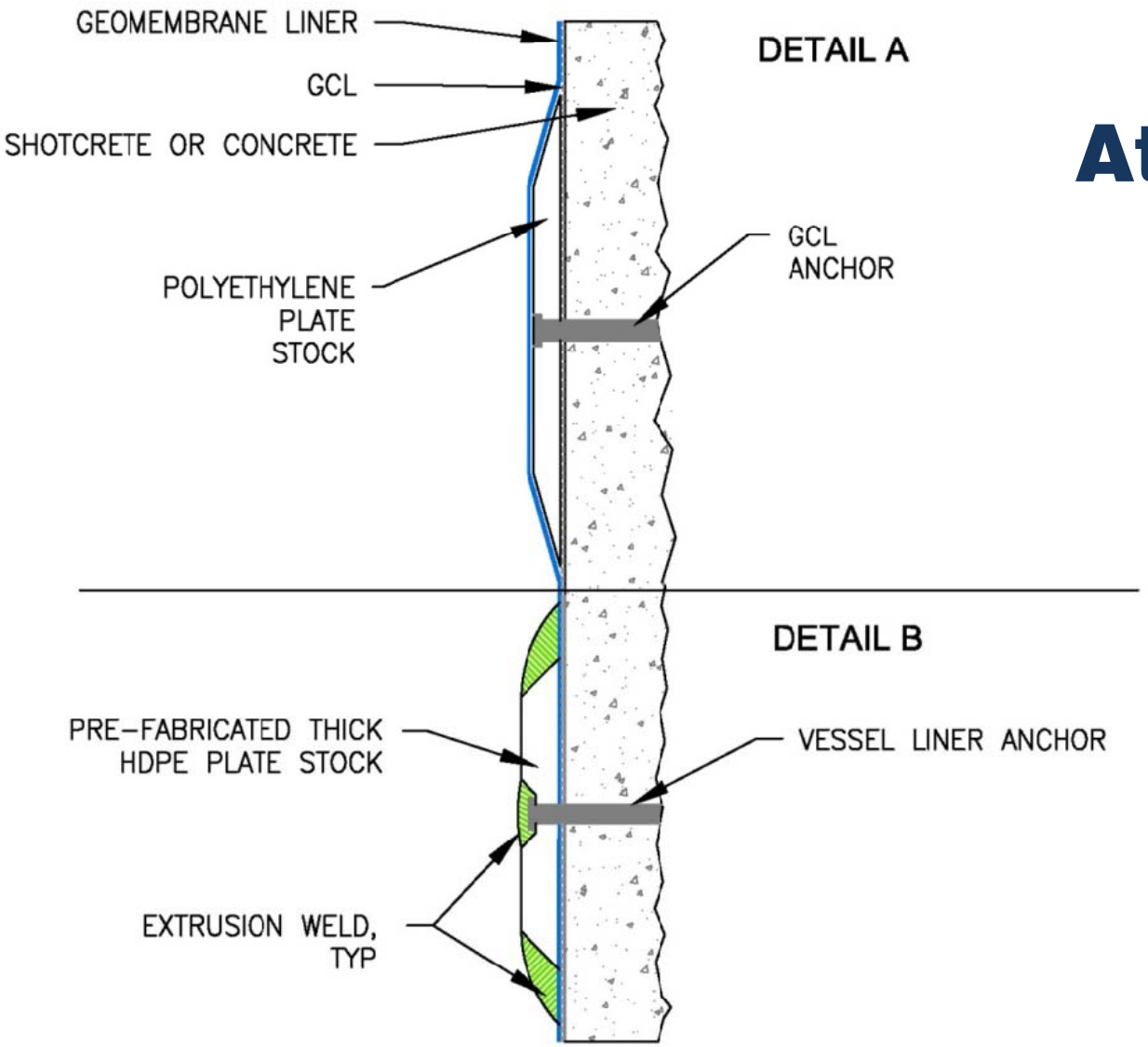
Carlisle coating butyl (PSL VL 008)



