Committee to Evaluate DOE-SC Options for Underground Science

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for

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Charge to the Committee

- **Help define cost-effective options for planned underground experiments, and strategies for implementing a world-class program of underground science, consistent with SC's mission in High Energy and Nuclear Physics.**
  - **Experiments: long-baseline neutrino experiment (LBNE), 3rd-generation (multi-ton) dark matter experiment (3G-DM), 1-ton scale neutrinoless double-beta decay experiment (DBD).**
  - **Assess cost and schedule estimates**
- **Committee was explicitly not to:**
  - **evaluate or set priorities on the science**
  - **review the DUSEL project or consider its future**
  - **pick experiment winners or losers**
  - **consider alternate sites, alternate technologies, etc.**

Scenarios the Committee was asked to consider

- **At Homestake mine:**
  - **LBNE using water Cherenkov detectors (WCD) at the 4850′ level**
  - **LBNE using liquid argon (LAr) detectors at the 800′ level**
  - **3G DM at the 4850′ level**
  - **DBD at the 4850′ level**
  - **3G DM at the 7400′ level**
  - **DBD at the 7400′ level**
- **At SNOLab:**
  - **3G DM at the 6800′ level**
  - **DBD at the 6800′ level**
- **An additional scenario was added by the committee:**
  LBNE with WCD at 4850′ and LAr at 800′ (1+1)

Review Committee Process

- **Received input (written and verbal) from**
  - **representatives of the experimental collaborations**
  - **the DUSEL and Fermilab LBNE project teams**
  - **Sanford Laboratory**
  - **SNOLab**
- **Committee members visited the Homestake mine and SNOLab.**
- **Assessed each of the scenarios to capture, at a high level, the readiness, technical risks, and the design, construction and operations costs and schedule.**
- **Not a Lehman-type review. Costs are simple top-down evaluations based on the proponents' estimates, with standard rules for adjusting contingencies based on design maturity.**
- **Estimates are in current-year dollars.**

Major Conclusions

(Committee assessment of each scenario is in the report. See http://science.energy.gov/~/media/hep/hepap/pdf/june-2011/Review_of_Underground_Science_Report_Final.pdf)

1. **The committee concludes that at the current level of maturity of the cost estimates for the three experiments, the cost estimates for the 3G DM and ton-scale DBD experiments should be taken as accurate to about 1 significant figure.**

   The cost estimates for the LBNE and associated infrastructure costs are more mature; however, they are not greater than the conceptual design level.

2. The committee's evaluation of the likely costs (TPC):

- **LBNE**
  - **Including detectors, beamline, and infrastructure**
  - **Approximately 1.2-1.5B in FY11$**
- **Each 3G DM experiment**
  - **Approximately 0.1B in FY11$ (infrastructure not included; site dependent- specified in conclusion #3)**
- **Each ton-scale DBD experiment**
  - **Approximately 0.2-0.3B in FY11$ (infrastructure not included; site dependent-specified in conclusion #3)**
- **Operations costs (FY11$)**
  - **LBNE detector alone & Homestake infrastructure: $18-23M/year**
  - **DM or DBD: without LBNE, including Homestake infrastructure ~$20M/year; ~$2-3M/year marginal operations cost if LBNE already established**
  - **DM or DBD at SNOLab ~$2-3M; further work to understand if any shared facility/infrastructure operations costs**

3. **With LBNE at the 4850′ level at Homestake, the additional cost of infrastructure to allow construction of 3G DM or ton-scale DBD experiments is:**
   - **Approximately 0.15B in FY11$ for the first experiment and ~$15M for each subsequent experiment if infrastructure for all is done up front.**
     - **This would exceed the infrastructure costs at SNOLAB for a single DM or DBD experiment by something like $100M (to be confirmed).**
     - **Adding a second DM or DBD experiment at Homestake 4850′ level requires infrastructure cost roughly that of SNOLAB**
4. **It is not cost effective to consider 3G DM or ton-scale DBD experiments as stand-alone experiments at Homestake because of infrastructure costs, unless there are three or more of these experiments that would be constructed at the same level so the infrastructure costs could be shared.**

