CO_2 Multi-Phase Sequestration

– Quantifying Fluid Phase Transition, Gas Migration, Supercritical CO_2 Injection, and Carbon Cycle Information from Dewatering, Exploring the Potential for Extended Use of Multiple Sites at Homestake DUSEL

Drafted Revision by Joe Wang for the

CHEERS Collaboration[1]

To DEDC 20080630

Preface: (primarily for DEDC and for potential collaborators and participants)
This is a revision based on a version of 20080502 sent to DEDC[2] to address the review comments of 20080605 by Derek Elsworth for the DEDC. The current revision focuses on reorganizing the tasks to focus more on Task 2 with liquid and supercritical CO_2 injection, and expand Task 2 to link to CO_2 migration in caprocks and in rupture and coupled process experiments. Task 1 focuses on E&O and EH&S associated with gaseous releases. Task 3 is streamlined for aqueous evolution, and Task 4 is retained on extended uses of the facility. The main concern from DEDC is that this S-4 preproposal is not well focused, while the scope could be expanded to be more relevant.
For collaborators, participants, and colleagues, please assist to achieve this goal this summer and certainly after the S-4 call is announced. Please advise.

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[1] **CHEERS** stands for **C**arbon in **H**ydrological **E**nvironment for **E**nhanced **R**etention and **S**equestration, 4/26/2008. See Appendix B for the vision and development of the Collaboration, supports, and interactions with other working groups and communities.

[2] http://www.lbl.gov/nsd/homestake/aprilworkshop/whitepapers/CO2Sequestration.pdf . DUSEL Experiment Development Committee (DECC) plans to coordinate the submittals of Initial Suite of Experiments (ISE) to the Solicitation-4 (S-4) to the National Science Foundation (S-4).

Executive Summary

Carbon dioxide (CO_2) is a greenhouse gas responsible for the global warming. Carbon dioxide concentration in the atmosphere has raise above the pre-industrial value with its 1995-2005. This greenhouse gas increase is attributed to the use of fossil fuel as well as to change in land use (ICPP 2007). Homestake DUSEL can contribute to fundamental understanding at relevant field scales for CO_2 sequestration, a solution to global warming.

CO_2 in its liquid and supercritical phases is lighter than water, in its gaseous form heavier than air, can be easily dissolved in water and itself a great solvents for many trace elements and petroleum products. We propose to use existing infrastructure (levels, "sand-holes", drain-holes, etc.) at Homestake, South Dakota to systematically evaluate the sequestration potential of earth materials in transforming and retaining injected CO_2, and the migration of CO_2 through surrounding low-permeability rocks, fractures, and in block experiment sites. The main activity Task 2 will focus on two fundamental processes: (1) the upward movement and phase transitions of injected CO_2 that are likely escaped back to the atmosphere, and (2) the absorbed CO_2 on rock grain surfaces left behind. The absorbed CO_2 will likely to interact with solid minerals and slowly, chemically, converted into calcite, thus "sequestered" or imbedded into rock matrix. This main technical activity of conducting controlled field experiment Activity 2 is supplemented by Activity 1 focusing on education and outreach (E&O), environment, health and safety (EH&S) associated with gaseous dispersion through the upper levels to the atmosphere, and by Activity 3 on carbon and other traced elements dissolved in water at depths.

Activities 1 and 3 can be conducted now in the Early Implement Phase (EIP), and Task 2 can be developed into the DUSEL ISE Phase[3]. Tasks 1 and 3 are also necessary to address associated educational, environmental and technical challenges to monitor gaseous releases, to evaluate evolution of hydro-chemical-biological-geophysical setting of the Homestake site – a kilometer-scale test bed. Concurrently, we propose to initiate a

[3] National Science Foundation NSF has adopted a staged approach since 2004 to issue solicitations for developing Deep Underground Science and Engineering Laboratory (DUSEL): with S-1 on Deep Sciences, S-2 on Conceptual Design and Site Evaluation, and S-3 on Preliminary Technical Design. The S-4 call is pending and is supposed to be on Design for Initial Suite of Experiments (ISE), and S-5 on selection of ISEs.

systematic design in Task 2 of field scale controlled experiments imbedded within this large test bed: started with the existing "sandline" network used historically for slurry transport for underground stope-filling. The experiments to be designed in this Solicitation-4 (S-4) Proposal will initially focus on setups with controlled deposition of rock fragments ("sands") and with controlled releases of fluid sources from selected levels. We envision that a well-designed test sequences at relevant field scales starting at tens of meters toward kilometer scale can address many "Basic Research Needs" identified in CO_2 Sequestration[4].

This pre-proposal for S-4 or for other calls is thus aimed for both the Early Implementation Program and for the development of one of the initial suite of experiments (ISEs). The S-4 proposal is aimed to contribute to the establishment of a Multiphase, Multi-location and Multidisciplinary Collaboration – the CHEERS Collaboration - for site evaluation and preliminary design. Since we plan to systematically evaluate existing infrastructures from surface, levels by levels, and follow the dewatering to reach the deeper levels, the CHEERS Collaboration also envisions carrying out Activity 4: locating, exploring and estimating the feasibility of extended uses and targeted research opportunities for not only earth sciences experiments but also other physics investigations and technology developments. These scientific uses would take advantage of the unique features of the Homestake site beyond the "standard campuses" expected to be established at 300L, 4850L, 7400L, and 8000L. CHEERS Collaboration strives to be inter-disciplinary, reaching out to invite industrial and international collaborators.

The first activity on using the 300 Level is related to the DUSEL R&D Proposal submitted on 12/3/2007 (Appendix A). Appendix B presents additional support letters, review comments, and updates of the evolution of the CHEERS Collaboration. Activity 1 is also important from education and outreach prospective, as both the surface and the 300L are amendable for developing activities with direct implications for E&O, such as ecological studies on surface plots and along the stream and channels, displays and lecture halls underground along drifts, demonstration of cosmic ray damping below variable overburden, etc. In addition to interface with public and students, the scientific and technical demonstrations at shallow levels are good starting points or proto-types for more advanced activities at depths.

The second activity on CO_2 sequestration is expanded from the 2006 Letter of Interest (LOI) #85 submitted by Drs. Curt Oldenburg, Sally Benson, Jens Birkholzer, and Joe Wang of LBNL (Lawrence Berkeley National Laboratory, Appendix C). Ongoing field demonstration projects in CO_2 Sequestration will help us to articulate the needs for fundamental controlled field experiments. The third activity on dewatering supplements the SDSMT project funded for instrumentation (Appendix D), and we will focus on the carbon cycle modeling aspect. The fourth activity on Extended Uses and Research

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[4] Basic Research Needs for Geosciences Workshop led by Don dePaolo (February 2007) http://www.sc.doe.gov/bes/reports/files/BRN_workshops.pdf

Opportunities (EURO) is inspired by the white paper on other uses developed by Professor Bob Lanou of Brown University (Appendix E[5]).

The CHEERS Collaboration welcomes international participation. This S-4 preproposal incorporates potential new participants from several institutions who participated in the 2nd International Conference on Underground Science, April 2-4, 2008 at the Low Noise Underground Laboratory, Laboratoire Souterrain à Bas Bruit (LSBB[6]). Relevant information on this conference and the Keynote talk given by Joe Wang on "Scientific Investigations at Homestake DUSEL" are given in Appendix F. This activity continues to evolve with international rock mechanics symposiums and other international conferences for years to come.

This S-4 proposal is for the next 2 years (2009-2010), at approximately 8 FTE level annually, to be supplemented by S-5 tasks (2010-2011). The scopes for S-4 and S-5 will be developed collectively to build up the CHEERS Collaboration and implement controlled field experiments at Hoemstake DUSEL. We can start with several gathering or workshops to articulate further the scopes. The S-4 scopes are expected to be coordinated with other ISE candidates through the DUSEL Experiment Development Committee (DEDC). We believe that the sequence of tests and tasks designed in this S-4, S-5 Proposal lead to meaningful and fundamental CO_2 multiphase experiments in hydrological and petroleum environment which contributes to the quantification of enhanced carbon displacement, retention and sequestration, one of the ISE to be deployed at Homestake after DUSEL establishment (2012 onward).

We plan in the long run to seek funding from multiple agencies, coordinate academia, national labs, and private industry participation, and evaluate multiple sites for extended uses of unique Homestake facilities. We value inputs, appreciate supports, and welcome participation and endorsement. We continue to reach out and coordinate with leaders and participants of other S-4 Pre-proposals. The framework of this Pre-proposal will evolve accordingly as we develop. Ultimately, the soundness of the proposal will depend on all of us in the Collaboration collectively.

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5 http://hep.brown.edu/users/lanou/B2-session-draft-v5.pdf

6 http://lsbb.unice.fr

Main Text:

CO_2 Multi-Phase Sequestration

by the **CHEERS Collaboration**

– Quantifying Fluid Phase Transition, Gas Migration, Supercritical CO_2 Injection, and Carbon Cycle Information from Dewatering; Exploring the Potential for Extended Use of Multiple Sites at Homestake DUSEL

- a Multiphase, Multi-location, and Multidisciplinary Collaboration for site evaluation and preliminary design

List of Potential Participants and Supporters:

(This list was the same presented in the 20080502 version and presented in the April Homestake ISE Workshop. Additional participants will be added upon contacts individually for their agreements. Appendix B under development will explicitly describe the interactions and coordination with DEDC, Homestake Scientific Collaboration, Sanford Lab-SDSTA, other Working Group Leads, industrial partners, foreign visitors, etc. We will continue the Collaboration building during proposal preparation to determine the roles and responsibilities, funding requests, and budget estimates, etc. to explicitly address the S-4 call requirements, focuses on major activities while continuing broaden the Collaboration vision.)

In the United States:

LBNL: Joe Wang, Jens Birkholzer, Paul Cook, Stefan Finsterle, Marc Fisher, Barry Freifeld, Susan Hubbard, Tim Kneafsey, Jennifer Lewicki, Hui-Hai Liu, Curt Oldenburg, Rohit Salve, Dmitriy Silin, Eric Sonnenthal, Liviu Tomutsa
SDSMT: Arden Davis, Andy Detwiler, Bill Roggenthen, Larry Stetler, P.V. Sundareshwar
SDSTA: Kathy Hart, Tom Regan, Greg King, Jack Stratton, Susan von Stein
BHSU: Ben Sayler
Brown U.: Bob Lanou
UC Berkeley: Steven Glaser, Kevin Lesko
UC Irvine: Hank Sobel
Columbia: Christen Klose (to be confirmed)
Fermi Lab: Chris Laughton
Georgia Tech.: Leonid Germanovich, Todd Rasmussen (to be confirmed)
New Mexico Tech: Tom Kieft, John Wilson
Oak Ridge: Tommy Phelps
Oglala Lakota College: Jay Roman
U. Penn: Ken Lande
Penn State: Derek Elsworth
Princeton: Tullis Onstott
Stanford: Sally Benson
SDSU: Gary Anderson (to be confirmed)
U. Tennessee: Susan Pfiffner, Qiang He
U Virginia: George Hornberger

From Abroad:
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Géosciences Azu, U. Nice: Yves Guglielmi, Federic Cappa
U. Montpellier: Fredric Boudin
IM2NP: Karine Castellani-Coule
L2MP: Jannie Marfaing
UBC: Mathew Yedlin
Roule Lab: Lionel Tenailleau
U. Avignon: Remi Blancon
U. Comte: Catherine Bertrand
U. Malaga: Bartolome Andreo
U. Napoli: Ruggero Stanga
I. Tech Chime: Gerald Ziegenbalg (to be confirmed)
Dalhousie U.: Dmitry Garagash (to be confirmed)

Overview

The upper levels of the Homestake mine, Lead, South Dakota, are accessible during the early implementation period of Sanford Lab over the next several years. The Sanford Lab of the South Dakota Science and Technology Authority owns the land and currently focuses on safe reentry into all the underground workings. The new collaboration proposed here can start with the following assessment and evaluation activities: (1) releases of CO_2 and noble gases from the 300 ft level (300L campus) and their migration to the ground surface and to the atmosphere; (2) injections of supercritical CO_2 from underground levels, (3) carbon cycle associated with dewatering of the mine to reach deep campuses, and (4) development of extended uses for the infrastructures at Homestake.

