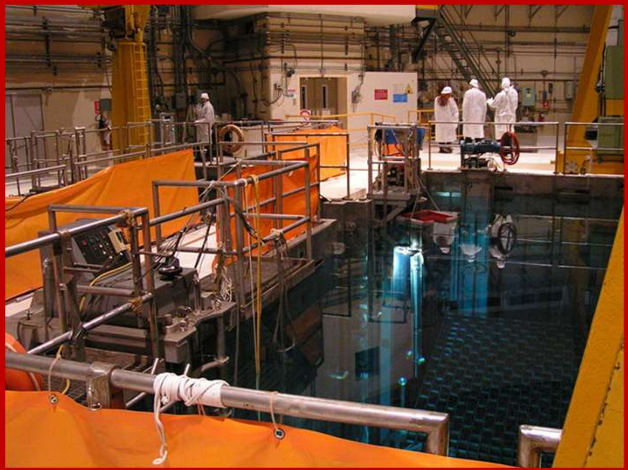
Spent (Used) Nuclear Fuel Management



"My situation, after all sophistry and reflection, had to finally to be summed up in three awful words—Lost! LOST!! LOST!!!

—Henry Lawson in "Journey to the Center of the Earth" by Jules Verne.

Spent (Used) Nuclear Fuel Management

At present, NRC licensees must store UNF at their reactor facilities.

During the early years of nuclear energy, UNF was expected to cool in on-site pools for only a few years before being sent to chemical reprocessing plants.

Options for UNF Management

For decades, experts throughout the world have studied many options for permanently managing UNF (and HLW)— including:

Storing UNF material at current storage sites.

Burying it in the ocean floor.

Options for UNF Management

Placing it on polar ice sheets.

Sending it into outer space.

Placing it underground in a geological repository.

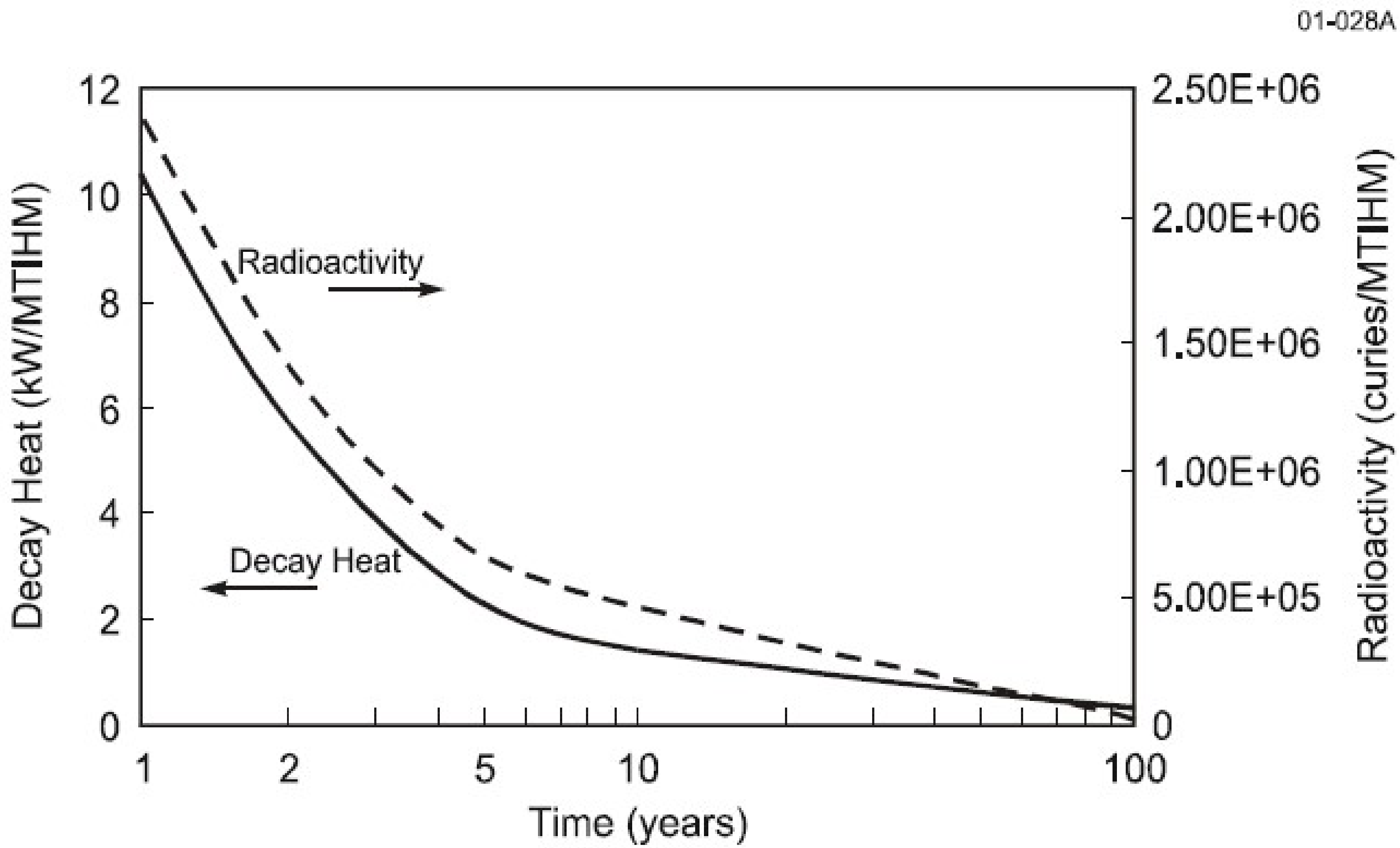
Chemical reprocessing it for future use (later lectures).

Wet Storage

When spent fuel is first removed from a reactor, it is placed in a pool of water contained in a steel-lined concrete basin on site.

The water serves 2 purposes:

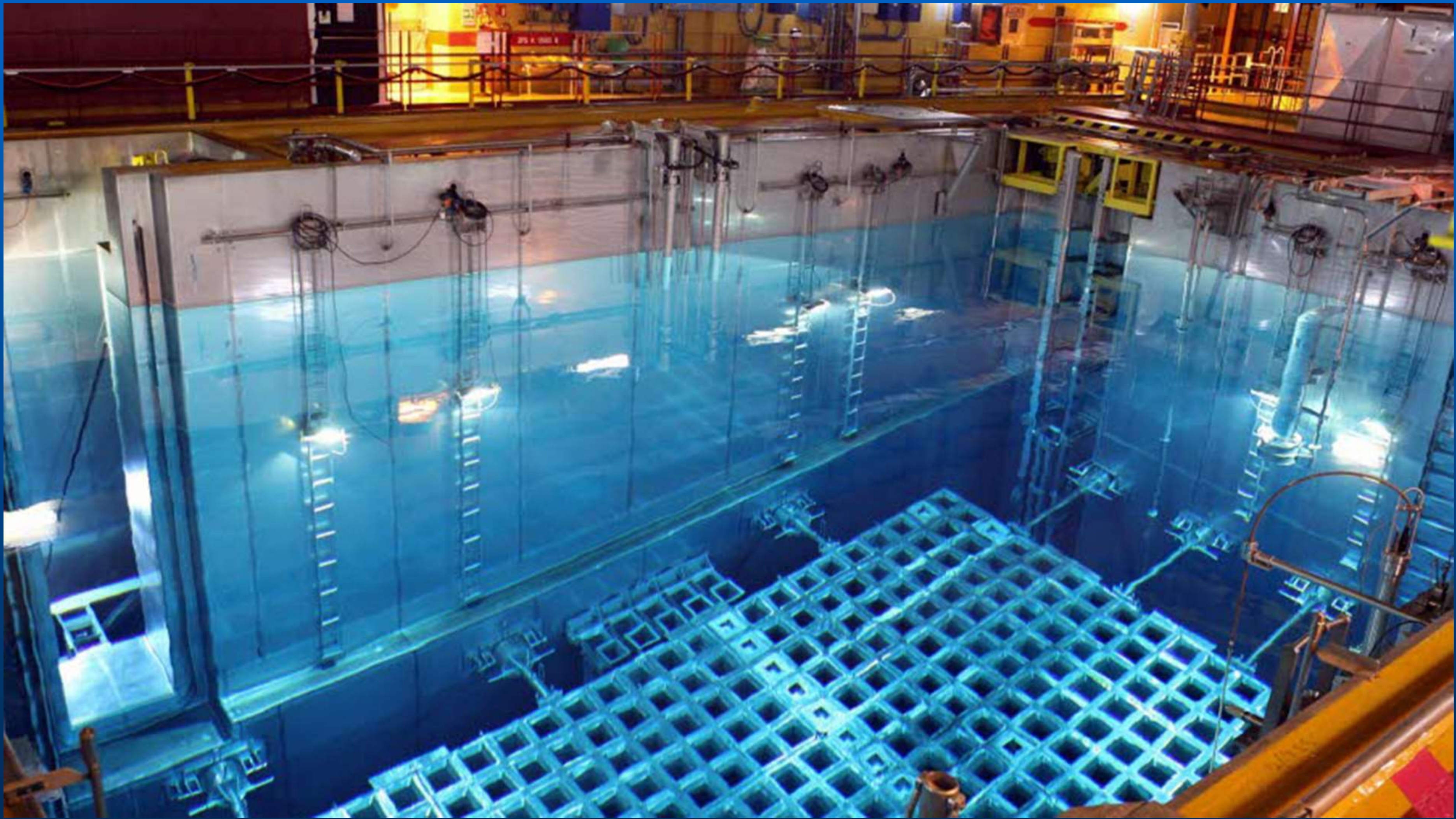
1. It serves as a shield to reduce the radiation levels that people working above may be exposed.
2. It cools the fuel assemblies that continue to produce heat (decay heat) for some time after removal.

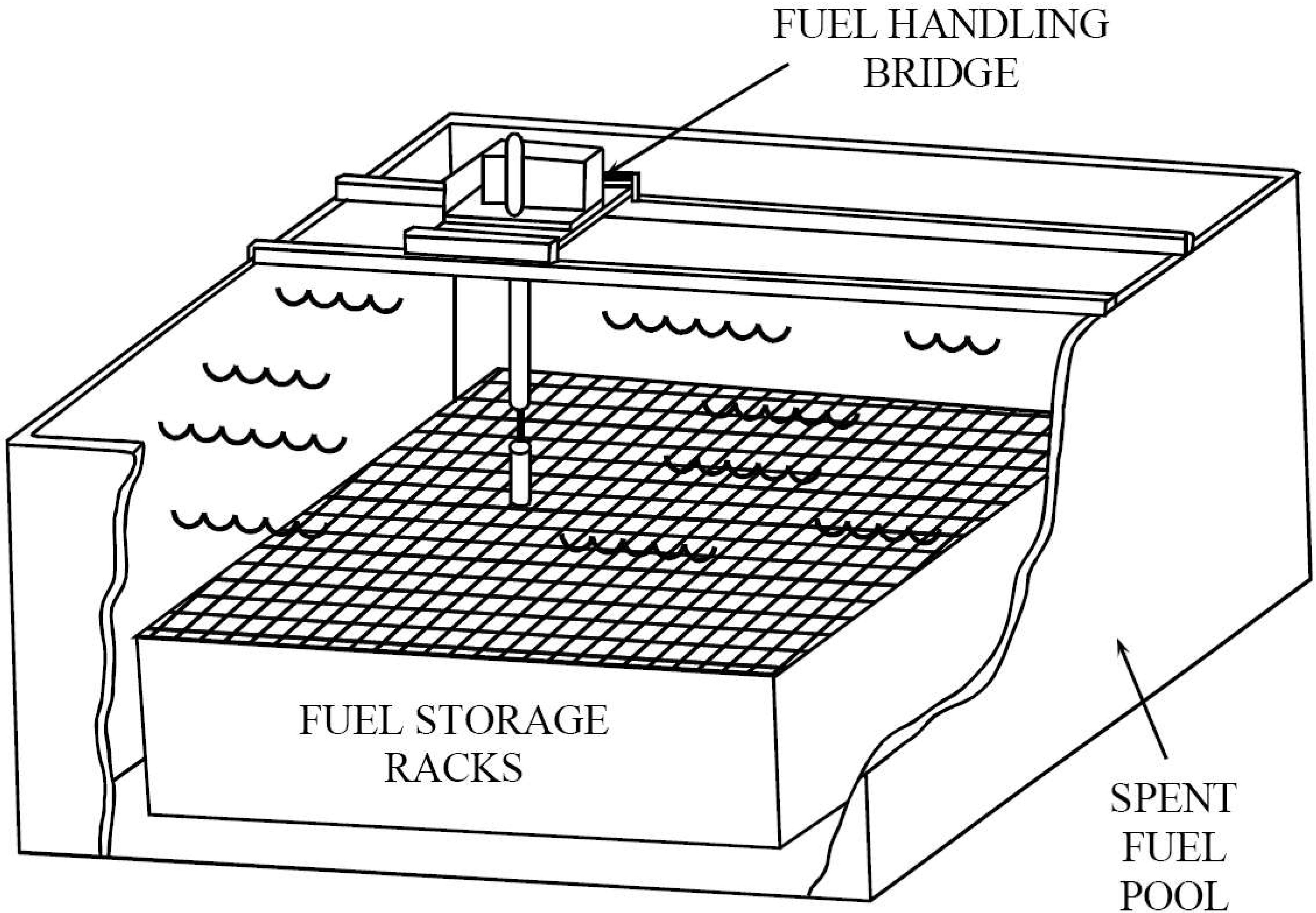


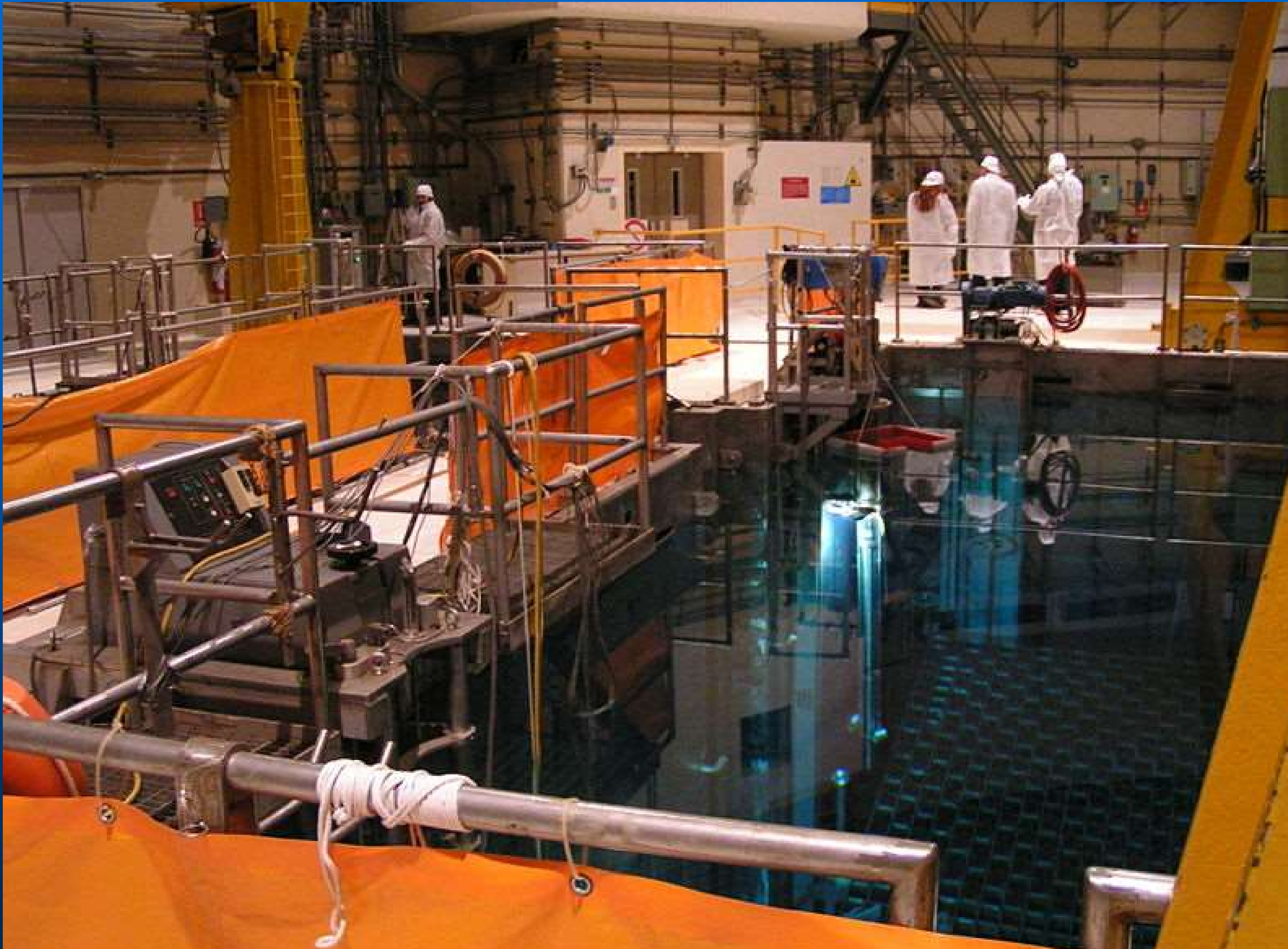
20 tons of UNF per year = 5 x 10^7 Ci after one year (1.9 x 10^6 TBq)

Fig. 2. SNF Radioactivity and Decay Heat Vs Time.