List of Good Material

304 CRES, part no # EX-2171B bolt		3.76E-06	
RPP-7845 JWPW 05	Liner	0.091	Cooley group
VL-009 GSE Conductive White smooth, 60mil, HDPE	Liner	0.091	GSE
VL-010 GSE Conductive Smooth, 60mil HDPE	Liner	0.091	GSE
PSL VL-011 GSE HD Smooth, 60mil HDPE	Liner	0.091	GSE
PSL VL-012 GSE Ultra Flex Textured, 60mil LLDPE	Liner	0.091	GSE
PSL VL-013 GSE HD Textured; 40mil HDPE	Liner	0.091	GSE
PSL VL-014 GSE Ultra Flex Smooth, 60mil LLDPE	Liner	0.091	GSE
VL000 Uncoated SS316	Liner	0.091	
PSL VL015 Green Plastics Virgin HDPE, 62mil	Liner	0.091	
PSL MS001 (Magnetic Shielding)	Magnetic Shielding	0.00394	Bolshaya Cheremushkinskaya, 25, 117218 Moscow, Russia;
PSL VL016 Spray On Plastic's Five Star Polyurea	Liner	0.085	
Asahi PolyPure unpigmented (Natural Polypropylene)	pump water (from 4850m)	5.40E-02	
Asahi PP Pure pigmented (Natural Polypropylene)	pump water (from 4850m)	5.40E-02	Asahi/America, Inc

Liner Attachment



Schedule Optimization

- **Construction schedule for the vessel and liner is one of the most critical components of the overall project schedule. There are two basic approaches for vessel construction:**
  - **The entire cavern is excavated before the construction of the liner starts,**
  - **The construction of the liner is concurrent, in part or in whole, with cavern excavation.**
- **Evaluation of different construction concepts is in progress**
- **Our baseline approach is for serial construction**
- **So far, we have opinions on both sides as to feasibility of concurrent construction**
- **Main issue is possible damage to liner during blasting**
- **With 65 m diameter and spiral excavation this may be possible**

Good Things You Learn

Geosynthetic Institute

GSI's Mission is to develop and transfer knowledge, assess and critique geosynthetics, and provide services to the member organizations.

IAGI strives to provide a forum for geosynthetics installers to advance installation and construction techniques, and to strengthen the knowledge, image and communication within the industry.

Summary

- **Baseline design is polymeric sheet on smoothened shotcrete**
- **Have cost estimates from two sources that are in reasonable agreement**
- **Alternate designs are under study**
- **Developing test and prototype plans for liner and penetrations**
- **Material testing is in progress**
- **Leak rate estimates will allow us to specify realistic construction and QA techniques**
- **Studying methods of contracting, performance and warranty**
- **Developing list of vendors for design, manufacturing and installation**

Near infinite experience for liners near surface and in nearly horizontal condition. Application to 65 m x 85 m cavern at 1500 m depth is the question.

