CHAPTER 5. SCHEDULE DATA SUMMARIES

The NAS labeled the lack of an existing international regime for surplus plutonium a "clear and present danger" and urged that actions should be initiated to effect the disposition of surplus plutonium without delay. Thus timeliness should be a primary determinant for the selection of approaches for plutonium disposition. Congress has urged the Department to demonstrate to the world its commitment to effect the disposition of surplus weapons-grade plutonium.[1] Based on Departmental focus on reducing exposure to the "present danger" and comments from interested parties, the Department has established its schedule requirements for initiating disposition (within 10 years) and completing disposition (within 25 years) after authorization.

Section 5.1 is a discussion of the schedule methodology. Sections 5.2 through 5.5 are discussions of the reactor, immobilization, borehole, and hybrid alternatives schedules, respectively. Section 5.6 is a tabular summary of schedule information. Some key uncertainties are discussed in Chapter 6.

5.1 SCHEDULE ESTIMATION METHODOLOGY

Schedules were generated by the Alternative Teams presuming a moderate national priority for plutonium disposition, as opposed to the very high national priority associated with the Manhattan Project or the Apollo Project. Furthermore, the Alternative Teams assumed no protracted delays such as those associated with the high-level waste repository program. The schedules presented here are neither inherently optimistic nor inherently pessimistic and include expert judgments of time required for technical activities such as research and development, engineering, design construction, licensing, and permitting. None of the schedules that are presented here have been optimized, and it is possible that schedule improvement could be realized as more details become available. Assuming one or more alternatives are selected at the Record of Decision, a dedicated effort will be applied to attempt to accelerate and optimize the schedules.

The Alternative Teams generated the schedules for their alternatives based on their assessment of all the key events that must occur to implement the alternatives. The basis for the schedules were established to be as consistent as possible, recognizing the inherent technology differences which exist among the alternatives. The overall approach for generating the schedules included:

- Identifying the necessary steps to implement the alternatives.
- Establishing the assumptions necessary to link the facilities and the events.
- Determining the critical schedule parameters.

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[1] House Energy and Water Report accompanying the FY 1997 Appropriation Bill, HR-3816.

- Preparing nominal schedules.
- Identifying strategies which could be selected to accelerate schedules relative to the nominal cases.

In defining the schedule elements for a government project, one must be aware that there are a number of activities for federal projects that may not apply or are less important for a private sector project. These activities are reflected in the schedules provided in this report and include the following elements:

- Need for Congressional approval and funding authorization.
- Need for compliance with the National Environmental Policy Act.
- Special procurement and vendor selection rules and regulations.
- Need for external oversight of existing, non-licensed facilities. For the purposes of these analyses, DNFSB is assumed to provide oversight of existing DOE facilities.

As an example, for federal projects, the authority for the start of a project might occur later than the ROD. Given the urgency of the plutonium disposition mission, the authority to start the project is assumed to be coincident with the ROD.

The project activities considered by the Alternative Teams were analyzed by facility. These activities can be categorized generically as follows:

- Project definition and approval.
- Research, development, and demonstration.
- Siting, licensing, and permitting.
- Design, engineering, and procurement.
- Construction and/or facility modification.
- Operations, including pre-operational start-up activities.
- Decontamination and decommissioning.

For each alternative, two or more facilities are required for implementation. Consequently, completion and operation of each of the facilities must be properly sequenced to permit the facilities to operate as a system. The need for sequencing facilities appropriately is illustrated by the use of evolutionary light water reactors in conjunction with new facilities for plutonium processing and mixed oxide fuel fabrication. Clearly, the three facilities must be staged such that the operations in each facility are coordinated with operation of the other two.

The facilities analyzed include the following:

1. Plutonium processing (or front-end) facility, including extraction of plutonium from pits.
2. Fuel fabrication facility, for reactor options.
3. Reactors, immobilization plants, or borehole site facilities, as applicable.

5.2 REACTOR ALTERNATIVES SCHEDULES

5.2.1 Reactor Schedule Assumptions

Oversight and Licensing:

- For new fuel fabrication facilities, a five-year licensing duration is used. This duration is based on discussion with and input from the NRC.
- For existing LWRs, a three-year lead use assembly (LUA) license process is included prior to loading the LUA in the reactor. An 18-month reload license review period is included after the LUA has been irradiated; a review of the LUA performance is done during the second irradiation cycle. After this review is complete, the mission fuel may be loaded in the reactors during the next reload cycle. The LUAs and initial cores for the existing facilities variant would be fabricated in European facilities.
- For the evolutionary reactor alternative, a three-year licensing process is assumed before any site preparations may begin. The LUAs are irradiated for a two-year period with the initial LEU core load before starting to load mission fuel.
- A LUA from the American MOX fuel fabrication facility, when available, will be required for LWRs.
- For CANDU alternatives, no dedicated LUA test is required; rather, the fuel test and qualification processes achieve the objective of LUA demonstration.
- The baseline schedule for the CANDU alternative does not assume use of European MOX fuel fabrication capability. However, in the Schedule Summary Table (Table 5-1), a two-year acceleration in start-up is credited, based on the judgment that half the schedule acceleration achievable by the LWRs using European capability (4 years) should be achievable with CANDU reactors. Although the structural design of CANDU and LWR fuel assemblies are very different, the fabrication of the fuel pellets for the two reactor types, which is the distinguishing feature between MOX and uranium fuel fabrication, is similar.
- DNFSB review of the use of existing DOE facilities is assumed to be five years.

