Milestones for Disposal of Radioactive Waste at the Waste Isolation Pilot Plant (WIPP) in the United States

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1.4 Compute crystal properties

The function Ref. Ind. can be used to compute refractive indices, group velocities, group velocity dispersions, and birefringent walk off for a given propagation angle, temperature, and wavelength. This is useful if you want to make your own calculations of phase matching, group velocity matching, etc.

3. NONLINEAR MIXING MODELS

HOW do I:

2.1 Model single-pass mixing

The functions with 'mix' in their title are for single pass mixing, as opposed to mixing in an optical cavity. The functions with the 'PW pref' model plane-wave mixing, those with the '2D' prefix include Gaussian spatial profiles with diffraction and birefringent walk off. The functions with suffix 'LP' ignore group velocity effects and can be used for ns and longer pulses or for cw beams. Functions with suffix 'SP' incorporate group velocity effects and are useful for ps and fs pulses. Suffix 'BB' indicates that the pulses are long but broad band so there is temporal structure on a time scale short enough to require inclusion of group velocity effects. The function Focus is included to help decide the wavefront curvature at the crystal entrance face. Generally for mixing low power beams you want to focus into the crystal with a confocal length comparable to the crystal length. The models of SNLO are based on split-step propagation methods. They are state-of-the-art in technique, and are all-numerical to cover the widest possible range of applications. I have carefully validated them against analytical expressions and against each other.

2.2 Model mixing in a cavity (OPO, frequency doubling, etc.)

The functions with 'OPO' in their title are for mixing in a cavity. Note that they will model not only OPO's but also any mixing process in a cavity such as frequency doubling in a build-up cavity. The functions with the 'PW prefix model plane-wave mixing with planar cavity mirrors, that with the '2D' prefix includes Gaussian spatial profiles with diffraction and birefringent walk off and can accommodate curved cavity mirrors. The functions with suffix 'LP' ignore group velocity effects and can be used for ns and longer pulses or for cw beams. The function with suffix 'SP' incorporates group velocity effects and is intended to model synchronously-pumped OPO's pumped by ps or fs pulses. The suffix 'BB' indicates that the pulses are of long duration but have a broad bandwidth so there is temporal structure on a time scale short enough to require inclusion of group velocity effects. Generally for mixing of low power beams you want to use a stable cavity with focusing mirrors. The cavity can be designed using the Cavity function which will also help you find the wavefront curvature of the input beams at the input mirror, and the cavity round-trip phase which must be known to achieve exact resonance in the cavity. The models of SNLO are based on split-step propagation methods. They are state-of-the-art in technique, and are all-numerical to cover the widest possible range of applications. I have carefully validated them against analytical expressions and against each other.

2.3 Model OPG (optical parametric generation)

The function PW-mix-BB can be used to model OPG in the plane-wave approximation. You must specify the correct signal and idler energies, bandwidths, and mode spacings to simulate start-up quantum noise. The mode spacing should be the inverse of the signal/idler pulse length. For example, if you have a 1 ps pump pulse, you could use 5 ps signal and idler pulses (to allow for temporal walk-off) and a signal/idler mode spacing of 100 GHz. The bandwidth should be set to several times the OPO acceptance bandwidth, and the pulse energy of the signal and idler should be set so there is one photon per mode, i.e., energy = hνxbandwidth + (mode spacing). Because the gain is very high for OPG, the number of z integration steps must be quite large. I suggest you start with 100 steps and double it until the results converge. Each run will use different start up noise, so convergence does not mean identical results here. A good test is to look at both the irradiance and spectra plots and make sure they are both similar to the previous run with fewer integration steps.


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Milestones for Disposal of Radioactive Waste at the Waste Isolation Pilot Plant (WIPP) in the United States

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Abstract

Six years (1983 to 1989) were spent constructing the Waste Isolation Pilot Plant (WIPP) in southern New Mexico for disposal of transuranic radioactive waste. However, not until 1999, 25 years after its identification as a potential deep geologic repository, did the WIPP receive its first shipment of waste. This report presents a concise history in tabular form of events leading up to its selection, including the development of regulatory criteria, major political conflicts, negotiated agreements, and technical milestones of the WIPP. In general, technical programs and engineering analysis of the WIPP before the mid 1980s were undertaken primarily (1) to develop general understanding of selected natural phenomena, (2) to satisfy needs for environmental impact statements, and (3) to satisfy negotiated agreements between the U.S. Department of Energy and the State of New Mexico. In the final segment of the project, federal compliance policy was developed and technical programs and engineering analysis evolved to assess the compliance of the WIPP with these specific regulations. During this ten-year period, four preliminary performance assessments, one compliance performance assessment, and one verification performance assessment were performed.
Preface

The milestones table for the Waste Isolation Pilot Plant (WIPP) Project was originally prepared as a section in the report, *An Introduction to the Mechanics of Performance Assessment Using Examples of Calculations Done for the Waste Isolation Pilot Plant Between 1990 and 1992*, SAND93-1378, by Rob P. Rechard. The milestones table, a particularly popular section, has been reproduced separately here and has been updated to include 1996 through 1999. As before, some text accompanies the milestone tables, but the emphasis remains on the tables because of their usefulness in providing a comprehensive but concise history of the WIPP. The usefulness of the milestones table is due in part to Anita Reiser, Darrell Munson, and Wendell Weart, all of Sandia National Laboratories, who helped with verification of information; C. Crawford of ASAP, Inc., who verified references; M. Minahan and J. Chapman, of Tech Reps, Inc., who edited the text; and S. K. Best, of Tech Reps, Inc., who placed the text in tables.
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Acronyms/Initialisms

A/E – architect/engineering firm
AEC – Atomic Energy Commission, the forerunner of the DOE, was formed in 1946 (August 1, 1946, 60 Stat. 755).
AG – Attorney General
AL – Albuquerque Operations Office, largest of several operations offices set up by DOE
ALARA – As low as reasonably achievable with costs and benefits taken into account; a basic policy of radiation protection initially proposed in 1948 and promulgated by NRC in 1975.
BRWM – Board of Radioactive Waste Management, a permanent board formed in 1968 in the National Research Council, the operating agency of the U.S. National Academy of Sciences (NAS)
BSPP – Bedded Salt Pilot Plant, initial name for WIPP in 1974
C&C – Consultation and Cooperation Agreement Between the State of New Mexico and the DOE
CAG – Compliance Application Guide, a non-binding guidance document developed by the EPA to supplement the WIPP implementing regulation, Title 40 CFR Part 191
CAMCON – Compliance Assessment Methodology CONtroller, computational system for assessing the performance of a disposal system (usually for nuclear wastes). When first developed in the early 1990s, this information management system provided for (1) the interfacing of individual computer codes of the WIPP PA modeling system, and (2) quality assurance of the computations.
CAO – Carlsbad Area Office, DOE office for managing WIPP Project, was formed in 1993 to replace the WIPP Project Integration Office (WPIO) that had been established in 1991, and the WIPP Project Office (WPO), which had been created in the 1980s and moved to Carlsbad, NM, in 1984.
CARD – Citizens Against Radioactive Dumping, New Mexico special interest group
CCA – Compliance Certification Application to the EPA to evaluate compliance with Title 40 CFR Part 191 of the Waste Isolation Pilot Plant; application coordinated by Westinghouse for the DOE with input from Sandia National Laboratories
CH-TRU – contact-handled Transuranic waste, packaged TRU waste whose external surface dose rate does not exceed 200 mrem per hour and can thus be directly handled by personnel
CFR – Code of Federal Regulations
DCCA – Draft Compliance Certification Application, prepared and sent to EPA in 1995
DHLW – Defense high-level waste, that is, high-level waste (HLW) that has been generated by the DOE in reprocessing spent nuclear fuel from experimental and military reactors. Because the possibility of commercial reprocessing was stopped under the Carter Administration in 1980 and never initiated thereafter, only about 72 MTHM equivalents from the West Valley Demonstration Project in New York or 0.75% is commercial HLW in the United States. Hence, the distinction between defense and commercial HLW is usually unimportant, except when highlighting the source of HLW or when discussing reprocessing and disposal plans for HLW in the United States prior to 1980.
DOI – U.S. Department of Interior
DOL – U.S. Department of Labor
DOT – U.S. Department of Transportation
EDF – Environmental Defense Fund, U.S. environmental special interest group
EEG – Environmental Evaluation Group, formed in 1978 by New Mexico from funds provided by the DOE to conduct independent technical evaluation of the WIPP. The National Defense Authorization Act, Fiscal Year 1989, Pub. L. 100-456, Section 1433 assigned administrative oversight of EEG to the New Mexico Institute of Mining and Technology.
EIS – Environmental Impact Statement, environmental documentation required by federal law (NEPA) (Pub. L. 91-190) for large, federally funded programs
EPA – U.S. Environmental Protection Agency, formed by Congress on December 2, 1970, in Reorganization Plan No. 3 of 1970 (5 U.S.C. 903; 40 CFR 1). In this act, Congress transferred to EPA the tasks of monitoring research, setting standards, and performing enforcement activities related to pollution abatement and control such that the environment could be considered as a single, interrelated system.
ERDA – Energy Research and Development Agency, a forerunner of the DOE, was formed in 1974 (Pub. L. 93-438).

