MORE THAN A WASTE REPOSITORY, WIPP IS A NATIONAL RESOURCE

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ABSTRACT

Congress authorized the development of the Waste Isolation Pilot Plant (WIPP) in 1980 to demonstrate the safe disposal of radioactive waste resulting from defense programs of the United States. Today, WIPP represents the nation's first deep geologic repository for transuranic (TRU) waste, and is operating. Importantly, the same attributes that made WIPP an ideal setting for a permanent TRU waste disposal facility also represent unique qualities that make it attractive for a variety of research and development (R&D) opportunities, including subjects that are related to the safety and accountancy of waste management. The U.S. Department of Energy (DOE) recently established the Center for Applied Repository and Underground Science (CARUS) at WIPP as an efficient way to leverage its existing infrastructure and provide a vehicle by which WIPP's unique attributes could be used for R&D activities in addition to the primary mission of TRU waste disposal.

The WIPP repository is mined from an ancient massive sequence of salt beds 655 meters below the surface. With halite in all directions, the repository is naturally shielded from cosmic rays. In addition, the salt contains virtually no naturally occurring radioactive elements like uranium and thorium. Thus, the natural radioactivity environment within the repository is extremely low – possibly lower than any other accessible land-based location in the world. This extremely low background radiation environment makes it possible to make extremely sensitive measurements (of many kinds) of radiation and radiobiological effects that would otherwise be confounded by the presence of typical background radiation. Details of the radiation background environment at WIPP are presented. Another unique attribute of WIPP that makes many diverse research efforts possible is the nature of the massive sequence of salt beds. The relative homogeneity of the thick salt deposit and its geophysical and seismic stability open the possibility for new subterranean gravity and other deep geophysics experiments.

As an operating radioactive waste disposal facility, WIPP also makes it possible to design and conduct tests of actual nuclear material management and control. CARUS is presently supporting the demonstration tests related to non-proliferation "transparency" using the TRU waste disposal system as a model test-bed. WIPP can also serve as a test bed for experiments and research conducted by or for other nations that are evaluating bedded salt as the repository medium.

CARUS allows the scientific community to perform experiments in a deep geologic setting at a lower net cost by sharing an existing infrastructure. Access to the underground with ventilation, power, extensive data communications, safety oversight, surface support, emergency services and security are all in place. More, and more-extensive experiments can be conducted for the net research dollar through CARUS than at other typical choices open to the underground research community. Descriptions of these research possibilities are provided.

INTRODUCTION

"WIPP" is the acronym for the Waste Isolation Pilot Plant, a DOE facility located in southeastern New Mexico, 42 kilometers southeast of Carlsbad. The site chosen for the 655-meter-deep WIPP is a 43-square-kilometer tract of federal land that consists of a 600-meter-thick layer of rock salt deposited about 250 million years ago under an overlying 400-meter-thick layer of crustally typical siliceous rock.

Congress authorized the development of WIPP in 1980 to demonstrate the safe disposal of radioactive waste resulting from defense programs of the United States. Today, WIPP represents the nation's first deep geologic repository for radioactive TRU waste, and is operational. However, the same attributes that made WIPP an ideal setting for a permanent TRU waste disposal facility also offer unique qualities that make it attractive for a variety of research opportunities unrelated to radioactive waste disposal.

This paper describes a vision for the WIPP beyond that of a dedicated radioactive waste disposal facility. The prime mission of WIPP (to serve as the nation's defense TRU waste disposal facility) can be safely and efficiently preserved, while simultaneously using other unique attributes of the WIPP setting to conduct basic and applied research in a variety of disciplines which may be unrelated to TRU waste disposal. The Center for Applied Repository & Underground Science (CARUS) at WIPP is an integrated entity, conducting its work within the safety and operations envelope and constraints of TRU waste disposal at WIPP.

The following sections provide an introduction to the CARUS concept and describe the domestic and international opportunities, rewards, constraints, and operational elements that define it.

Introduction to CARUS

CARUS represents an efficient way to leverage the existing infrastructure of WIPP to provide added value to the Nation's taxpayer. It was conceived as the vehicle by which WIPP's unique attributes could be used for purposes other than radioactive waste disposal. While CARUS is inherently linked to the WIPP site, it is not limited to research and development using the WIPP underground. Many research possibilities will take advantage of the unique underground setting, but many others will simply take advantage of the scientific and technological resources that are a part of the WIPP infrastructure. A cross section of various research areas that CARUS makes possible is summarized below.