Earth science and engineering have intrinsic interests in exploring subsurface environments with extensive spatial coverage. Homestake represents a heterogeneous site with localized flow paths and distinct transitions of geochemical zones (e.g., from sulfur-rich to sulfur-poor conditions). It also offers multiple locations for designing coupled process block experiments, fractured zone experiments, and for research associated with large cavern excavations. The activities of this collaboration will interface with all experiments, including deep life search for biology and sensitive detector housing for physics experiments.

Activities:

The first three activities have in common that they start with existing infrastructures without (or with limited) drilling and excavation: i.e., using existing drifts for Activity 1, started with semi-vertical and extensive “sandlines” for Activity 2, and existing boreholes from 4850’ Level (Middle Campus) for Activity 3. These infrastructure-specific activities are examples for Activity 4: to explore the range of available infrastructures for extended uses. The challenge is for us to develop a coherent approach for a wide range of activities at very different sites. In the following, an overview for each activity are first given, and then supplemented by recent field observations and by fast growing information collected during on-going reentry activities.

Activity 1: 300L and Surface Assessment for CHEERS' E&O and EH&S

Overview of CHEERS-300L:

The 300L, with its horizontal access through multiple drifts to the Kirk Canyon and to the Open Cut, is of interest for early development of physics experiments that require modest shielding, to address safety and environmental issues associated with uses of cryogens (liquid nitrogen, liquid noble gases, dry ice, etc.), to conduct preliminary geotechnical designs of excavations for equipment housing, education and outreach (E&O) accesses and displays. CO_2, with molecular weight of 44 will be evaluated as an analog for Argon (Ar) with atomic weight of 40. There are indications that 300L represents the water table before mine excavation activities de-saturated the subsurface to a depth greater than 2.4 km (8,000 ft). There are also old stopes at 300L that were likely backfilled. Thus, 300L can be relatively quickly developed first as a "Critical Hydrology, Ecology, and Earth Research Site" (CHEERS).

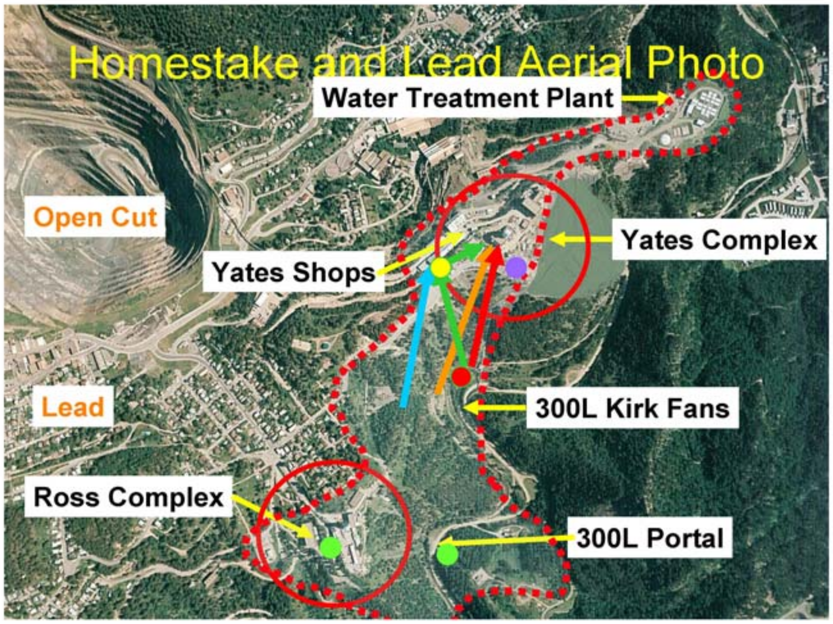
With 300L close to the surface—its overburden ranging from a few meters to over 100 m—and with existing boreholes connected to upper and lower levels and shaft to the surface, we may develop an integrated program for underground processes coupled to traced gas dispersion studies in the atmosphere. Gaseous releases underground need to be vented to the surface for dilution; they act as controlled sources for flux measurements through surface plots and vertically along towers erected in the surface campus.

Observations and Implications – Surface and 300L:

Along the two drifts currently allowed for inspection, we have observed that one drift, the Kirk, seemed to be relatively free of water drips, but with some walls wet covered with "biofilms", and some ceilings with "calcite-like" precipitates. In comparison, the neighboring drift, the Oro Hondo, had frozen seepages observed during the same visit on 2/20/2008. These "icicles", distributed at some but not all locations, clearly demonstrated that Oro Hondo Drift has more seepage from the ground surfaces above the drift, with infiltration strong enough to freely enter the drift. There were no (or less) biofilms observed along the Ore Hondo drift as compared to hose observed along the Kirk Drift.

The observed differences could be simply due to the differences in the surface conditions, including the presence or absence of soil covers, rock fractures, topographic reliefs, and local ponding conditions. These observations and associated interpretations can be simple and easily developed for E&O purposes. We thus propose to instrument both drifts and the surface areas directly above, to correlate precipitation (including snow), infiltration, and seepage. We will also construct a local model over both drifts, with topographic variations, soil and tree coverage, mapped fracture networks taken into account to interpret the field observations. Such an exercise or task could contribute to advancement in hill hydrology, mountain front recharge, and many interesting issues associated with watershed water balance modeling. (This is why we have “Critical Hydrology” for our first two letters in the Activity title “CHEERS”.) From the outset, we plan to display our results along the drift, to be developed by students, and show the results to the public. With multiple years of observations of surface and near-surface processes, Homestake is effectively studying effects of climate changes and global warming.

Another interesting observation from the satellite photo is that we have fewer trees per unit area on the ground surface within the SDSTA property boundary, in comparison with the denser coverage across the Kirk Road on the eastern side of the property. Obviously we have no trees in the township and in the administrative building areas. This satellite photo inspires the proposed task for soil monitoring, with areas within the SDSTA property divided into plots, each with different densities of tree coverage, soil covers, and ecological characteristics. (Now we have “Ecology” for the third letter in “CHEERS”). CO_2 releases (and later argon and others) and sensing at surface and from 300L are planned. Again the surface plot evaluations can be conducted by students as class projects for E&O.



Proposed Tasks:
Task 1.1 Education and Outreach
Task 1.2 Safety of Underground Structure
Task 1.3 Environment and Health

Task 1.1 Education and Outreach

Task 1.1.1 E&O Center Locations and 300L Accesses
Task 1.1.2 Dispersion through Soils and Atmosphere above 300L
Task 1.1.3 Seepage and Biochemical Alternation along 300L Drifts

Task 1.1.1 E&O Center Locations and 300L Accesses

Task 1.1.1 explores options to link 300L with Sanford Education and Outreach Center. Options may include new drift branching out of existing drifts, new drifts from the Kirk Canyon, dedicated shaft/raise-bore for E&O direct tours to the underground, excavate a new station at Yates shaft, and other configurations which might be more convenient, more economical, or satisfying other project requirements and needs.

The 300L development are driven by users of 300L: (1) to house a prototype detector, say a 5 kt Liquid Argon detector, a germanium detector, etc., (2) for rooms needed for E&O classroom, display, and for other equipment fabrications, or (3) for connections to the Yates Complex for E&O tours through raise bore and ramps directly from the Sanford E&O Center. The 300L, with its horizontal accessibility, is a logical place for underground tours, for equipment staging, or for component fabrications protected from direct exposure to sun lights.

Sanford E&O Center is located most likely within the SDSTA property boundary shown in the Areal photo. The long building of the Yates shops is one of the candidate sites (yellow dot) accessible from the Lead township and Open Cut visitor center. In 2007 and 2008, the tourist groups to SDSTA have staged behind the Administrative Building at the Yates Complex (purple dot). These two locations may have raise-bore excavated for independent elevator accesses to the underground away from the Yates traffic. Three other locations (red dot and two green dots) are also illustrated for options without the need for raise-bores for underground E&O experiences. The locations along the Kirk Canyon Valley require relatively longer busing of visitors than to Ross Complex or Yates Complex.

Currently the 300L is accessible vertically only through the Ross shaft. There is a baseline plan (not shown) to excavate at 300L one new drift and two halls, one for equipment material fabrication (e.g., copper forming), and one for E&O lectures and displays. The new portal is planned to be located at the Kirk Fan parking lot (the begging of the orange arrow), the new drift is oriented toward and connected to the Kirk drift near the Ross shaft. In the figure above, we illustrate several additional drifting options toward the Yates Complex: orange arrow from the Kirk parking lot towards Yates shaft, turquoise arrow from a branching point from the new drift inside toward the yellow dot E&O raise-bore, and green arrows from a Kirk Road bend parking area toward the yellow dot raise-bore then towards the Yates shaft. The options towards Yates shaft will require the construction of a new 300L station. Finally, we include the red arrow which may require the short drifting from a south facing hill side. Task 1.1.1 will contribute to further design and planning of these E&O underground experience options and determine if the red arrow option (perhaps with purple dot raise-bore) is more viable, economical, and functional than other options, or the whole notion of 300L-Yates Complex connection is unwarranted.

Task 1.1.2 Dispersion through Soils and Atmosphere above 300L

For Task 1.1.2, SDSMT Atmospheric Sciences may define and lead the major components: (1) monitoring of weather and vertical concentration/flux profiles from surface to ~ 100 m above ground with a tower similar to the one existing Black Hills tower illustrated above, and (2) measurements through surface plots. The sources range from point releases at ventilation outlets, to areal releases through the bed rocks. These are two types of releases anticipated from accidental gaseous releases. We plan to design experiments specific for different scenarios with controlled releases, to be integrated with Task 1.3.3 for the whole site evaluation.

Task 1.1.3 Seepage and Biochemical Alternation along 300L Drifts

Task 1.1.3 is aimed to address the field observations of heterogeneous distributions of seepages, biofilms, and precipitates. We expect that the in-drift observations have both spatial and temporal variations. We thus should have cameras and rock surface sensors mounted to continuously monitor (1) inflow seepage associated with precipitations, (2) frozen occurrences in winters, (3) melting in springs, and (4) dry up in summers. It is possible that we can observe the effects of climate changes, with one year wet and the next year dry. This task will need interfaces with many site characterization activities, such as weather measurements in Task 1.1.2, results of other mapping exercises, and in-rock measurements from the drift level to the ground surfaces through variable thickness (also part of Task 1.3.3). We will also evaluate the bio-chemical sampling procedure and its applicability to 300L and system wide in this task.