FEPs – features, events (natural and anthropogenic phenomena of short duration), and processes (natural phenomena of long duration)

GAO – General Accounting Office, U.S. Congress

HLW – high-level (radioactive) waste, "... the highly radioactive material [fission products and some actinides,] resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations ..." (NWPA, 1982, §2[12]). Although not used in this manner in this report, general articles regarding radioactive waste use the term high-level waste to imply any combination of spent nuclear fuel and HLW (and sometimes transuranic [TRU] waste) that requires disposal in a deep, geologic repository. 10 CFR 60, which was promulgated by the NRC prior to NWPA, also includes spent nuclear fuel in its definition of high-level waste.

HSWA – Hazardous and Solid Waste Amendments of 1984 (Pub. L. 98-616) (see also RCRA)

IAEA – International Atomic Energy Agency, Vienna, Austria, established in 1957 by General Assembly of the United Nations to foster research and development in the peaceful uses of nuclear energy

INEEL – Idaho National Engineering and Environmental Laboratory, a multiprogram laboratory in Idaho Falls, Idaho, furnishing engineering services and products on primarily nuclear energy and related technologies. The Idaho Chemical Processing Plant (ICPP) at the Idaho site processes highly enriched uranium fuel from spent nuclear fuel stored at the site. In addition to receiving spent nuclear fuel from throughout the DOE defense complex, it stores a large volume of TRU waste from Rocky Flats destined for the WIPP. Prior to 1970, it buried this TRU waste, but now stores it on the surface.

IRG – Interagency Review Group on Nuclear Waste Management. The Carter Administration formed this group on the recommendation of Secretary of Energy Schlesinger. The group consisted of the DOE and eight other agencies together with several entities within the Executive Branch, including the Council on Environmental Quality.

LANL – Los Alamos National Laboratory, a multiprogram laboratory in Los Alamos, NM, conducting research and development on all facets of nuclear weapon design and basic research in a variety of areas. A large volume of TRU waste stored on site is destined for the WIPP.

LEAF – Legal Environmental Assistance Foundation, U.S. environmental special interest group


MED – Manhattan Engineering District of Army Corps of Engineers; assigned task of developing atomic bomb in 1942

MIT – Massachusetts Institute of Technology

MTHM – metric tons of heavy metal; regulatory mass unit in Title 40 CFR Part 191 where heavy metal is all the uranium, plutonium, and thorium initially placed in a nuclear power reactor

MRS – Monitored Retrievable Storage Facility for spent fuel from commercial power reactors, proposed in 1982 in NWPA and discussed in 1987 in NWPAA (see also RSSF)

NAS – National Academy of Sciences, a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research. The Academy was chartered by Congress in 1863 with the mandate to advise the federal government on scientific and technical matters.

NEFTRAN – network flow and transport computer program

NEPA – National Environmental Policy Act of 1969, federal law that sets environmental policy by requiring an environmental impact statement on all major federal project (Pub. L. No. 91-190, 83 Stat. 852)

NMED – New Mexico Environment Department.


NRDC Natural Resources Defense Council, U.S. environmental special interest group


NWPPA – Nuclear Waste Policy Amendments Act of 1987, amendments to the Nuclear Waste Policy Act of 1982 specifying that only a repository site at Yucca Mountain was to be characterized by the DOE and placing less emphasis on the monitored retrievable storage option

ORNL – Oak Ridge National Laboratory, Y-12 Plant, Oak Ridge Reservation, Oak Ridge, TN. A large volume of TRU waste in storage is destined for the WIPP.

OTA – Office of Technology Assessment, U.S. Congress
PA – Performance assessment, the process of assessing whether a system meets a set of performance criteria. For the WIPP PA, the process is a stochastic simulation. The system is a deep geologic repository disposal system (in salt) for DOE TRU waste. The performance criteria are various long-term environmental metrics in U.S. government regulations (not short-term operational safety issues).

PRA – Probabilistic risk assessment, the process of assessing, through a stochastic simulation, the risks from a system. A PRA is identical to a performance assessment (PA) in the United States; however, the connotations of the two terms differ. A PRA usually connotes (a) a system composed solely of human-engineered components, and (b) performance criteria that include risk to health over a short time (e.g., human lifetime) relative to geologic time. A PA usually connotes a system composed of both natural and human-engineered components over geologic time. Because the time frame is different, many phenomena for a PRA can be termed events (short-term phenomena); because the components are all human engineered, measured failure rates of components are often available. The modeling tools in a PRA can include elaborate event and fault trees and can substitute empirical data for mechanistic models. For a WIPP PA, the event trees are simpler, fault trees are not used, and mechanistic models are used directly.

QA – quality assurance, all those planned and systemic actions necessary to provide adequate confidence that a structure, system, or component will perform satisfactorily in service. Quality assurance for a product is ensuring that the product does what it is supposed to do to meet the specifications of the customer. The customer expectation, as related to a performance assessment, is that the analysis results present an adequate view (primarily from a legal standpoint) of the WIPP performance based on currently available data and information.


RH-TRU – remotely-handled transuranic waste, packaged TRU waste whose external surface dose rate exceeds 200 mrem per hour, but not greater than 1000 rem per hour, and thus must be handled remotely

RSSF – Retrievable Surface Storage Facility for spent nuclear fuel and high-level waste proposed in 1972 by the AEC

RWMC – Radioactive Waste Management Complex, a nuclear waste storage facility for the DOE complex built in 1952 at Idaho National Engineering and Environmental Laboratory (INEEL)

SA – Stipulated Agreement between the State of New Mexico and the DOE

SAB – Science Advisory Board, EPA

SAR – Safety Analysis Report

SNF – spent nuclear fuel, "... fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing" (NWPA, 1982)\(^6\). Spent fuel can include intact and failed fuel assemblies, consolidated fuel rods, non-fuel components that are a part of a fuel assembly (such as neutron sources, instrumentation, and fuel channels). Although spent nuclear fuel has fissionable useable value, some countries choose to recycle it (recycling becomes more attractive after the short-lived fission products have decayed away). It is also designated separately from other high-level and transuranic wastes in the U.S. Environmental Protection Agency's standard on disposal of radioactive wastes, Title 40 CFR Part 191.

SNL – Sandia National Laboratories, a multiprogram laboratory located in Albuquerque, NM, and Livermore, CA. SNL is operated and managed for the DOE by the Sandia Corporation. From 1949 until October 1993, Sandia Corporation was a wholly owned subsidiary of AT&T. Sandia Corporation is currently a wholly owned subsidiary of Lockheed Martin Corporation.

SPDV – Site and preliminary design validation phase performed by Bechtel National, Inc.

SPM – System Prioritization Methodology, developed by Sandia in 1994 and 1995 as an attempt to combine probabilistic performance assessment results with decision theory to help prioritize experimental work conducted for the WIPP

SRP – Savannah River Plant Laboratory Production Reactors Defense Waste Processing Facility, located southeast of Augusta, Georgia. A large volume of TRU waste produced and stored on site is destined for the WIPP.

SWCF – Sandia WIPP Central Files

SWIFT II – Sandia waste isolation flow and transport computer code initially developed in the late 1970s and updated in the mid 1980s
SWRIC – Southwest Research and Information Center, New Mexico special interest group

TRU – TRansUranic, all elements of the periodic table having atomic numbers greater than 92

TRUPACT-I – Transuranic Package Transport, design I, designed to be a vented package in the same shape and size as standard shipping containers to facilitate shipment. The EEG objected to a vented container; so the package was completely redesigned (see TRUPACT-II)

TRUPACT-II – Transuranic Package Transport, design II, designed to be a pressurized hemispherical package for use on flatbed trucks

USGS – U.S. Geological Survey, Department of Interior (DOI)

WIPP – Waste Isolation Pilot Plant, a full-scale research and development repository for transuranic wastes near Carlsbad, NM. WIPP was authorized in 1979 (Pub. L. 96-164) for the management, storage, and eventual disposal of waste generated by DOE defense programs that is contaminated with transuranic radionuclides and some RCRA hazardous chemicals.

