Homestake DUSEL

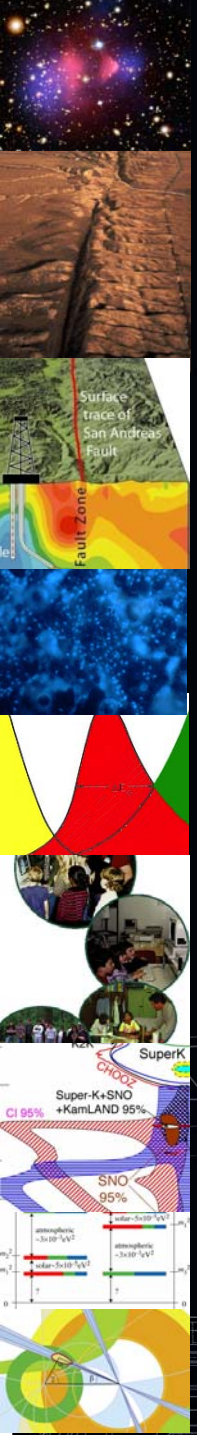
Large Cavity Detectors

Richard W. Kadel

Senior Scientist,

Physics Division, LBNL

VLBL Collaboration meeting
UC Davis, 26 February 2009



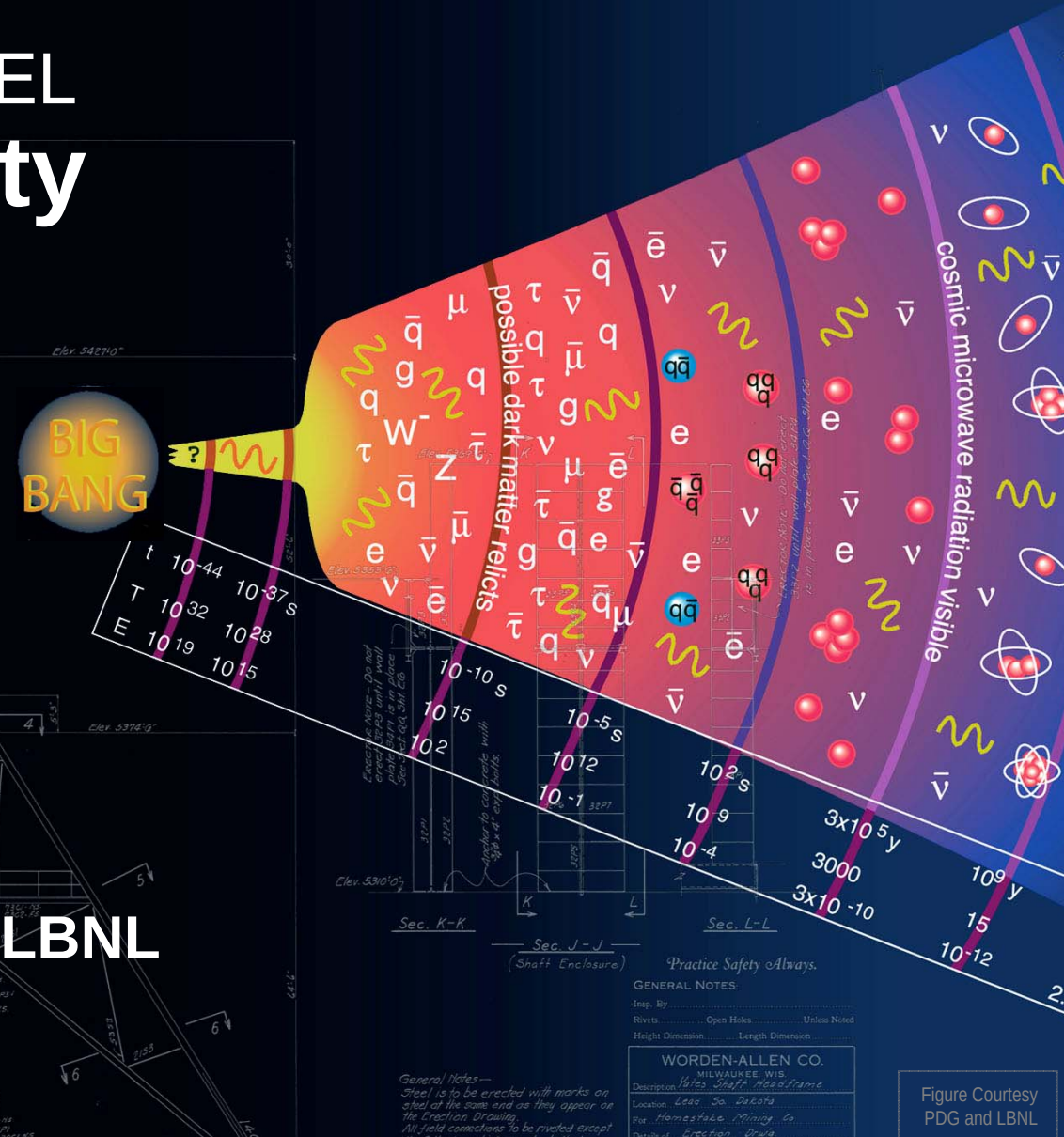


Figure Courtesy PDG and LBNL

Outline

- NSF Review
  - Slides from Large Cavity Experiments talk
  - Depth, Size of detector
  - Cavern Spec, shapes
  - Cavern Cost Estimates
  - “C6” Committee
  - NSF Committee Recommendations for Large Cavity
- Large Cavity Advisory Board
  - Recommendations
- Site Investigation Plan

First year Review of the Cooperative Agreement between NSF & U. C. Berkeley for DUSEL

- UCB, January 27-29, 2009
- ~ 40 Reviewers in 6 disciplines, E. Temple Chair.
  - SC-1: Surface and Underground Construction
  - SC-2: Underground Experiments.
  - SC-3: Education and Outreach
  - SC-4: ES&H
  - SC-5: Costs and Schedule
  - SC:6 Project management
- DOE representatives present.

