Chapter 6

The Mission Plan

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Chapter 6
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INTRODUCTION

With the enactment of the Nuclear Waste Policy Act of 1982 (NWPA), the Federal Government has, for the first time, committed itself in law to a specific date—January 31, 1998—for beginning the disposal of nuclear waste in a geologic repository. Meeting that commitment will require the Government to surmount many unprecedented technical and institutional challenges in a sustained effort over a period of decades. If that commitment is to be credible-particularly in view of past problems—it must be supported by a Mission Plan that makes ample allowance for the technical and institutional uncertainties associated with development of the first geologic repository.

In developing the Mission Plan, two points must be considered. First, it is ***important to develop a Plan that will be widely regarded as feasible and achievable, to show that there is at least one workable approach to managing spent fuel and high-level waste using the authority provided by NWPA.*** OTA believes that this can be done relatively quickly by using a conservative system design based on currently available information and analysis. While such a Plan would not be optimal, the credibility of the Federal waste management program is far more dependent on the realism and achievability of the Mission Plan than on its optimality.

Second, it maybe possible to reduce significantly the radiation exposure to workers and the public, the costs, and the overall complexity of the waste management process by developing a carefully integrated waste management system design. However, the analytical basis needed to design an optimized integrated system is still under development. Further research, development, and demonstration (RD&D) on waste container designs for such a system will also be required.

For these reasons, the Mission Plan would contain two elements: 1) an achievable initial Plan that includes ample allowances for those uncertainties, and 2) a strategy for revising the initial Plan as appropriate in the light of new data and experience. Each is discussed below.

AN ACHIEVABLE INITIAL PLAN

Basic Elements of the Initial Plain

As part of its analysis, OTA developed an initial Mission Plan that is: 1) consistent with the authority provided by NWPA, 2) likely to be achievable, and 3) responsive to the principal concerns of the major affected parties. While it is sometimes referred to hereafter as the OTA Plan, ' this approach represents for the most part an expansion, rather than a major redirection, of the approach that the Department of Energy (DOE) has followed in the past and presented in the ***Draft Mission Plan*** released in the spring of 1984. The following sections summarize the basic elements of the OTA Plan and compare it with DOE's ***Draft Mission Plan*** in order to highlight key issues.

OTA's proposed Mission Plan emphasizes certainty and places great weight on the importance of minimizing the risk of major programmatic delays or failures. Because of the long history of difficulties in the Federal waste management program, there is limited tolerance for failures. Any major failure—real or perceived—could have grave consequences for both the waste management program and the future use of nuclear power. Thus, the Plan described below is designed to give a high level of confidence that it both ***can*** and will be achieved.

To ensure it can be achieved, the OTA Plan includes a ***conservative waste management plan*** that can be met despite remaining uncertainties. Because geologic repositories are the only large-scale waste facilities authorized and required by NWPA, the heart of a waste management plan based on the authority provided by NWPA is a ***repository loading schedule:*** a target schedule for moving spent fuel from reactor sites (where practically all of it will be stored) to Federal geologic repositories.

The crucial decision concerning the repository loading schedule is the balance between the degree of ***certainty*** that the schedule can be met, and the ***promised speed*** of the schedule. Developing a geologic repository is a complex endeavor involving many first-of-a-kind technical and institutional steps. The faster the promised schedule, the less margin there is for delays or problems at any of these steps, and the less confident one can be that the schedule can be met. To provide utilities and the communities near reactors with a highly reliable schedule for removing spent fuel from interim storage, the OTA Plan emphasizes certainty by using a repository loading schedule that does not require everything to go smoothly the first time.

The OTA Plan also includes an ***implementation program*** designed to give confidence that the conservative loading schedule will be met. The crucial choice to be made in the implementation program concerns the balance between the ***certainty*** that the program will achieve the objectives of the waste management plan on schedule, and the ***initial costs*** of the program, both financial and political. The ***basic fact that must be faced is that it is impossible both to maximize the certainty of achieving the objectives on schedule and to minimize the initial costs at the same time.*** In designing an implementation program, DOE has essentially two choices: 1) a ***preventive approach*** that identifies in advance the most serious potential sources of failure and delay, and includes measures to reduce the chance that they will occur or cope with them if they do; or 2) a ***reactive approach*** that meets the minimum requirements and standards of the Act and assumes that no major failures will occur, or that problems can be dealt with adequately after they occur. The first approach treats the requirements of the Act as a floor rather than a ceiling on DOE's efforts. It will cost more at the start, but over the long run its financial and political costs may be less-perhaps far less—than those incurred by the other approach. Because it includes measures to anticipate and avoid potential delays and failures, the preventive approach is also likely to reduce the time required to develop an operating repository. With this approach, confidence that the Mission Plan will be carried out successfully is based on the anticipation and allowance for potential problems.

To minimize the chance of real or perceived program failures, the OTA Plan uses a preventive implementation strategy. Its central feature is the pursuit of enough backup components of the isolation system (e. g., the waste form and waste container) and candidate repository sites to ensure a high probability that at least one acceptable combination will be available on the target date, even if somewhat predictable failures occur. Such use of backups is a standard technique for achieving high reliability in technical systems.

Major Advantages of the Initial Plan

Because the Mission Plan outlined below requires DOE to go beyond the minimum requirements of NWPA, it may involve higher financial and political costs than those contemplated in DOE's ***Draft Mission Plan.*** These potential costs could be regarded as unnecessary by those who believe that geologic disposal is a relatively straightforward technical enterprise. However, they could also be seen as the price of insurance for a program that cannot afford any major failures or delays. If those who believe that geologic disposal will be easy to implement are proved right, this approach will produce a broad range of technical options and qualified sites ***before*** they are required by the conservative waste management plan. If they are wrong, this approach will be more successful at preventing major delays and will be cheaper in the long run.

While NWPA does not require this approach, it provides sufficient authority for its use and provides a source of funding I hat can be adjusted to cover the costs of such a program.

The Mission Plan presented below offers several other advantages. First, it can serve as an important early step toward demonstration that high-level radioactive waste can and will be disposed of safely. A Plan with adequate provisions for dealing with the remaining technical and institutional uncertainties can increase the consensus in the technical community that the waste management plan and the implementation program are feasible and that regulatory standards will be met. Second, by ensuring that cost estimates, necessary for any future revisions of the waste disposal fee, are based on a program that is widely regarded as being achievable, the Plan should significantly reduce the uncertainty about the ultimate cost of disposal that now faces utilities and ratepayers. Third, the high-confidence approach can contribute to the acceptability of the Plan, since the measures needed to give confidence that the waste management plan can be met should also address some of the key concerns of interested parties such as States and environmental groups. In particular, basing contracts on a conservative repository loading schedule that makes allowances for delays can reduce concerns that safety might be sacrificed for speed, while development of backup repository sites and technologies can reduce concerns that less-than-satisfactory options might be used for lack of any suitable alternatives.

THE WASTE MANAGEMENT PLAN

While NWPA sets a target date of 1998 for initial operation of the first geologic repository, it does not clearly indicate either how fast DOE is to accept waste for disposal after the repository is available or what is to occur if the repository does not begin operating in 1998. To fill in those crucial details, the initial Mission Plan must contain an explicit waste management plan that includes: 1) a credible repository loading schedule that could be met even if there were delays in the repository program, 2) a plan for interim spent fuel storage after 1998 (who is responsible and where storage is to be provided) if the repository is delayed, and 3) a backup plan for monitored retrievable storage (MRS) or alternative disposal facilities that would allow the Federal Government to accept spent fuel or reprocessed waste eventually, even if there are major unforeseen difficulties with geologic disposal.

Repository Loading Schedule

NWPA clearly established the Federal responsibility for disposal of high-level waste and spent fuel and adopted a schedule for development of geologic repositories for that purpose. Since the Act defines a repository as a "system . . . for permanent deep geologic disposal, and disposal as "emplacement in a repository, " the geologic repositories required by the Act are the only facilities that DOE can use to discharge the Federal responsibility for high-level waste disposal. ***Thus, a conservative initial Mission Plan based on the authority now provided by NWPA would focus on the credibility of the repository loading schedule as the basis of the credibility of the Federal commitment to take possession of spent fuel and ultimately remove it from reactor sites.***

The schedule for the first geologic repository is of particular importance, because that repository is the only large-scale waste management facility that NWPA authorizes DOE to construct. Although DOE is required to find a suitable site for the second repository and submit it to the Nuclear Regulatory Commission (NRC) for licensing, further authorization by Congress will be needed for construction of that repository. (As discussed below, the Act's limitation on the amount of spent fuel that can be placed in the first repository before the second begins operation will require eventual construction of the second to accommodate the spent fuel expected to be generated by the reactors now operating or under construction.) NWPA also directs DOE to prepare site-specific designs for MRS facilities, but the Act neither authorizes nor requires DOE to actually site or construct such a facility.

The rate at which spent fuel can be transferred to repositories will be determined primarily by the dates on which the facilities begin operation and by the loading rate of each repository. These are discussed below.

Schedule for Full-Scale Operation of the First Repository

A major reason for the contractual commitment to a schedule for accepting waste at a repository, included in the integrated waste management policy described in chapter 5, is to provide a basis for confidence that spent fuel will ultimately be removed from reactor sites to a permanent resting place, and thus that interim storage will not become a long-term measure by default. OTA's study concluded that the single ***most effective measure to facilitate efforts to provide additional interim spent fuel storage is to provide a highly credible schedule and program for siting and operating geologic repositories.***

To create confidence that interim storage would indeed be interim and not permanent, the certainty of the schedule for repository operation is more important than the speed. Thus the Mission Plan would contain a conservative repository loading schedule that is a ***high-confidence prediction of when repositories are likely to be operating despite the kinds of delays that might be anticipated in a first-of-a-kid venture.*** Such a repository loading schedule must take into account four broad sources of uncertainty: 1) the time that will be required for the technical and institutional steps involved in characterizing and licensing the first repository site, 2) the possibility that NRC will not grant a construction authorization or operating license for the first site submitted for approval, 3) the possibility that the disposal system design might be rejected by NRC or might require substantial modifications to meet regulatory requirements, and 4) the possibility that the target loading rate of each repository cannot be achieved in practice. A repository loading schedule that would provide for these uncertainties would allow ample time for: 1) delays in the siting and licensing process, including rejection of the first site submitted to NRC and the licensing of a backup; and 2) development, licensing, and demonstration of two disposal system designs at the first repository site, before the full-scale packaging and loading facilities are constructed.

The Plan will also need to include more optimistic management goals that show the earliest time that spent fuel could be delivered to the Federal Government, if all goes well. Such goals are needed as program management tools to prevent the allowances for delay in the conservative loading schedule from being used up by avoidable procrastination. However, to avoid ***raising false expectations, such management goals should be clearly distinguished from the conservative "best estimate" schedule used as a basis for contractual commitments.*** Questions about the credibility of the Federal waste management program in the past have stemmed in part from plans and schedules that could only be met if no Technical or institutional difficulties arose. The credibility of the Mission Plan would be enhanced if cent contractual commitments are based on a conservative repository loading schedule that does not assume that everything will go right the first time.

MANAGEMENT TARGET SCHEDULE

The repository management target schedule suggested here provides for operation of the first repository to be accomplished in two phases—a ***demonstration phase*** and an ***operational phase.*** These phases are designed to address separately the two distinct reasons for a repository:

1. ***To demonstrate that a suitable disposal technology exists and that NRC will license it.*** This is needed to allay concerns that there is no solution to the waste disposal problem and can be accomplished with initial licensed emplacement of waste : n a repository.
2. ***To dispose of radioac,bive waste at a scale comparable to the rate at which it is being generated.*** This is needed to ensure that at some definite point waste will actually be removed from storage and moved to a permanent resting place. It requires a full-scale operating repository system.

The target for initial operation in the demonstration phase is January 31 1998, as required by NWPA. For this phase, a small amount of waste (e.g., several hundred tonnes) would be placed in conservatively designed packages during the generic packaging and handling R.D&D program required by NWPA. Permission would be requested from NRC to emplace this material in the repository as soon as possible following issuance of a construction authorization, before the repository's packaging facilities are constructed.

Providing for separate demonstration and operational phases of operation of the first repository offers several advantages:

1. ***It increases the likelihood that the 1998 deadline for initial repository operation will be met,*** Analysis by DOE indicates that the 1998 deadline probably cannot be met if operation of the first repository is deferred until the full-scale packaging and handling facilities can be built. [1] Under the conservative Plan described in this chapter, initial emplacement of waste in the repository would be accomplished before the repository's packaging facilities had been constructed”. This should minimize the time between the construction authorization and the first licensed disposal in the repository, thus increasing the chances that the 1998 deadline can be met even if there are delays in receiving the first construction authorization.
2. It allows ***an early demonstration of licensed disposal.*** What is needed to demonstrate that radioactive waste can and will be safely disposed of is not only the physical technology of disposal, but also the institutional capacity of NRC to make a regulatory decision that a repository at a specific site can be expected to provide the required degree of waste isolation. NRC approval of a licensed phase of low-level operation, as soon as possible after the construction authorization is granted, could provide an early demonstration of both the physical and institutional requirements for disposal. Licensed low-level operation may also be adequate to satisfy the requirement in some State moratorium legislation that no new nuclear reactors be licensed until a demonstrated disposal technology has been approved by the Federal Government.[2]
3. ***It allows time to optimize the system design for the operationa[l]-phase.*** Meeting the January 1998 deadline with an initial phase of low-level operation could also separate the question of demonstrating the existence of a disposal technology from that of full-scale operation. The demonstration phase would use a conservative repository system design (discussed below), based on the principle that the certainty of obtaining NRC approval with a minimum of technical disputes should take priority over cost-effectiveness. Deferring the operational phase would allow more time for DOE to develop, and NRC to approve, a full-scale system design in which broader waste management system considerations such as cost and worker radiation exposures are given higher priority. This might allow relaxation of initial conservatism in repository design, if justified by the results of low-level operation and testing, thus reducing the risk that adoption of a conservative baseline system design in the initial Mission Plan could lead to costs that later prove to be unnecessary.

This approach may also reduce disposal costs in the long run compared to DOE's proposed approach, which involves construction of full-scale packaging and handling facilities quickly after a construction authorization is granted.[3] There are several sources of possible cost savings. First, this approach allows time to develop and license an optimized system design. As noted earlier, recent studies suggest that it may be possible to significantly reduce total waste management system costs and radiation exposures during operation by using a carefully integrated system design.[4] DOE's cur-

[1] U. S. Department of Energy, *Draft Mission Plan for the Civilian Radioactive Waste Management Program,* DOE/RW-0005 DRAFT, April 1984, pp. 3-A-36 and 3-A-37 (hereafter *Draft Mission Plan).*

[2] Analysis by the presiding member of the Nuclear Fuel Cycle Committee of the California Energy Resources Conservation and Development Commission concludes that the last step needed for demonstration is confirmation of the existence of a suitable site. Emilio E. Varanini, III, ‘ ‘Aspects of Demonstrating Nuclear Waste Disposal, statement presented to the Waste Disposal Technology Symposium, University of Arizona, Tucson, Ariz., Feb. 27, 1979. This could be accomplished by NRC approval of initial disposal at a site.

[3] DOE's *Draft Mission Plan* includes two phases of repository operation but initiates construction of the full-scale facilities at the same time as the pilot-scale facilities. There is no allowance for a period of low-level operation before the design of the full-scale facilities is locked in. Instead, the two-phase aproach is used primarily as a way of meeting the 1998 deadline, rather than allowing time to develop and test an optimized system design before commiting to construction of the full-scale system.

[4] Raymond E. Hoskins, “Concept for an All-Purpose Transport, Storage and Disposal Cask for Spent Nuclear Fuel Management, ” published *in Proceedings of the 1983 Civilian Radioactive Waste Management Information Meeting, CONF-8312 17,* U.S. Department of Energy, February 1984, pp. 362-368. See also Westinghouse Electric Corporation, Waste Technology Services Division, *Preliminary Cost Analysis ofa Universal Package Concept in the Spent* Fuel *Management System,* WTSD-TME-432, September 1984.

rent plans may not allow time to develop and incorporate an optimized integrated design in the first repository, however, since DOE did not formally initiate an effort to develop concepts for an integrated system until 1984. To avoid foreclosing prematurely the option of using such an integrated system for the first repository, the ***DOE management target schedule for construction of the full-scale packaging and handling facilities for the operational phase would be determined by the time required to develop, test, and license an optimized integrated system design.*** Whether or not this would require an adjustment of several years in DOE's current planning schedule (for operation of full-scale facilities in 2001) is by no means certain. However, the potential benefits to be obtained could more than offset the cost of the additional storage required if a delay of several years were involved.

