A salient question is how the theory support for underground science should be structured. In the long term we envision that DUSEL has a resident group of research physicists; this includes a theory group. To be viable and attract the best senior people this theory group should include at least 10 - 20 Ph.D. scientists including postdoctoral research associates with diverse interests. A resident theory group would create a scientific environment and intellectual atmosphere where all visiting scientists can participate. The creation of such a resident theory group would foster strong ties with the local universities.

In the short term we envision a group of theorists in internet-based communication year-round, plus DUSEL running a series of summer programs (possibly additional activity in January as well). A theory coordinator is in residence during this time (perhaps serving 2~3 years and rotating). The theory coordinator is responsible for the day-to-day operations and activities. (This could be a person away from his/her university only during the summers). An Advisory Committee of experts chosen to represent different subfields of underground science selects the programs. The summer programs should start as soon as infrastructure permits. It should be emphasized that these summer programs are not geared towards education of students. These are intended for focusing on the science goals of the laboratory, sharpening its vision, explore the boundaries of underground science, and hopefully form a synergy between the goals of different scientific subfields. This activity should be viewed as a core mission of the laboratory and, as a result, its success should be ensured at the highest level of the management.

In addition to the summer programs, we recommend that a yearly summer school in underground science directed to graduate students and postdoctoral research associates start right away. Such a school could rotate between physics, geology and microbiology, or include topics at the intersection of these fields. Besides this school we also fully support the efforts directed towards K-12 and undergraduate students as well as outreach efforts directed to the general public.

The theoretical participation at the DUSEL town meeting has been limited. We suggest that in order to fully develop further theory involvement in DUSEL, NSF support a theory workshop devoted to DUSEL science. This workshop should include theorists working in geophysics, microbiology and particle/astro/nuclear physics topics.

It will be impossible to cover all the theory related to the underground science in a short white paper and most of the key theory issues will be addressed by the other working groups. Consequently in the following paragraphs we briefly touch on a few salient theory issues.

Dark Matter: A major emphasis of the DUSEL should be to house and deploy experiments designed for the direct search for dark matter in the form of weakly interacting massive particles (WIMPs), which occur in many theories of physics beyond the standard model, such as supersymmetry and theories involving extra spatial dimensions. While detection of a WIMP signal would be an exciting, even revolutionary, scientific discovery, it would be only the first step in a sustained new program of WIMP astronomy. A candidate signal seen by one experiment will have to be verified by others. It will be important to check that a scalar WIMP interaction indeed scales according to nuclear mass, a fact which can be checked by observing signals on at least several different nuclear targets. If the energy deposited by WIMP-nuclei collisions is well-measured, then it is possible in many cases to extract an estimate of the WIMP particle mass if enough scattering events are recorded. Such WIMP astronomy will usually require dark matter detectors of ton-size or greater, located deep in the DUSEL site. In addition, for nuclear targets which carry spin, the WIMP-nuclei spin-dependent cross section can also be measured, and may provide information on the WIMP particle's spin quantum number. It should be noted that nuclear physics uncertainties for such cross-sections are minimal, unlike as in double beta decay. Some detectors are being developed which have directional capability, i.e. they can actually measure a finite recoil nuclear track. Such detectors would likely consist of many modules of low pressure gas targets, which would again need to be placed deep underground. Due to the earth's motion through the galaxy, such experiments stand a good chance to see day-night and perhaps even seasonal variations in the WIMP velocity distribution. Thus, WIMP detection experiments at DUSEL will likely provide new information on the dominant component of matter in the universe, which is in every way complementary to searches for new physics at the CERN LHC, the ILC, and indirect dark matter search experiments.

