CHAPTER 2

PROPOSED ACTION AND ALTERNATIVES

Some types of experiments are best (or only) performed deep underground. For this reason, scientists have considered WIPP as a potential site for these types of experiments and have sought permission from DOE to conduct several types of experiments there. As an example, astrophysicists are searching for very small particles with no charge called neutrinos. These particles are so small that they typically pass through the Earth. The only way to detect them is to look for them using facilities as far underground as possible so that the Earth's surface layers filter out other cosmic particles and radiation.

The first basic astrophysics-like experiments were begun at WIPP in 1993 by LANL scientists who used WIPP's low background radiation to test materials to use in constructing specialized detectors. These materials had to be tested in a deep underground facility (SNO 1999). They are currently being emplaced in the deepest neutrino observatory in the world, that in Sudbury, Ontario (the Sudbury Neutrino Observatory), which is 2,070 meters (6,800 feet) below the surface. The LANL scientists followed this effort in 1997 with efforts to develop a very pure silicon-based solid-state detector that they believed might detect "dark matter" (see the text box titled "Of Dark Matter, WIMPs, and Neutrinos and Their Flavors"). This experiment continues underground at WIPP, and scientists believe it may need to be there 1 or 2 more years before they have the data they need (Nelson 2000a).

Other scientists have since expressed interest in moving experiments to WIPP, leading to a meeting in Carlsbad, New Mexico, on June 12-14, 2000. This meeting was attended by nearly 60 astrophysicists and other scientists from throughout the nation interested in conducting experiments at WIPP (Nelson 2000b). (The web page for this meeting can be found at http://www.wipp.carlsbad.nm.us/leptontown; it includes copies of slides presented at the meeting).

Because of the interest of the scientific community in using WIPP for experiments that must be conducted underground, DOE is preparing this document to inform decision-makers about the environmental impacts of allowing the placement of the experiments in WIPP. The Proposed Action is to authorize the use of WIPP facilities for different types of scientific experiments, as described below. For comparison purposes, this EA also examines the no action alternative.

2.1 THE PROPOSED ACTION

The Proposed Action is to allow the astrophysics and basic science experiments described in Section 2.1.1 to be conducted in the experiment gallery and other areas of the WIPP facility, to the extent that they do not interfere with WIPP's mission of disposing of TRU waste. These experiments would be proposed and sponsored by scientists outside of the Department, although some may receive DOE funding. The conduct of the experiments could require some modifications of or additions to the underground experiment gallery at WIPP.

Under the Proposed Action, experiments would not all begin or end at the same time and each would be operated on its own schedule, as funding became available. The experiments could run from 2 years to up to 35 years. For purposes of analysis, however, it is assumed that (1) all experiments would begin simultaneously after preparation of the experiment gallery, (2) each would run for 35 years (the planned operation life of WIPP), and (3) they would then be decommissioned.

OF DARK MATTER, WIMPS, AND NEUTRINOS AND THEIR FLAVORS

Experiments already proposed for the WIPP facility focus on dark matter, WIMPs, and neutrinos, all obscure subjects to the average U.S. citizen. Basically, each experiment, in one way or another, tries to answer the questions, “What is the universe made of?” and “How was it created?”

For years, astrophysicists have tried to mathematically calculate the mass of the universe. Because of the relationship between mass and gravity and the speed of the stars and other heavenly bodies, they can estimate how much mass should exist. But when they calculate the mass of the heavenly bodies we can see, they find the two numbers don’t compare. About 90 percent of the mass is missing. Two astronomers are given credit for identifying this problem: Jan Oort in 1932 and Fritz Zwicky in 1933 (MAU 1996).

As a solution to this puzzle, scientists have postulated a yet-unknown substance they call “dark matter.” But where and what is it? Astronomers believe that dark matter may be in what are called “MAssive Compact Halo Objects” (MACHOs), which are not luminous to their telescopes but which may be out there and may be very massive. The mass of these objects could be so great that their gravity will not allow light to be reflected back to the scientists’ telescopes. These MACHOs may be red dwarfs or black holes, or they may be some other massive object, yet unidentified (MAU 1996).

Physicists, though, believe that there is something more basic but unknown in the universe that may have mass but not interact with other matter. They call these basic particles WIMPs. WIMPs would have escaped detection to date because they have no or little charge and do not interact with, but in fact pass through, most other objects. Several experiments proposed for WIPP are searching for these WIMPs. They are detectors designed to shield out cosmic rays, and yet allow some evidence of the WIMPs to be identified (MAU 1996).

Another candidate for the missing matter is the neutrino. Neutrinos were first postulated by Wolfgang Pauli in 1931, then later became important to Enrico Fermi in 1934. While studying a form of radioactive decay in which a neutron decays into a proton and electron, these two scientists were unable to account for all of the energy and matter released. They postulated that a new particle existed, the neutrino, which they believed at that time had no charge and no mass (as noted below, the belief that the neutrino has no mass has changed in light of more recent findings). This type of radioactive reaction is common to a supernova, a stellar event during which the energy released can be a billion times that of the sun. Therefore, when supernovae occur, large numbers of neutrinos pass through the earth (UCI 2000).

Since the 1930s, scientists have learned much about neutrinos. They’ve defined them as a fundamental particle of the universe, which has no charge (so they are not affected by electric-magnetic forces like electrons). Because they have no charge, they can go long distances through matter without being affected by it. They also understand that there are at least three “flavors” of neutrinos: one related to electrons, another related to the slightly heavier and charged muon, and the third related to the heavier and charged tau (UCI 2000). The neutrino, though, is still evasive. The last of these flavors, the tau neutrino, had been understood in theory for many years, but was finally detected just this past summer. And scientists have never been able to find evidence of as many neutrinos as theoretically should exist.

Finally, to be a candidate for the universe’s missing mass, neutrinos must have mass. In spite of numerous experiments throughout the world, it was only in 1998 that scientists obtained the first evidence that neutrinos do have mass (Physical Review Focus 1998). No measurement of that mass, though, has been obtained to date, and many of the experiments proposed for WIPP hope to be the first to do so.

Much is at stake, for without dark matter of some type, scientists are unsure whether such basic theories as the Big Bang Theory withstand modern scrutiny. Others believe that if neutrinos do have mass, one of the principal theories of physics, the standard model, will be called into question. To the layman, though, the strangest finding may be that a particle modern scientists still struggle to detect and understand may be responsible for more mass in the universe than all of the planets and stars combined.

As part of the Proposed Action, DOE would mitigate potentially significant impacts that might be associated with the conduct of these experiments. Mitigation measures that are already in place at WIPP or that could be used to mitigate various hazards are discussed in Chapter 4. Actual mitigation measures that would be instituted for individual experiments would be determined based on the hazards analysis that DOE would conduct for each experiment before it commences.

2.1.1 Range of Possible Experiments

To date, various organizations have submitted descriptions of nine experiments they would like to locate in WIPP sometime during the next two decades. All of these experiments focus on the search for dark matter, WIMPs, or knowledge concerning neutrinos (Nelson and Bennington 2000).

An underground facility such as WIPP could also be used for other types of experiments, including those in low radiation dose physics, health effects of magnetic fields, fissile materials accountability and transparency, remote sensing, deep geology and seismology, and biological studies of darkness, silence, and radiation on plants and animals. Further, WIPP's status as a working deep geologic waste repository also makes it a resource for experiments in other fields such as mining, waste repository science, and deep geophysics.