SC-2 Underground Experiments Committee
Allison Lung, TJNAF (Chair)
Charles Dowding, Northwestern
Abe Seiden, UCSC
Moira Ridley, Texas Tech
Mike Witherell, UCSB
Marty Breidenbach, SLAC

Following slides are from (or as a consequence) of this review

Physics Objectives: Large Cavity Experiments (Examples of plots shown)

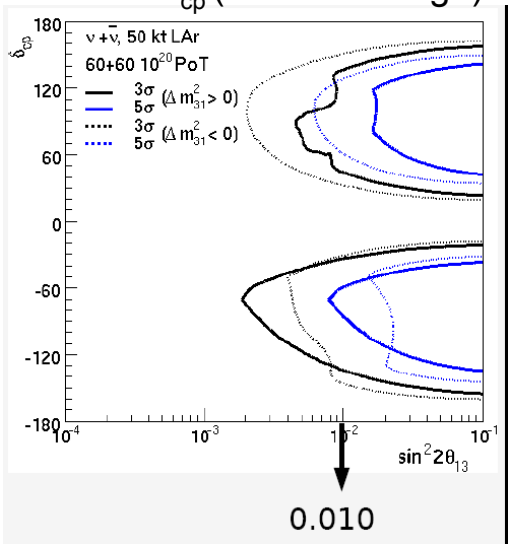
Accelerator Driven

- Measure CP violation in neutrino sector
- Determine the Mass Hierarchy (normal or inverted) for neutrinos
- Measure the Value of θ_{13}
- …

Non-Accelerator Physics

- Detect Proton Decay
- Super Nova searches
- Detect diffuse neutrinos from past supernova
- Astrophysical Neutrinos…

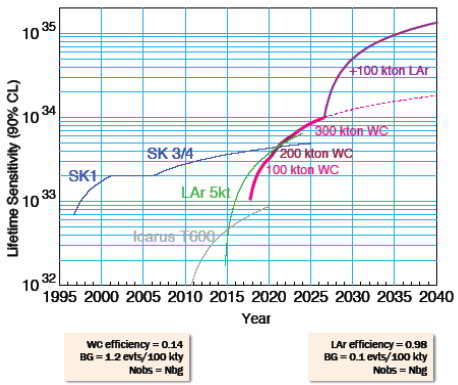
δ_{cp} (50% Coverage)



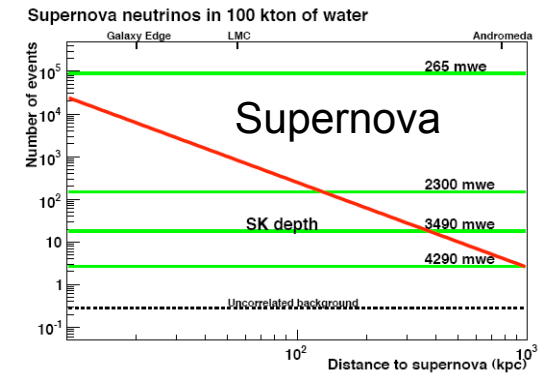
Dierckxsens UDig Workshop

Proton Decay

$p \rightarrow K^{+}\nu$



E.Kearns



Report of the US Long Baseline Working Group, FNAL -0801-AD-E

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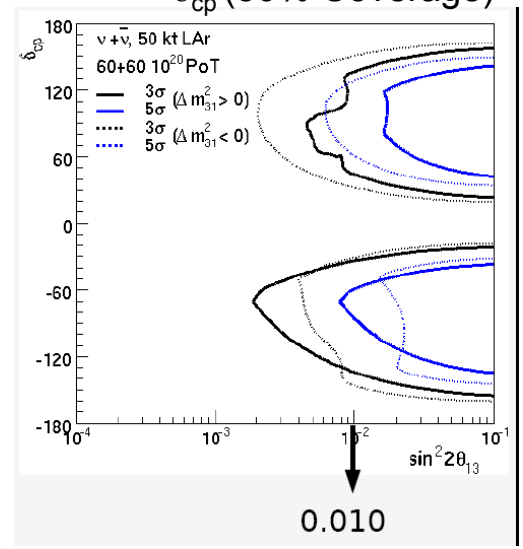
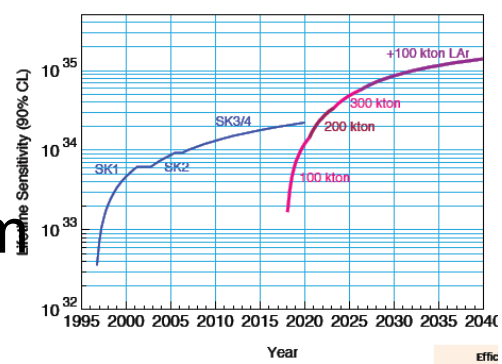


M.Dierckxsens UDig Workshop

Proton Decay

$p \rightarrow e^+\pi^0$



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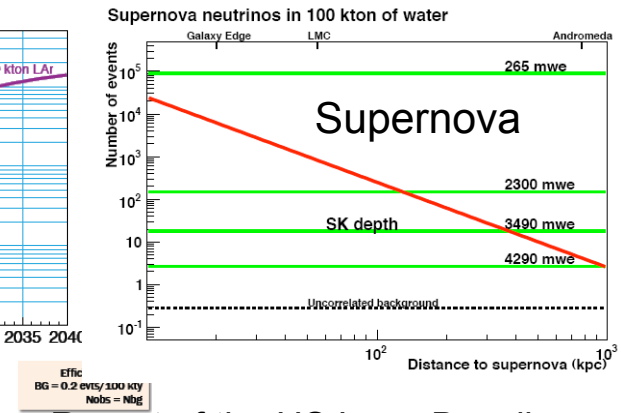


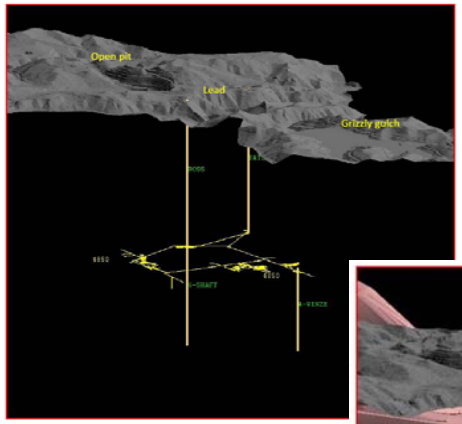
Report of the US Long Baseline Working Group, FNAL -0801-AD-E

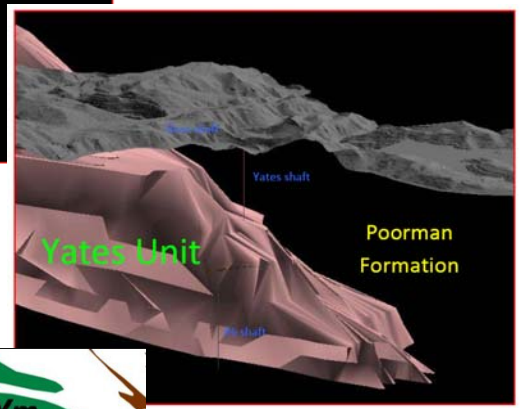
Depth Requirements Summary

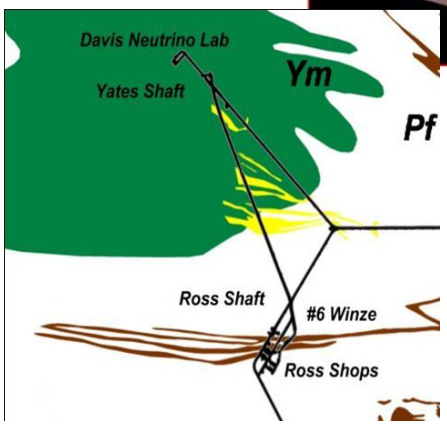
Physics	Water Cherenkov (mwe)	Liquid Argon (mwe)
Long BaseLine Accelerator	1000	0-1000
$p \rightarrow K^{+}\tilde{\nu}$	>3000	>3000
Day/Night ^{8}B Solar ν	~4300	~4300
Supernova Burst	3500	3500
Diffuse ν from Supernova	4300	>2500
Atmospheric ν	2400	2400

Siting criteria for Large Cavities*.