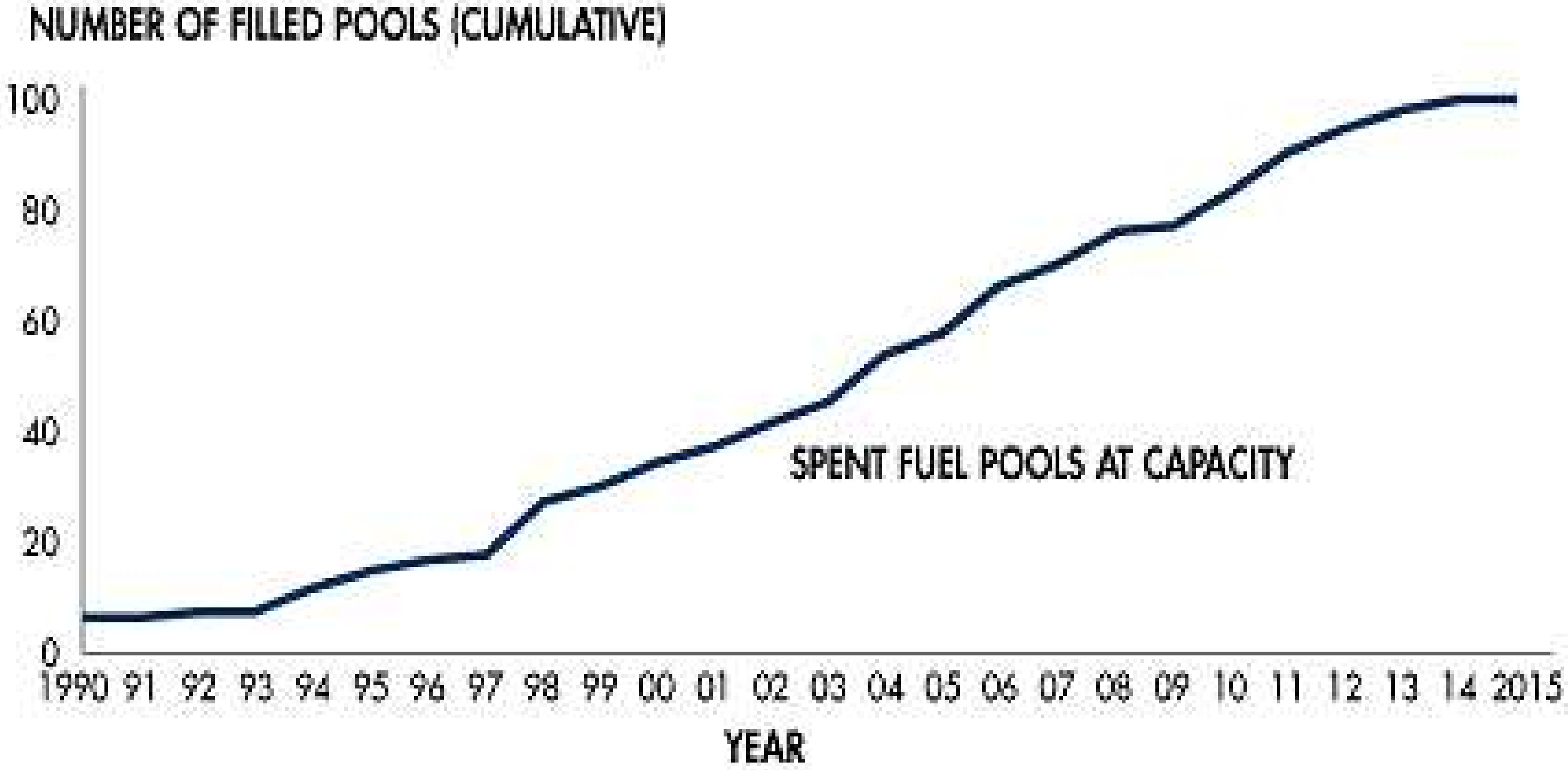
Wet Storage of UNF




FUEL HANDLING
BRIDGE
FUEL STORAGE
RACKS
SPENT
FUEL
POOL



Nuclear Fuel Pool Capacity



Note: All operating nuclear power reactors are storing used fuel under NRC license in spent fuel pools. Some operating nuclear reactors are using dry cask storage. Information is based on loss of full-core reserve in the spent fuel pools.

Source: Energy Resources International and DOE/RW-0431 – Revision 1

Nuclear Fuel Pool Capacity

About 43,000 tonnes of UNF are stored in pools at 110 operating and closed reactor sites across the United States, with 2+ billion Ci (7+ x 10^7 TBq) of long-lived radioactivity.

DOE estimates that storage space for an additional 10,000 tonnes of UNF will be needed in the future.

Dry Storage of UNF

After it has cooled considerably, some commercial power plants and government facilities move the fuel to dry-storage containers made of steel and/or concrete to shield from radiation.

The containers are either placed upright on concrete pads, or stored horizontally in metal canisters in concrete bunkers.

Dry Storage of UNF

The NRC has approved seven cask designs listed in its regulations (10 CFR, Part 72). Casks can be made of metal or concrete and are either placed horizontally or stand vertically on a concrete pad above ground.

Thirty-two U.S. States are currently storing UNF using the dry-storage option.

Dry Storage of UNF

The NRC approves the designs for UNF dry storage systems. The casks used in the dry storage systems are designed to resist floods, tornados, missiles, temperature extremes. They are to hold spent fuel already cooled in the spent fuel pool for at least 5 years.

"*NRC has determined that dry storage of SNF at reactor sites is generally safer than pool storage*" (CRS, 1998).

What is a “cask?”

A <u>canister</u> is a sealed container employed in many used fuel storage and transport cask systems.

Transfer Cask – a used-fuel cask that is employed strictly for transferring used nuclear fuel (individual assemblies or canisters) into storage or transport casks.

What is a "cask?"

Storage Cask – a used-fuel cask that is employed strictly for storage of used-nuclear fuel.

Transport Cask – a used-fuel cask that is employed strictly for off-site shipping (over the road or by rail) of used-nuclear fuel.

What is a "cask?"

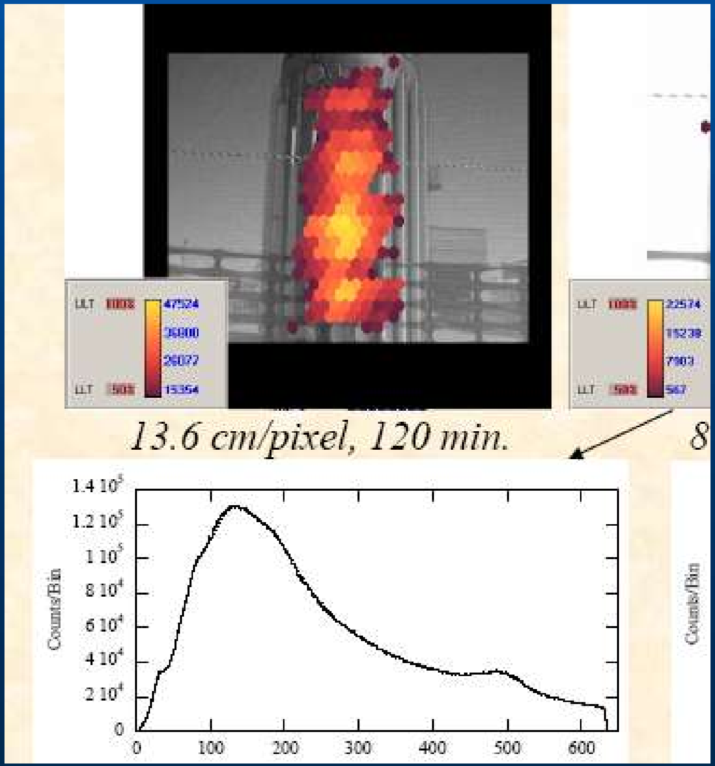
Dual-Use/Purpose Cask – a used-fuel cask that may be used for both storage and transportation of used nuclear fuel. Dual-use or -purpose casks are designed and licensed for dry storage and for transportation to a geological repository. Dual-purpose casks may elicit greater public acceptance because the name implies that the cask will be moved eventually, and not become a *de facto* permanent disposal practice.

"Ready For Yucca"

The TN68 is the Most Modern Transportation Cask in The Industry

Dry Storage of UNF. Dual purpose casks in Belgium

Various designs for dry storage casks have been tested.



Gamma ray and thermal neutron emissions (Battelle, 2003)




Table 6.4. The major vendors of dry storage casks, and examples of model names currently in use (from Greene et al., 2013).

Vendor	Examples and applications	Cask body composition
EnergySolutions (FuelSolutions™)	W150 (storage cask) W100 (transfer cask) TS 125 (transportation cask) VSC-24 (storage cask)	steel with concrete overpack steel with lead steel with lead vertical concrete cask
GNS Gesellschaft für Nuklear Service	CASTOR and CONSTOR (storage and transportation casks)	iron
Holtec International	HI-TRAC (transfer cask) HI-STORM and HI-STAR (storage and transportation overpacks)	steel with lead steel with lead or concrete
NAC International Inc.	MAGNASTOR and NAC series (storage and transportation casks) MAGNATRAN (transportation casks)	steel with concrete and steel with lead
AREVA-TN (formerly Transnuclear)	NUHOMS series (storage and transportation canisters) TN series (storage and transportation casks)	steel

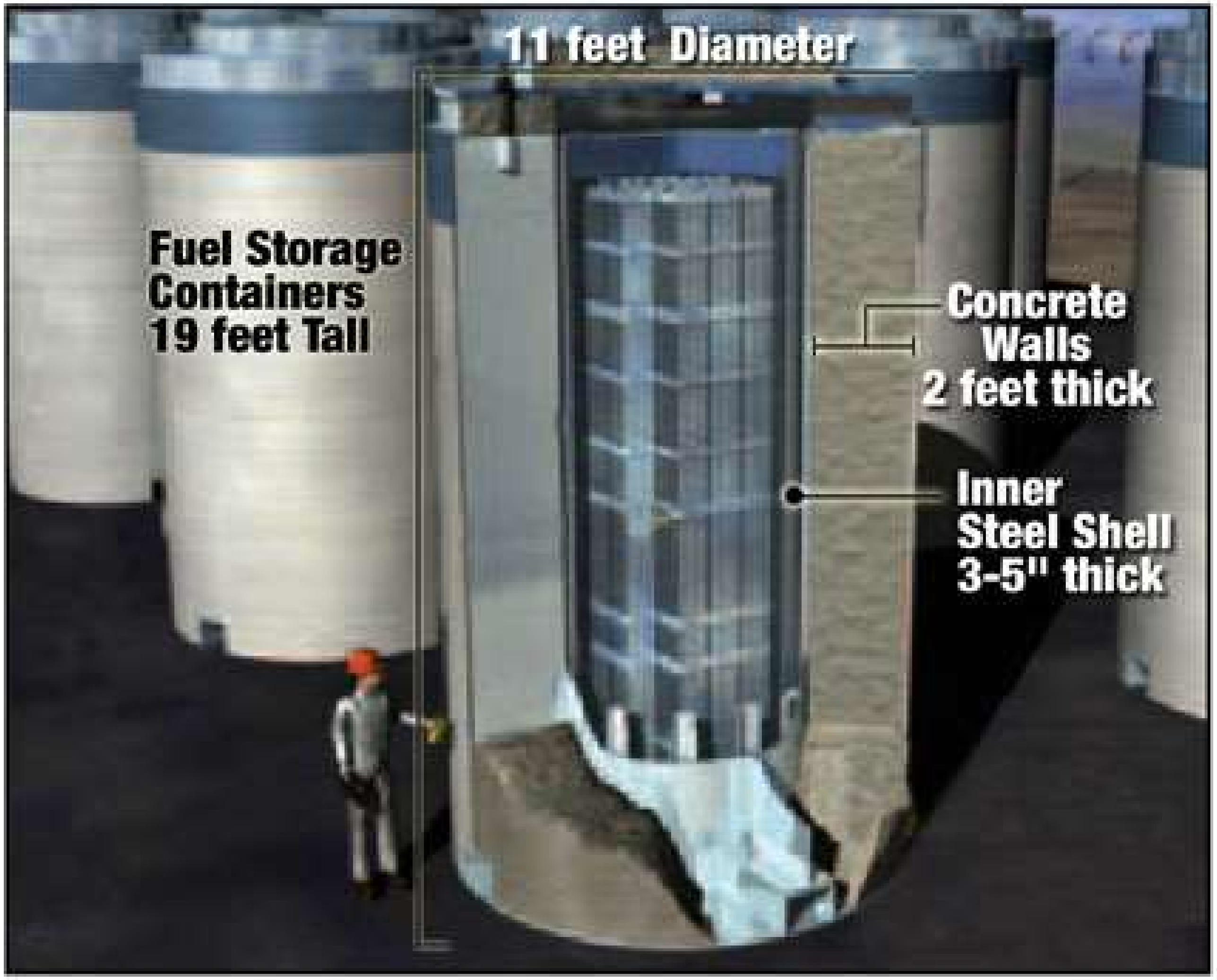
UNF storage at Indian Point Energy Center (NY)

Fuel Storage Containers
19 feet tall
11 feet diameter

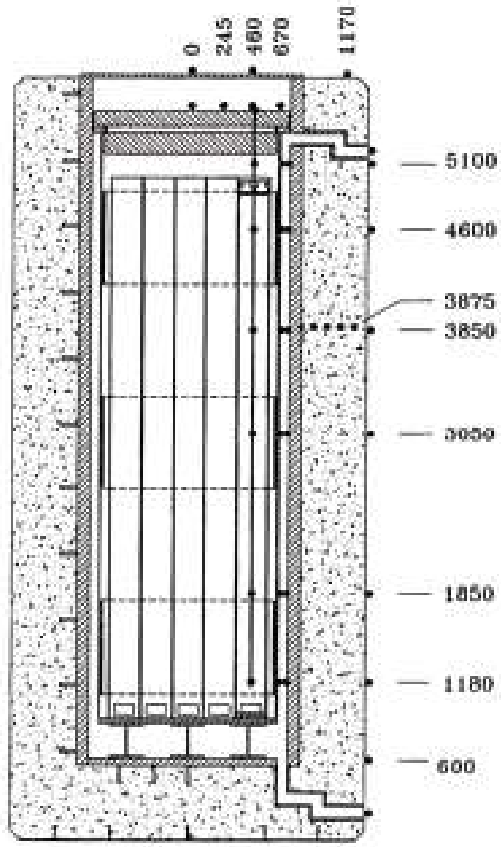
Concrete Walls
are at least 2 feet thick

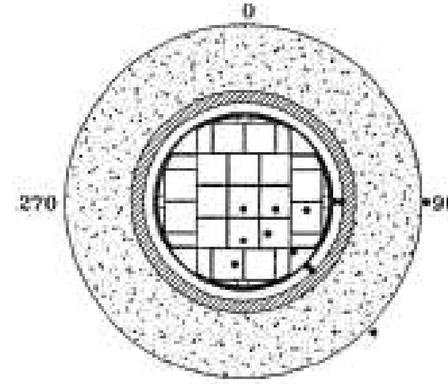
Inner Steel Shell
Is in the neighborhood of 3-5 inches thick

Total Weight
is over 180 tons

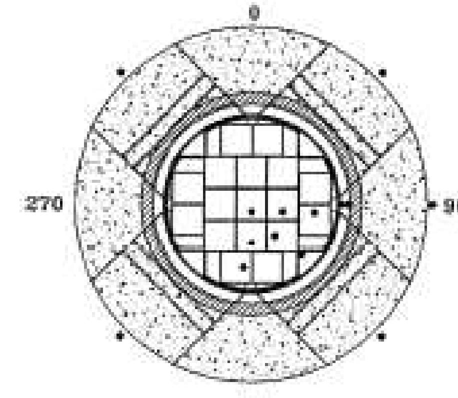


Dry Cask VSC-17

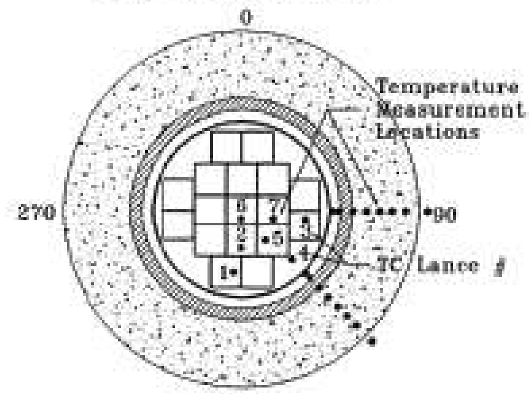




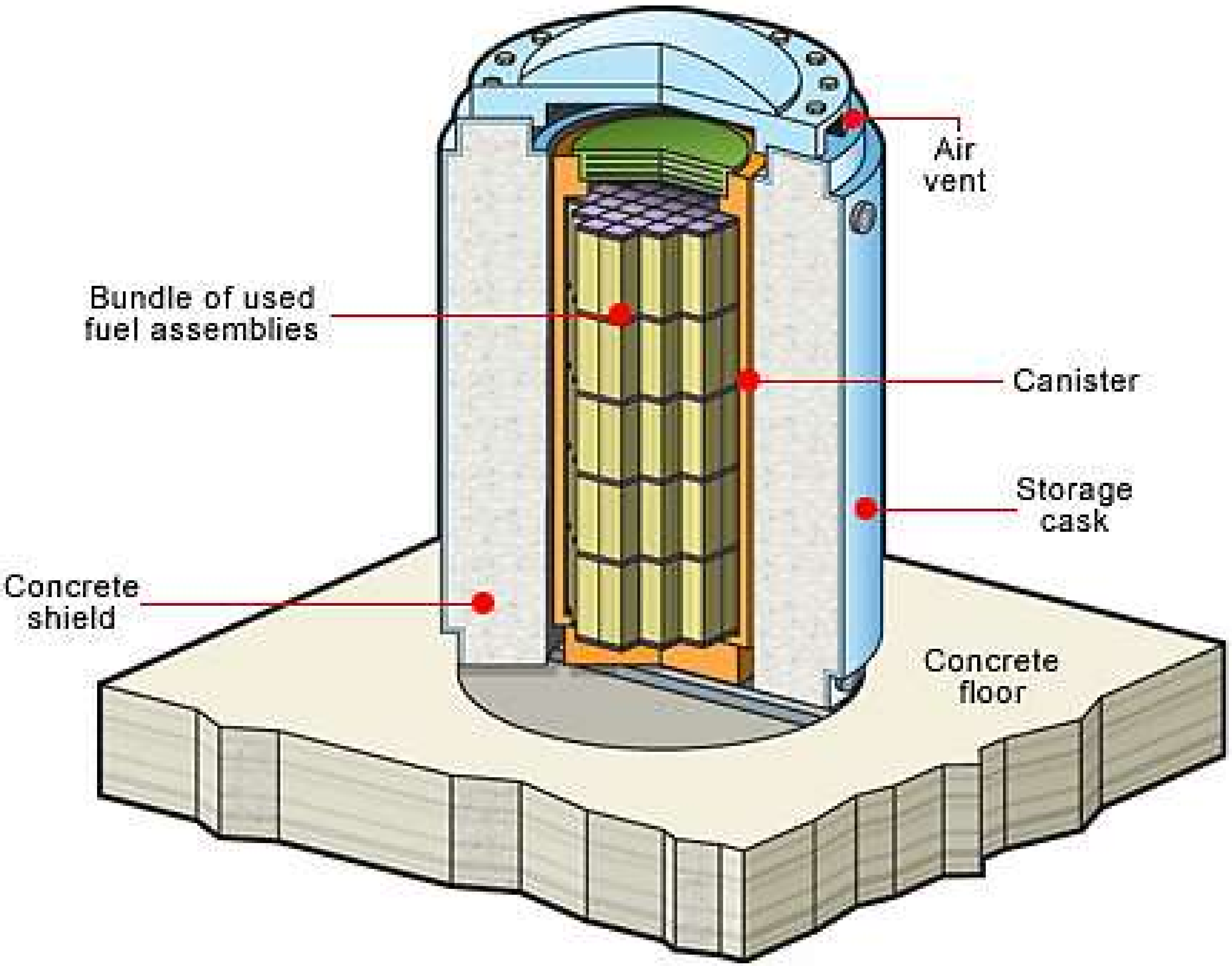
ELEVATIONS 3050 & 4600



ELEVATIONS 1180, 1850, & 5100
PLUS BOTTOM VENTS



ELEVATIONS 3850/3875


Air vent
Bundle of used fuel assemblies
Canister
Storage cask
Concrete shield
Concrete floor