Task 1.2 Safety of Underground Structure

Task 1.2.1 Geotechnical Designs - Shallow to Deep (R&D Proposal Task)
Task 1.2.2 Deformations below Overburdens (to be correlated with Suggestion 4.1)
Task 1.2.3 Drainage below 300L and Accesses to Open Cut

If the Project do decide to proceed with development of 300L as the Upper or Near Surface Campus for DUSEL early, we need to have a well-defined methodologies established. Task 1.2.1 is to be led by Fermi Lab, integrating underground excavation experiences associated with neutrino beam line housing (MINO tunnel), physics experiment hall construction (Soudan mine), and near-surface designs (Nova and Ash River off-axis). The design-and-built procedures, cost estimates, and state-of-art mining advances to be developed at Task 5 will be extremely valuable for similar excavations at greater depths. (See Appendix A for more detailed scope description.)

We propose Task 1.2.2 to identify a ~100 m long drift segment in 300L (first choice, floor along the Orfor controlled deformation measurements: (1) a pressure-pulse experiment, and (2) a long base tiltmeter experiment. Pulse injections into a packed interval below the drift floor will induce deformations both along the borehole and in the shear directions. We can monitor induced pressure and deformations as the fluid pressure overcomes the confining stresses. We can also monitor the tilts induced by the injections, with deployment of long base tiltmeters. Two groups from France plan to carry out this pair of tests 300 m underground at the Low Noise Underground Lab (LSBB). Both groups expressed interests to collaborate with DUSEL scientists and carry out the tests at two depths, one along 100 m at 300L with up to 100 m overburden, and another along 1 km distance at 2000L with 600 m overburden. Our S-4 activity selects test locations, addresses the logistics and EH&S issues, participates in the test design, and collect the data for complimentary modeling and understanding. (Note: this Task will be integrated with Suggestion 4.1).

We have identified so far for Task 1.2.3 an interesting location along the Kirk Drift. The Kirk Drift crosses over a Savage Tunnel located 5 m below. Currently we have drain holes from Kirk Drift to the Salvage Tunnel. The field photos at this "intersection" indicate that the Ellison formation rocks at this location is in fairly good conditions, possibly feasible for a new excavation ~5 m in diameter and ~5 m in depth to house a physics detector. Task 1.2.3 will also explore the extensive drifts towards the Open Cut, with some partially backfilled already. Blocked drifts require extensive rehabilitations to reopen – a challenge for EH&S and an opportunity for ecologists and biochemists to explore one of the oldest parts of the mine.

Before excavation, we may drill arrays of boreholes or constructed slots into the rock for cryogenic stressing of the rock masses in the vicinity of this location or at other selected locations. Physics experiments may use cryogens for their detectors while rock mechanics experiments may be interested to use freezing to crack the rocks for understanding the crack initiations and failure controls. While the stress state at 300L is not high, we can prototype this type of experiments in this task before deployment at deeper campuses and locations. The EH&S can also use the opportunities to assess the handling of cryogen concerns.

Task 1.3 Environment and Health

Task 1.3.1 Environmental Sensors and Sensing
Task 1.3.2 Ventilation and In-Drift Measurements and Monitoring
Task 1.3.3 Critical Zone Processes (R&D Proposal Task)

Task 1.3.1 on environmental sensors and Task 1.3.2 on ventilation measurements are interfaces with underground control systems for routine operations and emergency responses. Most of sensors for relative humidity, temperature, barometric pressure, oxygen contents, CO, CO_2, CH_4, NOx, and for flow rates, velocities have hand-held versions and can be mounted along the drifts. We can include in Task 1.3.1 evaluations on wireless technologies, on leaky feeders and power line communication systems, and on more traditional twisted pairs, fiber optics cables, and Ethernet for data transmissions. We will also evaluate argon and other tracer gas detection technologies, document the range and sensitivities, and commercial availability and installation requirements.

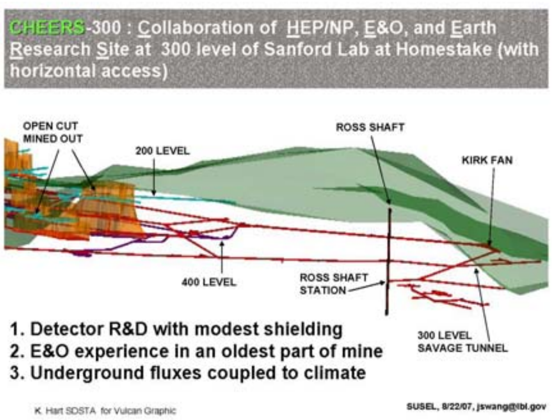
The Kirk Fan at 300L is currently used for ventilation purpose for the whole mine facility. Upon dewatering, Sanford Lab or Homestake DUSEL may switch to #5 Shaft and open up the drift behind the Fan for access. In Task 1.2.2, we will work with SDSTA and DUSEL design teams to understand the ventilation options, and to conduct dispersion assessments for released CO_2 or other gases underground as part of our EH&S effort associated with controlled experiments.

Task 1.3.3 Critical Zone Processes (R&D Proposal Task)

Task 1.3.3 is the integrating task for 300L monitoring and testing tasks. It will be responsible for designing any gas release experiments driven Task 1.1.2 and Task 1.3.2, interpreting coupling between climate and in-drift seepage and biochemical alternation observed in Task 1.1.3, coordinating pressure injection tests and deformation monitoring of Task 1.2.2, characterizing the drainage site and coordinating data collections along backfilled drifts in Task 1.2.3, and working with engineers, physicists, E&O, EH&S in Task 1.2.1. Task 1.3.3's additional focus is on the design and installation of a nest of boreholes to judiciously charactering all processes from 300L through the varying overburdens to the ground surfaces. We believe that all important processes operating over the “critical zone” (from tree tops to water table) are present in this system: the CHEERS-300L. If we need to extend the CHEERS to deeper levels, we recommend the extension based on our 300L findings. From a critical zone viewpoint, we may eventually regard the whole DUSEL facility to 8000L and beyond as one integrated CHEERS.

Note on Relationship to DUSEL R&D Proposal (Appendix A)

Task 1.2.1 and Task 1.3.3 described in this S-4 proposal are related to the 2 tasks in a DUSEL R&D Proposal submitted 12/3/2007 to DOE Office of Science High Energy Physics (Proposal FY08-004 from LBNL Earth Sciences Division, pending). Please note that we had a different vision for the R&D definition of “CHEERS”: with “CHE” standing for Collaboration with High-energy physics/nuclear physics and with Education and outreach. The last three letters “ERS” stand for the same: Earth Research Site as in the early definition of CHEERS (Critical Hydrology, Ecology and Earth Research Site). We retain the same acronym to maintain the continuity in developing 300L from different prospective. Obviously we will not have duplicating efforts and have coordinating efforts for Tasks 1 and 2. (In the final S-4 proposal we will clearly articulate the division and transition from DOE HEP project to NSF S-4 project, each with distinct and discreet emphasis. The details will be further articulated.)



CHEERS-300L Infrastructure and STSDA Support Needs

Task 1.1.1: Provide inputs on location of Sanford E&O Center.
Provide cost estimates for a new 300L station along Yates shaft. (Update raise-bore cost estimates if revised)
Provide cost estimates for drifting toward Yates Complex.

Task 1.1.2: Erect a 100-m tall pole (the tower itself is available from SDSMT) within the SDSTA property boundary.
Interact with local high schools, Indian tribes, and Sanford E&O Center to develop surface plots for high school projects.

Task 1.1.3: Mount cameras and sensors on walls, with seepage and moisture measurements and auto-sampling for biochemical evaluations.

	Provide logistical supports for E&O displays on climate changes along drifts.
Task 1.2.1:	Provide inputs on locations and site features for geotechnical evaluations. Provide logistic supports for geotechnical evaluations.
Task 1.2.2:	Characterize test sites ~100 m along Oro Hondo or other 300L drifts, drill injection and monitoring boreholes on the drift floor. Recommend and characterize test sites ~1,000 m along 2000L drift, drill injection and monitoring boreholes on the drift floor. Mount long base tiltmeters (see Suggestion 4.1).
Task 1.2.3:	Drill borehole arrays or excavate slots for cryogenic evaluations Provide inputs on the use of Samage tunnel towards Open Cut of modular Liquid Argon prototype or for waste rock transports from deeper campus developments
Task 1.3.1:	Provide inputs on the environmental sensors and data transfer methods already deployed or planned to be deployed at Homestake.
Task 1.3.2:	Provide inputs on ventilation systems and availability of other 300L drifts for site evaluations. Provide logistic supports for reentries into old drifts with hydro-bio-chemical sampling.
Task 1.3.3:	Provide inputs on potential for samplings by boreholes from 300L to cover the critical zone above and below the 300L. Provide support to drill boreholes and mounting sampling ports. Provide data transfers.

CHEERS-300L Funding:

A request of $500K is pending for CHEERS-300L from DOE Office of Sciences High Energy Physics, supporting LBNL, Fermi Lab, and associated interfaces with physicists, “Transparent Earth”, Sanford E&O, and SDSTA supports.

The S-4 funding requests will be further determined with SDSMT on Task 1.1.2, with Fermi Lab on Task 1.2.1, and with interested parties on other tasks. We suggest a total of 1.5 FTE for design Task 1 on CHEERS-300L beyond R&D request in S-4:

Task 1.1.1:	0.1 FTE for interfaces on E&O Center locations and 300L accesses
Task 1.1.2:	0.5 FTE for SDSMT Atmospheric Sciences led surface instrumentation
Task 1.1.3:	0.2 FTE for seepage monitoring and biochemical sampling
Task 1.2.1:	(Part of R&D proposal, geotechnical evaluations)
Task 1.2.2:	0.2 FTE for design of flow injection and long-range tilting experiments
Task 1.2.3:	0.2 FTE for interfaces with cryogenic fracturing, long baseline liquid argon prototype and waste rock disposal planning
Task 1.3.1:	0.2 FTE on sensor survey
Task 1.3.2:	0.1 FTE on ventilation interface
Task 1.3.3:	(part of R&D proposal, critical zone evaluations)

Activity 2: Large Scale Migration for CO_2

Overview of CO_2 Controlled Sequestration Experiment:

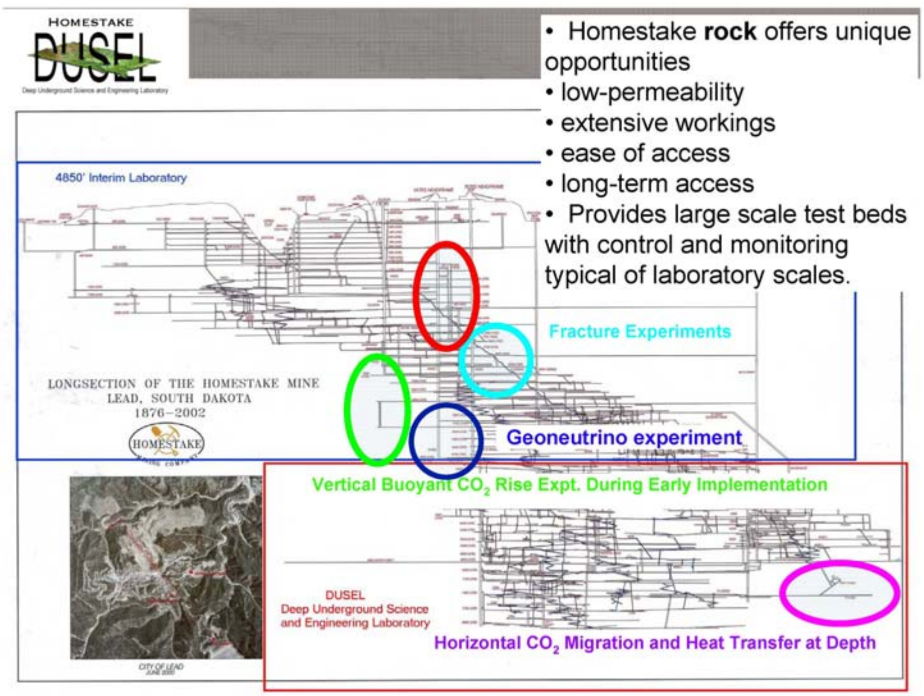
At Homestake, a considerable number of boreholes have been drilled between layers for drainage, ventilation, ore dump, and fluid transport over many years of mining there. We have identified some of the existing infrastructure for potential deployment of field-scale controlled experiments, namely the use of sandlines for CO_2 experiments, which involved the injection of supercritical CO_2—measuring phase transitions and residual CO_2 trapping. Sand-filled columns can be designed with sensors imbedded inside or mounted on the casing of pipe segments (each, say 5m long), to be assembled along ~0.3 m (12 ¼”) diameter sandlines of length ranging from ~50 to 150 m (150 to 450’). These sandlines can be further connected at test stations located at intermediate depths. This activity will also address basic research needs identified for multiphase transport associated with basic energy sciences, with applications to CO_2 geological sequestration. Note that we are not restricted to only pure supercritical CO_2 injections, but also open to other fluid phases and co-injections with multiple species (see Tasks 2.2). As noted in footnote #1, we have redefine CHEERS for Carbon in Hydrologic Environment for Enhanced Retention and Sequestration – our main focus in the S-4 development for CO_2 Multiphase Sequestration as an ISE.

After the sandline pipe-segment tests, or concurrently using other available sandline and other boreholes, we can characterize through boreholes with air-permeability packer tests to characterize the rock masses between layers, inject fluids directly into the metamorphic formations with tertiary intrusions, and to effectively evaluate “caprocks” with potential leakage paths. The most important technical challenges for geological sequestration is the leakage through the caprocks. While most of CO2 sequestration demonstration projects and initiatives focus on sandy formations capped by clayey, argillaceous, or hard rocks with low permeability, we can study the basic flow, transport, and coupled processes in fractured and faulted rock masses at Homestake with fairly heterogeneous metamorphic rock formations. We can then apply to other caprock assessment with the basic processes and understanding gained from our controlled experiments at varying scales.

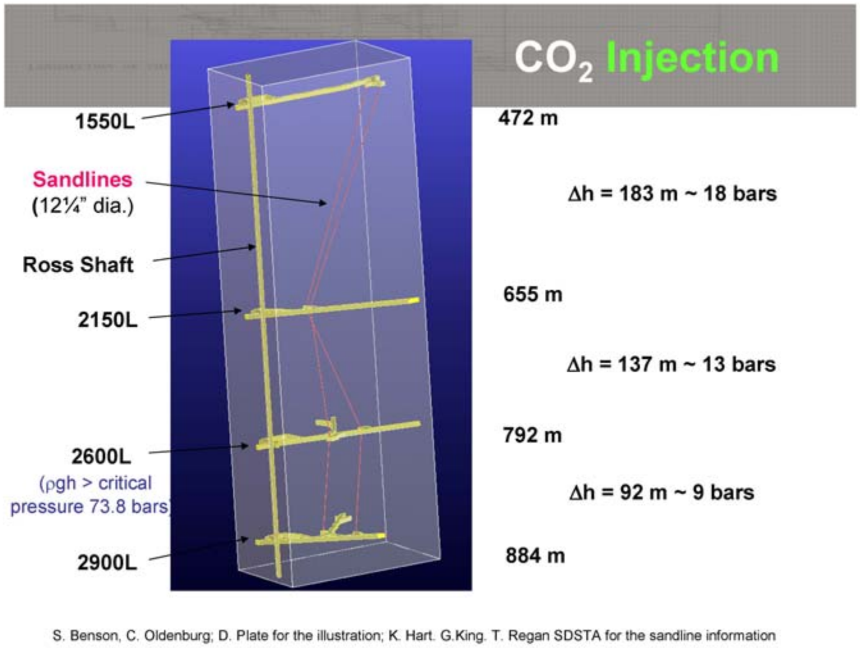
The site characterization, together with laboratory measurements of basic rock properties, can be used for site selections to locate blocks of rock for other coupled process testing, fracture testing, and multiphase, multi-component testing. We include in our CO_2 sequestration experiments the feasibility to incorporate petroleum materials as separate phases, as dissolved species, or as part of composite for injection fluids. These testing possibilities are applicable to both the quasi-linear sandline borehole configuration, or in three-dimensional block configurations. CO_2 flooding is one industrial process already deployed for enhanced oil recovery. We will evaluate what the EOR has learned about CO_2 – petroleum interactions and use the findings and synergies in designing CO_2 injection and displacement experiments.

Observations and Implications using "Sandlines":

During the early years right after Year 2000 when the Homestake was first proposed as a DUSEL site (known as NUSL then, with N for National, and no E for Engineering), we were looking for sites at grater depths (higher pressures and temperatures), larger diameters (shafts or wintzs with up to 12', not 12" in diameter), and isolated segments at the end of drifts. However, we are more practical now, with interests on shallower regions, easier to access, etc. We also recognize that one of the most attractive feature at Homestake is its existing infrastructure, with layers ~50 m (150') apart. We should take advantage of the unique characteristics offered by Homestake, and design controlled experiments not feasible or practical anywhere else.



The SDSTA team was instrumental with the suggestion to use "sandlines" for the CO_2 sequestration experiments. It was pointed out that there are many nearly vertical holes, with relative large diameters on the order of 1', drilled for transporting sand slurries from the surface to "stopes" left behind after ore extraction operations. The wasted rocks, or "sands" after gridding, were mostly disposed by reinjection back to the empty spaces left behind after ore removal. The backfill operations greatly reduced the potential for dangerous collapses. We thus plan to focus on pairs of "sandlines", specifically the ones from 1550L to 2150L, 2150L to 2600L, and 2600L to 2900L. There are many other sandlines continue down throughout the mine. We plan to use the others after we demonstrate in S-4 that we can indeed design and implement controlled experiments, before searching for boreholes and drift ends for deeper, hotter, and potentially higher pressure regions.



Sandlines start and end at "bathtubs" at different levels. The "bathtubs" are located in specially excavated niches or rooms, with half-walls built to form a "basin" for slurry to depressurize before continuing downward to the next set of "bathtubs" through "sandlines". We propose to convert these "bathtub" stations to "geo-test" stations, not just for CO_2 injection experiments, but for many other experiments sharing the common requirements.

One potential experiment potential related to CO_2 or other carbon gases is a bio-fuel related microbe test using carbon compounds as feedstock. With culture-able and transformable microbes derived from stains found underground, the test of using syngas or test for algae operations could be collocated with CO_2 injection tests at these geo-test stations.

Proposed Tasks:

Here we list the S-4 tasks for technical design for this activity to become one of the candidates in the initial suite of experiments:

Task 2.1 Sandline CO_2 Injections
Task 2.2 Sandline CO_2 Injections with Petroleum Products
Task 2.3 Characterization and Testing of Rock Masses between Layers
Task 2.4 Petroleum and Alternative Energy and Resource Tests
Task 2.5 Multi-Dimensional Controlled Experiments in Backfilled Drifts
Task 2.6 Controlled Field Experiments to Address Basic Research Needs

Task 2.1 Sandline CO_2 Injections

Task 2.1.1 Selection of Test Locations.
Task 2.1.2 Design of Field Implementation Sequences.
Task 2.1.3 Selection of Fluids, In-filled "Sands" and "Rocks", and Pre-Assembled Test Segments
Task 2.1.4 EH&S Procedures Associated with CO_2 Injections
Task 2.1.5 Field Demonstration of CO_2 Injections

In this task, we systematically evaluate the utilization of sandline holes, with pipe segment insertion, to conduct CO_2 injection experiments. The selection of using pipe filled with sands are driven by: (1) easiness to instrument segments with sensors both inside the pipi and on the outside of the pipe, or casing. (2) focus on quasi-linear phenomena of buoyancy displacement of other fluids, counter flows, and phase transition. (3) Containment of inject fluids within the pipe segments (with controlled venting if necessary) to address EH&S concerns associated with releases.

Task 2.1.1 Selection of Test Locations

We have revisited only one "bathtub" site at 1550L. In the coming months and years, we plan to access more sites to prioritize which are feasible. There are various considerations to be incorporated: the proximity to power, compressed air, water, gas lines, etc. This is only possible if STSTA endorses this experiment. We also need to consult with other experiments to explore the idea of sharing the same "geo-test" beds, perhaps even extending to low background counting, radiation evaluations, mobile biological labs, bio-fuel experiments, algae growth experiments, etc. This is the scope of Task 2.1.1 envisioned.

Task 2.1.2 Design of Field Implementation Sequences

Task 2.1.2 is on the practical constraints on field implementation. Can we indeed ship 5 m long segments of PVC or aluminum tubes, threading through from one bathtub through a sandline to the next level 50 m to 150 m below?

Task 2.1.3 Selection of Fluids, In-filled "Sands" and "Rocks", and Pre-Assembled Test Segments

Task 2.1.3 addresses: What kind of sands, rocks, or a combination of different media? Do we have the medium properties characterized already in the labs? What kind of fluids do we start with: Just water without sand? Compressed-air injection? Liquid nitrogen injection? Dry ice as sources of CO_2? Liquified CO_2? Supercritical CO_2? CO_2 with petroleum additives/tracers? Argon or other noble gases?

For the segments, one option we are exploring is whether we should have a uniform design or could have different segments designed by different groups (including potential industrial partners with "smart-well")? Each segment has both in-bore and out-bore sensors for hydro-chemical-biological measurements and for geophysical imaging tools to monitor phase changes and counter flows?

Task 2.1.4 EH&S Procedures Associated with CO_2 Injections

Task 2.1.4 addresses the critical procedures associated with field implementation. Since we are dealing with fluids other than pure water and air, we need to have sensors deployed around potential leakage points (led by Steven Glaser). This task will work closely with STSTA and DUSEL EH&S teams to make the experiments implementable.

