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# Mixed-Oxide Fuel Fabrication Plant and Plutonium Disposition: Management and Policy Issues

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# Summary

The Mixed Oxide Fuel Fabrication Facility (MFFF) in South Carolina has been a key component of the current U.S. strategy for disposing of surplus weapons plutonium from the Cold War. Disposition of surplus plutonium is required by a 1998 agreement, amended in 2010, between the United States and the Russian Federation. Each country agreed to convert 34 metric tons of surplus weapons-grade plutonium to a form that could not be returned to nuclear weapons, to begin in 2018. Russia suspended its participation in the agreement in October 2016 due to what it called "hostile actions" by the United States. However, both countries appear to be continuing their plans for surplus plutonium disposition.

The U.S. disposition strategy called for the surplus plutonium, in oxide form, to be blended with uranium oxide to make mixed oxide (MOX) fuel for U.S. commercial nuclear reactors. The plutonium in MOX fuel would be mostly destroyed in the reactors by fission (splitting into other isotopes). At the same time, isotopes of plutonium undesirable for weapons would be created, along with highly radioactive fission products. As a result, after several years in a reactor, spent MOX fuel would have less total plutonium than when it was freshly loaded, and the remaining plutonium would be degraded for weapons purposes. Moreover, the fission products would make the material difficult to handle, in case of future attempts to use the plutonium.

Because of sharply rising cost estimates for the MOX project, the Obama Administration proposed to terminate the project in its FY2017 budget request. The Trump Administration in its FY2018 request also proposed replacing the MFF with the dilute and dispose option. Starting with the FY2015 budget request, the Administration proposed placing MFFF in "cold standby" and studying other plutonium disposition options. However, Congress authorized and appropriated $345 million for FY2015 to continue construction at a reduced level and required the Department of Energy (DOE) to procure an independent cost and schedule estimate for MFFF and alternative disposition approaches. Pending the results of those analyses, DOE requested $340 million for FY2016 to continue construction at about the FY2015 level. DOE's FY2017 budget proposed to instead pursue a dilute and dispose (D&D) program.

The federal plutonium disposition program is run by the National Nuclear Security Administration (NNSA), a semiautonomous agency of DOE. NNSA estimated in 2002 that MFFF would cost about $1 billion to design and build. DOE said in its budget justification for FY2014 that the MFFF contractor had estimated the project's total construction cost would rise to $7.78 billion, and that construction would not be completed until November 2019. DOE's FY2015 budget justification said the life-cycle cost estimate for the MOX program had risen to $30 billion.

Differing sharply from the U.S. MOX strategy, Russia is planning to use its BN-600 and BN-800 fast breeder reactors for plutonium disposition. According to the World Nuclear Association, the BN-800 started producing electricity in 2015, and the reactor is "capable of burning 1.7 metric tons of plutonium per year from dismantled weapons." The DOE FY2015 through FY2018 budget requests included no funds for support of the Russian plutonium disposition program.

The debate over U.S. plutonium disposition strategy raises several issues for Congress. The Administration asserts that the rising cost estimates for MFFF are unsustainable in the current budget environment and proposes a different disposal method. The effects of alternative disposal options on DOE's Savannah River Site in South Carolina, where MFFF is located, will also be an important element of the debate.

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# Introduction

With the end of the Cold War and breakup of the Soviet Union in the early 1990s, control of surplus nuclear weapons material became an urgent U.S. foreign policy goal. Particular U.S. concern focused on plutonium from Soviet nuclear warheads, which it was feared posed a major nuclear weapons proliferation risk. The United States supported a successful effort to consolidate the storage of Soviet nuclear weapons and materials in Russia, and then began negotiating reductions in weapons material stockpiles.

Congress has been closely involved in formulating U.S. policy on surplus plutonium disposition, as well as funding the necessary facilities, operations, and Russian assistance to implement the program. Because of sharply rising cost estimates for plutonium disposition facilities under construction in South Carolina, the Obama Administration proposed in its FY2017 budget request to end construction and pursue a "dilute and dispose" (D&D) option. The Trump Administration proposed the same strategy in its FY2018 budget request.

In September 1998, the United States and Russia each agreed to convert 34 metric tons of surplus weapons-grade plutonium to a form that could not be returned to nuclear weapons under the Plutonium Management and Disposition Agreement (PMDA). The agreement was designed to ease concerns about the possible theft or diversion of weapons-grade plutonium by nations or others seeking to develop their own nuclear weapons. According to the agreement, the parties could use two methods for disposing of the plutonium—they could either convert it to mixed oxide (MOX) fuel for nuclear power reactors or immobilize it and dispose of it in a way that would preclude its use in nuclear weapons. However, Russia had expressed little interest in the permanent immobilization and disposal of plutonium, or burning it in conventional reactors, preferring to use the material as fuel for its civilian fast reactor program. The United States initially intended to pursue both immobilization and MOX fuel for conventional reactors. However, after reviewing U.S. nonproliferation policies in 2001, the Bush Administration concluded that the dual approach would be too costly. Instead, it outlined a plan for the United States to convert almost all its surplus plutonium to MOX fuel.

The PMDA was amended with a Protocol which entered into force on July 13, 2011. The PMDA Protocol renewed the commitment of each side to dispose of 34 metric tons of weapons-grade plutonium. It also laid out conditions for Russian use of the plutonium as fast reactor fuel, including restrictions on breeding additional plutonium in fast reactors.[1] The two countries agreed to begin plutonium disposition in 2018. The United States pledged to pay $400 million to support the Russian plutonium disposition. The Russian government was to fund the remainder of the approximately $2.5 billion in estimated costs. The plutonium disposition program, including U.S. assistance for the Russian program, is administered by the National Nuclear Security Administration (NNSA), a semiautonomous agency of the Department of Energy (DOE).