Plutonium Availability for Use of European Fuel Fabrication Schedules:

- For the existing LWR, existing facilities variant and the LWR hybrid alternative, the plutonium will be processed in a staged start. These variants require plutonium oxide feed before the ARIES production facility could provide it. For these variants, it is expected that the ARIES prototype, which is being developed to demonstrate the ARIES process and support design of the production facility, would also be used to disassemble some quantity of additional pits to provide a limited amount of feed to support MOX production in Europe.

MOX Fuel Fabrication:

- Whether the American MOX fuel fabrication facility is placed in a new building at a DOE site or placed in an existing building at a DOE site, the same schedule would be used in both situations.

Reactors:

- Existing reactors would be selected based on the remaining plant life under their current licenses such that sufficient life exists in the reactors to accommodate the plutonium disposition without any plant life extension actions[2].
- Finishing construction of the two partially complete reactors is staged so that the completion of the reactors corresponds to when MOX fuel from a domestic source would be available. Licensing is assumed to proceed in parallel with the reactor construction.

5.2.2 Reactor Alternatives Analysis

Generic Issues

There are key uncertainties in the schedule that are the same for all reactor alternatives. These key uncertainties include the following elements and are discussed qualitatively. A quantitative assessment of some of the key uncertainties is presented in Chapter 6.

Fuel qualification issues:

- The acceptability of the gallium in the plutonium oxide powder feed to the fuel fabrication processes needs to be demonstrated. It is expected that the gallium issue will have been addressed and resolved without impacting the schedule.
- For the alternatives using integral neutron absorbers, this novel approach will involve a significant fuel qualification program and its associated schedule uncertainty.

Availability of facilities:

- Modification and use of existing facilities for front-end processing and MOX fuel fabrication could potentially shorten the disposition schedule through the use of existing infrastructure, licenses and permits. However, there are also risks associated with modifying existing facilities that could offset these reductions in schedule,

[2] The existing LWR, greenfield facilities variant assumes four BWRs with a particular core management strategy as a basis. It happens that there are not four BWRs available to complete the mission before their licenses lapse (see Figure 5-2). This shortfall is not material to this report because the shortfall is only a couple of years and because this difference can be easily rectified by making minor changes to core designs and core management strategies (see Chapter 2).

such as the need to decontaminate some of these facilities for reuse and the impact associated with force-fitting processes into existing buildings, resulting in non-optimum operations. Also, some of the facilities that might be considered for plutonium processing operations are applicable to other Department missions, and use of them for the plutonium disposition mission could adversely impact those other Department missions.

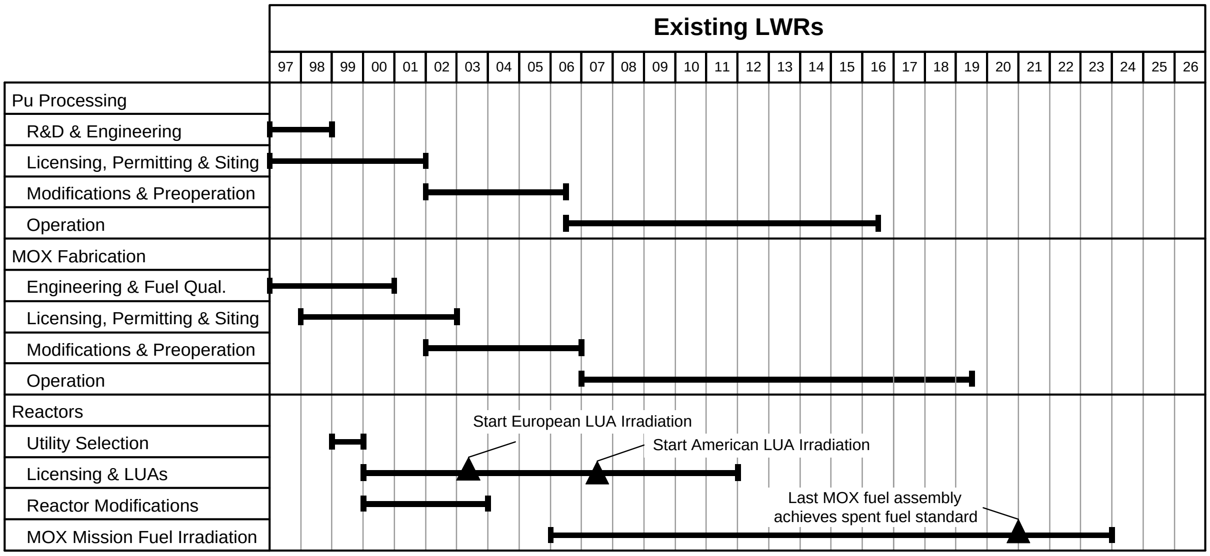
- New facilities involve a long series of actions for design, engineering, and construction, any of which can be delayed. The opportunities for delay include public policy changes or regulatory delays, as examples.