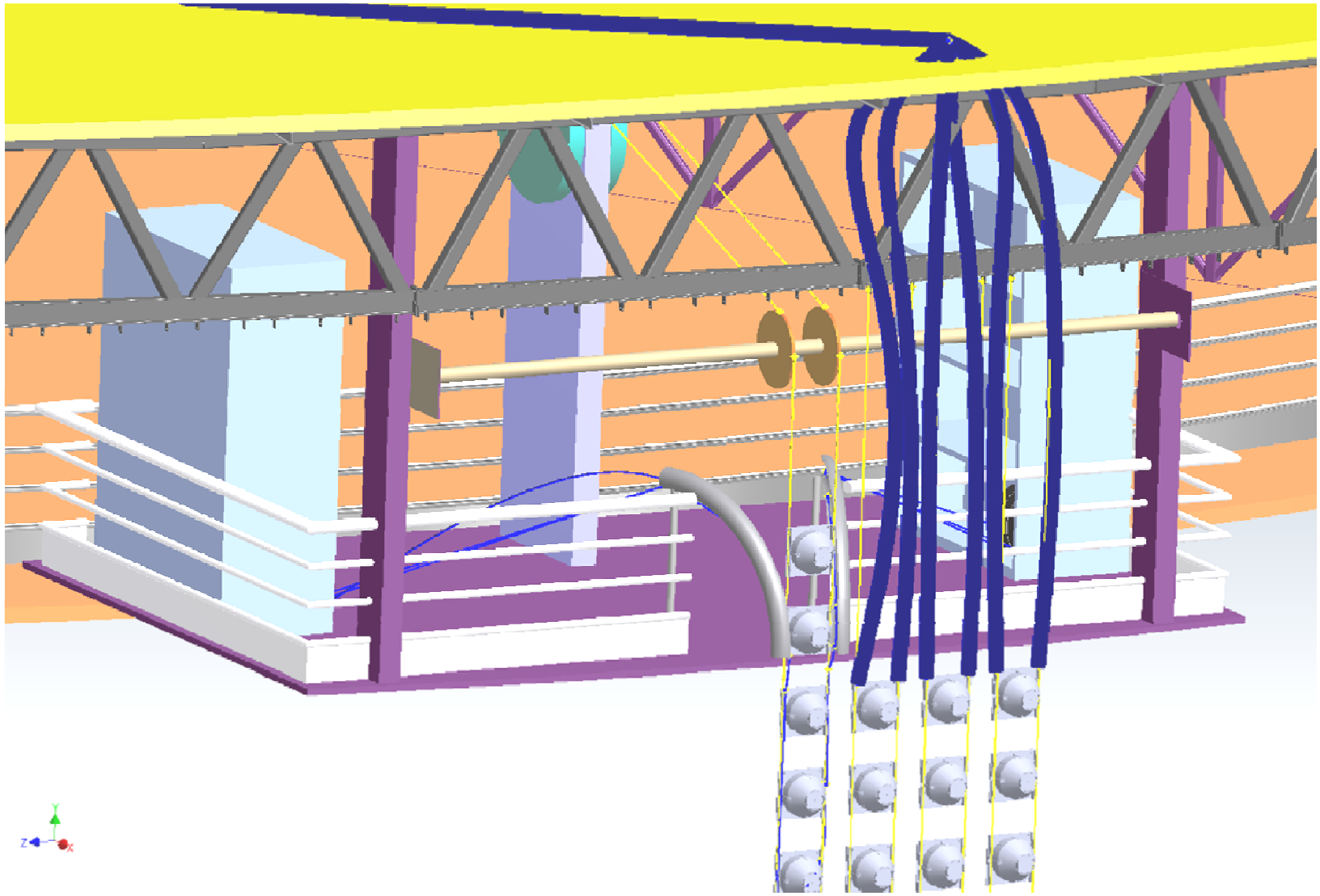
Additional Slides

Floor Construction

- **Static water load is 800 kN/m^2 (16,300 lbs/sq ft)**
- **Concentrated mast climber load is about 20 ton in 8 to 10 spots**
- **Liner and drainage layer static rating must be sufficient**
- **A protective layer over liner may be required**
- **Penetrations are requited for attachment of PMTs**
- **A slope to perimeter of about 0.5% is required**
- **Magnetic compensation coils are under floor slab, joint is required to wall coils**
- **Thickness allowance is 1m total for slab, coils, drainage and liner**
- **Detector water distribution manifolds are above floor and not in the slab**