Second, it would provide greater certainty that the full-scale system could be operated at the target rate required by the repository loading schedule, since the final design would have the benefit of the experience gained during low-level operation in the demonstration phase. This would reduce the risk of costly and time-consuming modifications to an already constructed facility unable to operate at the target rate.[5]

Third, it would allow more time to resolve questions about whether and when spent fuel might be reprocessed. This would allow the operational disposal system design to be optimized based on better information about the relative proportions of spent fuel and high-level waste from reprocessing it would have to handle, and would reduce concerns that irreversible decisions about the fate of spent fuel would be made prematurely.

Fourth, deferring the large costs of full-scale operation can reduce the total discounted cost of disposal, thus offsetting to some extent the costs of the additional interim storage that would be required.

[5]While the DOE *Draft Mission Plan* provides for an initial phase of repository loading using partial loading facilities, it does not allow time to test the loading facility design before full-scale facilities are constructed. Since there is no experience at packaging and handling highly radioactive materials at the rates expected during full-scale repository operation, constructing the full-scale facilities without experience at an intermediate scale increases the risk that repositories will not be able to achieve their target loading rates in practice.

CONTRACTUAL REPOSITORY LOADING SCHEDULE

The repository loading schedule used for contracts with utilities would be based on operation of full-scale loading facilities beginning no later than 2008 at the first repository. This date is a credible basis for commitments because, unlike the more optimistic management schedule, it can be met even if significant technical and institutional difficulties are encountered. For example, the first repository could be operating by 2008 even if none of the sites initially evaluated at depth (' 'characterized' proved acceptable and a new site not now under consideration had to be used. (By contrast, the DOE ***Draft Mission Plan*** estimates that the ***second*** repository could be operating by 2004, even if both a new site and a new geologic medium [granite] were used.) Spent fuel could be accepted some years earlier than the commitment date if the contingencies that have been allowed for, such as the need to use a backup site, do not materialize-provided that the repository program has been managed firmly enough to prevent the allowances from being used up by avoidable delays.

The 2008 commitment date for operation of full-scale facilities at the first repository is consistent with some independent assessments of the likely availability of a repository. NRC has determined in its "waste confidence' rulemaking that there is reasonable assurance that a geologic repository would be available between 2007 and 2009.[6] The Tennessee Valley Authority, in an analysis of its own needs for additional spent fuel storage, estimates no better than a 50-50 chance that DOE will be able to accept spent fuel on a large scale by 2008.[7] OTA believes that use of the implementation program described below can substantially increase the level of confidence that a repository would be available by that time.

Schedule for Operations of the Second Repository

The Act does not commit to a specific date by which the second repository is to come on line, but rather sets a limit of 70,000 tonnes on the amount of spent fuel or equivalent high-level waste that can

[6]*Federal* Register, vol. 48, No. 99, May 20, 1983, p. 22730.
[7]Hoskins, op. cit.

be placed into the first repository before the second begins operation. DOE analysis shows that the second repository could open by 2005, at the earliest, if the first site recommended for that repository is approved by NRC and there are no substantial delays in the siting process. At most, it could open as late as 30 years after the first, since it would take about that long to emplace 70,000 tonnes in the first repository, according to DOE's most recent repository loading schedule. (It should be noted that because the reactors that are currently ope ating or under construction are expected to discharge over 100,000 tonnes of spent fuel during their lifetimes, the 70,000-tonne limit on the first repository implies that the second ***must*** ultimately be built if projected amounts of waste are to be accommodated without amendment of NWPA.)

The proposed Mission Plan would commit to operation of the full-scale facilities of the second repository to begin no later than 2012—4 years after the commitment date for full-scale facilities of the first repository. An explicit commitment to operation of a second repository soon after the first would allay concerns that the first repository would become the Nation's sole "nuclear waste dump' for many decades, and would provide a backup to the first repository to ensure that some disposal operations could take place even if problems developed with one repository. In addition, if an acceptable site for a second repository can be found nearer the bulk of the reactors in the East, it will significantly reduce the costs and impacts of full-scale transportation of high-level radioactive waste from reactors to disposal. Planning for a short delay between operation of the first and second repositories allows more time to identify suitable sites in the East, and time for experience at operating the first repository before the second starts up.

Target Full-Scale Annual Loading Rate

The target loading rate of each repository is a major design decision affecting the entire waste management system. It will determine how long each repository will be in operation, how quickly the buildup of spent fuel in storage at reactors can be stopped, and how long it will take to eliminate the backlogs that are already in storage at the time repository loading begins. The higher the target loading rate, the more rapidly the backlogs can be eliminated. At the same time, increasing the repository loading rate will increase the cost of the packaging and handling facilities, the number of transportation casks needed to deliver waste to the repository, and the number of shipments needed each year.

Three considerations are relevant to choosing a design maximum loading rate: the projected types and amounts of waste that must be accepted, the goal for removing waste from interim storage, and the desired reserve margin in the loading capacity. Each will be discussed briefly.

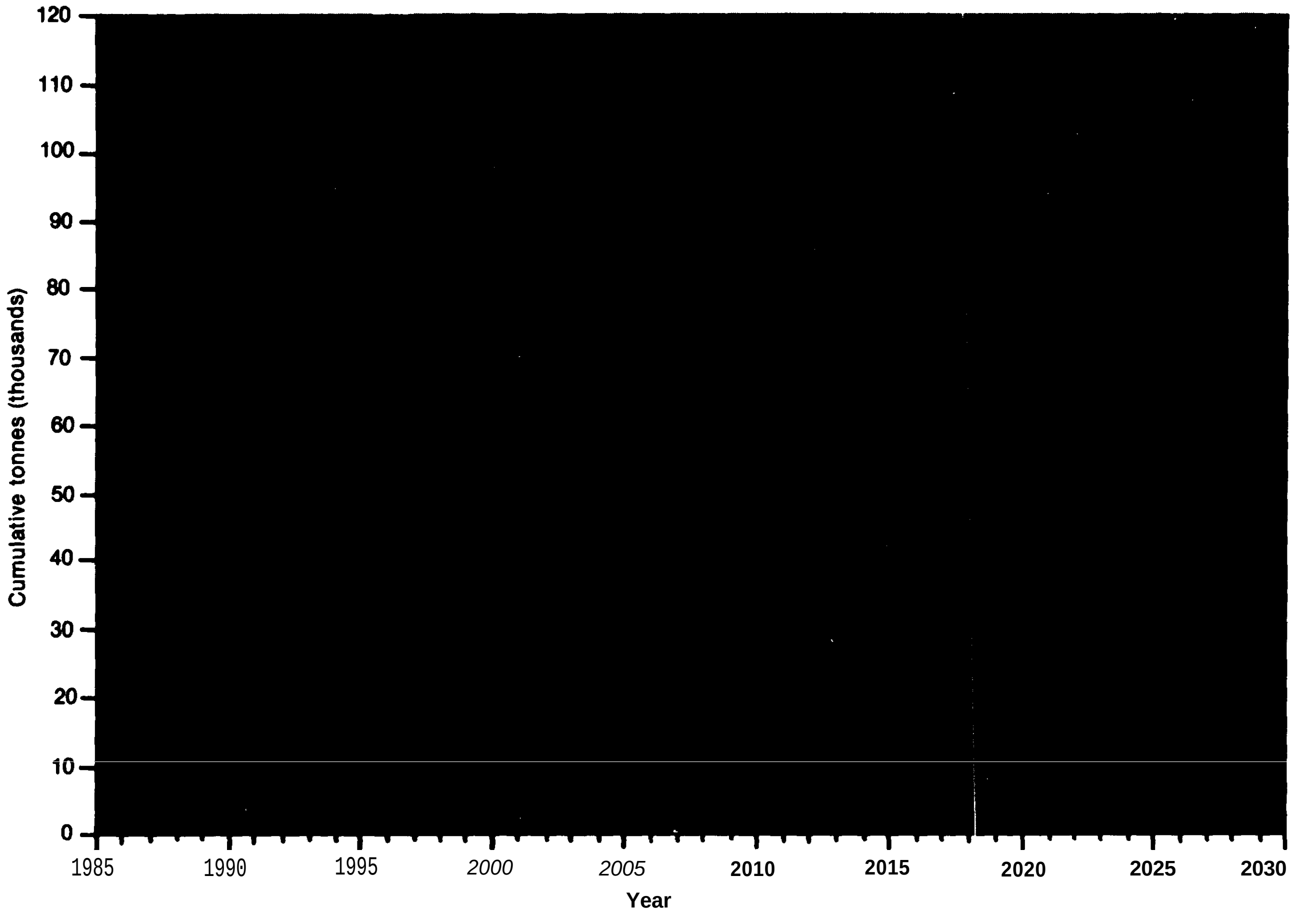
WASTE PROJECTIONS

A waste management plan must be based on some assumptions about the amount of spent fuel that will be generated in the future. The more reactors that are expected to be operating when the repositories begin operation, the greater the loading capacity that will be needed to stop the buildup of spent fuel in storage. OTA suggests that, as a base case for the waste management plan, DOE consider the spent fuel expected to be generated by the reactors that are now operating or are under construction (see fig. 6-1). If additional reactors are ordered in the future, the Mission Plan can be revised as needed. (If the increase over currently planned construction is relatively small, it could probably be handled by increasing the design loading rate of one or both of the two repositories required by the Act, or by extending the operational period of the repositories. If the increase is large, additional repositories may be required.) This would provide a conservative basis for estimating the fee that will have to be charged to ensure full-cost recovery, as required by NWPA. A fee based on the expectation of revenues from reactors that have yet to be ordered could turn out to have been too low if those orders do not materialize, [8] and could produce insufficient revenues in the early years of the program.

The waste projections must also make assumptions about the relative amounts of spent fuel and high-level waste from reprocessing that would be delivered for disposal. A conservative ***assumption is*** that all spent fuel would be delivered directly to

8U. S. Department of Energy, *Report on Financing the Disposal of Commercial Spent Nuclear Fuel and Processed High-Level Radioactive* Waste, DOE/S-0020 (Washington, D. C., June 1983), p. 30.

Figure 6=1.-Spent Fuei Projections: LWRS Operating and With Construction Parmlts on Dec. 31, 1932



[a]Assumes basins are reracked to the maximum extent, but no rod consolidation. Consolidation could significantly increase the capacity of the existing basins.

SOURCE: Data supplied by U.S. Uepartment of Energy (aea app. E).

repositories without reprocessing. This would give a high estimate of the number of packages of highly radioactive waste to be received, packaged, and emplaced in each repository each year, since it is expected that there would be fewer packages of solidified high-level waste than of spent fuel for a given amount of electricity generation. At the same time, a conservative plan would provide capacity to dispose of the high-level waste from the West Valley reprocessing plant and the defense nuclear programs.

Planning to provide capacity for direct disposal of all spent fuel simply ensures that disposal will be available as an option according to the planned schedule, not that spent fuel must be disposed of according to the schedule. Thus, it does not preclude future decisions to defer disposal. In fact, once the repository packaging and handling facilities needed to meet the reference loading schedule have been constructed, it would be possible to store the packaged spent fuel on the surface at the repository if that were desired.

GOAL FOR REMOVING WASTE FROM STORAGE

DOE estimates that by 1998, some 36,000 tonnes of spent fuel will be in storage (practically all of it at reactor sites), and about 2,300 additional tonnes will be discharged each year by the reactors that are in operation at that time.[8] While it is possible

[8]U.S. Department of Energy, *Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics,* DOE/RW-0006, September 1984, table 1.2, p. 30.

that one repository loading at 3,000 tonnes per year could handle the total annual discharge from the reactors that are already operating or under construction, it would have little capacity left over to begin reducing the backlog. A major design question, then, is how much loading capacity to provide beyond the amount needed to stop the buildup of spent fuel. This decision will depend upon how quickly it is desired to remove waste from interim storage sites, and, in particular, how quickly to remove spent fuel from reactor sites.

As discussed in chapter 3, once fuel has been placed into storage, it may be cheaper to leave it there for an extended period than to construct the additional transportation and disposal capacity needed to allow it to be removed quickly. Furthermore, NRC has concluded in its "waste confidence' rule that spent fuel can be left safely at reactor sites up to 30 years after expiration of the reactor's operating license. Nonetheless, the prospect of spent fuel remaining in storage at reactor sites for decades after the reactors cease operation may be objected to by the surrounding communities and may be viewed as a negative factor in decisions about siting and construction of new reactors. The repository loading schedule must strike a balance between these considerations.

Allowing 10 to 15 years after reactor shutdown for spent fuel removal could be advantageous because it would avoid the strains on the transportation and handling systems that would result if a reactor's lifetime discharge had to be removed within a few years.[10] In addition, designing and licensing the transportation cask fleet to handle only fuel that is at least 10 years old would provide an additional safety margin because of the reduction in heat output of the fuel.[11] Under the current DOE contract, spent fuel must be at least 5 years old before it can be delivered to DOE, which means that some spent fuel will remain at reactor sites for at least 5 years after decommissioning.

Operation of full-scale facilities of the first repository as late as 2008 and the second repository as late as 2012 would not lead to large amounts of spent fuel being left at reactor sites for an extended period after decommissioning. Even with that schedule, two repositories, each loading at 3,000 tonnes per year, could dispose of all the spent fuel expected to be generated by the reactors now operating or under construction by about 2030, and could ensure that spent fuel is removed from each reactor site within 10 to 15 years after the reactor ceases operation.[12]

RESERVE MARGIN

Confidence that the desired annual loading rates will be achieved in practice can be increased by planning to construct one more independent processing line than the minimum expected to be required to meet target loading rates. Available studies suggest that a single processing line ***may*** be capable of achieving the loading rate of 3,000 tonnes per year now being used in DOE plans.[13] However, construction of two lines provides a reserve margin that can, in several ways, increase the confidence that that rate will be achieved in practice.

First, the loading rate depends on both the number of packages per year that the processing line can handle and the amount of waste that can be placed in each package. Even if one line is able to process the required number of packages each year, it is possible that site-specific considerations might require a lower package waste load than anticipated. Provision of a second packaging line would allow the waste load per package to be reduced by half without lowering the total loading rate.

Second, the reserve margin provided by a second packaging line is insurance against the possibility that unanticipated operational difficulties might force each line to operate at a lower rate than planned. The risk that this would occur could be reduced by planning to begin full-scaie operation following construction of the first processing line, and to defer construction of the second until the design is confirmed in practice and any needed modifications are made.

[10] Ali Ghovanlou et al., *Analysis of Nuclear Waste Disposal and Strategies for Facility Deployment*, The MITRE Corporation, (McLean, Va., April 1980), p. 6-51.

[11] As discussed in ch. 3, cask design studies show that increasing the age of fuel from 5 to 10 years leads to a 1000 F reduction in maximum fuel temperature during a design-basis fire.

[12] Data on light-water reactors that are operating and with construction permits provided by DOE. See app. G for calculations.

[13] Westinghouse Electric Corporation, Advanced Energy Systems Division, *Engineered Waste Package Conceptual Design Defense High Level Waste (Form 1) and Spent Fuel (Form 2)* Disposal *in Salt*, AESD-TMA-3131, September 1982, pp. 422-423.

Third, a second processing line provides backup loading capacity against the possibility of accidents or other problems that would halt, interrupt, or slow down the operations of the first line, or loading of the other repository. In fact, if a single line proves capable of handling the target rate of 3,000 tonnes per year, the second line would provide fully redundant capacity to handle material intended for the other repository if loading of that repository were halted for any reason.

Addition of a second processing line is estimated to cost between $18 million and $60 million, depending on the package design .14 In addition to increasing confidence that the loading schedule will be achieved, it could also allow defense high-level waste to be loaded in the repository (if a decision is made to do so) without seriously affecting the loading of commercial waste.