To identify the range of the experiments that could be conducted in WIPP or another underground facility, DOE reviewed the nine experiments currently proposed and consulted scientists from Pacific Northwest National Laboratory (PNNL) regarding the needs and potential hazards of these experiments. Eight of the nine experiments are likely candidates for inclusion at WIPP and are described in Section 2.1.1.1. (The ninth, an experimental facility called the Ultimate underground Nucleon decay and neutrino Observatory [UNO], is discussed in Section 2.1.1.6, "Other Experiments Considered But Not Included in Analyses"). In addition, the PNNL experts identified other potential experiments that could be conducted in WIPP and for which authorization could be sought in the future. Based on these efforts, 15 experiments in the following five categories were identified and are included for analysis in this EA:

- Particle physics experiments (Section 2.1.1.1)
- Other astrophysics and physics experiments (Section 2.1.1.2)
- Mine safety and geophysical studies (Section 2.1.1.3)
- Nonproliferation and nuclear accountability experiments (Section 2.1.1.4)
- Chemical and material processing experiments (Section 2.1.1.5)

The intent of this EA is not to limit the experiments conducted at WIPP to only those analyzed in the EA. Other experiments could be permitted at WIPP in the future under this EA as long as the environmental impacts of those experiments are encompassed within the scope of the impacts considered in this EA.

2.1.1.1 Particle Physics Experiments

The following particle physics experiments have already been proposed to DOE and are under consideration for emplacement in WIPP.

LANL WIMP Dark Matter HpSi Detector

This experiment is an outgrowth of the neutrino detector development work conducted by LANL staff for the Sudbury Neutrino Observatory beginning in 1993. Using the same electronics and equipment that were placed in WIPP in 1996, LANL staff have developed silicon crystals and installed them as a dark matter detector in WIPP. The detector has a secure data communications link and is visited by a LANL staff member once a month. The experiment would continue for 2 more years. The experiment is currently in a small blind room in the repository but would be moved to the experiment gallery if it became available for occupation (Nelson 2000b; Nelson and Bennington 2000).

Observatory for Multi-flavor Neutrino Interactions from Supernovae (OMNIS)

OMNIS is a collaboration from all over the world, but led by Ohio State University and the University of California, Los Angeles. The OMNIS team has proposed to the National Science Foundation to install a 9,000-metric-ton (10,000-ton) detector system constructed of lead and/or iron, with 20 modules of 450 metric tons (500 tons) each. The detector would be installed in phases. If the National Science Foundation funded the effort (nearly $40 million would be requested), Congressional approval would be expected in the following fiscal year (FY). The money would lead to 1 year of detector development followed by 3 or 4 years of construction in WIPP. The long construction time would be needed to move the lead and iron into the experiment gallery and assemble the detector.

A related proposal by the University of California, Los Angeles to DOE’s Office of Science requests funding to develop plastic scintillators for the OMNIS detector described above. Scintillators show the activity of neutrinos by flashing a particular light that can be detected and measured by scientists. If the plastic scintillators were not produced or prove less sensitive, a standard scintillation liquid would be used. This scintillation liquid would consist of mineral oil containing small amounts of 1,2,4-trimethylbenzene and aromatic fluors, with nearly 106,000 liters (28,000 gallons) contained in the equipment. OMNIS would have a very long operating lifetime. Its main purpose would be to observe neutrinos from supernovae in our galaxy, and the estimated mean time between nearby supernovae is thought to be from 10 to 30 years. The most recent supernova was in 1987. A similar facility is being considered for the Boulby Mine Observatory in the United Kingdom. Scientists hope that by having two facilities, they would increase their chances of finding the data they are pursuing (Nelson and Bennington 2000; Brodzinski et al. 2000; Boyd et al. undated).

This experiment would demand a relatively large area of the experiment gallery that is relatively easily accessible. Moving such a large amount of lead and/or iron into the repository would take several years. Once assembled, though, the detectors would appear as three rows of metal boxes, two of iron and one of lead. Each row would be about 80 meters (260 feet) long, 5 meters (16 feet) wide, and nearly 4 meters (13 feet) high (Figure 2-1). Another 4 meters in width would be needed for access to the equipment. The cost of the facility is currently estimated at $30 million (Nelson 2000b).

There are many potential hazards associated with this experiment. Transportation of the materials, including the equipment and scintillation fluid, would pose acceleration and impact hazards (Nelson and Bennington 2000; Brodzinski et al. undated). The lead used in the detector could pose a toxicity hazard; however, protective equipment and handling procedures would alleviate this hazard. Contact and inhalation hazards could result from the use of or a fire involving scintillation liquid (Bichron 1995).

Surface Experiment Related to OMNIS

In addition to the underground activities of the OMNIS, which are proposed to detect neutrinos from supernovae, another team of scientists has proposed that an array of detectors be constructed on the surface of the WIPP site to help identify the nature of the cosmic radiation that would be detected by OMNIS while waiting for a supernova to occur. This surface experiment would involve burying several hundred detectors in a 6- to 8-square-kilometer (2- to 3-square-mile) area above the WIPP facility. The detectors would be plastic with a plastic scintillator and electronics to detect the cosmic radiation. Each would be approximately 1 to 2 meters (3 to 6 feet) on a side and several centimeters thick. They would be buried 2 to 2.4 meters (6 to 8 feet) deep in an array, using a backhoe, on approximately 200-meter

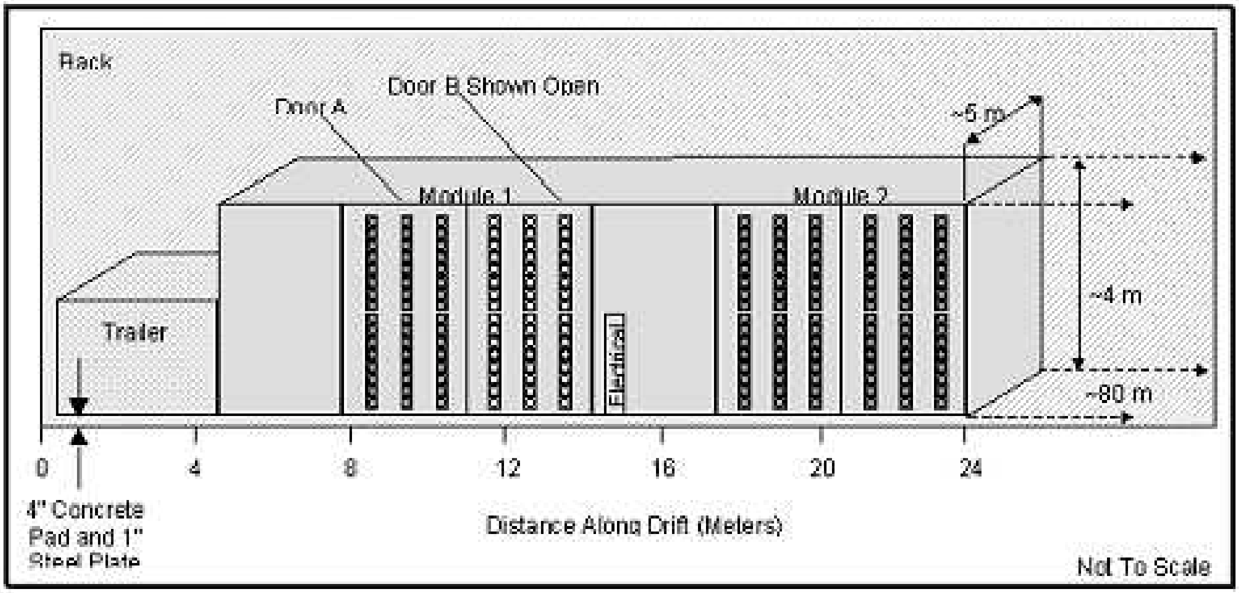

Figure 2-1. OMNIS Lead Detector

(660-foot) centers. Each would include a metal pole that would extend out of the surface about 2 meters (6 feet) high. On the pole would be a solar collector that would power the electronics and a radio transmitter to transmit the data to a central data collector. The detectors, therefore, would not be connected and no cabling would need to be buried between them (Nelson 2000d). The exact location of a particular detector in the surface grid could be displaced from a proposed location should archeologists, biologists, or other scientists find that a particular location would lead to impacts (Nelson 2000d). Hazards associated with this experiment would arise from the surface excavation and handling of the plastic scintillator.