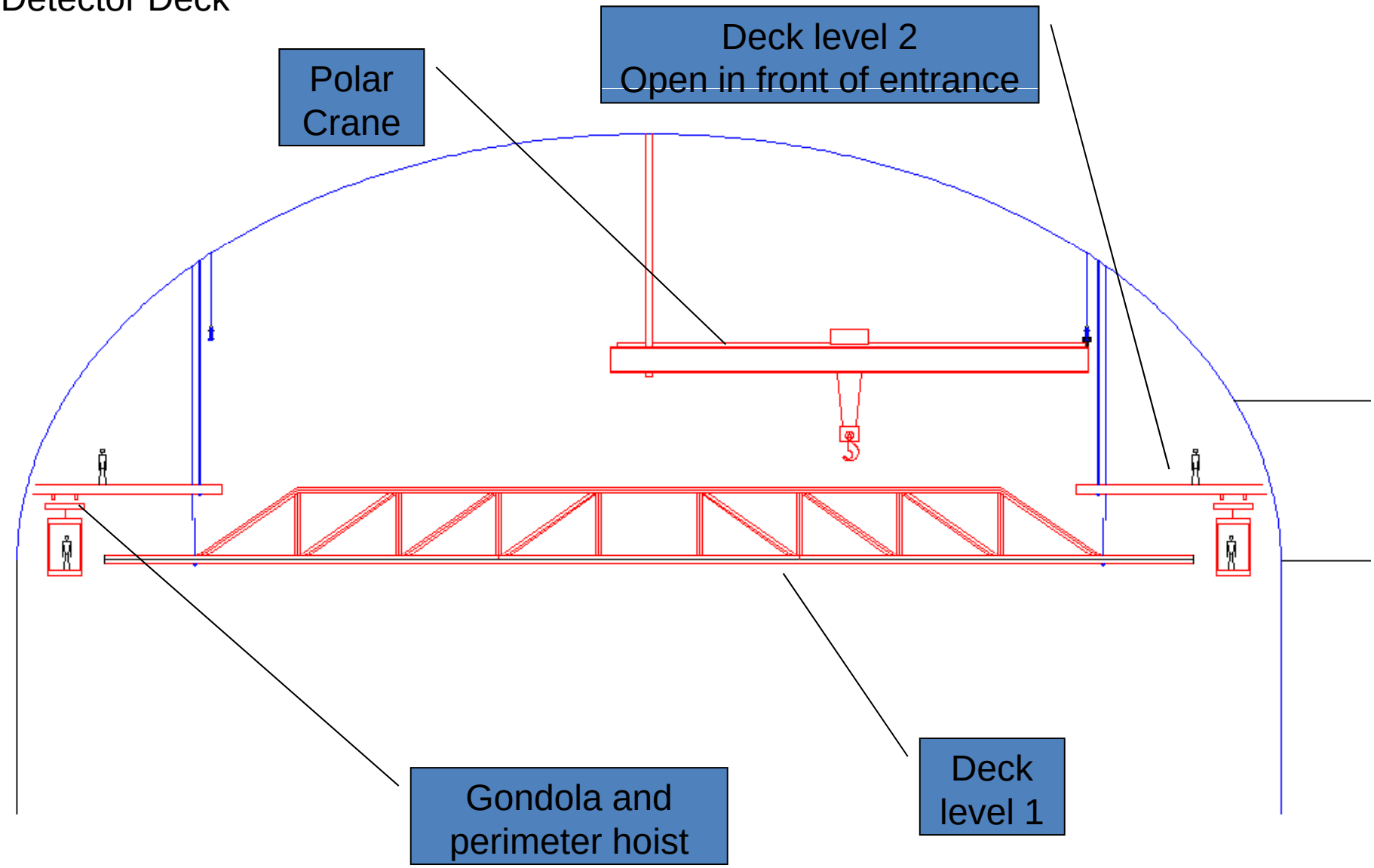
Mast Climber

PMT Deployment from Deck