Storage: The Role of the MRS in the Waste Management Plan

Although the major focus of NWPA is the siting and operation of two permanent geologic repositories, the Act also requires DOE to submit designs for, and a study of the need for, one or more monitored retrievable storage (MRS) facilities. This study is to be submitted to Congress in mid-1985, to provide a basis for possible deliberations concerning whether to authorize siting and construction of such a facility.

Proposals for construction of Federal storage facilities have played a major role in debates about waste management policy since 1974, when the Atomic Energy Commission, following failure of the attempt to site a first repository at Lyons, Kansas, suggested Retrievable Surface Storage Facilities (RSSFS) as an interim measure to allow several decades to develop permanent disposal facilities. (See the discussion of storage in ch. 4 and app. A.) Two distinct functions have been proposed for such storage facilities:

1. To provide relatively short-term interim storage as part of a waste management program predicated on fairly rapid development and operation of geologic repositories. This role was the focus of debate on the Carter administration's proposal to provide Federal away-from-reactor (AFR) storage facilities in the 1980's, discussed in issue 4 of appendix B.
2. To provide a long-term waste management option that would allow more time to be taken in developing geolo!gic repositories or other disposal technologies (tie proposed role for the RSSF), or to serve as an alternative to geologic repositories in the event that such repositories cannot be developed for a long, and perhaps indefinite, period. The construction of long-term storage facilities as an alternative to rapid development of geologic repositories is discussed in issue 1 of app. B.

Proposals for construction of MRS facilities have included both functions. 1 t would be valuable for the Mission Plan to analyze the need for each of these principal functions in an integrated waste management system. This would provide a useful perspective for the plan, required to be included in the MRS need and feasibility study, for integrating any MRS facilities that are constructed with the other storage and disposal facilities authorized by the Act. Such analysis would also be responsive to NWPA's requirement that the Mission Plan provide "an informational basis sufficient for informed decisions. A brief discussion of each function follows.

Post-1998 Interim Storage

While the repository program is the principal focus of the Mission Plan, it must also address the issue of interim storage after the 1998 deadline for repository operation. Additional storage capacity will be required after 1993 for three reasons:

- Even if the repository begins operating on schedule in 1998, it will take some time to reach a high enough annual loading rate to equal or exceed the rate at which spent fuel is being generated. DOE currently estimates that this would not occur until 2003.[15]
- Some slippages in the repository operation schedule are possible if: not likely. Even a conservative repository development program might experience some relatively short delays resulting from foreseeable but unavoidable

[14] Ibid., pp. 423 and 434.

[15] DOE, *Draft Mission Plan.*

events such as lawsuits, construction accidents, rejection of a repository site, strikes, and bad weather. While such events could delay repository loading by years, they would not lead to extended or open-ended delays and would not raise major questions about the eventual availability of geologic repositories.
- Even after the repository is operating at full scale, there will be a need for buffer storage capacity in the waste management system to allow reactors to continue operating without disruption even if there are any operational difficulties at the repository that would prevent it from accepting spent fuel at the desired rate.

NWPA provides that utilities be responsible for additional interim storage as needed until DOE can accept the waste at a repository, and the Act does not authorize construction of Federal storage facilities. In accordance with this law, an initial Plan based on the authority in NWPA would provide for ***interim storage by utilities at reactor sites until a repository or alternative long-term waste management facility is available.***

Providing post-1998 interim storage at reactor sites appears to be quite feasible.[16] NWPA contains measures to facilitate utility efforts to provide at-reactor storage until a repository is available, and, as noted earlier, NRC has concluded in its waste confidence rulemaking that spent fuel could be safely stored at reactor sites for up to **30** years after termination of the reactor license. Thus, if no further action were taken by Congress to authorize storage by the FederaI Government, it appears now that the needed storage could and would be provided by the utilities themselves. This shows that the existing authority provided by NWPA is sufficient to carry out a workable waste management program unless currently unforeseen major problems are encountered in developing geologic repositories.

Nonetheless, discussions concerning the Mission Plan have raised the issue of whether the Federal Government has a responsibility or an obligation to take spent fuel after 1998 if a repository is not available as required by NWPA. This involves two interrelated questions: who should be responsible for post-1998 interim storage, and *where* should it be done? These need to be discussed separately, although they are often merged in the comparison of two alternatives: utility responsibility, with storage at the reactor sites; or Federal responsibility, with storage at an MRS facility. There is also a third option that bears consideration, since NWPA allows DOE to take title to spent fuel at reactor sites: Federal responsibility for post-1998 storage at the reactor sites.

[16] DOE "exwcts the increased efficiency of onsite spent fuel storage, that is expected to result from successful completion of the fuel rod consolidation and dry storage demonstrations (now underway), to be sufficient to preclude the need for Federal Interim Storage. " DOE, *Draft Mission Plan,* p. 3-D-5.

RESPONSIBILITY FOR POST-1998 INTERIM STORAGE

Some feel that NWPA requires utilities to provide interim storage for as long as is necessary until a repository is available. Others feel that the Act's 1998 deadline for a repository, and the fact that utilities are now paying fees for disposal services, obligates the Federal waste program to take responsibility for spent fuel beginning in 1998. This is primarily an equity issue rather than a technical question, since NWPA allows DOE to take title to spent fuel at the reactor sites before it is delivered to a repository. Thus, title and responsibility could be transferred according to any arbitrary schedule that could be agreed upon. The options range from continuation of utility responsibility until spent fuel is physically delivered to the repository, to having the waste management program take responsibility for all spent fuel in 1998. OTA's analysis of an integrated waste management policy concluded that it may be possible to reach agreement on the principle that the costs of additional spent fuel storage, beyond the contractual acceptance date (and perhaps title to and liability for the spent fuel), would be transferred from the utility to the waste management program on that date.

It should be noted that under NWPA, the costs of the waste management program are to be recovered from users through fees. Thus, any costs for additional interim storage would be paid for by utilities rather than the Federal Government, whether that storage is provided by the utilities directly or by the Federal waste management program. The question is whether the cost will be paid only by those utilities that would have to provide additional storage if the repository loading schedule is delayed, or by all utilities through the Nuclear Waste Fund.

NWPA currently requires that utilities, to the extent possible, provide interim storage until the spent fuel is accepted by the waste management program, and requires that the costs of the limited 1,900-tonne Federal interim storage program be borne by those utilities that use it. While NWPA provides that any MRS facilities subsequently authorized by Congress would be paid for for the Nuclear Waste Fund, it also requires that the MRS proposal be accompanied by a funding plan that would provide that the costs of constructing and operating such facilities be borne by the generators and owners of the material to be stored in the facilities.

While the decision about who is responsible for post-1998 spent fuel storage would affect primarily the equity of the distribution of waste management costs among the utilities themselves, it could also affect the total costs to the utilities. This will depend on the interest rate set by the Secretary of the Treasury for borrowing by the Nuclear Waste Fund in years when the expenditures exceed the revenues from the waste disposal fee. If that rate is set at the rate for Government securities, rather than at competitive market rates that utilities would face if they were raising capital themselves, shifting the storage costs to the waste management program could reduce the total costs to the utilities and would to some extent represent an implicit Federal subsidy to the waste management program.

LOCATION OF POST-1998 INTERIM STORAGE

If the utilities are responsible for interim storage, it appears likely that most of the storage would be located at reactor sites. If the Federal waste management program takes responsibility, the storage could be done either at centralized MRS facilities located away from the reactor sites, or at the sites themselves, using one of the dry storage technologies that will be demonstrated as part of the program required by NWPA. If combination storage/transportation casks prove feasible and licensable, DOE could simply provide those casks to utilities as needed to store spent fuel that cannot be stored in the reactor basin, since DOE has authority under NWPA to provide transportation casks. (DOE has suggested this option in the ***Draft Mission Plan.)*** Once a repository begins operation, title to the spent fuel could also be transferred to DOE at any desired rate even if the target loading schedule is not achieved, since title can transfer at the reactor site.

If multipurpose casks are not feasible, Congress could authorize DOE to provide other storage facilities directly at reactor sites, as is already authorized under the limited Federal interim storage program in NWPA. This approach maybe desirable unless there are substantial safety and cost benefits to centralized storage, and it would avoid the potential complications of siting and licensing MRS facilities.

If DOE provided additional storage using multipurpose casks, the costs would be borne by the waste management program rather than by the individual utility. If Congress authorizes DOE to construct additional storage facilities, either a centralized MRS or at-reactor facilities, a decision could be made at that time about whether the costs would be borne by all utilities.

The questions involved in providing a centralized Federal MRS for post- 1998 interim storage are essentially similar to those involved in earlier proposals for a Federal AFR storage facility that were considered at the time N WPA was being debated. (These questions are discussed in issue 4 of app. B.) The major difference is that the interim storage provisions of NWPA have dealt with a principal argument made for a Federal AFR: the concern that utilities would not be able to provide additional storage capacity quickly enough to prevent reactor shutdowns. As noted earlier, it now appears likely that utilities will be able to provide their own storage by and after 1998 even if no large Federal storage facility is provided. While a systematic and detailed comparison of storage options must await completion of the MRS needs and feasibility study, available studies suggest some preliminary conclusions, which are discussed below.

Available analyses suggest that decentralized at- reactor storage ***could be economically competitive with centralized storage, and may even be less expensive under some conditions.*** [17] The principal reason is that the at-reactor approach allows the capital cost of handling facilities to be spread out over time as small increments are added on a reactor-by-reactor basis as needed. A centralized approach

[17] A recent analysis of universal container concepts shows that an optimized at-reactor approach using storage transportation casks could be as much as 20 percent less expensive than an optimized approach including centralized MRS facilities, Westinghouse, *Preliminary Cost Analysis,* table 1-3, pp. 1-10 and 1-11.

involves a large front-end expenditure for packaging and handling facilities that may not be fully utilized, and that to some extent would duplicate at-reactor facilities that the utilities would already have constructed to meet their pre-1998 interim storage obligations under NWPA.[18]

In addition, expanding at-reactor storage may be more reliable than building a centralized storage facility for assuring adequate buffer storage in the event of delays in repository siting or interruptions in repository operations. A centralized storage facility would itself be subject to many of the same sorts of 'expected' delays that would affect a repository. In addition, a centralized MRS facility, like a repository, would be potentially vulnerable to operational problems that could adversely affect many reactors simultaneously unless provisions have been made for buffer storage at the reactor sites. Furthermore, the history of strong and successful opposition to past efforts to provide Federal storage facilities suggests that a policy of providing MRS facilities might be relatively difficult to sustain over an extended period. Thus, the effort to develop MRS facilities may not provide much more insurance against such delays than would the measures to increase confidence in the repository loading schedule described below.

On the other hand, it is possible that a need could be shown for offsite storage before a repository can be expected to be available. For example, some reactor sites may be limited in their physical capacity for additional storage, although further analysis is needed to determine the extent to which this would lead to a requirement for offsite storage before repositories are likely to be available. (There will be a need for some spent fuel prior to that time for packaging and handling tests, dry storage RD&D, and low-level operation of the first repository. This requirement may be sufficient to eliminate any physical need for offsite interim storage beyond the 1,900 tomes of backup offsite storage already provided for by NWPA.) It is also possible that there may be overall system benefits, in terms of safety and cost, to providing centralized facilities for the additional interim storage that would be required if all the contingencies provided for in the conservative repository loading plan came to pass. However, this remains to be demonstrated.

[18]See chapter note at end of chapter.

To provide Congress with a complete basis for its decision, it would be valuable for the MRS need and feasibility study to include an analysis of an optimum Federal at-reactor storage option for comparison with the centralized MRS options. Comparisons would be made in terms of total waste management system costs, worker and public radiation exposures, geographic distribution of waste management impacts, and vulnerability to delays or disruption of operation of any facilities in the system. Consideration of providing Nuclear Waste Fund-financed interim storage at reactor sites, as an alternative to centralized MRS facilities, would allow a comparison of the relative merits of at-reactor and away-from-reactor storage that is not complicated by institutional differences in funding and ownership arrangements between the two options.[19]

It would also be useful for the MRS need study to analyze the advantages and disadvantages of deferring a decision on post-1998 interim storage until 1990, when DOE is expected to recommend the first site for a repository. This would allow the decision to be made after: 1) evaluation of the results of the commercial spent fuel storage RD&D program required by NWPA, which is expected to be completed in 1989; 2) development of an integrated system model and evaluation of optimized integrated system designs; and 3) completion of characterization of the first round of candidate repository sites, at which time the projected schedule for repository availability would be much better known. If a decision were made to proceed with an MRS facility at that time, it could still be available by around 2001, the current target date for operation of full-scale facilities at the repository.

Finally, it would be useful for the MRS study to contain analysis of the impact of storage options on the rate of progress in the repository program. As discussed in chapter 4, one of the major sources of resistance to efforts to provide a Federal storage facility in the past has been concern that the availability of such a facility would lead to deferral of the politically and financially costly steps involved in siting a geologic repository. In OTA'S

[19]DOE comparisons of at-reactor and away-from-reactor storage to date have assumed that the at-reactor facilities would be financed at private utility borrowing rates, while the centralized facility would be financed at lower Federal borrowing rates and would not be subject to taxation. This biases the results in favor of away-from-reactor facilities.

view, this is the principal programmatic risk in attempting to site and construct a large Federal storage facility before a permanent repository site is selected and licensed. The risk arises from: 1) the possibility that the effort to site and construct a Federal storage facility would divert resources and energy from the repository program; and 2) the fact that, once such a facility is available, it will be easier and less expensive to expand the storage capacity from year to year than to proceed rapidly to develop a geologic repository. (For further discussion of this point, see issue 1 in app. B.) On the other hand, some argue that making the Federal Government responsible for storing growing inventories of spent fuel would put more pressure on the Federal program to find a permanent solution. Because such considerations may be more important in an MRS decision than the relative technical merits of at-reactor vs. away-from-reactor facilities for interim storage, they are worthy of rigorous analysis in the MRS need study.

Backup Waste Facility Plan

The other possible role of MRS facilities is as a long-term alternative to geologic repositories. A comprehensive Mission Plan must address the possible need for such an alternative. To date, no insurmountable technical obstacles to geologic disposal have been identified. However, there is always some possibility that major difficulties could lead to extended delays or even rejection of the concept. Thus, a complete specification of the Federal commitment to utilities must identify what will be done if that occurs. The principal question to be addressed is when to provide long-term alternatives to repositories so that the Federal Government can accept spent fuel in the event that geologic repositories are delayed for a long time. The answer to this question will determine the ***backup waste facility plan.***

Generally speaking, only two alternatives will ensure that the Federal Government can take physical possession of waste or spent fuel from utilities if a geologic repository is delayed: 1) MRS facilities; or 2) disposal capacity based on some other disposal technology, such as subseabed emplacement. NWPA provides for the development of both options: section 141 requires the development of designs and construction plans for MRS facilities, and section 222 requires the accelerated development of alternative permanent disposal technologies.

If MRS facilities are provided for post-1998 interim storage, they would be available as long-term backup facilities if there are major problems with the disposal program. However, if it is decided to provide interim storage at reactor sites, a time may come when alternative facilities must be provided to prevent the spent fuel from remaining at the reactor sites indefinitely. Because the Act does not require or authorize construction and operation of such facilities, a comprehensive Mission Plan would identify a time at which DOE would address the question of whether to seek such authority from Congress and would discuss the criteria for making an affirmative decision.

To avoid the need for additional authority as long as possible, the proposed Mission Plan defers this decision until it is clear that there are major technical problems with geologic disposal. Specifically, it provides for the decision to be made after completing NWPA'S mandatory process for siting two repositories, which will occur when NRC decides on the second site in 1998. This should provide ample time to obtain the evidence that might justify a reevaluation of the entire concept of geologic disposal. For example, rejection of one or more candidate sites during characterization, or even NRC disapproval of the first site submitted for licensing, would not be strong evidence that geologic disposal might not work, any more than drilling one or two dry holes on an otherwise promising potential oilfield proves that the field does not contain oil. Since there is little experience with at-depth characterization or licensing of a geologic disposal site, and since at least some geologists believe that it is impossible to tell on the basis of surface exploration alone whether a site is suitable for a repository, one can expect some "dry holes' before a site that can be licensed is found. On the other hand, if no such site can be found after completion of a conservative siting program designed to site two repositories (see discussion of the siting program below), ample grounds might exist for reevaluating the feasibility of geologic disposal.