WPIO – WIPP Project Integration Office, formed in 1989, forerunner of the Carlsbad Area Office (CAO)

WPO – WIPP Project office, forerunner of the Carlsbad Area Office (CAO)
Milestones for Disposal of Radioactive Waste at the Waste Isolation Pilot Plant

New Mexico has a long history of involvement in nuclear phenomena: In 1942, the Manhattan Engineering District (MED) of the Army Corps of Engineers selected New Mexico for assembling the scientists, engineers, and technicians to develop the first atomic bomb and what was to become Los Alamos National Laboratory and Sandia National Laboratories (SNL). In 1945, the first atomic explosion occurred in the desert near Alamogordo, New Mexico. In 1961, the U.S. detonated a device to explore nonmilitary uses of nuclear explosives in bedded salt near Carlsbad, New Mexico (Gnome Project). Since 1973, New Mexico has been a potential disposal site for waste contaminated with transuranic (TRU) nuclear elements created during the production of nuclear weapons. A brief description of this latter aspect is presented below followed by a detailed tabulation of milestones of the Waste Isolation Pilot Plant (WIPP).

Early History of Nuclear Waste Disposal Related to the WIPP

Around 1944, the MED initially decided to bury solid nuclear waste in shallow trenches and augered holes at Los Alamos National Laboratory in New Mexico, and in railroad cars, trenches, and underground caissons at the Hanford Reservation in Washington. Liquid nuclear waste was stored in ponds at both sites. The Atomic Energy Commission (AEC), formed in 1946 and the precursor to the Department of Energy (DOE), continued the practices of the MED. The AEC also constructed storage tanks in the late 1940s at Hanford and completed a nuclear waste storage complex at Idaho National Engineering and Environmental Laboratory (INEEL) in 1952.

From 1955 through the late 1960s, the AEC explored more permanent solutions for radioactive waste disposal in the United States, beginning with its request in 1955 that the National Academy of Sciences (NAS) examine the disposal issue. In 1957, the NAS reported that while various options and disposal sites were feasible, disposal in salt beds was the most promising method to explore. The NAS reaffirmed that recommendation in 1961. Frustration at the lack of a formal waste policy at AEC caused the NAS to strongly criticize AEC disposal practices in 1966.

In 1970, the Board of Radioactive Waste Management of the NAS concluded that bedded salt was satisfactory and was the safest choice then available for nuclear waste disposal. From 1961 through the early 1970s, Oak Ridge National Laboratory (ORNL) conducted radioactive-waste disposal experiments, most notably Project Salt Vault in an abandoned salt mine near Lyons, Kansas, from 1963 to 1967.

In May 1969, the Rocky Flats Plant, built by the AEC in 1951 to machine plutonium for nuclear weapons, caught fire. Located only 26 km (16 mi) from Denver, Colorado, the fire attracted public attention. In its coverage, the press reported that the cleanup waste was eventually to be sent to Idaho. Idaho state officials voiced concerns that it was becoming the nation's nuclear waste disposal site by default. Hence, the AEC quickly moved to find a more suitable site and tentatively selected the Kansas mine as a repository in June 1970. At the same time, the AEC told Idaho Senator Church that the waste stored in Idaho would be removed by 1980 and sent to the salt mine. Later in 1970, a conceptual design was completed for a nuclear waste repository in salt.

Earlier in the year, in March 1970, the AEC had directed that thereafter TRU nuclear waste would be retrievably stored on the surface in Idaho and elsewhere rather than disposed of in trenches with low-level waste. In a related action, the AEC directed in 1971 that high-level waste (HLW) be solidified within five years, stored retrievably at all DOE facilities, and delivered to a federal repository within 10 years.

In the same year, a large number of drill holes and some solution mining were discovered at the proposed repository site near Lyons, Kansas. Soon after, Congress directed the AEC to stop work on the Lyons project until safety was certified.
Although the Lyons project was not officially abandoned until 1975, the AEC announced plans in May 1972 for a Retrievable Surface Storage Facility (RSSF). However, the recently formed U.S. Environmental Protection Agency (EPA) and anti-nuclear groups claimed the RSSF to be de facto permanent disposal, which prompted the AEC to continue searching for a more suitable disposal site.

**Early Studies at the WIPP**

With the encouragement of local citizens and the tacit approval of Governor Bruce King, the AEC, ORNL, and the United States Geological Survey (USGS) recommended the extensive salt beds of southeastern New Mexico. After an initial study of existing information, a potential site near the edge of the basin was identified in 1973. The first large-scale field test was conducted in March 1974 when ORNL drilled wells AEC-7 and AEC-8. Also, in 1974, ORNL conducted the first scenario development and deterministic analysis for the proposed repository, although the project was suspended two months later.

In April 1975, SNL was chosen as the lead laboratory to (a) select and characterize, (b) develop a conceptual design, (c) draft an environmental impact statement (EIS), and (d) initiate scientific studies for the repository. After some site characterization, SNL recommended locating the WIPP site nearer the basin center where the stratigraphy was more predictable. (A minor repositioning of the disposal panels also occurred in 1982.) The newly positioned site would become the current WIPP repository, near Carlsbad, New Mexico.

National policy issues, court settlements, and negotiated agreements had a strong influence on the amount and type of scientific data collected during the early phase of the WIPP Project. The passage by Congress of the National Environmental Policy Act of 1969 established a broad national policy requiring an EIS on large federally funded projects. The EIS process exerted its influence during the 1970s as the AEC, which later became the Energy Research and Development Agency (ERDA) and then the DOE, continued investigations on bedded salt in general and, specifically, the salt deposit in New Mexico as a satisfactory medium for hosting a repository.

SNL’s support of the EIS consisted of (among other things) detailed computer modeling of radioisotope escape through human intrusion and faulting, and the potential transport of radioisotopes through the aquifer overlying the WIPP to the Pecos River over a 250,000-year time frame (~10 half-lives of 239Pu), followed by dose calculations to humans.

During 1978 and early 1979, and without consultation with the State of New Mexico, the mission of the WIPP oscillated between including and excluding commercial spent nuclear fuel (SNF) and HLW in the repository, in addition to TRU wastes. Also, the new Carter administration required a fresh look at sites and options for nuclear waste disposal.

Because some of the examined options created uncertainty about DOE’s intentions within the state and were counter to the ideas of some Congressional members, Congress firmly established the purpose of the WIPP Project as a research and development facility for storage and disposal of TRU waste only (i.e., HLW and commercial and defense SNF were excluded). Congress also specifically exempted regulation by the Nuclear Regulatory Commission (NRC) and thus by default granted self-regulation to the DOE.

A national advisory group, the WIPP Panel, which was set up under the Board of Radioactive Waste Management of the NAS, and an independent state-selected group, the

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* The Atomic Energy Commission (AEC) was formed by the Atomic Energy Act of 1946. The Energy Research and Development Agency (ERDA) and the Nuclear Regulatory Commission (NRC) were formed by splitting the Atomic Energy Commission in the 1974 Energy Reorganization Act. ERDA became the Department of Energy (DOE) in 1977.

** Although regulation by the Nuclear Regulatory Commission (NRC) would have been possible, the NRC had been established to regulate primarily commercial nuclear reactors and waste. Also, Congress did not favor NRC oversight of defense-related activities.
New Mexico Environmental Evaluation Group (EEG), were established on the initiative of the DOE to monitor its self-regulation.

After the final EIS was published in 1980 and a record of decision published in January 1981, the DOE proceeded to the preliminary design of the WIPP. Planning activities included a site and preliminary design validation (SPDV) phase, consisting of drilling two shafts in 1981 and 1982 and mining an experimental area. Full construction of the WIPP surface facility, an extensive underground experimental area, and one underground disposal panel began in 1983 after meeting the terms of the “Consultation and Cooperation Agreement” with the State of New Mexico and continued to completion over the next five years. Simultaneously with design and construction, SNL began fielding many in situ salt creep experiments to characterize the local disposal system. Although, from a practical standpoint, the predicted and measured values of creep were close, the measured salt creep was nevertheless about three times greater than the predicted values noted in 1985 and so by 1989 an alternative mathematical expression for the creep phenomenon was developed.

In addition to developing a general understanding of selected natural phenomena as deemed prudent by SNL scientists (working with peers in waste management) and/or scientists on the WIPP Panel of the NAS, many of the geotechnical experiments conducted during the 1980s were undertaken to satisfy agreements with the State of New Mexico. Specifically, in 1981 in response to a lawsuit, a “Stipulated Agreement” and the “Consultation and Cooperation Agreement” mentioned earlier were negotiated that defined the relationship of the WIPP Project with the State of New Mexico and listed required geotechnical experiments to be conducted primarily by SNL.