Existing LWRs

For the existing reactor alternatives, the opportunity exists to start the plutonium disposition mission earlier by using existing European MOX fuel fabrication capability. MOX fuel fabrication in Europe can be used to make LUAs and several core reloads as desired. To do so would require that high purity plutonium oxide be available. This oxide would be provided by the ARIES demonstration/prototype. The schedule advantage realized by using the ARIES-derived plutonium oxide in conjunction with European MOX fuel fabrication facilities is to accelerate the start-up of the plutonium disposition mission by approximately four and a half years for the existing LWR, existing facilities variant. The disadvantages for the strategy to accelerate reactor deployment, other than the cost increment, relate to requiring dedicated effort to extract plutonium from the ARIES demonstration/prototype in a production-like environment, the need to transport plutonium over international waters, and the need to negotiate terms and conditions associated with the use of foreign fuel fabrication.

Either BWRs or PWRs can be used for the mission. Two variants are considered to establish a range of possibilities for the existing LWRs. In the first variant (Figure 5-1) five PWRs use fuel with no integral neutron absorbers that is fabricated in European facilities for the first cores. Subsequent cores use fuel fabricated in modified domestic facilities. Plutonium processing is also accomplished in modified domestic facilities. In the second variant, four BWRs use MOX cores containing integral neutron absorbers and new domestic facilities are used for both plutonium processing and MOX fuel fabrication. As pointed out in Chapter 2, the selection of reactor types with the options of using integral neutron absorbers and European fuel fabrication capacity was arbitrary. Therefore, the advantages and disadvantages of variant 1 compared to variant 2 are the results of the construction of the variants and are not necessarily attributable to the difference in reactor type.

Figure 5-1. *Existing LWR, Existing Facilities Schedule*



The schedule for the existing LWR, existing facilities variant is shown in Figure 5-1. The following observations are provided:

- Securing a fuel supply is on the critical path for reactor deployment. Note that the reactors are available to accept MOX fuel in 2004, well before the fuel can be delivered from a domestic MOX facility. Initial use of European fuel fabrication alleviates the schedule gap.

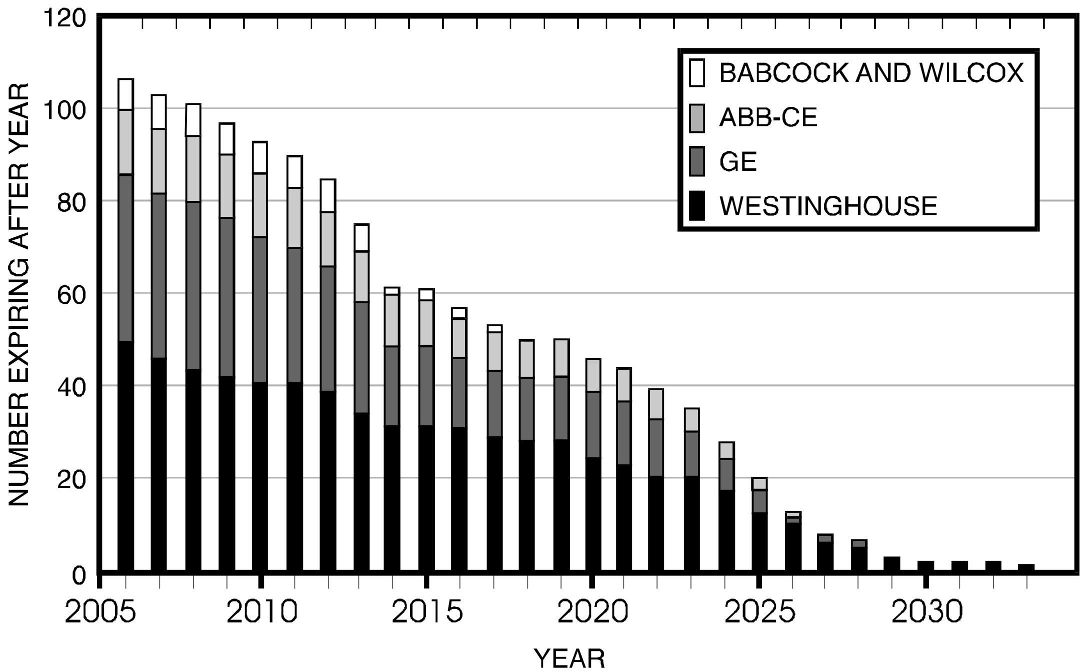
- The time to complete the campaign is a function of two variables, namely, which reactor design(s) is (are) selected and how many reactors are deployed for the mission. Everything else being equal, PWRs have a higher plutonium throughput than BWRs because PWRs generally do not have the same neutron utilization as BWRs. Likewise, all else being equal, full MOX core designs with integral neutron absorbers can achieve higher plutonium throughputs than partial core designs or full core designs without integral neutron absorbers because the integral neutron absorbers tend to counteract the positive reactivity effects of higher fissile loading. Higher plutonium throughputs yield shorter irradiation campaigns. Illustrative values for plutonium throughputs are provided in Chapter 2, Table 2-2.

- For LUAs, existing LWR options can begin irradiation of MOX fuel in approximately six years (for the European initial MOX fuel fabrication) to ten years without European fuel fabrication.

(Information moved to beginning of section.)

In the event that start-up of the campaign is significantly delayed, the viability of some of the existing LWR alternatives may become suspect as the number of licensed reactors begins to fall off after about 2015, as can be seen in Figure 5-2.