If no proposed repository site has received a construction authorization by 1998, authorization to construct two MRS facilities (or alternative disposal facilities, if suitable technology is available) would be sought. Since DOE estimates that an MRS could be sited, licensed, and constructed in about 11 years after authorization, it should be possible to have backup facilities in operation between 2008 and 2012, the commitment dates for operation of the two geologic repositories, even if a decision to construct such facilities is not made until 1998. Operation of backup storage or disposal facilities with a capacity of 6,000 tonnes per year (DOE's reference loading rate for two MRS facilities), even if it came as late as 2012, could still assure that the spent fuel discharged by reactors now operating or under construction could be removed from the sites of most reactors (except a few of the oldest ones) within about 15 years after reactor shutdown. (See app. G.)

Deferring a decision on long-term alternatives until a full and fair effort has been made to site and license the geologic repositories required by NWPA has several advantages:

- ***It avoids the risk that early availability of long-term storage facilities, or perhaps simply the effort to provide such facilities, might create pressures to defer difficult repository siting decisions, as discussed above.*** While long-term MRS facilities might be constructed earlier, to allow more time for repository siting, it must be recognized that such a step may make it more difficult to precede with selection and evaluation of repository sites at all.
- ***It provides ample time to develop backup technologies,*** A conservative schedule for backup facilities allows time to test the feasibility of alternative disposal technologies and to develop MRS designs that are most suitable for use as a long-term alternative to geologic repositories. In this regard, it would be valuable for the MRS need and feasibility study to discuss the design criteria that would be appropriate for MRS facilities intended as long-term alternatives to geologic repositories, in contrast to those intended for relatively short-term interim or buffer storage, and to identify any RD&D needed to develop technologies for very long-term monitored storage. (This is discussed further in the analysis of the technology development program, below.)

IMPLEMENTATION PROGRAM

To be credible as a basis for contractual commitments with utilities, the proposed repository loading schedule requires not only allowances for delays, but also an implementation plan that contains measures to avoid delays in the first place and to mitigate the impact of difficulties that do occur.

As noted earlier, the key feature in the high-confidence implementation program described in this chapter is the use of backup sites and technologies, to give confldence that at least one acceptable combination of site and repository design will be available when needed even if some candidates are rejected. While this program emphasizes certainty rather than minimized front-end costs, it represents a ***minimum*** use of backups, since it involves using only one more candidate site and technology at key stages than the minimum required number. It ***is a major conclusion of OTA analysis that this min -l im urn backup strategy can substantially increase confidence that the waste management plan can and will be carried out on schedule.***

Present Siting Program

The major source of uncertainty in the repository schedule lies in the process for finding suitable sites and for NRC review and approval of a repository constructed at those sites. Unlike many more familiar technologies, the site of a geologic repository is itself a central component of the technology. The natural barriers produced by the properties of the site are expected to provide the ultimate long-term insurance against any significant release of the waste. Thus, the process of finding sites with the right properties and of convincing NRC that those properties do exist is at the heart of the process of developing geologic repositories.

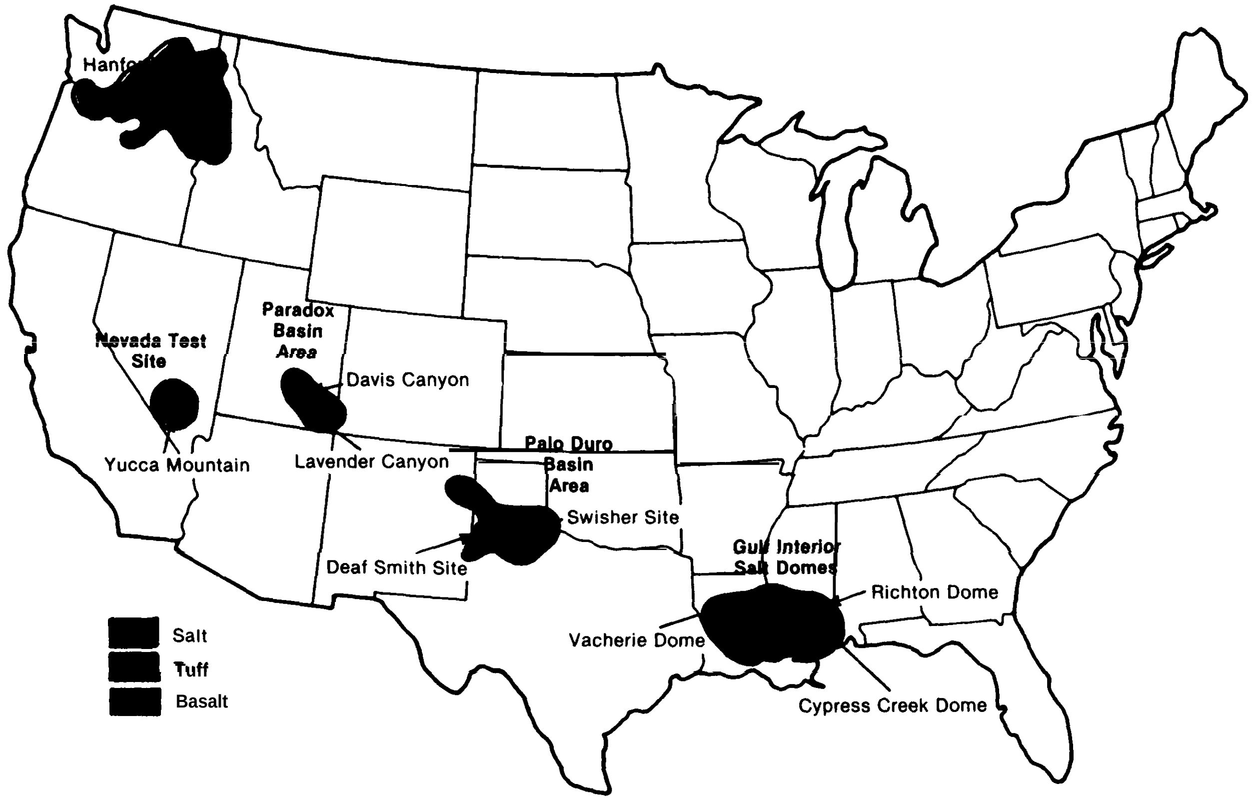
NWPA prescribes a detailed process for finding and licensing sites for two geologic repositories. The major steps are:

1. ***Development of guidelines for site selection.*** DOE, with NRC concurrence, issues general guidelines for recommending sites for repositories. This was accomplished in December 1984.
2. ***Nomination.*** Following issuance of guidelines, DOE must nominate at least five sites suitable for detailed evaluation for the first repository. This is anticipated in early 1985. No later than July 1, 1989, DOE must nominate five sites for the second repository.
3. ***Characterization.*** The crucial step in site evaluation involves tests performed in tunnels at the base of a large shaft excavated to the proposed depth of the repository. These tests are intended to determine the suitability of the site for a repository. Both NWPA and NRC regulations require DOE to characterize three nominated sites for each repository. The first sites are expected to be named in 1985.
4. ***Presidential recommendation and congressional review.*** Following characterization, the President must recommend to Congress a site for the first repository no later than March 31, 1987, and a site for the second repository no later than March 31, 1990. (DOE has concluded that these recommendations cannot be made until June 1990 and October 1995, respectively; see below.) At that time, the host State or Indian tribe has an opportunity to disapprove of the recommendation. Such disapproval prevents further development of the site unless Congress overrides it by passage of a joint resolution.
5. 'NRC construction authorization. If the site is not disapproved, it is submitted to NRC for review and issuance of a ***construction authorization—i. e.,*** approval to proceed to construct a repository at the site. NRC must act on the DOE application within 3 years, which can be extended by one year at the Commission's discretion. This is the last step explicitly prescribed in detail in NWPA.
6. ***Construction.*** After NRC issues a construction authorization, DOE will construct the surface facilities and some portion of the underground facilities of the repository.
7. ***Operating license.*** NRC regulations prescribe that, following construction, NRC will review an application from DOE to begin disposing of waste at the repository, an application that will incorporate any new data about the site obtained during construction. If this license is granted, DOE can begin operation.

Imposing this detailed siting process and ambitious schedule on the ongoing DOE siting program raised certain concerns that need to be considered in the siting strategy. First, the 1998 deadline for initial repository operaticn can most likely be met only by using sites in areas that were already under investigation at the time the Act was passed, although full-scale operation of the first repository could be achieved by 2008 even if a site not now under consideration had to be used (see fig. 6-2). While this was recognized at the time NWPA was passed, some have questioned whether it is possible to apply the guidelines required by the Act fairly and effectively if the sites for initial consideration were already selected before the guidelines were developed. In addition, some are concerned that, because there is a wide variation in the quantity and quality of data available for- the various sites under consideration, and because the siting guidelines were delayed nearly two years beyond the deadline specified by NWPA, it may not be possible to make a sound technical choice among the available sites at this time. Some are thus concerned that considerations other than technical ones might unduly influence the choices. They argue that DOE should postpone selecting sites far characterization until more information on the current sites can be obtained, or even until additional sites can be identified and evaluated.

Any major delay of site characterization (e. g., to allow new sites to be considered) would make it practically impossible to meet NWPA'S 1998 deadline for the first repository. Thus, a Mission Plan based on the requirements of the Act must assume that the initial selection of sites for characterization will be made from among those now under consideration. The problem is how to proceed to the characterization stage while minimizing the risk that doing so would lead to premature decisions. ***In fact, there is considerable agreement in the technical community that it is important to proceed now t~ detailed characteriza-***

Figure 6-2.—Potentiaiiy Acceptable Sites for the First Repository



NOTE: In December 1984, DOE published draft environmental assessments on these sites, indicating that the Hanford, Yucca Mountain, and Deaf Smith sites are the top three candidates for characterization.

SOURCE: U.S. Department of Energy, *Draft Mission Plan for the Civilian Radioactive Waste Management Program,* DOE/RW-0005 DRAFT, April 1984.

tion of speeific sites in order to make progress in developing geologic disposal.[20] If that step is deferred because of concerns that there is not enough data now to proceed, the siting program might get caught in a vicious circle: before sites could be selected for at-depth characterization, much more data about the sites would have to be obtained; yet to get more data about the sites, characterization is necessary.

[20]For example, the Interagency Review Group concluded that "Acre is an urgent need to obtain access to potential repository sites to begin the process of site characterization. Laboratory studies and in situ testing . . . cannot substitute for thorough examination of actual sites. " *Subgroup Report on Alternative Technology Strategies for the Isolation of Nuclear Waste,* TID-28818 (draft), October 1978, p. 78. Similarly, a DOE/U. S. Geological Survey (USGS) study concluded that "The major impediment to the resolution of technical questions leading to the establishment of a mined geologic repository for commercial radioactive wastes is the lack of specific sites on which to conduct detailed in situ geological research. DOE and USGS, Earth Science *Technical Plan for Disposal of Radioactive Waste in a Mined Repository, DOE/TIC-l 1033* (draft), April 1980, p. 1.

The principal risk in choosing sites for characterization using currently available data is that of prematurely discarding a site that in fact has a better chance of ultimately being licensed by NRC than one of the sites that is selected. Comparing sites will be a difficult task. Because there is no single generally accepted measure of the quality of a repository site, a judgment that one site is better than another must be based on a subjective balancing of many incommensurable factors. Such judgments will be particularly difficult before the data from in situ characterization are available, since the basic questions about site suitability can only be answered by at-depth testing. There is no assurance that the sites that appear most likely to be licensable on the basis of currently available information would turn out to be those that appear most favorable after characterization has been completed. ***Carrying extra sites through critical stages of the site evaluation process would reduce the risk of pass-***

ing over a good site in favor of a less-favorable one by deferring the crucial decisions to screen out some sites in favor of others until more data are available. This approach will be discussed further in the following description and analysis of the proposed high-confidence siting strategy.

High-Confidence Siting Plan

A high-confidence Mission Plan, using only the authority now provided by NWPA, would use an expanded repository siting strategy to provide confidence that the two repositories required by NWPA would be available no later than required by the proposed loading schedule. Evaluation by OTA of DOE's analysis of possible sources of delay in the repository program[21] suggests that ***there is considerable confidence*** that ***the*** target dates ***of 2008 and 2012 for full-scale operation of the first and second repositories can be met if one more site than the minimum required bylaw is carried through each*** stage ***of the siting process,*** prior to the actual construction of each repository. Thus, four sites rather than three would be characterized, and two rather than one would be recommended for submission to NRC for construction authorizations.

Sources of Uncertainty

The effect of this expanded strategy on the level of confidence in the repository schedule can be seen by considering the two principal sources of uncertainty in the siting process:

- the time required to complete each stage of the siting process; and
- the likelihood of a site being rejected at each stage.

TIME REQUIRED TO COMPLETE EACH STAGE OF THE SITING PROCESS

Table 6-1 shows DOE's estimates of the possible range of times that might be required for each major stage of the siting process. A ***strategy of*** *car*-***rying one more site than the required minimum through each stage provides insurance against the possibility*** that ***extended delays*** at any ***one*** site will ***delay the entire process.*** For example, NWPA requires that characterization be completed at three sites before one can be recommended for licensing. If only three sites are characterized, then the date on which one can be recommended will be determined by the rate of progress at the slowest site. If four sites are characterized, one can be recommended as soon as the fastest three are completed; extended delays would have to be encountered at two sites to delay the entire process. Similarly, submitting two sites to NRC for licensing, rather than one, means that construction could proceed as soon as authorization is granted for either.

Table 6-2 shows how extra sites can reduce the risk that the entire process will be delayed by delays at one site. Notice, for example, that even if the likelihood of experiencing an extended delay at any one site during characterization is as low as 20 percent, there is about a 50 percent risk that at least one site will experience a delay that would hold up the site recommendation process. Characterizing four sites instead of three can reduce that risk to about 20 percent. In general, the largest improvement is provided by the first site added beyond the minimum number needed to proceed to the next stage. This finding is the basis for OTA's conclusion that a siting strategy using only one more than the minimum required number of sites at key steps can substantially increase confidence that large delays will be avoided.

LIKELIHOOD OF SITE REJECTION

Analysis performed for OTA indicates that there is a lack of consensus in the technical community about how much information about the ultimate suitability of a site can be determined at each stage of the site evaluation process-surface testing, in situ characterization, repository construction, and operation.[22] Some experts feel that a site that appears suitable on the basis of tests performed from the surface will have a high probability of being acceptable as a repository. Others believe that there could be as much as a 50 Percent chance that such a site would be rejected on the basis of information obtained during characterization, and as much as a 40 percent chance that a site that survived characterization would subsequently be rejected on the

[21] DOE, *Draft Mission Plan,* pp. 3-A-27—3-A-44.

[22] Ghovanlou et al., op. cit., ch. 8. Also published in Ghovanlou, et al., "Selecting a Repository Site, " *Underground Space, vol. 6, 1982,* fig. 1, p. 244.

Table 6-1.—Possible Alternatives for Completion of Major Program Phases of First Repository

Recommend sites for characterization	Characterize sites	Select site and obtain site approval	NRC licensing review	Construct and test repository
Assumotlons and schedule durations:				
1-A " Secretary recommends three sites to President by January 1985, President approves sites in minimum time provided by Act (15 months)	2-A Recommendation based on surface studies and ES construction data (22 months)	3-A President recommends site, no State or Indian Tribe disapproval (17 months)	NRC adopts two-step construction authorization 4-A NRC review expedited (24 months)	Construction under two-step construction authorization 5-A Phased construction, Phase One complete (53 months), Phase Two complete (90 months)
1-B NRC requires significant changes to siting guidelines, President approves site in minimum time provided by Act (21 months)	2-B Parallel permitting, in-situ testing (49 months)	3-B President recommends site, State or Indian Tribe disapproval filed, Congress overrides (20 months)	4-B NRC review takes nominal period allowed by the Act (36 months)	5-B Full scale repository (70 months)
1-C Extensive modification required to EAs, President approves site in minimum time provided by Act (27 months)	2-C Sequential permitting, in-situ testing (73 months)	3-C Additional DEIS review, President recommends site, State or Indian Tribe disapproval filed, Congress overrides (29 months)	4-C NRC requires additional review time as allowed by the Act (48 months)	5-C Phased construction, exploratory shafts not used for construction, Phase One complete (89 months), Phase Two complete (126 months)
1-D Secretary requires additional data to support site recommendation, President requires additional review period allowed by Act (45 months)	2-D Sequential permitting, ES construction delays, extensive in-situ testing (133 months)	3-D Additional DEIS review, President recommends site, site disapproved, select new site (43 months)	4-D NRC requires extensive additional information to support CA (60 months) 4-E NRC rejects site, new site selected, approved and CA issued (108 months)	5-D Phased construction, exploratory shafts not used for construction, construction delays. Phase One co-m; plete (101 months), Phase Two complete (138 months)

KEY: EA = environmental assessment
ES = exploratory shaft
DEIS = Draft Environmental Impact Statement
CA = construction authorization

SOURCE: U.S. Department of Energy, *Draft Mission Plan for the Civilian Radioactive Waste Management Program,* DOE/RW-0005 DRAFT, April 19S4.

basis of information obtained during construction or operation.