Task 2.1.5 Field Demonstration of CO_2 Injections

Task 2.1.5 conducts dry runs with the steps developed in Task 2.1.2 for readiness assessment before injections. How do we connect the segments in the field without leakage? Do we fill the segments in the field or on the surface in the lab? How to sample residual saturation, with CO_2 stuck on rock surfaces, i.e. assess sequestration potential? *In situ* or direct sampling?

Task 2.2 Sandline CO_2 Injections with Petroleum Products

- Task 2.2.1 Dissolution of Petroleum Organic Compounds and Contaminants in CO_2 and Aqueous Phases
- Task 2.2.2 Use of CO_2 for Enhanced Oil Recovery
- Task 2.2.3 Field Demonstration of CO_2 Injections with Petroleum Products
- Task 2.2.4 Use of Injection Sites for Bio-Fuel, Algae Growth, and Other Geo-Tests

We will first evaluate the properties of CO_2 and its interactions with petroleum products. We will also evaluate the possibilities of share the infrastructure with other experiments.

Task 2.2.1 Dissolution of Petroleum Organic Compounds and Contaminants in CO_2 and Aqueous Phases

Oils and many organics and contaminants can solve in liquid and supercritical CO_2 and effectively removed. Supercritical CO_2, with its low surface tension, can spread easily over surfaces and is an effective dry cleaning agent. We can evaluate the dissolution rates of petroleum organic compounds and contaminants to determine the mixtures with CO_2 for injection studies. We can also evaluate the corresponding dissolution rates in aqueous solutions.

Task 2.2.2 Use of CO_2 for Enhanced Oil Recovery

In CO_2 Enhanced Oil Recovery,(EOR) application, a combination of CO_2 and water pumping into depleted oil wells to repressurize wells and "push" additional oil toward production wells. CO_2 dissolve in oils also reduces the viscosity.

Task 2.2.3 Field Demonstration of CO_2 Injections with Petroleum Products

We can either conduct this set after the pure CO_2 injections, then repeat with CO_2 laced with petroleum products, or conduct the tests in other sandlines independent of the tests in Task 2.1. We will also evaluate if we can use sands from oil wells in CO_2 injection tests.

Task 2.2.4 Use of Injection Sites for Bio-Fuel, Algae Growth, and Other Geo-Tests

In addition to petroleum relevant studies, we will evaluate in this task if we can co-locate with many other tests at "geo-test" beds where one set of sandlines terminate and another set continue to the levels below. Bio-fuel research and algae growth research are two such examples. Mobile or stationary hoods can be located at access drifts and rooms for bio-chemical preparation and characterization of test panels for cultures and mutation experiments. CO_2 and syngas sources can be developed and deployed for common uses.

Task 2.3 Characterization and Testing of Rock Masses between Layers

Task 2.3.1 Air-Permeability Tests with Packers
Task 2.3.2 Geophysical Tomography
Task 2.3.3 Hydrological and Biochemical Features
Task 2.3.4 Selection of Blocks for CO_2, Petroleum, Resource, and Coupled Process Experiments

In Task 2.3, we evaluate the metamorphic rocks at Homestake as analogs for 'caprocks' over sequestration reservoirs. The containment of injected CO_2 in depleted oil reservoirs, in coal seams beds, or in saline aquifers, all depends on the effectiveness of caprocks to stop or delay upward migration and prevent escape of buoyant CO_2 plumes. Controlled experiments at the metamorphic rocks at Homestake can address many fundamental and practical issues associated with sequestration. We will first characterize the rock masses along the sandlines before injections, and to determine if blocks can be located for other coupled processes and control fracturing experiments in the vicinity of snadlines.

Task 2.3.1 Air-Permeability Tests with Packers

The sandline from 1100L to 1550L was observed to have only drips of water at the "bathtub" or "geotest" site at 1550L. We could first deploy air-permeability test with packers to quantify the permeability distributions along the sandlines. Dry air can be injected at packed intervals and pressure and flow rate are used to measure the permeability of each interval. We may also design the packer assemblies to also measure the moisture content and temperature, and deploy water collection at the bottom packer to determine if liquid water inflows are observed at each interval. We can design packers with variable intervals to achieve meaningful spatial resolution.

Task 2.3.2 Geophysical Tomography

Seismic tomography is one of geophysical imaging tools to track the movement of plumes. The ground penetrating radar is another methodology sensitive to presence of fluid phases with different dielectric contrasts. We can also test other electromagnetic imaging methods with different frequency and penetration length. The transmitter and sensors can be mounted at different layers and along sandline and other holes. During the site characterization, we will likely use air (or water) injections. During CO_2 injections, we will probe for the leakage patterns through the metamorphic and tertiary rocks between layers.

Task 2.3.3 Hydrological and Biochemical Features

We will interact with other ISE and baseline data investigators to assembly hydrological observations and biogeochemical features found along drifts and boreholes. Together with the packer characterization and geophysical tomography, we will have a more constrained 3D description for regimes between layers.

Task 2.3.4 Selection of Blocks for CO_2, Petroleum, Resource, and Coupled Process Experiments

We will use the 3D description from Tasks 2.3.1-2.3.3 above to judge and select if blocks can be identified with well defined features and characteristics for injections, stress, heating, and other control experiments.

Task 2.4 Petroleum and Alternative Energy and Resource Tests

Task 2.4.1 Design Block Experiments
Task 2.4.2 Instrumented the Selected Blocks through Holes and Boundary Imaging Tools
Task 2.4.3 Field Demonstration of Displacement of Nitrogen or CH_4 to Evaluate Natural Gas Storage and Displacement
Task 2.4.4 Field Demonstration of Displacement of Oil Products in Blocks

Task 2.4.1 Design Block Experiments

The block tests will be jointly designed with other ISE and interested investigators for simultaneous or sequential tests to serve multiple research purposes.

Task 2.4.2 Instrumented the Selected Blocks through Holes and Boundary Imaging Tools

With selected block, we can deploy all conceivable testing and imaging tools to instrument the both from the sides and within the block volume. We will evaluate other block experiments designed or executed at other underground research laboratories to optimize our designs. Some techniques are amendable to periodic deployments to search for discrete changes, while others will continuous record the signals from induced changes.

Task 2.4.3 Field Demonstration of Displacement of Nitrogen or CH_4 to Evaluate Natural Gas Storage and Displacement

One proposed study is to understand the natural gas storage and displacement by CO_2, with the blocks filled initially with nitrogen (an analog for more flammable CH_4). We can start with using nitrogen (instead of air) in the permeability tests while purging the block with nitrogen. We then inject CO_2 to evaluate the mixing and displacement of natural gas.

Task 2.4.4 Field Demonstration of Displacement of Oil Products in Blocks

The other class of tests is on the displacement of viscous oil products trapped in low permeability formations. In addition to CO_2, thermal and water flooding can be tested in the blocks for enhanced recoveries.

Task 2.5 Multi-Dimensional Controlled Experiments in Backfilled Drifts

Task 2.5.1 Selection of Dead-Ended Drifts or Niches/Rooms
Task 2.5.2 Characterization of the Surrounding Damaged Zones
Task 2.5.3 Macro-Permeability Tests with Air Circulations
Task 2.5.4 Design and Instrumentation Needed for Backfilled Tests
Task 2.5.5 Field Demonstration of CO_2 Displacement of Nitrogen (or CH_4), Petroleum Products, and Heat Harvesting in Sands

In Task 2.5, we will design sand filled tests in backfilled spaces. This is a counter part of Task 2.4 in hard rock blocks, and complements Task 2.1 on sandline tests with water ad Task 2.2 with petroleum products.

Task 2.5.1 Selection of Dead-Ended Drifts or Niches/Rooms

We are seeking dead-ends of drifts or niches or rooms with lateral dimensions of 2-3 m, and length of ~10 m for sand-filled tests. The space will be sealed off with a bulkhead after characterization and instrumentation. It is desirable to locate at deeper levels with higher ambient pressure and temperature. We will work with SDSTA closely to identify and explore candidate sites.

Task 2.5.2 Characterization of the Surrounding Damaged Zones

Once a candidate site is identified, we will characterize the surrounding rock masses with geophyusical tomography and with an array of holes for ambient measurements of rock conditions. We will have stress-relaxed zones surrounding the empty space. The damaged zone typically extends several drift diameter into the rock mass where ambient conditions with higher pressure and temperature are maintained.

Task 2.5.3 Macro-Permeability Tests with Air Circulations

One test we can performed upon bulkhead construction is the macro-permeability measurement with air pump in and out of the enclosed space. The difference of moisture contents between in and out flows, together with the flow rate, is the amount of water effectively removed from the surrounding rock masses. If the gradients from the drift wall toward the interior can be measured from hole instrumentation, we can calculate the effective or macro-permeability of the surrounding confining rock masses.

Task 2.5.4 Design and Instrumentation Needed for Backfilled Tests

We can then design tests and instrument the holes, drift surfaces, and interior before backfilled the space with sands or other media. Most of the lessons learnt from snadline tests will be used in the test designs to address issues associated with multiple dimension, larger lateral scale, and different phases.

Task 2.5.5 Field Demonstration of CO_2 Displacement of Nitrogen (or CH_4), Petroleum Products, and Heat Harvesting in Sands

The sandfilled macro-tests may have nitrogen as the initial gas to represent CH_4 or other natural gases, or with sands filled with viscous petroleum products. CO_2 or other fluids may be injected to displace the gases or liquids. If the temperature and pressure are in the relevant regimes, we can evaluate concepts such as using CO_2 as heat exchange fluids for enhanced geothermal extraction.

Task 2.6 Controlled Field Experiments to Address Basic Research Needs

Task 2.6.1 Scaling and Heterogeneity
Task 2.6.2 Multiple Phase and Multiple Component Processes
Task 2.6.3 Biological and Geochemical Processes
Task 2.6.4 Monitoring and Imaging of Features, Events, Processes
Task 2.6.5 Energy and Environmental Issues and Challenges

Task 2.6 will embark on the integrated design and interfaces with lab preparation and modeling. We have reviewed some results of lab measurements, and used solutions of counter flows in response to gas injections to initiate the test designs. We have plans to use equation of state packages for supercritical CO_2 injections into sand columns. This Task will systematically use models and lab results to estimate the test durations and locations of the phase transition zones along the sandlines. We have also reviewed the Basic Research Needs from the 2007 DOE BES report to articulate the role of controlled field experiments to address basic questions and technical challenges associated with CO_2

sequestration specifically and multiphase flow processes in general (assessed by Curt Oldenburg). Task 2.6 will be the task to interpret the test results and analyze if key issues are resolved. The following are some basic research needs (referenced to page number from BRN report).

Task 2.6.1 Scaling and Heterogeneity

- Buoyancy-driven flow at all scales (p. 12).
- Flow and transport properties of seals, faults, and fractures (p. 18).
- Modeling multiple processes at interacting scales (p. 51).
- Scaling laws for flow, transport, reactions and coupled processes (p. 45).

Task 2.6.2 Multiple Phase and Multiple Component Processes

- Impact and coupling of interfacial phenomena (p. 12).
- Dynamic imaging for complex multiphase systems (p. 20, 121).
- Transport properties and in situ characterization of fluid trapping, isolation, and immobilization (p. 131).

