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Reactor-Based Tritium Production - FFTF Tritium Production Capacities and Ability to Meet Future Stockpile Requirements

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Reactor-Based Tritium Production - FFTF Tritium Production Capacities and Ability to Meet Future Stockpile Requirements

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1. Executive Summary

This study provides an update of the current status of the use of the Fast Flux Test Facility (FFTF) at Hanford to produce tritium to meet future nuclear weapons stockpile requirements. It focuses on information and analysis results that have arisen since earlier studies, principally the 1996 JASON study,[1] were completed. The areas addressed by the present study and its findings are summarized as follows.

- Under prospective arms reduction efforts (START II and III), FFTF could meet stockpile requirements at a tritium production level of 1 to 1.5 kilograms per year. FFTF would not meet tritium requirements under conditions where stockpile sizes remain at START I levels or at START II with augmentation requirements back to START I levels.
- At lower levels of tritium production (1 kg/yr extending possibly to 1.5 kg/yr) many of the operational and safety concerns raised in previous assessments[1] may not be valid because existing fuel types using nominal enrichments will be used. Safety analyses still must be performed to investigate target reactivity effects, but straightforward enhancements to FFTF safety envelopes appear reasonable for low tritium production levels.
- Fuel type and supply continues to be a major issue, particularly if surplus weapons plutonium were to be used in FFTF fuel. Such actions could create significant opposition from arms control and disarmament communities. However, an alternative may exist via use of higher (highly) enriched uranium fuels, but yearly tritium production is estimated to be about 20% lower based on the relative values of η for the two fuels. Further study of such fuels is required.
- The political and institutional barriers surrounding FFTF are very important. Support for the facility as a tritium producer exists in some parts of Washington and Idaho, but not in Oregon. If, however, FFTF can produce medical isotopes as the long-term mission, political support may strengthen. These issues could have a large impact on both cost and schedule. Other institutional issues that will have considerable impact on the restart schedule for FFTF include completion of an Environmental Impact Statement (EIS) and who will be the authority for restart licensing approval (DOE or NRC).
- Unique features for FFTF tritium include eight open test assemblies in the core, the interim examination facility, and the Fuels and Materials Examination Facility (FMEF). These features can be coupled with a number of tritium target options to meet overall tritium production requirements (1 to 1.5 kg/yr).
- Verification of tritium target performance using lithium aluminate or lithium oxide can only be addressed by testing in FFTF under prototypic conditions. Testing of lithium aluminate targets in a light water reactor (LWR) environment may not be applicable to FFTF conditions.

2. Introduction and Summary

This report describes results from a study to determine the potential of the Fast Flux Test Facility Reactor for tritium production under changing stockpile and FFTF technical system conditions. In particular, it focuses on potential changes in tritium requirements and status of FFTF operations that are occurring, or have occurred, since the last, major independent FFTF study made by the JASONs in October 1996.[1] At that time the JASON study was concerned primarily if FFTF could:

- meet START-I levels of tritium production requirements by 2005 given regulatory requirements and the need to renegotiate the Tri-Party Agreement on FFTF shutdown;
- do so under safe and publicly acceptable operating conditions; and
- whether FFTF fuel containing weapons plutonium fractions approaching 50% could be used and disposed of straightforwardly.

The present study focuses on the following areas and the implications for FFTF tritium production:

- implication of continuing START arms reduction activities on future stockpile tritium needs and the capability of FFTF to meet them;
- technical development and testing, particularly concepts aimed at enhancing tritium production rates and/or extraction ease;
- issues surrounding weapons plutonium sources for FFTF fuels plus alternative fuel approaches; and
- the present status of Advanced Nuclear and Medical Systems (ANMS) proposal to privatize the facility and to use it for medical isotope production.