Figure 5-2. ***Existing Reactor Availability***



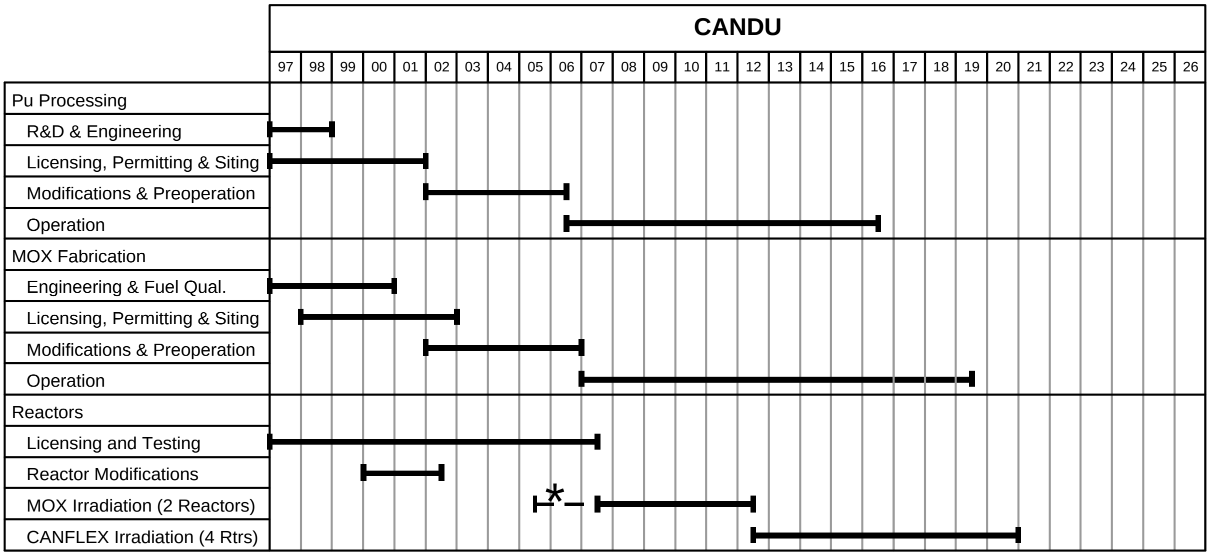
<u>*CANDU Reactors*</u>

The CANDU schedule shown in Figure 5-3 is similar to the schedule for the existing LWR, existing facilities variant schedule. The two variants have similar start times and critical paths, and both can be accelerated using modified facilities for plutonium processing and MOX fuel fabrication. Since CANDU fuel bundles are very short in length, it is easier to perform fuel qualification tests at full scale, and since CANDU reactors are refueled on-line, fuel performance testing is not delayed due to reactor outage scheduling. European fabrication of MOX fuel for CANDUs is possible, although no credit is given in the CANDU schedule baseline. The European data on MOX fuel for LWRs is not as applicable to CANDUs because of technical differences between the fuel types, including the pellet diameter, fissile content, and pellet surface finish. Therefore, a longer fuel qualification effort will be required for CANDU reactors than for LWRs. A smaller schedule credit of two years is given to the CANDU schedule using European fuel fabrication for start-up in Table 5-1.

The alternative uses the advanced CANFLEX fuel form when it is available, approximately five years after starting with low-plutonium-content reference fuel. An alternate approach is to start on the CANFLEX fuel form from the outset and further compress the mission schedule; however, this approach entails the higher schedule risk of putting the CANFLEX fuel qualification effort on the critical path.

In addition to the issues for existing reactors without integral neutron absorbers, the CANDU schedule risks include the efforts associated with fuel fabrication, design, and qualification, the issues relating to transportation and public, and institutional issues on both sides of the border.

Figure 5-3. ***CANDU Schedule***



* Assumes European fuel fabrication

Partially Complete Reactors

While the reactors can be completed well in advance of the availability of MOX fuel, to defer costs, the completion of the reactors is staged such that the completion of the first of the two reactors is accomplished when fuel from the MOX fuel fabrication plant would be available. The first core load of the first reactor would be a low-enriched uranium (LEU) fuel with a MOX fuel LUA embedded within. This strategy is believed to be necessary to ensure that a LUA is tested in a prototypic core. The first reactor would transition to full core MOX fuel by replacing LEU assemblies at normal refuelings. The second reactor would be completed on a schedule to correspond to the end of the review of the LUA in the first reactor; the second reactor would begin operation with a full core MOX fuel load.

Partially complete reactors will require integral neutron absorbers. The reason that the partially complete reactor alternative is constrained to the use of integral neutron absorbers relates to the mission goal of completing the disposition mission in 25 years. Assuming two reactors for the mission, the plutonium throughput for cores without integral neutron absorbers is insufficient to meet the schedule constraint.

A major schedule risk exists for the partially complete alternative in that only a few partially complete reactors exist. Since only limited capacity exists, there is essentially no back-up if one of the two reactors becomes unavailable, in contrast with the existing LWR alternatives for which more plants exist. This risk is in addition to the schedule risks for completing the reactors and the risks for integral neutron absorbers.

Evolutionary LWRs

The evolutionary LWRs are the only reactors for which the availability of the reactors is critical to the start-up of the disposition mission. In all other cases, the fuel supply is the rate-limiting step. Additionally, the integral neutron absorber and reactor capacity arguments for the partially complete reactor alternative also apply here.