A key component of the U.S. strategy for disposing of surplus weapons plutonium has been the Mixed Oxide Fuel Fabrication Facility (MFFF) at DOE's Savannah River Site in South Carolina. NNSA estimated in 2002 that MFFF would cost about $1 billion to design and build. That estimate had risen to $4.8 billion when the construction of MFFF began in 2007. According to DOE's FY2014 budget request, the MFFF contractor then estimated that the project's total construction cost would rise to $7.78 billion, and that construction would not be completed until

[1] 2000 Plutonium Management and Disposition Agreement as amended by the 2010 Protocol, Article III, http://fissilematerials.org/library/PMDA2010.pdf.

November 2019. DOE slowed construction during FY2013 and FY2014 while other disposition options were evaluated.

DOE's FY2015 budget justification said the total lifecycle cost of the MOX fuel program for plutonium disposition—including construction, operations, waste management, and facility decommissioning—had risen to $30 billion. Because of that increase, according to DOE, "the MOX fuel approach is not viable within the available resources." DOE planned to put MFFF and related facilities currently under construction in "cold standby," reducing funding for the U.S. plutonium disposition program from $560.3 million in FY2014 to $286 million in FY2015. DOE planned to "further analyze options to complete the plutonium disposition mission more efficiently."[2] Congress rejected the Administration's plan to put MFFF in "cold standby" in FY2015. The FY2015 National Defense Authorization Act (P.L. 113-29) and the FY2015 Consolidated and Further Continuing Appropriations Act (P.L. 113-235) each required DOE to conduct independent cost and schedule estimates for MFFF and analyze alternative disposition approaches. The two acts authorized and appropriated $345 million to continue MFFF construction at a reduced level from FY2014. DOE's FY2016 budget justification said that Aerospace Corporation had been contracted to carry out the required analyses, and, pending that decision, DOE requested $345 million for FY2016 to continue MFFF construction at the FY2015 level.[3]

The analyses of the MOX disposition program and the alternatives were concluded before submission of DOE's FY2017 budget request. "These analyses confirm that the MOX fuel approach will be significantly more expensive than anticipated and will require approximately $800 million to $1 billion annually for decades," according to the DOE budget justification. "As a result, beginning in FY 2017 the MFFF project will be terminated."[4] DOE proposed reducing funding for MFFF from $340.0 million to $270.0 million to develop a termination plan and begin implementing it. At the same time, DOE planned to begin developing a "detailed lifecycle baseline" for diluting the plutonium for disposal in a deep geologic repository. Congress approved $15 million for DOE planning activities for the dilute and dispose option, but it also appropriated $335 million to continue MFFF construction in FY2017, a 1.5% reduction from FY2016 (P.L. 115-31).[5]

In its FY2018 request to Congress, the Trump Administration supported the proposal to "terminate the MOX project and pursue the dilute and dispose strategy as an alternative." The FY2018 National Defense Authorization Act, enacted by Congress on November 16, 2017 (H.R. 2810), requires DOE to continue MFFF construction unless the Secretary of Energy certifies that an alternative plutonium disposal option would cost less than "approximately half" of the remaining costs of building and operating MFFF. In addition, the Secretary would have to commit to remove surplus plutonium from South Carolina and "ensure a sustainable future for the Savannah River Site." Full-year FY2018 appropriations for the federal government have not been enacted. An omnibus FY2018 appropriations bill passed by the House (H.R. 3354) would provide $340 million to continue MFFF construction in FY2018 and prohibit "the use of MOX funding to

[2] DOE, *FY 2015 Congressional Budget Request*, Vol. 1, March 2014, pp. 523, 525, 543, http://energy.gov/sites/prod/files/2014/03/f12/Volume%201%20NNSA.pdf.

[3] DOE, *FY 2016 Congressional Budget Request*, Vol. 1, February 2015, pp. 561-569, http://energy.gov/cfo/downloads/fy-2016-budget-justification.

[4] DOE, *FY 2017 Congressional Budget Justification*, Vol. 1, February 2016, p. 474, http://www.energy.gov/sites/prod/files/2016/02/f29/FY2017BudgetVolume1.pdf.

[5] Explanatory Statement, *Congressional Record*, May 3, 2017, p. H3753, https://www.congress.gov/crec/2017/05/03/CREC-2017-05-03-bk2.pdf.

terminate the project while the Congress is considering an alternative approach for disposing of these materials." The Senate Appropriations Committee's FY2018 Energy and Water Development Appropriations bill (S. 1609) accepted the Administration's request for $270 million to terminate MFFF construction and included $9 million for alternative plutonium disposal planning.

## Procedures for Changes to the Agreement

The proposals by the Obama and Trump Administrations to cancel the MOX fuel disposition path have led to questions about whether and how the Russian government would need to agree to such a change to the U.S. disposition pathway. The amendments made to Article 3 of the PMDA by the 2010 Protocol may have provided for more flexibility in adjusting the disposition paths chosen by each country in the future. Nevertheless, any future change still would be subject to a written agreement by both parties.