These requirements and early drafts of the EPA nuclear waste disposal regulation in Title 40 of the Code of Federal Regulations Part 191 (40 CFR 191) influenced the type of in situ experiments and activities initially planned at the WIPP. For example, when the WIPP-12 was deepened in 1981 as part of the negotiated settlement with the State of New Mexico, the project encountered a brine reservoir which resulted in moving the disposal region ~1800 m to the south in 1982. By March 1983, SNL and the USGS had examined many of the geotechnical issues. For example, they had explored and dismissed the possibility of extensive dissolution disrupting the repository.

The decision by Congress in 1987 to characterize only Yucca Mountain, Nevada, for the first commercial SNF and HLW repository caused the DOE to cancel many of the experiments being performed at the WIPP in support of a potential commercial repository elsewhere in bedded salt. The presence or absence of additional pockets of brine below the repository became of concern to the EEG in the early 1980s. Therefore, some studies were conducted to try to dismiss their presence. Though the studies strongly suggested brine pockets were not present below the waste rooms in the anhydrite layer in which other brine pockets had been found, the studies were unable to show unequivocally that brine pockets did not occur in deeper anhydrite layers in the Castile Formation. Long-term slow seepage of brine trapped in the salt into the repository became a topic of great interest in 1988, and the full Board of Radioactive Waste Management of the NAS examined the issue. Members of the NAS concluded that rapid salt creep combined with low permeability of the salt meant that the repository would be fairly well consolidated before much brine could enter the repository.

In preparation for the WIPP’s planned opening by the end of the 1980s, SNL summarized past work and data, and performed numerous bounding calculations to support a Draft Supplemental EIS in 1989. The summary identified gas generation—the gas being generated through anoxic corrosion of waste containers and degradation of organic material—as an important issue to study. This issue had been identified in the mid 1970s, but it was dismissed based on the assumption that high salt permeability values obtained from measurement in boreholes drilled prior to excavating the repository would allow any gas generated to dissipate without producing large pressures.

Studying gas generation became an important purpose of proposed tests using actual TRU waste within the repository during a monitored pilot phase, after better in situ measurements of the salt permeability within the excavations in the
mid 1980s suggested values three orders of magnitude less than those measured in the mid 1970s. However Congress stipulated in 1992 that the waste could be brought to the WIPP prior to demonstrating compliance only if the tests were scientifically necessary. Although the tests would have been potentially reassuring as a demonstration, the monitored pilot phase was not considered a scientific necessity.

Therefore, in October 1993, the NAS recommended to eliminate the tests with actual waste at the WIPP (pilot phase) and to perform additional experiments in laboratories. Without a pilot phase, the DOE decided to accelerate to the compliance phase for the WIPP and closed the in situ experimental area in October 1995.

Compliance Setting for the WIPP

A major task of the WIPP Project, which was initiated about 1986, was developing evidence of compliance. The promulgation of 40 CFR 191 in 1985 established the primary probabilistic regulation with which the WIPP would have to comply. However, a legal ruling in 1984 and regulations in 1986 and 1987 resulted in defining as much as 60% of the waste destined for the WIPP as chemically hazardous. This legal ruling established another set of regulations that the WIPP also had to comply with—those for hazardous waste (40 CFR 260-270 and analogous New Mexico regulations) promulgated in response to the Resource Conservation and Recovery Act (RCRA). F13

In 1992, Congress defined the process by which the WIPP compliance would be evaluated, transferred ownership of the WIPP site to the DOE, and designated the EPA (rather than the DOE) as the regulator of the WIPP (Waste Isolation Pilot Plant Land Withdrawal Act). This act officially marked the transition from the construction and disposal-system-characterization phase to the compliance and testing phases. However, these latter phases had begun informally in 1985 and 1986 when the EPA issued 40 CFR 191 and its interpretation of mixed hazardous waste, and in 1989 when SNL first assessed performance using the EPA standard. T110, T111

Finally, in 1996, the EPA promulgated 40 CFR 194, a regulation to implement its 40 CFR 191 standard, which imposed several new interpretations, such as expanded human intrusion activities (specifically, potash mining), and requirements, such as peer review on waste characterization, engineered and natural barriers, and conceptual models. F53 Also in 1996, Congress removed one of the RCRA land disposal requirements (i.e., seeking a no-migration variance), which required calculations similar to those for 40 CFR 191.

Development of Methodology for Assessing Compliance of the WIPP

The history of assessing performance of a geologic disposal system began formally in 1976 when the ERDA funded two conferences to bring engineers and geologists together to explore the modeling of geologic disposal systems. By 1977, demands for permanent solutions to nuclear waste provided an impetus for President Gerald Ford to request the EPA to more vigorously pursue applicable standards for proposed waste repositories. D12, D13

During the EPA’s development of 40 CFR 191 in the late 1970s and early 1980s, analysts at SNL were advocates for a thorough approach in evaluating modeling uncertainty (caused by various parameters in models of the exposure pathways and the uncertainty about the various pathways) as a way to gain insight about the behavior of a geologic waste repository. For example, an analysis that SNL had conducted for the EIS had relied heavily on mathematical modeling.

SNL’s position on this matter had developed indirectly from participation by a few Sandians on the 60-member team for the Nuclear Reactor Safety Study and Sandia’s direct involvement on several subsequent reactor accident studies for the NRC. In addition, SNL’s advocacy for a probabilistic approach was influenced by its use of the approach in evaluating the reliability of weapons systems and also by the growing acceptance externally for evaluating technological risks.

During this period, the term performance assessment (PA) was adopted internationally to
describe the process of evaluating whether a geologic disposal system complied with the regulatory criteria—criteria that were probabilistic in the United States, thus making the assessment identical to probabilistic risk assessments (PRA) for nuclear reactors.

Performance assessments of systems for the disposal of radioactive wastes nevertheless differed from most simulations used by federal agencies to explore policy options in two significant and related ways. First, in contrast with simulations for policy analysis, the EPA chose to use the PA results for the WIPP ultimately to test compliance of a real system with an existing environmental standard, not merely to gain insight into the behavior of the system. Second, the fact that part of the disposal system was geologic created several differences with some other types of risk assessments. For instance, the geologic portion of the disposal system introduced the necessity to characterize rather than design. Furthermore, geologic components of a waste disposal system are subject to natural processes over geologic time with no discrete failure points; hence, computer-implemented phenomenological models were needed in order to include geologic processes.

In August 1986, SNL accepted DOE's formal request to take responsibility for showing compliance of the WIPP with 40 CFR 192. To gain proficiency and also to enable the project to better adapt efforts to collect information on important processes, SNL conducted four preliminary performance assessments from 1989 through 1992, each one building upon the other. The use of mathematical models and the general long-term flow path for radioisotope release was similar to the initial EIS, but the simulations were stochastic and numerous complexities were added, such as human intrusion causing radioisotope releases from drill cuttings. Hence, between January 1988 and December 1991, a significant effort was expended in developing a computational modeling system, CAMCON. Furthermore, vast numbers of records and documents were produced to ensure that the reasoning behind choices for data and models was traceable and repeatable.

In October 1996, the performance assessment for the Compliance Certification Application (CCA) was submitted to the EPA showing compliance with 40 CFR 191. While not responsible for evaluating compliance, the NAS also issued a report in October that noted the excellent features of the WIPP site for containing nuclear waste. These same conclusions were echoed in the 84,000-page second Supplemental EIS issued in November.

Between 1995 and 1997, the EPA and its contractors evaluated the CCA and supporting documentation. The Conceptual Model Peer Review Group (formed in response to requirements in 40 CFR 194) concluded in early 1997 that 22 of the 24 conceptual models were adequate. The panel thought that, though conservative, the model for spallings (particulates carried to the surface by pressurized gas and/or brine during a hypothetical drilling intrusion in the repository at a future time) lacked sufficient realism; hence, the panel required the model to be redeveloped. The panel also thought the description of the behavior of the magnesium oxide (MgO) backfill needed improvement. During the next few months, more detailed calculations of the spalling phenomenon were run to demonstrate the conservatism of the current model and DOE's commitment to develop a more realistic model before the next certification in five years. Also, additional information was provided on the behavior of the MgO backfill such that the Conceptual Model Peer Review Group concluded in an April meeting that these two modeling issues had been resolved. In addition, under the direction of the EPA, the PA calculations were rerun by SNL during the spring and summer, using EPA-selected values and distributions for 26 parameters to help bolster EPA confidence in the results.

Finally, in October 1997, the EPA published a draft rule proposing to approve the WIPP. In May 1998, the EPA issued certification. In March 1999, Judge Penn lifted his injunction associated with a 1992 lawsuit by the State of New Mexico, and four days later the WIPP received its first shipment of non-RCRA waste.