The possibility that disqualifying data would be found after a site is recommended for licensing is of particular importance in view of current DOE siting plans. According to those plans, the initial license application would be based on 8 to 22 months of in situ testing (depending on the medium), while data from about 7 more years of at-depth tests, including 4 years of extensive underground construction, would be available before NRC is expected to act on the application for an operating license.[23] The shorter the time spent obtaining data prior to the license application, the greater the likelihood that any disqualifying problems at a site will not be discovered until after the application has been submitted.

[23]DOE, *Draft Misson Plan*, p. 3-A-32, and fig. 3-A-5, p. 3-A-38.

Table 6.2.—Risk That Delay or Rejection of Sites in One Stage of Repository Development Will Delay Progress to the Next Stage

Sites needed to proceed to next stage	Number of sites considered at each stage 2	3	4	5
	P = 20%0			
		I %	0.2%	.03%
; : : : : : : : : : : : : : : : : : :	3%:	10%	30/0	0.7%
3	NA	49%	18%	6%
	P = 50%			
. . . .	25%	13%	60/0	3%
; : : : : : : : :	75%	50%	31%	19%
3	NA	870/o	690/o	50%

NOTE: In this table, P represents the probability that any individual cite would experience major difficulties in one stage of the siting process, either a delay in competing the process or outright disqualification. Since no cite has aver gone through any of these stages, P is a subjective judgment. if N is the number of sites evaluated in the stage (columns) and K is the number of sites that muat complete the stage to go to the next (rows), then the risk of a delay in the stage is simply the probability that at least N -K+ 1 sites have difficulties. Using the simplifying assumptions that each site hee the eeme probability (P) of experiencing difficulties, and that there is no interdependence of results among the cites, probability theory shows that the rick is given by the following statement:

$$\text{Risk} = \sum_{J=(N-K+1)}^{N} \frac{\quad}{J \;\&\; !} p^{J} (1-p)^{(N-J)}$$

SOURCE: Of fice of Technology Assessment.

Because there is no experience in most of the steps for developing high-level waste repositories (and since final EPA performance criteria for repositories have not yet been adopted), this lack of consensus cannot be resolved at present and is a factor that must be considered in determining the appropriate approach for investigating sites for repository development. The expanded strategy described above reduces the consequences of rejection of any one site by providing an additional site as backup at each stage and by increasing the pool of viable sites. For example, if there is a 20 percent chance that any one site submitted for a construction authorization will be rejected by NRC, then submitting two sites instead of one reduces the risk of not having an approved site from about 20 percent to only 4 percent.

Characterizing four sites rather than three also provides insurance against a potentially important ambiguity in the requirements of NWPA. DOE considers that it can proceed to recommend a site for licensing even if one or more of the three sites to be characterized is found unsuitable during or after characterization .24 However, DOE also recognizes the possibility that this interpretation of the requirements of NWPA might be found invalid, and that NWPA might be interpreted as requiring that before DOE can recommend a site for licensing, it must have three sites that appear suitable for a repository ***after*** characterization.[25] Table 6-2 clearly suggests that this more demanding interpretation would make the characterization stage much more vulnerable to delays if only three sites are characterized initially. For example, even a 20 percent probability that an individual site would be rejected would lead to a ***50*** percent risk that characterizing three candidate sites would produce fewer than three that were suitable after characterization. Characterizing four sites would reduce that risk to about 20 percent. If steps to characterize additional sites are not taken until this question can be resolved, which may not occur until DOE recommends a site, there is a risk of a delay of 4 or more years if the more demanding interpretation were upheld, and if it were necessary to find and characterize a replacement site for one rejected during the initial characterization phase.[26] In any case, if the legal uncertainty is not resolved before the end of the characterization process, and if fewer than three good sites are available at that time, there could be a delay of a year or more for consideration of a lawsuit to resolve the question.

Steps to Increase Confidence

The following section discusses the high-confidence siting strategy in more detail as it relates to each of four key areas:

- relationship of the siting processes for the two repositories required by NWPA;
- characterization of candidate sites for each repository;
- recommendation of sites to NRC for construction authorizations; and
- screening to identifi new backup sites potentially suitable for characterization.

[24] 1 bid., p. 3-A-33.

[25] Recent discussions between DOE and NRC concluded that the issue remains to be resolved regarding how many sites need to be determined to be suitable after characterization. The Radioactive Exchange, vol. 3, No. 11, June 30, 1984, p. 1.

[26] DOE, *Draft Mission Plan*, p. 3-A-41. The *Draft Mission Plan* does not indicate an explicit plan for assuring that backup sites would be available.

HAVE TWO FULL, SEPARATE PROGRAMS FOR SITING A FIRST, WESTERN, REPOSITORY AND A SECOND, EASTERN, REPOSITORY

The overall goal of the siting program is to provide confidence that two repositories will be operating within a relatively short time of each other. Because the Act requires that transportation costs and impacts be taken into account in siting the second repository, the siting plan is also designed to maximize the likelihood that one repository would be located in the East and one in the West.

A clear commitment to a credible plan for siting both repositories may be needed to allay the concerns of those areas being considered for the first repository that they might by default wind up being the nation's only nuclear waste "dump' if financial and institutional pressures lead to indefinite deferral of the second repository. Since most of the sites under consideration for the first repository are in the West, a serious effort to site the second repository in the East, near most of the reactors, should help deal with concerns of the first round States about regional equity.

In this approach, the first round of site characterization—for the first repository-would contain only western sites. The eastern sites now under consideration would not be characterized in the first round.

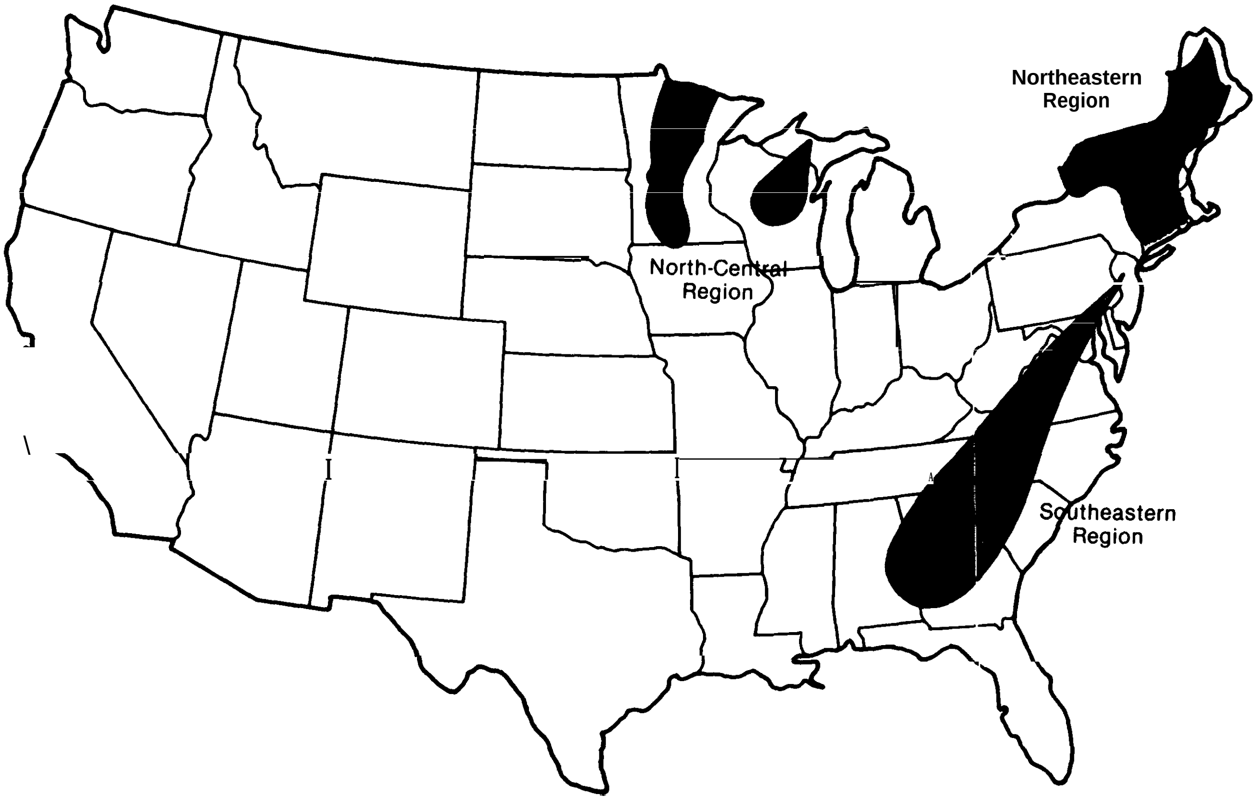
For each round of site characterization to focus on one region, as proposed in the high-confidence siting plan, the first round must use western sites. Six of the nine sites now under consideration are located in the West (see fig. 6-2), and one of the two westernmost sites (in Nevada and Washington) ***must*** be included in the first round in order to meet NRC requirement that at least one nonsalt site be characterized before the first repository site can be licensed (all of the other sites are in bedded or dome salt). Considering only the western sites in the first round, as proposed in this strategy, ensures that both the primary candidate for NRC licensing and its backup (explained later) would be western. In addition, it may be easier to reach agreement about the suitability of a site located in a relatively arid region the first time the licensing process is attempted. The six western sites now under consideration represent four distinct geohydrologic settings and three geologic media (basalt, tuff, and bedded salt), and thus should provide a sufficiently wide range of choices for characterization in the first round.

The second round of site characterization—for the second repository—would involve only eastern sites. Thus, sites characterized for the first, western, repository would not be considered again in the second round, as now contemplated by DOE. At present, the DOE ***Draft Mission Plan*** provides that one of the sites from the first round of characterization be counted among the three that must be characterized before the second repository is selected, as allowed (but not required) by NWPA.[27] DOE plans to characterize only two additional sites for the second round, and is currently screening crystalline rocks in the East to identify potential candidate sites (see fig. 6-3). The third site, to be carried over from the first round, most likely would be western, although it could be eastern if one of the eastern sites now under consideration were characterized in the first round.

Because OTA's high-confidence siting strategy provides for only western sites in the first round, they would not be used again in the second, eastern, round. Instead, DOE would evaluate four eastern sites before selecting the site for the second repository (unless the results of the first round of characterization show that three would give sufficient confidence that delays could be avoided). This approach would increase the chances that both a primary site and a backup (discussed below) for a second repository will be found in the East. It would also reduce the stakes involved in selecting the sites for the first round of characterization. If some sites from the first round are also used in the second, as now contemplated by the DOE Draft ***Mission Plan,*** sites selected for the first round face some chance of being selected for the second repository even though they are not the first choice for the first repository. Of course, there will always be some possibility that one of the sites from the first round of characterization would ultimately be needed for the second repository, but in this expanded siting plan that would be done only as a last resort, i.e. if a full and fair effort to find a suitable eastern site fails.

27DOE, *Draft Misson Plan,* p. 10-4.

Figure 6-3.—Regions Being Considered for the Second Repository



SOURCE: U.S. Department of Energy, *Draft Mission Plan for the Civilian Radioactive Waste Management Program,* DOE/RW-0005 DRAFT, April 19S4.

CHARACTERIZE FOUR SITES FOR EACH REPOSITORY INSTEAD OF THE THREE REQUIRED BY NWPA

Characterizing more than the minimum required number of sites is the principal, and perhaps only, way to reduce substantially the likelihood of major delays or other complications at the crucial step of recommending the first site for a repository. Significant problems at this point could damage the credibility of the Federal waste management effort. Characterizing one more site than required by NWPA would provide insurance against the possibility of extended delays (see above). Characterizing four sites also gives greater confidence that at least two suitable ones will be available after characterization, allowing a backup to be submitted to NRC more quickly, as discussed below, and avoiding the delay of as much as 10 years that could occur if characterization of backups were not started until the principal candidate had been rejected.

The increased confidence that at least two suitable characterized sites would be available without extended delays also would reduce the risk that Congress might have to consider a State's objection to the President's recommendation of the first site without having a suitable alternative candidate available. In fact, NWPA requires DOE to recommend a second site for licensing for a repository within 1 year if the first recommendation is vetoed by the State and the veto is not overridden by Congress. This can only be done if a second suitable characterized site is availabls from among the first set of sites that are characterized.

Characterizing additional sites also reduces the risk that proceeding now to site characterization would prematurely narrow the available options on the basis of relatively little information. For example, characterizing four sites for the first repository allows one site to be selected from each of the four western geohydrologic settings. The decision about which settings to reject could be deferred until after a site in each setting had been characterized, so that the decision could be based on comparable and more extensive data from each site. This minimizes the risk that a site that has a better chance of ultimately being licensed by NRC might be passed over in favor of a less suitable site because the currently available data gives a misleading picture.

In this approach, the only narrowing of choices before characterization of sites for the first repository would be selection of one of the two sites under consideration in the Paradox Basin area and the Palo Duro Basin area, the western settings that each contain two sites. Comparing nearby sites in the same setting should be easier than comparing sites in substantially different settings. Thus, the first use of the siting guidelines would be in the relatively limited choice between sites in the same setting. The guidelines' major application would come at the later stage of selecting sites to recommend to NRC for licensing based on the data from site characterization, which are needed for the full application of the guidelines in any case.

Characterizing an extra site for each repository could increase total expected program costs by up to several percent. The actual amount would depend on the geologic medium involved and the extent of at-depth investigation required. This is discussed below.

RECOMMEND TWO SITES TO NRC FOR CONSTRUCTION AUTHORIZATIONS FOR EACH REPOSITORY, RATHER THAN JUST THE ONE REQUIRED BY NWPA

The conservative contractual commitment dates (2008 and 2012) for operation of full-scale facilities at two repositories allow for the possibility that the primary candidate sites will be rejected by NRC at some point during the licensing process. To give further confidence that the commitment dates will be met, a backup site for each repository would be submitted for a construction authorization as soon as possible after the primary site for each repository had been recommended. NRC would be asked to license both alternatives, rather than to choose between them.

If only one site per repository is recommended to NRC for licensing, then the selection of the final repository site must be made at the recommendation stage on the basis of only the information available after characterization. Recommending two sites per repository for licensing allows the final selection to be made after NRC's review of both sites, including review of the additional data that would be obtained from both sites during the 3 or more years of the licensing process.

The additional cost of submitting a second site per repository for licensing, assuming that two good sites are available after characterization, should be very small compared to the cost of characterizing the site in the first place. Furthermore, it would be inexpensive insurance against the delays that could result if licensing of a second site were not initiated until after the first was rejected. Even if neither site were rejected by NRC, this approach might still reduce the time required for the first repository to begin operation by aIlowing construction to begin as soon as either site for that repository is approved.

If both sites for a repository receive a construction authorization, the one not selected for development would be held as a backup in case problems are discovered during construction or during the first 5 to 10 years of operation of the repository at the primary site. If the backup site is not needed by the end of that period, it could be used for subsequent repositories beyond the first two.

When combined the first step, this step is designed to give confidence that DOE could recommend to NRC both a primary western site with a western backup, and a primary eastern site with an eastern backup. Separating the siting process into western and eastern rounds also reduces the risk that a good site from the first round that would otherwise be needed as a backup in that round would instead be needed for the second repository.