Article 3.1 states that the parties may agree "in writing" if they choose "other measures" of disposition: "Disposition shall be by irradiation of disposition plutonium as fuel in nuclear reactors or any other methods that may be agreed by the Parties in writing." Article 12 of the PMDA established a Joint Consultative Commission (JCC) to address implementation issues, and the JCC is the forum where any changes would be decided. The Department of State chairs the JCC on the U.S. side and DOE participates, in coordination with the White House. The Russian Atomic Energy Agency (ROSATOM) and the Russian Ministry of Foreign Affairs participate on the Russian side.

U.S. officials appear to interpret the proposed change to a dilute and dispose method as falling under the Article 3.1 category of "any other methods." After a decision has been made about how to proceed with the U.S. program, the U.S. side would bring its proposal, and interpretation of whether it would require an amendment, to the Joint Consultative Commission. The Russian government would then evaluate the proposed change and would render its own interpretation of whether it would require an amendment. If the Russian side determines that a change falls within the scope of the current agreement, then an exchange of diplomatic notes or other written agreement would suffice. If the Russian government determines that the new proposed disposition path does not fall within the agreement's parameters, then it is possible that a new protocol to the PMDA would need to be negotiated.

At a hearing held by the Subcommittee on Strategic Forces of the House Committee on Armed Services on October 7, 2015, Lieutenant General Frank G. Klotz, Administrator of the National Nuclear Security Administration (NNSA), testified that Secretary of Energy Ernest Moniz had discussed this issue recently with Rosatom head Sergei Kiriyenko.[6] Lieutenant General Klotz said that in that conversation, the Russians recognized that the United States had been flexible when Russia wanted to change its disposal method in 2010, and said, "When you have a plan, come back to us and we'll sit down and negotiate."

In response to the U.S. debate, Russian officials, including President Putin, have claimed that the United States is not living up to the agreement, and have implied in press interviews that the dilute and dispose method would not fall under the terms of the agreement and would therefore require Russian approval. Rosatom head Sergei Kiriyenko claimed that the United States may wish to use the plutonium for weapons in the future. However, some U.S. experts counter that the

[6] U.S. Congress, House Committee on Armed Services, Subcommittee on Strategic Forces, *Plutonium Disposition and the MOX Project*, 114th Cong., 1st sess., October 7, 2015.

dilute and dispose method could irreversibly alter the plutonium depending on how it is done, and therefore would be acceptable for meeting nonproliferation goals.[7]

Senators Graham and Scott of South Carolina, who support the current MOX disposition path, have argued that Russian agreement may be needed before the U.S. disposition plan is changed, and this could be difficult to achieve.[8] Some reports had been skeptical of the Russian government's flexibility while others are optimistic. The current poor political climate between the United States and Russia was another factor to consider. DOE's Plutonium Disposition Red Team, established in June 2015, stated in its final report, "The combination of evolving international circumstances and the fact that the U.S. has already accommodated a Russian national interest in a previous PMDA modification causes the Red Team to believe that the federal government has a reasonable position with which to enter PMDA negotiations."[9] Lieutenant General Klotz in his October 2015 testimony stated that "there are a lot of other political, economic, strategic variables that get injected into any discussion with them [the Russians] on any issue in this area."

Indeed, on October 3, 2016, the Russian president issued an executive order that suspends Russian participation in the PMDA due to U.S. "hostile actions" toward Russia and the lack of assurance that the United States will fulfill its plutonium disposition obligations.[10] The Russian executive order includes a list of conditions that the United States should meet before Russia would return to the agreement, such as changes to NATO force structure and compensation for economic sanctions. The Russian foreign minister's statement said, "Our decision is a signal to Washington that it cannot use the language of force, sanctions and ultimatums with Russia while continuing to selectively cooperate with our country only when it benefits the U.S." The statement also says that Russia will keep the 34 metric tons of plutonium out of weapons use.[11]

# Russian Program

Russia promised after suspending its participation in the PMDA not to use its 34 metric tons of surplus plutonium for weapons. Russia's plutonium disposition program is based on using surplus plutonium as fuel for fast reactors. Because fast reactors can be configured to "breed" more plutonium (from uranium) than they consume, the PMDA prohibits such "breeding" until Russia's plutonium stockpiles have been reduced by 34 metric tons. It remains uncertain whether Russia would continue refraining from breeding plutonium in its fast reactors.

[7] "Russia Raises Concerns About Changes in U.S. Plutonium Disposition Plan," International Panel on Fissile Materials blog, April 2016, http://fissilematerials.org/blog/2016/04/dealing_with_russias_conc.html, and "Dealing with Russia's Concerns about the Isotopics of Disposed Plutonium," Ibid., http://fissilematerials.org/blog/2016/04/dealing_with_russias_conc.html.

[8] "South Carolina Senators Note 'Insurmountable' Problems with DOE Plan to Scrap MOX Program," April 11, 2016, http://www.lgraham.senate.gov/public/index.cfm/press-releases?ID=8B9476FB-CAB8-42AF-8F69-5EBF91D9C9EC.

[9] U.S. Department of Energy, Oak Ridge National Laboratory, *Final Report of the Plutonium Disposition Red Team*, August 13, 2015, p. xi, https://nnsa.energy.gov/sites/default/files/nnsa/inlinefiles/Pu-Disposition-Red-Team-Report-081315vFinal-SM.pdf.

[10] CRS Insight IN10594, *Recent Developments in U.S.-Russian Nonproliferation Cooperation*, by (name redacted) and (name redacted)

[11] Alissa Tabirian, "U.S.-Russia Plutonium Disposition Deal Collapes Under Weight of MOX Battle," *Nuclear Security & Deterrence Monitor*, Vol. 20, No. 39, October 7, 2016.