5. **Constructing the 3G DM or ton-scale DBD experiments at the 7400′ level at Homestake appears to be prohibitively expensive because of infrastructure costs and uncertainties.**
   - **The DM experiments can likely be accomplished at the 4850′ level with additional shielding.**
   - **Whether shielding can be sufficient for DBD experiments at the 4850′ level will not be known for several years.**
6. **Significant investments in infrastructure will be necessary to safely construct, commission and operate a modern underground laboratory at Homestake.**
   - **Modernizing the Yates and Ross shafts at Homestake are necessary prerequisites and should not be considered an opportunity for "value engineering".**

7. **Constructing a 3G DM or ton-scale DBD experiment at SNOLAB appears to be the most cost effective option even if a U.S. investment is needed to dig and outfit a pit and provide utilities and other support. This should be verified by detailed studies.**
8. **The time needed to carry out the three experiments (LBNE, ton-scale DBD and 3G DM experiments) will extend over two decades or more from now, including about one decade before data taking begins.**
   - **In each case it is quite likely that there will be upgrades and follow-on experiments that will further extend the time scale of these physics programs.**

9. Given the scale of investment needed to carry out these experiments and the long timescales and likelihood of follow-on experiments in each of these areas of research, the committee recognizes there are major advantages to developing a common underground site for these experiments.

- **Advantages include**
  - **Opportunities to share expensive infrastructure and coordinate design efforts, construction, management and operations.**
  - **Significant benefits in training of the next and subsequent generations of scientists by having a common facility serve as an intellectual center in these fields of research.**

Locating the facility in the U.S. would help to promote U.S. leadership in these fields for the foreseeable future.

10. The LBNE technology choice (water Cherenkov vs. liquid argon TPC) strongly impacts the strategic options for siting 3G DM and ton-scale DBD experiments.

- **If the LBNE choice is a WCD at the 4850′ level at Homestake, then the 3G DM and/or ton-scale DBD experiments at the 4850′ level becomes significantly more cost effective.**
- **If the LBNE technology is a LAr detector closer to the surface then this would not be so.**

Therefore the committee emphasizes there is a very significant strategic benefit to making the LBNE technology choice as soon as possible.

11. A "1+1 Option" for LBNE (WCD at the 4850′ level plus a LAr detector at the 800′ level) is discussed in the report even though it is not in the charge.

- **There may be considerable physics advantages due to complementary detectors (different systematic uncertainties for neutrino oscillations and sensitivity to different channels in proton decay and supernova detection, get physics started at lower initial cost), but further study is necessary.**
- **Implementing a WCD initially, while continuing with LAr R&D for possibly adding this capability later would be an option that is consistent with sharing infrastructure between LBNE, the DBD and DM experiments at the Homestake 4850′ level.**

Summary

- **The committee believes there are compelling scientific motivations for all three experiments and *an important opportunity for the U.S. to take a leadership position for the foreseeable future*.**
- **There are important advantages and opportunities in developing a common site for these experiments *if the needed infrastructure can be shared in a cost-effective manner*.**

- **A common site only works in the scenario where LBNE has one or more detectors at 4850′ at Homestake.**
  - **Either an early technology choice for water Cerenkov or the 1+1 option would support this scenario but it may be several years before it is known if DBD is feasible at 4850′.**
  - **If LBNE pays for the infrastructure that LBNE needs, there would be additional infrastructure costs for DM or DBD experiment that would exceed those at SNOLAB by something like $100M; worthwhile considering the advantages of a common site and the multi-decade timescale**
- **If no LBNE at Homestake 4850′ level, DBD and DM are not cost effective at Homestake**
- **The lowest cost option for DM or DBD is SNOLab.**