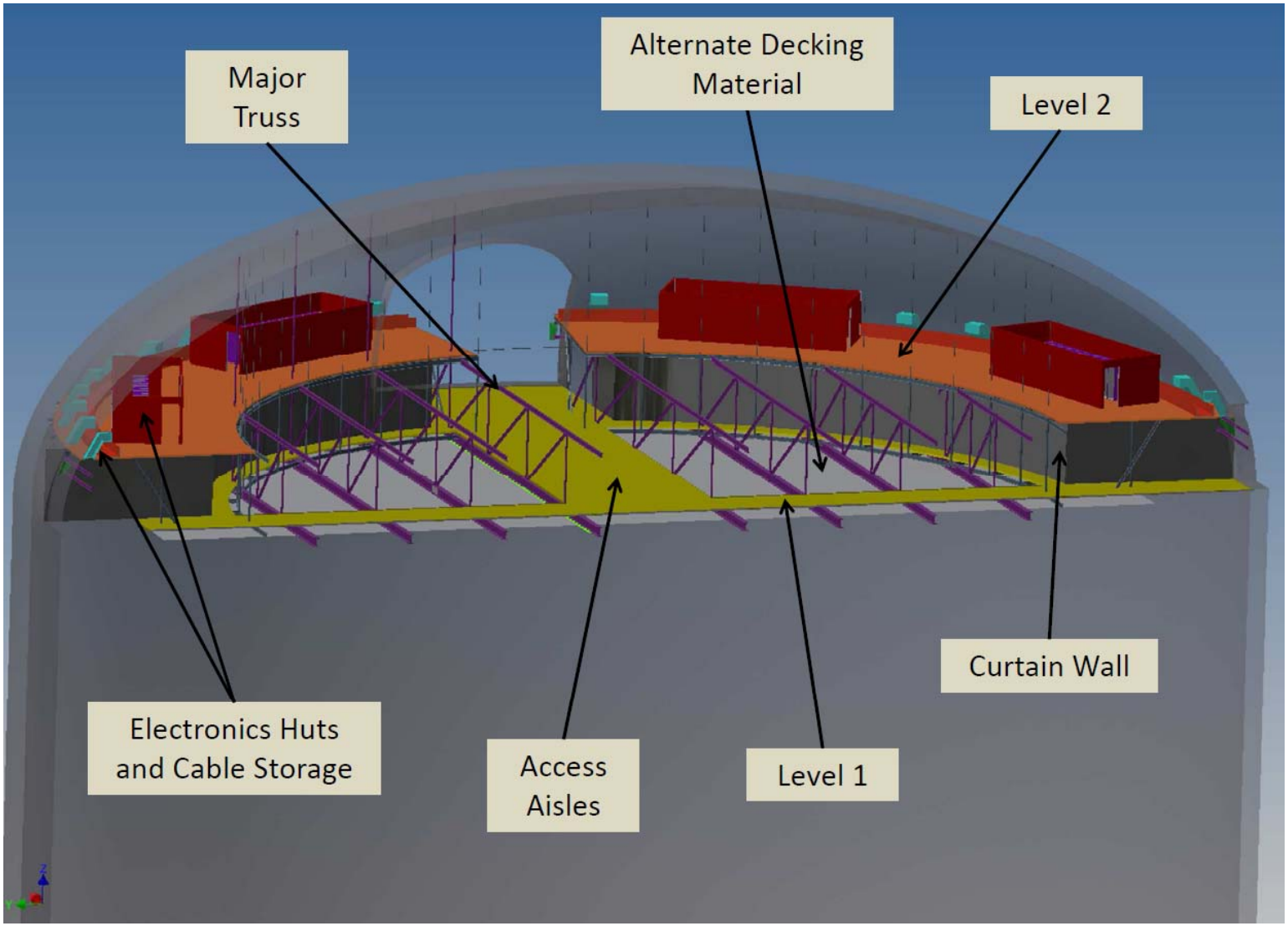
J. Fowler, Duke Univ.