In addition, this document summarizes the present status and issues in political and institutional areas, safety issues for tritium production, and FFTF tritium production economics. Much of the discussion in these latter areas is similar to that included in the earlier JASON's report and is provided to the interested reader for completeness. Finally, this report is a continuation of previous Los Alamos studies on other reactor systems and tritium targets.[2]

3. Background

FFTF is a sodium-cooled research reactor located in the 400 area of the Hanford site near Richland, Washington. It is a fast-spectrum experimental breeder reactor that does not produce electricity. It was constructed in 1980 and operated from 1982 to 1992 to test fuels and components for breeder reactors. FFTF operated for a 10-year period, accumulating the equivalent of seven reactor years of operation, and achieved an outstanding safety record and demonstrated performance with high capacity factors. In December 1993, the Department of

Energy (DOE) ordered it shut down (to occur over five years) after it concluded there were no future prospective financially viable missions for FFTF. The shutdown of FFTF was estimated to cost about $290 million and would place the facility in an industrially safe shutdown condition, good enough for a surveillance and maintenance phase after decontamination and decommissioning (D&D). (The surveillance and maintenance phase, and the D&D phase would be the responsibility of the DOE Office of Environmental Restoration.)

Subsequent to the decision to shut down FFTF, the DOE studied alternatives for supplying tritium for the nation's nuclear weapons stockpile. FFTF was reviewed as a possible tritium production source but was discarded by DOE because it was believed it could not meet the tritium production goals at that time. There were also some questions about FFTF's remaining lifetime. After studying other alternatives for new tritium production sources, DOE decided on a two-track strategy to determine the viability of commercial light water reactors (CLWRs) and accelerator production of tritium (APT) with a downselect to occur in late 1998.

The DOE initiated reconsideration of FFTF for tritium production in December 1995. DOE Nuclear Energy and Defense programs both produced technical assessments of tritium production capability of FFTF in March 1996. Secretary O'Leary chartered the JASONs to study FFTF technical issues, cost, and schedule for a 30-year tritium production mission.[1] The JASON report was, for the most part, positive about tritium production but had concerns about reaching a 2 kg/yr production rate by 2005 given regulatory and FFTF Tri-Party Agreement renegotiation requirements. The report also identified concerns on the fuel cycle implication of using excess weapons plutonium for FFTF fuel and the challenge of final disposition of this fuel.

In October 1996, Secretary O'Leary commissioned a study by Putnam, Hayes and Bartlett (PHB) [3] to examine (1) the cost to produce tritium with FFTF and (2) the net economic benefits, if any, from using FFTF to produce tritium. PHB used a baseline tritium production capability of 1.5 kg/yr. In January 1997, this study concluded that immediate FFTF restart would likely increase the total cost of tritium production -- it recommended not to immediately restart FFTF for tritium production. It was also concluded that FFTF in hot standby would likely lower DOE budget requirements in the near-term (avoiding decommissioning costs) and had the potential to provide long-term economic benefits, if tritium program constraints changed, either in restart or in hot standby. Thus, it was recommended that FFTF be maintained in hot standby as an option for later restart and that FFTF status should be revisited in 1998, along with the primary and backup tritium options, in the context of then-current requirements on the tritium mission. In January 1997, Secretary O'Leary directed that FFTF be maintained in a standby condition while an evaluation was conducted of any future role that the facility might have in the DOE's tritium production strategy. The purpose was to maintain FFTF as near-term insurance, given uncertainties associated with the dual-track approach and future stockpile requirements. Secretary Peña has since stated during a visit to Hanford in August 1997, that he would objectively evaluate FFTF as a short-term or backup tritium production source with an eventual long-term mission of producing medical isotopes.[4]

4. Stockpile Requirements and FFTF Capacities

A number of scenarios have been studied to determine possible FFTF tritium production roles for the stockpile under START arms control efforts initiated since completion of the earlier JASON and DOE reports. The requirements and production scenarios have been studied using complex analyses of the tritium in the stockpile, the pipelines, and various inventories.

For START I stockpile levels, tritium requirements using FFTF can only be met for a few years even if FFTF tritium production started immediately. However, the situation becomes more favorable for FFTF if the START II or START III treaties come into effect. A 1 kg/yr production level starting in FY 2002 would support indefinitely a nominal START III stockpile. If the 1 kg/yr production level were increased to 1.5 kg/yr sometime after FY 2002, FFTF could support a nominal START II stockpile indefinitely.