5.3 IMMOBILIZATION ALTERNATIVES SCHEDULES

5.3.1 Immobilization Schedule Assumptions

Each deployment schedule has been developed by combining the schedules for each of the individual facilities involved in the alternative. The estimated duration of individual activities are based on previous experience with starting plutonium processing facilities. These schedule estimates also assume that there are no major problems with funding, licensing, or technical implementation.

Licensing:

- For new immobilization facilities, a five-year duration is assumed based upon discussion with and input from the NRC. However, non-safety related construction is assumed to start about one year prior to the issue of a license.
- For existing DOE facilities, a five-year duration for DNFSB review is assumed.

Plutonium Availability for Start-up Schedules for Can-in-Canister Variants:

- The immobilization schedules assume that all front-end plutonium processing facilities would be constructed prior to start-up of the immobilization facilities, except for the start of the can-in-canister alternatives. However, the start-up of the facilities could be staged to support an accelerated start of the plutonium disposition mission. In a staged start, available stabilized oxides would be available prior to 2004. Use of these materials would allow immobilization of existing oxides for at least two years prior to the full-scale ARIES production.

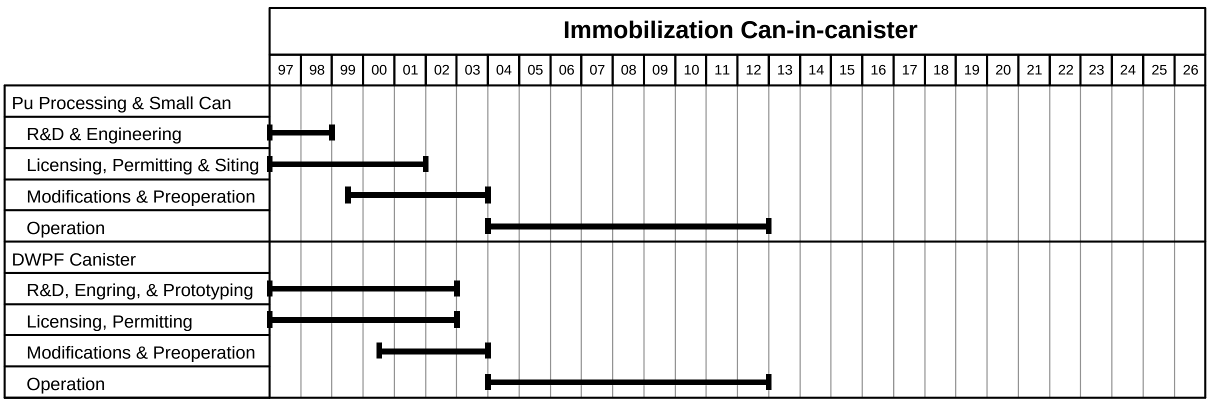
- The can-in-canister approaches are expected to start-up with plant operation at less than the full 5 MT/yr production rate for producing the small plutonium cans that are subsequently emplaced in the DWPF canisters. Doing this will require using oxide sources which are expected to be available in the next several years as a result of other Department missions. As much as three years advancement in the start-up schedule can be realized.

5.3.2 Immobilization Alternatives Analysis

<u>*Vitrification*</u>

The deployment schedules for variants of the vitrification alternative are strongly dependent upon whether existing facilities can be modified for the plutonium disposition mission. The greenfield variant uses new facilities, the can-in-canister variant uses modified facilities for both plutonium processing and immobilization functions, and the adjunct melter alternative represents an intermediate variant.

Figure 5-4. ***Vitrification Can-in-Canister Schedule ****



* Schedule for Ceramic Can-in-Canister would be similar

Each of these three variants also has two cases: 1) a dry plutonium oxide feed to the melters and 2) a wet plutonium nitrate solution feed to the melters. These two cases were considered to assure a viable process. The most rapid start-up would be for the dry feed case since virtually no processing is required for oxide feed materials which comprise about 1/3 of the potential non-pit feed material (about 6 MT). In this case, start-up is limited by the time needed to qualify the waste form and to install the immobilization equipment in existing plutonium facilities. The relatively small amount of feed processing capability needed for the balance of non-pit plutonium feed can be installed later after the early start-up. The schedule for the can-in-canister variant is shown in Figure 5-4, taking advantage of the minimal dry feed processing for start-up. For the vitrification variants, the following observations are provided:

- The schedule for the vitrification variants is driven by the selection, design, and installation of a suitable melter that can produce the vitrified product (while preventing any possibility of a criticality accident) that is acceptable to the high-level waste repository.

- The schedule assumes that existing facilities can be modified with minimal plutonium processing to house the melter to accelerate the mission approximately six years earlier than new facilities (late 2003 versus 2009).