1. Above or at 4850L.
2. Ross-Yates access.
3. Excavations in Yates at a single level.
4. Existing Waste Rock facilities
5. Room for ≥ 3 cavities.
6. Support Life Safety & Hazard mitigation.
7. Avoid areas of high stress.
8. Avoid Formation Contacts.
9. Avoid Significant geo-structural features (shear or fracture zones).







Figures courtesy Z. Hladysz

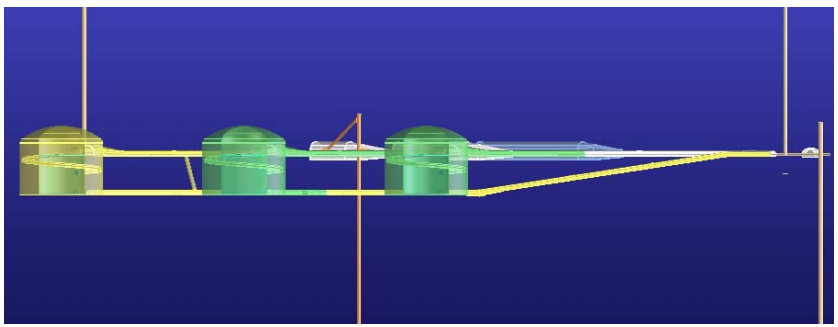
*Lesko, Roggenthen, "Siting Large Cavities in Homestake," DUSEL 58, August, 2008.

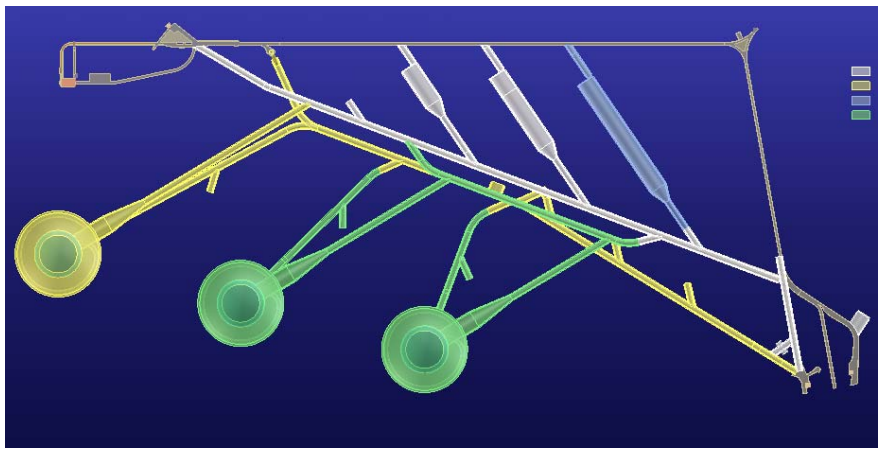
Detector Depth Conclusion

No large cavity physics goal requires a depth deeper than the 4850 Level

Significant burden to go deeper (requires all material, waste rock, equipment and personal change shafts)

<u>Conclusion</u>: The depth required by physics goals weighed against the siting criteria suggest that the 4850L is the best location to search for candidate sites suitable for the large cavity detectors.





Figures Courtesy D. Plate & S.DeVries

Detector Sensitivity versus Size and Exposure: Neutrino Accelerator Physics

Detector Size (kT)	POT ($\times 10^{20}$) @120GeV (1MW = 10^{21}/yr)	Years $\nu+\tilde{\nu}$	3 σ Sensitivity Minimum value of $\sin^2 2\theta_{13}$		
			$\sin^2 2\theta_{13} \neq 0$	Mass Hierarchy	CPV (50% of δ_{cp} coverage)
H20 100 Bishai	30+30	3+3	0.014	0.031	>0.1
H20 300 Bishai	30+30	3+3	0.008	0.017	0.025
H20 600 Bishai	30+30	3+3	0.005	0.012	0.012
H20 300 Bishai	60+60	3+3	0.005	0.012	0.012
LAr 50 Dierckxsens	60+60	3+3	0.005	0.011	0.010

Detector Size: Conclusion

≥ 300kT for a water Cherenkov detector is
e Physics goals of:

nent of CP violation in the neutrino sector,

nent of the neutrino mass hierarchy, and

nent of the angle θ_{13}.

tor physics goal of

decay

H_20 Cherenkov detector of ≥ 300kT.

ented by more mass or the addition of a large
argon detector as this technology matures.

to non-relativistic particles

sensitivities to ν_e vs $\bar{\nu}_e$events.

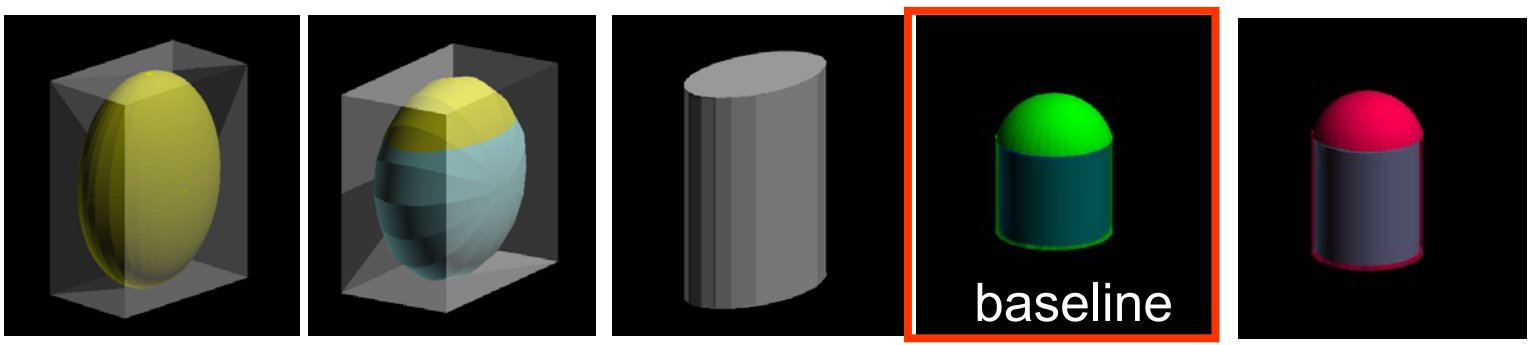
Example of a Physics Spec for Cavern: Water Cherenkov Detector

- Depth: 4850L.
- Total fiducial Mass: >300kT.
- Minimum fiducial mass per cavity: ~ 100kT.
- Allow for multiple detectors near-by:
  - Maximum distance between detectors perpendicular to beam line ~ 5km.
- Max dimension between PMT's (light attn): ~80 m.
- Cavity Lifetime: >30 years.
- Safety:
  - Dual egress or refuge locations from all drifts & cavities;
  - Design should inherently protect the rest of DUSEL from catastrophic flood.
- Reasonably minimize the surface area for a given volume.