Other factors and scenarios (still unknown at this point) can complicate these conclusions. START II requirements are the most complex under a FFTF-only production decision. For one possible START II scenario, it has been proposed to keep a hedge that allows return to START I stockpile levels rapidly. This means the tritium requirements are nearly equivalent to those of START I and FFTF would not meet the requirements. However, if the proposed hedge is reduced in time, early or maximum production from FFTF could meet stockpile requirements especially if a more likely scenario of small hedge strategies is implemented.

For START III, FFTF could meet all stockpile requirements for tritium except for the most demanding, hedge-dominated scenarios. If a hedge to return rapidly to START I levels is assumed (which is probably unlikely), then a situation similar to START II arises. With reasonable estimates of a START III stockpile with a nominal hedge, 1 kg/yr FFTF production scenarios could meet stockpile requirements to 2020 if production starts in 2002; increasing this number to 1.5 kg/yr would allow needs to be met well past 2030. FFTF could meet most any other START III stockpile requirement indefinitely even if implementation of such agreements were delayed for a number of years.

These changes in probable stockpile requirements resulting from START II and follow-on initiatives are the single largest factor contributing to FFTF technical credibility in meeting national tritium needs. To do so would require production levels around 1 kg/yr -- a requirement which the JASON study concluded could be met with high confidence. Based upon estimated lifetime remaining for the FFTF facility (30 to 40 years), 1 kg/yr tritium production could continue well past 2030.

5. Review and Status of Political and Institutional Issues

Several political and institutional issues must be resolved before a satisfactory case can be made for FFTF tritium production. These issues are discussed here with emphasis on status and changes since the earlier JASON and DOE analysis.

5.1 FFTF Privatization Proposal

The Advanced Nuclear and Medical Systems corporation proposed a plan to privatize the operation of FFTF, FMEF, and supporting facilities for production of medical isotopes and tritium to DOE in 1995 followed by an updated proposal in 1996.[5] ANMS secured a $450 million line-of-credit stated to be sufficient to cover costs for target adaptation, environmental permitting, facilities modifications, and initial FFTF operation. Under the proposal, ANMS would restart FFTF under DOE lease in 2000 and provide tritium production services to DOE. DOE would transfer the title of the FMEF and related Hanford surplus facilities to ANMS. The proposal also included a phaseout of FFTF tritium production over a 10- to 15-year time frame and a transition to primary production of medical isotopes. After completing a review of the ANMS proposal in 1997, DOE determined it was premature to consider private proposals to return FFTF to operation for tritium and medical isotope production although privatization of the facility could be considered at a later time. It was reported in August 1997, that ANMS was on the verge of ending its efforts at privatization of FFTF operations.[6]

5.2 Fuel Supply

A concern for continued operation of FFTF is the supply of plutonium fuel. The primary sources of fuel for FFTF are the remaining fuel from earlier operations, which would last about 1.5 years, and the 38.2 metric tons of weapons plutonium that has been declared surplus. However, as pointed out by the JASONs, there are political concerns with using this surplus plutonium to produce new materials for use in nuclear weapons. Opponents argue that this would be counter to strong U.S. positions on nonproliferation, arms control, and agreements with the Russians. The JASON study also concluded that after FFTF use, fuel fabricated from weapons plutonium would represent a larger challenge for disposition than plutonium that had been utilized in light water reactors. They concluded that dilution with larger amounts of uranium, or possibly reprocessing, would be required before such fuel could be sent to Yucca Mountain. Fuel availability for FFTF is thus probably the biggest institutional issue that has to be resolved before any tritium production mission can begin. An alternative to using plutonium for FFTF fuel is to use highly enriched uranium (HEU) as the fuel material. However, based on the relative values of η, there would be a concurrent penalty of about 20% on tritium production quantities. Under many START II and III scenarios use of HEU-based fuels could allow tritium production requirements to be met but further physics and safety analyses are needed to determine the feasibility of this approach.