Russia plans to use its BN-600 and BN-800[12] fast neutron reactors for plutonium disposition. The BN-600 began operating in 1980 and is currently scheduled to shut down in 2025. The BN-800 had initial criticality in mid-2014 and is being used as a demonstration unit to prepare for the larger BN-1200 design planned for the 2030s. The BN-600 and the BN-800 are reportedly not configured to breed plutonium. Because of a lack of plutonium fuel, 75% of the BN-800's initial core consisted of enriched uranium fuel, but it is supposed to switch to 100% MOX fuel in 2019.[13] At the end of 2014, Russia was reported to hold 52.8 tons of separated civilian plutonium.[14]

The United States and Russia, along with the International Atomic Energy Agency (IAEA), were negotiating an agreement on verification of disposition of the designated 34 metric tons of plutonium in each country. The IAEA would have a role in verifying the quantities of weapons-grade plutonium converted to fuel in both countries. The United States and Russia were also negotiating a "Milestones" plan, which would outline how the U.S. assistance to the Russian plutonium disposition effort would be spent. Negotiations related to the plutonium disposition agreement are led by the Department of State's Bureau of International Security and Nonproliferation together with NNSA. These discussions have been on hold since the Russian government announced it was suspending its participation.

The Russian Surplus Fissile Materials Disposition program, run by NNSA, is to provide $400 million to help Russia dispose of its surplus weapons plutonium.[15] However, no funds have been requested since FY2013. As shown in **Table 1**, DOE requested $10.174 million for the Russian plutonium disposition program for FY2012. The Senate Appropriations Committee recommended $1 million for FY2012, and that level was enacted. The Senate committee included this reasoning in its report (S.Rept. 112-75):

> *Russian Surplus Materials Disposition.*—The Committee recommends $1,000,000, a reduction of $9,174,000. No funding shall be used to support research and development of the Gas Turbine-Modular Helium Reactor in Russia. The Committee understands that the United States committed $400,000,000, subject to future appropriations, to help Russia dispose of 34 metric tons of excess weapon-grade plutonium, but the Committee will not provide funding for this effort until NNSA can explain how the United States would spend the $400,000,000 and the milestones that Russia must meet before the United States releases any of those funds.

The FY2013 budget justification said that the requested funds would be used to "provide technical support to the DOE in meeting U.S. obligations to support disposition of weapon-grade plutonium in Russia; provide U.S. technical oversight of work in Russia associated with the disposition of surplus Russian weapon-grade plutonium in the BN-600 and BN-800 fast reactors; and support the implementation of IAEA verification activities in both the U.S. and Russia."

The FY2014-FY2018 budget requests included no funds for the Russian plutonium disposition program. NNSA plans to use prior-year funds to support these activities in FY2015. The $400 million in U.S. assistance was to be paid to Russia after FY2018, when plutonium disposition was

[12] The reactor's rated thermal power is 2,100 megawatts (MWt), generating 864 megawatts of electricity (MWe), http://www.world-nuclear.org/info/Current-and-Future-Generation/Fast-Neutron-Reactors/.

[13] World Nuclear Association, "Nuclear Power in Russia," November 2017, http://www.world-nuclear.org/information-library/country-profiles/countries-o-s/russia-nuclear-power.aspx.

[14] International Panel on Fissile Materials, "Fissile Material Stocks," July 29, 2016, http://fissilematerials.org/.

[15] This is a sub-program of the NNSA's Defense Nuclear Nonproliferation budget. In the FY2016 request, this program is in the Material Disposition subaccount under the Office of Material Management and Minimization. It was formerly in the Fissile Material Disposition account.

to begin. The Russian Federation is to fund the remaining costs of roughly $2 billion, including through possible contributions from other international donors.

**Table 1. Funding for the NNSA Russian Plutonium Disposition Program**

(in $ thousands)

| | FY2012 | FY2013 | FY2014 | FY2015 | FY2016 | FY2017 | FY2018 |
|---|---|---|---|---|---|---|---|
| DOE Request | 10,174 | 3,788 | 0 | 0 | 0 | 0 | 0 |
| Senate Appropriation | 1,000 | 3,788 | n/a | n/a | n/a | n/a | n/a |
| House Appropriation | 10,174 | 0 | n/a | n/a | n/a | n/a | n/a |
| Enacted | 1,000 | 922 | 0 | 0 | 0 | 0 | n/a |

**Source:** Department of Energy Congressional Budget Justifications; S.Rept. 112-164, H.Rept. 112-462.

**Notes:** All of the above funds are to be spent in the United States. Appropriations for FY2013, FY2014, and FY2015 are to be supported from prior-year uncosted balances. n/a: not available or not specified. No funds were requested for FY2018.

# U.S. Program

The U.S. Plutonium Disposition Program is also conducted by NNSA. The program had long planned to blend surplus plutonium from the U.S. nuclear weapons program with uranium to make MOX fuel for commercial nuclear reactors. After fueling a reactor for several years, the plutonium in MOX fuel would be mostly destroyed by fission, and remaining plutonium would be isotopically less desirable for weapons use. In addition, the used MOX fuel would contain highly radioactive fission products that would provide an obstacle to diversion for weapons purposes.