The Transnuclear, Inc. TN 32 SNF Cask

Gamma radiation from a CASTOR V/21

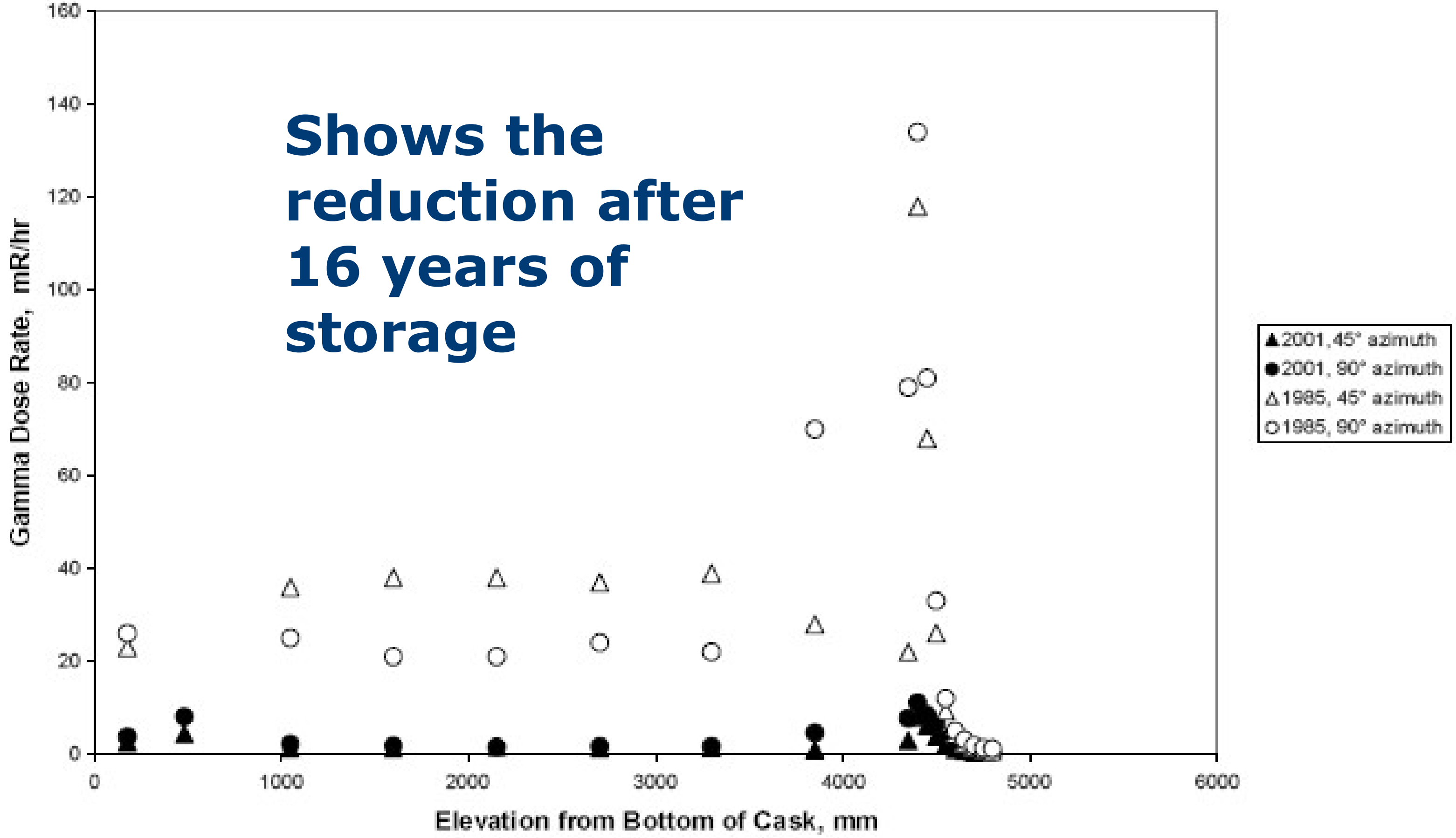


Figure 3-3. Comparison of the 2001 and 1985 gamma dose rates on the cask sidewall at the 45 and 90-degree azimuths.

Surface temperature of a V/21

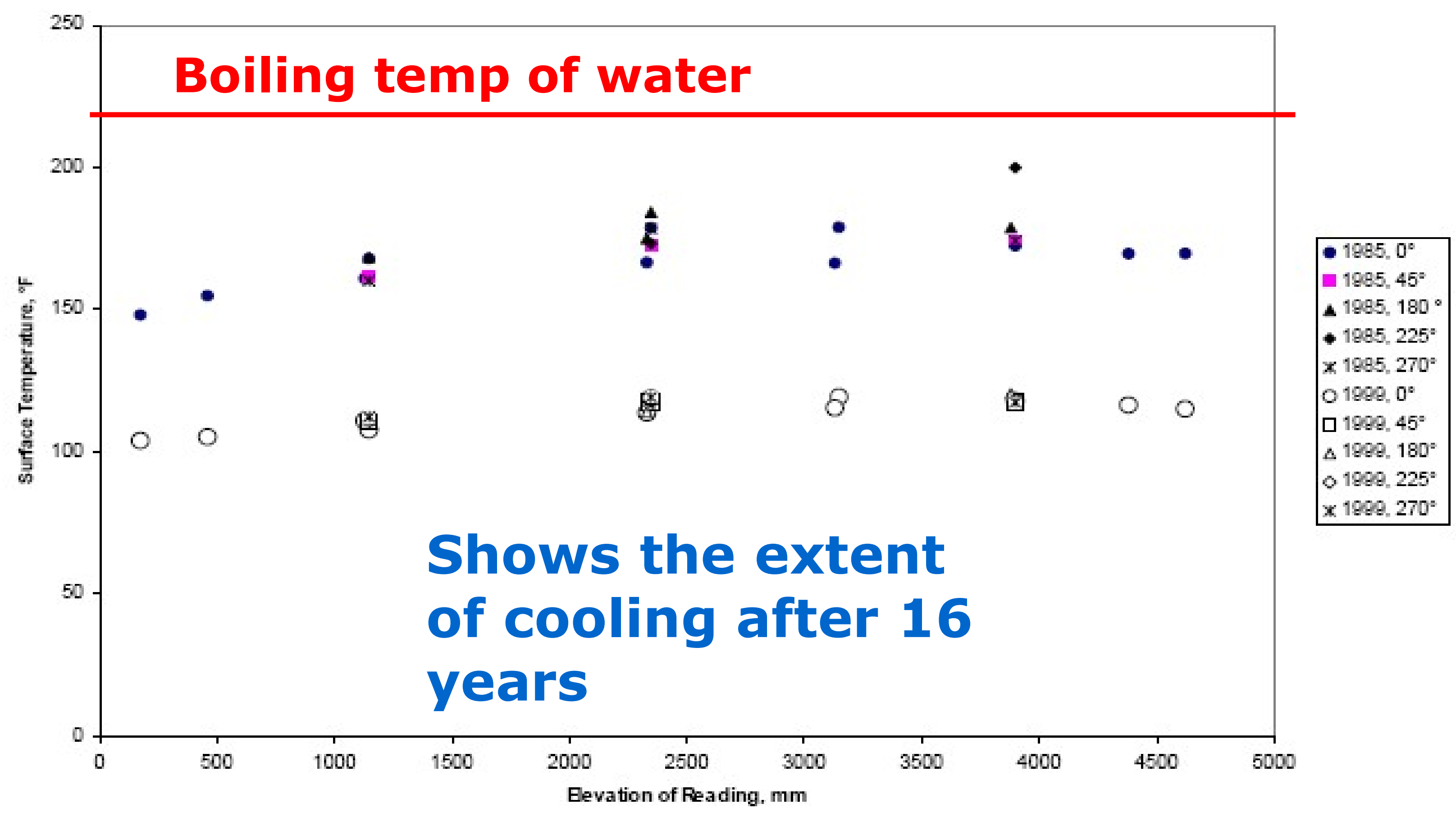


Figure 2-25. Surface temperatures of the CASTOR V/21 Cask.

General characteristics of a SNF cask

Outer steel envelope (0.6 to 15 inches thick [1.5 to 38 cm]), made of Alloy 22, a Ni-Cr-Mo alloy; resistant of corrosion, excellent for welding.

Inner basket canister/containment vessel.
Cask evacuated and filled with He to reduce metal corrosion.
Inner canister not to exceed 400º F (204° C, 478 K)

General characteristics of a SNF cask

Calculated dose rate at surface on sides about 147 mrem/hour (1.47 mSv/hr) and 1,460 mrem/hour 14.6 mSv/hr) at the top in a Safety Evaluation Report for a TN-68.

TN-68 can hold 68 BWR fuel assemblies

Weight of TN-68: 182,000 lbs (82,550 kg)

Loaded with SNF: 230,000 lbs (104,300 kg)

Cost of dry storage

Cost per storage cask: about 2.5 million U.S. dollars.

An EPRI (2012) study to move all U.S. 5-year cooled SNF into dry storage during at 10+ year effort would be 3.5 to 3.9 billion dollars, including procurement of the dry casks, cask loading operations, construction of the dry storage facility, and annual monitoring.

Regulatory point of shielding compliance (NRC)

The controlled area property boundary is the compliance point.

At a minimum distance from a single cask or group of casks to the compliance point of 100 m, the applicant must show that the radiation at the compliance point is less than 25 mrem/year (0.25 mSv/year).

NUREG-1536

Models available for applicants

TORT\DORT (three- and two-dimensional discrete-ordinate neutron/photon transport codes)

ONEDANT/TWODANT (one- and two-dimensional multigroup discrete-ordinate transport codes)

MCNP (Monte Carlo n-particle transport code)

ANISN (one-dimensional neutron attenuation code)

Skyshine (air-scattering code)

MORSE (Monte Carlo multigroup three-dimensional neutron and gamma transport computer code)

QAD-CGGP (three-dimensional point kernel gamma transport shielding computer code)

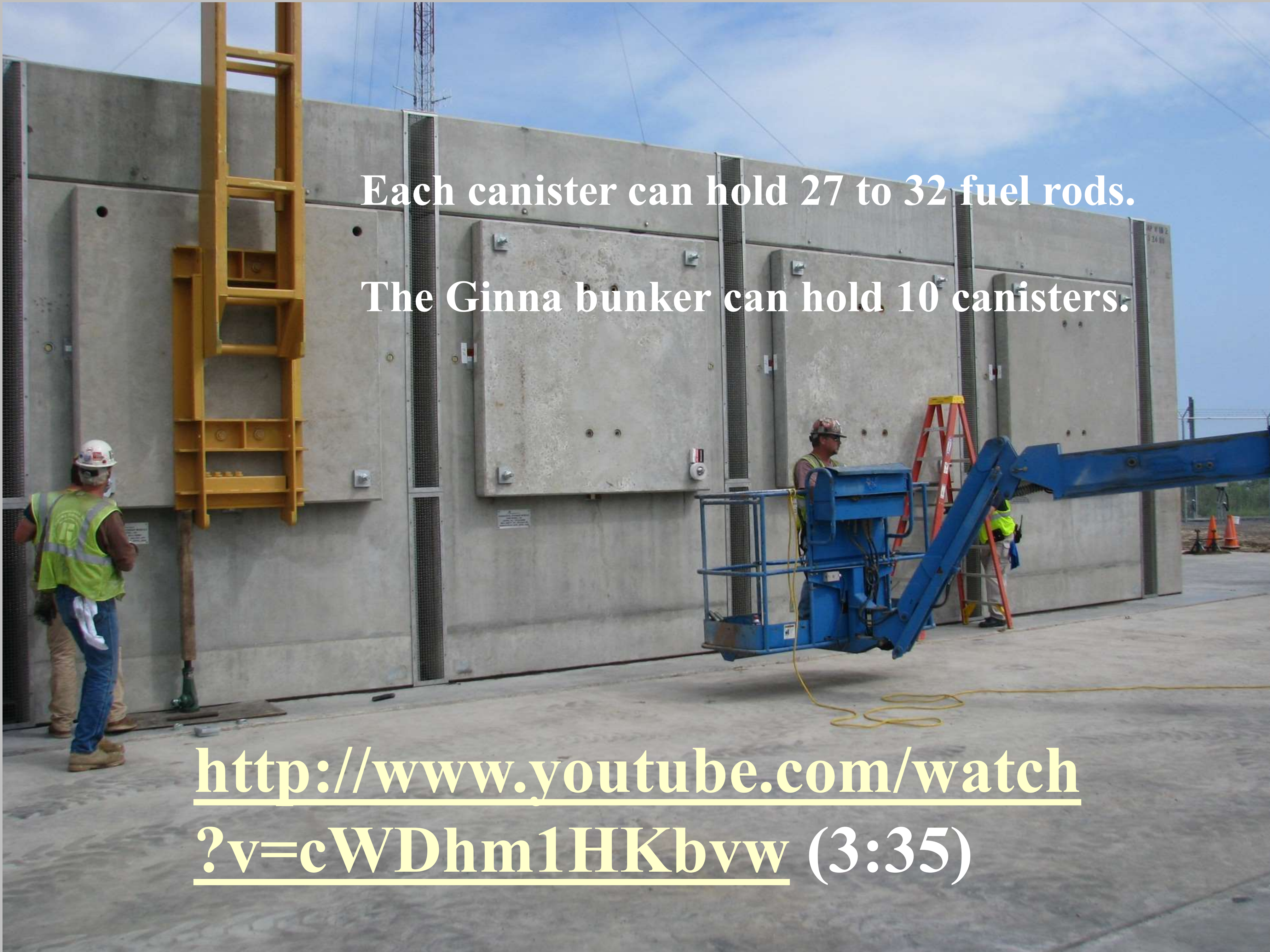
SCALE (a modular code system for performing standardized computer analyses for licensing evaluation)

Horizontal Storage Modules for SNF

Case study: The Robert E. Ginna (gah-nay) plant in New York.

Constellation Energy Group spent $70 million to build an above-ground SNF storage Facility.