Enriched Xenon-136 Observatory (EXO)

EXO is a worldwide collaboration led by Stanford University that is proposing to build a 9-metric-ton (10-ton) xenon-filled gas detector to measure neutrino-less double beta decay. This experiment's primary purpose is to determine neutrino mass. Compared to OMNIS, this is a small experiment that would be completed a decade after installation. The experiment depends on availability of enriched xenon-136, which currently does not exist. Production of this material is being proposed on a separate track and may be produced by a gaseous centrifuge operation in Russia organized under the auspices of the DOE Nuclear Cities Initiative. Production of the xenon would take several years, making FY2004 the earliest time that the experiment could be constructed at WIPP. Some small-scale development and measurement activities might occur as early as 2002. The full detector would be assembled in pieces underground at WIPP and might require some new excavation. The experiment would use 9 metric tons (10 tons) of the xenon-136 under up to 20 atmospheres of pressure, which could present a hazard if subjected to catastrophic release in a confined environment. In addition to the explosion and high pressure potential caused by such a catastrophic release, this amount of xenon would displace about half the air in a standard WIPP waste disposal room. There are about 70 standard rooms planned for the WIPP repository.
Only 14 have been excavated at this time. The experiment would be in a container about 4 by 5 meters (13 by 16 feet), containing mirrors, light sensors, and lasers (Figure 2-2). The lasers could create a radiation hazard (Breidenbach at al. 2000; Brodzinski et al. 2000; Nelson and Bennington 2000).

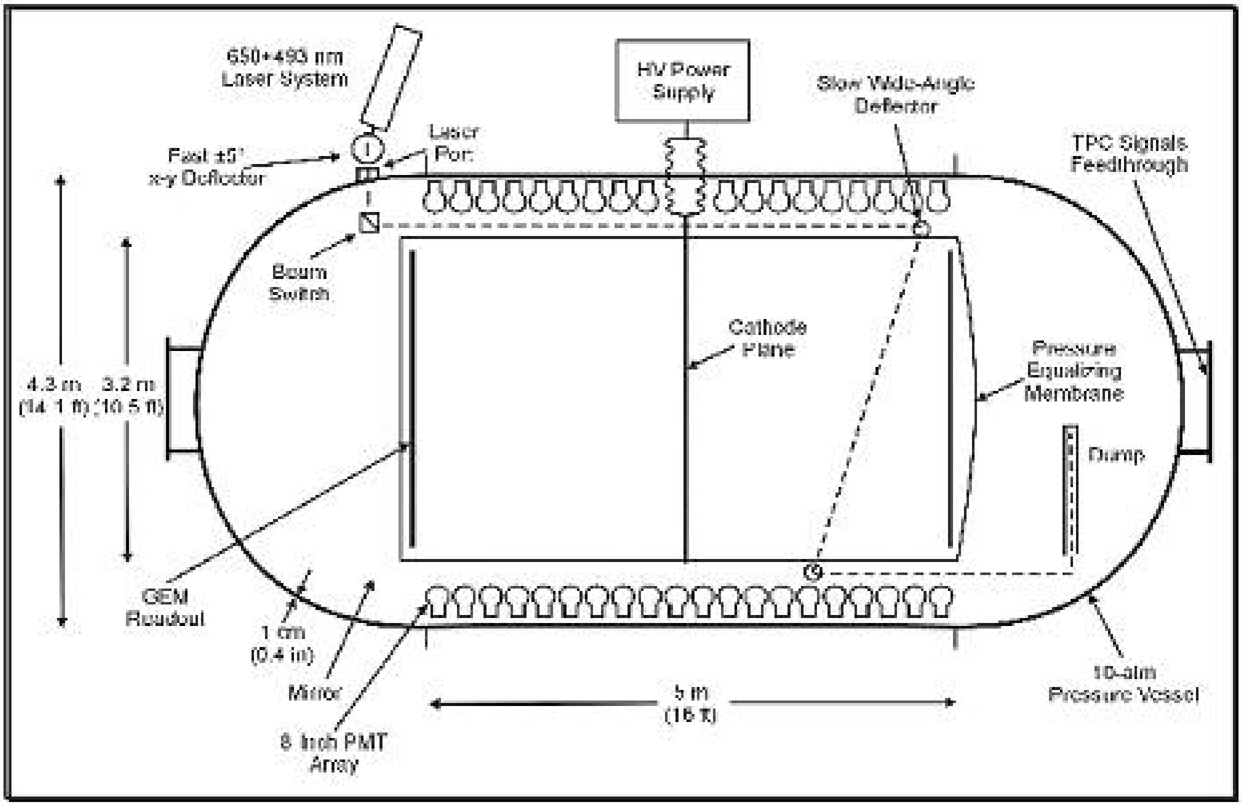

Figure 2-2. Conceptual Layout of EXO Experiment

Germanium in Liquid Nitrogen Underground System (GENIUS)

GENIUS is another experiment aimed at identifying dark matter. This effort is sponsored by the Max Planck Institute in Germany and is a search for dark matter using naked germanium detectors submerged in up to 450 metric tons (500 tons) of liquid nitrogen (Figure 2-3). The principal detector material would be germanium metal, with the germanium-76 isotope of most significance. GENIUS would require significant new excavation and very robust safety analysis and protection systems. The major hazard associated with this experiment would be the cryogen tank of liquid nitrogen in which the detectors are submersed. The tank would contain 1,400 cubic meters (49,440 cubic feet) of liquid nitrogen, which if instantaneously released could displace the air from nearly a million cubic meters, or more than the entire WIPP site. DOE, aware of the hazard, has stated that engineering and safety requirements for this experiment must ensure that, even in a catastrophic accident, the liquid nitrogen released would not present a hazard (Brodzinski et al. 2000; Nelson and Bennington 2000).

Institute for Nuclear and Particle Astrophysics and Cosmology (INPAC)

INPAC is a multi-campus research unit of the University of California. INPAC has proposed to the Keck Foundation that it develop a general purpose underground nuclear physics laboratory at WIPP. The design of the laboratory would include a 9-meter (30-foot) in diameter by 6-meter (20-foot) tall tank filled with ultrapure water, with an adjoining electronics room. To reduce the effects of leakage or flooding, the tank would be placed in secondary containment to capture any spills. Some new excavation for the secondary containment tank is likely (the base for a 2- to 5-meter by 12-meter [8- to 16-foot by 40-foot]