The WIPP repository is mined from an ancient massive sequence of salt beds with a shielding depth of about 2000 meters of water equivalent (mwe). With halite in all directions, the repository is naturally shielded from virtually all cosmic rays. In addition, the salt contains virtually no naturally occurring radioactive elements like uranium and thorium. Thus the natural radioactivity environment within the repository is extremely low – possibly lower than any other accessible land-based location in the world. This extremely low background radiation environment makes it possible to make extremely sensitive measurements (of many kinds) that would otherwise be confounded by the presence of typical background radiation.

The long term radioactive waste disposal advantages exhibited by bedded salt are recognized around the world. While most international radioactive waste disposal programs in developed countries are currently focused on hard rock repositories, there is continuing interest from the world's radioactive waste disposal community for disposal in salt. Thus, WIPP can serve as a test bed for experiments and research conducted by or for other nations working towards this common solution to a world wide problem.

Another unique attribute of WIPP that makes many diverse research efforts possible is the nature of the massive sequence of salt beds. The relative homogeneity of the thick salt deposit and its geophysical and seismic stability open the possibility for new subterranean gravity and other deep geophysics experiments.

By establishing CARUS as the vehicle for fostering and guiding research in the WIPP underground, all of these possibilities become feasible. CARUS enables the unique attributes found at WIPP to be used for research and experimentation, while ensuring the WIPP's prime mission is not compromised.

CARUS allows the scientific community to perform experiments in a deep geologic setting at a lower net cost by sharing an existing infrastructure. Access to the underground with ventilation, power, extensive data communications, safety oversight, surface support, emergency services and security are all in place. More, and more-extensive experiments can be conducted for the net research dollar through CARUS than at other typical choices open to the underground research community.

Finally, as an operating radioactive waste disposal facility, WIPP also makes it possible to design and conduct tests of actual nuclear material management and control. Tests related to non-proliferation "transparency" can be conducted from cradle to grave. This paper describes all research possibilities at WIPP, but emphasizes those activities that are related to transparency.

The Low Background Radiation Environment at WIPP

The shielding depth in the WIPP underground is about 2000 mwe, which is comparable to that at many other astrophysical research facilities around the world that conduct cosmic ray and elementary particle astrophysics observations. Not only is the underground environment well shielded from cosmic ray background, the very nature of the halite deposit makes naturally occurring radioactive elements very rare. This results in a reduced dose rate in the WIPP underground that is only a few percent of the background radiation dose rate found anywhere on the surface of the earth, or in any known hard-rock mine.

The primary source of background radiation in the WIPP underground is from residual levels (impurities) of potassium present in the anhydrite interbeds. While there are some levels of thorium and uranium (the other two predominant naturally occurring isotopes in the earth's crust) also found, their presence is more than an order of magnitude below typical crustal abundance levels. The net result is a very low background gamma radiation field almost exclusively made up of Compton scattered 1.464 Mev gamma rays from the electron capture decay of potassium-40. Free neutron levels from (alpha, n) reactions and spontaneous fission are also very low.

Because of the extremely low levels of thorium and uranium, radon and radon daughter concentrations are almost solely due to atmospheric radon drawn into the underground through the ventilation air from the surface. Averaging a few tenths of a picoCurie/liter at the surface, the radon present in the underground is "young" radon with low daughter product build-in. Therefore, the intrinsic alpha levels are also low.

CARUS AT WIPP FOCUSES ON FIVE AREAS OF RESEARCH

Taking advantage of the inherent attributes of the WIPP facility and its infrastructure, there are five major areas of focus that have been identified for CARUS. Research in all areas is planned:

1. Low Dose and Dose Rate Radiobiology and Health Physics Research
2. Elementary Particle Astrophysics Research
3. Research and Development for Other Deep Geologic Waste Disposal Repositories
4. Natural Resource Research
5. Transparency and Non-Proliferation Demonstration and Technology Development

Each of these is described in the following sections. Particular emphasis is placed on transparency and non-proliferation demonstration and technology development.