**Summary**

The opening of the Waste Isolation Pilot Plant on March 26, 1999, was the culmination of a regulatory assessment process that had taken 25
years. National policy issues, negotiated agreements, and court settlements during the first 15 years of the project had a strong influence on the amount and type of scientific data collected up to this point. Assessment activities before the mid 1980s were undertaken primarily (1) to satisfy needs for environmental impact statements, (2) to satisfy negotiated agreements with the State of New Mexico, or (3) to develop general understanding of selected natural phenomena associated with nuclear waste disposal.

In the last 10 years, federal compliance policy and actual regulations were sketched out, and continued to evolve until 1996. During this period, stochastic simulations were introduced as a tool for the assessment of the WIPP's performance, and four preliminary performance assessments, one compliance performance assessment, and one verification performance assessment were performed.
Detailed Tabulation of WIPP Milestones

In the following tabulation of WIPP milestones, the history of the WIPP is divided into four main categories. One category highlights technical milestones, and three categories highlight the major political events that have influenced the WIPP Project, as briefly summarized above. Noteworthy events from all four categories are also shown schematically. The tabulation also indicates two temporal categories of the WIPP Project—one used officially by the DOE for the project as a whole and one used informally by SNL to describe its various activities.
## Milestones for Disposal of Radioactive Waste in the United States

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<tr>
<td>1942</td>
<td></td>
<td>● 1943 - All types of waste initially dumped in canyons at Los Alamos National Laboratory (LANL). ¹¹</td>
<td>★ 1942 - Manhattan Engineering District (MED) Corps of Engineers selects site for LANL to develop a nuclear bomb.</td>
<td>(None)</td>
<td>(None)</td>
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<tr>
<td>1943</td>
<td>● MED's 1st waste disposal site chosen</td>
<td>● 1943 - Plutonium operations commence and disposal of nuclear waste begins on site at Oak Ridge National Lab (ORNL) in trenches and Clinch River. ¹¹ Water has saturated the bottoms of some trenches, and migration of radioactive waste has been observed.</td>
<td>★ 1943 - MED's earliest decision on managing waste: store high-level waste (HLW) as liquids in tanks and bury other waste (solid or liquid) in trenches. ¹²</td>
<td>(None)</td>
<td>(None)</td>
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<tr>
<td>1944</td>
<td></td>
<td>● 1944 - Disposal of nuclear waste begins on site at LANL (using trenches, ponds, augered holes) and Hanford Reservation (using railroad cars, trenches, ponds, tanks, underground cells). ¹²</td>
<td>(None)</td>
<td>(None)</td>
<td>(None)</td>
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<tr>
<td>1945</td>
<td>★ Atomic bomb test in NM</td>
<td>★ 1945 - Atomic bomb exploded at Trinity Site near Alamogordo, NM.</td>
<td>(None)</td>
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<tr>
<td>1946</td>
<td>³³</td>
<td>(None)</td>
<td>(None)</td>
<td>(None)</td>
<td>(None)</td>
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<td>1949</td>
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<td>(None)</td>
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<td>1951</td>
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<td>1952</td>
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<tr>
<td>1953</td>
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<td>● 1952 - Idaho National Engineering and Environmental Lab (INEEL) completes Radioactive Waste Management Complexes (RWMC) for storing and burying waste; migration of radioisotopes downward into the alluvium has been observed.</td>
<td>(None)</td>
<td>(None)</td>
<td>(None)</td>
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<tr>
<td>1955</td>
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<td>● 1953 - Sevier Mule River Park (SRP) begins waste storage and disposal on site at &quot;Old Burial Ground&quot;; water in trenches from precipitation has caused migration of radionuclides.</td>
<td>(None)</td>
<td>(None)</td>
<td>(None)</td>
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<tr>
<td>1957</td>
<td>★ NAS recommends exploiting waste in salt beds</td>
<td>★ 1957 - NAS recommends radioactive waste disposal in salt as most promising method. ¹¹ ORNL begins research in salt (1957-81). ¹⁴ May: Rocky Flats Plant catches fire but kept secret. ¹⁵</td>
<td>★ 1955 - AEC Chairman: Strauss</td>
<td>(None)</td>
<td>(None)</td>
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<tr>
<td>1959</td>
<td></td>
<td>★ 1959 - NAS commission on oceanography reports on coastal disposal of low-level radioactive waste. ¹⁶</td>
<td>(None)</td>
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<td>1960</td>
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<td>Year</td>
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<tr>
<td>1961</td>
<td>Gnome test</td>
<td>NAS reaffirms use of New Mexico salt tests for disposal. US Geological Survey (USGS) evaluates stratigraphy and waste disposal methods at Gnome test site. AEC mines into Salado Fm. at Gnome site near Carlsbad, NM. Gnome test as part of Plowshare program.</td>
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<td>1962</td>
<td>1962 - USGS reports on domestic salt deposits suitable for waste disposal in Permian Basin in parts of NM, KS, TX, and OK; one area identified.</td>
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<td>1963</td>
<td>ORNL begins Project Salt Vault, a large-scale field test in which irradiated fuel elements and electrical heaters are placed in an existing salt mine at Lyons, KS; up to 1967, the tests primarily study near-field effects. INEL accepts oxidation of liquid HLW to form solid salts (&quot;calcine&quot;) for storing HLW.</td>
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<td>1965</td>
<td>Nevada River Plant (SNIP) begins disposing TRU waste in trenches on site.</td>
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<td>1966</td>
<td>1966 - NAS reaffirms use of salt beds for disposal and strongly criticizes current disposal practices.</td>
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<td>1967</td>
<td>Committee on Radioactive Waste Management established by NAS; later permanent “Board” (BRWM). First task is to reevaluates the use of brackish salt.</td>
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<td>1968</td>
<td>1968 - AEC asks NAS to revisit the issue of nuclear waste disposal. At request of Congress, General Accounting Office (GAO) audits AEC waste management practices and finds faults with records and management. AEC forms task force to address criticisms.</td>
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<tr>
<td>1969</td>
<td>Congress passes National Environmental Policy Act (NEPA)</td>
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<td>1969</td>
<td>May - Rocky Flats Plant catches fire and cleanup waste sent to Idaho for disposal at PAMIC. Event focuses public attention on AEC nuclear waste problems. International Atomic Energy Agency (IAEA) forms advisory committee to categorize nuclear waste. Alpha-contaminated waste one category defined.</td>
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<td>1970</td>
<td>NAS concludes brackish salt disposal program; issues report concluding brackish salt satisfactory and safest choice now available for nuclear waste disposal.</td>
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<tr>
<td>1970</td>
<td>Conceptual design completed for HLW repository in salt. New (BRWM) of NAS issues report concluding brackish salt satisfactory and safest choice now available for nuclear waste disposal. INEL accepts oxidized waste as &quot;calcine&quot; for storage.</td>
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<td>1970</td>
<td>Mar - AEC Chairman: Schlesinger. AEC directs TRU waste be stored retrievably at all DOE facilities rather than disposed of low-level waste. June - AEC tells Sen. Church that the waste stored at INEL will be removed by 1980 and sent to salt mine. AEC tentatively selects mine in Lyons, KS, as repository.</td>
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<tr>
<td>1971</td>
<td>Many drill holes and some solution mining discovered at Lyons, KS. USGS tests permeability of strata around Gnome site (Plowshare program) for closure studies by AEC.</td>
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<td>1971</td>
<td>AEC states all commercially generated HW must be isolated within 50 yr and delivered to a federal repository within 10 yr.</td>
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<tr>
<td>1971</td>
<td>AEC contracts to stop Lyons project until safety is certified. Appeals court requires AEC to look at all environmental impacts in EIS.</td>
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<td>1971</td>
<td>Attorney General (AG) - Noyelle; NM Environmental Improvement Act creates state environmental agency.</td>
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### Milestones for Disposal of Radioactive Waste in the United States

