A HOLISTIC APPROACH FOR DISPOSITION OF LONG-LIVED RADIOACTIVE MATERIALS

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ABSTRACT

During the past 45 years, one of the most challenging scientific, engineering, socio-economic, and political tasks and obligations of our time has been to site and develop technical, politically acceptable, solutions to the safe disposition of long-lived radioactive materials (LLRMs). However, at the end of the year 2002, the Waste Isolation Pilot Plant (WIPP) site in the United States of America (USA) hosts the world’s only operating LLRM-disposal system, which 1) is based on the LLRM-disposal principles recommended by the National Academy of Sciences (NAS) in 1957, i.e., deep geological disposal in a “stable” salt vault/repository, 2) complies with the nation’s “Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes”, and 3) may receive 175,584 cubic meters (m^3) of transuranic radioactive waste (TRUW)[a]. Pending the scheduled opening of repositories for once-used nuclear fuel (OUNF) in the USA, Sweden, and Finland in the years 2010, 2015, and 2017, respectively, *LLRM-disposal solutions remain the missing link in all national LLRM-disposition programs*. Furthermore, for a variety of reasons, many nations with nuclear programs have chosen a “spectator” stance in terms of enhancing the global nuclear safety culture and the nuclear renaissance, and have either “slow-tracked” or deferred their LLRM-disposal programs to allow time for an *informed national consensus* to evolve based on LLRM-disposition experiences and solutions gained elsewhere. In the meantime, LLRMs will continue to amass in different types and levels of safeguarded storage facilities around the world.

In an attempt to contribute to the enhancement of the global nuclear safety culture and the nuclear renaissance, the authors developed the *sample holistic approach for synergistic disposition of LLRMs* shown in Figure 1 comprising LLRM-disposition components considered either “proven” or “promising” by the authors. The fundamental principles of the holistic approach are: (1) *Risk minimization*; (2) *Minimization of the LLRM volume requiring deep geological disposal*; and (3) *LLRM-disposition flexibility*. An integral element of these principles is to allow time for LLRM-disposition solutions to evolve/mature technically, financially, and politically. Furthermore, contingent upon the desired outcome(s), available financial, scientific, and technical resources, and political will, these *components may be implemented separately or in combinations by one or a group of nations*.

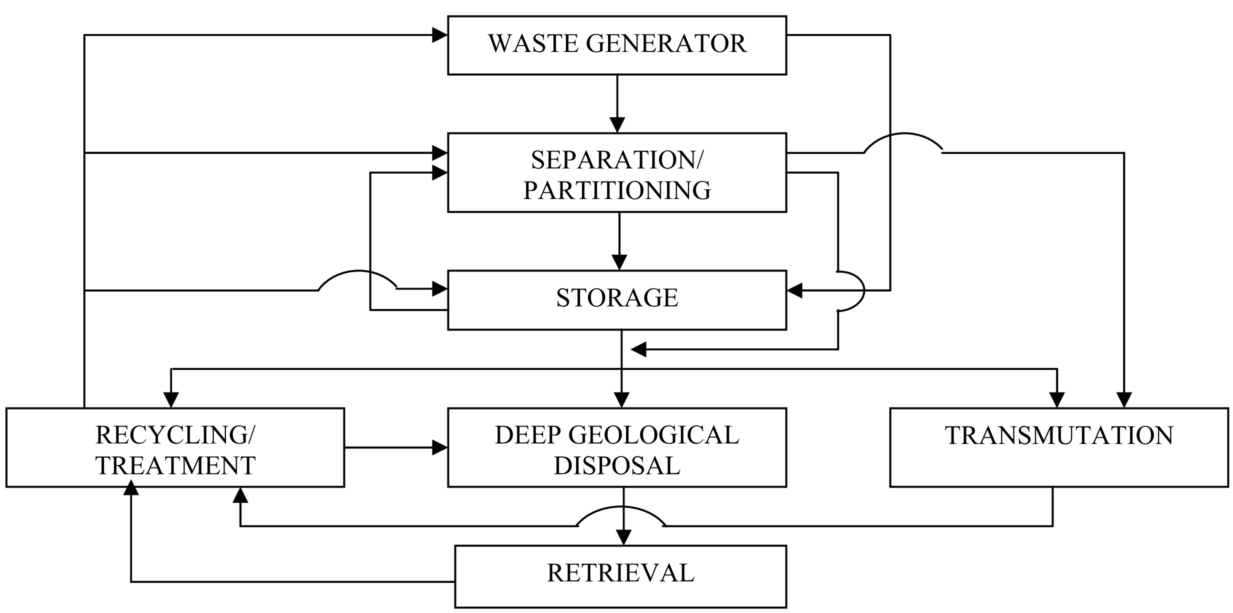

Fig. 1. Schematic illustration of a sample holistic approach for safe management and disposal of LLRMs.

INTRODUCTION

Two globally accepted ethical and moral imperatives are that the generation creating the LLRM (a) is responsible for its safe management, and (b) shall choose LLRM-disposition solutions that do not place any undue burdens or risks on future generations and environments (1). Beginning in the 1957 NAS report and to date, deep geological disposal is considered the safest viable LLRM-disposal solution (2-6). However, based on the experience gained around the world during the past 45 years of large financial, emotional and intellectual investments, it is clear that the siting and development of any LLRM-disposal solution faces the following challenges:

1. A broad range of issues, including anti-nuclear and pro-nuclear dogmas, and political liabilities.
2. Strong emotional reactions, including anti-nuclear and pro-nuclear mantras.
3. Significant schedule delays and cost-increases.