Other Cavern Specs?

- Maximum Water Depth (Photomultiplier Tube collapse): ~ 60m?
  - Mitigate with R&D to increase PMT strength.
- Vertical walls (ease PMT mounting)?
- Chronic water leak recapture strategy if gadolinium doped?

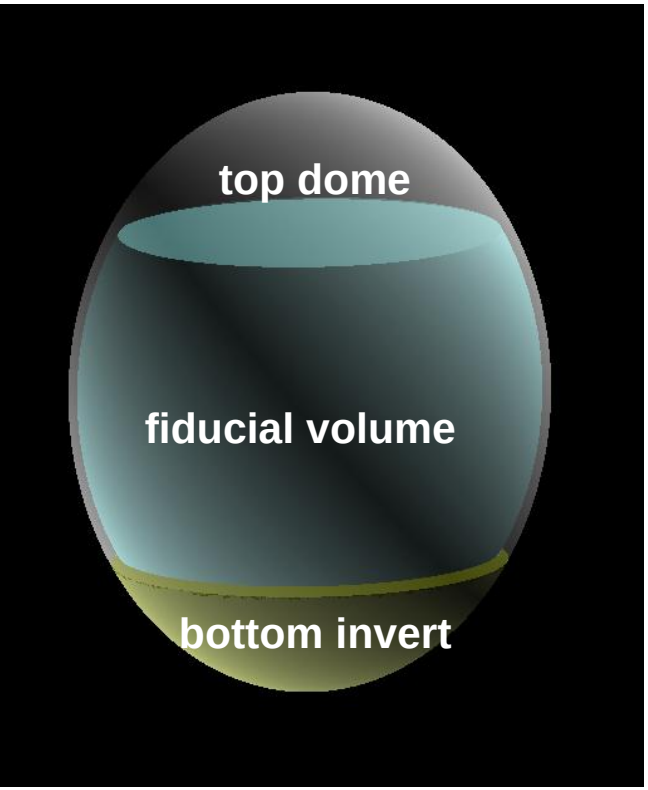
Some Potential Cavern Shapes:



Figures, Courtesy, Z. Hladysz

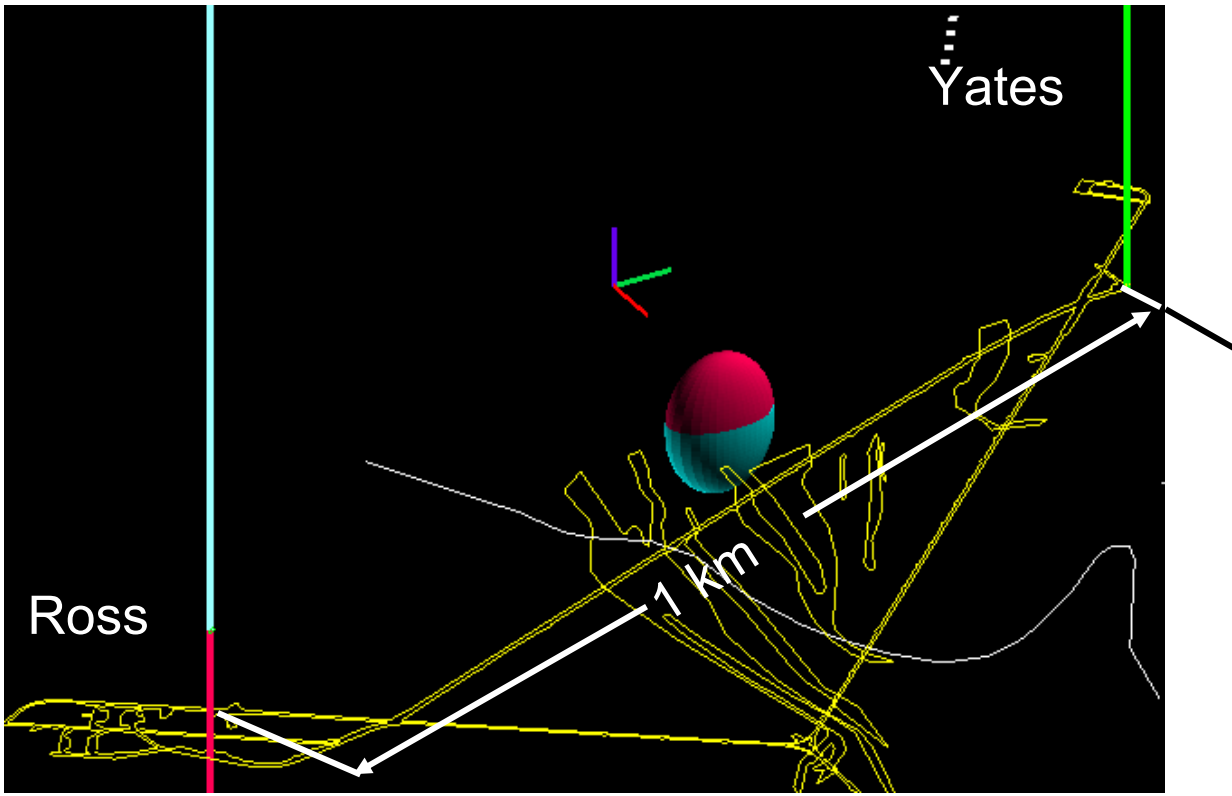
ellipsoid | discus | ellipsoidal prism | **circular cylinder** | circular cylinder (max height)

Example of Larger cavity: Elliptical Cavity



Courtesy,
Z. Hladysz

If rock conditions permit, ~ 300kT fiducial volume with only two cavities



100kT Fiducial Volume Cavern Cost estimate

Laurenti, FNAL 2008 Aug 1($Millions)