Low Dose and Dose Rate Radiobiology and Health Physics Research

Current scientific opinion is that normal physiological processes generate toxic oxidative products that are damaging, even mutagenic, and possibly carcinogenic. Yet cells and people survive because of the cell's ability to repair the majority, if not all, of this oxidative damage. Because the relationship between normal oxidative damage and the incidence of cancers in human populations is unknown, it is possible that the risk of cancer may be the price we pay for the very biological processes that keep us alive.

Cells are also constantly exposed to low levels of natural background radiation from cosmic radiation and from naturally occurring radioactive materials. Even low levels of radiation induce biological damage, and this damage is similar to the oxidative damage induced by normal cell processes. Thus an important, yet unanswered, question is whether biological damage induced by low dose/rates of radiation is treated by the same cellular processes and with the same efficiency as normal oxidative damage that all living cells routinely employ.

It is also known that oxidative free radicals produced by normal cellular metabolism cause DNA damage. The types of DNA damage from these free radicals overlaps many of the types of molecular damage produced by ionizing radiation. Cellular DNA repair mechanisms evolved to remove these endogenous oxidative DNA damages and thus preserve genomic integrity. Because free radical-induced DNA damage is efficiently repaired, cells have low rates of spontaneous mutation. This raises two important and related questions. Does low level ionizing radiation induce damage that can be efficiently repaired by the same or similar repair systems as damage caused by oxidative free radicals? If so, does this result in a threshold for adverse effects induced by low doses of radiation?

These and related questions may be answered through experiments conducted at doses and dose rate levels well below that to which all living organisms are routinely exposed from background radiation. The WIPP underground represents an ideal environment in which to conduct these experiments. While man-made shielding chambers have been historically used to reduce background radiation, these have been typically only used to improve radiation detector sensitivity, and can only eliminate the terrestrial component of the dose. The dose from cosmic rays can only be reduced by moving to an underground setting.

Recent advances in cell and molecular biology and concomitant advances in chemical and biological technology have created an extraordinary opportunity to definitively resolve this critical low dose issue. Research to decode the genome, to understand structure-function relationships for genes and proteins, and to apply molecular biology to medical problems has resulted in the development of new scientific resources and technologies. It is now possible to understand normal processes that repair oxidative and radiation-induced damage at the molecular, cellular and tissue levels. It is also possible to evaluate molecular processes that modify the expression of these changes during cancer growth, and to determine the role of low dose and rate in these processes.

CARUS provides a unique opportunity to promote and coordinate low dose and dose rate research. While laboratory shielding chambers may be used to reach dose and dose rates about 10-20% of typical background levels at the surface, the underground environment at WIPP makes it possible to achieve doses much lower. With little or no air filtration to eliminate the contribution from radon, about 2000 mwe of shielding from the cosmic ray contribution, and the very low and degraded gamma field, it is possible to achieve almost zero dose and dose rates. CARUS is prepared to support molecular and cellular studies at this time. Animal studies may be supported in the future. Experiments and studies by domestic and international institutions around the globe are welcomed.

Elementary Particle Astrophysics Research

The search for neutrino oscillation and confirmation of many of the predictions of the "Standard" quantum model integrating all known forces of nature, except gravity, holds the interest of the majority of nuclear, particle and cosmological physicists today. The recent (1998) observation in Japan of neutrino mass has raised many more questions than it has answered.

The question of how particles acquire mass is one of the deepest unsolved mysteries of elementary particle physics. Neutrinos had been thought to be the only fundamental constituent of nature that did not have a mass. In light of this discovery, that long-standing belief will need to be revised. However, the Standard Model itself does not "predict", one way or another, whether neutrinos have mass - this is one of the many parameters of the model that must be input by hand. This is in fact one of the universally recognized shortcomings of the Standard Model, and why most physicists doubt it is the complete, final theory. A truly complete theory would predict the masses of the elementary particles rather than requiring them as inputs.

The problem of missing mass or dark matter has also received widespread exposure. In observational astronomy, gravitational influences are evident, within and among galaxies, which exceed those expected from the visible matter (i.e. stars). Neutrinos have been suggested as one source of this gravitation, but the small neutrino masses implied by the recent results may be insufficient to account for all, or even most, of it. This has caused renewed attention to the cosmological effects of neutrinos with mass. At the very least, the neutrino is the first serious particle physics dark matter candidate actually known to exist.