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<tr>
<td>1972</td>
<td>1972 - Lyons site judged unacceptable</td>
<td>1973 - Nationwide search for suitable salt site resumed.</td>
<td>1972 - May: AEC abandons Lyons project. AEC announces plans for Retrievable Surface Storage Facility (RSSF) for radioactive waste.</td>
<td>1973 - EPA and anti-nuclear groups challenge RSSF de facto permanent disposal in RSSF EIS.</td>
<td>1973 - With tacit approval of Gov. King, local political leaders and potash mine operators invite AEC to southeastern NM (This strong local and political support from southeastern NM facilitates the WIPP process.)</td>
</tr>
<tr>
<td>1975</td>
<td>1975 - WIPP moved toward basin center</td>
<td>1976 - SNL begins site characterization and engineering design program at new site; various natural barriers such as salt beds or salt basins.</td>
<td>1976 - Jan: ERDA asks SNL, located in NM, to oversee investigations rather than ORNL and suggests an opening date of 1982. ERDA removes WIPP from commercial repository program.</td>
<td>1976 - Resource Conservation and Recovery Act (RCRA) seeks to reduce or eliminate hazardous waste generation to minimize present and future threat to human health and environment. Dec: EPA announces intent to develop radiation protection standards for HLW disposal.</td>
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</tr>
<tr>
<td>1976</td>
<td>1976 - ERDA-6 drilled at center of WIPP site</td>
<td>1978 - Bidwell's Lodge Conference to explore PRA for HLW disposal.</td>
<td>1976 - Jan: Project is officially named the &quot;Waste Isolation Pilot Plant.&quot; Oct: FD orders major expansion of ERDA program to demonstrate permanent disposal for nuclear waste by 1985 and orders EPA to develop generally applicable standards. ERDA funds conference on modeling of geologic disposal systems to bring engineers and geologists together to explore predicting geologic features, events, and processes (PEPs).</td>
<td>1978 - FD orders major expansion of ERDA program to demonstrate permanent disposal for nuclear waste by 1985 and orders EPA to develop generally applicable standards.</td>
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### Federal Legislation, Judicial Decisions, and Regulatory Requirements Related to Nuclear Waste Disposal

- **1973** - EPA and anti-nuclear groups challenge RSSF de facto permanent disposal in RSSF EIS.
- **1975** - Oct: NRC promulgates "As Low As Reasonably Achievable" (ALARA) policy for limiting radiation exposure.
1977

- DOE Sec. Schlesinger. Apr: Carter announces plan to defer indefinitely reprocessing of commercial spent nuclear fuel (SNF).
- DOE's expansion of the project requires NRC licensing (even if for demonstration only). Dec: Congress delves mission of WIPP.
- DOE defines project as a combination military/commercial repository in Draft EIS. Based on site permeability tests in AEC-7 well, DOE cancels all gas generation and some backfill experiments. DOE buys oil and gas leases for $19 million.

1978

- Oversight by WIPP Panel of NAS and NM EG begins.
- DOE begins design of the Transuranic Package Transport design (TRUPACT-I) using standard cargo box concept.
- SNL begins design of the Transuranic Package Transport design (TRUPACT-I) using standard cargo box concept.
- SNL begins gas generation trials with second design for TRU waste.
- DOE Deputy Sec. J. O'Leary promises NM Congressional delegation "if NM did not want to have the WIPP, then it could veto the plan."
- DOE Deputy Sec. J. O'Leary presses on with second recommendation until 1979 enabling law for WIPP as a way to satisfy California law banning nuclear waste disposal.
- DOE Deputy Sec. J. O'Leary orders preliminary testing for WIPP.

1979

- Congress defines mission of WIPP and passes WIPP bill for TRU waste only.
- DOE Deputy Sec. J. O'Leary orders preliminary testing for WIPP.
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### Milestones for Disposal of Radioactive Waste in the United States

<table>
<thead>
<tr>
<th>Time Line</th>
<th>Noteworthy Events</th>
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<tr>
<td><strong>1980</strong></td>
<td>1980 - Final EIS on WIPP.</td>
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<tr>
<td><strong>1981</strong></td>
<td>1981 - Tests begin in nearby potash mine, Mississippi Chemical Mine Co., to evaluate corrosion of potential waste canisters and overpack alloys. Mar: WIPP begins auguring for first shaft, which would be in SPDV phase of WIPP. Fenix &amp; Sons, SPDV construction contractor, begins auguring first shaft (this exploratory shaft later called construction and salt handling shaft and then salt handling shaft). Jul: Drilling of second 3.6 m shaft begins (this waste shaft initially called ventilation shaft). Aug: After reviewing preliminary design, DOE declares detailed design of WIPP. 20th Century Fox, Sony, and HBO agree to produce a movie about WIPP.</td>
</tr>
<tr>
<td><strong>1982</strong></td>
<td>1982 - DOE publishes Record of Decision to proceed with SPDV phase. Feb: After reviewing preliminary design, DOE decides to proceed with SPDV phase. DOE Sec. Edwards. Jun: DOE WP plans to begin construction. 20th Century Fox, Sony, and HBO agree to produce a movie about WIPP.</td>
</tr>
<tr>
<td><strong>1983</strong></td>
<td>1983 - DOE WP plans to begin construction. 20th Century Fox, Sony, and HBO agree to produce a movie about WIPP.</td>
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</table>

### Technical Milestones Related to the WIPP

- 1980 - First Safety Analysis Report (SAR). General Atomic Technologies started as AIE for TRU PACT.1 (used SNL basic concept but changed details). SNL asked to analyze and test TRU PACT.1 when built.
- 1980 - DOE issues final EIS eliminating SNF and HLW disposal and thereby eliminates WIPP mission defined by Congress in 1979. New: DOE applies to Department of Interior (DOI) for administrative withdrawal of land for Site and Preliminary Design Validation (SPDV) experiments at WIPP.
- 1980 - DOE WP plans to begin construction. 20th Century Fox, Sony, and HBO agree to produce a movie about WIPP. |

### U.S. President and DOE: Directives and Decisions

- 1980 - Feb: Carter orders SNF reprocessing to stop. Mar: Carter resounds 1980 funds for WIPP and announces interim strategy to set aside money for possible future waste disposal projects at WIPP. Oct: DOE issues final EIS eliminating SNF and HLW disposal and thereby eliminates WIPP mission defined by Congress in 1979. New: DOE applies to Department of Interior (DOI) for administrative withdrawal of land for Site and Preliminary Design Validation (SPDV) experiments at WIPP.
- 1980 - Jul: House Armed Services Committee disagrees with Carter proposal; therefore, rescinded funds are returned to WIPP mid-year.

### Federal Legislation, Judicial Decisions, and Regulatory Requirements Related to Nuclear Waste Disposal

- 1980 - NM and DOE begin negotiations on C&C Agreement to define procedures and process of cooperation. |

### Legal Challenges and New Mexico, National, and World Issues

- 1981 - Feb: NRC promulgates licensing procedures for SNF and HLW disposal in geologic repositories. District Court denies Citizens for Alternatives to Radioactive Dumping (CARD) motion for a preliminary injunction against constructing WIPP. Draft (but not final) Nuclear Waste Policy Act (NWPA) defines TRU waste as waste contaminated with transuranic radioisotopes with half-life greater than 20 yr and activity greater than 100 mCl/g. Mar: Developing generic disposal criteria for radioactive wastes is difficult, thus EPA starts developing standards for each waste type. |

- 1981 - Jan: DOE WP plans to begin construction. 20th Century Fox, Sony, and HBO agree to produce a movie about WIPP. |


- 1981 - Jan: DOE WP plans to begin construction. 20th Century Fox, Sony, and HBO agree to produce a movie about WIPP. |

- 1981 - Aug: DOE WP plans to begin construction. 20th Century Fox, Sony, and HBO agree to produce a movie about WIPP. |

- 1981 - Sep: After reviewing preliminary design, DOE declares detailed design of WIPP. 20th Century Fox, Sony, and HBO agree to produce a movie about WIPP. |
1982
USGS dismisses concerns about breccia pipes

1982
Disposal area moved to south of shafts

1982 - Mar: Second 1.8 m shaft completed (-40 m in Castile Fm) of drilling fluid left in the shaft. Westinghouse suggests eliminating fourth shaft along with other cost saving measures.  

May: Repository level selected. June: Army Corps of Engineers assumes responsibility for all phases of construction management. July: Drilling of DOE-1 started and completed to top of Amerydite I in Castile Fm. Oct: Underground excavation started to connect the two shafts. Nov: Excavations connect the two existing shafts. Following evaluation of WIPP-12, TRU disposal area moved to 1980 m south (experimental area left in original area). Schedule calls for opening WIPP in April 1989. First shaft sealing concepts presented. SNL publishes report outlining in situ tests to be performed in next several years.  

Dec: SNL completes interim report on dissolution of evaporites in and around the Delaware Basin. (part of SA). USGS completes breccia pipe report (part of SA) and dismisses concerns.  

1982
DOE-2.  

1983
Full construction begins

1983 - Mar: SNL, USGS, and contractors complete most reports required by SA (e.g., USGS reports data from transmissivity at 20 locations)  

SNL reports groundwater flow in Rustler Fm.  

Technical support contractor, Westinghouse, reports on brine reservoirs in the Castile Fm.  

Excavation of experimental rooms begins, and Rachels begins final (T) design. Apr: WIPP Panel-NAS tours WIPP underground to examine SPQV tests.  