As a result, many nations have employed a "slow-track" or "wait and see" policy based on "long-term" LLRM storage rather than actively pursuing the development of domestic or regional LLRM-disposal solutions. In the meantime, LLRMs continue to amass in storage facilities around the world, many of which are vulnerable to amplified environmental, safety, and security risks. Only a few nations are actively pursuing LLRM-disposition programs designed to enhance national security and reduce the burden on current and future generations and environments by providing or considering, *long-term storage in easily safeguarded (controlled ingress and egress), terrorist resilient (structurally stable and pollution containing), well-below-ground (50 m or more) facilities*.

In an attempt to contribute to the enhancement of the global nuclear safety culture and the nuclear renaissance, the authors developed the *sample holistic approach for synergistic disposition of LLRMs* shown in Figure 1. It comprises components/technologies deemed either "proven" or "promising" based on the authors' almost 100 years of combined involvement in and monitoring of LLRM-disposition programs in the USA and abroad during the past 45 years. Provided below are: (a) background information on the LLRM-disposition components listed in Figure 1; (b) a concise description of the premises for the holistic approach; and (c) a discussion of the potential benefits of the holistic approach illustrated in Figure 1.

As indicated above, *the missing link in almost every national LLRM-disposition program is the disposal solution*. Hence, *the focus below is on LLRM-disposal*, including the utilization of other LLRM-disposition solutions that may offset the current scarcity of disposal solutions. Specifically, *the emphasis below is on public and political acceptance, and interim monitored storage*. Furthermore, the development of a deep geological disposal facility (repository) for OUNF in the USA at the end of the year 2002 were chosen by the authors as a realistic example of a *"hypothetical"* partial application of the holistic approach, i.e., interim monitored storage, that, perhaps, could mitigate some current challenges. The selection of this particular example is based on the USA's long-standing, large financial and intellectual investments in LLRM-disposition solutions, including the world's only operating LLRM-disposal facility, the WIPP repository, and the pending *opening of the world's second LLRM repository in the year 2010.* They embody a diverse, state-of-the-art spectrum of LLRM-disposition conditions and challenges that may apply to and/or affect national LLRM-disposition programs both in the USA and abroad for a foreseeable future and, thus, also affect the global nuclear safety culture and the nuclear renaissance.

Although there are many potential LLRM-disposition solutions pursued in the world today, only the LLRM-disposition solutions shown in Figure 1 are addressed below and in the (biased) context/categories of either "proven" or "promising" solutions. Specifically, of the LLRM-disposition solutions shown in Figure 1, interim storage, separation/partitioning, recycling/treatment (includes reprocessing), and deep geological disposal are currently employed on an "industrial scale" and are henceforth referred to as "*proven*" LLRM-disposition solutions, whereas transmutation, and retrieval are not employed on an "industrial scale" and, therefore, are henceforth referred to as "*promising*" LLRM-disposition solutions.

As illustrated in the preceding paragraph, *this text solely reflects the opinions of the authors and, unless explicitly stated, any resemblance to an existing national or program policy is sheer coincidence.* References are indicated by numbers in parenthesis in the text and listed in full after the main text. Key words and terms are highlighted in *italics* throughout the text.

BACKGROUND

As partially illustrated in Figure 2, *excluding any licensing stage*, all LLRM-disposition facilities involve the following six primary, life-cycle stages:

1. Site screening.
2. Site characterization (Site Geostudy in Figure 2).
3. Facility design.
4. Facility construction.
5. Facility operation.
6. Facility decommissioning and closure.

In addition, an LLRM-repository requires post-closure monitoring and controls. As indicated by the frequent "interaction" and "decision" points in Figure 2, *early and continuous local involvement and support are important cornerstones to gaining the public and political acceptance required for the timely and cost-effective development of any LLRM-disposition facility*. Hence, following are concise overviews of:

- "Proven" LLRM-disposition solutions;
- "Promising" LLRM-disposition solutions; and
- Potential means for gaining and maintaining public acceptance.