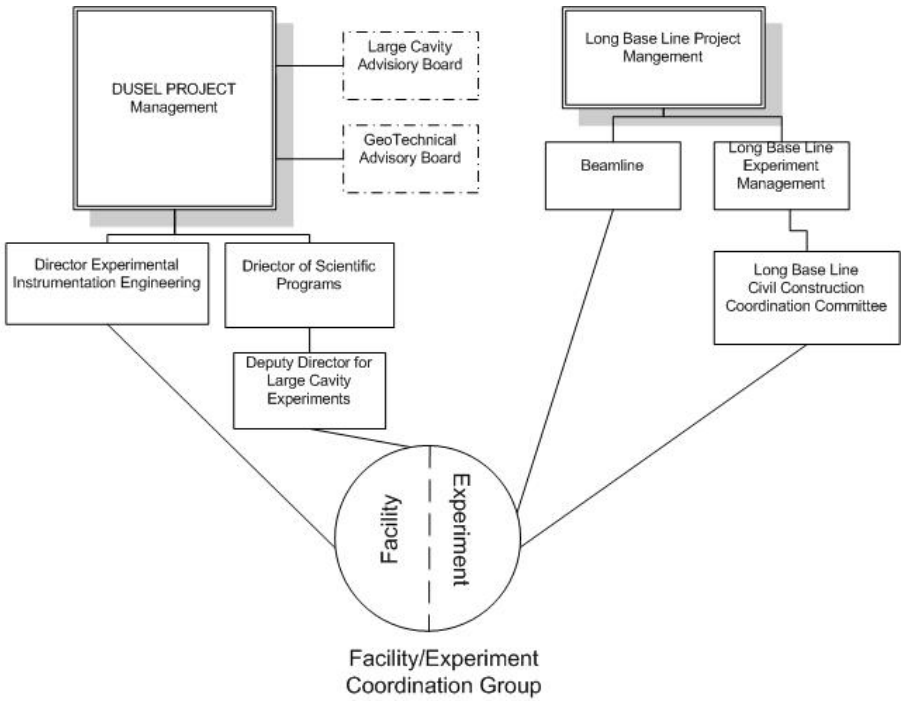
- Cavern excavation: 33.1
- Equipment 10.0
- Overhead (10%) 4.4
- Markup(20%) 8.7
- Contingency (40%) 22.8
- Skipping cost ($4/Ton) 2.0 (500 kT)
- Disposal ($10/Ton) 5.0 (500 kT)
- TOTAL $86.1M (1 cavern)

Costs associated with geotech work has been removed from Laurenti's estimate. DUSEL pre-construction budget for the Large Cavity (including geotech work) is shown below.

	FY09	FY10	FY 11	FY12	Pre-construction Totals
Total Expenses ($K)	1459	3378	4687	5314	14838
Staffing ($K)	232	1213	1372	1489	4306
Contracts ($K)	1227	2165	3315	3825	10532
Staffing (FTE)	0.3	4.5	4.5	5	14.3
LBNL (FTE)	0.3	2	2	2	6.3
SDSMT(FTE)		2.5	2.5	3	8

DUSEL Facility-Experiment Coordination

- Relevant Documents: Existing
  - List of available levels DUSEL
  - VLBL Collaboration Depth Document
  - List of infrastructure provided by DUSEL
- Proposed ad-hoc Facility/Experiment coordination group.



RWKadel
6-Jan-2008
V.2

"C6" = "Cherenkov Cavern and Cavity Civil Construction Coordination" Committee

Facility/Experiment Coordination

- Will require MOU between VLBL Project office and DUSEL PM to clarify responsibilities, organization and interaction between parties.
- Interface documents that delineate requirements, who is responsible for what, when, and where the dividing lines are drawn.
- Continuous communication via Facility/Experiment Coordination Group(s) to refine requirements, clarify problems, identity new issues, report on progress and unresolved issues, & problems

$3M Geotech work on 4850L: S3 Supplement

Plan:

- Preliminary design in End CY2010
- Costs here do not cover all of preliminary or final design
- Overhead not included

Requested Budgets for Supplemental Funding	FY09 (k$)	FY10 (k$)
1) Large Cavity Advisory Board (LCAB)	120	80
2) 4850L Mapping	50	
3) Large Cavity #1 (geotech)	900	900
4) Lab Module #2 (geotech)		400
5) Initial Cavity Modeling	50	
6) Geotech Advisory Committee (GAC)	50	50
7) Subsequent Cavity Design		125
TOTALS	**1170**	**1555**

SC-2 Technical Review Comments (Paraphrased)

Underground Experiments, Overall Recommendations:

- Success of the laboratory will depend on the DUSEL having a significant management role in the integrated suite of experiments.
- The DUSEL management team needs to integrate the experiments into the DUSEL WBS, schedule, and other project controls.

SC-2 Technical Review: Large Cavity Experiments (paraphrased)

- Findings
  - Science is well motivated
  - Integration issues understood in terms of depth requirements, size and interface between the two possible experimental techniques and the facility
- Comments
  - Significant progress
  - List of integration issues appropriate for project status.
  - Congratulations to DUSEL team and collaboration for identifying science requirements for experiment and facility infrastructure.
- Recommendations
  - None.