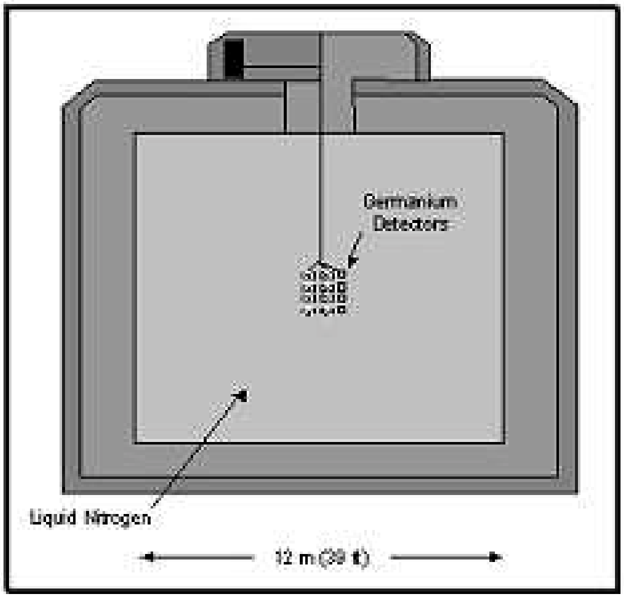

Figure 2-3. Conceptual Layout of GENIUS Experiment

catchment tank) (Figure 2-4). Funding of this project is currently unknown and it is not likely to be a reality for several years. This facility is proposed to provide scientific infrastructure to all the experiments occupying the site, as well as to serve as the site for several efforts to identify other dimensions and WIMPs. It would last for the duration of all experiments (INPAC 1999; Nelson and Bennington 2000; Brodzinski et al. 2000). This proposal is predicated on the requirement of all experimenters to have access to clean rooms, machine shop facilities, electronics shops, computational facilities, etc. Since most of the proposed experiments are intended to measure some rare nuclear phenomenon, it is imperative that other, more common, nuclear phenomena not produce signals that mimic the expected rare event. Most obvious are unwanted radioactive impurities in the materials composing the various experiments. Therefore, it would be necessary to provide a “screening” laboratory for evaluation of potential construction materials. This laboratory, as proposed, would house the evaluation instrumentation in a large volume of pure water as a shield from environmental radiation (INPAC 1999; Nelson and Bennington 2000; Brodzinski et al. 2000).

Majorana Project

A collaboration with Duke University has proposed the Majorana Project, another double-beta decay experiment based on the use of germanium-76. This experiment also is a mid-size experiment that would operate for about a decade after installation. The quantities of germanium-76 required for this experiment do not currently exist, and would likely be produced in Russia, via the gaseous centrifuge process, organized under the auspices of the Nuclear Cities Initiative. Like GENIUS, the Majorana Project’s germanium detectors also require liquid nitrogen for cooling, but unlike GENIUS, the quantity of liquid nitrogen is not very large, nor is it all contained in one tank. This experiment would use up to 10 Dewars-size containers each with up to 100 liters (26 gallons) of liquid nitrogen (Figure 2-5). A catastrophic release of any one of these containers would only displace about 65 cubic meters (2,295 cubic feet) of air, or only a small fraction of the air in a WIPP room. Prototype detectors have been constructed and tested in the basement laboratories at Duke, and the collaboration wants to move the development work to WIPP in the near future. The development work would be of about the same scale

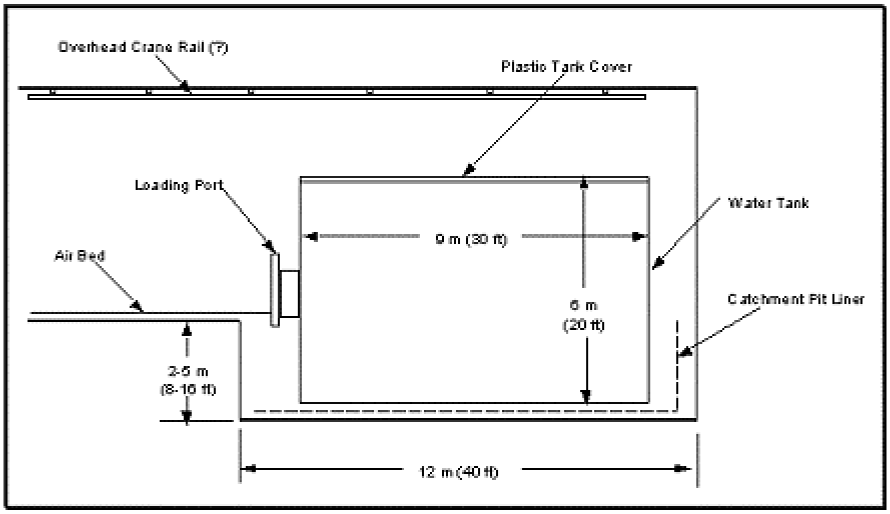

Figure 2-4. INPAC Experimental Cavity

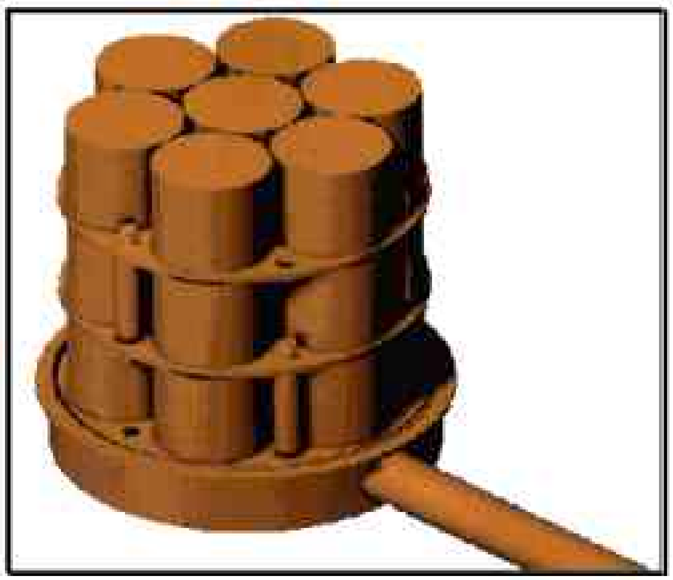

Figure 2-5. Majorana Project Detector Experiment

as the LANL WIMP project described above. Full-scale development is several years away, but if funded in 2003, this project could begin detector and equipment assembly in 2004. The detector would not require a large amount of space. Conservative estimates are that an area equivalent to 5 meters by 10 meters by 4 meters (16 feet by 33 feet by 13 feet) high would be suitable (Brodzinski et al. 2000; Nelson and Bennington 2000).

Neutrino Factory Detector at WIPP

Within the next decade, a collaboration of scientists is proposing to build a muon collider at either Brookhaven National Laboratory or Fermi National Accelerator Laboratory. The muon collider would begin with construction of a muon storage ring at one of the two facilities. The facility would be capable of sending neutrinos through the earth to detectors at WIPP and at the other neutrino observatories throughout the world (see the text box titled "Other Underground Astrophysics Experimental Observatories"). The proposed WIPP detector would most likely be a 4- to 5-meter (13- to 16-foot) in-diameter, iron or lead detector that would use magnets to deflect daughter products for neutrino interactions in the detector (Nelson and Bennington 2000; Brodzinski et al. 1999). The lead involved could pose toxic hazards, while the magnetized iron could pose radiation hazards. The length of the detector could be as long as 300 to 500 meters (980 to 1,640 feet) and would have to point toward either the Fermi or Brookhaven facilities.

The facility would have to be constructed underground. Additional excavation would be necessary and would probably be east of the experiment gallery. Figure 2-6 shows the latest proposed location for the detector.

2.1.1.2 Other Astrophysics and Physics Experiments

Study of Magnetic and Radiation Field Interaction

Physicists have long known there is a relationship between magnetic and radiation fields due to research done as part of the nuclear weapons program, but they do not understand the interactions between those fields. Because cell phones, television stations, radio stations, and power and transmission lines all emit electromagnetic radiation, and other technological developments such as hospital x-ray machines and new products create radiation fields, a better understanding of this relationship may be important to future health research.

An underground laboratory with low radiation levels would allow scientists to build a laboratory for such studies. The laboratory was estimated at 12 meters by 9 meters by 4.5 meters (40 feet by 30 feet by 15 feet). It would need to be isolated from fields generated by other experiment equipment. Within the laboratory, scientists would create and control magnetic fields and monitor them as small radiation fields would be introduced. The radiation sources envisioned would be the type used to calibrate equipment (Brodzinski et al. 2000; Jarvis 2000).