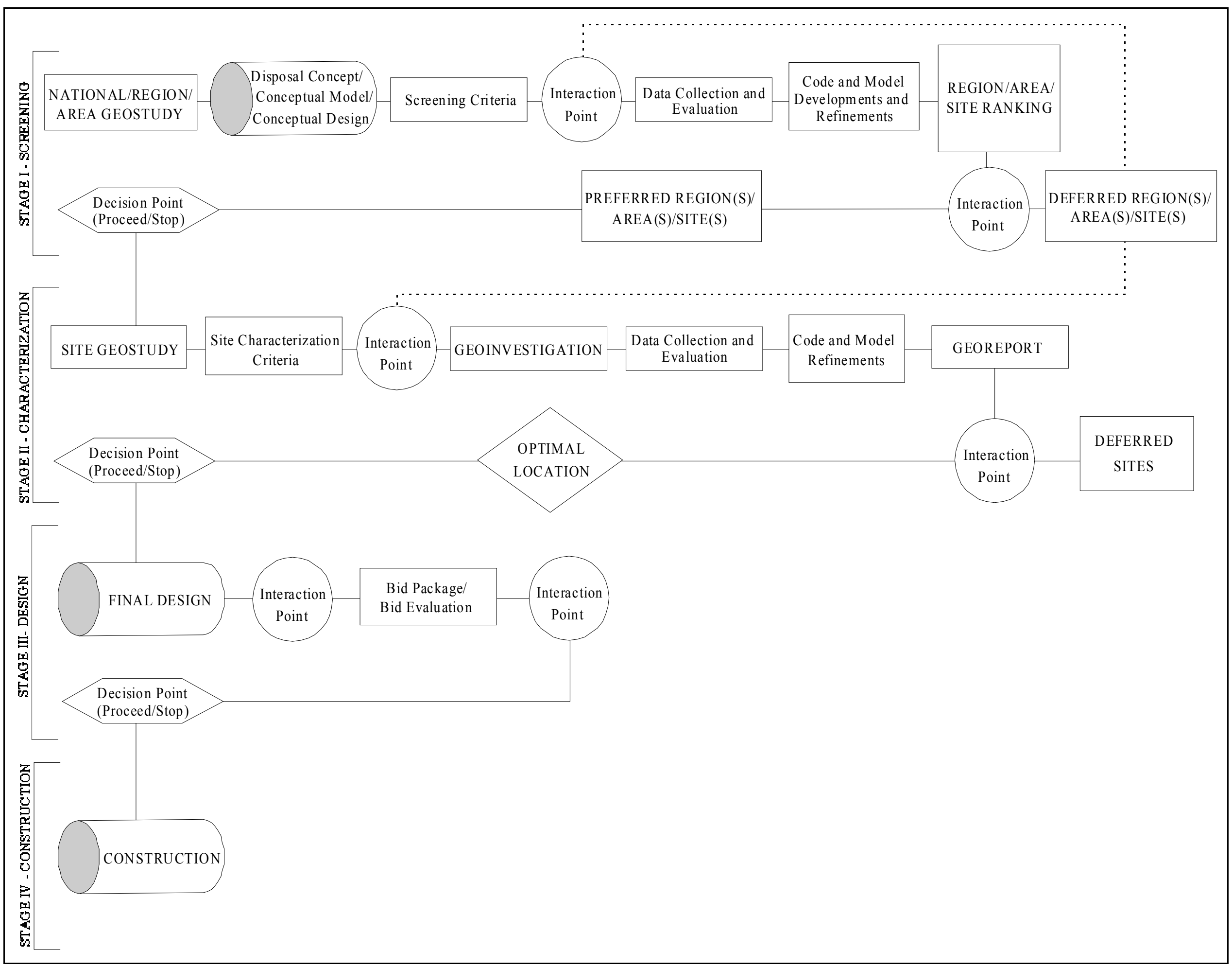

Fig. 2. Schematic illustration of the major elements involved in the initial four stages for the cost-effective and timely development of a publicly accepted LLRM disposition facility.

Proven LLRM-Disposition Solutions

Separation/partitioning

Separation/partitioning of different radioactive (and chemical) components has been available on an industrial scale for more than 30 years (5,7). However, in many countries, separation/partitioning of LLRMs is not an integral component of the national energy policy. Two main reasons for this policy appear to be:

- The absence of a holistic energy-management policy; and
- Lack of incentives or requirements for the nuclear utilities to pursue nuclear-fuel-conservation and waste-minimization/reduction measures.

Notwithstanding these constraints, *separation/partitioning* offers the benefit of *strictly controlled waste streams* and the generation of *constituents that may be either directly used or used as feed for other LLRM-disposition solutions* such as *transmutation and reprocessing*.

Storage

In the USA, federal/government-operated *LLRM-storage* facilities have been in safe use since the early 1940s and utility-managed/operated LLRM storage facilities have been in safe use since the early 1950s. At the end of the year 2002, more than 30 nations are storing civilian-generated and some defense-generated LLRMs in surface and near-surface facilities with different level of protection against terrorist actions. In terms of safeguards, the specially designed *underground facility* for long-term (30-50 years) monitored retrievable storage (MRS) of OUNF in Sweden, (6,8) which has been in operation for more than 10 years, is an excellent example of an environmentally robust and "terrorist-unfriendly" LLRM-storage facility.

In summation, *both the technology and operating experience required for safe storage of LLRMs are well proven around the world* for a broad range of different LLRM-storage concepts (e.g., 3,4). The major current global challenge seems to be to find LLRM-storage sites with adequate local acceptance and support away from the sites where the LLRMs are generated, if needed. A related national/domestic challenge is that the operational life and productivity/ efficiency of existing nuclear power plants have continued to increase, which, in turn, results in more LLRMs that require more and, in some cases, earlier storage solutions due to the accelerated filling of available storage space. As illustrated by recent international and national actions, e.g., in Russia and USA, respectively, the development of additional LLRM-storage solutions is a recognized need that, in our opinion, could benefit both in terms of cost and schedule reductions from collaborations among the LLRM generators, including the joint siting, development, and operation of LLRM-storage facilities, and other LLRM disposition solutions.

Recycling/treatment, including Reprocessing

Recycling and treatment, including reprocessing, of LLRMs are common industrial processes (e.g., 3,4,7). Indeed, reprocessing is an LLRM-disposition technology/solution that has been safely used on an industrial scale in France, England, and the USA for more than 30 years. Reprocessing essentially enhances the concentration of radioisotopes required for nuclear energy and nuclear weapons production; however, it produces large quantities of waste.

Deep Geological Disposal

At the end of the year 2002, *the WIPP repository is the only operating deep geological LLRM-disposal facility in the world.* As schematically illustrated in Figure 3, the WIPP repository and the adjoining WIPP underground research laboratory (URL) are *situated approximately 650 m below the ground surface in the lower half of a 250-million-year-old, approximately 600-m-thick, virtually impermeable, laterally extensive bedded salt formation; the Salado Formation* (9,10). In May 1998, the U.S. Environmental Protection Agency (USEPA) confirmed (11) that the WIPP disposal system complied with the nation's "Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes" and the related regulatory compliance criteria (12,13). When filled to its statutory capacity, WIPP may contain up to 175,584 m^3 of TRUW (14). After almost four years of safe operation, the WIPP site/repository has safely received, handled, and disposed almost 2,000 shipments of TRUW from five sites located diagonally across the USA (10).