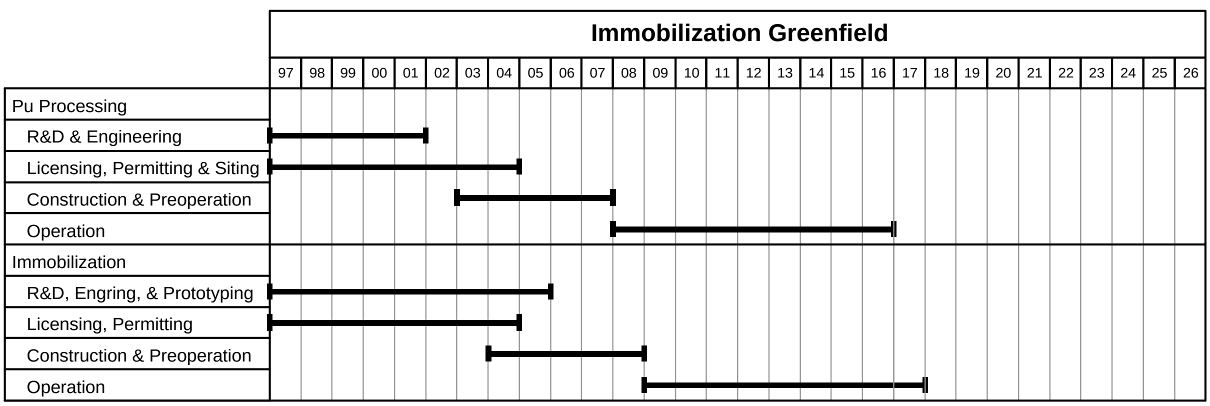
- Primary schedule drivers include the kinetics of the incorporating a plutonium in glass and the number of melters installed.

Key schedule uncertainties include determining the kinetics of incorporating a plutonium into a specific glass formulation and qualifying the vitrified product for inclusion into the high-level waste repository.

Ceramic Immobilization

There are two variants for ceramic immobilization: a new facility and a can-in-canister variant utilizing existing facilities at Savannah River. Each of these variants also has two cases: 1) a dry plutonium oxide feed to the ceramic immobilization process and 2) a wet plutonium nitrate solution feed to the ceramic immobilization process. For an accelerated start for the can-in-canister variant, the dry feed approach would not require feed processing for about 6 MT or approximately 1/3 of the potential non-pit feed material which is available. As in the can-in-canister vitrification variant, processing facilities would not be required to make use of the existing oxides, so the only time required would be for the installation of the immobilization system in an existing facility. Additional processing equipment could be installed at a later date for the balance of the non-pit plutonium feed after start-up.

Figure 5-5. ***Ceramic Greenfield Schedule***



The nominal schedule for the greenfield ceramic immobilization variant is presented in Figure 5-5. The following observations are provided:

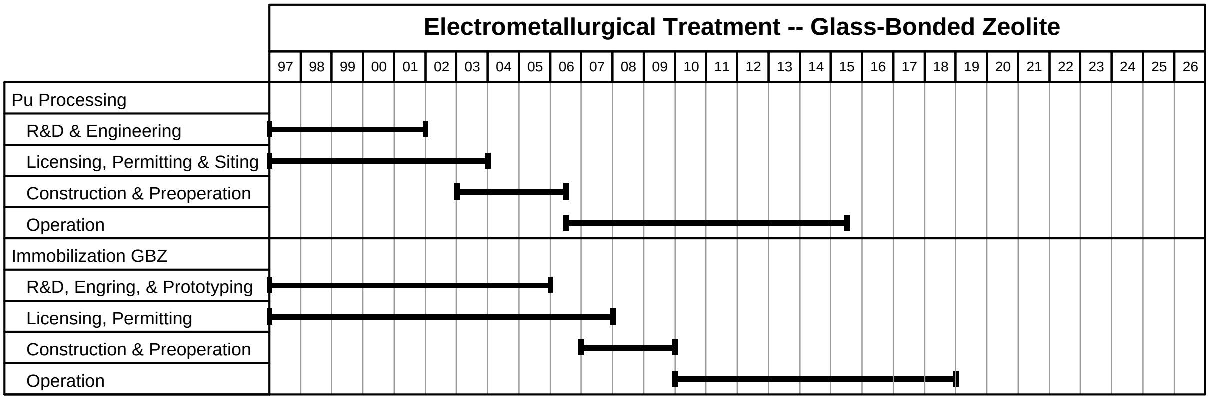
- The critical path for the ceramic immobilization variants is dominated by the selection of a formulation that can be demonstrated to be acceptable to the high-level waste repository.
- The time to complete the mission is a function of the ceramic process chosen (either hot pressing or cold-press and sinter) and the rate at which plutonium oxide can be supplied to the facility.

The key uncertainty in the schedule is qualifying the ceramic product for inclusion into the high-level waste repository.

Electrometallurgical Treatment

There is one variant for the electrometallurgical treatment which involves utilization of the ANL-W facilities. The nominal schedule for this variant is presented in Figure 5-6.

Figure 5-6. ***Electrometallurgical Treatment Schedule***



The following observations are provided:

- The critical path for this alternative is dominated by the selection of a formulation that can be demonstrated to be acceptable to the high-level waste repository and the demonstration of the lithium reduction of oxides-to-metal operations.

- This schedule is predicated on the underlying technology being selected and developed for the disposition of some DOE spent fuels.

The key uncertainty in the schedule is qualifying the glass-bonded zeolite product for inclusion into the high-level waste repository.

5.4 DEEP BOREHOLE ALTERNATIVES SCHEDULES

5.4.1 Deep Borehole Schedule Assumptions

Plutonium feed:

- Plutonium will be available as oxides or as metals, as required, from the plutonium processing facility to support emplacement.

Oversight, licensing and siting:

- The legislative and rulemaking framework can be established in about three years.
- Site selection, site characterization, NEPA compliance, and research and development can be accomplished within six years.