5.3 Fuel Fabrication

After present FFTF stocks of fuel have been exhausted (about 1.5 years), new fuel will have to be fabricated for continued operation. The Fuel Materials and Examination Facility located next to FFTF could be used for fuel fabrication, but it will have to be licensed and upgraded for operation -- a process that is estimated to take up to five years,[7] but could take significantly longer. Some interim fuel fabrication and test pin fabrication could be performed at the Los Alamos Plutonium Facility (TA-55) including higher plutonium enrichment, if required. Assemblies could be built at Los Alamos facilities and shipped to FFTF. However, a more comprehensive study is required to determine how much fuel could be produced at Los Alamos and on what schedule. This analysis would examine requirements, fabrication capacities, floor space availability, facility operating envelope impacts, storage capacity, equipment and facility modification requirements, worker radiation protection effects, criticality safety issues, schedules, etc.

5.4 Regulatory Requirements

According to the JASON report, DOE would need to amend the current record of decision (ROD) on U.S. policy on developing a tritium production capability to expand it beyond the civilian light water and accelerator production options. This augmented or new ROD would represent a first step for FFTF to be a viable competitor among possible tritium-producing facilities.[1]

An environmental impact statement (EIS) would also be required for restart of FFTF and opening of FMEF as a fuel fabrication facility. Earlier operation of FFTF was done under an environmental assessment (EA). The requirements for performing an EIS are lengthier and include hearings and opportunities for public involvement (and, hence, possible delays). The FFTF-Standby Project Office has filed a notice of intent to perform a new EIS in case a decision is made to proceed on considering FFTF for tritium production. This EIS is estimated to take about one year to complete, but has not yet been authorized by DOE.[7] This EIS would be for an interim supply of tritium from FFTF, not to replace the more general programmatic tritium production EIS. Upgrades to the existing systems would not be needed, but some older systems would be replaced, such as some of the plant protection system.

An important institutional issue for the restart of FFTF is who would have responsibility for licensing — the Nuclear Regulatory Commission (NRC) or DOE. If FFTF continues to be under DOE regulation, the reactor could probably be restarted on a more definite schedule. If the NRC would be the regulator, then more uncertainty in the restart schedule would be introduced because FFTF could be treated as a new license application with a lengthy review process. NRC was involved with FFTF in the late 1970s and approved the start-up operation then. However, NRC rules and regulations have changed considerably since that time.

5.5 Political Issues

Significant political support was given to the continued operation of the FFTF by the Washington State congressional delegation and the governor of Washington State. Much of this support was based on potential economic redevelopment in the region through the continued employment of personnel at the Hanford site. Additionally, the ultimate goal of production of medical isotopes as originally proposed by ANMS was viewed as a desirable activity for the site and region with the possibility of establishing the area as a major medical research and treatment center. Tritium production was seen as a bridge until the market for medical isotopes with properties aimed at specific treatment protocols developed. The political support of Washington State is very important. FFTF shutdown and decommissioning is a part of the Tri-Party Agreement, largely concerning environmental cleanup at Hanford, among DOE, EPA, and Washington State.[1] Under the Tri-Party Agreement, there are enforceable milestones in the deactivation process. DOE would have to renegotiate that agreement and obtain EPA and the state of Washington agreements to eliminate the deactivation milestones and change the mission of FFTF.

The Oregon congressional delegation is not supportive of continued FFTF operation. They view this possibility unfavorably, owing to concerns that the restart of FFTF could divert funds intended for cleanup at the Hanford site (this is also a concern for some in Washington State).

Idaho is supportive of continued FFTF operation because the restart of FFTF could advance the cause of liquid metal reactors, which could help Idaho National Engineering and Environmental Laboratory and Argonne National Laboratory. Additionally, development and verification activities related to target assemblies might use Advanced Test Reactor at Idaho for support work.