The world's next three LLRM repositories scheduled to open are in the USA (welded tuff), Sweden (crystalline/igneous rocks), and Finland (crystalline/igneous rocks) in the years 2010, 2015, and 2020, respectively. Notwithstanding the current global scarcity of operating LLRM-disposal facilities, deep geological disposal of LLRMs has been pursued around the world for more than 45 years, and it is presently by far the most scientifically and technologically advanced/mature and internationally accepted LLRM-disposal solution (e.g., 1-6,15-17). Pending the development, opening and operation of additional repositories, WIPP provides an invaluable national environmental management and restoration (cleanup) solution that also serves as a global physical demonstration of:

- The feasibility of the deep geological disposal concept;
- Rock salt's excellent radionuclide containment and isolation characteristics; and
- The feasibility of safe long-distance (truck) transportation of LLRMs.

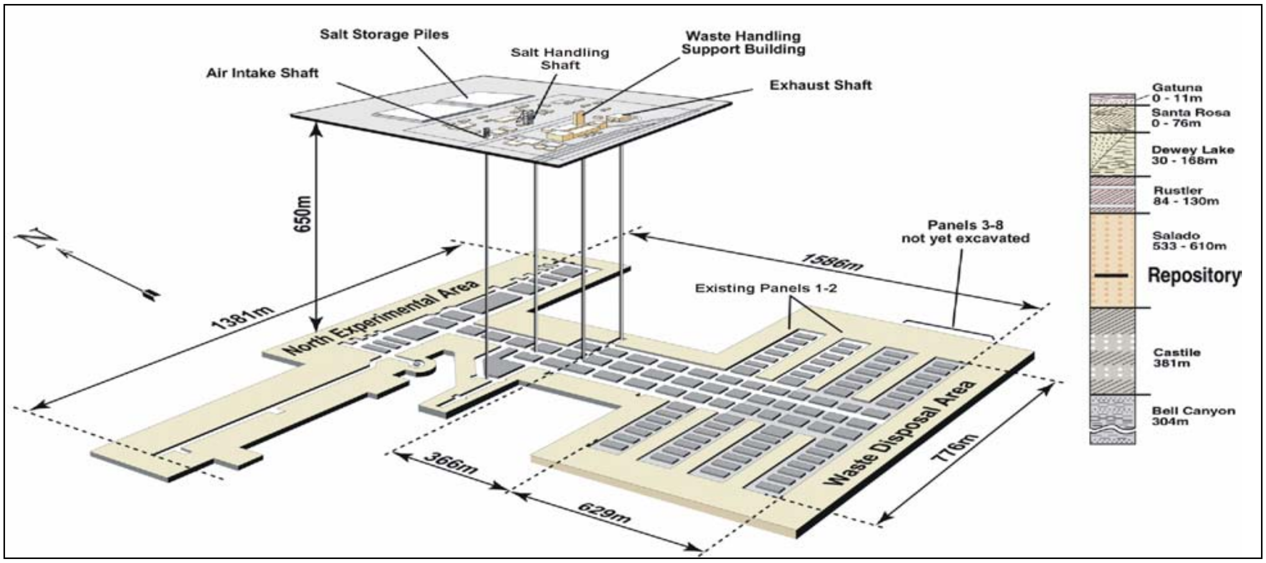

Fig. 3. Schematic illustration of surface and subsurface facilities and the stratigraphic column at the WIPP site (the 75 km^3 WIPP disposal system comprises a surface area set aside by law from public use measuring 6.4 km by 6.4 km and the underlying portion of the geosphere down to a depth of 1.83 km).

Promising LLRM-Disposition Solutions

Transmutation

During the past decade, *transmutation* has often been touted and promoted as the ultimate solution to the safe "elimination" of the world's present and future LLRMs, including removing the need for deep geological disposal. Large financial and intellectual investments have been and continue to be made both in the USA and abroad to establish its full potential (e.g., 3,6-8). For example, the European Commission (EC) has and continues to sponsor transmutation-related research and development (R&D) activities on the order of 25 million U.S. dollars per year or more. Whereas a large portion of the world's scientific community presently questions whether transmutation may eliminate the need for deep geological disposal, there seems to be a global consensus that transmutation offers the potential to *reduce* the amount of LLRMs (actinides) requiring deep geological disposal (3-8). However, considerable additional investments and, likely, a couple of additional decades, are needed before transmutation may be available on the industrial scale required for practical LLRM-disposition solutions. In the meantime, there are major technical, social, economic and political problems to overcome to plan and develop/establish the safeguards and solutions required for the safe disposition of the existing and to be generated stockpiles of LLRMs.

Retrievability

Until the last decade, retrieval of LLRMs for up to 50 years after the completion of the disposal operation was essentially a concept pursued only in the USA (18). However, during the past decade, retrieval and related permutations of this concept, such as removal, recovery, and reversibility (all of the aforementioned concepts are hereinafter referred collectively to as retrieval), have gained considerable global support and are now integral components of many national LLRM-disposal programs for extended time periods after the termination of the disposal operation (3,6,8,15-17). One reason given for incorporating retrieval is to provide future generations options to either use, treat, and/or otherwise dispose the LLRMs emplaced in a repository (e.g., 6). However, *we have not been able to identify a single case to date where retrieval of LLRMs from a deep geological repository would increase the post-closure performance of a deep geologic repository in terms of safety. Although the retrievability option/component has been referred to as bringing a parachute while flying a test plane, we are concerned that the retrieval of LLRMs from a repository would require measures that increase the risk to workers, cost more, and require more time than the “retrieval” of the same LLRMs from a carefully designed and safeguarded LLRM-storage facility*.