Initially, the U.S. program planned to dispose of 34 metric tons of surplus weapons plutonium in this manner—"enough for thousands of nuclear weapons," according to NNSA.[16] NNSA subsequently proposed making MOX fuel from an additional 7.1 metric tons of plutonium from retired nuclear weapons pits and another 6 metric tons of weapons-useable plutonium from other sources (non-pit plutonium), for a total of 47.1 metric tons.[17] DOE announced on April 5, 2016, that it would dispose of the 6 metric tons of non-pit plutonium by dilution and disposal at the Waste Isolation Pilot Plant (WIPP) in New Mexico.[18]

The first step in the plutonium disposition process is to disassemble the plutonium "pits," or cores, from nuclear weapons or other sources. Then the plutonium metal must be converted to plutonium oxide to be useable as nuclear reactor fuel. NNSA announced in 2012 that it had produced 442 kilograms of plutonium oxide at Los Alamos National Laboratory in New Mexico and had begun plutonium oxide production at the Savannah River Site.[19] One hundred kilograms

[16] NNSA, "Plutonium Disposition," http://nnsa.energy.gov/aboutus/ourprograms/nonproliferation/programoffices/fissilematerialsdisposition/plutoniumdisposition.

[17] NNSA, "Surplus Plutonium Disposition Supplemental Environmental Impact Statement," http://www.nnsa.energy.gov/aboutus/ouroperations/generalcounsel/nepaoverview/nepa/spdsupplementaleis.

[18] NNSA, "Surplus Plutonium Disposition," *Federal Register*, April 5, 2016, p. 19588, https://www.gpo.gov/fdsys/pkg/FR-2016-04-05/pdf/2016-07738.pdf.

[19] NNSA, "NNSA Completes Milestones for Initial Steps in Plutonium Disposition," press release, November 16, 2012, (continued...)

was to be converted at Los Alamos and 250 kilograms at Savannah River during FY2016, according to DOE's FY2016 budget justification.

Under the MOX disposition approach, the plutonium oxide produced at Los Alamos and Savannah River would be blended with uranium, placed in fuel rods, and connected into fuel assemblies for standard commercial power reactors (light water reactors). This fuel fabrication process would take place at the Mixed Oxide Fuel Fabrication Facility. After receiving a construction permit from the Nuclear Regulatory Commission (NRC) in 2005, MFFF construction began in August 2007.[20] MFFF is designed to convert up to 3.5 metric tons of plutonium per year into MOX fuel and would operate for about 20 years.[21]

Getting utilities to commit to loading MOX fuel into their reactors has been a major problem for the plutonium disposition program. Although MOX fuel has been routinely used in Europe, it has enough differences from the conventional uranium fuel currently used by U.S. nuclear plants that it would require separate NRC licensing and special handling. The use of MOX fuel would also probably create public controversy. Two utilities that had previously planned to use the MOX fuel, Dominion and Duke, are no longer involved. The Tennessee Valley Authority (TVA) subsequently entered into an agreement with DOE "to evaluate the use of mixed oxide fuel in reactors at TVA's Browns Ferry and Sequoyah Nuclear Plants." However, TVA has not yet committed to using MOX fuel, or indicated which of its reactors would be used.[22] The selection of reactors is important, because MOX fuel assemblies must be fabricated to fit particular reactors. Especially significant are the design differences between fuel assemblies for boiling water reactors, such as Browns Ferry, and pressurized water reactors, such as Sequoyah.

## Management and Cost

NNSA's initial February 2002 report to Congress for the MOX plutonium disposition program estimated construction of MFFF would begin in FY2004 and cost about $1 billion to design and build. By July 2005, the design and construction cost estimate had risen to $3.5 billion, according to the DOE Office of Inspector General (OIG). OIG identified numerous management weaknesses that contributed to the rising costs. However, NNSA contended that much of the cost increase resulted from changes in project scope, such as increases in up-front design work, and delays in Russia over liability issues, which caused parallel delays in the U.S. program.[23]

By the time MFFF construction began in 2007, the construction cost estimate had risen to $4.8 billion. About $100 million of that cost increase was caused by congressional funding holdups, according to NNSA.[24] For example, the Bush Administration requested $653.1 million for fissile

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http://nnsa.energy.gov/mediaroom/pressreleases/oxideprod111612. A somewhat smaller amount of plutonium metal would be used as feed material for the plutonium oxide.

[20] NNSA, "NNSA's MOX Fuel Fabrication Facility and U.S. Plutonium Disposition Program," fact sheet, February 14, 2011, http://www.nnsa.energy.gov/mediaroom/factsheets/mox.

[21] Shaw Areva MOX Services, "MOX Fuel Fabrication Facility Construction," http://www.moxproject.com/construction.

[22] NNSA, "Surplus Plutonium Disposition Supplemental Environmental Impact Statement," op. cit.

[23] DOE Office of Inspector General, *Audit Report: Status of the Mixed Oxide Fuel Fabrication Facility*, DOE/IG-0713, December 2005, http://energy.gov/sites/prod/files/igprod/documents/CalendarYear2005/ig-0713.pdf.

[24] Daniel Horner, "Hill-Imposed Delay in MOX Program Costing $115 Million, DOE Says," *NuclearFuel*, April 23, 2007.

materials disposition in FY2006, while Congress appropriated $473.5 million. But for FY2004, in contrast, Congress approved the full request of $656.5 million.

Congress required in 2002 that MFFF produce at least 1 metric ton of MOX fuel by the end of 2008 and complete the then-planned program of 34 metric tons of plutonium conversion by January 1, 2019 (P.L. 107-314, Section 3182). Section 3116 of the National Defense Authorization Act for FY2013 (P.L. 112-239) extended the deadline for starting MOX production to January 1, 2014 (50 U.S.C. 2566).