If either the primary site or the backup is rejected, another site would be submitted for a construction authorization as soon as possible to ensure that one backup would be available with minimum delay. If a suitable characterized site were available, the additional cost of submitting it for licensing would be small. If a suitable characterized site were not available, a contingency siting plan could provide for characterization of an additional site to be initiated immediately (see discussion of screening program for backup sites below).

CONTINUE SITE SCREENING TO IDENTIFY NEW SITES SUITABLE FOR CHARACTERIZATION AS BACKUPS FOR THE FIRST TWO ROUNDS

The preceding steps are intended to increase confidence in the repository schedule by increasing the number of sites initially considered at crucial stages of the siting process. However, there is always some possibility that even the increased number would not be sufficient and that, eventually, additional sites would have to be characterized. A high-confidence siting strategy would therefore include a backup site-screening program to identify additional new sites suitable for characterization for both the western and eastern repositories.

Characterization of an additional site could begin, for example, in the unlikely event that only one site survives the initial round of characterization and would ensure that a backup site for each repository can be recommended to NRC for a construction authorization. Or an additional site might be characterized in case one of the two sites submitted to NRC is rejected and there is no other suitable characterized site available. Such a step would minimize the delay that would result if the sole remaining site were rejected at some later point in the licensing process. (In either case, this would mean that all but one of the sites initially characterized had been rejected at some point in the process. This would be evidence that the more pessimistic view about the difficulty of finding suitable sites is correct, and that having a backup available is even more important than originally expected.)

This contingency siting plan increases confidence that the conservative contractual repository loading schedule can be met even if there are major problems with the first round of site characterization. As noted in the discussion of the repository loading schedule, it is possible that the first repository could be operating by 2008 even if none of the first four sites characterized proved suitable and one of the sites identified through the backup screening program had to be characterized and used. This contingency plan also gives added confidence that each of the two licensed repositories required by the Act will be backed up by a second site with a construction authorization, which could be developed into a full repository if problems are discovered with the operating repositories during their initial years of operation.

The backup site screening process would not replace the ongoing DOE siting program, which would continue as the meii.ns for meeting the schedules in NWPA for identifying the first candidate sites for characterization for the first and second repositories. DOE's analysis of the repository development schedule suggests that a siting program designed to make a best effort to meet the 1998 deadline for the first repository must proceed to site characterization in the next year or so. Yet it would probably take several years to identify new candidate sites and to complete the necessary procedural steps for characterizing them; for example, DOE does not expect to be able to begin characterizing sites for the second repository until 1989. Thus the NWPA repository schedule appears to require that characterization begin with the sites now under consideration, in order to determine if they include at least one that is suitable for a repository.

To give confidence that both a western and an eastern site can ultimately be found, the backup siting program would search for backups in the West for the western sites now under consideration for the first repository site, as well as backups in the East for the second site. This requires an expansion of the program in the DOE draft Mission Plan, which suggests that sites under consideration for the second repository be considered as backups for the first, if backups are needed.

The backup sites for possible characterization for a repository in the West could be obtained, for example, by continuing the screening of the Basin and Range province now being conducted by the U.S. Geological Survey (USGS) .[28] This USGS effort uses a site screening process, proposed in 1980 by a Federal interagency working group,[29] that searches for favorable geohydrologic environments instead of focusing initially on particular host rocks or on federally owned land, as in past siting efforts.[30] (Identifying new sites that are not now

[28]M. S. Bedinger, et al., "Status of Geohydrologic Screening of the Basin and Range Province for 1:.elation of High-Level Radioactive Waste," in DOE, *Proceedings of the 1983 Civilian Radioactive Waste Management Information Meeting,* pp. 193-195.

[29]U.S. Geological Survey, *Plan for Identification and Geological Characterization of Sites for Mined Radioactive Waste Repositories,* Water-Resources Investigations Open-File Report 80-686 (Reston, Va., May 1980).

[30]The siting program outlined in the *Draft Mission Plan* is a continuation of the two principal approaches to site identification that have been used in tha past by DOE and its predecessors: 1) search-

under consideration for the first repository would avoid having to use as backups any of the current sites that were not judged good enough to be included among the first four selected for characterization, and would address the concerns of those who feel that siting efforts should not be limited to the current sites.) Backups for an eastern repository could be identified by using this same screening process in the East, or by considering media in addition to crystalline rocks, which are the focus of current efforts to identify sites for the second repository.[31]

Costs and Benefits of the High-Confidence Siting Strategy

The basic issue in selecting a siting strategy is the balance between the initial cost of the strategy and the degree of confidence that long delays will be avoided. As noted earlier, OTA'S conclusion that there can be considerable confidence in the conservative repository loading schedule is based on the assumption that the backup siting strategy described above would be used.

The crucial near-term siting question is whether to characterize one extra site for the first repository, in addition to the three required by NWPA. DOE's current plan to characterize only three sites is identical to the plan in place before NWPA imposed the 1998 deadline for initial repository operation. Characterizing one additional site is the principal significant expansion that could be made to increase the confidence that a licensed repository would be available by 1998. While characterizing an additional site would increase program costs over the next 4 years or so, it could reduce total program costs in the long run by reducing or avoiding potentially costly delays. Thus the decision on how many sites to characterize raises important questions for the Congressional appropriations process.

To give Congress a clear understanding of the implications of decisions about the siting program, especially the decision about how many sites to characterize, it would be valuable for the Mission Plan to present the results of a rigorous comparison of the costs and benefits of alternative siting strategies. This should evaluate both a minimum strategy that does no more than explicitly required by NWPA and an expanded strategy that includes one more than the minimum required number of sites at key stages. This comparison should consider: 1) the increased initial costs of a backup siting strategy, 2) the long-term cost savings that can result if delays can be avoided by such a strategy, and 3) the non-quantifiable costs and benefits of the siting strategy. The remainder of this section discusses some preliminary observations concerning each area.

INCREASED INITIAL COST

The principal cost impact results from the number of additional sites that would be characterized under the expanded siting strategy; the other provisions, such as submitting two sites for licensing, should have considerably less impact. The additional cost of characterization is difficult to determine at this time for several reasons. First, the actual cost of characterizing an additional site is difficult to determine from available information. It will depend upon the amount of work that must be done at the site. At one extreme, it is possible that preliminary borehole tests could lead to the site being rejected before an exploratory shaft is sunk.[32] At the other extreme, the ***Draft Mission Plan*** envisions carrying out at each characterized site a considerable amount of engineering and construction that is actually required only for a site that is recommended for development and licensing. While this can save some time in the repository schedule, it adds perhaps hundreds of millions of dollars to the costs incurred at the sites that are not used,[33] without in-

ing for favorable locations containing a potentially suitable candidate host rock, and 2) searching for favorable locations with suitable host rocks on Federal reservations dedicated to nuclear activities. Of the six areas now under consideration for the first repository, four with salt deposits (Texas, Utah, Mississippi, and Louisiana) were identified by the first method, while two (the Hanford Reservation in Washington and the Nevada Test Site) were identified by the second. Candidate sites for the second repository are being identified by the first method, focusing on crystalline rocks (granite) in the East.

[31] DOE, *Draft Mission Plan*, pp. 2-%—2-47.

[32] Characterization can include boreholes from the surface as well as an exploratory shaft. If there is reason to suspect that additional tests from the surface might disclose factors that would preclude use of the site, those tests could be performed first to determine whether it is worth incurring the costs and impacts of sinking an exploratory shaft. If the site were rejected before the shaft was sunk, characterization activities could be terminated and the site reclaimed, as required by section 113(c) of NWPA.

[33] The DOE *Draft Mission Plan* proposes that characterization at each site include sinking two large shafts that can subsequently be used for repository construction (p. 3-A-21), a step which is expected

creasing the certainty of the schedule in the same way that characterizing an additional site would. To facilitate congressional deliberations on the DOE waste management budget, it would be useful for the Mission Plan: 1) to distinguish clearly between characterization costs that are required to determine which sites are suitable for recommendation, and those additional costs that are required only for a site which is selected for development; and 2) to compare DOE's current proposed approach with one in which four sites are characterized only to the extent necessary for DOE to select the most promising two for submission to NRC (as provided above), with the more expensive detailed work needed to support a license application to be done only at those two sites.

The additional cost is also uncertain because it is unclear how many extra sites would ultimately have to be characterized. At the outside, all of the steps described above could require characterization of three more sites than the five contemplated in current DOE plans (one extra site as a backup for each repository, and an additional eastern site to replace the one that DOE plans to carry over from the first round.) However, just as many additional sites might be required under a minimal strategy-if only one site survives the first round, for example, it would be necessary to characterize at least three new sites for the eastern repository. Thus, characterizing extra sites before they are needed, rather than after, merely incurs those costs earlier than would otherwise be the case. In addition, it may not be necessary to characterize more than three for the second repository in any case, if experience with the first round shows that an additional site is not needed to give the desired level of confidence in the schedule for the second repository.

REDUCED LONG-TERM COSTS

The major quantifiable benefit of the expanded siting strategy is that it can reduce the likelihood of the delays that would result if backup sites are developed only after it is certain that they are needed. Such delays would require additional interim spent fuel storage, for example-for this alone a delay of as much as 5 years, while additional sites were characterized, could cost between $600 million and $1.1 billion.[34] A rigorous comparison of the costs and benefits of alternative siting strategies must balance the expected costs of such delays against the expected initial siting costs.

NONQUANTIFIABLE COSTS AND BENEFITS

Perhaps the most important nonquantifiable benefit of the expanded siting strategy is that it reduces the risk that the credibility of the Federal waste management program would be damaged by major delays at key stages of the siting program, particularly at the crucial early step of recommending the first site for a repository. Because of its troubled history, the program does not appear to have a large reservoir of goodwill left to cushion it in the event of major difficulties in the future. From this perspective, it is important to compare siting strategies in terms of the risks they involve if siting turns out to be difficult, as well as the benefits they yield if siting proves to be relatively easy.

If the most optimistic view proves to be correct, the conservative siting strategy described in this section will produce more sites than are needed—which should increase confidence that repositories can be made available as needed if a significant expansion of the use of nuclear power is contemplated. Potentially suitable sites can be banked, saved for later use, and developed as they are needed. If the sites are eventually developed, the initial cost of site evaluation is not lost, only incurred sooner than absolutely necessary. If the more pessimistic view proves to be correct, the sizing strategy will reduce the likelihood of costly delays and adverse political impacts that might result if the current siting

to save about 3 years in the DOE schedule (p. 3-A-37). The additional cost of a second large shaft is estimated to be about $75 million to $100 million per site (footnote on p. 10-4). The *Draft Mission Plan also* provides for detailed engineering work including limited final waste package and repository designs for all characterized sites, including those not selected for development (p. 10-2). The additional cost of preparing limited final designs for all characterized sites is difficult to estimate but could amount to $160 million per site or more (table 10-1, p. 10-5, and fig. 3-A-5, p. 3-A-38). By comparison, NRC estimated in 1981 that $25 million to $30 million was an upper limit for the "at-depth" portion of site characterization (in soft rock), assuming that the test facility included two shafts and up to 1,000 feet of tunnels. U.S. Nuclear Regulatory Commission, ' 'Disposal of High-Level Radioactive Wastes in Geologic Repositories: Licensing Procedures," *Federal Register, vol. 46, No. 37,* Feb. 25, 1981, p. 13973.

[34] Boeing Engineering Company Southeast, Inc., *Spent Fuel Storage System Options: A Comparative Cost Analysis,* a report prepared for the Electric Power Research Institute, 1984, table 2-5, p. 2-13.

process fails to produce enough suitable sites at any key decision point in the siting process. In addition, by providing for backups at key stages of the repository development process, the conservative siting strategy would increase the credibility of the process by reducing fears that crucial decisions might be prejudiced by the absence of any real alternatives.

It can be argued that expansion of the site evaluation process beyond the minimum required by NWPA would increase the political costs involved in locating radioactive waste repository sites, since it would increase the number of States affected by DOE siting activities. On the other hand, it can be argued that, because it would increase confidence that two repositories would in fact be available on schedule, with one in the East and one in the West, the expanded program would offer advantages to States that do not wish to see their nuclear reactors become de facto spent fuel repositories and to States that would be substantially affected by waste transportation if there were only one repository. Furthermore, keeping the processes for siting the first and second repositories separate, and not using sites characterized for one repository for the other as well, could reduce the concerns of the targets for the first repository that they would also be under consideration for the second, and the concerns of the targets for the second repository that they may wind up being the first-and perhaps the only—repository.

Waste Management Technology Development Program

The second element of a high-confidence implementation program is a *conservative waste management technology development program.* This program includes parallel development of both a ***conservative baseline waste management system design,*** intended to be widely viewed as workable despite the remaining technical uncertainties, and an ***optimized system design.*** The conservative baseline system design, to be widely viewed as workable, would be based on currently available data and on the assumption that current technical and regulatory uncertainties could be resolved in the direction of increased, rather than reduced, demands on system performance. This approach minimizes the probability that the design would have to be modified substantially in the light of unfavorable developments, and thus would build confidence ***that*** a conservative loading schedule based on the design could be met even if such developments occurred. It also provides a useful basis for a conservative estimate of disposal costs.

As noted earlier, the conservative design would be intended only for implementation during the demonstration phase of repository operation, while the optimized system design would be implemented for the operational phase. However, the conservative design would be available as a backup if problems are encountered with the alternative. Furthermore, the existence of a conservative design that is widely viewed as workable would reduce the likelihood that disagreements in the technical community, about whether a proposed "optimal' design is suitable, would be interpreted by the public as disagreement about whether there is any design that will work.

This section will describe in general terms both a conservative baseline design and the related RD&D program for each element of the waste management system.

Geologic Repositories

NWPA requires that a conceptual repository design be included in the site characterization plan to be prepared for each site proposed for detailed evaluation. In addition, baseline repository designs are needed as a basis for determining the waste disposal fee and to provide additional focus for the RD&D program.

DOE and its predecessors have generally used the approach of developing reference repository designs that appeared most cost effective in light of the best information available at the time. As new information about site conditions, waste characteristics, repository performance, or regulatory requirements became available, the designs were modified to conform to the new information and to maintain their cost effectiveness. This has sometimes led to ongoing technical disagreements about whether the designs would be acceptable, and to repeated changes in the system design. The object of developing a conservative baseline design is to minimize the technical debates about whether the system would be able to meet regulatory requirements, and to provide a basis for a workable disposal system that is not likely to require continued modification.

One risk of using conservative baseline designs is that they could lead to higher waste disposal costs than necessary if additional RD&D indicated that their conservatism was excessive but it proved institutionally difficult to relax that conservatism once, the designs had been adopted. This risk would be reduced by proving for a demonstration phase of low-level operation at the first repository before the full-scale packaging and handling facilities are built. The conservative system design is in fact explicitly intended for that initial demonstration phase, with development of an optimized full-scale system design deferred until the principal remaining technical uncertainties have been resolved.

Using a conservative design for the demonstration phase should reduce the likelihood of difficulties during the licensing process, and could minimize the time required to gain NRC approval for initial emplacement of waste in the repository. Until the final design is completed, the conservative reference design could be used as a basis for a conservative estimate of the waste disposal fee, thus reducing the likelihood of insufficient revenues. It should be noted, however, that even if a conservative design must ultimately be used, the additional costs should not substantially affect the overall economic competitiveness of nuclear power.[35]

[35]A revie„ of the **papers presented** at a recent international **conference** on radioactive waste management concluded: "Though (disposal) costs are higher than had been assumed previously, they do not seem likely to have a serious or decisive impact on the use of nuclear **power—** and this even in countries with **small** nuclear programmed. Economics was not and will not be a major driving force for simplifying or reducing conservatism in radioactive waste management systems; elaborate systems that meet long-term safety and stringent radiation protection requirements can be **afforded,** even though they may not always be justifiable on technical grounds. " S. Fareeduddin and J. **Hirling,** "The Radioactive Waste Management Conference, " ***International*** *Atomic Energy Agency Bulletin, vol. 25,* no. 4, December 1983, p. 4. For perspective, DOE projects that the price of uranium in the year 2000 might range somewhere between $25 and $120 per pound (in current 1983 dollars), compared to a price of about $20 per pound in 1984, and that an increase of **$10** per pound in the price of uranium increases the nuclear fuel cost to utilities by about 0.8 mills (.08 cents) per kilowatt-hour **(kWh).** U.S. Department of Energy, ***United*** *States Mining and Milling Industry: A Comprehensive Review,* DOE/S-0028, May 1984, pp. 47 and 60. This range of uncertainty represents a range of about 8 **mills/kWh** in nuclear fuel cost (measured in 1983 dollars), compared to the 1 **mill/kWh** waste disposal fee established by NWPA.