Large Cavity Advisory Board

Ed Cording Evert Hoek John MacDonald Derek Martin

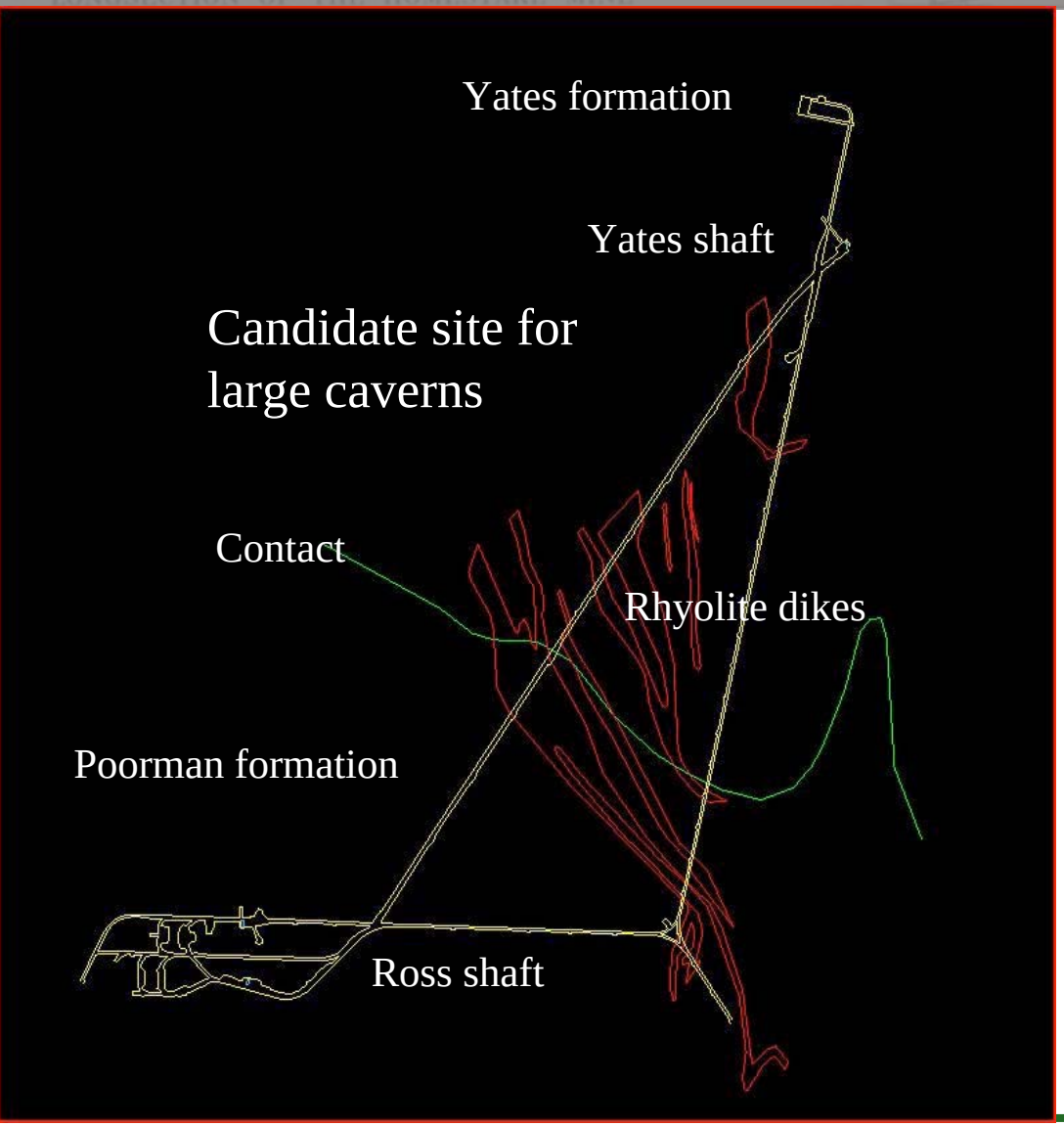
The Large Cavity Advisory Board (LCAB) was established in January 2008 to provide technical expertise and advice to the DUSEL project directorate on issues of siting, excavation, excavation stabilization and monitoring of large-scale excavations at significant depth in Homestake. All members have experience in the design and construction of large underground cavities in a wide range of rock mass and in situ stress conditions.

The LCAB will report to Kevin Lesko in his capacity as DUSEL Principal Investigator, UC Berkeley.

DUSEL's Large Cavity Advisory Board

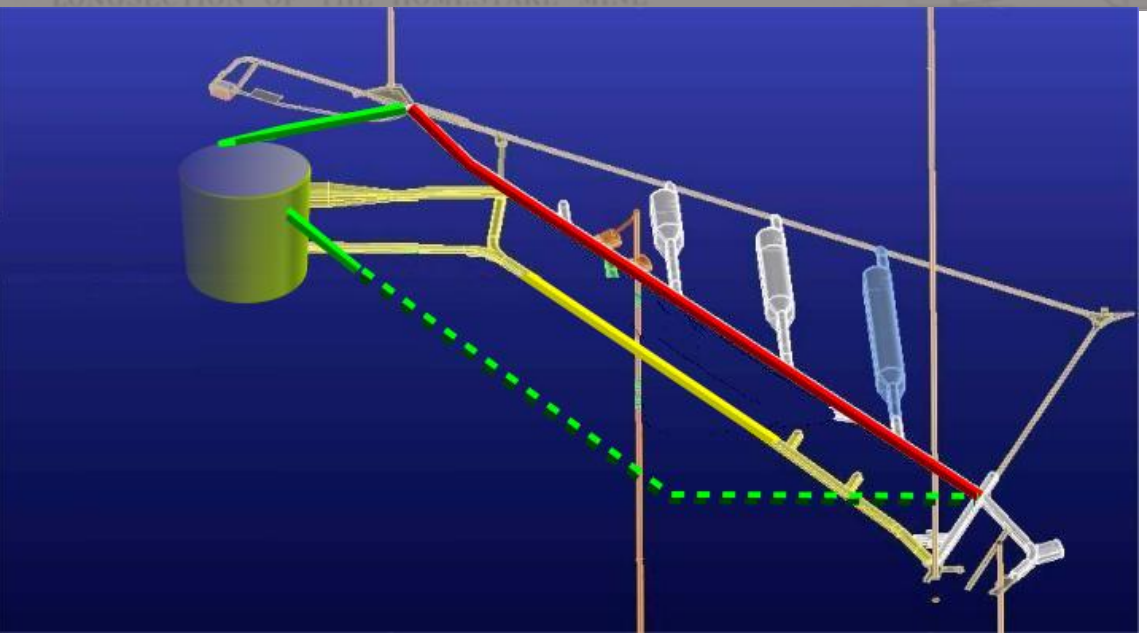
- Organized to advise DUSEL on large cavity construction, 4 members, Evert Hoek, Chair
- Function as so-called "owners representatives"
  - "recommends and comments" versus "approves"
- Met for the first time at DUSEL January '09 Annual Review
- Recommendations/Comments
  - Enthusiastic that stable ~60m wide caverns could be excavated at Homestake
  - Large scale structure is likely more important than intact rock properties
    - Joints
    - Dykes
    - Faults, etc.
  - favored "**drifting** + coring" vs "just coring and boring."
  - Evaluate 2 caverns instead of 3 (ie. ~150kT vs 100kT fiducial mass)
  - Map 4850 L (some of which is already part of existing contract), 4100L
  - Meet again at Homestake after reconnaissance mapping is complete

Structural geology at 4850 level



The candidate site for the large caverns is in the Yates formation to the west of the drift connecting the Yates and Ross shafts. The geology of this area is largely unknown since it is in waste rock and therefore of little interest to mine geologists. However, there is ample evidence to suggest that there are several joint sets, through-going rhyolite dikes and possible some faults in the area. **It is probable that these structural features, rather than the properties of the intact rock, will dominate the design of the caverns.**

LCAB suggested exploration sequence



1.Create a detailed structural geology map along the drift between the Yates and Ross shafts (shown in red).

2. Combine this mapping with mapping along drifts on levels above 4850 and use Vulcan to create a 3D map of joints, dikes and faults in the target rock mass.

3.Based on this 3D model, carry out an optimization of cavern location(s).

4. Mine an exploration drift (shown in green) into the top of the proposed cavern location and extend it, in a direction crossing major geological features, far enough to provide sufficient information for a reliable structural model. This drift can be extended later (shown dashed) to investigate alternative or additional cavern locations.

5. Short hole diamond drilling can be carried out for sample collection, stress measurements or other studies from this exploration drift.

6. Locate the first cavern and carry out detailed studies on optimum shape, support requirements, excavation method and sequence.