GNP W 1B 3
3 25 09

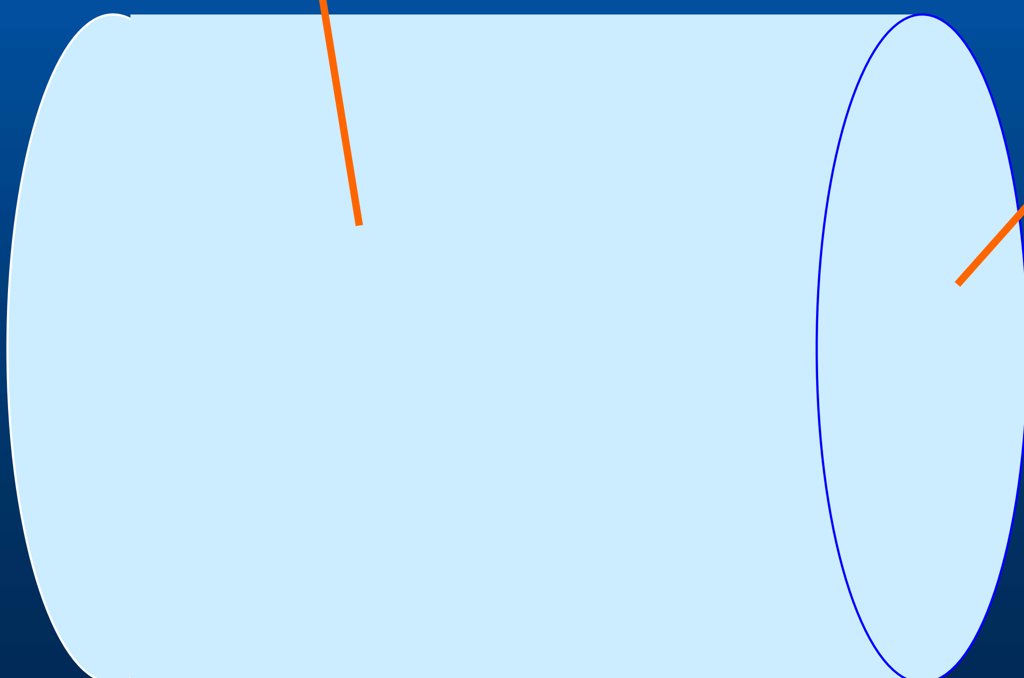

Each canister can hold 27 to 32 fuel rods.
The Ginna bunker can hold 10 canisters.
http://www.youtube.com/watch?v=cWDhm1HKbvw (3:35)

About the Transfer Cask

At the surface on the side: 200° to 300° F (99° to 149° C, 367 to 422 K) ,

< 950 mrem/hour (< 9.5 mSv/hr)

At 2 m, 225 mrem/hour (2.25 mSv/hr)



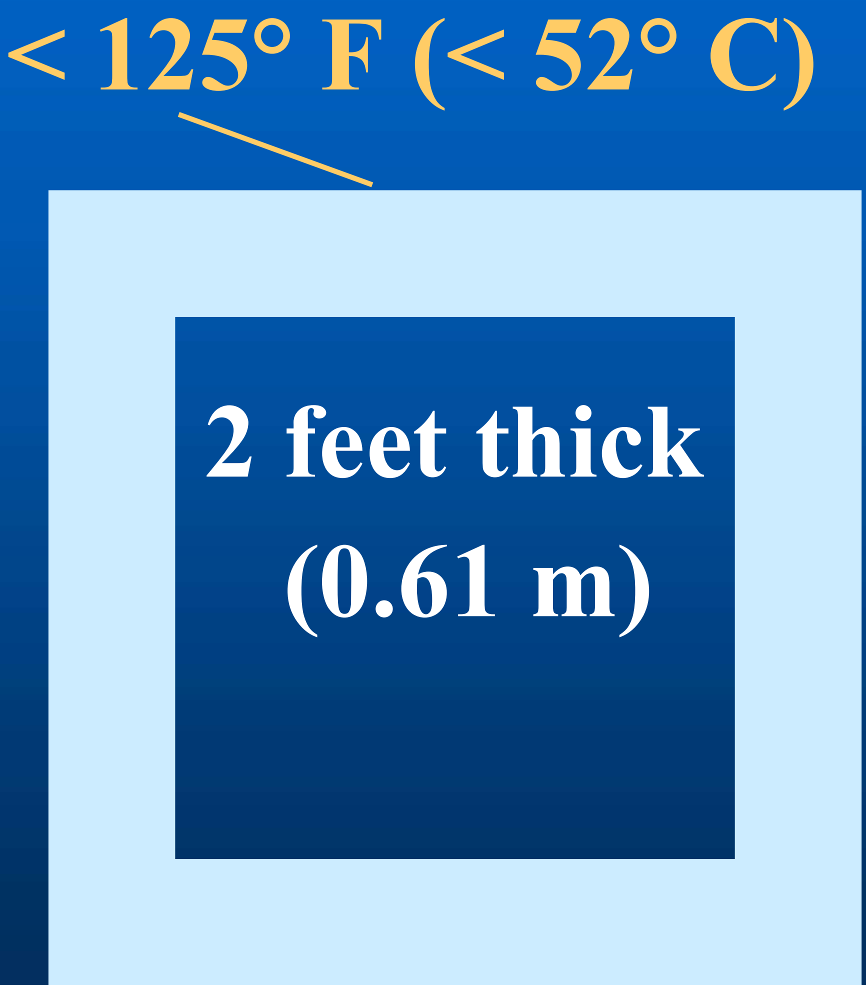
At the surface on the end:

< 50 mrem/hour (< 0.5 mSv/hr)

1 m distance: 15 mrem/hour (0.15 mSv/hr)

2 m distance: < 7 mrem/hour (0.07 mSv/hr)

About the Horizontal Storage Module



- Reinforced concrete
- Provides additional shielding and heat dissipation
- At 10 feet (3 m) away, < 9 mrem/hour (< 0.09 mSv/hr)
- At 100 feet (31 m) away, 0.2 mrem/hour (0.002 mSv/hr)
- (1,752 mrem/year = 2.8 x background)

Drywell storage at DOE facilities

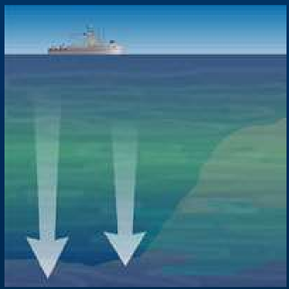
Drywell storage at Argonne National Laboratory

Table 6.3. Summary of the countries that have used or plan to use dry cask storage for used nuclear fuel, and the design capacity of the facilities (from International Atomic Energy Agency – Nuclear Fuel Information Service, 2015).

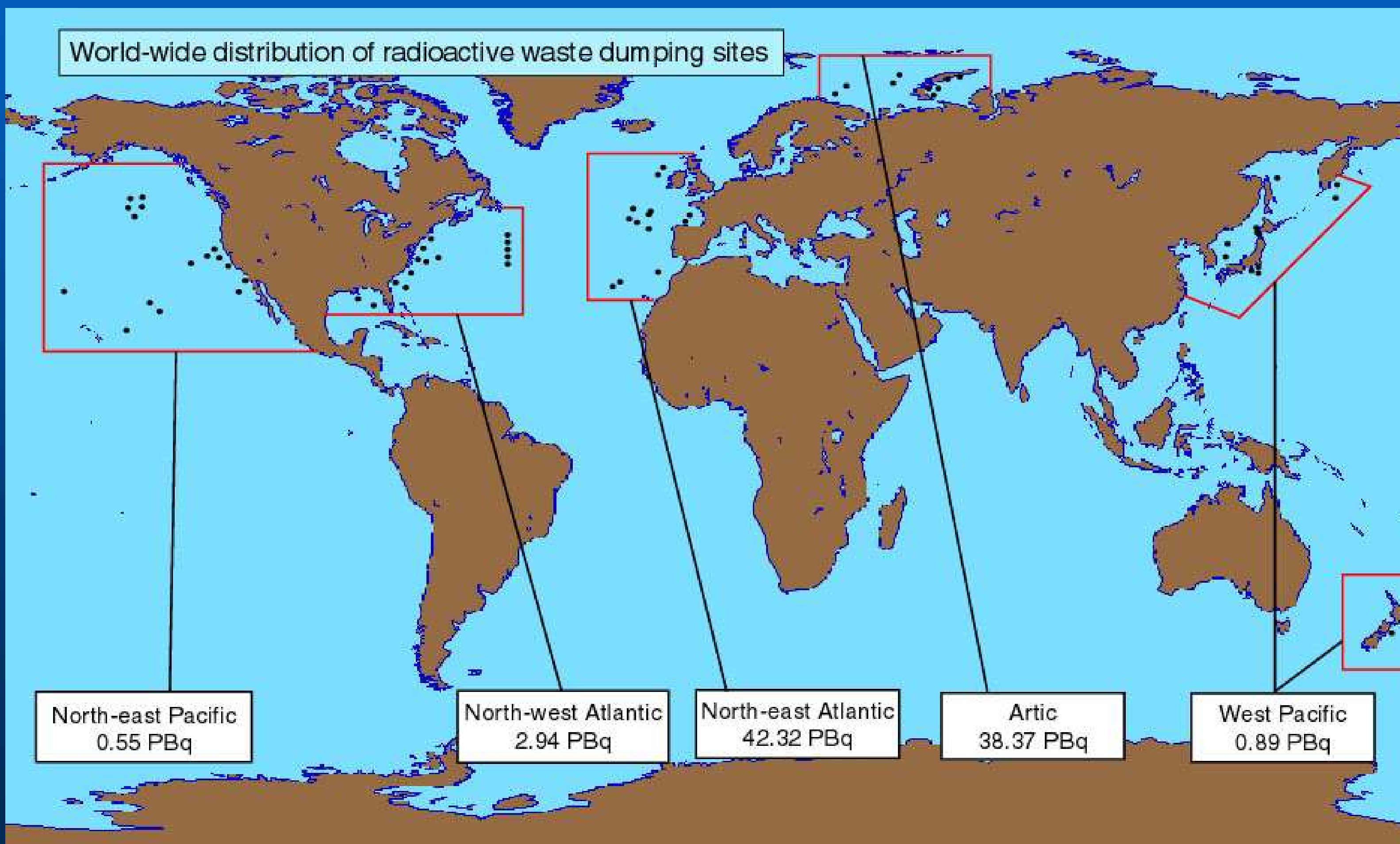
Country	First used	Design capacity (tonnes of heavy metal)
Argentina	1988	986 and 2,000
Armenia	2000	74 and 80.7
Belgium	1995	1,760 and 2,100
Bulgaria	1984	300 to 600
Canada	1985	Not given
Czech Republic	1995	600 to 1,370
Germany	1995	120 to 3,960
Hungary	1997	850
India	1990	20 and 570
Japan	1995	408 to 6,840 bundles
Republic of Korea	1992	6250
Lithuania	1998	98 bundles
Romania	2003	36,000 bundles/year
Russian Federation	2011	8,130
Slovakia	2017	780
Spain	1993	805
Switzerland	2001	600 and 2,500
Ukraine	1986	2,518
United Kingdom	1979	700
U.S.A.	1986	26 to 1,112

Ocean Disposal

Radioactive wastes were once routinely disposed in the world's oceans. Ocean disposal is essentially a technique that relies on dispersion and dilution rather that long-term containment as would be expected by placing the wastes into a deep, geological repository.



The first sea disposal by the USA in 1946; last by the Russian Federation in 1993. During the 48-year history of sea disposal, 14 countries have used more than 80 sites



Ocean Disposal

The depth of disposal ranged from 11 to 5,310 m, and it has been estimated that a total of 85,100 TBq (2,300 kCi) of radioactive waste were disposed in oceans from 1946 to 1993. The United Kingdom and the former USSR accounted for 87% of the total.

Table 6.1. Ocean disposal of radioactive waste from 1946 to 1993 (from IAEA, 1999).

Country	Activity of the wastes (TBq)	Period of disposal
USSR + Russia	39,246	1959-1993
United Kingdom	35,088	1948-1982
Switzerland	4,419	1969-1982
USA	3,496	1946-1970
Belgium	2,120	1960-1982
France	354	1967-1969
Netherlands	336	1967-1982
Japan	15.1	1955-1969
Sweden	3.2	1959, 1961, 1969
New Zealand	1.0	1954-1976
Germany	0.2	1967
Italy	0.2	1969
South Korea	Not reported	1968-1972

Ocean Disposal

The London Dumping Convention in 1973, which went into full force in 1975 to stop the disposal of high-level wastes.

***Control of Transboundary Movements of Hazardous Wastes and Their Disposal of 1989. The International Convention for the Prevention of Pollution from Ships in 1973*. The momentum created by a sequence of revisions that lead to a complete ban by 1993. The Russian Federation then ceased ocean disposal. They were the last to stop.**

Ocean Disposal

Field data suggest that global-scale ocean disposal/dumping without any regulatory framework did not result in widespread contamination of sea water or the marine food chain (see Chapter 5).

Ocean Disposal

Could ocean disposal be a valid option if it was conducted safely?

Sub-seabed sequestration: engineered placement of waste containers in bore holes within clay formations *beneath* the seabed.

Sub-seabed sequestration

Sub-seabed sequestration should be evaluated by conducting a pilot-scale project by the U.S. The waste containers could be disposed at depth of 4,000 to 5,000 m in the abyssal plain within U.S. Exclusive Economic Zone. Drill boreholes for the insertion of titanium or stainless steel containers, followed by a concrete plug.

Site selection process would be similar to siting a geological repository such as avoiding areas of seismic or tectonic activity.

Department of Nuclear, Plasma and Radiological Engineering
UNIVERSITY OF ILLINOIS AT URBANA - CHAMPAIGN

NPRE – 458: Nuclear Design

Spent Nuclear Fuel: Sub-Seabed Storage

***Authors**:*
Tim Norman
Connor O'Donnell
Edward Vaughn
***Instructors**:*
Prof. J. F. Stubbins
***Advisors**:*
Prof. W. Roy

2020

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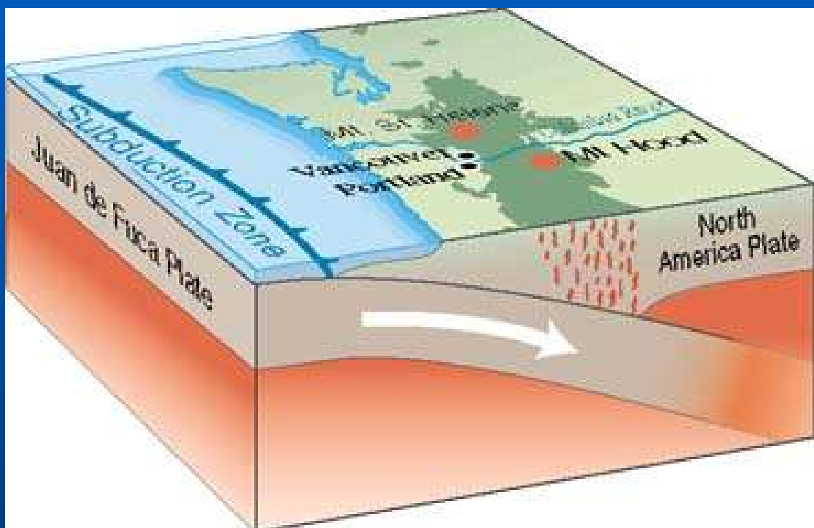
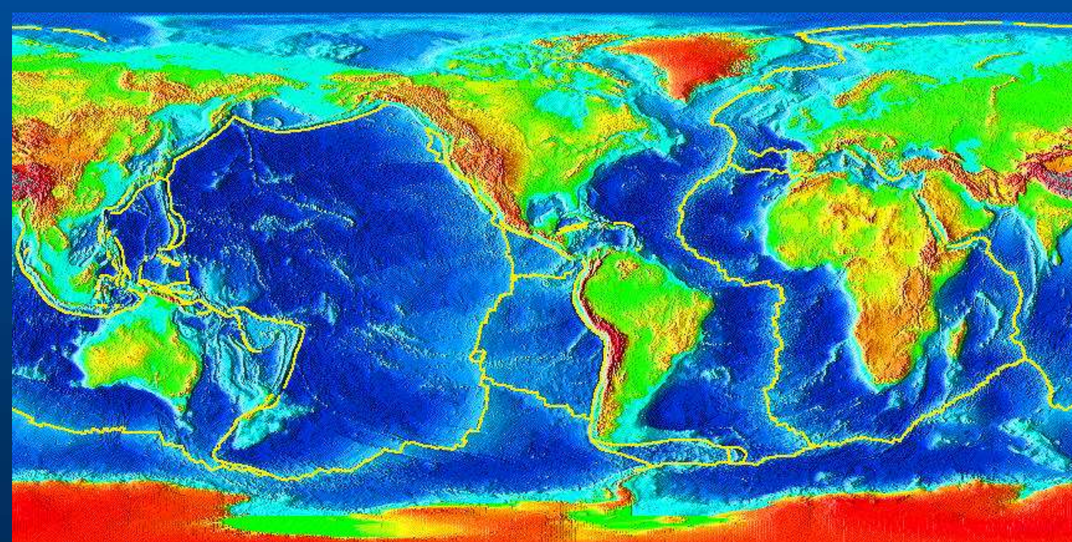
Abstract

While nuclear power has continually become safer and more efficient since its inception, one unsolved problem continues to loom over the industry, having no long-term answer for the query of spent nuclear fuel. Yucca Mountain, the US Department of Energy's proposed solution, has proved impractical and lost funding. Meanwhile, the amount of SNF in the US has already surpassed the capacity of Yucca Mountain. Many reactors are approaching the end of their operating license limits, and states are hesitant to approve relicensing or construct new plants without knowing where the spent fuel will end up. If a safe, flexible, long term solution is not

Subduction zones: one plate is being pushed under another plate.





Crustal Plate Boundaries

Subduction Zone Burial

First proposed in about 1950.

Place UNF (or any hazardous wastes) within a subduction zone of the oceanic crust.