Detector Deck



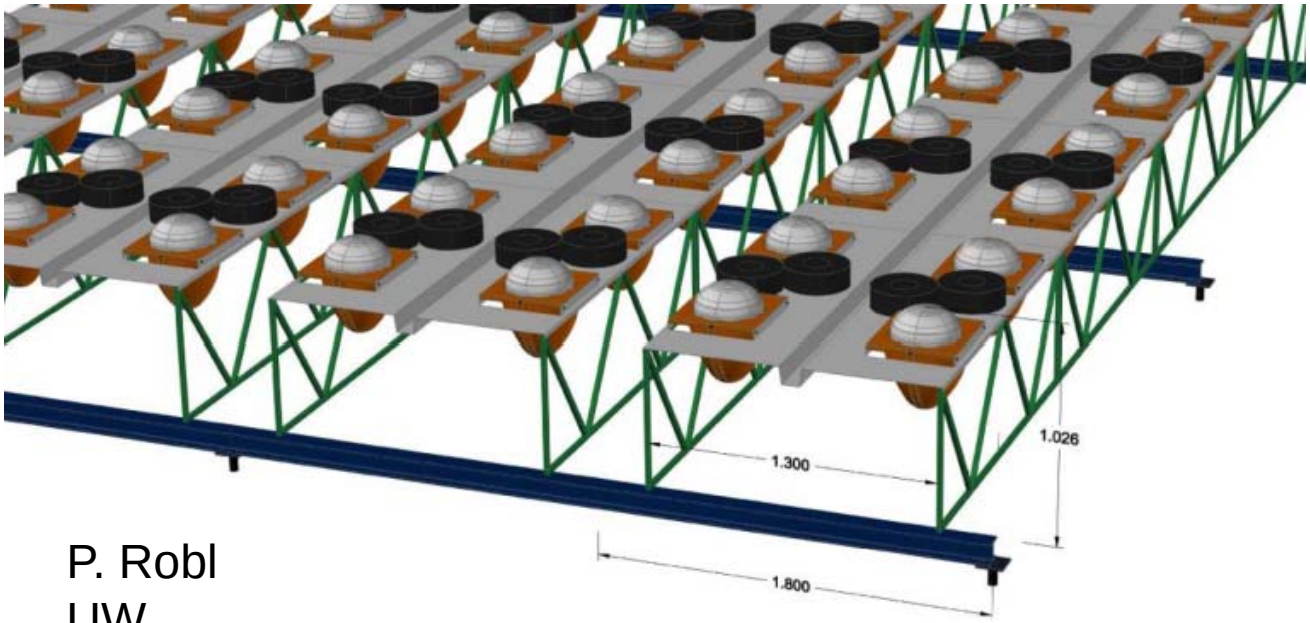
More from J. Fowler

Detector Deck

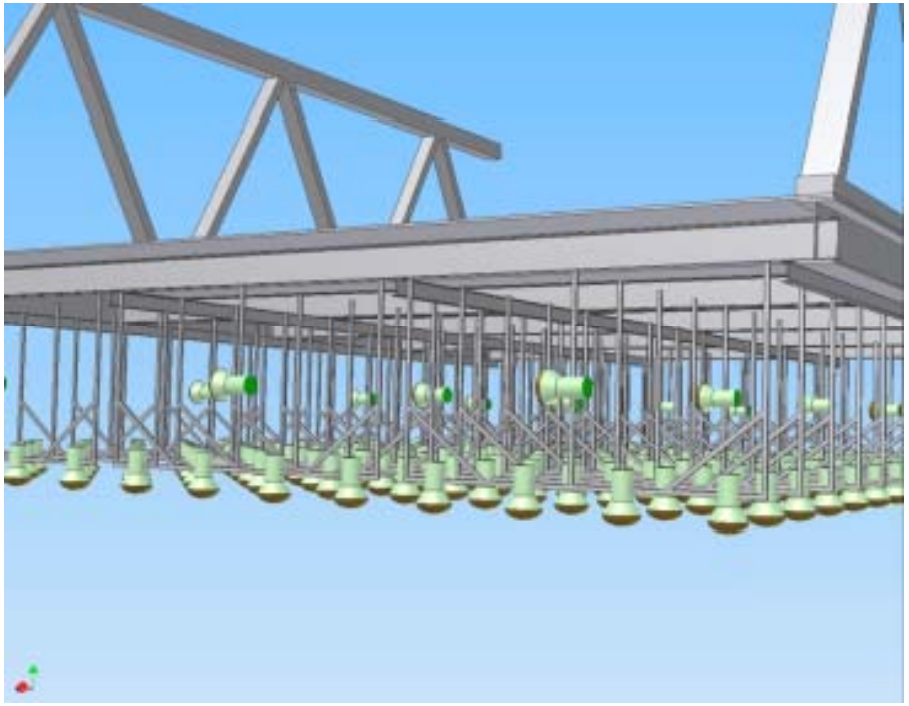


J. Fowler, Duke Univ.

Floor and Deck PMTs



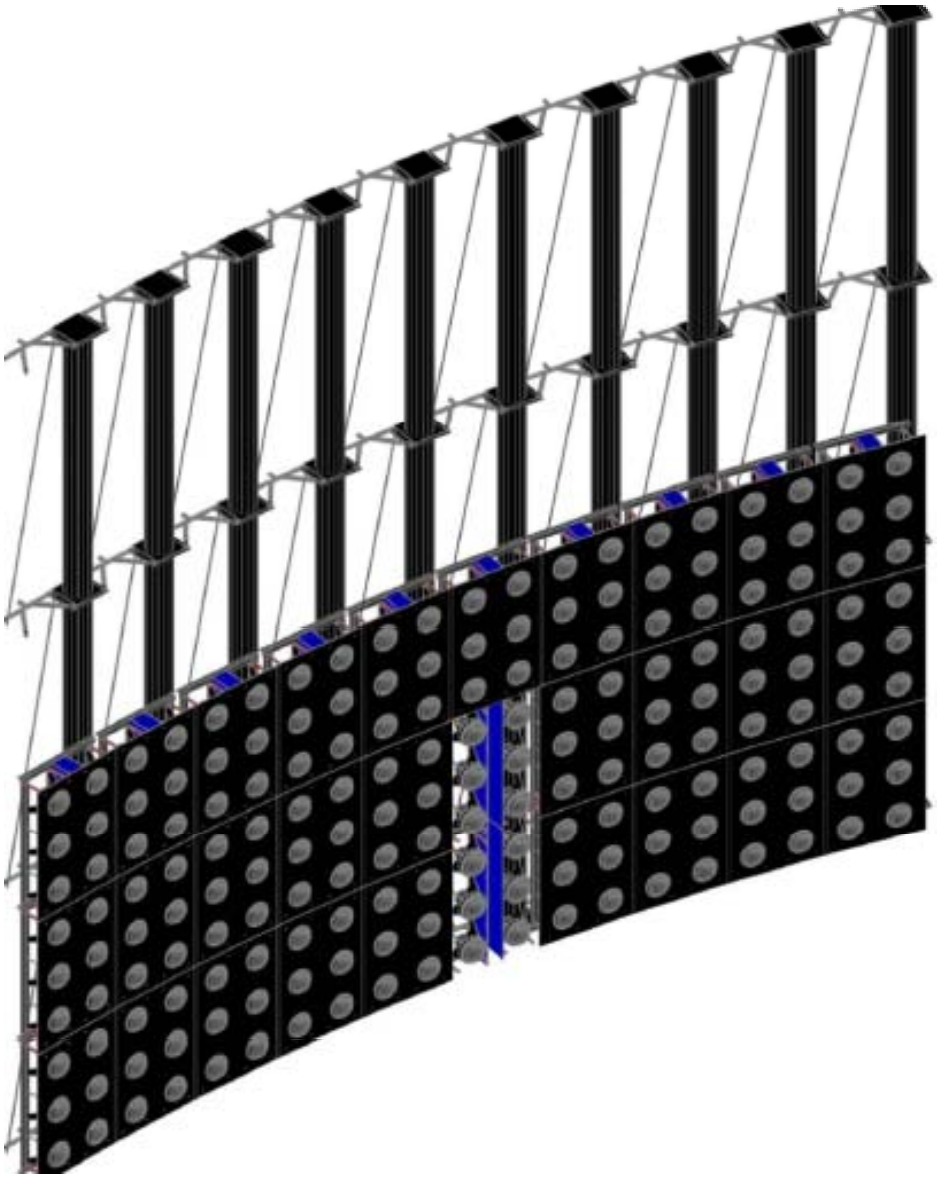