These exciting directions have resulted in a new wave of neutrino experiments - all using new techniques to uncover the secrets of the neutrino and other particle physics soon coming on line, and more are planned. The unique attributes of the WIPP underground make it an ideal laboratory setting for these experiments. With excellent cosmic ray shielding, low background radiation, and an existing (and accommodating) infrastructure, the WIPP underground is unique among typical choices available to the particle physics research community.

Note that one basic research program in this area is already currently being conducted in the WIPP underground. For the past several years, Los Alamos National Laboratory (LANL) elementary particle physicists have been developing a neutron detector that requires an very low intrinsic decay purity level. This detector will form an important part of the detector system to be used in the near future for solar neutrino observation at the Sudbury Neutrino Observatory (SNO). LANL recognized the unique advantage of using the WIPP underground to test the sensitivity and intrinsic impurity of the detector for qualifying it for use at SNO.

CARUS promotes elementary particle and related cosmological research by institutions and organizations around the globe. With many different experimental designs possible (footprints, detection principles, shielding and anti-coincident requirements), CARUS maintains the flexibility to change entire rooms in the underground excavation configuration.

Research and Development for Other Deep Geologic Waste Disposal Repositories

The WIPP was originally conceived as the safest and most cost effective solution to permanently disposing U.S. nuclear waste. Over the past three decades, political and public opinion have evolved this vision such that only defense-related TRU waste forms the current WIPP waste envelope. Unlike the U.S., other nations with nuclear waste disposal needs do not intend to arbitrarily segregate waste forms on the basis of their origin and most will likely dispose of their entire waste inventory at a single repository.

There are 41 other nations with nuclear waste disposal needs. Many of these nations may also benefit from appreciable rock salt deposits within their respective borders. These are Australia, Brazil, Canada, China, France, Germany, Italy, Mexico, Poland, Romania, Russia, Spain, and the United Kingdom. Many of the other 41 (e.g., India and Pakistan) likely possess suitable salt deposits, but their extent is largely unknown. Thus, there is global interest in WIPP as an underground test facility to develop and optimize disposal methods by those nations that have their own "disposal-in-salt" option. This interest is exemplified by the hundreds of site visits and tours of WIPP by foreign institutions and governments over the past several years.

CARUS invites inquiries by foreign institutions and governments to use the underground at WIPP for experimental development and tests of their disposal concepts. Because the prime mission of WIPP is to serve as the disposal site for the U.S. defense TRU waste, and as such is highly regulated, WIPP cannot accommodate tests that involve radioactive or hazardous materials. However, much can be learned through tests that involve surrogate waste materials.

Natural Resource Research Opportunities

In addition to the unique underground setting of WIPP, other research opportunities exist that are not related to the extensive ancient salt beds. In the general area near WIPP, many other geologic natural resources are also found. These include extensive potash deposits, oil fields, natural gas fields and sulfur deposits. Research to enhance resource extraction, including improving exploration and resource characterization, lowering costs, increasing production efficiency and improving safety can all be conducted through the CARUS umbrella. The organizations that licensed WIPP and operated the facility over the past decades represent an enormous intellectual resource that can be brought to bear on research in these areas.

An example of such resource-related research that CARUS will foster and guide is found in a recent solicitation from the DOE Federal Energy Technology Center (FETC), and an associated proposal by a consortium from the potash industry, academia and a National Laboratory. Due to the aging potash reserves near the WIPP site, an innovative research program has been proposed to apply solution mining techniques to recover the pillars and other reserves left in the underground potash mine workings (at the economic end of conventional room and pillar primary mining). The unique capabilities of existing WIPP resources (due to their efforts for WIPP) will play a key role in this research, including geochemical studies, extraction modeling, and underground mapping of solution mining progress.

Other resource-related research areas fostered by CARUS include, advanced drilling methods (such as thermally enhanced spallation drilling) and oil field technology development. Discussions with industry representatives have identified a broad range of technologies needed to reduce sucker-rod failure (microstructural understanding of metallurgical failure processes), scale control and inhibition (paraffin control, Naturally Occurring Radioactive Material – NORM, etc.) and other reservoir practices such as enhanced oil recovery (e.g. understanding sweep efficiencies). CARUS provides the vehicle to integrate all these resource-related research efforts with the intellectual resources established through WIPP.