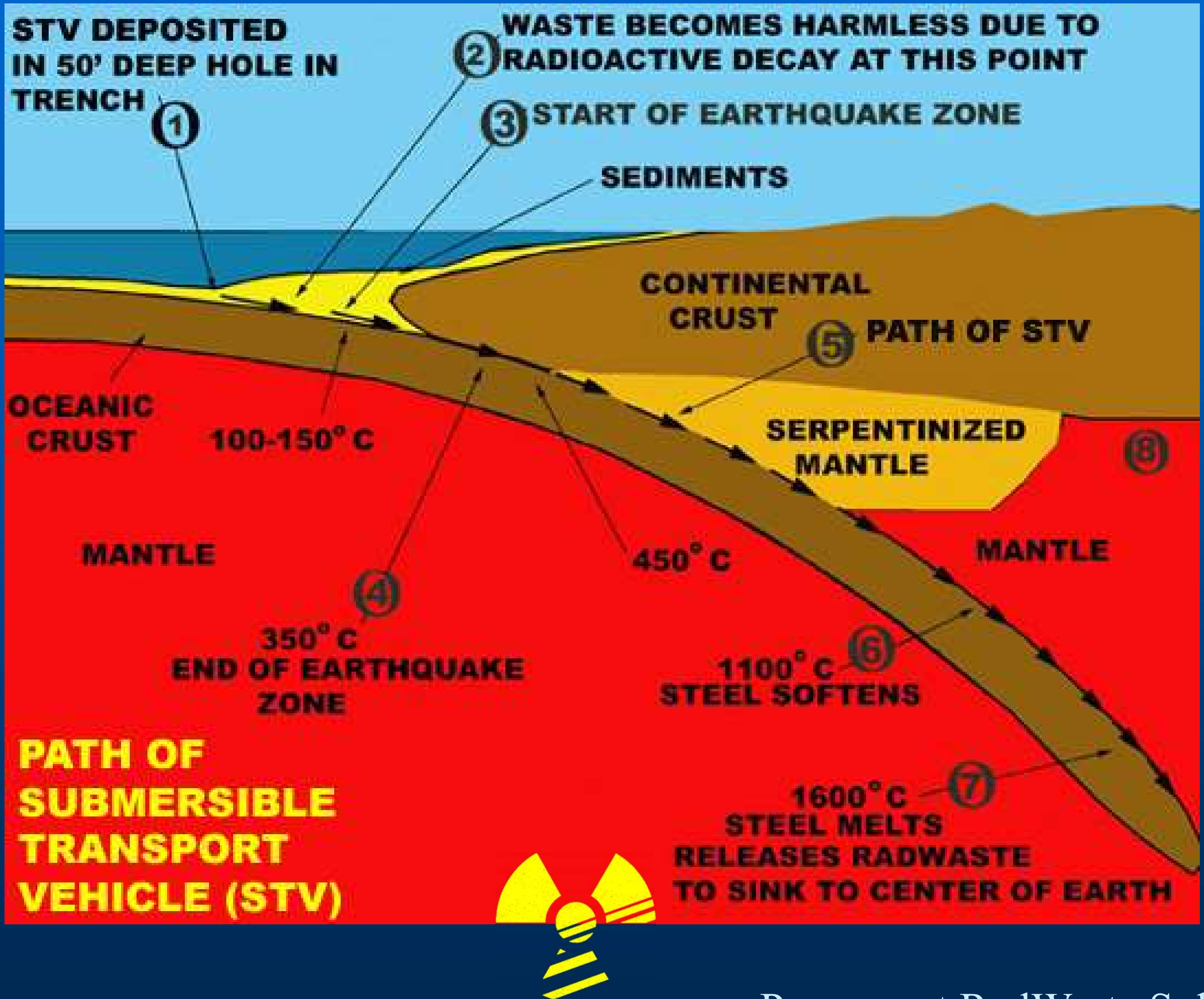
The wastes are then slowly transported or subducted below the continental crust and are effectively buried for geological time.

Subduction Zone Burial

Several approaches have been proposed and some have received patents.

"Submarine Transport Vehicle"
It would contain several UNF assemblies and would be placed in a hole dug in sediments in the zone.

Subduction Pathway



Ice-Sheet Disposal

Disposing of nuclear wastes in ice at Antarctica or Greenland. This would involve placing waste containers on the surface or in a shallow hole where the heat from the waste would cause them to slowly melt to the bottom of the ice sheet.

Ice-Sheet Disposal

Advantages include the lack of population in polar regions and the stability and thickness of polar ice.

Disadvantages:

Transportation costs; distance and weather. Potential effect of climate changes on the stability and size of polar ice masses.

Article V of the Antarctic Treaty of 1959 prohibits disposing of radioactive waste on the Antarctic continent.

Space Disposal

Space disposal offers the attraction of permanent separation of waste from the human environment. However, the risk of an accident during launch makes this an unacceptable option. Impractical because of the number of launches that would be required.

Establishing international agreements on how such a program would be operated and regulated would also be difficult.

Waste management philosophies

A geological repository is an excavation within solid rock used for the long-term containment and isolation of radioactive waste.

Disposal The permanent emplacement of radioactive waste in a geological repository with no intention of retrieving the waste in the future.

Storage Emplacement of radioactive waste in a geological repository with the option of retrieval in the future which requires some type of accessibility before final closure.

The Theory of Retrievability

*The option of being able to reverse the waste emplacement process before final closure.

*The physical removal of some fraction of the waste packages that were stored in a geological repository.

Potential benefits of retrievability

When waste management problems are recognized after emplacement, but before final closure, the wastes can be removed.

Future generations have the option to remove the wastes for chemical reprocessing, or to treat the wastes by new forms of transmutation.

Potential benefits of retrievability

If better alternatives to geological repositories emerge in the future, the repository can be emptied and decommissioned.

If societal acceptance to a geological repository deteriorates, the wastes can be removed.

Potential problems with retrievability

*If not sealed completely to allow for future accessibility, there could be the movement of groundwater, gases, and radionuclides from the repository, and hence requiring air, and groundwater monitoring.

*Will be more expensive.

*May eliminate some types of disposal options like deep boreholes (future lecture).

Current U.S. policy

"The Nuclear Waste Policy Act (1982) states that *any* geological repository shall be designed and constructed to permit retrieval. Reasons for retrieval include public health and safety, environmental concerns, and recovery of economically valuable contents of spent nuclear fuel. The NRC requires that waste must be retrievable at any time up to 50 years after start of emplacement."

Geological Repositories

The Nuclear Waste Policy Act of 1982 made DOE responsible for finding a site, building, and operating a geological repository by 1998.

To fund the program, utilities were required to pay one-tenth of a cent per kW-hour of nuclear electricity.

Geological Repositories

That money went to the Nuclear Waste Fund, and the DOE Office of Civilian Radioactive Waste Management (OCRWM) was established to run the program.

In 1983, DOE selected nine locations in six states for consideration as potential repository sites.

The chosen nine sites

Vacherie Dome, Louisiana (salt dome)
Richton Dome, Mississippi (salt dome)
Cyprus Creek Dome, Mississippi (salt dome)
Deaf Smith County, Texas (bedded salt)
Swisher County, Texas (bedded salt)
Davis Canyon, Utah (bedded salt)
Lavender Canyon, Utah (bedded salt)
Yucca Mountain, Nevada (volcanic tuff)
Hanford, Washington (basalt).

Geological Repositories

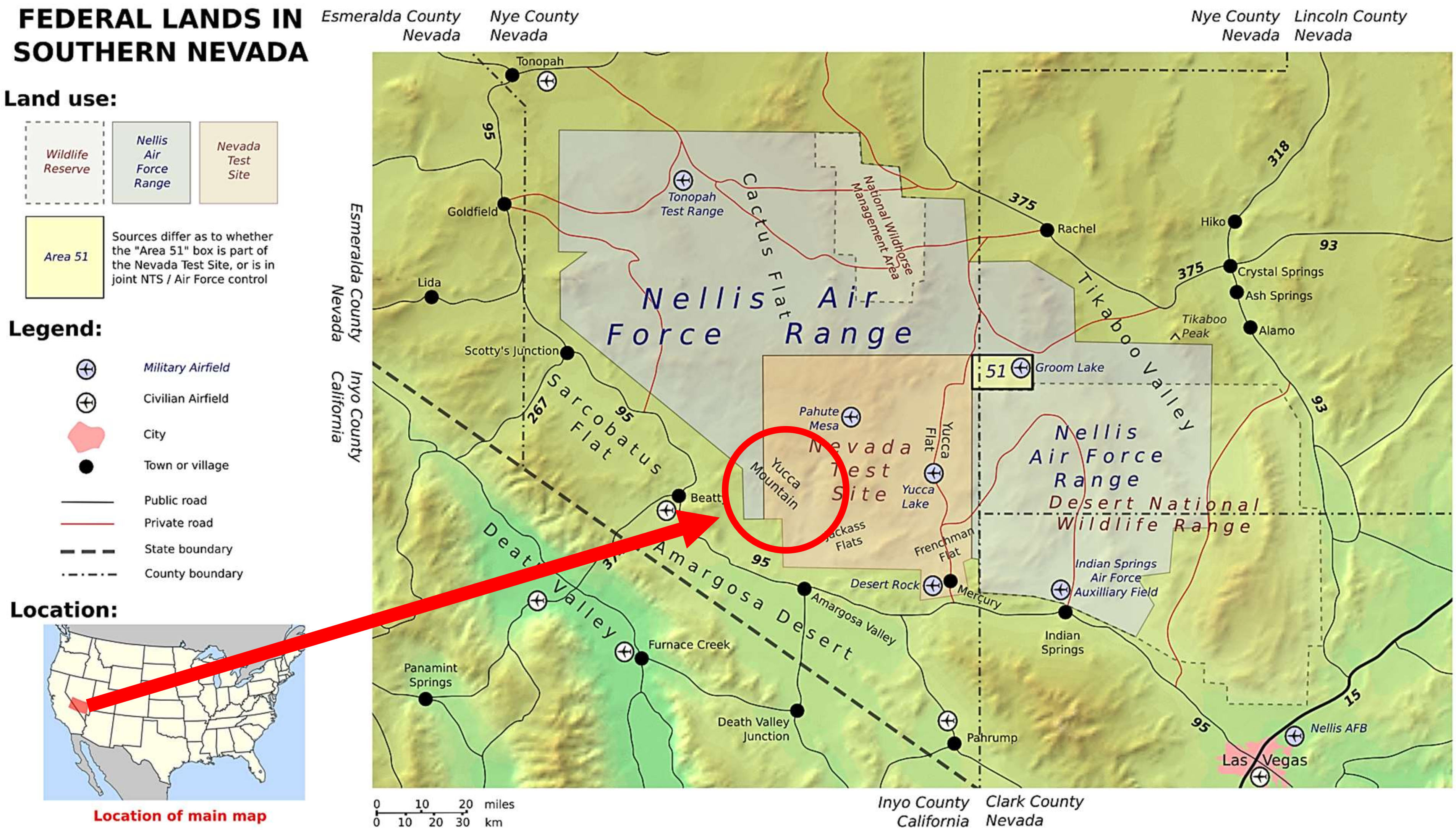
Three sites were then chosen for intensive site characterization: Hanford, Washington; Deaf Smith County, Texas; and Yucca Mountain, Nevada.

In 1987, Congress amended the Nuclear Waste Policy Act and directed U.S. Department of Energy to study only Yucca Mountain.

Why just Yucca Mountain?

The congressional action was spearheaded by Louisiana Senator J. B. Johnson.

His motivation was to push the selection process to Yucca Mountain to ensure that the salt beds of Louisiana were permanently taken off the table for consideration.


FEDERAL LANDS IN SOUTHERN NEVADA
Land use:
Wildlife Reserve
Nellis Air Force Range
Nevada Test Site
Area 51
Sources differ as to whether the "Area 51" box is part of the Nevada Test Site, or is in joint NTS / Air Force control
Legend:
Military Airfield
Civilian Airfield
City
Town or village
Public road
Private road
State boundary
County boundary
Location:
Location of main map
Esmeralda County Nevada
Nye County Nevada
Lincoln County Nevada
Inyo County California
Clark County Nevada
Nellis Air Force Range
Nevada Test Site
Desert National Wildlife Range
Tonopah Test Range
National Wildhorse Management Area
Cactus Flat
Sarcobatus Flat
Tikaboo Valley
Death Valley
Amargosa Desert
Yucca Mountain
Pahute Mesa
Yucca Flat
Yucca Lake
Jackass Flats
Frenchman Flat
Groom Lake
51
Tonopah
Goldfield
Lida
Scotty's Junction
Beatty
Rachel
Hiko
Crystal Springs
Ash Springs
Alamo
Tikaboo Peak
Desert Rock
Mercury
Indian Springs Air Force Auxilliary Field
Indian Springs
Amargosa Valley
Furnace Creek
Panamint Springs
Death Valley Junction
Pahrump
Nellis AFB
Las Vegas
95
267
375
318
93
15
0 10 20 miles
0 10 20 30 km

Yucca Mountain

A ridge composed of layers of rock called "tuff" made of ash that was deposited by successive eruptions from volcanoes between 11 and 14 million years (11 and 14 Ma) ago.

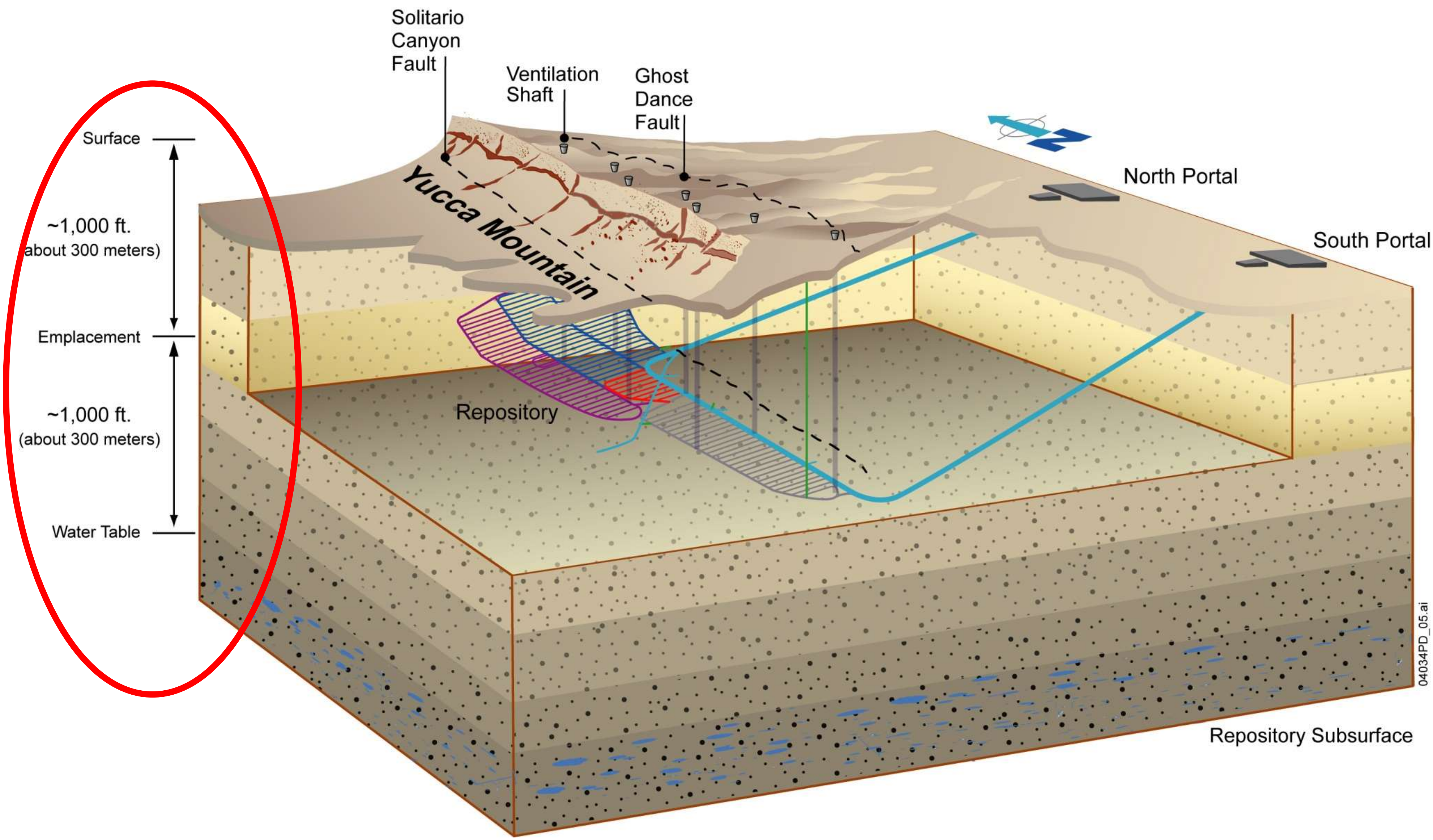
The waste repository was to be 1,000 feet (305 m) below the surface and about 1,000 (305 m) above the water table.

Yucca Mountain: retrievable and monitored storage until closure.

DOE intended for Yucca Mountain to maintain a retrieval capability throughout the pre-closure period.

Repository closure includes sealing all accessible portions of the repository, including ventilation shafts, access ramps and boreholes. Drip shields were to be installed over the waste packages. Access to the repository after closure was not intended.

Yucca Mountain



Solitario Canyon Fault
Ventilation Shaft
Ghost Dance Fault
Yucca Mountain
North Portal
South Portal
Surface
~1,000 ft.
(about 300 meters)
Emplacement
~1,000 ft.
(about 300 meters)
Water Table
Repository
Repository Subsurface
04034PD_05.ai

Requirements of the repository

A multiple-barrier approach using natural and engineered barriers.

The U.S. EPA required U.S. DOE to consider the long-term effects of climate change, earthquakes, volcanoes, and corrosion of the waste packages during a 1 million year- (1 Ma) period.

Requirements of the repository

Dose limit of 15 mrem/year (0.15 mSv/year) for the first 10,000 years (10 Ka) after disposal for each nearby resident.

Dose limit of 100 mrem/year (1 mSv/year) between 10,000 to 1,000,000 years (10 Ka to 1 Ma).

Scenarios from the Performance Assessments

100 to 1,000 years. Intact canisters. Decay heat evaporates groundwater near the canisters.

1,000 to 10,000 years. Canisters begin to corrode. Less decay heat.

Groundwater enter the repository.

Engineered barriers begin to degrade.

Minor releases of radionuclides

Doses are dominated by Tc-99 and I-129.