Task 2.6.3 Biological and Geochemical Processes

- Microbial processes relevant to CO_2 sequestration (p. 15).
- Biogeochemistry in extreme subsurface environments (p. 28, 145).
- Equilibrium and reaction rates in perturbed geochemical environments (p. 29).
- Rates of dissolution and mineral reactions involving CO_2 (p. 15).

Task 2.6.4 Monitoring and Imaging of Features, Events, Processes

- Monitoring dynamic subsurface processes (p. 43)
- .Improved geophysical imaging techniques (p. 46)
- Relating geophysical measurements to in situ properties/processes (p. 84).
- Developing integrated monitoring approaches (p. 85).
- Coupled monitoring and modeling approaches (p. 87).

Task 2.6.5 Energy and Environmental Issues and Challenges

From the SECURearth initiative, energy resources (petroleum, geothermal, water) and environmental resolutions (remediation, CO_2 sequestration, nuclear waste isolation) have common issues and challenges:

- Characterization of fast flow paths.
- Alternation by physical and geochemical changes
- Transformation by biological engineering and technologies

CO_2 Experiment Infrastructure and STSDA Support Needs

Task 2.1 Sandline CO_2 Injections

Task 2.1.1 Selection of Test Locations. SDSTA Teams will support the selection of sites and determine the constraint to use different "bathtubs' and sandlines.

Task 2.1.2 Design of Field Implementation Sequences. The test sequence can be tested and refined with SDSTA field supports.

Task 2.1.3 Selection of Fluids, In-filled "Sands" and "Rocks", and Pre-Assembled Test Segments. Fluids, sands, rock media, tracers are evaluated with Material Safety Data Sheets together with SDSTA.

Task 2.1.4 EH&S Procedures Associated with CO_2 Injections. Pressure, temperature, fluid releases are monitored with sensors acceptable to STSTA EH&S procedures.

Task 2.1.5 Field Demonstration of CO_2 Injections. The readiness dry-runs are conducted with SDSTA.

Task 2.2 Sandline CO_2 Injections with Petroleum Products

Task 2.2.1 Dissolution of Petroleum Organic Compounds and Contaminants in CO_2 and Aqueous Phases. Dissolution rates are evaluated with Material Safety Data Sheets together with SDSTA.

Task 2.2.2 Use of CO_2 for Enhanced Oil Recovery. Findings will evaluated with SDSTA.

Task 2.2.3 Field Demonstration of CO_2 Injections with Petroleum Products. The readiness dry-runs are conducted with SDSTA.

Task 2.2.4 Use of Injection Sites for Bio-Fuel, Algae Growth, and Other Geo-Tests. Bio-hazards are evaluated with Material Safety Data Sheets together with SDSTA.

Task 2.3 Characterization and Testing of Rock Masses between Layers

Task 2.3.1 Air-Permeability Tests with Packers. Field deployments are coordinated with STSTA. Compressed air sources are needed.

Task 2.3.2 Geophysical Tomography. Field deployments are coordinated with STSTA. 120 V electric powers are needed.

Task 2.3.3 Hydrological and Biochemical Features. Will work closely with the STSTA reentry and inspection teams.

Task 2.3.4 Selection of Blocks for CO_2, Petroleum, Resource, and Coupled Process Experiments. Will consult SDSTA for feasibilities.

Task 2.4 Petroleum and Alternative Energy and Resource Tests

Task 2.4.1 Design Block Experiments. Feasibilities are consulted with SDSTA.

Task 2.4.2 Instrumented the Selected Blocks through Holes and Boundary Imaging Tools. Feasibilities are consulted with SDSTA.

Task 2.4.3 Field Demonstration of Displacement of Nitrogen or CH_4 to Evaluate Natural Gas Storage and Displacement. Coordinated with SDSTA.

Task 2.4.4 Field Demonstration of Displacement of Oil Products in Blocks. Feasibilities are consulted with SDSTA. Coordinates with SDSTA.

Task 2.5 Multi-Dimensional Controlled Experiments in Backfilled Drifts

Task 2.5.1 Selection of Dead-Ended Drifts or Niches/Rooms. Consult wit SDSTA for available spaces.

Task 2.5.2 Characterization of the Surrounding Damaged Zones. Work with SDSTA to coordinate drillings.

Task 2.5.3 Macro-Permeability Tests with Air Circulations. Coordinate with SDSTA on compressed air and electric power requirements.

Task 2.5.4 Design and Instrumentation Needed for Backfilled Tests. Coordinates with SDSTA.

Task 2.5.5 Field Demonstration of CO_2 Displacement of Nitrogen (or CH_4), Petroleum Products, and Heat Harvesting in Sands. Coordinates with SDSTA.

Task 2.6 Controlled Field Experiments to Address Basic Research Needs. .Consult SDSTA in adjustments in test designs.

CO_2 Experiment Funding

We suggest a total of 4.5 FTE for design and limited demonstration in Task 2 on CO_2 Experiment request in S-4. 2 FTE CO_2 sandline test and 0.5 FTE for the other five tasks each. We anticipate that we may need more FTEs annually for this activity after proof of concept.

Task 2.1 Sandline CO_2 Injections

Task 2.1.1 0.1 FTE for Selection of Test Locations.

Task 2.1.2 0.3 FTE for Design of Field Implementation Sequences.

Task 2.1.3 0.3 FTE for Selection of Fluids, In-filled "Sands" and "Rocks", and Pre-Assembled Test Segments.

Task 2.1.4 0.3 FTE for EH&S Procedures Associated with CO_2 Injections.

Task 2.1.5 1 FTE for Field Demonstration of CO_2 Injections.

Task 2.2 Sandline CO_2 Injections with Petroleum Products

Task 2.2.1 0.1 FTE for Dissolution of Petroleum Organic Compounds and Contaminants in CO_2 and Aqueous Phases.

Task 2.2.2 0.1 FTE for Use of CO_2 for Enhanced Oil Recovery.

Task 2.2.3 0.2 FTE for Field Demonstration of CO_2 Injections with Petroleum Products. The readiness dry-runs are conducted with SDSTA. This effort expected to be greatly increased after preliminary assessments.

Task 2.2.4 0.1 FTE Use of Injection Sites for Bio-Fuel, Algae Growth, and Other Geo-Tests. This effort is expected to be greatly increased after preliminary assessments.

Task 2.3 Characterization and Testing of Rock Masses between Layers

Task 2.3.1 0.2 FTE for Air-Permeability Tests with Packers. This effort is expected to be greatly increased after preliminary assessments.

Task 2.3.2 0.1 FTE for Geophysical Tomography. This effort is expected to be greatly increased after preliminary assessments.

Task 2.3.3 0.1 FTE for Hydrological and Biochemical Features. This effort may be increased after preliminary assessments.

Task 2.3.4 0.1 FTE for Selection of Blocks for CO_2, Petroleum, Resource, and Coupled Process Experiments. This effort may be increased after preliminary assessments.

Task 2.4 Petroleum and Alternative Energy and Resource Tests

Task 2.4.1 0.1 FTE for Design Block Experiments. This effort is expected to be greatly increased after preliminary assessments.

Task 2.4.2 0.1 FTE for Instrumented the Selected Blocks through Holes and Boundary Imaging Tools. This effort is expected to be greatly increased after preliminary assessments.

Task 2.4.3 0.1 FTE for Field Demonstration of Displacement of Nitrogen or CH_4 to Evaluate Natural Gas Storage and Displacement. This effort is expected to be greatly increased after preliminary assessments.

Task 2.4.4 0.2 FTE for Field Demonstration of Displacement of Oil Products in Blocks. This effort is expected to be greatly increased after preliminary assessments.

Task 2.5 Multi-Dimensional Controlled Experiments in Backfilled Drifts

Task 2.5.1 0.1 FTE Selection of Dead-Ended Drifts or Niches/Rooms. This effort is expected to be greatly increased after preliminary assessments.

Task 2.5.2 0.1 FTE for Characterization of the Surrounding Damaged Zones. This effort is expected to be greatly increased after preliminary assessments.

Task 2.5.3 0.1 FTE for Macro-Permeability Tests with Air Circulations. This effort is expected to be greatly increased after preliminary assessments.

Task 2.5.4 0.1 FTE for Design and Instrumentation Needed for Backfilled Tests. This effort is expected to be greatly increased after preliminary assessments.

Task 2.5.5 0.2 FTE for Field Demonstration of CO_2 Displacement of Nitrogen (or CH_4), Petroleum Products, and Heat Harvesting in Sands.

Task 2.6 Controlled Field Experiments to Address Basic Research Needs.

Task 2.6.1 0.1 FTE for Scaling and Heterogeneity

Task 2.6.2 0.1 FTE for Multiple Phase and Multiple Component Processes

Task 2.6.3 0.1 FTE for Biological and Geochemical Processes

Task 2.6.4 0.1 FTE for Monitoring and Imaging of Features, Events, Processes

Task 2.6.5 0.1 FTE for Energy and Environmental Issues and Challenges

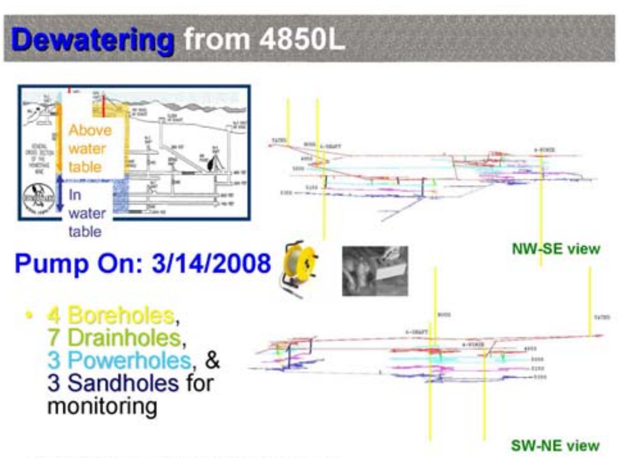
Activity 3: Carbon-Cycle Evaluation in Dewatering

Overview of Dewatering:

The rise of the water table since mine closure in 2003 is the result of localized inflow from the open cut and ground surfaces, as well as from the surrounding groundwater. When the Sanford Lab reclaims the upper levels and conducts the scheduled dewatering operation, we can use the water table changes in shafts and many boreholes to characterize the entire site, to verify that the formation is tight, and to determine how much the water-rock interactions affect the water quality, both locally and regionally. The unique data set can be used to develop and calibrate site models. The effective open space volume (i.e., tunnels, open space in backfill material, and connected pore space in the geologic formation) is not known accurately. The site models can inversely determine this type of parameters, as well as effective hydraulic parameters in the cone of water table depression, from matching the slow rising and subsequent responses to dewatering by pumping. Seeps observed in freshly de-saturated drifts are expected to flow either for a short period determined by the local storage capacity, or for long time periods determined by connected flow paths to the infiltration sources. We can also verify whether localized and/or pressurized water pockets are present at depths, and assess the distances to the water not affected by previous mining activities in the surrounding formations.