2.1.1.3 Mine Safety and Geophysical Studies

Mine Tremor and Sensor Studies

A variety of in-mine monitoring systems are used throughout the nation to detect rock bursts and tremors in mines. The accuracy and precision of some of these systems are poorly known. Testing of prototype systems and their capabilities and limitations might be better characterized using small explosive caps in a deep geologic mine. The experiment would use such caps after installation of a three-dimensional grid with centimeter-size sensors. The sensors would be connected to a central personal computer in the mine (Rohay 2000; Brodzinski et al. 2000; Smoot 2000).

OTHER UNDERGROUND ASTROPHYSICS EXPERIMENTAL OBSERVATORIES

Below is a list of other major astrophysics observatories and major experiments searching for Dark Matter, WIMPs, and neutrinos.

Sudbury Neutrino Observatory: The Sudbury Neutrino Observatory is 2,070 meters (6,800 feet) underground in an active nickel mine in Sudbury, Ontario. It has a 30-meter (98-foot) wide barrel-shaped container filled with water. In the middle of the water is a round container with 900 metric tons (1,000 tons) of heavy water inside (about $300 million worth). Around the heavy water are 9,600 photomultiplier tubes that can detect changes in light so small that they could detect a candle on the moon. The objective of the observatory is to identify neutrinos, which sometimes give off a slight glow as they pass through water, deep underground (SNO 1999).

Kamiokande and Super Kamiokande: Kamiokande is the oldest of the underground detectors used in neutrino research. It was first completed in 1983 and later upgraded in 1985. It is a 16-meter by 15.6-meter (52-foot by 51-foot) tank containing 1,000 photomultiplier tubes in 2,700 metric tons (3,000 tons) of pure water. It is located 1,000 meters (3,300 feet) underground in the Mosumi Mine of the Kamioka Mining and Smelting Company in Japan. Super Kamiokande is also in the mine. Completed in 1996, it contains two tanks, one inside the other. The outer tank contains 29,000 metric tons (32,000 tons) of water; the inner tank contains 16,300 metric tons (18,000 tons) of water and 11,200 photomultiplier tubes. Super-Kamiokande has ten times the volume and twice the density of photomultiplier tubes as the older Kamiokande (University of Tokyo 2000; University of Washington 1999).

Gran Sasso: Gran Sasso, a more general physics laboratory, is located in a tunnel off the 10.4-kilometer (6.5-mile) Gran Sasso Tunnel in Italy containing the highway connecting Teramo and Rome. The distance between the laboratory and the surface, at the maximum point, is about 1,400 meters (4,600 feet). The laboratory contains three halls where the experiments are conducted, each more than 100 meters (330 feet) long and 18 meters (59 feet) high (Gran Sasso Laboratories 2000).

Boulby Mine Dark Matter Experimental Facility: Also planned for a portion of the OMNIS experiment, the Boulby Mine Dark Matter Experimental Facility is located 1,100 meters (3,600 feet) underground in the United Kingdom in a salt seam of a mine owned by Cleveland Potash Ltd. The facility is the location for several current and future experiments (Cleveland Potash 2000).

AMANDA: The Antarctic Muon and Neutrino Detector Array (AMANDA) and several other similar experiments (DUMAND, RICE, and RAND) are searching for neutrinos and WIMPs by placing detectors deep under ice or deep under the ocean’s waters. AMANDA is being constructed at the South Pole by drilling deep into the polar ice cap and placing the sensors in deep water-drilled holes (Berkeley 2000; Autodynamics 2000).

Soudan Underground Laboratory: Located 690 meters (2,260 feet) underground, in the Minnesota’s Soudan Underground Mine State Park, this laboratory is jointly operated by the University of Minnesota and various other research organizations. The mine is operated by the State of Minnesota as a tourist park where sightseers can view historical mining practices. Originally opened in 1980, Soudan is the site for a large detector for a neutrino beam from Fermi National Accelerator Laboratory, 730 kilometers (450 miles) away (University of Minnesota 1996; Minnesota DNR 2000).

Other experiments or observatories (of lesser significance) are located in Russia, France, and South Dakota (Autodynamics 2000).

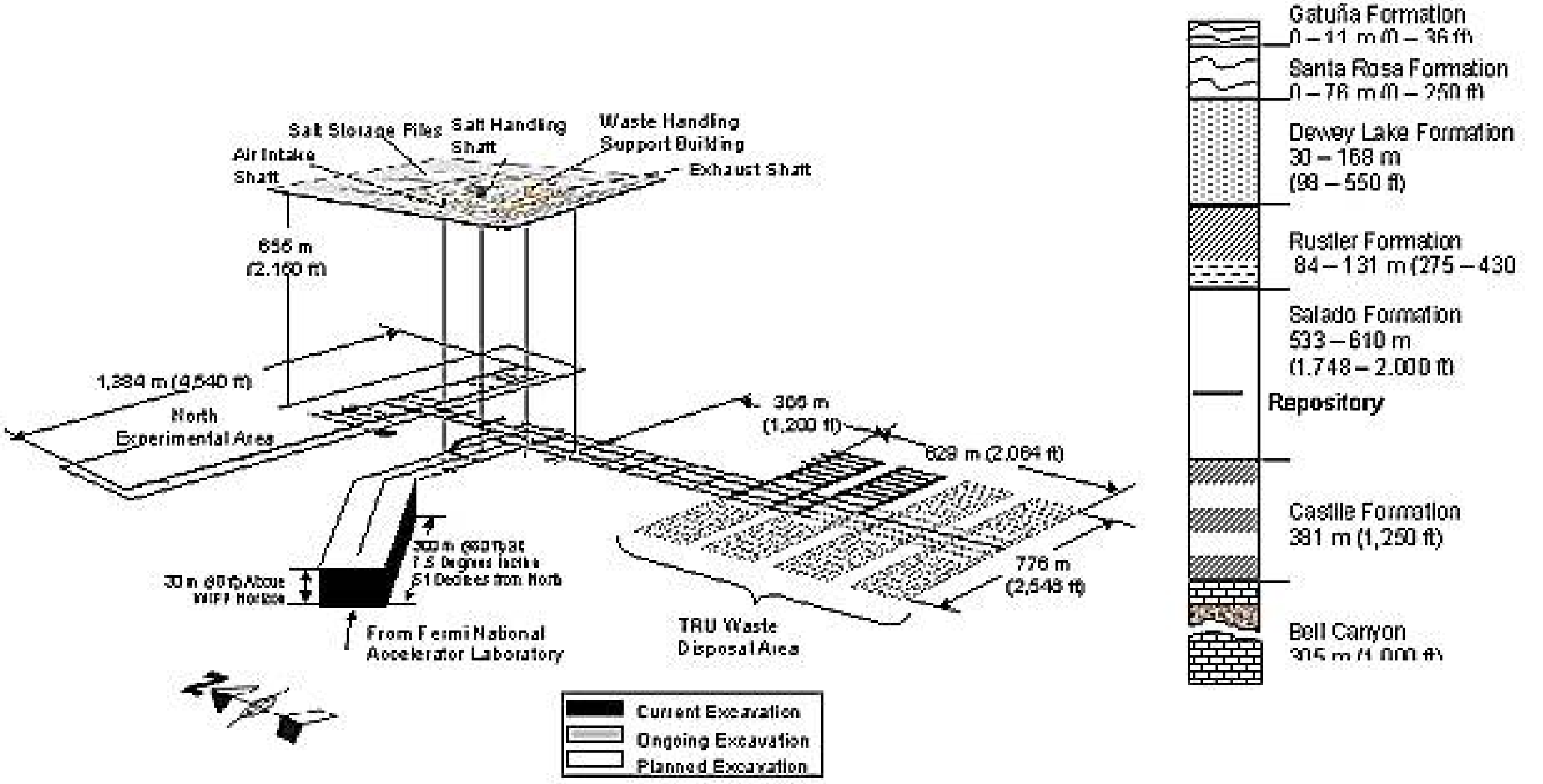

Figure 2-6. Proposed Neutrino Factory Detector at WIPP

Decoupling of Explosive Events in Salt

One of the difficulties in monitoring for compliance of a comprehensive test ban is that salt mines can be used to conceal mining and explosions. Salt can be mined by solution, making mining activity hard to detect. Salt also presents the opportunity to separate an explosion from the surrounding rock, making explosions hard to detect. Also, there are numerous salt mines in areas of the world where nuclear tests may occur. To better understand explosions in salt mines, small holes could be drilled into a part of a salt mine (1 centimeter to 1 meter [0.4 inch to 40 inches] long) in which small explosive charges (blasting cap, M-80, or shotgun size) could be ignited. The sensors used for the mine tremor study described above could be used to determine and model how decoupling in salt may occur (Rohay 2000; Barnett 2000).