Scenarios from the Performance Assessments

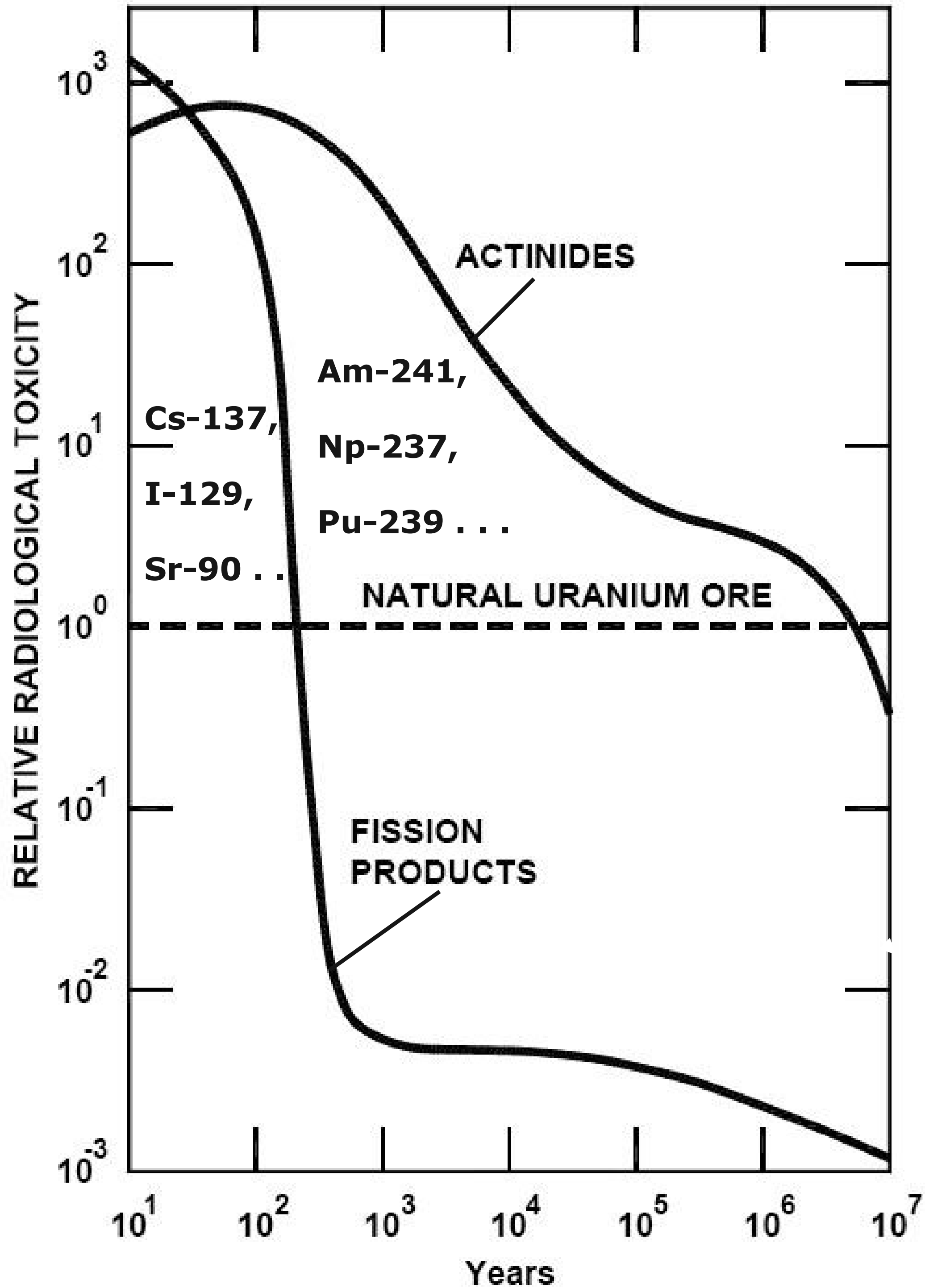
10,000 to 1,000,000 years.

Some canisters fail via corrosion.

Groundwater dilutes and transports radionuclides from the repository.

Drip shields fail via corrosion.

Doses dominated by Np-237.



RELATIVE RADIOLOGICAL TOXICITY
10^3
10^2
10^1
10^0
10^-1
10^-2
10^-3
ACTINIDES
Am-241,
Np-237,
Pu-239 . . .
Cs-137,
I-129,
Sr-90 . .
NATURAL URANIUM ORE
FISSION PRODUCTS
10^1
10^2
10^3
10^4
10^5
10^6
10^7
Years

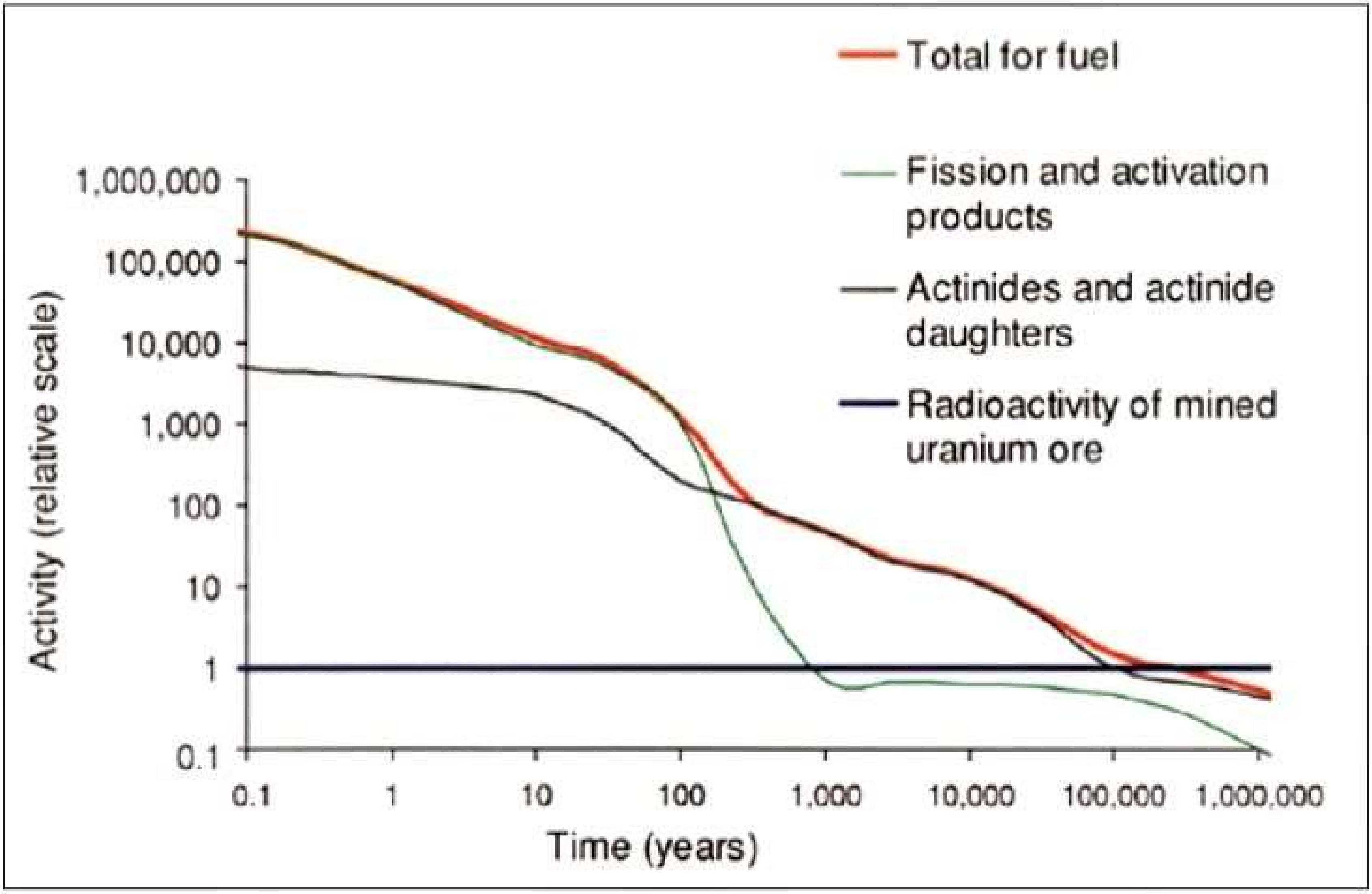
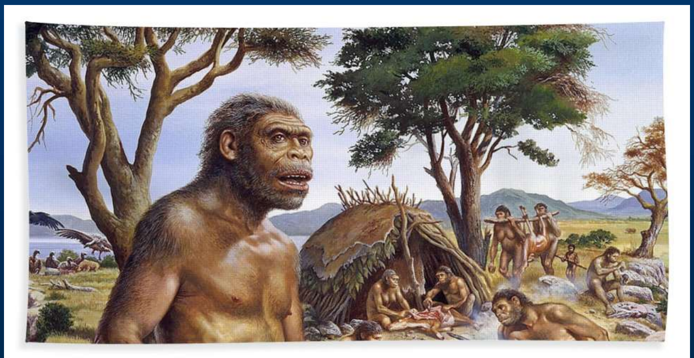
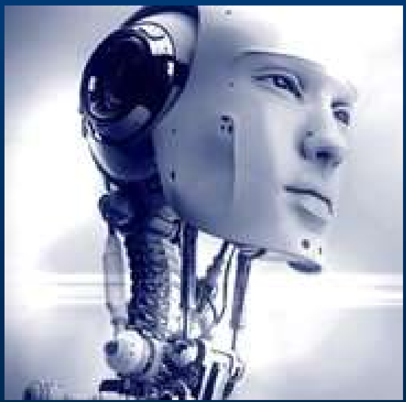


FIGURE 1 Relative radioactivity of spent nuclear fuel with a burn-up of 38 MWd/kg U. The activity is dominated by fission products during the first 100 years, thereafter by actinides (Hedin 1997).

Not in a Million Years

It may be inconceivable that a performance standard for a geological repository has been evaluated for such a long period. Consider that—one million years ago—*homo sapiens* had not yet evolved on the earth. It is difficult to predict who or what will be protected from radiation emitted by spent nuclear fuel in the far, distant future.



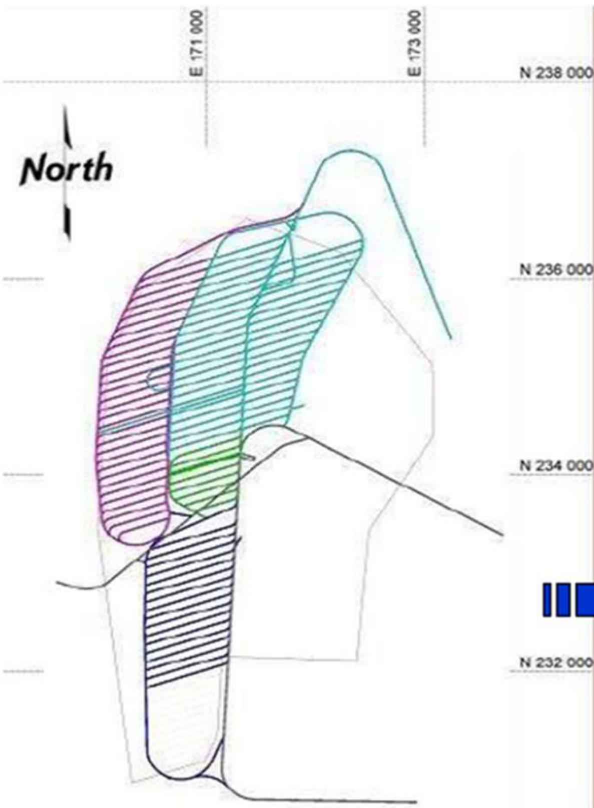


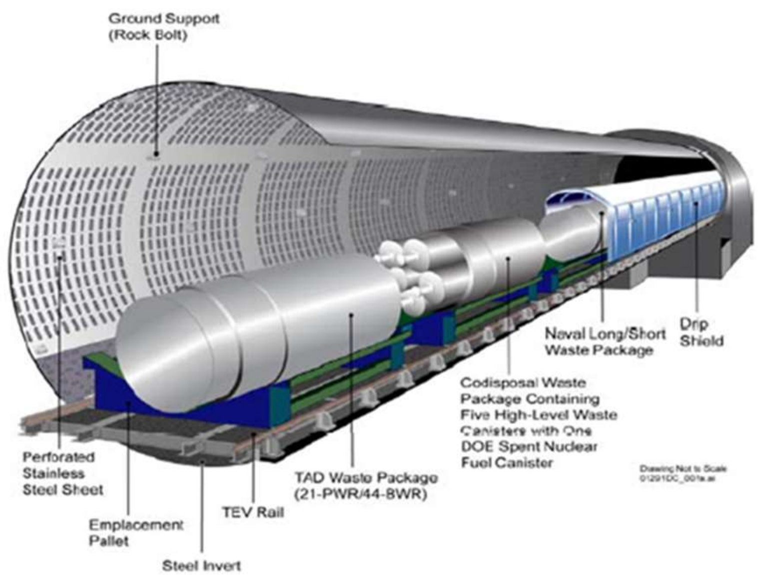
Yucca Mountain Subsurface Design

Emplacement drifts
- 5.5 m diameter
- approx. 100 drifts, 600-800 m long

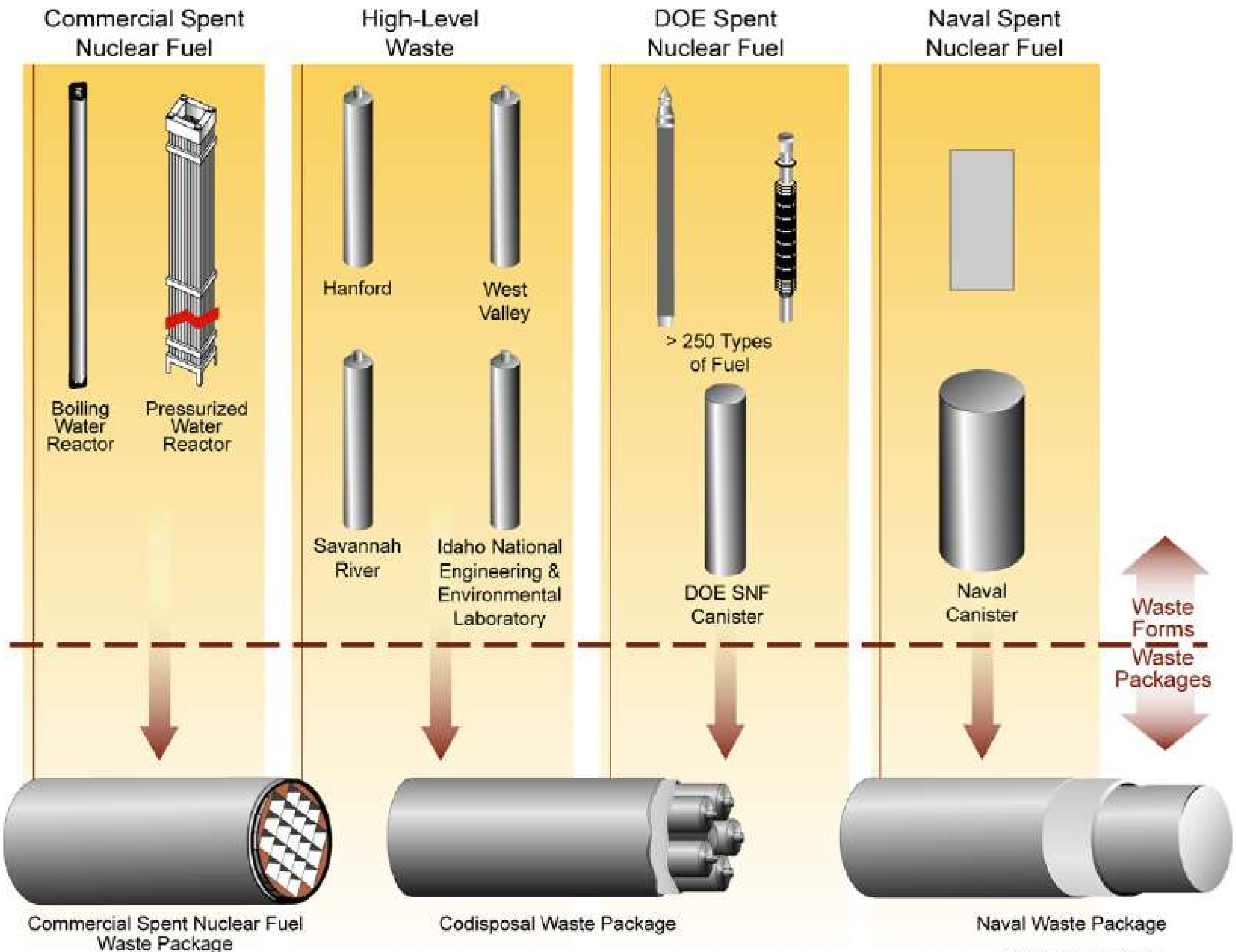
Waste packages
- ~12,000 packages
- ~ 5 m long, 2 m diameter
- outer layer 2.5 cm Alloy 22 (Ni-Cr-Mo-V)
- inner layer 5 cm stainless steel
  - Internal TAD (transportation, aging, and disposal) canisters for commercial spent fuel, 2.5 cm stainless steel