May: Repository level selected. Oct: Drilling of pilot hole for third shaft begins (exhaust shaft) and is completed in December.  

Dec:  

1984
SNL begins testing many underground experiments

1984 - Feb: Raised bore reaming completed of third shaft. Apr: As rooms excavated, SNL begins many thermal and structural and waste package (e.g., defense HLW) field tests defined in 1982, ushering in the system characterization phase of project.  

May: Pumping tests at DOE-1 suggest fracture flow in Castile. First in situ gas flow measurement conducted around underground drift.  

June: Second shaft enlarged from 1.8 m to 9 m.  


General Atomic Technologies completes one container; SNL sends it to ORNL test facility because container exceeds SNL weight limit for 30 ft drop and puncture test, etc., required in 10 CFR 71.  


1984 - Feb: EPA SAB endorses probabilistic approach of 40 CFR 191 but states performance criteria too restrictive and recommends several changes.  

Apr: LEAF vs. DOE The USGS reports that DOE is not meeting performance criteria of the test facility.  

1984 - Nov: First modification to O&C Agreement limiting remote-handled (RH) TRU waste amount to 1 x 10^9 Ci.
### Milestones for Disposal of Radioactive Waste in the United States

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<tr>
<td>1985</td>
<td>1985 EPA issues 40 CFR 191</td>
<td>Starred flies at half of depth in 1982</td>
<td>• 1985 - Jan: Blasting of third shaft to final 4.8 m diameter completed. Excavation begins for circular room H. SNL reports on discrepancy between measured and predicted salt creep first reported at 90.4 m south in 1985. SNL General Atomic Technologies disassembles TRUPACT-I and cuts in half with door rebuilt, while rebuilding, punctures damage replicated to match damage in original TRUPACT-I. With the definition of a 5-m boundary to the disposal system in 40 CFR 191, project begins to focus more on near-field hydrologic modeling rather than regional modeling. Apr: SNL turns to heat for simulated defense high-level waste (DLW) canister experiments.</td>
<td>• 1985 - DOE Sec. Harrington: President approves the three repository candidates as recommended by DOE for SNAF and HLW. President concurs with DOE recommendation that defense SNAF and HLW be disposed of in commercial repository. Note: DOE attempts to define &quot;by-product material&quot; to include mixed waste and thus exclude EPA regulation.</td>
<td>• 1985 - Jan: NM receives EPA authorization to regulate hazardous wastes. Feb: Natural Resources Defense Council (NRDC) sues EPA to issue 40 CFR 191 as mandated by NWPA of 1982. NRDC notifies DOE that the single-shelled, vented rectangular transportation container for TRU waste, TRUPACT-I, is unacceptable for NM.</td>
</tr>
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<td>1987</td>
<td>1987 BRU pockets cannot be disseminated</td>
<td>• 1987 - May: DOE redefines &quot;by-product material&quot; to exclude most new radioisotopes, and thereby TRU waste is subject to RCRA (and HSWA). July: DOE requests NASA, Nuclear Regulatory Commission (NRC), and Department of Energy (DOE) to develop a consensus document for waste characterization for potential TRU. Aug: DOE selects Nuclear Packaging conceptual design for TRUPACT-II.</td>
<td>• 1987 - July: In response to legal challenges to individual and groundwater protection requirements in subpart B of the Court of Appeals, DOE certifies that the City of Boston lacks a sufficient number of triples for the standards set by the state. DOE certifies that the City of Boston lacks a sufficient number of triples for the standards set by the state.</td>
<td>• 1987 - Mar: NRC and World Issues</td>
<td>• 1987 - Feb: Strabec Amicipating compliance with NWPA of 1982. Oct: Environmental groups sue EPA over groundwater and individual protection standards in 40 CFR 191.</td>
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</table>

### Noteworthy Events
- 1985 EPA states mixed waste subject to RCRA
- 1986 EPA issues 40 CFR 191
- 1987 BRU pockets cannot be disseminated

### Technical Milestones Related to the WIPP
- Starred flies at half of depth in 1982
- 40 CFR 191
- TRUPACT-I
- CS+TRU and IH+TRU container behavior

### U.S. President and DOE: Directives and Decisions
- President approves the three repository candidates as recommended by DOE for SNAF and HLW.
- President concurs with DOE recommendation that defense SNAF and HLW be disposed of in commercial repository.
- Note: DOE attempts to define "by-product material" to include mixed waste and thus exclude EPA regulation.

### Federal Legislation, Judicial Decisions, and Regulatory Requirements Related to Nuclear Waste Disposal
- EPA states that mixed waste (radioactive waste also meeting hazardous waste definition) is subject to RCRA and hazardous waste regulations.
- Sep: NRC promulgates probabilistic safety goals for nuclear reactors that are similar to 40 CFR 191.

### Legal Challenges and New Mexico, World Issues
- NRDC notifies DOE that the single-shelled, vented rectangular transportation container for TRU waste, TRUPACT-I, is unacceptable for NM.
1988

1988: Brine seepage into WIPP big issue

1988: May: WIPP begins drilling fourth shaft (air intake shaft) after reevaluating 1982 decision to eliminate it. Sep: SNL reports on in situ permeability (1000 times lower than 1979) and small potential brine inflow. Members of NAS BRWM (not WIPP Panel) study brine inflow; conclude no problem but suggest brine inflow test and less waste be used for pilot phase. First prototype of TRUPACT-II passes structural tests, but fails engulfing fire test at seals. SNL begins work on CAMCON to link detailed consequence models in probabilistic PA. SNL also simultaneously begins work on prototype of CAMCON to meet Dec. 1989 deadline. SNL completes pumping tests at H-II and begins using results to calibrate regional flow model.

1989

1989: Brine Wall falls

1989: Demo for WIPP PA

1988: NM Congressmen ask NAS BRWM to study brine inflow controversy. With continued technical problems (e.g., TRUPACT-II not yet licensed), NM Congressional delegation cannot reach consensus, and WIPP legs allow release without human intervention out of 26 parameters, solubility, intrusion time, and borehole permeability most important, cuttings from direct drilling set at three drums.

1988: DOE announces that WIPP will not open as scheduled in Oct. Dec: DOE abruptly cancels SNF and HLW experiments because of NWFPA (no funds available to remove and examine simulated disposal containers).

1988: DOE files request for administrative withdrawal of 16 mi with DOI (less than half of land allowed by 40 CFR 191). Dec: DOE issues Draft Supplemental EIS. Mar: SNL completes report to support Draft Supplemental EIS; report identifies generation of gasses from container and waste corrosion as issue (see 1978) because salt permeability factor of 1000 lower than thought in 1979. Based on initial analysis results in 1988, DOE funds SNL to conduct new studies of gas generation. Also, different flow direction in past during wet climate hypothesized to explain discrepancy between geological analysis and current hydrologic flow in Culebra. DOE issues Draft Supplemental EIS. Dec: SNL reevaluates release scenarios and issues WIPP PA demonstration outlining process for future PA. No release without human intervention; out of 26 parameters, solubility, intrusion time, and borehole permeability most important, cuttings from direct drilling set at three drums.

1989-1989: Legislature unanimously removes "WIPP exemption" in hazardous waste laws so EPA will grant authority to regulate radioactive mixed waste. Now: Berlin Wall falls signaling the end of the Cold War and greatly changing future demands for nuclear weapon material and, thus, amount and composition of TRU waste going to WIPP.

1989: NRC approves the pressurized transportation container for shipping contact-handled (CH) TRU to TRUPACT-II.
Milestones for Disposal of Radioactive Waste in the United States

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<tr>
<td>1990</td>
<td>- Jan: Construction officially complete. SNL and Westinghouse complete report on the pilot test phase of WIPP. Construction officially complete, testing phase (~5 yr) should proceed, and then another Supplemental EIS should be prepared before going to full operation.</td>
<td>- 1990 - Jan: DOE issues Final Supplemental EIS.</td>
<td>- 1990 - Oct: EPA issues no-migration variance for first phase of WIPP.</td>
<td>- 1990 - Jul: NM granted authority by EPA to regulate radioactive mixed waste, and thus WIPP waste becomes subject to NM regulations. NM Environmental Improvement Division requests submittal of Parts A and B of FCPA permit.</td>
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<td>1991</td>
<td>- Apr &amp; Aug: To extend life of room 1, panel 1 for gas generation tests; internal and external panels meet and recommend roof support.</td>
<td>- 1991 - Westinghouse completes Parts A and B of RCRA permit application.</td>
<td>- 1991 - In response to audit, AL manager creates WIPP Project Integration Office (WPIO) in Albuquerque over WPO in Carlsbad.</td>
<td>- 1991 - Jul: DOI modifies administrative land withdrawal order to allow test phase of WIPP.</td>
<td>- 1991 - Jul: NM granted authority by EPA to regulate radioactive mixed waste, and thus WIPP waste becomes subject to NM regulations. NM Environmental Improvement Division requests submittal of Parts A and B of FCPA permit.</td>
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Federal Legislation, Judicial Decisions, and Regulatory Requirements Related to Nuclear Waste Disposal:

- 1990 - Oct: EPA issues no-migration variance for first phase of WIPP.
- 1991 - Jul: NM granted authority by EPA to regulate radioactive mixed waste, and thus WIPP waste becomes subject to NM regulations. NM Environmental Improvement Division requests submittal of Parts A and B of FCPA permit.