Heat Study of Salt Deposits

The thermal stress response of salt deposits would allow a better understanding of the past and future behavior of such deposits. Scientists, therefore, proposed to place a 5-meter (16-foot) long electrode into a hole in either the floor or wall of a drift in the experiment gallery and establish an array of sensors at a radius of 15 meters (50 feet) around the electrode. The electrode would be connected to a 220-kilovolt power source; the salt around the electrode would be allowed to reach equilibrium over several weeks. The sensor would be connected to a data logger that would record how the salt reacts to the additional heat.

2.1.1.4 Nonproliferation and Nuclear Accountability Experiments

In addition to the decoupling experiment described in Section 2.1.1.3, nonproliferation and nuclear accountability experts proposed using TRU waste to be disposed of at WIPP as a surrogate for fissile materials to test monitoring devices for such materials for accountability purposes. Among the possible surveillance techniques to be tested are (1) placing radio frequency tags on the material to be monitored; (2) placing radiation monitors on the shafts to see if material is being removed; and (3) conducting acoustic imaging of materials to see if they can be identified through the salt formation. Other methods would include burying neutron detectors with some of the waste to monitor the neutron flux. Before doing so, natural flux in the salt environment would need to be identified. Testing and calibrating equipment would demand a small room in the experiment gallery into which equipment and small amounts of nuclear material (equivalent to sealed sources used to calibrate equipment) would be brought (Griggs 2000).

2.1.1.5 Chemical and Material Processing Experiments

Deep Mine Electroplating

Cosmic rays induce unwanted radioactivity in all materials. Though typically this radioactivity is at a level that does not result in concern, some materials for particularly sensitive experiments are often damaged by these cosmic rays. Many of these materials can be purified, but it is difficult to do so in an environment with cosmic rays present because the rays cause the materials to be redamaged. Producing these materials in a production facility deep underground would allow them to escape the cosmic rays. A typical production facility would involve several modular rooms 3 meters by 3.6 meters (10 feet by 12 feet) in size. In the rooms, a half dozen electroplating baths ranging in size from a couple of gallons of liquid to 189-liter (50-gallon) drums would be necessary. Typically, the purification process involves sulfuric acid (7 percent) and sometimes other acids. A portable fume hood with high-efficiency particulate air (HEPA) filtration would be used to contain any fumes from the acid baths or pickling processes (Brodzinski et al. 2000).

Crystal or Microprocessor Development

Crystal or microprocessor development experiments would use the same types of chemical baths and techniques described in the discussion of deep mine electroplating, above.

2.1.1.6 Other Experiments Considered But Not Included in Analyses

The UNO experimental facility (formerly the Next generation Nucleon decay and Neutrino experiment) is one of the nine experiments currently submitted for consideration to be conducted at WIPP. The UNO is more than a decade from proposal and has been estimated to cost up to $0.5 billion. The detector, proposed by a collaboration of numerous U.S. and international astrophysicists, would involve excavating a room large enough to hold a tank containing more than 450,000 metric tons (500,000 tons) of ultra-pure water. Some scientists have estimated that the room would be nearly 10 stories high and might be larger than the WIPP facility itself. The UNO has been proposed by scientists who believe it is time to discuss replacing one of the world’s top neutrino detectors, the Super-Kamiokande detector in Japan. The UNO would observe cosmic neutrinos as well as those generated by a neutrino (muon) factory like that proposed for Brookhaven National Laboratory or Fermi National Accelerator Laboratory. The anticipated operating life of the UNO, if ever built, could be more than 50 years. Because it would be so large, would involve so much water, and would operate so long, DOE believes construction of the UNO at WIPP is well beyond the scale of other near-term experiments. For this reason, it is not analyzed in this EA. A separate NEPA document describing the impacts of the UNO would be necessary, if the project were developed beyond the current conceptual stage (Brodzinski et al. 2000; Nelson and Bennington 2000).

Numerous other experiments were postulated by experts at PNNL, all of them interesting to various scientific disciplines. They included the study of biorhythms, the ability of birds to navigate (some believe it is by the stars), plant and animal development in an atmosphere without cosmic rays or magnetic fields, biological dosimetry experiments, experiments in acoustics, and behavioral and sociological studies. These types of experiments would employ equipment that is similar to the experiments described in previous sections or would not involve the use of hazardous materials. For this reason, they are not included in the analyses, and their impacts are considered to be included within the impacts assessed (Brodzinski et al. 2000). Should additional experiments be proposed that are unlike the experiments described above or that could pose unidentified hazards, additional NEPA analysis would be conducted.

2.1.2 WIPP Experiment Gallery

The WIPP facility is 655 meters (2,150 feet) underground (WIPP 2000a). Underground facilities offer an environment far from electromagnetic fields and suitable to experiments that require absolute darkness and acoustic isolation (WIPP 2000b). The experiment gallery (Figure 2-7) is one of the earliest areas of the WIPP repository to be excavated (Nelson 2000c). The gallery includes a north/south drift that connects the North Experiment Area with the central part of the facility. It also includes two cross-cutting drifts. This area of the repository has been fully excavated and is not currently in use (Nelson 2000c).

The north/south drift in the experiment gallery is 100 meters (330 feet) long by 10 meters (33 feet) wide (Figure 2-7). The crosscutting drifts each have approximately 46 meters (150 feet) on each side of the north/south drift. They too are 10 meters (33 feet) wide. The result is an area shaped similar to a capital I with 2,850 square meters (30,690 square feet) of floor space. The ceilings throughout this area are 6 meters (20 feet) high (Nelson 2000c). The experiment gallery would be nearly 0.8 kilometer (0.5 mile) from the nearest TRU waste emplacement cell.