Vulcan Survey and Implications:

There are many information and records about 4850L. Since it has not been inspected yet in the reentry operation, we have reviewed the Vulcan database and identified holes in the record from 4850L to lower levels. This information is illustrated to demonstrate the possibility of using the small holes together with large shafts to monitor the planned dewatering operations. With the instruments needed for shaft monitoring recently funded and transducers ordered, we will briefly summarize the potential supplementary deployment of handheld sensors in additional to the shaft monitoring.



Proposed Tasks:

The SDSMT Hydrology team and the STSTA Rehabilitation team are installing pressure sensors and collecting water samples in shafts. We will consult and coordinate the following tasks with the ongoing and future data collection efforts in dewatering.

Task 3.1 Hydrological Evaluation
Task 3.2 Biogeochemical Evaluations of Carbon Compounds and Contaminants

Task 3.1 Hydrological Evaluation

Task 3.1.1 Evaluation of Holes Available in Levels Above Water Levels.
Task 3.1.2 Supplementary Data Collection with Handheld Meters and Collectors.
Task 3.1.3 Seepage Monitoring During Dewatering.
Task 3.1.4 Synthesis of Water Flow Data.
Task 3.1.5 Site Water Models Calibrated with Both Flooding and Dewatering Data.

Barrick/Homestake has prepared a water recovery report in 2002 before mine closure and updated since for comparisons with the flooding evolutions. We hope to work with Barrick through STSTA and with SDSMT Hydrology team to further calibrate the hydrologic models.

Task 3.1.1 Evaluation of Holes Available in Levels Above Water Levels

Nearly vertical holes exist at all levels. We will continue to evaluate holes available at drift levels above the water table as potential observation points. There are indications that water level can locally fluctuate. We propose that we can observe the water levels at multiple points beyond the shafts (Ross, #6, and later Yates) where pressure transducers are planned to be deployed and water samples have been collected.

Task 3.1.2 Supplementary Data Collection with Handheld Meters and Collectors.

If nearly vertical holes are available, we propose to use handheld meters to measure the water levels at each available holes, and collect water samples concurrently. We can deploy these measures at or above 4550L, and later at 4700L, 4850L, 5000L, and lower levels as the dewatering proceeds.

Task 3.1.3 Seepage Monitoring During Dewatering.

As we recover the flooded levels, we should observe, measure, and sample any seepages observed as the rehabilitation team treks through the recovered levels. Some of the seeps are expected to be transient while others are semi-continuous. These are valuable and un-retrievable data useful for model formulation and calibration.

Task 3.1.4 Synthesis of Water Flow Data.

The observed water data from areal surveys, in addition to shaft measurements, can shed light on the hydrological responses. The water tables during flooding and dewatering may not follow a classical cone configuration.

Task 3.1.5 Site Water Models Calibrated with Both Flooding and Dewatering Data.

We have this task to periodic update models that can interpret the observed water level evolution, both temporally and spatially. The Homestake formations may have low permeability and isolated water pockets may respond to flooding and dewatering non-uniformly. We aim to establish site models that can credibly account for all available observations and measurements. If water tables are well defined and lateral hydraulic communications are good, we will have a relatively simple hydrological description of flooding-dewatering at Homestake. On the other hands, we may have different conceptual models with pockets trapping excess water bodies.

Task 3.2 Biogeochemical Evaluations of Carbon Compounds and Contaminants

Task 3.2.1 Evaluation of Carbon Sources at Homestake.
Task 3.2.2 Synthesis of Water Quality and Carbon-Related Data.
Task 3.2.3 Site Biochemical Models Calibrated with Historical and Dewatering Data.
Task 3.2.4 Assessment of Conceptual Models and Model Uncertainties.
Task 3.2.5 Comparison of Homestake Hydrology and Biochemical Environment with Other Settings.

Barrick/Homestake commissioned in 2003 a geochemical evolution model for the flooding, from inorganic data collected before mine closure. We hope to work with Barrick/Homestake through SDSTA and with the SDSMT Hydrology team to further establish and calibrate the geochemical models, with additional biochemical information collected during dewatering, to evaluate the biogeochemical evolution and conditions, focusing on carbon-related compounds and contaminants.

Task 3.2.1 Evaluation of Carbon Sources at Homestake.

While most of the petroleum products in equipments and rail carts were removed during mine closure, there are historical wastes and carbon sources introduced during decades of mining in backfilled stopes and drifts. This task will evaluate available sources in the mine spaces.

Task 3.2.2 Synthesis of Water Quality and Carbon-Related Data.

During the dewatering operations, water samples are collected for regulatory compliance with discharge permits, and for biochemical measurements by the scientific teams. We will work with SDSTA and scientific teams to synthesize available water quality and carbon-related data.

Task 3.2.3 Site Biochemical Models Calibrated with Historical and Dewatering Data.

If organic data are aquired, we will work with teams to establish and calibrate site scale biochemical models consistent with site hydrological models, using both historic and new data collected during dewatering operation.

Task 3.2.4 Assessment of Conceptual Models and Model Uncertainties.

The 2003 Geochemica model indicates that there are magnesium-sulfate (Mg-SO4) water existed from approximately 3050L to 5000L. This may explain the lowering of pH observed in some recent samples as water level raised above the 5000L, with sulfate concentration increased. The teams will assess the conceptual models and model uncertainties associated with observations and measurements.

Task 3.2.5 Comparison of Homestake Hydrology and Biochemical Environment with Other Settings.

This is aimed to synthesize and compare the Homestake setting with other settings evaluated in the literature, or in Task 4 below for collaborations in other sites and countries. We will explore both the uniqueness of Homestake and assess if our findings will contribute to better understanding of hydrological and biochemical processes, features, and events in different earth formations.

Carbon in Hydrological Environment Infrastructure and STSDA Support Needs

We advocate that the reentry team periodically monitor visually and with handheld meters to collect supplemental data. The dewatering is a one time operation. We try to confirm that the water table during dewatering is well-defined, with no localized water columns lagging behind the water table declines. We also chack if well-mixed models are reasonable for the biochemical observations.

Task 3.1 Hydrological Evaluation

Task 3.1.1 Evaluation of Holes Available in Levels Above Water Levels. SDSTA will provide data on available holes at levels.

Task 3.1.2 Supplementary Data Collection with Handheld Meters and Collectors. The SDSTA rehabilitation team will conduct most of the surveys during inspection, accompanied by researchers if feasible.

Task 3.1.3 Seepage Monitoring During Dewatering. The SDSTA rehabilitation team will collect or assist researchers for seepage observations and monitoring.

Task 3.1.4 Synthesis of Water Flow Data. STSTA will provide water recovery models and updates for scientific teams to collectively synthesize available data.

Task 3.1.5 Site Water Models Calibrated with Both Flooding and Dewatering. SDSTA will continue update the water recovery models.

Task 3.2 Biogeochemical Evaluations of Carbon Compounds and Contaminants

Task 3.2.1 Evaluation of Carbon Sources at Homestake. SDSTA will provide historical data on potential sources of carbon compounds/contaminants.

Task 3.2.2 Synthesis of Water Quality and Carbon-Related Data. STSTA and other scientific teams will provide water quality data to collectively synthesize available data.

Task 3.2.3 Site Biochemical Models Calibrated with Historical and Dewatering Data. STSTA will provide geochemical evolution models and updates for scientific teams to collectively synthesize available data.

Task 3.2.4 Assessment of Conceptual Models and Model Uncertainties. SDSTA will provide inputs and participate in the assessments.

Task 3.2.5 Comparison of Homestake Hydrology and Biochemical Environment with Other Settings. SDSTA will contribute to the comparison.

Carbon in Hydrological Environment Funding

We tentatively assign 1 FTE for initial modeling effort to supplement SDSTA and SDSMT efforts. For hydrological models to carbon-cycle models, we have:

Task 3.1 Hydrological Evaluation

Task 3.1.1 0.1 FTE for Evaluation of Holes Available in Levels Above Water Levels.

Task 3.1.2 0.1 FTE for Supplementary Data Collection with Handheld Meters and Collectors.

Task 3.1.3 0.1 FTE for Seepage Monitoring During Dewatering.

Task 3.1.4 0.1 FTE for Synthesis of Water Flow Data.

Task 3.1.5 0.1 FTE for Site Water Models Calibrated with Both Flooding and Dewatering Data.

Task 3.2 Biogeochemical Evaluations of Carbon Compounds and Contaminants

Task 3.2.1 0.1 FTE for Evaluation of Carbon Sources at Homestake.

Task 3.2.2 0.1 FTE for Synthesis of Water Quality and Carbon-Related Data.

Task 3.2.3 0.1 FTE for Site Biochemical Models Calibrated with Historical and Dewatering Data.

Task 3.2.4 0.1 FTE for Assessment of Conceptual Models and Model Uncertainties.

Task 3.2.5 0.1 FTE for Comparison of Homestake Hydrology and Biochemical Environment with Other Settings.

Activity 4: Extended Use and Research Opportunities (EURO)

Overview of EURO

We will collaborate with the physics and biology research communities to explore uses of existing and new infrastructure (drifts, rooms, ramps, boreholes) and to stimulate interdisciplinary activities. Knowledge from ongoing studies associated with reentry operations and funded research will be integrated and presented to new investigators interested in developing new ideas and new applications. We will also assist DUSEL in exchanging information with many underground research laboratories for both physics-detector housing and for coupled-processes evaluations. While each site and each setting is unique, there is knowledge and experience (e.g., in sensors R&D) of mutual benefit to the advancement of underground science and technology. Given that DUSEL represents the U.S. frontier in deep underground science, we can certainly offer the Homestake site as a hub for international collaborations.

interdisciplinary Underground Science and Technology (*i*-DUST) Implications

We are using the findings from a recent trip as examples for further developments in international collaborations. The trip was to the Low Noise Underground Laboratory (LSBB, http://lsbb.unice.fr), at Rustrel-Pays-d'Apt in southern France. LSBB has well-defined infrastructure established within 10 years with focused science and technology activities. The LSBB - Laboratoire Souterrain à Bas Bruit is a horizontal tunnel complex converted from a land-based missile-launch control center into a laboratory dedicated to *interdisciplinary* Underground Science and Technology (*i*-DUST). Since its inception in 1998, LSBB has developed and established international participations with its focus on deploying small and intermediate size experiments for both basic scientific investigations and practical technology testing in low noise background environment.

The experience and findings over the development of LSBB for i-DUST is relevant to the Homestake DUSEL as a successful case study in making direct and smooth transition into a user facility. Furthermore, the "Extended Uses and Research Opportunities" theme in Homestake DUSEL can be further developed realistically by inviting investigators in LSBB *i*-DUST and worldwide to collaborate with us, to conduct R&D on sensitive equipments, to adopt state-of-the-art approaches, and to develop international and inter-disciplinary collaborations.

The current scientific investigations at LSBB include dark matter search at room temperature, superconductivity quantification in low magnetic environment, seismic monitoring with sensitive equipments, seismic to electro-magnetic coupling from epicenters to ion-sphere, borehole-, drift-, to regional scale hydrology, geochemistry, and coupling to rock deformations in the fractured karst rocks, coupling to earth tides and earth rotation, and others. The technologies being tested include reliability of nano-components of electronic devices, calibration of satellite-bound equipments, effects of micro-wave irradiations on biological metabolisms in low noise environment, and others.