DOE announced a major reevaluation of the plutonium disposition program in its FY2014 budget submission to Congress. According to the budget request, the MFFF contractor then estimated that the project's total construction cost would rise from $4.8 billion to $7.78 billion, and that construction would not be completed until November 2019. Moreover, MFFF's operating costs were estimated at $543 million per year, up from $100.5 million estimated in 2002.[25] The Government Accountability Office (GAO) in a February 2014 report said NNSA had provided several major reasons for the most recent cost increases, including DOE's approval of a cost and schedule estimate in 2007 when the overall design was only about 58% complete. Other problems included higher-than-anticipated equipment installation costs, difficulties in finding qualified suppliers, high staff turnover, and further changes in project scope.[26] GAO had found in 2010 that MFFF had experienced consistent delays during the previous two years, partly because of the installation of nearly 4,000 tons of substandard reinforcing bars.[27]

Because of the cost increases, the Obama Administration slowed the project in FY2013 and FY2014 to consider "alternative plutonium disposition strategies." A Plutonium Disposition Working Group established by the Secretary of Energy began comparing the MOX option with plutonium destruction in fast neutron reactors and non-reactor disposal options, such as blending and spiking with highly radioactive materials.

DOE's FY2015 budget justification said the total lifecycle cost of the MOX disposition option had risen to $30 billion—from $24.2 billion in April 2013.[28] "Due to these increases, the MOX fuel approach is not viable within available resources," according to the DOE justification. "As a result, the MOX project will be placed in cold stand-by while we further study implementation and costs of options to complete the plutonium disposition mission more efficiently."

The Plutonium Disposition Working Group issued its report in April 2014, providing life-cycle cost and schedule estimates for the following options:[29]

- *Irradiation of MOX fuel in light water reactors (current program):* $31 billion including costs already expended (sunk costs), estimated completion by 2043;
- *Irradiation in fast (advanced) reactors:* $58 billion including sunk costs, estimated completion by 2075;

[25] DOE, *FY 2007 Congressional Budget*, Vol. 1, p. 558, http://energy.gov/sites/prod/files/FY07Volume1.pdf.

[26] GAO, Plutonium Disposition Program: DOE Needs to Analyze the Root Causes of Cost Increases and Develop Better Cost Estimates, GAO-14-231, February 2014, http://www.gao.gov/assets/670/660927.pdf.

[27] GAO, "Nuclear Nonproliferation: DOE Needs to Address Uncertainties with and Strengthen Independent Safety Oversight of Its Plutonium Disposition Program," GAO-10-378, March 2010, p. 9, http://www.gao.gov/assets/310/302279.pdf.

[28] GAO, 2014, op. cit.

[29] DOE, Plutonium Disposition Working Group, *Analysis of Surplus Weapon-Grade Plutonium Disposition Options*, April 2014, http://nnsa.energy.gov/aboutus/ourprograms/dnn/fmd/plutonium/pudispositionoptions.

- *Immobilization with high level (highly radioactive) waste:* $36 billion including sunk costs, estimated completion by 2060;
- *Downblending and disposal (potentially in the existing Waste Isolation Pilot Plant repository in New Mexico):* $16 billion including sunk costs, estimated completion by 2046; and
- *Deep borehole disposal:* costs unknown, estimated completion by 2051.

Under the Administration's FY2015 request, construction funding for MFFF would have been cut from $402.7 million (including reprogrammed funds) to $196.0 million as the facility was placed into "cold standby," or indefinite suspension. Contract personnel at the MOX project declined from 2,271 at the beginning of April 2013 to 1,523 by the end of December 2013, according to the budget justification.[30]

However, Congress rejected the Administration's plan to put MFFF in "cold standby." Instead, Congress appropriated $345 million to continue MFFF construction at a reduced level from FY2014 and required DOE within 120 days to conduct an "independently verified lifecycle cost estimate for the option to complete construction and operate the MOX facility and the option to downblend and dispose of the material in a repository." DOE requested $345 million for FY2016 to continue MFFF construction at the FY2015 level, pending a decision based on the new study. The MFFF project currently has about 1,700 workers, according to NNSA.[31]

After conducting the required studies, DOE concluded that the dilute and dispose option would be significantly faster and less expensive than the MOX fuel option. As a result, DOE proposed to halt further construction of MFFF in FY2017, requesting reduced funding from $340.0 million in FY2016 to $270.0 million. "The Department of Energy will request that the MFFF prime contractor determine activities required to place the facility and project in a safe and secure state, and wind down construction, design, support, and procurement efforts as quickly as possible so that termination can be done efficiently and cost effectively," according to DOE's FY2017 budget justification. About 500 craft personnel and 750 salaried personnel would be released.[32]

DOE also announced plans to conduct pre-conceptual design work during FY2016 and FY2017 for diluting surplus plutonium and disposing of it in a deep geologic repository, such as WIPP. DOE plans to begin developing a "detailed lifecycle baseline" for the dilute and dispose option in FY2017, including storage of surplus plutonium pits at the Pantex Plant in Texas, pit disassembly and oxide conversion at Los Alamos National Laboratory, and oxide conversion at the Savannah River Site.[33]

As discussed above, the Trump Administration's FY2018 budget request also proposed the dilute and dispose option, which was largely endorsed by the FY2018 National Defense Authorization Act. However, full-year FY2018 appropriations have yet to be enacted.

[30] DOE, *FY 2015 Congressional Budget Request*, op. cit.