Drip shields
- free-standing 1.5 cm Ti shell





Waste Form Types



Drawing Not To Scale
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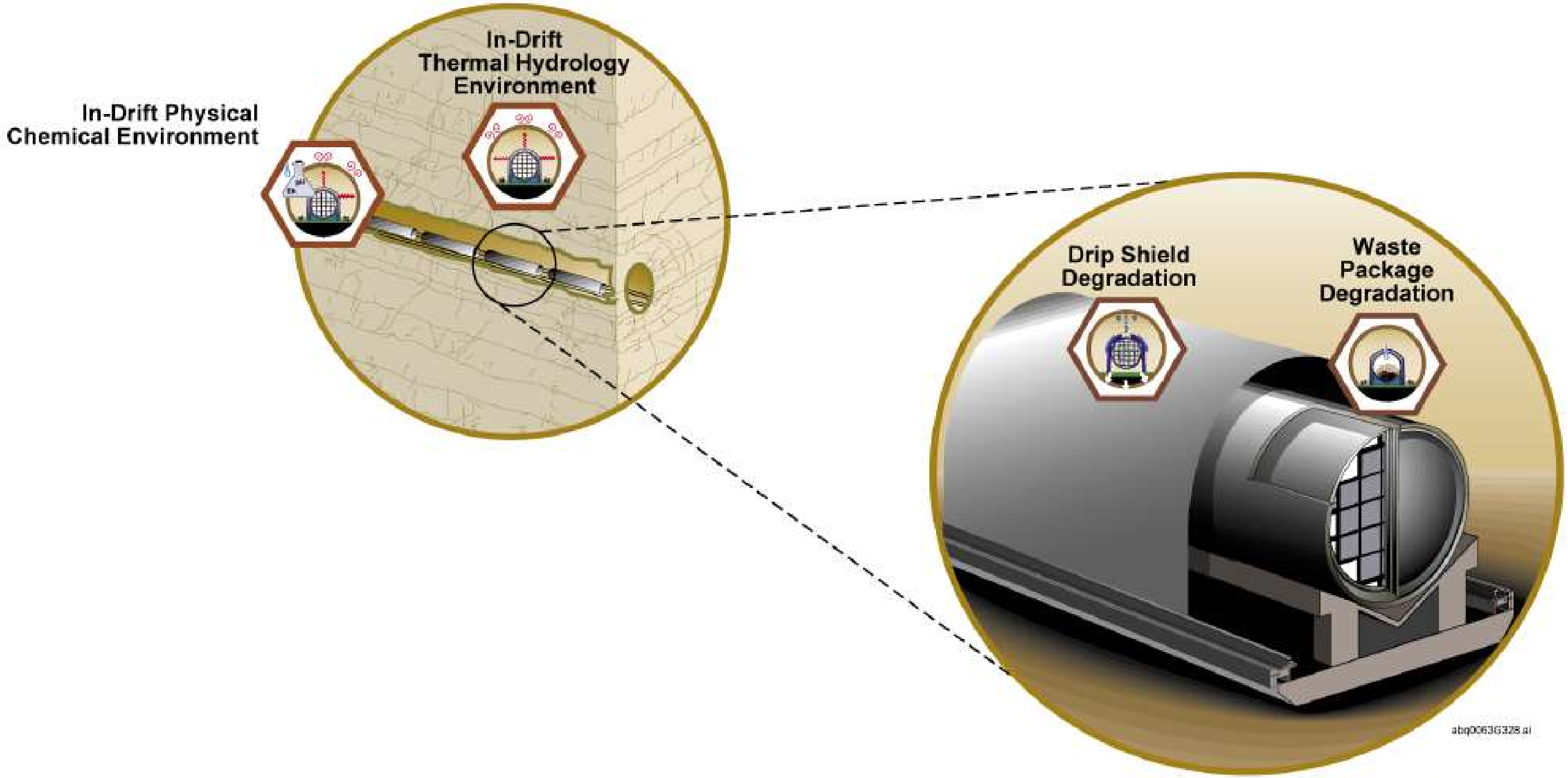
Waste Package and Drip Shield Degradation Process



- **Comprehensive testing of metals and alloys gives indication of behavior of these materials under anticipated and unanticipated conditions**

North Portal

South Portal


FIRE
HOSE
Inside Yucca Mountain - 2004

Yucca Mountain

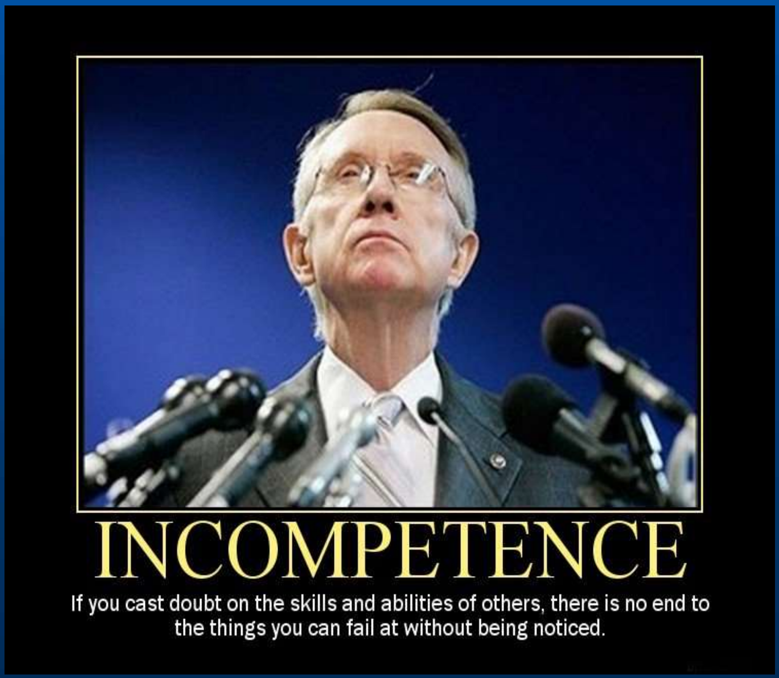
U.S. DOE sent the application to obtain a license to the U.S. Nuclear Regulatory Commission to construct a repository in 2008.

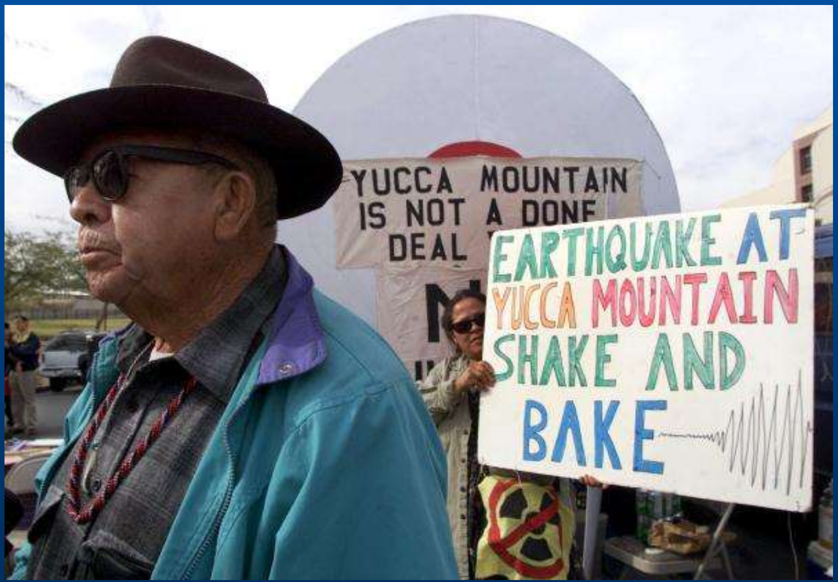
(U.S. *DOE missed the 1998 deadline after spending billions of dollars*)

But, will Yucca become a reality?

Public opposition, especially in Nevada.

Senator Harry Reid, Democrat, Nevada





But, will Yucca become a reality?

2010. The Obama administration declared "We're done with Yucca Mountain."

But, will Yucca become a reality?

U.S. DOE had spent <u>$38 billion dollars</u> during the last three decades on repository tests and studies. U.S. DOE had planned to store 77,000 short tons (70,000 tonnes) of radioactive waste (63,000 short tons (57,200 tonnes) as commercial SNF) from 80 sites in 35 states.

But, will Yucca become a reality?

The Obama administration formed a "blue-ribbon" panel to "study nuclear waste disposal alternatives."

The panel was headed by Lee Hamilton (Democrat, Indiana)

The panel was not allowed to consider Yucca Mountain.

Waste for Yucca Mountain

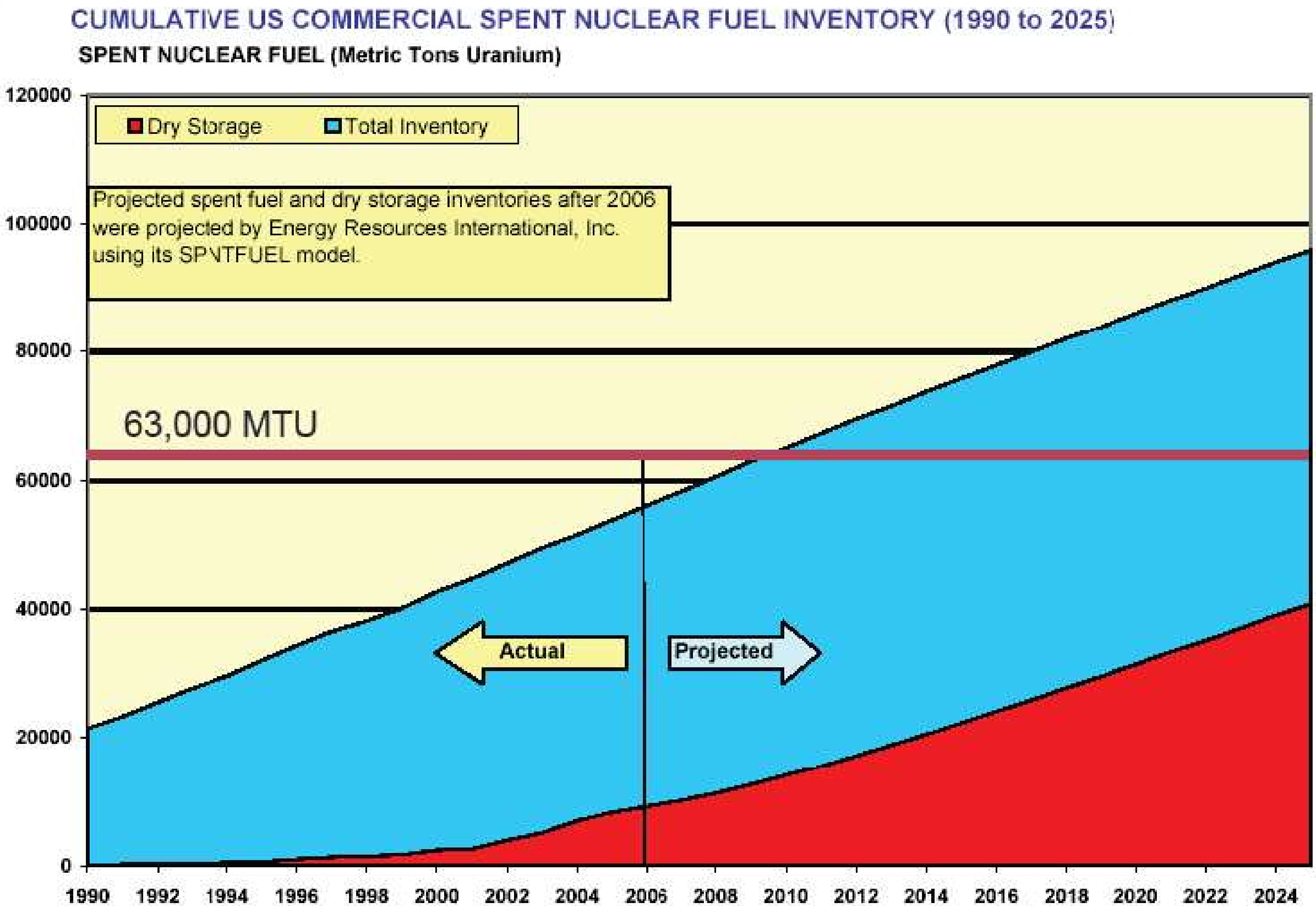
Commercial Spent Nuclear Fuel:
63,000 MTHM (~7500 waste packages)

DOE & Naval Spent Nuclear Fuel:
2,333 MTHM
(~400 naval waste packages)
(DSNF packaged with HLW)

DOE & Commercial High-Level Waste:
4,667 MTHM
(~3000 waste packages of co-disposed DSNF and HLW)

DSNF: Defense Spent Nuclear Fuel
HLW: High Level Radioactive Waste
MTHM: Metric Tons Heavy Metal

Spent Fuel Inventories are Rising Past 63,000 MTU



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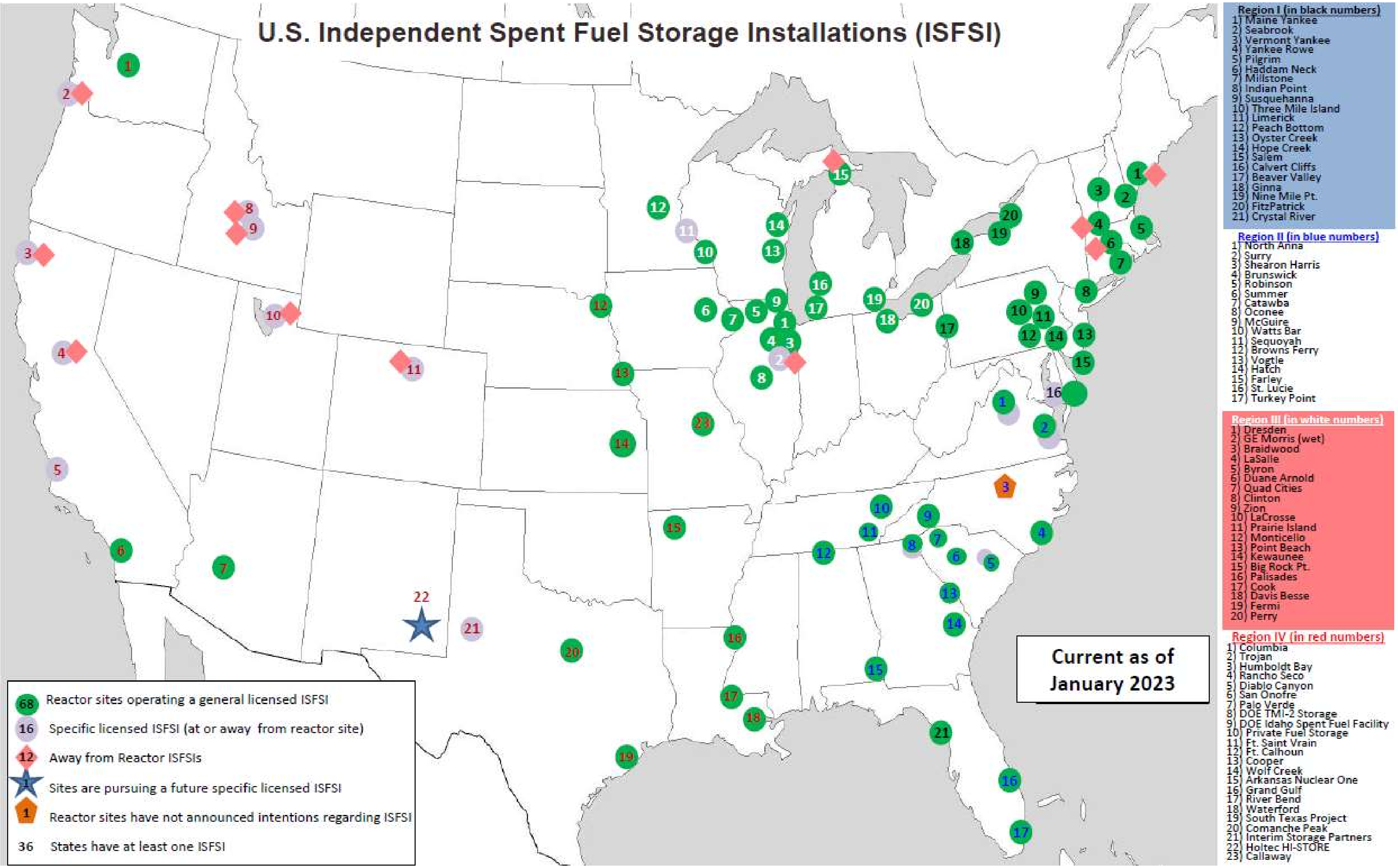
How much UNF is being stored?

Currently there are 62,592 MTU (metric tons of uranium) of UNF. Nationally, 25.3% of that is in dry storage. There are 57 Independent Spent Fuel Storage Installations (ISFSI) in the U.S.

In Illinois, there are 8,691 MTHM metric tons of heavy metal) of which 20.6% is in dry storage.


U.S. Independent Spent Fuel Storage Installations (ISFSI)
Region I (in black numbers)
1) Maine Yankee
2) Seabrook
3) Vermont Yankee
4) Yankee Rowe
5) Pilgrim
6) Haddam Neck
7) Millstone
8) Indian Point
9) Susquehanna
10) Three Mile Island
11) Limerick
12) Peach Bottom
13) Oyster Creek
14) Hope Creek
15) Salem
16) Calvert Cliffs
17) Beaver Valley
18) Ginna
19) Nine Mile Pt.
20) FitzPatrick
21) Crystal River
Region II (in blue numbers)
1) North Anna
2) Surry
3) Shearon Harris
4) Brunswick
5) Robinson
6) Summer
7) Catawba
8) Oconee
9) McGuire
10) Watts Bar
11) Sequoyah
12) Browns Ferry
13) Vogtle
14) Hatch
15) Farley
16) St. Lucie
17) Turkey Point
Region III (in white numbers)
1) Dresden
2) GE Morris (wet)
3) Braidwood
4) LaSalle
5) Byron
6) Duane Arnold
7) Quad Cities
8) Clinton
9) Zion
10) LaCrosse
11) Prairie Island
12) Monticello
13) Point Beach
14) Kewaunee
15) Big Rock Pt.
16) Palisades
17) Cook
18) Davis Besse
19) Fermi
20) Perry
Region IV (in red numbers)
1) Columbia
2) Trojan
3) Humboldt Bay
4) Rancho Seco
5) Diablo Canyon
6) San Onofre
7) Palo Verde
8) DOE TMI-2 Storage
9) DOE Idaho Spent Fuel Facility
10) Private Fuel Storage
11) Ft. Saint Vrain
12) Ft. Calhoun
13) Cooper
14) Wolf Creek
15) Arkansas Nuclear One
16) Grand Gulf
17) River Bend
18) Waterford
19) South Texas Project
20) Comanche Peak
21) Interim Storage Partners
22) Holtec HI-STORE
23) Callaway
Current as of January 2023
68 Reactor sites operating a general licensed ISFSI
16 Specific licensed ISFSI (at or away from reactor site)
12 Away from Reactor ISFSIs
1 Sites are pursuing a future specific licensed ISFSI
1 Reactor sites have not announced intentions regarding ISFSI
36 States have at least one ISFSI

The Nuclear Waste Fund

The U.S. Nuclear Waste Policy Act of 1982 mandated that a fee of 1 mill ($0.001) per kilowatt-hour ($1/MWh: 1 million Watts-hour-electric) generated by nuclear power be paid to the U.S. Treasury for long-term management of SNF.