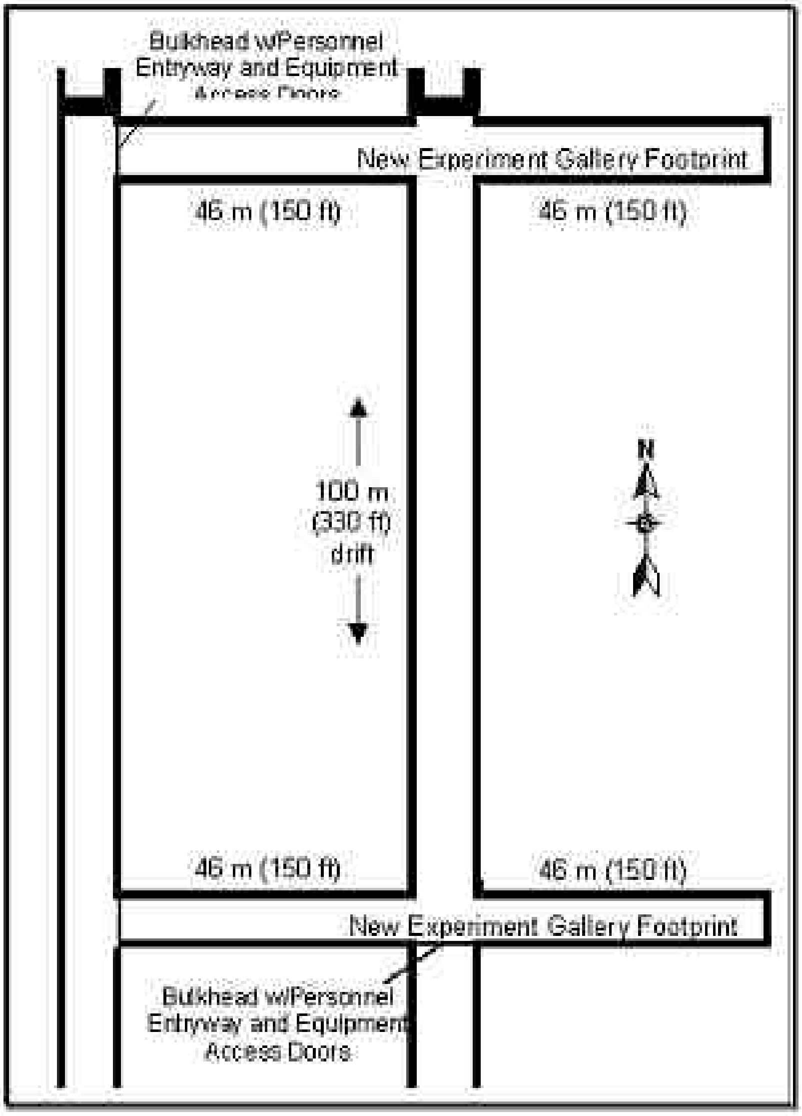

Figure 2-7. Closeup of Experiment Gallery

For wastes produced in the course of conducting the experiments, a less-than-90-day waste accumulation area would be located near the experiment gallery. The exact location of the waste accumulation area would be determined when DOE knows which experiments would be conducted in the experiment gallery and how the experiments would be arranged physically.

2.1.3 Construction, Preparation, and Maintenance Activities

At the WIPP site, construction, preparation, and maintenance activities would be minimal. DOE is proposing to seal the ends of each drift in the experiment gallery at its opening to the rest of the repository with bulkheads that would include both doors for equipment and doors for people. Air flow in the rest of the repository is maintained at a flow rate that allows the use of diesel equipment. Within the experiment gallery, such equipment would rarely be used, so the flow bulkheads would allow the flow rate to be reduced to just that for safe occupation. This would enable any salt dust to quickly settle within the experiment gallery (Nelson 2000a). Figure 2-8 shows the current airflow and ventilation system in the WIPP underground. The figure shows that the air supply in the area of the experiment gallery is "North

Area Air" (indicated by the letter "N" embedded in arrows representing intake supply air). This air supply is separated from other areas of the WIPP underground (for example, the embedded letter "D" in arrows representing intake supply air for the disposal area) by the use of engineered features such as bulkheads and airlocks; these features are also shown in Figure 2-8.

Some experiments would require air conditioning and humidity control to maintain experimental and data recording equipment within operating specifications. For those experiments, bulkheads would be required with exchangeable filters and/or refrigerated air conditioners (Nelson 2000a).

Some astrophysicists and other scientists have requested that DOE expand the experiment gallery to the east or west to allow for larger experiments or those that must be placed at particular locations or angles. As noted in the descriptions above, several have requested particular locations of modifications to the gallery. As part of the Proposed Action, DOE could authorize additional excavation near the experiment gallery as long as it could be done safely by DOE's current excavation staff, could be done without impacting emplacement of TRU waste, and would not impact repository performance. During any construction or modification activities, care would be taken to minimize fugitive dust emissions. For purposes of analysis, the additional excavation would be limited to east and west of the experiment gallery and to an extent no greater than that necessary for a standard WIPP disposal panel similar to Panels 1 and 2. The excavated area of such a panel is approximately 11,530 square meters (124,150 square feet) of floor space, including access drift (Balduini 2000). Salt from the excavations would be placed with the other salt from WIPP excavations at the surface of the facility (Nelson 2000a).

On the surface, the only anticipated disturbances due to these activities may be the construction of a small meeting place and laboratory from which experiment scientists could monitor activities below the surface or the placement of near surface detectors in conjuction with the OMNIS experiment. Any support buildings would be located in areas already disturbed by WIPP activities, within the fenceline for the facility.

Preparation of the experiments would demand the lowering of tons of lead, iron, liquids, equipment, and modular rooms over a period of 4 or 5 years. The elevator and hoist at the WIPP facility would be used for these activities, as they are available around disposal activities. The waste hoist at the WIPP facility is capable of lowering 41 metric tons (45 tons) of material at a time (Breidenbach et al. 2000). Once in the repository, the material would be moved north into the experiment gallery, where it would be assembled using standard construction methods.

Maintenance activities in the experiment gallery would be the same as maintenance activities in other areas of the WIPP underground. At WIPP, personnel working underground conduct a monitoring and excavation maintenance program. WIPP facilities are inspected a minimum of four times a year by the Mine Safety and Health Administration, as required by the Land Withdrawal Act. In addition, geotechnical instrumentation provides continuous information about rock mass movement and deformation. Underground workers also have the authority to close a suspect area to entry until it has been inspected by excavation safety personnel and made safe by bringing down loose rock or installing safety control measures.

Before any experiment is placed in the WIPP underground, a hazards analysis would be performed for that experiment. The hazards analysis would provide specific information about (1) the types of waste that could be produced in the course of conducting the experiment, and (2) the waste handling methods to