[31] Pete Hanlon, NNSA Assistant Deputy Administrator for Material Management and Minimization, meeting with CRS analysts, February 20, 2015.

[32] DOE, *FY 2017 Congressional Budget Justification*, vol. 1, February 2016, p. 540, http://www.energy.gov/sites/prod/files/2016/02/f29/FY2017BudgetVolume1.pdf.

[33] Ibid., p. 474.

# MOX and Nonproliferation

The extent to which the plutonium disposition programs help or harm nonproliferation goals has been debated since their inception. Some analysts have criticized the MOX option on the principle of opposing any use of plutonium in power generation. From this point of view, nations that do not possess nuclear weapons could use a plutonium-based fuel cycle for power reactors as a cover for developing nuclear weapons. If weapons states such as Russia and the United States used plutonium for power generation, according to this argument, it would be more difficult to persuade non-weapons states not to do so.

Another issue has been whether the Russian disposition program that will make fuel for fast reactors will result in more or less plutonium in the long run. Fast reactors can "breed" or "burn" plutonium as a net output. The reactor acts as a breeder (producing more plutonium than it destroys) if the core includes sufficient amounts of uranium-238, whose nuclei can absorb a neutron and then decay into the fissile isotope plutonium-239. Without uranium-238, the reactor would consume the original plutonium fuel without producing new plutonium in its place. The potential for breeding new plutonium was a major concern of the United States in negotiations over the PMDA Protocol and resulted in restrictions on producing new plutonium in the fast reactors using this material. The verification agreement negotiations include discussions of how to technically verify this. In the 2010 Protocol, Russia agreed to restrictions on the reactors that are intended to prevent the creation of more plutonium than is destroyed.[34]

An additional criticism of the program from a nonproliferation perspective is that the high cost required to date for the plutonium disposition program in the United States is funded out of the Defense Nuclear Nonproliferation budget. There is concern that money is being taken away from other programs which some consider to have a more direct impact on preventing the proliferation of weapons-usable nuclear materials. Programs cited include the Second Line of Defense border security program or the Global Threat Reduction Initiative.[35] Non-governmental nonproliferation experts have made recent public statements.[36] For example, Joe Cirincione of the Ploughshares Fund has said, "funding for the plutonium fuel facility falls within the nuclear nonproliferation budget. That means that every dollar spent on unnecessary programs like MOX is one dollar less for vital nonproliferation programs that keep nuclear material and technology out of the hands of terrorists."[37] In light of this concern, in June 2012 the House passed an amendment to the FY2013 Energy and Water Appropriations bill proposed by Representative Fortenberry to reprogram money from the U.S. MOX program to the Global Threat Reduction Initiative.[38] The provision ultimately was not enacted, however.

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[34] Governments of the United States and the Russian Federation, 2000 Plutonium Management and Disposition Agreement as Amended by the 2010 Protocol, Article III.3, http://fissilematerials.org/library/PMDA2010.pdf.

[35] In FY2016, NNSA divided the Global Threat Reduction Initiative between Material Management and Minimization and Global Material Security.

[36] Reif Kingston, "New Obama Budget Slashes Nonproliferation," The Center for Arms Control and Non-Proliferation, March 6, 2014, http://armscontrolcenter.org/issues/nuclearterrorism/articles/new_obama_budget_slashes_nonproliferation/.

[37] Joe Cirincione, "The Federal Government's $10 Billion Plutonium Boondoggle," *The Atlantic*, April 27, 2012, http://www.theatlantic.com/politics/archive/2012/04/the-federal-governments-10-billion-plutonium-boondoggle/256470/.

[38] "House Accepts Fortenberry Measure to Strengthen Nuclear Security Efforts," Press Release, Office of Representative Jeff Fortenberry, June 6, 2012, http://fortenberry.house.gov/index.php?option=com_content&view=article&id=3662:house-accepts-fortenberry-measure-to-strengthen-nuclear-security-efforts&catid=41:press-releases&Itemid=2; "House Bill Shifts Money from MOX Plant to Nuclear Security," *Global Security Newswire*, June 7, 2012.

Other observers, including within the executive branch, note that the purpose of this program is nonproliferation—rendering weapons-grade plutonium unusable for nuclear weapons on the basis of mutual verification. The American Nuclear Society has come out strongly in favor of the program for nonproliferation reasons.[39]

# Issues for Congress

Recent public debate surrounding the U.S. plutonium disposition program has centered on the budget trade-offs of funding the U.S. plutonium disposition program in light of sequestration and other funding limitations. Local concerns have focused on potential economic losses around the MFFF project and the possibility that plutonium brought to Savannah River for use as nuclear fuel will end up being stored there indefinitely. National concerns had been raised that a halt or serious delay to the U.S. program would cause the Russians to reconsider their obligations to dispose of their excess weapons plutonium. It is not yet clear how or whether the Russian decision to suspend its cooperation in early October 2016 may affect U.S. implementation.