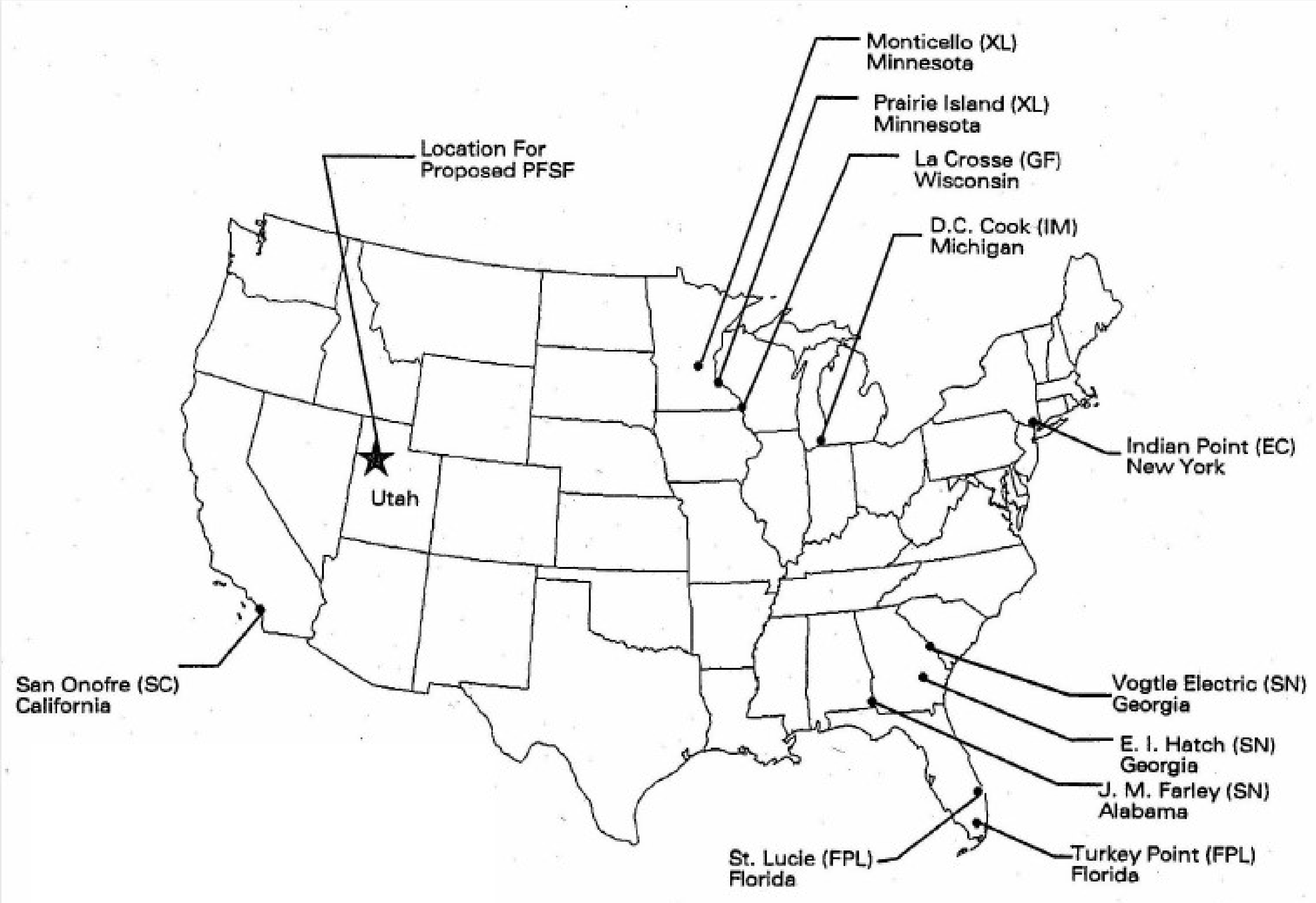
Illinois alone has paid $1,936,400,000
to this Fund. 34 States have contributed
a $18 billion dollars!
And what do we have to show for it?

Private Fuel Storage, LLC

Private Fuel Storage, LLC (PFS) was a consortium of 8 electric utilities:

33.7%	Xcel Energy (Northern States Power), Minnesota
11.8%	Genoa FuelTech (Dairyland), Wisconsin
11.5%	Florida Power & Light (Constellation)
11.5 %	Southern Company, Alabama
11.1%	Entergy (Con. Edison, New York)
10.5%	American Electric (Indiana-Michigan Power)
6.9%	First Energy (GPU)
3.0%	Southern California Edison

PFS Member Locations

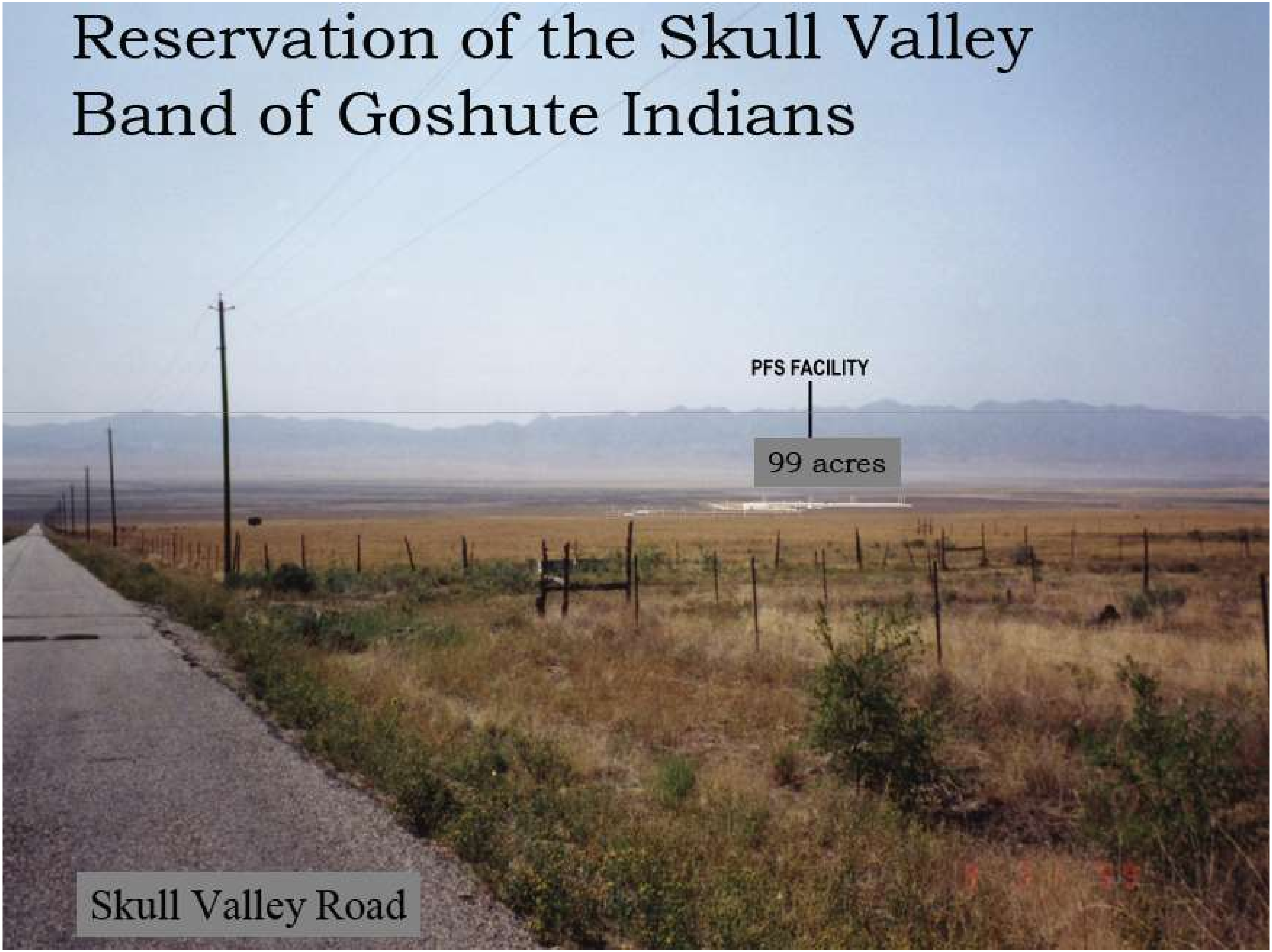


The Goshute Native Americans

The Skull Valley Band of Goshute Native Americans—a sovereign nation under Federal law—agreed to lease 820 acres (332 ha) of their 18,000-acre (7,300 ha) reservation in Skull Valley, Utah to PFS in 1997.

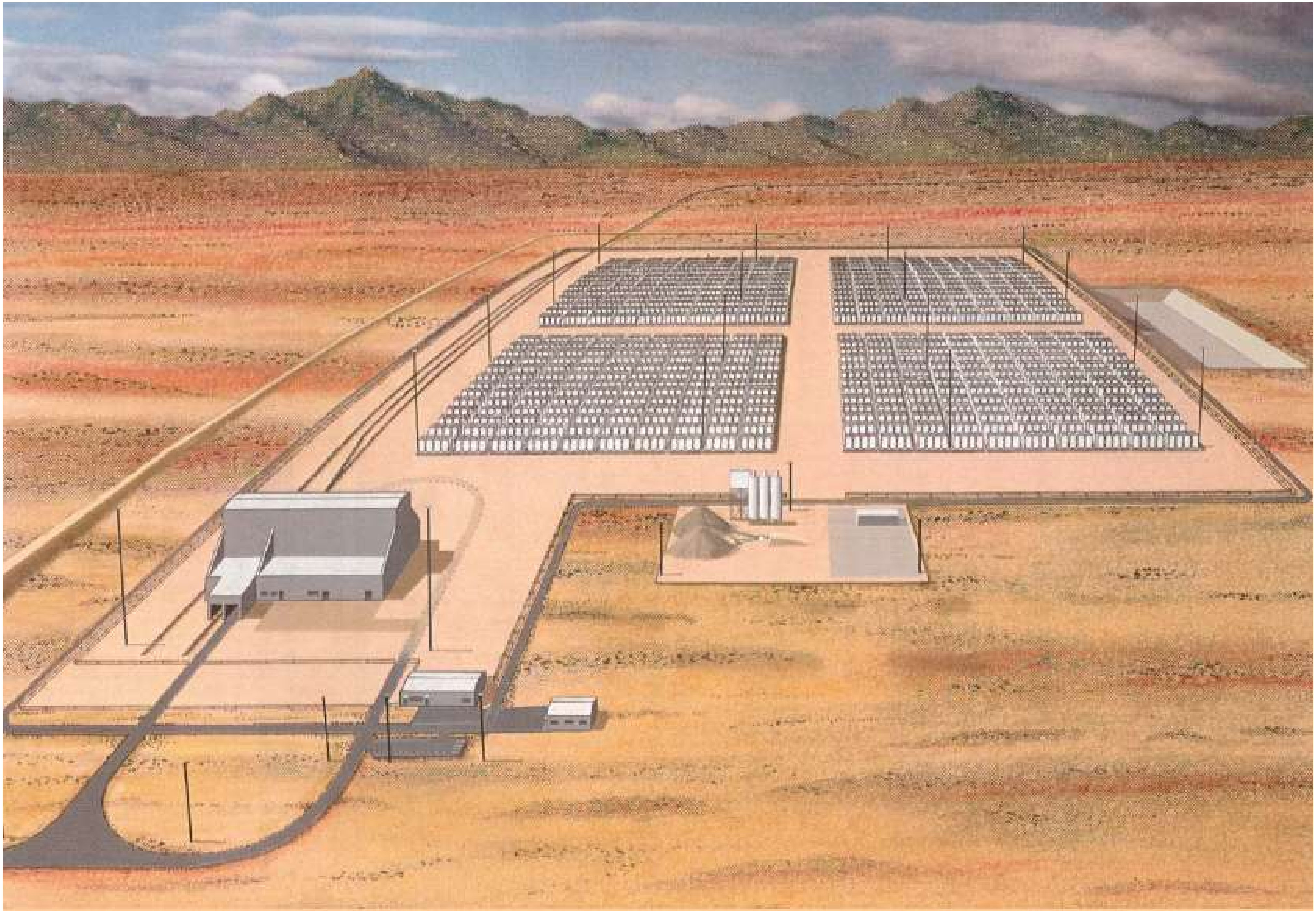
They currently lease a rocket test facility located on the Reservation from which they derive their income and benefits.

Location of Reservation


Reservation of the Skull Valley Band of Goshute Indians
PFS FACILITY
99 acres
Skull Valley Road

The PFS facility

- Open, above ground storage on concrete pads
- 40,000 MTUs SNF
- 4,000 casks – "modified" Holtec International, HI-Storm 100 (rev. 0) casks
- 20 year license + 20 year renewal
- Accept any commercial spent nuclear fuel



PFS Facility

False Start?

In 2006, the NRC issued PFS with a license to store up to 40,000 tonnes of SNF at the Skull Valley facility.

But in 2006, the Bureau of Land Management (BLM) and the Bureau of Indian Affairs (BIA) denied PFS a right-of-way to transfer and transport SNF by rail.

The project appeared to be dead . . . .

PFS ends

In 2010, the U.S. District Court overturned the decisions by the Department of the Interior and remanded PFS' right-of-way application and lease of tribal land to the Department of the Interior for further consideration.

2013. The Department of the Interior took no action on the court ruling, and did not publish another decision on the application. Private Fuel Storage then gave up on the project, and requested that the NRC terminate the unused license to terminate maintenance fees.

In response to the BRC

Based on the recommendations of the Blue Ribbon Commission (BRC) on *America's Nuclear Future*, the U. S. Department of Energy issued a new strategy for the management of used nuclear fuel and high-level radioactive waste in 2013. It was signed by Energy Secretary Chu, who then resigned.

Approach proposed

The approach used will be phased (implemented in steps), adaptive (use new information as it comes), and consent-based in terms of site selection and operation. Communities are to volunteer.

Pilot interim storage facility by 2021.

Initial focus on accepting UNF from shut-down reactor sites.

Intended to "build trust and demonstrate federal commitment."

Interim storage facilities

A larger interim storage facility by 2025.

Could have a capacity of 20,000 metric tons of heavy metal.

Two interim facilities would be an effort to centralize UNF management.

Should operate independently of siting a permanent repository.

No details given. Above-ground dry storage?

Lastly, a geological repository

A geological repository by 2048.

"Most cost-effective way of permanently disposing used nuclear fuel and high-level radioactive waste"

Goals: site selection completed by 2026. Designed and licensed by 2042.

Repository design simplification?

Retrievability of used nuclear fuel is not a priority for other than safety concerns.

"[No] need to ensure post-closure recovery for reuse consideration on the consideration of…economic recovery…"

"[It is likely] that the once-through fuel cycle will continue at least for the next few decades."

Back to Yucca

Since 2013, no progress has been made on DOE's draft consent-based approach.

In 2017, it was abandoned by the Trump Administration in favor of reviving the Yucca Mountain project.

A proposed budget for FY 2018 included $120 million to restart NRC licensing activities for Yucca. The NRC estimated 3 to 5 years to authorize construction.

The 2018 Amendment

The Nuclear Waste Policy Amendment Act of 2018 was passed by the House of Representatives. It was introduced by John Shimkus, a Republican from Illinois.

The Act re-established that Yucca is “the most expeditious path for . . . waste disposal.”

The 2018 Amendment

The Act also authorized creating privately-owned central interim storage facilities until Yucca is operational.

However funding for restarting the license process for Yucca Mountain was excluded by the Senate and the House.

No help from the Trump Administration

2020. "My budget stops funding for the licensing of waste storage at Yucca Mountain so we can focus on positive solutions."

"Why should you have nuclear waste in your backyard?" Trump said [to Nevada Democrats].

No help from the Biden Administration

2021. “The [Biden] Administration opposes the use of Yucca Mountain for the storage of waste,” said Energy Secretary Jenifer Granholm. She called nuclear waste storage a “very sticky situation” and said she would rely on recommendations from a Blue Ribbon commission and try to find a consensus solution that engages states and tribes.”

The Private Sector in the U.S.

While our dysfunctional government makes little progress, the private sector (utilities and industry) are active in the area of spent fuel management in the U.S. Investment is constrained by a lack of management policy for spent fuel.

The private sector supports interim storage.

The Private Sector

Private sector groups in New Mexico and Texas each proposed an interim storage facility for used nuclear fuel! NRC is currently reviewing applications for a Consolidated Interim Storage Facility

in Andrews County, Texas and a CISF in Lea County, New Mexico.

Proposed designs

New Mexico is working with Holtec, and the design is based on Holtec's Hi-Storm Umax underground dry storage system for 100+ years.

Texas is working with Waste Control Specialist and Orano, and the design calls for Nuhoms dry cask storage system for 40,000 tonnes of used fuel for 40+ years.

Hi-Storm Umax

In the future?

Interim storage with casks *must* be coupled with a long-term solution.

The Nuclear Energy Institute proposed that the private sector should take the lead role in citing and constructing a geological repository in the U.S.!

Why not? See Finland and Sweden.

We will soon!

Questions?