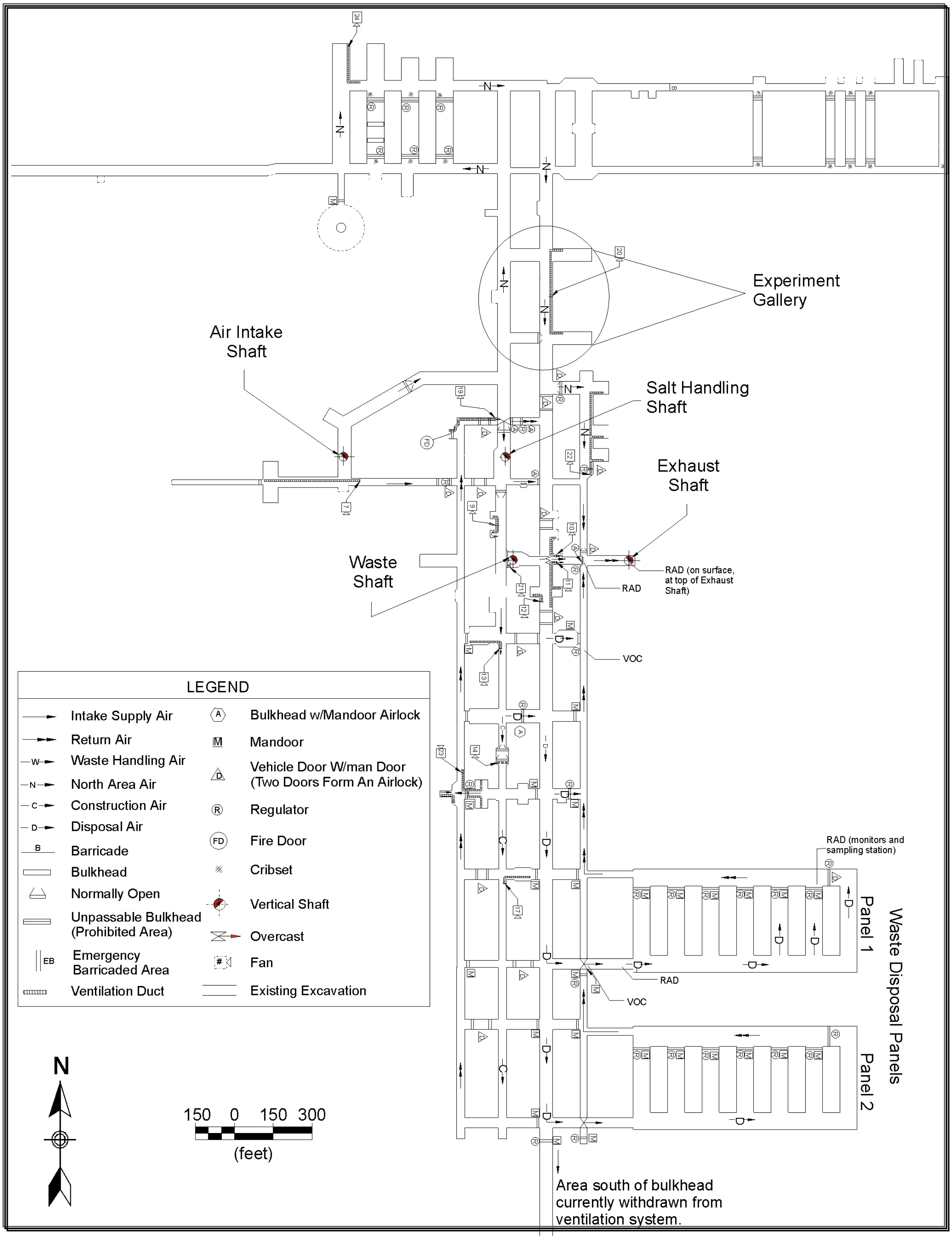

Figure 2-8. Air Flow/Ventilation System and RAD/VOC Monitors in the WIPP Underground

be used. The hazards analysis would also identify hazard mitigation measures to be implemented as part of a particular experiment to minimize the hazard to workers and the public.

2.1.4 Operation of the Experiments

Each experiment would be operated in a different fashion. Overall, most would require data-gathering using a computer system, replacement of components to test different materials, and chemical processes similar to those conducted in a standard laboratory aboveground.

For purposes of analysis, it is assumed that the 15 experiments would have two individuals in the repository, 40 hours over 5 consecutive days a week (the surface experiment would not need additional workers). A total of 30 people, therefore, would be expected in the repository's experiment gallery at any one time. In addition, another 8 to 10 individuals might be in the aboveground monitoring building.

For purposes of analysis, it also is assumed that each experiment would continue for 30 years, after 5 years of preparation and construction. Following the 35-year period, the experiments would be decommissioned with the WIPP facility. All of the experiments described above could be conducted within the experiment gallery at WIPP.

2.1.5 Decommissioning

Decommissioning activities for the experiment gallery would begin with removal of all experimental equipment and materials, including all lead, iron, liquids, and hazardous materials. The experiment gallery would be decommissioned in compliance with requirements of the New Mexico Environment Department's Hazardous Waste Facility Permit. The materials and equipment used in the experiments either would be decontaminated, if possible, and reused and recycled, or would be disposed of at permitted disposal facilities. The disposal of experimental materials and equipment would be the responsibility of the experimenters. Decontamination would be required as a result of the use of hazardous or radioactive materials in the experiments, not as a result of WIPP disposal operations.

Other decommissioning activities would be identical to those for the WIPP facility (see the text box titled "Closure and Decommissioning"). These activities were described and the potential environmental impacts of these activities were analyzed in WIPP SEIS-II (DOE 1997).

2.2 NO ACTION ALTERNATIVE

Under the no action alternative, no astrophysics or other proposed or anticipated basic science experiments would be conducted at WIPP. The area defined as the experiment gallery at WIPP would remain, as it currently is, until some other use for it is found or disposal operations are terminated and the facility is dismantled and decommissioned.

2.3 ALTERNATIVES CONSIDERED BUT NOT ANALYZED IN DETAIL

The only decision pending before the Department is whether to allow the use of WIPP for several different types of scientific experiments sponsored by scientists outside of the Department (although some may receive DOE funding). Although it is possible that these experiments could be conducted at other underground facilities (for example, the proposed Yucca Mountain Repository in Nevada, mines located in various parts of the United States or the world, existing astrophysics facilities) or that a new national underground laboratory could be constructed, these decisions are neither before DOE at this time nor even within DOE's jurisdiction. For these reasons, DOE examined only whether to authorize the use of WIPP for the type of scientific experiments described in Section 2.1.1.

CLOSURE AND DECOMMISSIONING

DOE will close the repository when WIPP achieves full capacity (currently 175,600 cubic meters [6.2 million cubic feet]) of TRU waste. Final facility closure will include the placement of a repository sealing system, which will consist of natural and engineered barriers within the WIPP repository to prevent water from entering it and impede gases or brines from migrating out.

Plans for the shaft sealing system include completely filling the shaft with engineered materials possessing high density and low permeability. Shaft seal components for that portion of the shaft that is within the Salado Formation will provide the primary barrier by limiting fluid transport along the shaft during and beyond the 10,000-year period. Shaft seal components within the Rustler Formation will limit commingling between brine-bearing members, as required by state regulations. Shaft seal components from the Rustler to the surface will fill the shaft with common materials of high density, consistent with good engineering practice.

The Department will decommission the site in a manner that will allow for safe, permanent disposition of surface and underground facilities, which will be consistent with the then-applicable regulations. Little or no contamination of facilities is expected. Equipment and facilities will be decontaminated as necessary. Usable equipment will be removed and surface facilities dismantled. A berm will be constructed around the perimeter of the closure area, which will include 70 hectares (175 acres). The area above the 10 panel equivalents will be 50 hectares (125 acres), the area of the salt pile will be 12 hectares (30 acres), and the area of the surface facilities will be 8 hectares (20 acres). The height of the berm will be sufficient to identify the closure area and impede access. DOE will restore the areas occupied by the salt pile and surface facilities and, if necessary, any of the area overlying the disposal panel area, although surface disturbance of this area will be minimal. This decommissioning period is anticipated to take up to 10 years. Any salt remaining after WIPP closure and construction of the berm will be sold or disposed of in accordance with the Materials Act of 1947.

The anticipated long-term controls for the WIPP site after the Department closes it include active controls, monitoring, and passive controls. The 100-year active institutional control period will extend through the year 2143, during which the Department will use a fence and an unpaved roadway along the perimeter of the repository surface footprint area (the waste disposal area projected to the surface) to control access. The fence line will be posted with signs that warn of the danger and that state that access by unauthorized persons is prohibited. Routine, periodic patrols and surveillances of the protected area will be conducted as well as periodic inspection and necessary corrective maintenance of the fence, signs, and roadway. In addition, the Department will prohibit drilling within the Land Withdrawal Area to preclude inadvertent intrusion into the repository.

The Department will place a number of permanent markers to inform and warn subsequent generations that radioactive waste is buried there. This permanent marker system will be designed to minimize the likelihood of human intrusion. Current plans include markers that will identify the site, relay warning messages, use multiple methods for marking the site, use multiple means of communications (e.g., language, pictographs, scientific diagrams), use multiple levels of complexity within individual messages on individual marker system elements, and be constructed of materials with little intrinsic value.

—Other actions under consideration by DOE include:

- Construction of two “information centers,” one on the surface and one buried beneath the surface, with more information on the type of waste disposed of at WIPP, why the waste is dangerous, and why TRU waste should not be disturbed
- Placement of additional warning messages approximately 6 meters (20 feet) beneath the surface, within the perimeter
- Placement of large permanent magnetic materials and radar reflectors within the berm so that the site can be remotely detected
- Creation of offsite archival records at several local, state, and federal organizations.