The principal areas for conservatism in repository designs are reduced thermal loading, retrievability, the waste form, and the waste package.

REDUCED THERMAL LOADING

A major source of conservatism in repository design would be in thermal design criteria-allowable heat load per acre and maximum temperatures of waste package and rock formation. The decay heat from the waste is a major source of uncertainty about the long-term behavior of the engineered barriers, the repository facility itself, and the hydrogeologic environment in the vicinity of the repository. One straightforward way to reduce technical uncertainties about repository performance is to keep the repository temperatures relatively low.[36] Available studies suggest that a conservative initial repository design would keep the maximum temperature of the rock in the repository in the vicinity of 100° C. For example, a recent National Research Council review of geologic disposal concluded that limiting the rock temperature to 100° C would provide confidence in the suitability of borosilicate glass, the reference waste form for reprocessed waste, until the necessary research is performed to show that it would be suitable at higher temperatures.[37] In contrast, current DOE reference designs have rock temperatures that range from 140° C (in unsaturated tuff) to 250° C (in basalt) .38 In addition to reducing rechnical disagreement about the expected performance of the repository, use of conservative thermal criteria may have the added benefit of reducing the amount of RD&D that is needed on waste forms and packages by reducing the temperature range for which their performance must be assured.

[36]**For example,** in its comments on DOE's preliminary draft Mission Plan, NRC **observed** that "DOE can reduce or eliminate uncertainties about testing needs by design measures such as limiting thermal loading. " Letter from John G. Davis, Director, **Office** of Nuclear Materials Safety **and** Safeguards, U.S. Nuclear Regulatory Commission, to Michael J. Lawrence, Acting Director, **Office** of Civilian Radioactive Waste Management, Department of Energy, Feb. 8, 1984, p. 2.

[37]***A Study of the Isolation*** System ***for Geologic Disposal*** *of* ***Radioactive*** *Wastes,* (Washington, D. C.: **National** Academy Press, 1983), p. 7. Conservative repository designs developed by the Swedish utilities would also limit maximum **temperat**ures to this range. See, for example, KBS, ***Final*** *Storage of Spent Nuclear* ***Fuel—KBS-3,*** (Stockholm: Swedish Nuclear Fuel Supply Co., May 1983).

[38]**National** Research Council, **op. cit. p. 8.**

A lower thermal loading can be achieved in three ways:

1. ***Cooling the waste prior to final sealing in the repository.*** Even with an optimistic repository loading schedule, with the full-scale facilities of the two repositories beginning operation in 1998 and 2005, the initial spent fuel emplaced would be 25 years old, and fuel as young as 10 years old would not be emplaced until after 2010.[39] Additional cooling could be obtained, if desired, by storing the spent fuel above ground at the repository site for a longer period before emplacement, or by keeping the repository rooms open for some period after emplacement and using active ventilation to remove heat before the rooms are backfilled and sealed.
2. ***Reducing the amount of waste in each canister.*** The amount of waste placed in each canister affects not only the maximum temperature of the canister after emplacement, but also the number of canisters that must be handled each year to accommodate a target waste loading rate, an important determinant of system design and cost. Recent DOE designs assume that the canister loading will be increased by disassembling spent fiel assemblies and consolidating the individual rods in the waste canister, allowing the rods from 6 pressurized water reactor assemblies, or 18 of the smaller assemblies from boiling water reactors, to be placed in a single canister. Since this involves an additional complex operation, a conservative design (for demonstration phase operations and initial cost estimates) would instead assume no rod consolidation. The RD&D program for developing an optimum system design would be intended to provide the data needed to justify larger canister loads.
3. ***Reducing the amount of waste per acre of repository.*** Reducing the amount of waste per acre (the emplacement density) will reduce the heat load per acre for waste of any given age, leading to lower temperatures. At the same time, it would increase the number or size of repositories required for a given amount of radioactive material, thus increasing the disposal cost. From a technical point of view, increasing the emplacement density is an easy way to relax the thermal conservatism used in the demonstration phase.

Using conservative thermal criteria for the baseline repository design is consistent with the principle of basing the baseline design to the maximum extent possible on data and analysis that are available now. The National Research Council study of geologic disposal concluded that current DOE design temperatures are much higher than the temperatures used in most studies of waste form dissolution,[40] and it suggested using conservative initial temperature limits, although it also concluded that research will probably eventually allow use of higher temperatures. While conservative thermal criteria would be used for initial emplacement of waste during the demonstration phase, the RD&D program would determine the extent to which those criteria could be relaxed for emplacement during the operational phase.

RETRIEVABILITY

NRC's regulations for high-level waste disposal require that the repository design keep open the option of waste retrieval throughout the period during which wastes are being emplaced, and thereafter until completion of a repository performance confirmation program and NRC review of the results. The regulations specify that the design provide for retrieval to be undertaken any time within 50 years after initiation of emplacement, subject to modification in light of the planned emplacement schedule and confirmation program .41 In addition, NWPA (sec. 122) also requires that repository designs allow for retrieval of spent fuel for safety or economic reasons, subject to NRC approval.

An important design question affecting the cost of disposal is whether to provide for "ready retrievability, " easy access to the waste, by keeping the repository rooms open during the retrievability period rather than backfilling them soon after waste emplacement. A period of ready retrievability offers two advantages. First, it reduces concerns that

[39] U.S. Department of Energy, *Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, DOE/RW-0006, September 1984, fig. C.2, p. 284.

[40] National Research Council, op. cit. p. 8.

[41] *Federal* Register, vol. 48, No. 120, June 21, 1983, p. 28197.

emplacement of waste in a repository is a practically irreversible step. Second, it enables economic recovery of spent fuel if reprocessing appears desirable after the fuel has been emplaced.

NRC's regulations do not require easy access, nor do they preclude backfilling. While there are some advantages to early backfilling, particularly in salt, remaining the hot backfill to retrieve the waste could be quite difficult and expensive.[42] Thus, the retrievability requirement may be an additional factor favoring conservative thermal design criteria.

Since the design implications of the NRC requirement have not yet been thoroughly assessed, a conservative initial design would provide for some period of ready retrievability after emplacement, although perhaps not for the full period of repository operation. DOE has analyzed 25-year ready retrievability and concluded that it is feasible, although it is more expensive because it requires reduced thermal loads per acre.[43] However, the additional cost could be reduced by using ventilation to remove excess heat; furthermore, the conservative thermal loads needed to meet a 100° C design temperature may enable ready retrievability at relatively small additional cost.

In any case, the assumption of some period of ready retrievability should provide a conservative estimate of the cost of disposal and could increase confidence in initial low-level emplacement of waste in the repository. The assumption could be relaxed for full-scale operation when analysis is available to show that NRC requirements can be met even if rooms are backfilled soon after waste emplacement, and when it is clear that ready retrievability of spent fuel is not needed for economic reasons.

WASTE FORM

DOE reference waste forms are borosilicate glass for solidified high-level waste and untreated fuel assemblies for spent fuel. Because EPA analysis concludes that either waste form could meet EPA's proposed environmental standards,[44] and because these are the two waste forms that have been studied in most detail, a conservative baseline system design would be based on these waste forms. This is consistent with the decision to use borosilicate glass as the waste form for solidifying the liquid commercial high-level waste stored at the inoperative Nuclear Fuel Services reprocessing plant at West Valley, NY, and the defense high-level waste stored at the Savannah River plant. The classified waste from West Valley, and some of the waste from Savannah River (if it is decided to place defense waste in commercial repositories), could be used in the demonstration phase of the first repository, along with an amount of spent fuel. As noted above, a National Research Council study concluded that keeping the temperature of the borosilicate glass below 100° C, as provided in the conservative repository design for the demonstration phase, would give confidence in its suitability as a waste form until the uncertainties in its performance at higher temperatures can be resolved through additional research.[45] The waste form RD&D program would determine whether this conservatism could be relaxed in the full-scale operational phase.

The RD&D program would provide for development of backup waste forms for both untreated spent fuel and high-level waste as a hedge against unforeseen problems such as regulatory difficulties. In particular, the recent National Research Council study of geologic disposal concludes that neither waste form may be able to meet NRC criterion that the engineered barriers allow no more than one part in 100,000 of each critical radionuclide to escape each year.[46] While this criterion is not absolute, and might be adjusted by NRC for individual radionuclides in light of the EPA standard or the geochemical characteristics of the repository and

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[42] National Research Council, op. cit., p. 9.

[43] The cost impact is greatest for a repository in salt, because, unlike hard rock, salt flows under pressure, making it more difficult to keep tunnels open for an extended period. U.S. Department of Energy, *Final Environmental Impact Statement, Management of Commercially Generated Radioactive Waste,* DOE/EIS-0046F, (Washington, D, C.: October 1980), vol. 2, app. K, pp. K.23-K.25.

[44] U.S. Environmental Protection Agency, *Draft Environmental Impact Statement for 40 CFR 191: Environmental Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic* Radioactive Wastes, EPA 520/1-82-025, (Washington, D. C.: December 1982).

[45] National Research Council, op. cit., p. 7. This study concluded that "borosilicate glass is the appropriate choice for further testing and for use in current repository designs" but also that "there are uncertainties about its performance in a repository that need to be better understood before glass waste would be acceptable for emplacement in a repository." Ibid., p. 78.

[46] National Research Council, op. cit., pp. 237-238.

its environs,[47] it is possible that less soluble waste forms might be necessary for at least some candidate repository sites. In addition, the National Research Council study concluded that significant improvements in repository performance could be achieved if highly insoluble waste forms could be developed. The study participants recommended a backup technical program that would: 1) provide insurance against the contingency that release rates from currently preferred waste forms prove considerably higher than now estimated, and 2) develop better waste package alternatives that could be used in later stages of waste emplacement.[48] The potential effect of a reduced waste form release rate on the risks from geologic disposal is shown in table 6-3.

The RD&D program could examine such waste forms, as well as processes for treating spent fuel (e.g., by powdering or chemical dissolution) so that it could be incorporated in such a waste form directly if reprocessing and plutonium separation is not otherwise undertaken for resource recovery reasons. However, later decisions about whether to use an alternative waste form that involves significantly more complex treatment and handling processes than the reference waste forms involve (e. g., dissolution and resolidification of spent fuel) should take into account the increased costs, risks, and operational exposures that would be entailed.[49] Conservatism also suggests that the entire waste management process be kept as simple as possible.

WASTE PACKAGE

A conservative baseline waste package would use the package design that has received the most study to date: a metal canister, containing several spent fuel assemblies, which would be emplaced in vertical boreholes drilled in the floor of the repository rooms. Since the package would be unshielded, it would require remote handling. Potentially more cost-effective emplacement techniques now under consideration by DOE, such as insertion into long horizontal boreholes drilled out from the walls of the rooms, would not be used in the baseline design because they have not been studied as thoroughly as the vertical emplacement concept.

A major aspect of conservatism in the waste package concerns the design lifetime of the package. Proposed EPA criteria encourage use of multiple barriers to increase confidence about long-term isolation, and NRC final regulations require that the waste package provide assurance of containment of the waste for a period of from 300 to 1000 years, the period during which the heat released by the waste will have its greatest effect. Some argue that analyses using mathematical models to project repository performance show that such a package would not significantly improve the predicted per-

[47] 10 CFR Part 60.113(a)(1)(ii)(B).
[48] National Research Council, Op. cit., pp. 82-83.
[49] The National Research Council review of geologic disposal observed that the operational considerations of producing different waste forms could be a factor in the choice between waste forms, and concluded: "The analysis of the release of radioactivity to the environment must include the entire waste disposal cycle, beginning with waste-form manufacture, to achieve overall minimal release objectives. National Research Council, op. cit., p. 14

Table 6-3.—Effects of Canister Life and Waste Form Release Rate on Projected Population Risks Over 10,000 Years

	Projected health effects		
	Granite	Bedded salt	Basalt
Canister life:			
Reference Case (100 years)	—	190	—
(500 years)	760	—	4,400
1,000 years	575	90	3,900
5,000 years	120	40	180
Waste form release rate:			
Reference case (10^{-4}/year)	760	190	4,400
High estimate (10^{-3}/year)	2,500	200	18,000
Low estimate (10^{-6}/year)	10	50	50

— = Not applicable.

SOURCE: U.S. Environmental Protection Agency, *Draft Environmental Impact Statement on 40 CFR Part 191, Environmental Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes,* EPA 52011-82-025, December 1982.

formance. Others, including NRC, argue that it may be needed to give greater confidence in the predictions of repository performance.[50]

A conservative approach would be to provide for a waste package with a design life exceeding the regulatory requirements, and to use that waste form as a fully redundant barrier, rather than as a compensation for any defects in the geologic features of the site. (The potential effect of increased canister life on the risks from geologic disposal is shown in table 6-3.) Long life is achieved by using thick canister walls and/or corrosion-resistant material, such as copper, titanium, or zirconium. For example, a Swedish-designed copper canister for use in a granite repository has been estimated to have up to a 1-million-year life.[51] DOE estimates that a titanium canister would add about $6 per kilogram to the cost of disposal,[52] compared to current waste package designs using a simple canister of stainless steel (for tuff) or carbon steel (for salt or basalt).[53] A conservative baseline system design would include a long-lived package in its plans for the demonstration phase and in estimating disposal costs, while the RD&D program to develop an optimized design would determine whether that conservatism could be relaxed for full-scale operation.

While the conservative baseline design would use the borehole waste package concept, recent analyses have suggested that there may be significant advantages to a waste package design that is significantly different from the borehole design. This alternative design involves a massive (70 to 100 tonnes) cast iron or cast steel cask holding up to 10 to 20 tonnes of spent fuel, which could also conceivably be used for storage and transportation .54 Such a cask would provide radiation shielding so that complicated hot cell operations, shielded transport vehicles, and shielded storage vaults would not be required.[55] The casks would simply be placed in repository rooms, eliminating the need for drilling holes for holding the package.

It maybe possible to design such a cask as a universal container for storage, transportation, and disposal. If so, it could substantially reduce the complexity of the waste management process and reduce worker exposures, since the spent fuel would be handled directly only once—at the time it is placed in casks at the reactor. This universal container would also provide great flexibility in the system, since once spent fuel; has been placed in the cask in which it will ultimately be buried (unless it is removed for reprocessing), slippages in the repository schedule would not cause additional storage problems. Even if such a multipurpose outer cask cannot be used, the universal container concept could be applied to an inner container that could be inserted into separate outer containers for storage, transportation, and disposal.

Because of the potential advantages of this unproven concept, the RD&D program to develop an optimized system design would resolve questions about its feasibility as quickly as possible, so that this concept can be considered as an option for the operational phase of the first repository, (It is important to resolve the question before full-scale packaging facilities are des;igned and constructed, because the different waste packages impose different requirements on the design of the handling facilities and on the repository itself. The operational implications of using a massive disposal cask may have to be determined during the generic packaging and handling test program, required by the Act, before a decision could be made to adopt that concept.) Although DOE plans to examine this system, it is unclear from the ***Draft Mission Plan*** whether this system's feasibility would be determined in time for its use in the full-scale facilities of the first repository. As discussed above, the two-phase approach to operation of the first repository is designed to allow ample tlme to determine whether this technology is feasible and desirable before a commitment is made to a final design for the operational-phase system.

5010 CFR Part 60.11 3(a)(1)(ii)(B). The importance of an effective engineered barrier in addition to the waste form itself is discussed in ''Achieving Performance Objectives for the Engineered Barrier System," a Staff Report prepared by the Subcommittee on Energy Conservation and Power of the Committee on Energy and Commerce of the U.S. House of Representatives, Committee Print 98-II, November 1984.

31 National Research Council, *A Review of the Swedish KBS-3 Plan for Final Storage of Spent Nuclear Fuel* (Washington, D. C.: National Academy Press, 1984), p. 3.

52DOE, *Report on Financing the Disposal of Spent Fuel,* p. 23.