In summation, the aforementioned goals for retrievability seem to be much better satisfied by proven long-term-storage options rather than any deep geological disposal option. The storage option would also remove any repository-related retrieval requirement that might compromise the ability of the natural barriers to contain and isolate the disposed LLRMs.

Public Acceptance

As evidenced/experienced in Canada, Finland, France, Sweden, Switzerland, the U.K., and the USA, *public acceptance is one cornerstone to the political acceptance, cost-effectiveness, and timely development of an emotionally charged project in a democratic society*, such as an LLRM-disposition solution or a related URL. However, deep geological disposal of LLRMs involves unprecedented considerations that are beyond the comprehension of most people in terms of:

- The scientific and engineering concepts employed; and
- The temporal and spatial scales involved.

Indeed, as illustrated on a national scale in Canada, Germany, and U.K., and on local scales in Sweden (Malå and Storuman), Switzerland (Wellenberg), and the USA (the State of Nevada), one of the most challenging aspects of developing safe LLRM-disposition solutions is to make the proposed disposal concept understood and accepted by the general public and their elected representatives in the vicinity of the proposed site. Hence, for professionals engaged in the search for LLRM-disposition solutions that enhance the global nuclear safety culture and the nuclear renaissance, it is appropriate to ask the following question:

> *To what extent can the successful opening and safe operation of WIPP be transferred to other LLRM-repository programs*?

Based on our long-standing interest and involvement from different vantage points in the WIPP evolution (e.g., 9,19,20), in no order of priority/value, we would like to recognize the following ten conditions and stratagems as particularly important to the local acceptance and national acceptance leading to the May 18, 1998 certification and the March 26, 1999 opening of the WIPP site/repository for safe disposal of LLRMs:

1. Regulations that are perceived by the general public as adequately protecting current and future generations and environments.
2. A regulatory body perceived by the general public as adequately protecting current and future generations and environments.
3. Local governmental involvement through an independent technical oversight group, the New Mexico Environmental Evaluation Group (EEG)
4. Early engagement of affected and interested parties in an active, continuous dialogue. As illustrated in Figure 4, between October 1993 and September 1998, the USDOE engaged in 48 pre-scheduled public interactions with affected and interested parties, including regulators and oversight groups for the WIPP TRUW repository.
5. Periodic evaluations by domestic expert groups assembled and directed by the National Academies’ National Research Council.

6. Evaluation of the long-term safety/performance of the WIPP disposal system by recognized international experts assembled and directed jointly by the Organisation for Economic Co-operation and Development/Nuclear Energy Agency (OECD/NEA) and the International Atomic Energy Agency (IAEA).
7. A "straight-forward", readily understood disposal concept that doesn't invoke unnecessary concerns or fear among the general public.
8. A "simple", comfortably-thick-and-laterally-extensive, reasonably-predictable (uniform) geologic setting.
9. The ability and willingness to describe/convey the risks and benefits involved in terms that are understood by the general public. The "relational" database developed at WIPP to describe the advanced sciences and engineering concepts and results at WIPP in terms of events and conditions more familiar to the general public was particularly effective in conveying the risks and benefits associated with the WIPP repository and to establish and maintain an informed participation in the process addressed in item 4.
10. Leadership, teamwork, and accountability among the key affected and interested parties.

