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Dear Committee Member,

My fields of research are in mining and geological engineering; specifically, mechanical excavation technology, rock fragmentation, the flow of fluids in fractured rock, and extra-terrestrial resource production. The Kimballton site offers a suitable location for research in these areas, and I am working as a member of the Kimballton team to help make this a reality.

The features of Kimballton which appeal to me are:

- The massive nature of the limestone exposed in the Kimballton Mine (low frequency of natural and induced fractures in the rock fabric). This aspect simplifies the constraints that control the flow of fluid in fractures, bridging the gap between laboratory experiments and real-world applications.
- The multiple repetition of stratigraphy in the study area. This may enable evaluation of the effect of depth alone on the response of rock to fragmentation and excavation techniques, and on the fluid-flow behavior of the rock. Rigorous comparison of the effects of different stress states on rock mass behavior is often confounded by the unavoidable inclusion of different rock types and geologic terranes. The utility of this site for such comparisons in repeated rock formations will have to be verified with a thorough site characterization program.
- The layered nature of the rock. The majority of the rock with which engineers must contend is sedimentary, or derived from it, even at depth.
- The potential depth for studies of rock behavior. As near-surface mineral resources are extracted and the Earth's population continues to grow, resources at increasing depth must be mined affordably. Mineral extraction problems associated with great depth in the crust include:
  - At what confining pressure is the anisotropy due to layering overcome?
  - How sensitive is rock at depth to perturbation?
  - Could deviatoric stresses be utilized to reduce the energy cost of rock fragmentation at depth?
  - What is the long-term behavior of an opening at great depth, and how can closure of openings under stress be efficiently mitigated?

The research and engineering communities of which I am a member should be represented in DUSEL because mineral commodities are essential to civilization, yet they are becoming harder to produce. Research performed at DUSEL can help to assure a continued or even enhanced supply of minerals for the maintenance of life as we know it, and as it may become.

Mining engineering and technology research have increased the productivity of miners astoundingly in the past two hundred years. Supported by mining companies, support industries, and mining industry groups, advances such as trackless equipment, low-sensitivity explosives, GPS tracking, rockbolts, and bulk mining methods have been developed and, even more importantly, disseminated among potential users. People with a wide variety of backgrounds

have been vital throughout. More than any other engineering discipline, mining engineering takes a systems approach to the myriad difficulties that must be overcome to produce minerals in an economically and environmentally sustainable manner. Accordingly, research teams tend to be highly multi-disciplinary, varying in size from single investigators to teams of a dozen separate companies.

Another growing area for research is mineral production from extra-terrestrial sources, also called ISRU (for *In Situ* Resource Utilization). Innovative technologies for fragmentation, excavation, and transportation developed for mining at depth will be highly applicable to the remote, hazardous mines of the Moon, Mars, asteroids, and beyond. Definite synergies can be developed between the deep and the final frontiers:

- Autonomous operation of equipment and systems. Full automation of the unit operations of mining is difficult even on Earth, due to the constantly changing nature of operational constraints (travel path, loading parameters, rock properties, *etc.*). It will be imperative in space.
- Innovative mining technologies. Although focused on apparently different environments, mining technology research at DUSEL and for ISRU will share many aspects. Innovative approaches to energy transfer from tool to rock that maximize useful fragmentation and minimize sound, heat, and rock damage will be useful in both areas.
- Environmentally sensitive mining technologies. The environments of the Moon, Mars, and other solar system bodies are very sensitive to disturbance. Technologies developed for low-impact mining at deep levels of the Earth's crust will be applicable off-Earth as well.
- Energy-efficient mining technologies. Much of the energy used in fragmentation and excavation goes to non-productive mechanisms, such as rock damage, which weakens the rock and increases the risk to miners. Gravity has long been used to help move broken rock, but what other "free" energy could be harnessed as well?

Roadmaps for the development of innovative technologies for all the unit operations of resource production are being worked out by teams of industry experts (mining, chemical, biological, mechanical, electrical, civil, and computer engineers and scientists) and NASA professionals. It is a widely held consensus that only research shared among U.S. government agencies and other groups both domestic and international can successfully expand permanent human activity beyond our single, fragile planet. No single entity -- NASA or ESA or the entertainment industry -- can achieve the momentum necessary to make this actually happen.

Accordingly, I support the creation of a DUSEL at the Kimballton Mine. Properly designed and operated, it will enhance the survivability of humanity in a universe full of hazards.

Sincerely,

Leslie Gertsch

Leslie Gertsch
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