6. Technical Issues — Production/Targets/Safety

6.1 Tritium Production and Associated Issues

Tritium production in FFTF is limited to a maximum of about 2.0 kg/yr due to its power level of 400 MWt.[1] However, FFTF has several unique attributes that enhance its capabilities for both tritium and medical isotope production as compared with a thermal neutron reactor of equivalent power. The fast neutron spectrum and plutonium fuel cause the number of neutrons liberated per fission (or equivalently per unit of reactor thermal power) to be higher than that for a thermal neutron spectrum, uranium-fueled system. The fast spectrum also allows for production of certain other medical isotopes that cannot be produced in a thermal spectrum. Another attribute is the sodium coolant, which has good tritium retention characteristics as compared with pressurized water cooling in most thermal reactors. Tritium leaked from the targets into the coolant would be retained there until it was removed via the primary loop cold traps. Other attributes pertain to operational features and facilities that exist on site. FFTF has eight open test assemblies that could enable rapid retrieval of targets, or enable flowing targets such as helium-3, or rapid retrieval of medical isotopes. FFTF also has the interim examination facility that contains a large hot cell integral with the containment which would be useful for target processing. Finally it could be possible to fabricate FFTF fuel and tritium production targets on site (FMEF).

Lithium aluminate targets (similar to those undergoing testing for CLWR tritium production) are baselined for tritium production in FFTF. Using lithium aluminate targets in FFTF to produce 1 kg/yr of tritium using existing fuel has a low technical risk because these targets will only be located in the reflector. Using lithium aluminate targets in FFTF to produce 1.5 kg/yr of tritium has a medium technical risk. The difference in the risk levels between producing 1 kg/yr and producing 1.5 kg/yr is caused by differences in the required location and quantity of tritium production targets in each of the two cases. To produce 1 kg/yr of tritium, targets can be located solely in the FFTF radial reflector region. These targets are exposed to a lower fast flux and temperature than in-core targets, and have a smaller effect on reactor physics than in-core targets. To produce 1.5 kg/yr of tritium, higher plutonium enrichment would be required for the fuel, and the targets must be located both in the FFTF reflector and the core. The use of in-core targets poses a higher technical risk, because these targets are exposed to a higher fast neutron flux and have a larger effect on reactor physics than reflector-situated targets. In any case, target testing in FFTF is required to verify target performance.

For both of these FFTF tritium production scenarios, several technical challenges exist for both the in-core and reflector targets. Lithium aluminate targets are being developed for LWR applications, and lithium aluminate has an adequate lithium density for use in FFTF at production rates up to 2 kg/yr. However, the peak FFTF coolant temperature is significantly higher than that in a pressurized water reactor (PWR) — 800°K versus 600°K — and the FFTF fast flux is more than an order of magnitude higher than that in a PWR. Target heating by gamma rays is significantly higher in FFTF than in a PWR. Lead test assemblies designed to show that lithium aluminate targets would work in a PWR environment may not provide adequate data to conclude that lithium aluminate targets will work in FFTF. In addition, lithium aluminate targets for FFTF would be of a different design than those for a light water reactor in order to provide adequate lithium loading and to fit properly into the core. No available test facility can simulate FFTF's operating environment adequately; thus target performance can only be fully assessed once FFTF is restarted.

Because of losses, there is also uncertainty associated with extraction and recovery rates of tritium from the lithium aluminate targets. Getters and barriers within the targets must be designed to retain tritium at high temperature. Extracting the tritium from the targets (especially the getter) will require a high-temperature extraction facility, capable of much higher temperatures than those required to extract tritium from the lithium aluminum targets used in the past. Until large-scale tritium extraction from lithium aluminate targets is demonstrated along with achievable efficiencies, there will be some technical risk associated with tritium recovery (these risks also occur for CLWR tritium production). If alternative target materials such as lithium oxide are to be used, the technical risk of tritium production in FFTF will also be higher.

6.2 Targets

Four types of tritium targets could be used in FFTF:

1. Targets based on lithium aluminate (enriched in lithium-6);
2. Targets based on lithium oxide (enriched in lithium-6);
3. Targets based on helium-3; and
4. Targets based on a combination of the materials listed above.