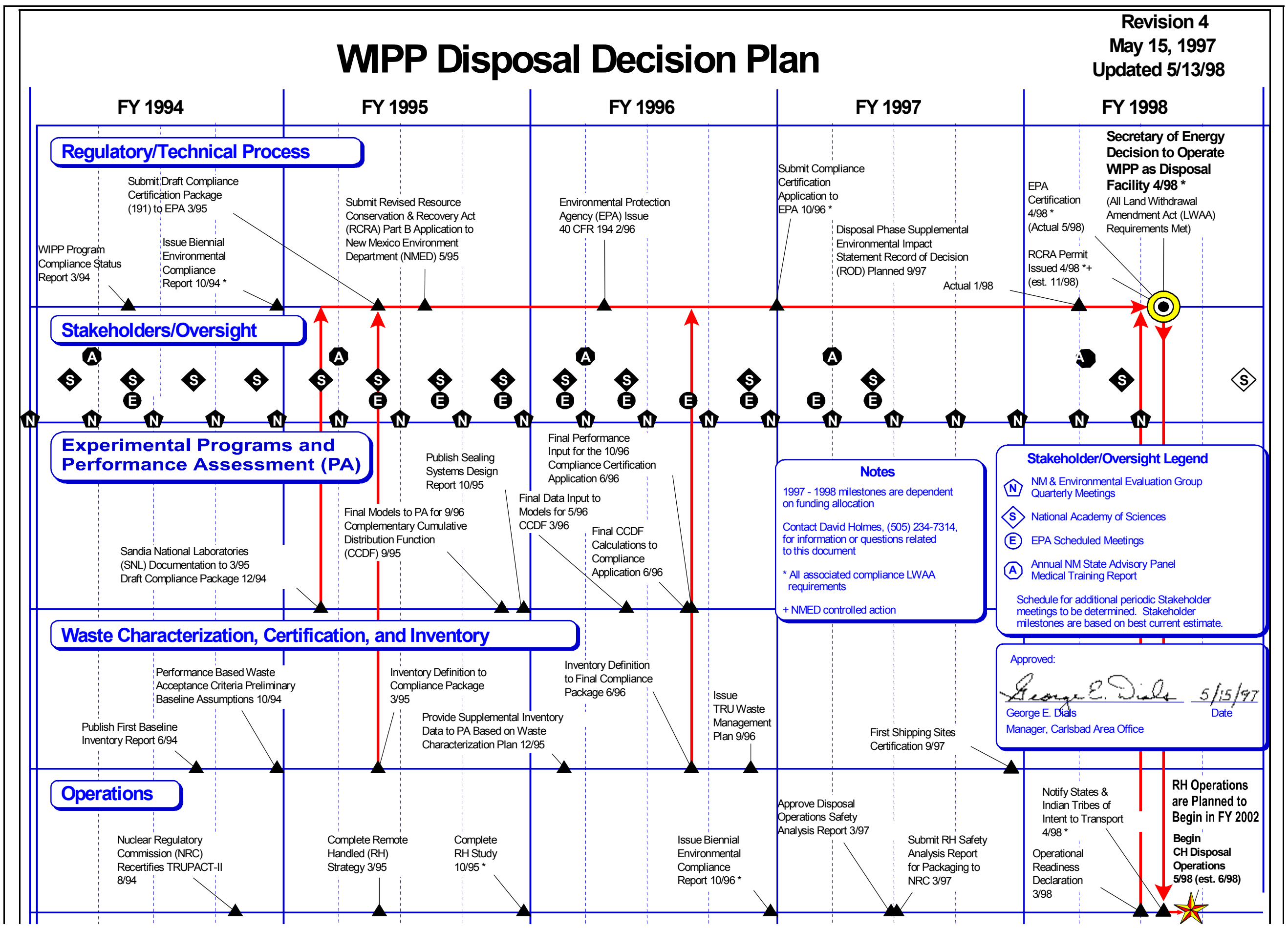

Fig. 4. The 1994 WIPP Disposal Decision Plan (Revision 4).

Despite the presence of a "proven" domestic LLRM-disposal solution and an unequalled amount of financial and intellectual resources, the development of a similar disposal solution at another location in a different geologic medium in the USA has experienced long-standing local opposition (e.g., 5,9). This opposition, among other things, has repeatedly delayed the projected opening of the nation's next LLRM repository, which is currently planned for opening in the year 2010. Furthermore, due to the lack of an alternate LLRM-disposition solution, the USDOE is currently more than five years behind its statutory mandate to begin taking title to OUNF from the utilities, which, in the year 2002, had resulted in 20 legal claims for financial compensation from the utilities that amounts to several billion dollars (9). Means to advance the USDOE's present ability to take title to OUNF from the utilities are outlined in the example on a partial application of the holistic approach describe below.

FUNDAMENTAL PREMISES OF THE HOLISTIC APPROACH

As mentioned above, the primary bases for the holistic approach described and discussed in this document are:

- The authors' almost 100 years of combined involvement in and monitoring of LLRM-disposition R&D and programs in the USA and abroad for the past 45 years; and
- Technologies deemed by the authors to be either "proven" or "promising" as key contributors to addressing or solving current LLRM-disposition challenges to the satisfaction and benefit of current and future generations and environments, and that could be implemented in a step-wise manner contingent upon the prevailing desired outcome(s), available financial, scientific, and technical resources, and political will.

The fundamental principles embodied in the holistic approach are:

1. The minimization of risks.
2. The minimization of LLRM volumes requiring deep geological disposal.
3. LLRM-disposition flexibility, including nuclear fuel preservation.
4. The recognition that safety, cost, and politics essentially govern the manner in which any LLRM is disposed.

Furthermore, an integral component of these principles is to allow time for proposed, promising, and new LLRM-disposition solutions to evolve/mature technically, financially, and politically. In addition, the holistic approach illustrated in Figure 1, embodies the following four fundamental "common-sense" elements:

1. Compliance with existing laws and regulations.
2. Taking full advantage of existing state of knowledge of science and technology (lessons learned) and infrastructure.
3. Refinements to the tail end of the nuclear fuel cycle that
   a. Enhance safeguards,
   b. Reduce national dependence upon foreign energy sources, and
   c. Reduce LLRM-waste volumes.

   Separation/partitioning and reprocessing are examples of Figure 1 components that *apply to at least one of the aforementioned performance objectives*.
4. Concurrent development of
   a. LLRM-disposition technologies that reduce the burden on future generations and
   b. Storage and disposal facilities that do not impose any undue burden on current or future generations and environments.

   Transmutation, monitored retrievable storage, and *deep geological disposal* are examples of Figure 1 components and facilities that apply to this element.

The subsequent text focuses on "common sense" element 4 above, because it is a missing link in most national LLRM-disposition programs. It also includes an example on the potential benefits of a "partial" application of element 4, i.e., *the prompt development of a long-term OUNF-storage facility,* that could mitigate some major current and, likely, future challenges to the "timely" disposition of OUNF and other high-level radioactive waste (HLW) in the USA. *Although the conditions in the USA, as well as elsewhere, largely involve State- and site-specific issue and conditions, the logic embodied in the subsequent discussion has global applications and benefits that could enhance both the global nuclear safety culture and the nuclear renaissance,* ***politics permitting****.*

POTENTIAL BENEFITS AND APPLICATIONS OF THE HOLISTIC APPROACH

Simply stated, the more of the components/technologies shown in Figure 1 that are available, the greater the flexibility of a national LLRM-disposition program as is the preservation of a limited natural resource to both current and future generations and environments. Furthermore, in view of the large costs involved, joint development and operation of the components/technologies shown in Figure 1, as well as any other component/technology, offer significant cost savings to the participating parties. Concisely described below are potential benefits embodied in each of the components/technologies shown in Figure 1.