P. Robl
UW



J. Thomson
UCD

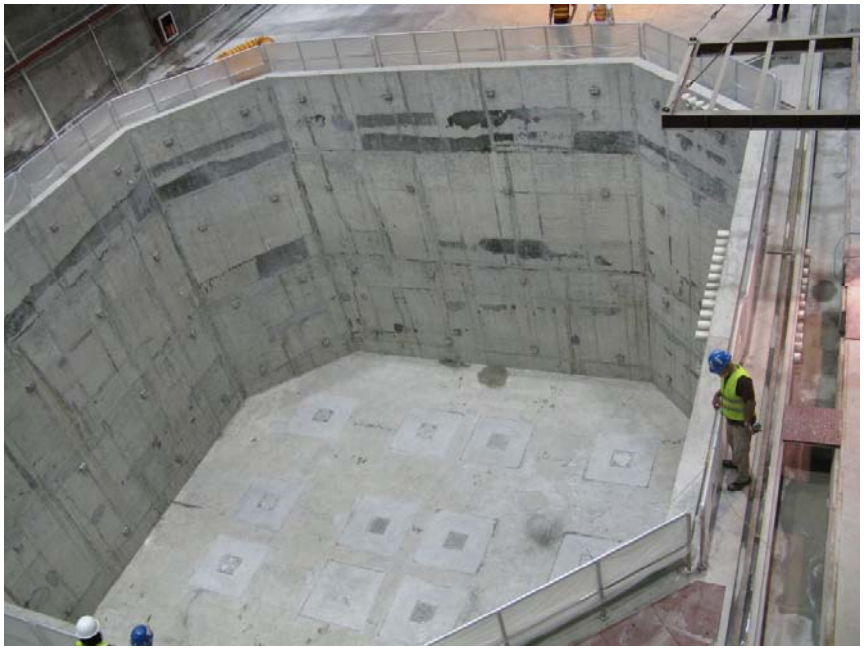
Free-Standing PMT Supports

- **Modular system erected from floor**
- **2x 3 arrays of PMTS attach to structure**
- **This is not baseline due to cist**