Proton Decay: Supersymmetric grand unified theories (GUTs) predict gauge coupling unification at a scale $M_G \sim 3 \times 10^{16}$ GeV and supersymmetric particles which should be observable at the LHC. They naturally provide a framework for a light Higgs boson, a dark matter candidate, the see-saw mechanism, and baryogenesis via leptogenesis. Four dimensional supersymmetric GUTs, consistent with gauge coupling unification, predict proton decay from both gauge exchange and color triplet Higgs exchange processes. The predominant decay mode for gauge exchange processes is $p \to e^+ \pi^0$, while Higgs exchange prefers second generation decay products and gives a dominant decay mode of $p \to K^+ \nu$. The minimal supersymmetric SU(5) theory results in a lifetime $\tau(p \to e^+ \pi^0) \sim 5 \times 10^{36} (M_X/3\text{x}10^{16}\text{GeV})^4 (0.015\ \text{GeV}^3/\beta_{\text{lattice}})^2$ years, where M_X is the mass of the gauge boson responsible for proton decay. Note that non-minimal SUSY GUT models typically lead to additional gauge exchanges with a spread in M_X. Hence it is very likely that the 10^{36} years lifetime is an upper bound. The minimal SUSY SU(5) theory is ruled out by Higgs mediated proton decay processes. However, more complicated Higgs sectors in GUT models can be made consistent with gauge coupling unification and proton decay. The nominal proton lifetime due to Higgs exchange is given by $\tau(p \to K \nu) \sim 1/3 - 3 \times 10^{34}\ (0.015\ \text{GeV}^3/\beta_{\text{lattice}})^2$ years, where the uncertainty is determined by the spread over models which also fit charged fermion masses and mixing angles. Recent progress in obtaining ultraviolet completions of SUSY GUTs leads to orbifold GUTs in 5 or 6 space-time dimensions and ultimately to string theory in 10 dimensions. The color triplet Higgs nucleon decay processes can easily be suppressed in 5 and 6 dimensional orbifold GUTs, however this occurs at the expense of significantly enhancing gauge exchange rates. For example in these theories M_X is typically less than M_G and thus the proton lifetime, by gauge exchange, can easily be as small as 10^{34} years. In string models, both gauge and/or Higgs exchange processes may be enhanced, compared to four-dimensional GUTs. Proton decay experiments have a tremendous potential for a major discovery. Moreover, if supersymmetry is discovered at the LHC the case for proton decay will increase ten-fold.

Solar neutrinos: Even though the research program in solar neutrino physics has been enormously successful in solving the "solar neutrino problem", it is far from being completed. We still need to accurately measure the total solar neutrino luminosity. This is a crucial test of energy generation during the main stage of stellar evolution. It is a test independent of the detailed dynamics of the solar models. To achieve this goal we need to know pp, pep, ^{7}Be, and CNO neutrino fluxes. Present uncertainty of the solar neutrino luminosity is very big, but a few percent accuracy is within reach. In addition, there is a possibility of observing signatures of physics beyond both the Standard Models of the Sun and of particles with solar neutrinos. Signatures of such new physics would show up at solar neutrino energies of about 1 to 2 MeV.

Supernova neutrinos: Recent results from neutrino physics experiments has given us some of the neutrino mass and mixing parameters. Neutrinos play a very important role in compact objects and supernovae since they can carry a significant fraction of the energy. Neutrino flavor distributions, fluxes, and energy spectra set the composition outside the inner core, influencing energy and entropy transport. It was recently shown that neutrino self-couplings can alter flavor evolution in supernovae ultimately causing large-scale flavor conversion deep in the envelope, despite the fact that measured mass differences are small. This could affect neutrino-heated nucleosynthesis and the supernova neutrino signal. Self-coupling induced collective modes can produce distinctive signatures that could allow the supernova signal to determine the neutrino mass hierarchy and θ_{13}. These signatures will show up at *solar neutrino* energies, providing a justification for running solar neutrino detectors for a longer time. Thus core-collapse supernovae act as ultimate neutrino physics laboratories, yielding signatures of further new physics such as flavor-changing neutral currents, CP-violation, and sterile neutrinos with tiny mixings with active species.

Neutrinoless double beta decay: Observation of neutrinoless double beta decay would definitely establish that neutrinos are Majorana particles. However a positive signal does not necessarily imply the existence of a *light* Majorana neutrino. Other mechanisms such as heavy neutrinos, right-handed gauge bosons or exchange of supersymmetric particles coming at a mass scale of $\Lambda \sim 1$ TeV may contribute as much as a light Majorana neutrino. Lepton flavor violation involving charged leptons may provide a "diagnostic tool" for establishing the mechanism of neutrinoless double beta decay. A big source of uncertainty is the size of the appropriate nuclear matrix elements. It should be noted that the problem with the nuclear matrix elements is *not* a computational problem; it is a question of creative ideas and a concentrated effort. There are several encouraging developments in nuclear structure physics and, if enough people are encouraged to work on this issue, it is very likely that nuclear matrix element uncertainties will be reduced further by the time experiments are ongoing at DUSEL.

Neutron-antineutron oscillations: B-L appears to be a good low energy symmetry. However, in seesaw models for neutrino mass B-L is broken by two units. In addition if one wants to understand the asymmetry between matter and antimatter, B and/or L must be broken. The violation of B-L may be observed in neutrinoless double beta decay experiments or possibly through observable neutron-antineutron oscillations. In non-supersymmetric models, neutron-antineutron oscillations probe the B-L breaking scale up to 300 TeV, whereas in their supersymmetric models, they can probe scales up to 10^{12} GeV due to the appearance of new operators that appear. Discovery of neutron-antineutron oscillations would establish the scale of B-L symmetry breaking somewhere between 10^{5} to 10^{12} GeV (to be compared with typical values in grand unified theories of 10^{16} GeV). However, models with observable neutron-antineutron oscillations are incompatible with grand unification. Hence observation of neutron-antineutron oscillations might rule out grand unified gauge symmetries.