- Borehole licensing proceedings, which are critical path activities, can be accomplished in five years.
- DNFSB review of the use of existing DOE facilities is assumed to be five years.

Operations:

- A half-year cold operation phase precedes hot-operations at the borehole site. The operational emplacement phase takes ten years to complete in the reference alternatives.

Post-closure:

- Decontamination and decommissioning of borehole facilities and a license to close subsurface facilities will occur after the boreholes are sealed. Post-closure monitoring of the boreholes will likely be required. A two-year period is assigned to this function.

Plutonium Availability for Rapid Emplacement:

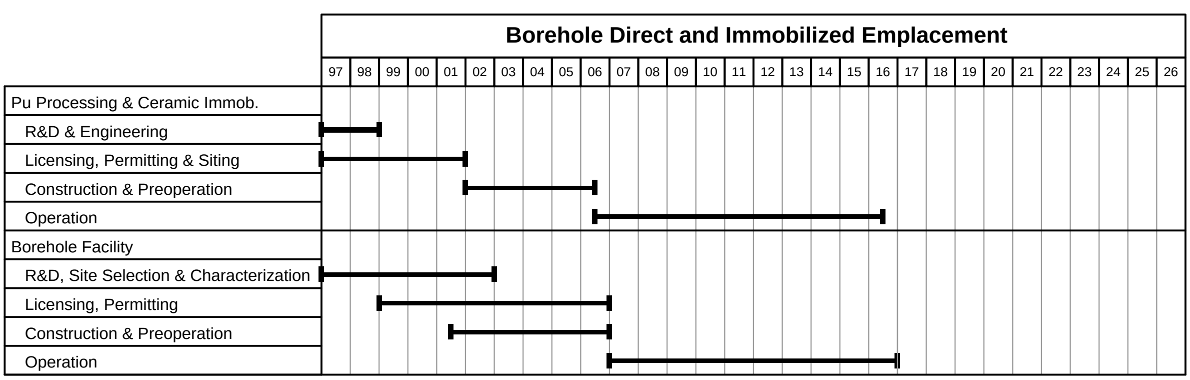
- Once sited and licensed, the critical path for emplacement is the supply of plutonium to the borehole facilities. Rapid emplacement of plutonium requires that extraction of plutonium from pits and other sources be accomplished on a schedule faster than otherwise demanded. It is assumed that plutonium processing will be accelerated if rapid emplacement is desired.

5.4.2 Deep Borehole Alternatives Schedules Analysis

Two significant functions drive the schedule for the deep borehole alternatives: namely, selecting and qualifying a site and obtaining the necessary licenses and permits.

Generally, plutonium processing and borehole facilities equipment and engineering do not appear to be critical path elements.

Figure 5-7. *Direct and Immobilized Emplacement Deep Borehole Schedule*



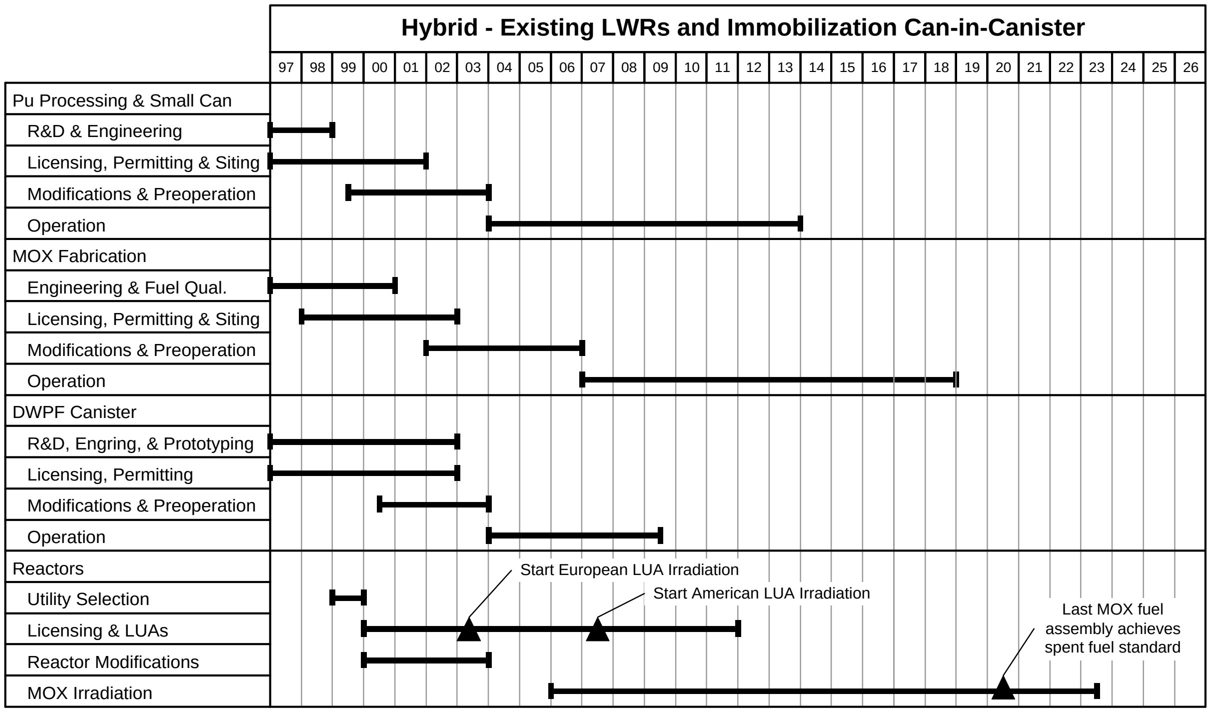
As shown in Figure 5-7, the 10-year duration includes a licensing schedule basis which was discussed with the NRC and appears to be obtainable. The time to emplace is a choice available to the designers.