Transparency and Non-Proliferation Demonstration and Technology Development

At the September 1998 General Conference of the International Atomic Energy Agency (IAEA) Secretary of Energy Richardson outlined six legacies from the first five decades of the nuclear century and the steps that must be taken to meet the future challenges they present. Among these six legacy issues are two that make clear the urgent need to provide for safe, secure, and transparent disposition of fissile materials resulting from both the weapons and civilian nuclear power fuel cycles. These legacy issues are:

"The vast amounts of fissile material from nuclear weapons reductions that need to be controlled."

and

"The challenge of managing the fuel cycle's back end and assuring the safe use of nuclear power."

All nuclear weapons and nuclear energy cycles eventually require long-term management of fissile materials in a repository of some form, either permanent geologic disposal or long-term interim storage. Given the significant national security implications for the United States as expressed in Secretary Richardson's *call to action*, there is a compelling need for technical, financial, and political investment to facilitate long-term disposition for nuclear materials streams that flow out of the back end of nuclear weapons and energy cycles. The importance of assuring the "grave" component in cradle-to-grave management of fissile materials in the international arena was highlighted by Secretary Richardson at the September 1998 IAEA Conference through his commitment to convene an "***International Conference on Geologic Repositories***". That Conference was held in November 1999 in Denver, Colorado and re-affirmed the U.S. commitment to a transparent back-end for both weapon's waste disposal and spent nuclear fuel disposal.

Long-term disposition of fissile materials in a safe, secure, and transparent manner will directly contribute to resolving the nuclear legacy in three important areas:

> ***Arms Control and Nonproliferation*** – Diversion of materials at the back end of the nuclear materials cycle is an important long-term risk that impacts national security; creation of viable back-end management options is an important component for implementation of some arms reduction processes.

> ***Political Viability of the Next Generation of Nuclear Energy*** - The *back end* of the nuclear materials management issue has now become the *front end* of the next generation of nuclear energy; political resistance to nuclear energy around the globe is strongly impacted by the perception of lack of a safe, secure, and transparent nuclear materials final disposition.
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> ***International Environmental Security*** – A well designed and managed back end of the nuclear materials cycle will significantly reduce the risk of radionuclide releases from operational accidents or poor repository performance that may result in transnational impacts on health, safety, and the environment, with associated negative impacts on transnational relationships.

Successful implementation of fissile materials repositories in national and international settings requires both proven repository technologies and political acceptance at local, national and international levels. Through the research and development activities associated with the two U.S. repository programs, WIPP and Yucca Mountain, the DOE has developed a strong science and technology basis for back-end nuclear materials management. Through existing international technical collaboration programs, both WIPP and Yucca Mountain have been active in technology exchange and collaborative development of new technologies with the international community.

Political acceptance is presently a major issue for fissile materials repositories, both in the US and around the globe. A key tool in developing political acceptance is transparency. "Transparency" is a combination of technologies and processes that provide information to outside parties for independent assessment of safety, security, and legitimate use. Transparency applies to all elements of the development of a repository system. Before operation, transparency applies to site selection and characterization, to design of the engineered facilities and transportation systems, and to system-level analyses that assure safety criteria are met. During operation, transparency applies to operational and environmental safety, and to security of material control. At local and national levels, transparency facilitates internal acceptance of the facility and associated operations. On an international level, transparency is a key mechanism for assuring that requirements of disarmament and nonproliferation agreements are satisfied.

Transparency technologies and processes have been developed for other parts of the nuclear materials cycle. However, in some key international settings such as Russia, gaining acceptance of these technologies and processes has been difficult higher up in the more sensitive parts of the nuclear materials cycle. One potential long-term benefit of working transparency at the back end of the materials cycle is the potential for gaining experience and acceptance of these technologies and processes at the less sensitive end of the cycle and, with time, moving their broad implementation higher up the cycle.

Globally, the infrastructure necessary for integrated, safe and transparent management of nuclear materials, materials processing, and storage/disposal is lacking. There is a compelling need for technical and political investment to provide permanent disposition of nuclear material streams at the back end of the nuclear weapons and fuel cycles. Disposition of these materials in a safe, transparent manner will directly contribute to resolving the nuclear legacy issues in the key areas of arms control and nonproliferation, and international environmental security. It will also promote management of the nuclear fuel cycle's back end as a path forward to the front end of future nuclear energy policy.