53DOE, *Draft Mission Plan, p. 3-A-19.*

54Westinghouse, *Engineered Waste Package;* Hoskins, op. cit.

55Westinghouse, *Engineered Waste Package,* p. 279.

TECHNOLOGY OF PREDICTION

As discussed in chapter 3, predictions of repository performance will be based heavily on the use of mathematical models. Use of such predictive techniques in a formal licensing process may well be one of the most difficult aspects of demonstrating disposal, and validation of those techniques will be of critical importance.[56] Since such long-term prediction has never been done in a formal regulatory process, many unforeseen problems will probably be encountered the first time it is attempted. A serious effort to anticipate and resolve such problems before the first formal licensing proceeding commences could avoid unnecessary delays at that critical stage of the waste disposal program. This could be accomplished, for example, if the site characterization plan required by section 113(b) of NWPA included a preliminary analysis by DOE of the expected performance of the conceptual repository design for that site, based on the data available prior to characterization. If this analysis were explicitly related to NRC and EPA performance requirements, a broad review process involving NRC, EPA, USGS, and others could begin at that time. This could allow ample time for thorough consideration of the issues that might arise. It would also provide a rigorous basis for the characterization program, so that efforts could be focused on resolving the uncertainties that were identified as centrally important to the predictions of repository performance.

While this approach might not lead to formal resolution of licensing issues, in the sense that they could not be reopened later, it is possible that a sufficient degree of technical consensus could be reached that some issues would be effectively resolved. This would permit attention to be focused on those issues that remained in dispute. If this were done at each site recommended for characterization, it should increase the probability that NRC would be able to reach a decision on a site within the 4 years' maximum time allowed in NWPA.

Storage

Available analyses indicate that there are technically promising interim storage methods that could substantially reduce the overall cost of waste management. These include rod consolidation and storage casks that could also be used for transportation and perhaps for disposal. Since these methods have not yet been demonstrated and licensed, a conservative system design would not assume that these technologies would be available, but would instead assume that all spent fuel would be received unconsolidated in casks optimized for shipping only. However, the RD&D program in the Mission Plan would contain an accelerated effort to examine these possibilities and determine the extent to which they could be incorporated into a later revision of the system design. It is important that this be resolved as quickly as possible, before final choices about interim storage systems are made by individual utilities (in deciding how to deal with their spent fuel until at least 1998) and by Congress (in deciding whether to authorize MRS facilities after the MRS proposal is presented in 1985). Because these decisions could be strongly affected by the availability of a multipurpose cask or other form of universal container, the Mission Plan should clearly show the relationship between the program for evaluating the feasibility of such containers and the timing of the storage decisions that would be affected by their availability.

The RD&D program must also address the technology requirements for monitored storage for indefinite periods. The storage technologies that are most mature today, and that would most likely be selected for an MRS facility if one were to be built in the 1990's, are the surface cask and dry-well concepts.[57] While these are particularly well suited for providing easily expandable storage capacity in the face of an uncertain level of demand (as would be the case for buffer storage to deal with small schedule slippages), they may not be optimal for providing large amounts of storage for an extended period in the event of major difficulties in the repository program—the principal role for MRS fa-

[56] The National Research Council study of geologic disposal noted that ' 'There is not yet a validated technique for predicting the performance of borosilicate glass—or of any other waste form—in a repository . . . Whatever technique the U.S. Department of Energy (DOE) adopts for predicting waste-form and waste-package performance must be carefully validated before any waste form and waste package can be considered acceptable. National Research Council, *Isolation System*, pp. 78-79. For a discussion of general issues in the development and use of predictive models, see Office of Technology Assessment, *Use of Models for Water Resource Management, Planning, and Policy*, OTA-O-159, August 1982, ch. 3.

[57] DOE, *Draft Mission Plan*, p. *3-B-7.*

cilities in the backup facility plan described above. In addition, storage facilities designed for a long and perhaps indefinite period of storage may raise licensing issues that are not faced by facilities intended for a limited period of interim storage. Thus the RD&D program in the Mission Plan would include a program for developing, testing, and perhaps demonstrating appropriate storage technologies so that a reliable long-term system can be provided with high assurance of success if needed.

Transportation System

A conservative baseline system design would assume that transportation during full-scale operation of the repository system would be accomplished with casks that are designed for transportation only and that are optimized for the repository loading schedule, taking into account the age of spent fuel or high-level waste at the time it would be transported to a repository. As noted in chapter 3, designing the casks for fuel that is at least 10 years old would provide an additional margin of conservatism by reducing the effects of self-heating in case of transportation accidents involving a fire. There is little question that such casks can be designed, licensed, and constructed in time for the conservative loading plan, although any transportation during the next decade or so would probably have to use the existing generation of casks. While detailed designs remain to be developed, currently available analysis should give a solid basis for initial estimates of cost and capacity.

The transportation section of the Mission Plan would also include a baseline reactor storage unloading plan, since that will have significant implications for transportation. For example, an unloading plan that provides for large amounts of stored spent fuel to be removed from a relatively small number of reactors each year, rather than for smaller amounts from a larger number of reactors, may simplify the transportation process and reduce its costs and impacts by allowing the use of dedicated unit trains. However, it would also require allowing larger quantities of spent fuel to build up at each reactor site before the site is unloaded. (See app. G for a discussion of the limitations on the rate at which spent fuel can be removed from reactor sites.) A conservative initial Mission Plan would assume that interim spent fuel storage would be unloaded according to the "oldest fuel first" principle included in the reference contract adopted by DOE. Assuming that all spent fuel is to be shipped by truck would maximize the number of shipments and the demands on the repository waste receiving facility as a basis for a conservative estimate of system costs and impacts.

One important focus of the transportation RD&D program is to determine whether casks that might be used for storage and/or disposal can be designed to be suitable for transportation as well. As noted earlier, this could greatly simplify the overall waste management process. This will require substantial coordination with the spent fuel storage and repository development programs to ensure that a fully integrated optimized system design can be developed in time to be considered for the operational phase of the first repository.

Packaging and Handling Technology

To ensure that unforeseen bottlenecks do not prevent the Federal Government from accepting waste according to the planned schedule, prior experience at handling, packaging, and emplacing radioactive waste at operational rates would be valuable. DOE now estimates that by the time a repository is to begin operation in January 1998 some 36,000 tonnes of spent fuel, representing over 126,000 individual spent fuel assemblies, will have been discharged by commercial nuclear reactors.[58] To store or dispose of this spent fuel at a central facility fast enough to stop the further buildup of inventories in at-reactor storage in 1998, without even beginning to work off the backlogs, would require handling about 2,300 tonnes, or about 7,900 assemblies, in 1998 alone. If this spent fuel were being canned for storage or disposal, it would require filling, sealing, and testing—using remote handling procedures—up to 5,000 canisters per year (depending on the final system design).

There is experience with all of the procedures for handling spent fuel through the step of canning for storage, but there is no experience at rates approaching those that must be achieved for full-scale operation. For example, DOE tests involving em-

[58] These are DOE's most current projections, found in *Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics, DOE/RW-0006,* September 1984, ch. 1.

placement of encapsulated spent fuel in a deep mined facility in granite at the Nevada Test Site have used only 11 spent fuel assemblies. Furthermore, there is no experience with the procedures that might be required for final packaging of either spent fuel or high-level waste for permanent disposal, procedures that may be more complex than those required for canning for temporary storage. While there is little doubt that waste can be packaged and loaded at relatively high rates, there is less certainty about the rates that could actually be achieved by the first facilities designed for that purpose.

The provisions of NWPA suggest a conservative RD&D program that could give a high degree of assurance that full-scale facilities will operate at the planned rates and thus minimize the risk that commitments to delivery schedules cannot be met. The program would involve three stages prior to full-scale repository operation, allowing development of hands-on experience with large amounts of spent fuel and/or high-level waste in a series of steps extending over the next 20 years. The first stage would take place before the first site is approved, while the next two would take place at the site following NRC approval.

GENERIC TESTS

The first stage would involve the generic packaging, handling, and emplacement tests required by section 217(d) of NWPA. Since many of the operational questions apply to large-scale storage as well as to disposal, it may be very useful to plan for an integrated storage and disposal operational testing program that could provide data useful to MRS designs, as well. The program could also include the 300-tonne dry storage R&D program authorized in section 218(c). Such a program would develop packaging and handling technology that would allow the packaged material to be emplaced either in surface storage or into a repository. This would help ensure that spent fuel or high-level waste could be accepted at operational rates at a repository on a target date, even if it were decided to defer full-scale loading of the repository itself. As noted above, handling and emplacement tests may be a particularly important part of determining the feasibility of using very large self-shielded casks for disposal and would also be useful in developing final designs for handling such large casks at operational rates even if the casks are only used for surface storage.

An integrated storage and disposal test facility would also allow the development and demonstration of the capacity to retrieve waste from a repository at a rate comparable to the emplacement rate— an NRC requirement—and to place it into temporary surface storage if necessary. This should help build confidence that initial emplacement of waste into a repository is not an irreversible step.

To gain needed operational experience might require a substantial quantity of spent fuel or high-level waste. For example, tests at a scale of 5 percent of both the total capacity and projected annual handling rate of DOE's current reference repository design could require over 1,000 tonnes over the next decade. The actual amount that should be used would be determined by an analysis of: a) the need for reliable data and experience concerning operations with highly radioactive materials over a sustained period, and b) the need for packaged waste or spent fuel for use in the second stage of preoperational tests, early tests of waste emplacement in a repository during the demonstration phase of repository operation.

It may be possible to conduct all of the needed generic operational tests using existing government facilities. If not, NWPA authorizes construction of a test and evaluation facility (TEF) that could allow unlicensed temporary emplacement of up to 100 tonnes of spent fuel in a repository-like facility at anticipated repository depths to test and verify handling and emplacement procedures.

EARLY REPOSITORY EMPLACEMENT TESTS

The initial stage of the demonstration phase would involve early emplacement in the repository of the material packaged conservatively during the first generic packaging and handling tests. This would occur after NRC had granted a construction authorization but before completion of the first process line of the packaging facilities of the repository. Informal discussion with NRC staff indicates that this would be possible within the framework of the existing regulations for repository licensing; it would be analogous to low-power licensing for a reactor. As noted earlier, emplacement during this phase would use the conservative disposal system design. Early emplacement of a small amount of waste under licensed conditions would be a logical extension of the activities at a TEF if one were constructed at the repository site.

Such tests would offer a number of potential benefits. First, it would allow an early test of one of the crucial steps in the licensing process: NRC's ability to decide to allow actual "disposal" as defined by NWPA—permanent emplacement of waste in a geologic repository with no foreseeable intent of recovery. Second, because emplacement of even a small amount of waste with NRC approval would be disposal, it should satisfy the requirement in section 302(a)(5) that disposal in a repository begin by January 31, 1998. NWPA does not specify the level of operation that must begin by that time, but it does specify that emplacement be disposal, which presupposes NRC permission for permanent emplacement with no intent of recovery. Thus, this approach could allow disposal to begin perhaps several years earlier than 1998, assuming that the construction authorization for the first repository is granted on schedule.

TESTS OF REPOSITORY PACKAGING FACILITIES

A final stage of testing in the demonstration phase would be operation of the initial process line of the full-scale packaging facilities. For this stage, one processing line would be constructed and operated for a period of several years in order to discover and correct any design problems before constructing the rest of the process lines in the facility. While initial emplacement during the demonstration phase will use the conservative baseline design, the optimized system design would be demonstrated in this phase. Thus, the schedule for earliest operation in this phase depends on the time required to develop and gain NRC approval of an optimized design. Once the final designs have been modified as needed in light of this operational experience and the rest of the processing lines have been built, the RD&D program would be finished and the full operational phase would begin.

Integrated System Model

Evaluation and comparison of alternative waste management system designs with the conservative baseline design would greatly benefit from development of an integrated systems model that allows analysis of the total costs, risks, worker exposures, and other operational characteristics of waste management system designs from the time spent fuel is discharged from the reactor to the time of final disposal. As noted in the discussion of the integrated waste management system in chapter 3, many elements already exist which could be combined into an integrated model.

It is important to recognize that an optimum system design may involve elements that are not optimum if viewed from a narrower perspective. For example, from the point of view of the individual utility, using a multipurpose container for spent fuel might appear to increase interim storage costs, yet use of such containers may substantially reduce the total system costs. As another example, steps that could improve safety in one area could reduce it elsewhere; for example, while treatment of spent fuel to reduce its volubility may improve repository performance in the long run, it would lead to increased operational risks and generation of additional waste streams that must be disposed of.

An integrated system model is needed to capture all of these effects, so that decisions can be made on the basis of a clear understanding of the implications of the options under consideration. Another area in which integrated analysis is needed concerns the tradeoffs between distance between waste packages when emplaced in the repository, concentration of waste in the waste form and package, use of a corrosion-resistant waste package, and additional cooling prior to disposal.[59]

Alternative Disposal Technologies

Confidence that a permanent disposal system will ultimately be available could also be enhanced by the development of alternative disposal technologies, Such development is required by section 220 of NWPA.

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[59]National Research Council, *Isclation System*, p. 15.

A STRATEGY FOR REVISING THE MISSION PLAN

It is to be expected that future analysis and research will provide information that may allow relaxation of some of the convervatisms in the initial Mission Plan or significant changes in the system design. The initial Mission Plan should identify those points in the repository development process at which it is expected that sufficient new information would be available to warrant reexamination of the Plan. Alternatively, provision could be made for reassessment of the Mission Plan every 3 years, to provide a basis for the triennial budget and authorization process established by NWPA. Use of the Mission Plan for that purpose is discussed further in chapter 7.

The initial Mission Plan could also specify what steps would be taken to review and revise the Plan. Because the choices to be made in the Mission Plan have significant implications for many affected parties, public acceptance of and confidence in the Plan might be enhanced by broad involvement of the various affected parties in the process of review and revision. (See discussion of the role of the Mission Plan in public participation in ch. 8.) This could also build consensus on the Plan, thereby reducing the likelihood of successful efforts to cause changes that favor one group or another or to thwart the Plan's implementation.

CHAPTER NOTE

Available analysis shows that there are strong financial incentives for use of cask or drywell storage at reactor sites—the same modular technologies that would also likely be used for a centralized storage facility designed to provide a limited amount of storage for a relatively short period. Thus, the main difference between at-reactor and centralized storage would be the difference in the cost of the packaging and handling facilities required in each case. DOE estimates that a cask storage facility with an annual receiving rate of about 2,000 tonnes would require handling and support facilities costing about $410 million.[60]

By 2008, the reactors that are now operating or under construction are expected to require about 2,300 tonnes per year of additional storage capacity beyond that available in their own basins (see app. E). About 1,500 tonnes per year of that amount would be from reactors that will have to provide their own storage facilities by 1998, so construction of new handling facilities for that fuel at a centralized site would duplicate costs that have already been incurred. The remaining 900 or so tonnes per year is from reactors that would not have to provide additional storage facilities until 1998 or later. This represents the annual discharge of about 30 1 -Gwe reactors.

The estimated capital cost of facilities for lifetime cask storage for *two* such reactors at the same site is $7,100,000.[61] This in turn suggests that the total capital cost for the at-reactor facilities for 900 tonnes per year would be well under $200 million. Since these costs would be spread out over the 10-year period, the discounted cost would be less, compared to the discounted cost of a centralized system in which most of the capital costs are incurred at the beginning. While a detailed analysis will be required to provide an accurate comparison of at-reactor and away-from-reactor storage costs (an analysis that would benefit from completion and evaluation of the dry storage RD&D program mandated by NWPA), this rough estimate indicates that there is no strong prima facie reason for concluding that dry storage using modular systems will benefit from large economies of scale if implemented at centralized sites.

[60] D. E. Rasmussen, *Comparison of Cask and Drywell Storage Concepts for a Monitored Retrievable Storage/Interim Storage System*, Battelle Memorial Institute Pacific Northwest Laboratory, PNL-4450, December 1982, table A.29, p. A.30.

[61] E. R. Johnson Associates, Inc., *A Preliminary Assessment of Alternative Dry Storage Methods for the Storage of Commercial Spent Nuclear Fuel, JAI-180, DOE/ET/47929-l*, Reston, Va., November 1981, table 8-2.