For the deep borehole alternatives, acceleration of the schedule start-up is not likely since the critical path to start-up involves site selection and qualification. However, the emplacement time can be reduced to as little as three years, if desired, rather than the ten years discussed in the nominal schedule by accelerating the availability of plutonium and by drilling boreholes in parallel rather than series. The downside to the rapid emplacement involves two factors. First, the plutonium would need to be processed through the front-end processes at an advanced rate, which implies cost and technical risk. Second, this option may require performing significant plutonium processing earlier and at risk since resolution of the siting issues may not have been attained when the plutonium processing would be required.

5.5 HYBRID ALTERNATIVES SCHEDULES

The schedules for hybrids utilize existing facilities for plutonium processing where high purity weapons-grade plutonium is fed to a MOX fuel fabrication facility to be made into fuel for existing reactors and the balance diverted to can-in-canister immobilization facilities. A hybrid schedule is shown in Figure 5-8 for the LWR hybrid alternative using existing plutonium processing facilities, European MOX fuel fabrication capability, and early start of can-in-canister immobilization variant. The CANDU hybrid alternative schedule would be similar except that the reactor portion of the hybrid may not start as early with CANDUs as with LWRs.

Figure 5-8. ***Existing LWRs and Immobilization Can-in-Canister Schedule***



Many of the observations for the existing reactor and can-in-canister alternatives apply here. Some additional schedule considerations are:

- Both the reactor and immobilization portions of the hybrid can be started up using their respective accelerated deployment strategies, namely use of European fuel fabrication capability for reactors and use of existing oxides and pilot-plant operation for immobilization. This combination of the technologies provides a higher confidence in an accelerated start than either of them separately.
- Deployment of two technologies will provide increased flexibility and assurance of mission accomplishment should technical problems develop with one technology.
- Flexibility is retained in that a decision to utilize a hybrid approach preserves the option to go exclusively to reactors or exclusively to immobilization at a later date.

5.6 SCHEDULE DATA SUMMARY

Table 5-1 is a summary of the schedule data for the disposition alternatives.

Table 5-1. *Disposition Schedule Summary*

	Time to start (yrs)[1]	*Time to complete (yrs)*[2]	*Remarks*
		Reactor Alternatives[3]	
Existing LWRs, Existing Facilities	9	24	Reflects initial use of European MOX fuel fabrication plant until domestic facility is available. Unavailability of European MOX fuel fabrication and/or plutonium oxide for LUAs and initial reactor core loads can delay the disposition mission up to 4 years.
Existing LWRs, Greenfield Facilities	13	31	
CANDU	8–10	<24	CANDU fuel irradiation likely could begin earlier with European fuel fabrication, just like LWRs. Since CANDU MOX fuel fabrication is less certain than for LWRs, only half of the LWR schedule acceleration of 4 years is assumed to apply to the CANDU alternative. The earlier date shown here assumes a two-year schedule credit for European MOX fabrication.
Partially complete LWRs	13	28	
Evolutionary LWRs	14	28	
		Immobilization Alternatives	
Vitrification Can-in-Canister	7	18	
Vitrification Greenfield	12	21	
Vitrification Adjunct Melter	12	21	
Ceramic Can-in-Canister	7	18	
Ceramic Greenfield	12	21	
Electrometallurgical Treatment	13	22	
		Deep Borehole Alternatives	
Immobilized Emplacement	10	20	The implementation time is assumed to be 10 years; it could be compressed to as little as 3 years
Direct Emplacement	10	20	The implementation time is assumed to be 10 years; it could be compressed to as little as 3 years
		Hybrid Alternatives	
Existing LWRs with Vitrification Can-in-Canister	7	<25	The 7 years corresponds to the immobilization portion of the hybrid. The reactor portion starts up in 9 years.
CANDU with Vitrification Can-in-Canister	7	<22	The 7 years corresponds to the immobilization portion. The reactor portion will start in 8–10 years.

[1] Time is measured from authorization to proceed. Start-up time refers to the initiation of production-scale operations, which for can-in-canister variants is taken to be 1.25 MT/yr capacity versus full scale (5 MT/yr) capacity.

[2] Time to complete is the entire duration from authorization to proceed to completion of the disposition mission. The disposition mission is considered complete: for LWRs – after the first irradiation cycle for the last MOX bundles; for CANDUs – after the last bundle has completed its intended irradiation; for immobilization – when the last immobilized waste form is fabricated; and for deep borehole – when the last borehole is sealed.

[3] For reactor alternatives, this start of production-scale operations is defined to be the beginning of the irradiation cycle for the mission fuel. For existing LWRs, this is 2–3 years after irradiation of lead use assemblies. For partially complete and evolutionary reactors, the mission starts when the reactors go to full power with their MOX cores.