LCAB Report

Recommendations - Highlights

- The construction of large cavities - with spans in the order of 60 m, at the 4850 level at the chosen location - is feasible.
- The optimum siting for the caverns within the current target location has to be based on currently available information, supplemented by mapping and interpretation of structural features in the existing drifts. There is an urgent need to create an engineering-geological model for use in the selection of an optimum site for the first large cavern.
- The stability of the proposed caverns will be controlled by structural features, such as the rhyolite dikes, rather than the intact rock properties. The properties of the intact materials, while still important, will play a secondary role.
- Construct an exploration drift to the target location to identify the relevant geology that can impact the construction of the large cavities

LCAB Report

Recommendations – Highlights

- Move the cavities approximately 100 to 150 m offset from the current access drift, rather than the proposed 300 m.
- Provide a single top access drift for all 3 cavities
- Provide a single bottom access drift to all three cavities for muck removal.
- Remove the spiral ramp from the cavern
- Evaluate the logistics for two caverns rather than 3

Large Cavity Preliminary Geotechnical Site Investigation Plan

Planned Sequence of Events

1. Develop a preliminary three dimensional model of structural geology in the Large Cavity Area using existing geological data. Start Date: March 15.
2. Perform detailed structural geology mapping at the 4100 L: completion date by 15 June.
3. Agree on the scope of geological mapping, laser scanning and interpretation for both the Lab Modules and Large Cavities with RESPEC. Completion date: 31 April, including contract extensions.
4. Map the 4850 level. Begin mapping ~15 May and complete mapping by 30 July. Approximately of 2.5 km of drift should be mapped.
5. Incorporate geological mapping and laser scanning data into Structural Geology Model. Target completion by 30 August.

Large Cavity Preliminary Geotechnical Site Investigation Plan

Planned Sequence of Events

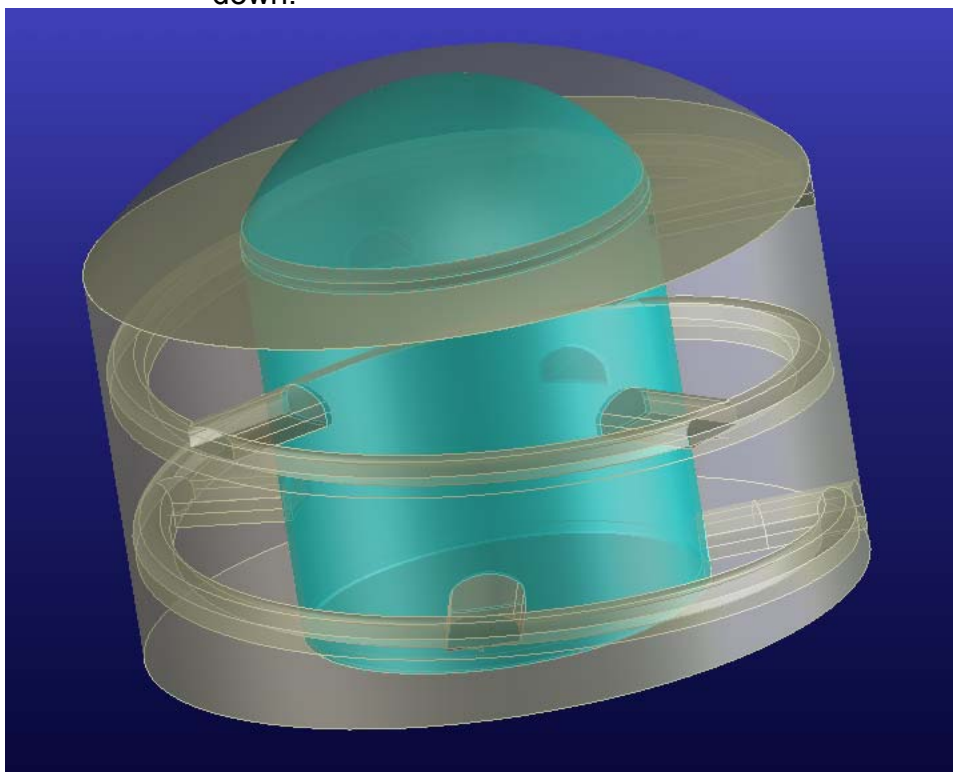
6. Confirm optimum location of first Large Cavity by drilling one or two horizontal holes from the 4850 L to extract core. Compare results from core to Structural Geological Model. Determine optimum plan for obtaining necessary geotechnical information. Target completion date - 30 September
7. Complete Preliminary Geotechnical Site investigation program incorporating Core Drilling, Testing, Exploration Excavation. Target Completion – August, 2010

Large Cavity Preliminary Excavation Design

Excavation Options

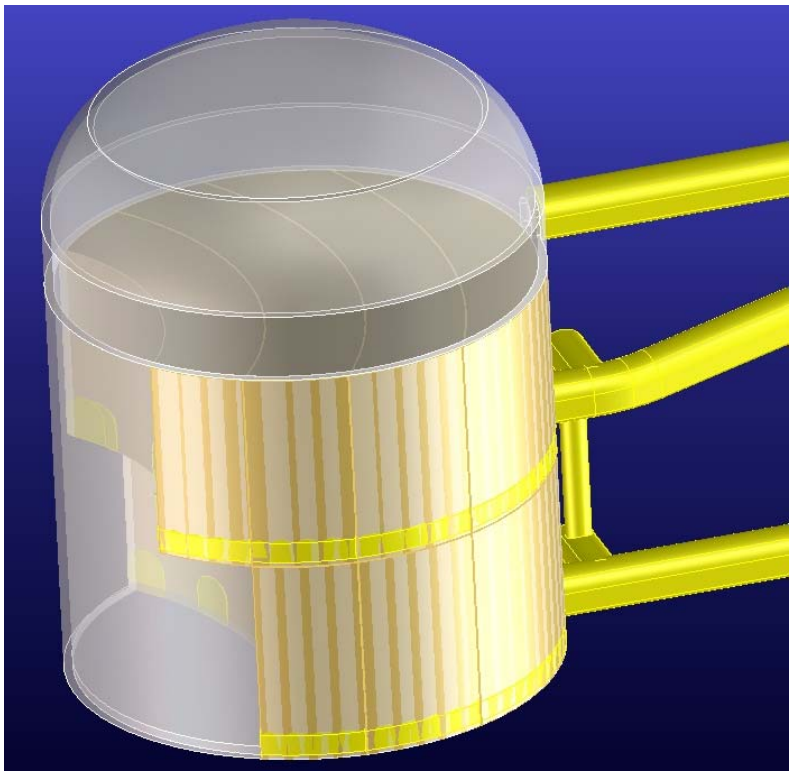
1. Benching Method

- Top Access at 4850 L, Bottom Access at 5000 L
- Spiral ramp around Perimeter for Horizontal Accesses every 20 ft
- 20 ft Vertical Benches excavated from the top down.