Targets based on lithium aluminate are being developed for potential use for CLWRs, and test irradiations are underway at the Watts Bar nuclear plant at Tennessee Valley Authority. These targets may be usable in the FFTF, but the higher fast flux and higher operating temperature of FFTF may degrade target performance. A facility at Savannah River for extracting tritium from lithium aluminate targets is currently being designed in support of CLWR tritium production.

Targets based on lithium oxide have a higher lithium number density (the number of lithium-6 atoms per cubic centimeter of target material) than targets based on lithium aluminate and thus may be better suited for use in the fast spectrum FFTF. This increased number density offsets the much smaller lithium-6 tritium production cross section that occurs for fast neutrons (as compared with that for thermal neutron energies). Lithium oxide targets may also be able to operate at a higher temperature than lithium aluminate targets.

Targets based on helium-3 have several attributes that could make them suited for tritium production in FFTF and have been investigated in previous studies.[8] If the targets are placed in the eight open test assemblies, it may be possible to flow the helium-3 through the targets and use a getter external to the core to recover the tritium that is produced. This would allow a low-temperature getter to be used, and would avoid activation of the getter material. About 600 grams (at 75% FFTF capacity factor using existing fuel) of tritium could be produced and captured on low-temperature nonactivated getters each year. Capturing the tritium on such a low-temperature nonactivated getter could greatly reduce the cost of shipping and tritium extraction. Radiation damage of the tritium-producing material is not an issue since helium-3 is a gas. Targets that use flowing helium-3 and recovery methods external to the core (external getters) could be less expensive to develop because the tritium partial pressure in the target would be quite low. This could reduce or eliminate the need for developing a diffusion barrier that could operate at FFTF temperatures.

The primary issue with using targets based on helium-3 has been the potential for a large reactivity insertion if the helium-3 is lost. Such a situation would result from the (sudden) availability of neutrons that would not be absorbed in helium-3 and could dramatically increase reactivity of the reactor. A Los Alamos target design described in Reference 2 greatly reduces the possibility for such a reactivity insertion. This target design, the inherently safe target (IST) concept, operates by keeping the effective neutron absorption cross section of the target constant, whether the helium-3 is present or not. This is accomplished by using either lithium aluminate or lithium oxide inside the helium-3 rod so that even if the helium-3 is lost, neutrons are absorbed in the lithium compound.

Targets based on a combination of helium-3 and lithium aluminate or lithium oxide may have the best characteristics of all. In addition to having the attributes of the helium-3 target, the combination target would have higher tritium production than a target that does not use a lithium compound. Tritium formed in the lithium aluminate or lithium oxide would diffuse into the helium-3, where (in the flowing loop target) it would be swept to the outside of the core and recovered along with the tritium produced in the helium-3. Finally, since tritium is produced in the lithium compound means that tritium production is not completely dependent on the U.S. helium-3 supply.

Tritium production calculations were performed on conceptual FFTF tritium targets that use a combination of helium-3 and lithium aluminate or lithium oxide. If the eight open test assemblies in FFTF contain such targets then 600 grams of tritium could be produced each calendar year (assuming a 75% capacity factor) with existing fuel. As discussed previously this tritium would be recovered externally to the core using low-temperature getters. The use of such low-temperature, nonactivated recovery methods could result in transportation and extraction cost savings and could provide tritium acceptable to the user where no additional processing would be required. This tritium could be viewed as high-quality tritium, as it would essentially be ready for use.

This 600 g/yr of high-quality tritium could be used to supplement tritium produced by other sources and would be available even if the Savannah River high-temperature tritium extraction facility was not yet operational. Additional tritium (up to 1.5 kg/yr total) could be produced using targets with tritium getters located above or below the active region of the core. An in-core getter arrangement could theoretically operate at near the FFTF core inlet temperature (630°K), but it would still require a high-temperature extraction facility for tritium recovery. The FFTF tritium production capability using these combination targets is similar to that production achieved using lithium-based targets. The primary reason for considering them is to determine if a cost saving could result from reduced target development, target fabrication, target shipping, and tritium extraction costs.