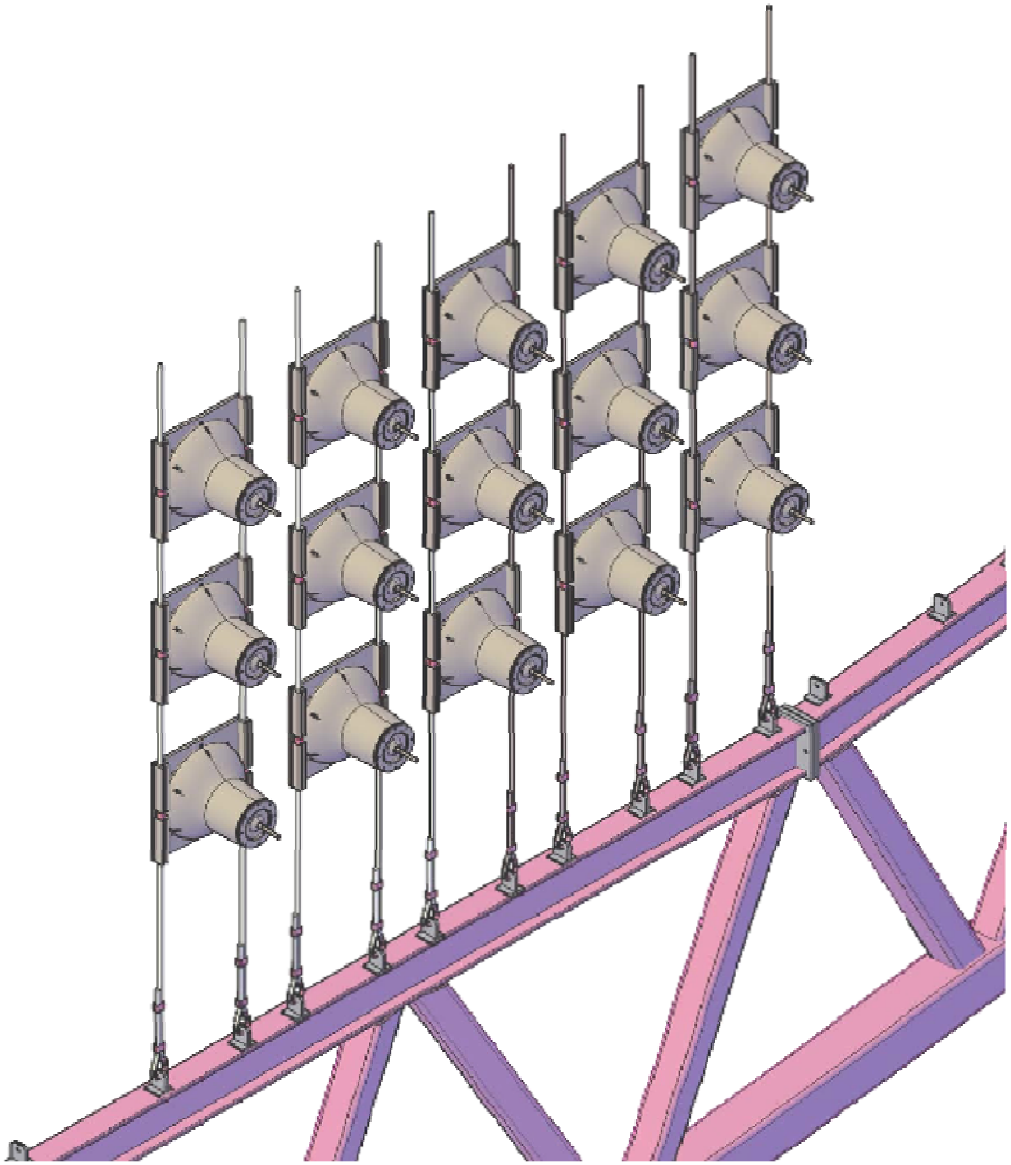


DayaBay

- **Permaflex (polyurethane) sprayed on**
- **Wall moisture and finish need good control**
- **Test results show it is not appropriate for LBNE**



Ring truss and Wall PMTs



Typical Liner Penetration