The *separation/partitioning* and *recycling/treatment* components shown in Figure 1, both individually and combined, enable the controlled separation of the different constituents in the LLRMs into well-defined categories. (7) These may then be subjected either to "secondary" use or have no need to be disposed in a deep geological repository resulting in significant cost-savings. In addition, for some radioactive constituents, additional "treatment" by means of *reprocessing and/or transmutation* may enable fuel conservation, "secondary" energy generation, and waste minimization in terms of the amount requiring deep geological disposal. Although reprocessing and reusing OUNF may be presently uneconomical, we are very supportive of leaving these options open to future generations for the following reasons:

1. OUNF still contains more than 90 percent (%) of its initial (pre-use) energy content.
2. Uranium is a limited natural resource.
3. They reduce the amount of LLRMs requiring deep geological disposal.

Furthermore, pending the potential availability of the *transmutation* option (and other LLRM-waste-minimization options) and the present scarcity of LLRM-disposal solutions, one important national issue is the consideration, planning, and implementation of LLRM-disposition solutions/programs that optimize current solutions without increasing the risks or compromising the benefits to either current or future generations should promising LLRM-disposition solutions succeed. In light of the present lack of an LLRM-disposal solution in the USA (other than WIPP) for at least another seven years, and the lack of an LLRM-disposition solution in the rest of the world for at least another 12 years, long-term LLRM storage provides/offers a proven disposition solution for LLRMs. Indeed, as already successfully implemented in many national programs, *an LLRM-storage component/facility is a proven centerpiece in the holistic approach* (Figure 1). Following are the primary reasons for the high value and importance assigned to the LLRM-storage component in the holistic approach:

1. The technologies required for the construction of a surface, near-surface, or well-below-surface (50 m or more) LLRM-storage facilities are well in hand.
2. The radiation risks to the public and the environment from a properly sited, designed, maintained, monitored, and safeguarded LLRM-storage (and disposal) facility are marginal.
3. A timely opened LLRM-storage facility with the requisite design and capacity may safely accommodate LLRMs for long periods of time during which the following potential benefits/options are or may become available:
    a. Waste minimization may be refined and/or become more economical;
    b. Fuel conservation technologies may be refined and/or become more economical;
    c. The pace of and pressure on the development of a disposal solution (repository) may be relaxed; and
    d. <u>The thermal energy from OUNF may safely dissipate in a controlled manner</u>.

Concerning item 3.d., the thermal energy output per unit volume/weight of OUNF after 40 years of storage is less than 10% of that from 5-year-old OUNF. In other words, contingent upon their respective post-use age and, all other conditions being equal, more long-term stored OUNF may be placed per unit repository area/volume than "young" OUNF, which, at the discretion of the owner, can be converted into either repository life-cycle cost reductions/savings, reduced thermal loading per unit repository area, or a combination of both. Indeed, *there is no apparent compelling <u>economic or nuclear-safety reason</u> for prompt disposal of OUNF*. On the contrary, national security and global non-proliferation concerns could actually be more early and more cheaply remedied by the development of carefully safeguarded OUNF-storage facilities than the development of a deep geological repository.

In the USA, the development of an interim storage facility at an existing government-operated site with a high level of security and, preferably, a long-standing nuclear culture would provide a particularly cost-effective LLRM storage solution and a model that may be applicable also in other nations. Furthermore, *the optimal solution* both in the USA and abroad *in terms of safeguards, non-proliferation, cost, and schedule, is LLRM-storage and -disposal <u>at the same site by multiple parties</u>.*

As discussed above, *retrievability* was included in the holistic approach shown in Figure 1 in recognition of its current political value. However, again, the retrievability concept does not embody a single physical safety component that can be incorporated into the design, construction, operation, closure, or post-closure performance of a repository to the benefit of current and future generations and environments. It may, however, impose conditions that compromise the ability of the natural barriers to contain and isolate the emplaced/disposed LLRMs.

As evidenced in many countries around the world, *the main current global challenge to the siting and development of deep geological repositories is to obtain the required public and political support*. This is particularly the case in the USA, where the USDOE Office of Civilian Radioactive Waste Management (OCRWM) projects that it will open the nation's first deep geological repository for OUNF and defense-generated HLW at the Yucca Mountain (YM) site in the State of Nevada in the year 2010 against the expressed will of the State of Nevada to host the YM repository (9). Notably, before the USDOE may open the YM repository (21), in *addition to being given the requisite annual financial resources by the U.S. Congress in a timely manner*, the OCRWM must accomplish the following *significant* programmatic milestones:

1. Satisfactorily resolve the 293 issues identified by the U.S. Nuclear Regulatory Commission (USNRC), some of which have already been resolved.
2. Provide the USNRC an "*adequately complete/acceptable"* construction license application (CLA) in the year 2004.
3. Receive a repository construction license from the USNRC in the year 2005.
4. Construct adequate disposal space in the YM repository by the year 2010 (Note: construction cannot commence until after the USNRC has approved the CLA).
5. Establish the national infrastructure required for safe shipment of OUNF and HLW to the YM site.
6. Obtain a land withdrawal permit from the U.S. Congress that removes the YM site from public use before commencing disposal operations.
7. Provide the USNRC a complete application to receive OUNF and HLW at the YM site.
8. Receive the USNRC's approval to receive OUNF and HLW at the YM site.
9. Obtain the required permits from the State of Nevada to operate the YM repository.
10. Overcome current (and pending) lawsuits, six of which have been filed by the State of Nevada at the end of January 2003.