6.3 Safety

The 1996 JASON review of FFTF tritium production described safety issues related principally to 2 kg/yr operations using fuel with higher levels of plutonium enrichment. At the lower levels of production of interest here (approximately 1 kg/yr) there do not appear to be any significant safety issues, although further analysis is needed. There also appears to be possible enhancements to safety. One issue that requires further investigation is the effect of the reduction in FFTF's small Doppler reactivity feedback coefficient that could occur under a tritium production configuration. FFTF's fuel constituent, plutonium-239, has a small positive Doppler coefficient, which partially offsets the negative Doppler coefficient from the uranium-238 also contained in the mixed oxide fuel. The magnitude of the negative Doppler coefficient would be further reduced by the addition of tritium producing targets because the targets decrease the population of neutrons in the resonance energy range. At higher tritium production levels where higher plutonium enrichment is required, the magnitude of the Doppler coefficient is further reduced (as noted in the JASON study). A significantly reduced Doppler coefficient will make the reactor more responsive when a control rod is moved, and there may be some overshoot in reactor power until feedback from axial expansion, sodium, and structural effects occurs.[9] If the reduced Doppler coefficient is unacceptable, it may be possible to increase its magnitude by using moderated targets or some other method for softening the overall neutron spectrum.

Several other factors associated with tritium production could affect safety, but appear to have either a small effect or sometimes a beneficial effect. According to personnel at FFTF,[9] producing tritium reduces reactor vessel damage rates by 50% to 80%, potentially benefiting safety and plant lifetime. For higher tritium production scenarios, the delayed neutron fraction in the tritium production core is smaller than that of the standard FFTF core (because the ratio of plutonium to uranium would be higher in the tritium production core). The effects of this change need to be quantified. The radial expansion reactivity coefficient of the tritium production core is also slightly less negative than that of the standard core, while the axial expansion reactivity coefficient is slightly more negative. The reactivity effect from voiding sodium is more negative for the tritium production core than for the standard core. These effects can lead to the situation where control and safety rods would have a lower reactivity worth in the tritium production core than in the standard core. However control and safety rods for the tritium production core should provide sufficient shutdown margin. Part of the worth can be regained by using enriched boron instead of natural boron in the rods. The reactivity effects of tritium targets located in the core could be significant; therefore mechanisms by which the targets could be removed from the core must be evaluated by performing additional independent safety analyses.[9]

Tritium release from the targets in FFTF could be less severe than for water-cooled reactors. Released tritium would form sodium tritide that would be removed by cold traps that make up part of the FFTF primary cooling system. FFTF personnel[7] estimate that nine kilograms of tritium could be released into the primary coolant without exceeding site boundary tritium release limits.

7. Cost and Schedule Estimates

The earlier JASON study did not quantitatively examine FFTF costing issues. Since the 1996 JASON report, the Putnam, Hayes, and Bartlett study estimated the cost for restart of FFTF at $450 million to $525 million.[3] The FFTF Standby Project Office (FFTF-SPO) estimates the capital costs of improvements to the reactor for restart of $320 million and $100 million for the fuel line, for a total capital cost of $420 million to return to operation.[7] The annual operating costs are estimated, by FFTF-SPO, at $88 million per year ($54 million for the reactor and $34 million for fuel and target costs), assuming the government would supply plutonium and uranium. Thus, the total operating costs would be $88 million per year.[7]

Restart is estimated by FFTF-SPO to occur approximately four years from a record of decision after the EIS is completed, which should take about a year.[7] Thus, restart could occur in 2002. The operating staff will need to be requalified. It is estimated that FFTF could then operate for approximately 30 years.

8. Current Status[10]

The Office of Nuclear Energy, Science and Technology has established an FFTF Standby Project Office reporting to the Richland Operations Manager.[7] The Standby Project Office is conducting the safety and environmental analyses that would be needed for required nuclear safety and National Environmental Policy Act (NEPA) documents prior to startup for tritium production. The Standby Project Office is also evaluating the use of FFTF for medical isotope production concurrently with tritium production.