1993 - DOE decides not to test waste at WIPP.

1993 - DOE submits application to New Mexico Environment Department (NMED) for RCRA permit for test phase.

1993 - Aug: DOE submits application to New Mexico Environment Department (NMED) for RCRA permit for test phase.

1993 - DOE concurs with NAS and decides not to emplace waste in a pilot phase at WIPP. DOE decides to make draft Compliance Certification Application (CCCA) to EPA, because actual waste not coming to WIPP. "Bin tests" cancelled. Dec: DOE publishes updated revision of WIPP inventory, COI.

1993 - DOE Sec Hazel O'Leary. Oct: DOE concurs with NAS and decides not to emplace waste in a pilot phase at WIPP. DOE decides to make draft Compliance Certification Application (CCCA) to EPA, because actual waste not coming to WIPP. "Bin tests" cancelled. Dec: DOE publishes updated revision of WIPP inventory, COI.

1993 - EPA recommutes 40 CRF 191.


1994 - DOE submits DCCA to EPA for review.


1995 - Feb: DRD completes computer specialists tried to modify CAMCON implementation to enforce software configuration management and control runs for PA calculations. Second attempt at SPM.
## Milestones for Disposal of Radioactive Waste in the United States

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<td>1996</td>
<td>For 40 CFR 194</td>
<td>1996 - Apr: SNL completes tracer test in Culebra, decides dual-porosity model is appropriate.</td>
<td>40 CFR 194; director preliminary decision to consider additional criteria in assessing system performance.</td>
<td>- Requires waste characterization analysis and engineered barrier evaluation</td>
<td>- NM AG Udall sues EPA for proposed 40 CFR 194 requirements.</td>
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<td>1996 - Oct: DOE sends 80,000-page, 400-lb. CCA to EPA.</td>
<td>1996 - Feb: EPA promulgates final rule 40 CFR 194, directs DOE to consider additional criteria in assessing system performance.</td>
<td>- Requires waste characterization analysis and engineered barrier evaluation</td>
<td>- EPA and DOE agree to comply with land disposal restrictions of RCRA but other requirements in proposed 40 CFR 194 still apply.</td>
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<td>1996 - Sep: Congress amends WIPP LWA and relieves WIPP of need to comply with land disposal restrictions of RCRA but other requirements in proposed 40 CFR 194 still apply.</td>
<td>1986 - Feb: EPA promulgates final regulation.</td>
<td>- Requires waste characterization analysis and engineered barrier evaluation</td>
<td>- NM AG Udall sues EPA for proposed 40 CFR 194 requirements.</td>
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<td>1997 - May: In letter to DOE secretary, EPA Administrator Browner directs DOE application &quot;complete&quot;; this starts the 1-year clock for review of CCA.</td>
<td>1997 - DOE Secretary: Pena, Jan: DOE holds hearings on second Supplemental Draft EIS for WIPP in Carlsbad, Albuquerque, and Santa Fe, New Mexico.</td>
<td>- Requires waste characterization analysis and engineered barrier evaluation</td>
<td>- EPA promulgates final rule 40 CFR 194, directs DOE to consider additional criteria in assessing system performance.</td>
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### Technical Milestones for Disposal of Radioactive Waste in the United States

- **1996 - Apr:** SNL completes tracer test in Culebra, decides dual-porosity model is appropriate. DOE directs preliminary decision to consider additional criteria in assessing system performance.
- **1996 - Oct:** DOE sends 80,000-page, 400-lb. CCA to EPA.
- **1996 - Sep:** Congress amends WIPP LWA and relieves WIPP of need to comply with land disposal restrictions of RCRA but other requirements in proposed 40 CFR 194 still apply.
- **1997 - Jan:** Conceptual Model Peer Review Group (formed in response to 40 CFR 194) concludes 22 of 24 conceptual models are adequate. DOE directs preliminary decision to consider additional criteria in assessing system performance.
- **1997 - May:** In letter to DOE secretary, EPA Administrator Browner directs DOE application "complete"; this starts the 1-year clock for review of CCA.

### U.S. President and DOE: Directives and Decisions

- **1996 - Feb:** EPA promulgates final rule 40 CFR 194, directs DOE to consider additional criteria in assessing system performance.
- **1997 - DOE Secretary: Pena, Jan:** DOE holds hearings on second Supplemental Draft EIS for WIPP in Carlsbad, Albuquerque, and Santa Fe, New Mexico.

### Federal Legislation, Judicial Decisions, and Regulatory Requirements Related to Nuclear Waste Disposal

- **1986 - Feb:** EPA promulgates final regulation.
- **1997 - DOE Secretary: Pena, Jan:** DOE holds hearings on second Supplemental Draft EIS for WIPP in Carlsbad, Albuquerque, and Santa Fe, New Mexico.
- **1997 - May:** In letter to DOE secretary, EPA Administrator Browner directs DOE application "complete"; this starts the 1-year clock for review of CCA.

### Legal Challenges and New Mexico, National, and World Issues

- **1996 - Apr:** NM AG Udall sues EPA for proposed 40 CFR 194 requirements.
- **1997 - May:** In letter to DOE secretary, EPA Administrator Browner directs DOE application "complete"; this starts the 1-year clock for review of CCA.
<table>
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<th>Year</th>
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<td>1998</td>
<td>EPA certifies WIPP.</td>
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<td>1999</td>
<td>NMED grants RCRA permit.</td>
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</table>

  - Apr: First shipment of non-RCRA waste arrives at WIPP from NIEEL.  
  - Jun: First shipment of non-RCRA waste arrives at WIPP from Rocky Flats.  

- **1998** - Jan: DOE publishes record of decision to proceed with opening WIPP based on second Supplemental EIS.  
  - Jul: DOE Secretary Richardson (former NM Congressman).  

- **1998** - May: EPA certifies WIPP.  

- **1998** - Jul: NM AG Uhl issues EPA alleging insufficient time to comment on CCA, CARD and SWRC also file lawsuits.  

- **1999** - Mar: Judge Penn lifts injunction placed on WIPP in 1992; also revokes decision and states WIPP does qualify for interim status under RCRA.  
  - Jun: Court of Appeals, District of Columbia, dismisses (without hearing oral arguments) CARD and SWRC petition to overturn EPA certification.  

- **1999** - Feb & Mar: NMED holds hearings in Santa Fe on RCRA permit for WIPP.  
  - Apr: NM AG Madrid withdraws from lawsuit challenging EPA certification.  
  - Oct: NM grants WIPP RCRA permit.  

- **1999** - Jul: NM AG Uhl issues EPA alleging insufficient time to comment on CCA, CARD and SWRC also file lawsuits.
References

References for U.S. President and DOE: Directives and Decisions


References for Federal Legislation, Judicial Decisions, and Regulatory Requirements Related to Nuclear Waste Disposal


Ridge, TN: Oak Ridge National Laboratory. 47-58.


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N7 SRIC (Southwest Research and Information Center, Inc.). 1981. “Nuclear Waste Disposal,” The Workbook. Vol. VI, no. 2. 44. (Copy on file in the SWCF as WPO#47565.)


N9 SRIC (Southwest Research and Information Center, Inc.), Peter Montague; Michael Rutherford; Bill Pierce; and June Naylor, Plaintiffs, v. United States Department of Energy; James Edwards, Secretary of the United States Department of Energy; United States Department of Interior; United States Bureau of Land Management; and Robert F. Burford, Director of the Bureau of Land Management, Defendants. Civil No. 81-0537-JB. United States District Court, District of New Mexico. Action filed July 10, 1981. Judgment rendered October 1, 1984, by U.S. District Judge Juan C. Burciaga. (Copy on file in the SWCF as WPO#47567.)


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McVey, D.F. 1981. Analysis of Data from Line Source Thermal Conductivity Measurements Taken In Situ in Dome Salt at the Avery Island Mine. SAND81-1232. Albuquerque, NM: Sandia National Laboratories.


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