The WIPP represents the world's only licensed, operating repository for disposal of nuclear materials in salt. It has uniquely undergone the comprehensive process of siting, characterization, regulatory definition and performance assessment for regulatory compliance, facility design and construction, and initial operations. The facility offers an immediate, unique opportunity for developing models of information acquisition, access, and independent assessment of safety, security, and legitimate use of nuclear materials by providing a platform for transparent monitoring and technology development and demonstration.

Recognizing the importance of transparency on the back-end of the fuel cycle, the Senate Committee on Armed Services included specific language in the National Defense Authorization Act for Fiscal Year 2000 to develop a plan to use WIPP as a test bed facility for transparent monitoring technologies for waste storage. An excerpt from Report 106-50 (which accompanied S. 1059 – Appropriation Authorization Act for FY2000) is reproduced below:

> *"Nuclear waste disposal demonstration test bed facility*
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> *The committee concludes that a critical need exists to develop and demonstrate technologies to ensure safe, secure, and transparent management and storage of nuclear waste materials by all nuclear states. The committee directs the Department of Energy to develop a plan to establish a demonstration and training program using the Waste Isolation Pilot Plant (WIPP) repository system as a test bed facility to develop transparent monitoring technologies for waste storage and to demonstrate them to the international community. The Department will report its plan to the Congress by March 1, 2000."*

At the time this manuscript was prepared, the DOE was aggressively preparing the requested report to Congress. It is expected that the report will lay out a plan for establishing the WIPP, through CARUS, as a Center for Repository Transparency [CRT].

The next section describes the anticipated efforts that will provide the foundation for a range of technology and transparency activities, including: international collaboration in repository technology development; development and testing of transparency monitoring technologies; international collaborative transparency demonstration experiments; and development of transparency information communications processes. It is important to remember that the use of WIPP as a test bed for these activities should not influence the application of transparency and non-proliferation safeguards to WIPP operations. WIPP's mission as a geologic repository for TRU waste does not warrant the imposition of the same practices as those for disposal of spent fuel or high level waste.

THE CENTER FOR REPOSITORY TRANSPARENCY AT WIPP

The CRT will consist of a physical center with a demonstration area for technologies and real-time links to U.S. and international monitoring experiments, conference rooms for international workshops, and workspace for technical staff , visiting international scientists, and educational outreach. It will be located in Carlsbad, New Mexico with organizational and infrastructure ties to the WIPP. Co-locating this center with WIPP is ideal for the following reasons:

- WIPP is a *complete system*, including all system elements: generator site interface, transportation system, materials handling system, and final disposition facility; therefore, WIPP has much of the necessary infrastructure in place.
- WIPP is *fully operational*; therefore, WIPP provides a very realistic and highly credible setting for operational testing.
- WIPP has *extensive experience with R&D for repository technologies*, including saturated zone geosphere characterization, engineered barrier design, and total system performance assessment and R&D prioritization; therefore, WIPP provides an important source of saturated zone repository technology
- WIPP has *extensive experience with transparency processes* through the critical development phase of a back-end facility; therefore, WIPP provides an important and available experience base for dealing with political implementation processes
- WIPP has *high visibility and extensive interactions with the international community.* The WIPP international program has ongoing technical collaborations with Japan, Sweden, Switzerland, Germany, and Canada; substantive technical exchanges with China and Taiwan; and active interactions in with international organizations such as IAEA and OECD/NEA.

WIPP's CRT will also serve as an organizational framework for coordinating transparency technology development, testing, and demonstration activities. These activities will include the following areas:

International Technical Collaborations on Repository Technologies **–** This activity will engage the international community in the repository development phase. Key elements of this phase include site selection and characterization, as well as safety analysis and performance assessment. WIPP currently has a strong international technical exchange and collaboration program. This program will be strengthened and broadened to include more active technical collaborations in Russia and Asia.

Development and Testing of Repository Safety and Security Monitoring Technologies **-** This activity will focus on development and testing of monitoring technologies for repository environments. Some of this development is expected to be an adaptation of existing technologies to operate in long-term, harsh subsurface conditions. Other components of this development are expected to be longer-term research and development to create new technologies to address specific monitoring needs.