Clearly, the OCRWM faces some Herculean tasks that seriously question the attainability of the currently projected year 2010 opening of the YM repository. Furthermore, pending the opening of the nation's first OUNF and HLW repository, the utilities are forced to store their OUNF longer than expected, because the OCRWM a) was required by law to begin taking title to OUNF from the utilities by January 31, 1998 (22), and b) has not developed any other option for taking title to OUNF from the utilities. By the end of the year 2002, the utilities had filed 20 lawsuits seeking several billion dollars in compensation because of the USDOE's overdue statutory obligation to take title to OUNF from the utilities (10).

Two of the USDOE's primary current statutory obligations (22) may be simply paraphrased as follows:

1. The USDOE (the Secretary of Energy) *shall take title to OUNF from commercial nuclear power plants by January 31, 1998.*
2. The USDOE *shall safely dispose all domestic LLRMs, such as TRUW, OUNF/spent nuclear fuel, and HLW, in deep geological repositories located in the USA*.

As ruled by the U.S. Federal Court in 1999, obligation 1 is not coupled to or contingent upon obligation 2. In other words, the manner in which the USDOE takes title to OUNF from the utilities is discretionary, whereas the disposal method is obligatory. For example, the USDOE could take title to OUNF from the utilities by providing a government-operated/managed OUNF-storage facility, which constitutes a very appealing option to us. The most apparent benefits of such an approach are summarized below.

First, in addition to demonstrating the USDOE's serious intent to make every effort to comply with statutory obligation 1 above, *a carefully sited and designed federal OUNF-storage facility would enhance the nation's safeguarding of OUNF*. Furthermore, if the storage facility is located well-below ground (50 m or more) and its ingress and egress is limited in a manner similar to that of the Swedish LLRM-storage facility (6,8), a) the safeguarding would be optimized and b) any radiation release within the facility, *regardless of cause*, would be readily contained, controlled, and mitigated, i.e., *radiation risks to the public would be minimized*.

Second, provided a willing and cooperative host site can be promptly found, in light of the ten OCRWM-milestones listed above for the opening of the YM repository in the year 2010, *the design, development, licensing, and opening* *of an OUNF-storage facility could be a faster, less costly, and publicly and politically more acceptable legal path for taking title to OUNF from the utilities than through the pending, strongly contested, licensing, development and opening process for the YM repository*. For example, as mentioned above, hosting a federal OUNF-storage facility may be particularly attractive to an existing federal facility/site with a well-developed nuclear/radiological history and culture, being considered or scheduled by the base closure program. However, as experience has shown in Canada, Finland, France, Sweden, Switzerland, U.K., and USA, *it would still be important to promptly establish local public and political support*.

Third, in addition to the financial, legal, political, and performance benefits summarized above, in general, *long-term (30-50 years) storage of OUNF also provides the following potential scientific and political benefits*:

1. A window of time for the continued development and/or implementation of other LLRM-disposition-related technologies, such as separation/partitioning, transmutation, and reprocessing.
2. The opportunity to reduce
   a. The size, construction time, and cost of the repository,
   b. The thermal loading per unit repository area, and
   c. The temperature-dependent/induced uncertainty in post-closure safety assessments. (Again, the thermal output from 40-year-old OUNF is typically less than 10% of the thermal output from 5-year-old OUNF.)

Lastly, the implementation of the storage component of the holistic approach would greatly enhance the flexibility of the U.S. LLRM-disposition. It would also comprise a second building block and a step toward timely and cost-effective future expansions of the U.S. LLRM-disposition program that embrace other, currently missing, building blocks of the holistic approach outlined in Figure 1. It is emphasized that ***the development of an LLRM-storage facility does not eliminate the need for deep geological disposal***. It does, however, as indicated in Figure 1 and discussed above, provide an element of flexibility that *reduces the legal, financial, and political pressures on both current and future LLRM-repository-development schedules,* and *facilitates R&D and repository-design options that could reduce financial and societal burdens on current and future generations and environments.*

In closing, one important lesson to be learned from the Finnish, French, Swedish, and U.S. OUNF-disposition programs is that *a well designed and timely implemented holistic national policy and program for safe LLRM disposition provides the flexibility and time required to:*

1. *Enhance national security by being able to store nuclear material at a highly safeguarded, centralized location.*
2. *Establish beyond any reasonable doubt that the proposed LLRM disposition solution is safe.*
3. *Explore technologies that may accommodate re-use of a limited natural resource and/or reductions in the total amount of LLRMs requiring deep geological disposal.*
4. *Demonstrate to the general public that the ultimate objective is to develop a safe LLRM-disposal solution rather than a deep geological repository at a given site by any means and at any cost*.

Figure 1 provides an example of a holistic national approach for synergistic disposition of LLRMs that, if properly implemented, would allow the current generation the flexibility and time required to adequately address and resolve all LLRM-disposition issues, which, in turn, would reduce the burden on and enhance the LLRM-disposition options available to future generations.

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Footnote

[a] Pursuant to current law and regulations,(12-14) only TRUW from *defense-related activities* containing at least 3,700 becquerels of alpha-emitting, transuranic (atomic weight/number greater than uranium-92) isotopes with half-lives greater than 20 years, per gram of waste, and not exceeding a canister surface dose rate of 10 sieverts per hour (Sv/h) may be disposed at the WIPP site. There are two activity-based TRUW categories: *contact handled* (CH) and *remote-handled* (RH), which may have canister surface dose rates of up to 0.002 Sv/h and between 0.002 Sv/h and 10 Sv/h, respectively. *Defense-generated radioactive waste* with activities below 3,700 Bq/g or above 10 Sv/h is classified as low-level (LLW) or high-level radioactive waste (HLW), respectively.