Suggestions and Examples:

Some specific activities envisioned from discussions at this 2nd International Conference on Underground Science are listed.

Suggestion 4.1	Technical Exchange on Seismic Monitoring at Homestake, and LSBB, and Worldwide.
Suggestion 4.2	Field Testing of Hydro-Mechanical Equipments and Coupling.
Suggestion 4.3	Multi-Scale Coupling of Electromagnetic and Seismic Waves.
Suggestion 4.4	Comparison between Karstic Aquifers and Metamorphic Rocks.
Suggestion 4.5	Radiative Characterization.

Suggestion 4.1: Technical Exchange on Seismic Monitoring at Homestake, LSBB, and Worldwide

The Director of LSBB and his many collaborators are interested in sensitive seismometers (STS2) to map the mountain of LSBB, and to monitor seismic events locally, regionally, and worldwide. The seismic station RUSF is a permanent observation point of international seismic network[7]. The seismic related interests at Géosciences Azur Laboratory, University of Nice – Sophia-Antipolis, include pendulum rotation, rock-fluid interaction, etc. The technical exchanges with Homestake DUSEL will be further developed with investigators of the "Transparent Earth" project of Homestake DUSEL, and with the investigators of the LIGO Project for laser interferometer gravity-wave observatory.

Suggestion 4.2 Field Testing of Hydro-Mechanical Equipments and Coupling

The High Pulse Poroelasticity Protocole (HPPP) developed at Géosciences Azur Laboratory, and the Long Base Tiltmeter (LBT) developed at Géosciences Montpellier are two examples of sensitive equipment to be deployed along a 250-m long LSBB gallery with on average 300-m overburden. It is feasible to test these equipments also at Homestake DUSEL in the 300-ft (100-m), the 2000-ft (600-m depth with lateral extent up to 4 km), and other levels for additional meso-scale evaluations. This suggestion is also given above in Activity 1, Task 1.2.2.

Suggestion 4.3 Multi-Scale Coupling of Electromagnetic and Seismic Waves

With its unique room shielded from magnetic field[8], LSBB is the site for tests of digital SQUID magnetometers led by Univ. Savoie. Early observations of the correlation

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[7] Wansand, G. 2006. "The low noise underground laboratory of Rustrel-Pays-d'Apt". J. Physics: Conference Series 39, 157-159. The article is available at http://lsbb.unice.fr. The article also provides overview of the low noise conditions and unique environmental and technical characteristics in terms of anisotropic activity. seismological noise, gravity, and electromagnetic shielding at LSBB.

[8] *Ibid.*: The main experimental area of LSBB is the old control room at 500 m depth, which was built as a Faraday cage isolated from mechanical vibrations, thus the shielding reduces the magnetic field. This EM shielded, mechanically isolated room (100 m^2 floor) has magnetic field less than 6 μT, a long time stability of better than 20 nT and fluctuations below 2.5 fT/√Hz.

between seismicity and superconductivity at LSBB has led to great enthusiasm about the coupling of electromagnetic waves with seismic waves. Other significant studies include the imagings with microwave antenna of Univ. British Columbia, the irradiation of microwave on plants planned by the Univ. Avignon, and the coupling of seismic signals to ionosphere study led by CNRS-Orleans. The EM waves travel faster than the seismic waves. It is likely that further development at underground labs worldwide on this coupling could open up new predictive methodologies and new fields.

Suggestion 4.4 Comparison between Karstic Aquifers and Metamorphic Rocks

We can use such a comparison to test (1) the hypothesis that local saturated condition near the tip of rock surface is responsible for seepage in man-make galleries (LSBB) and natural caves (observed by investigators in Chrono-Environnement - Besançon, EMMAH – Avignon - France, U. Magala - Spain), and (2) the hypothesis that regionally in karstic formations, mountains are unsaturated above water table due to its highly permeable and complex characteristics, while water tables follow the topographic variations in many other rock types. At Homestake, the permeability may be very low locally and water-table may be ill-defined. These are examples that comparative hydrological studies at both sites may shed light on fundamental understanding of hydrology at different formations.

Suggestion 4.5 Radiative Characterization

The planned radiative characterization at LSBB in 2008, the radioactivity survey assessment at French Navy's Roule underground laboratory (Cherbourg-France), and the intense interests at Homestake DUSEL to establish multi-user Low Background Counting Facility have many approaches and techniques in common. We can also include in this suggested collaboration the interests in tracer studies with dissolved organic matter or CO_2 (EMMAH – Avignon, CNRS-Grenoble), and other geochemical measurements in bio-chemical samplings.

Vision of Extended Uses and Research Opportunities (EURO)

LSBB with its low noise environment has attracted a long term testing program on self error rates in electronic chips (IM2NP – Marselle, Principal Engineer from San Jose, USA, LSBB, XILINX), on an electric force microscope for metal-semiconductor-insulator interface layers (U. Cezanne – Marseille), on a double torsion pendulum for testing LISA (a space interferometric antenna for gravitational waves) Gravitational Reference Sensor on the ground (U. Firenze - Italy), for a ring laser gyroscopes for Earth's absolute rotation rate (EOST-U. Strasbourg - France, Tech. U. Munich, U. Munich - Germany), and others. We could collaborate with LSBB to articulate Homestake DUSEL main characteristics – extensive infrastructure, heterogeneous rock formations, well-defined flow, benign geochemistry, and seismic quietness – to fully utilize our space and potential for underground science, engineering, and innovative technologies.

While the technical suggestions listed above are mainly on earth related investigations, the "EURO" suggestion should also include astrophysics and other physics experiments.

During the call for Letters of Interest (LOI) in 2006 for the Early Implementation Program (EIP) at Sanford Lab there were a number (~10) LOI's acted on favorably by the Program Advisory Committee (PAC) but which did not fit neatly into the standard disciplinary categorization. Nor did they necessarily require the full facilities of any of the various "campuses" envisioned for DUSEL. Rather, they more often wished to take advantages of spaces/features truly unique to Homestake relative to other underground facilities. Often they did not require extended occupancy for completion of the experimental program envisioned or in some cases they represented exploratory experimentation in the service of a broader future program on important science. Because of these LOI interests a group of us were charged by the S-1 organizers of the November 2007 Washington DUSEL Workshop to investigate "How to foster the science represented by these other uses." As a result of that Workshop some mechanisms were proposed to foster these ideas and to provide them with access to process and due consideration. Of what these processes might consist is presented in the White Paper on Other Uses requested by S-1 and which is contained here as Appendix E (http://hep.brown.edu/users/lanou/B2-session-draft-v5.pdf). Support is requested here for Activity 4 to initiate and implement this process and to insure that the mechanisms merge smoothly into the future DUSEL management structure for support of the experimental program.

EURO Infrastructure and SDSTA Support Needs

STSTA rehabilitation progress will dictate how much facility spaces are available for extended uses. While the research communities will articulate the opportunities in science, engineering, and technology that requires underground infrastructure. For the suggested examples, we anticipate the following interactions and needs.

Suggestion 4.1 Technical Exchange on Seismic Monitoring at Homestake, and LSBB, and Worldwide. SDSTA will provide the supports for site selection, sensor installation, and data transfer from seismic sensors.

Suggestion 4.2 Field Testing of Hydro-Mechanical Equipments and Coupling. SDSTA provides supports to characterize test sites at 300L and later at 2000L or other deeper levels, for drilling of injection and monitoring holes on the drift floors, and data transfers

Suggestion 4.3 Multi-Scale Coupling of Electromagnetic and Seismic Waves. SDSTA will provide the supports for site selection, sensor installation, and data transfer from electromagnetic sensors.

Suggestion 4.4 Comparison between Karstic Aquifers and Metamorphic Rocks. SDSTA will participate in site comparison studies.

Suggestion 4.5 Radiative Characterization. SDSTA will support the deployment of radiative sensors.

Vision for Extended Uses and Research Opportunities: The EURO vision can be achieved with SDSTA supports.

EURO Funding

We propose to use the suggested examples to develop the Extended Uses and Research Opportunities at Homestake. We tentatively assign 1 FTE effort for coordination and some travel supports. Thus we have 0.1-0.2 FTE effort to support and coordinate with each of 5-10 groups per year. We will use these funds as seeds to develop more extensive external and international projects that can use Homestake for sciencific and technological advances.

Cost Estimates

Within each task, we have tentatively assign funding envisioned for S-4, primarily for design of experiments with initial field demonstrations. In summary, the S-4 proposal costs are:
1.5 FTE for Activity 1 on 300L and Surface Assessment for CHEERS' E&O and EH&S.
4.5 FTE for Activity 2 on Large Scale Migration for CO_2.
1.0 FTE for Activity 3 on Carbon-Cycle Evaluation in Dewatering.
1.0 FTE for Activity 4 on Extended Use and Research Opportunities (EURO).

Total S-4 proposal costs are 8 FTE per year, or 16 FTE for FY 2009 and FY2010.

S-4 together with S-5 (FY2010 and FY2011) will define the costs for ISE at FY2012 and beyond.

We can envision that the Collaboration can grow 3-4 times to ~30 FTE per year, especially with inclusion of interests in petroleum and other resource testing. The ISE can take five to ten years to mature and fully implemented. The ISE will then cost ~200-250 FTE in its lifetime. The workshops during the first quarter of S-4 will start to refine these estimates.

Schedule

S-4: FY2009 – FY2010
S-5: FY2010 – FY2011
ISE: FY2012 and beyond

Facility

The infrastructure requirements and SDSTA support needs are described in Task descriptions. In summary, we require spaces:

300L drifts (especially floor spaces) for Activity 1 on 300L and Surface Assessment for CHEERS' E&O and EH&S.

Sandlines and "bathtub" geo-test sites at 1550L, 2150L, 2600L, 2900L, and deeper levels, dead-end drifts or niches.rooms, and blocks for Activity 2 on Large Scale Migration for CO_2.

Nearly vertical holes and drift segments at 4400L, 4550L, 4700L, 4850L, 5000L, and all lower levels currently flooded for Activity 3 on Carbon-Cycle Evaluation in Dewatering.
Multiple levels and sites for Activity 4 on Extended Use and Research Opportunities (EURO).

Utilities required are 120V power, compressed air, ventilation, data transmission, communication.

Education and Outreach

The Sanford E&O Center and the 300L drifting, halls, and displays along drifts, as described in Activity 1, are our main E&O focus. The other three activities at deeper levels will generate data to be transmitted to the SDSTA Administrative Building, and to be displaced at the Sanford E&O Center and in 300L.

Risk Identification and Management

We discuss EH&S in Activity 1 associated with CO_2 gas releases. For other materials, we will evaluate Material Safety Data Sheets together with SDSTA, as described in each task. Required procedures are also coordinated with SDSTA.

Linkage of Tasks to Potential Collaborators and Supporters

The linkage with tasks will be further determined during S-4 proposal preparation and documented in Appendix B.

Appendices A-F will be included in the final S-4 submittal. Appendix B under development will discuss funding, responsibilities of participants, etc. in more details.