International Demonstration Experiments **-** An important component of the strategy for convincing other countries to adopt transparency processes in development and implementation of repositories is to actively engage these countries in transparency demonstration experiments. These transparency experiments will have two objectives: 1) testing a specific transparency technology and/or process in a realistic setting and 2) actively engaging multiple international participants to gain experience and acceptance that will facilitate future implementation of these technologies/processes. A suite of transparency experiments will cover a range of specific transparency issues and a range of international scenarios for long-term disposition at the back end of the nuclear materials cycle. Each of these experiments will be implemented using process that includes an international workshop at the front end to define experiment goals and processes, and a second workshop following the experiment to process the information learned from the experiment. Initial experiment concepts have been developed for the following:

- Transparent environmental water quality monitoring experiment [Russia]
- Transportation monitoring for international spent-fuel storage experiment [Russia/Japan]
- Transparent environmental monitoring experiment [Asia]
- WIPP operational and environmental monitoring experiment [U.S.]

International Interactions - This activity will focus on transparency information communications with an emphasis on international interactions. Activity elements will include international workshops on repository technologies and transparency processes, and an exchange scientist program to bring foreign scientists to the U.S. and sponsor U.S. scientists to work directly with back-end disposition programs abroad.

Transparency Information Communications and Educational Outreach - This activity will include development of information dissemination processes such as variable access and real-time access web-based information dissemination. This activity will also include development of an educational outreach program.

INTEGRATING THE VISION OF CARUS WITH THE PRIME MISSION OF WIPP

The U.S. Department of Energy owns and operates the WIPP site as the nation's TRU waste disposal facility. Funding is congressionally appropriated annually. WIPP is currently operated for DOE by the Westinghouse Waste Isolation Division. Sandia National Laboratories currently serves as DOE's Scientific Advisor and ensures that WIPP will continue to comply with its regulatory requirements as a deep geologic radioactive waste repository. To ensure compatibility with WIPP's prime mission, CARUS is also operated through these contracting vehicles. This maximizes the infrastructure leverage that can be applied to CARUS.

Elements of the WIPP infrastructure that make CARUS an attractive option for the research community include:

- Commercial high power availability and flexible distribution options in the underground,
- Voice/data communications via fiber optics with multiple distribution options in the underground,
- Ready access to secure and patrolled surface facilities,
- Underground operations support for equipment transport, routine operation, new excavation, and ground control, and
- Underground emergency services including medical, fire and rescue.

There are four shafts at WIPP, with two primarily dedicated to mine ventilation. The 40-ton waste handling hoist can accommodate modular components as large as 4m x 4m by 3m high, and is the primary access for both equipment and personnel. The 20-ton salt handling hoist is also routinely used for both equipment and personnel.

A schematic illustration of the underground at WIPP is shown in Figure 1 at the end of this paper. It shows the footprint that is currently planned to be dedicated to CARUS activities. All waste disposal operations are conducted entirely to the south of the waste handling shaft and all experimental and research activities that could be compromised by proximity to radioactive materials will be conducted to the north of the waste handling shaft.

CONCLUSION

While research in deep geologic environments around the world has been successfully conducted for many years by the scientific community, CARUS offers many advantages to the typical experimental setting. Typically, research that requires conditions that can only be found in a deep geologic setting is inherently dependent on and constrained by the owner/operator of the facility. Mine operations usually compromise experimental design (and sometimes compromise results). While the WIPP facility is also focused on a mission that is unrelated to experimentation, the constraints it places on experimental design and operation are far less severe than at typical facilities. In addition, the prime mission to dispose of radioactive waste at WIPP is planned to continue for at least 30 years. This makes the underground setting at WIPP ideal for long term research efforts that require operational stability.

The primary qualities CARUS provides include:

- Very low background radiation (including radon)
- 2000 mwe cosmic ray shielding
- Hydrologically inactive (dry mine)
- Geophysical stability
- Seismically inactive and "quiet"

Today, WIPP represents the world's first licensed deep geologic repository for radioactive waste, and is operational. However, the same attributes that made WIPP an ideal setting for a permanent TRU waste disposal facility also offer unique qualities that make it attractive for a variety of research opportunities unrelated to radioactive waste disposal.

CARUS is the vehicle by which these research opportunities may be realized. CARUS leverages the significant investment in infrastructure made by DOE to provide a unique research environment in a broad array of disciplines. It provides these opportunities without compromising the success of WIPP's prime mission to meet the nation's defense TRU waste disposal needs.

Figure 1 – Schematic illustration of the WIPP underground layout and the planned footprint dedicated to CARUS activities.