2. Bulk Excavation Method

- Top Access at 4850 L, Bottom Access at 5000L, Center Access at 4925L
- Long hole drilling from 4850L, 4925L, and 5000L
- Blasting from 4850L and 4925L
- Waste rock removal from 4925L and 5000L



Excavation Option Comparison

1. Benching Method

Pros

- Well Established Method
- Good Access for Equipment with Spiral Ramp and Accesses
- Ground Support Installed close to excavation

Cons

- Crane is installed prior to the completion of Blasting – Risk of Damage
- Losses due to inefficiencies relating to changing work cycles
- Multiple Hydrostatic Bulkheads (7) required at Access points
- Ledges or steps formed in walls due to benching method

Excavation Option Comparison

SNO Lab

- Excavated using Benching Method
- Crane Installed prior to completion of Blasting – Damage resulted
- Ledges formed along walls

Excavation Option Comparison

2. Bulk Excavation Method

Pros

- Well Established Method
- Productive Excavation Method – Long Hole Drilling and Blasting
- Crane Installed after blasting is complete – no damage
- Smooth walls with minimal over break – Presplitting
  - Fewer ledges due to longer holes
  - Perimeter Drifts provide opportunity to check hole breakthrough locations prior to blasting. Allows for re-drilling if necessary
- More consistent work cycles
- Broken Waste Rock providing temporary support
- Only 2 Hydrostatic Bulkheads required

Cons

- Equipment captive during final ground support installation and waste rock removal
- More Development Required with Sublevels at 4925L and 5000L

Large Cavity Design Issues

1. Funding to Support Design
2. Geotechnical Data Collection
   - Determination of Optimum Cavern Location
   - Ground Support Design
     - Pre Excavation
     - Post Excavation
   - De-stressing determination if required
3. Determination of Optimum Excavation Option
4. Liner Determination
   - Shotcrete vs Concrete
   - Interface between Rock/Liner (Geotextile?)
   - Water Inflow Control Systems

Large Cavity Design Issues

5. Scientific Requirements to Determine
   - Excavation Volume
   - Excavations for Support Equipment and Storage
   - Facility Infrastructure Support and Utilities
     - Access
     - Electrical
     - Ventilation
     - Material Handling
     - Flooring
6. Crane Requirements
   - Required for Construction as well as Lab Operation
   - Consider Construction and Lab Operations Requirements in Determination of Final Design
7. Hydrostatic Bulkheads
   - Required at all locations where Accesses Intersect Cavity

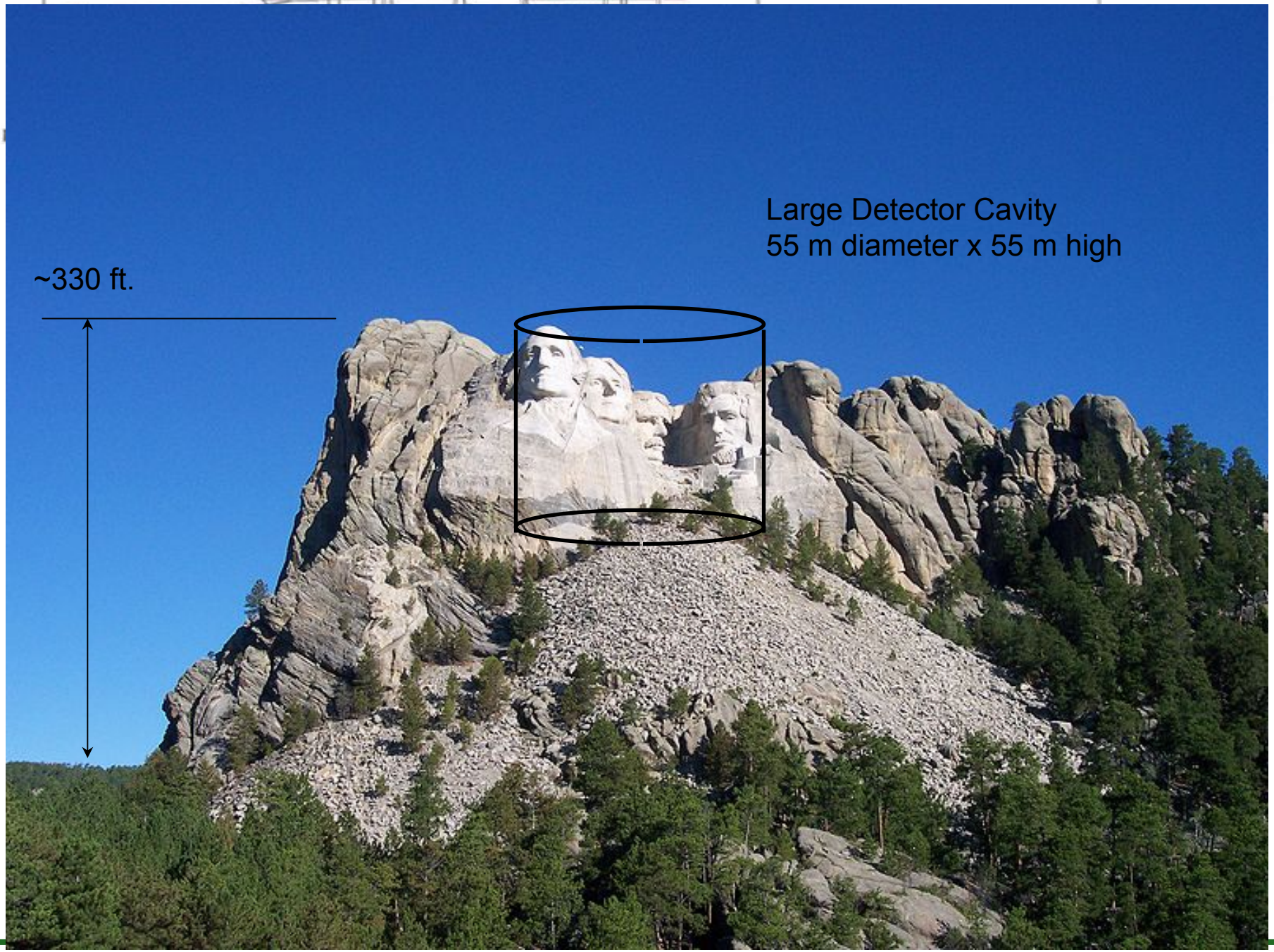
Conclusion

- Successful NSF review of DUSEL at the end of the first year
- Large Cavity Board is operating and will be an important resource for DUSEL
- Specific plans for geotech investigations now and through fall of 2009
- Thanks to everyone for their work on the “Depth Document”.

Private note

- This experiment desperately needs a name
- I, personally, would prefer it NOT include "LBL"
- I would prefer the name not end in words like "Experiment" or "Collaboration"

→Otherwise you become, for example "The SDC Collaboration" which translates to Solenoidal Detector Collaboration Collaboration.


Large Detector Cavity
55 m diameter x 55 m high
~330 ft.