The FFTF is currently in standby with the reactor completely defueled. The main heat transport system is being operated at approximately 400°F. Essential systems, staffing, and support services are being maintained. In addition, decommissioning activities continue consistent with maintaining standby, such as cleaning and storing of spent fuel and other reactor core components, maintaining equipment required for deactivation, and completing the planning necessary to resume an orderly transition to shutdown (if appropriate).

The following studies and analyses, focused around five major subtasks, are underway at Hanford by the FFTF-SPO:

1. Preparation of documentation that addresses FFTF environmental and safety issues developed in concert with external review groups, the Tribal Nations, regulators, and the public;
2. Development of a database for technical questions indicating current resolution of the proposed approach (including validation of existing FFTF tritium production estimates);
3. Preparation and independent review of FFTF restart and life-cycle cost and schedule estimates;
4. Preparation of a systems engineering management plan that addresses fuel and target supply, long lead time materials procurement, transportation, integration with Hanford Strategic Plan, tritium storage and processing sites, regulatory requirements, and staffing needs; and
5. Preparation of an FFTF medical isotope production assessment report, including economic and technical feasibility.

9. Conclusions

Based on our current technical knowledge of FFTF (after reviewing the JASON report, performing some independent calculations and meeting with the FFTF Standby Project Office), we believe that, if the stockpile is reduced to START II or START III levels, FFTF can provide required tritium amounts. If, the START II or START III treaties cannot be ratified, and stockpile levels remain at START I, FFTF tritium production alone is not adequate.

The following summarize major points (pro and con) discussed in this report that pertain to the feasibility of FFTF for tritium production that should be given careful consideration for further evaluations:

- FFTF is an existing DOE reactor facility located on a DOE reservation (Hanford) that is currently being maintained in standby condition and has a remaining useful life of approximately 30 years. Because FFTF is a DOE-owned facility and does not produce electricity, there are no commercial reactor nonproliferation policy implications from using FFTF to produce tritium.

- FFTF's operational and safety record over a period of 10 years was excellent. At lower levels of tritium production (1 kg/yr), existing fuel types using nominal enrichments will be utilized and therefore safety issues should be minimal. However, further safety analyses will be required for verification. At higher production rates, the reduced doppler coefficient will be a serious safety issue.

- Tritium requirements under proposed arms control scenarios (START II and III) will probably decrease making FFTF tritium production more feasible.

- For a production rate of 1 kg/yr, FFTF may be the lowest cost option with low technical risk.

- The fuel availability issue, particularly pertaining to use of surplus weapons plutonium, remains a key uncertainty. Use of weapons plutonium origin fuel would most likely create significant opposition within the arms control and disarmament community. This issue, plus others associated with fabrication and disposition of such fuels, could be circumvented by use of enriched uranium to replace plutonium presently comprising FFTF fuels. Penalties in tritium production around 20% would be expected to occur. This area of alternative fuel use is one area requiring further examination and discussion.

- FFTF can also be used to produce medical isotopes concurrently with tritium because medical isotope production requires a modest number of neutrons.

- Lithium aluminate targets must be tested in FFTF to verify tritium target performance. Therefore, FFTF must be restarted before target performance is known.

- Flowing helium-3 should be considered as an alternate tritium target option.

- Key uncertainties exist in the restart schedule for FFTF that include the time to complete an EIS and the time (and authority) for restart licensing.

10. References

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11. Acronyms

ANMS	Advanced Nuclear and Medical Systems
APT	accelerator production of tritium
CLWR	commercial light water reactor
D&D	decontamination and decommissioning

DOE	Department of Energy
EA	environmental assessment
EIS	environmental impact statement
EPA	Environmental Protection Agency
FFTF	Fast Flux Test Facility
FFTF-SPO	Fast Flux Test Facility Standby Project Office
FMEF	Fuel Materials and Examination Facility
HEU	highly enriched uranium
IST	inherently safe target
JASON	review group
LWR	light water reactor
NEPA	National Environmental Policy Act
NRC	Nuclear Regulatory Commission
PHB	Putnam, Hayes and Bartlett, Inc.
PWR	pressurized water reactor
ROD	record of decision