Due to the cost and management challenges of the MOX program, alternatives to MOX fuel production to fulfill the U.S.-Russian PMDA have been proposed for many years.[40] Supporters of the MOX option, however, counter that sunk costs in the current program would make pursuing an alternative path more expensive in the long run.[41]

In testimony before Congress, Obama Administration officials reiterated their commitment to the PMDA agreement with Russia.[42] The FY2014 and FY2015 DOE budget justifications stated that "NNSA remains committed to the plutonium disposition mission." However, as noted above, the Obama Administration switched to the dilute-and-dispose option for achieving that mission,[43] and the Trump Administration has adopted the same policy. According to the 2010 Protocol amending the PMDA, the United States would have to obtain written agreement with Russia to implement any alternative to irradiating plutonium in nuclear reactors.[44]

In its report on the National Defense Authorization Act for FY2014 (H.R. 1960, H.Rept. 113-102), the House Committee on Armed Services expressed concern about MFFF's "continuing escalating costs" but suggested that the Administration's proposed budget cuts "may not actually reduce costs to the taxpayer and will likely delay the disposition of 34 metric tons of weapons grade plutonium." The committee directed NNSA to study potential cost savings, consider adding international partners to the program, and study "the potential for achieving greater economic efficiencies by designating additional supplies of surplus plutonium for disposition through the

[39] American Nuclear Society, Position Statement 47, http://www.new.ans.org/pi/ps/docs/ps47.pdf.

[40] Frank von Hippel, Rodney Ewing, Richard Garwin, Alison MacFarlane, "Time to Bury Plutonium," *Nature*, May 10, 2012. For DOE's analyzed MOX alternatives, see *Draft Surplus Plutonium Disposition Supplemental Environmental Impact Statement*, summary, DOE/EIS-0283-S2, July 2012, http://nnsa.energy.gov/sites/default/files/nnsa/07-12-inlinefiles/Summary.pdf.

[41] http://us.arevablog.com/2013/02/19/answers-to-questions-about-funding-mox-project-budget/.

[42] House Appropriations Subcommittee on Energy and Water Development Hearing on the Proposed Fiscal 2014 Appropriations for the Energy Department's Nuclear Nonproliferation and Naval Reactor Programs and the National Nuclear Security Administration, February 26, 2013.

[43] DOE, *FY 2014 Congressional Budget Request*, Vol. 1, April 2013, p. DN-119, http://energy.gov/sites/prod/files/2013/04/f0/Volume1.pdf.

[44] 2000 Plutonium Management and Disposition Agreement as amended by the 2010 Protocol, Article III, http://fissilematerials.org/library/PMDA2010.pdf.

MOX facility." However, the bill as approved by the committee retained the Administration's proposed construction funding cut.

The Senate Armed Services Committee approved its version of the FY2014 defense authorization measure (S. 1034) on June 14, 2013. The committee voted to boost authorized funding for surplus nuclear materials disposition by $80 million over the Administration request.[45] Congress appropriated $526.1 million for Fissile Materials Disposition for FY2014, a cut of $136.7 million from the FY2013 level. However, the FY2014 appropriation was bolstered by a $59.2 million reprogramming from the International Material Protection and Cooperation account, according to DOE's FY2015 justification.

The State of South Carolina filed a lawsuit on March 18, 2014, to block DOE from placing MFFF in cold standby and to require that construction continue in FY2014. The suit maintained that the Bob Stump National Defense Authorization Act for Fiscal Year 2003 (P.L. 107-314) "was enacted to codify the commitments of the United States and DOE to the State of South Carolina that while plutonium may be placed in South Carolina, such placement was not final disposition for long-term storage of plutonium in the State, but rather a temporary storage to implement the disposition method of MOX processing in the MOX Facility."[46]

Some South Carolina lawmakers and officials have also stressed that South Carolina agreed to accept surplus plutonium from other weapons complex facilities with the understanding that it would be removed under a definite schedule. Plutonium that is made into MOX fuel, they point out, would be shipped off-site to commercial nuclear power plants, while alternatives such as immobilization in glass would provide no clear path for removal, given the current lack of a federal high-level waste central storage facility or underground repository.[47] Similar schedule uncertainty could be associated with the disposal of diluted plutonium at WIPP, because of legal and regulatory requirements and opposition from environmental groups.[48]

Section 3181 of the Bob Stump Defense Authorization (50 U.S.C. 2566) would penalize DOE if it misses various MOX fuel fabrication deadlines. As amended by Section 3116 of the National Defense Authorization Act for 2013 (P.L. 112-239), which delayed the previous deadlines by two years, the act requires that at least one ton of MOX fuel be produced each year, starting in 2014, or plutonium transfers into the state must be halted. If plutonium brought into the state since 2002 is not processed into MOX fuel by 2022, DOE must pay the state up to $100 million per year until it is removed.

DOE said in its FY2015 budget justification that it would not meet the 2014 MOX production deadline in P.L. 112-239. In light of the act's requirements, DOE said that it had "suspended any further transfers of defense plutonium and defense plutonium materials to be processed at the MOX facility in the State of South Carolina." DOE also said that it "will submit a report to Congress on options for removing an amount of defense plutonium or defense plutonium

[45] Senate Committee on Armed Services, "Senate Committee on Armed Services Completes Markup of the National Defense Authorization Act for Fiscal Year 2014," June 14, 2013, http://www.armed-services.senate.gov/press/releases/upload/SASC_NDAA_061413.pdf.

[46] *State of South Carolina v. United States Department of Energy*, United States District Court, District of South Carolina, Aiken Division, March 18, 2014, http://2hsvz0l74ah31vgcm16peuy12tz.wpengine.netdna-cdn.com/wp-content/uploads/2014/03/MOX-complain-3.18.2014-00269474xD2C78.pdf.

[47] Rob Pavey, "Sen. Lindsey Graham Says Reducing MOX Costs Could Save the Project," *Augusta Chronicle*, April 25, 2013, http://chronicle.augusta.com/news/government/2013-04-25/sen-lindsey-graham-says-reducing-mox-costs-could-save-project.

[48] Nuclear Watch New Mexico, "Stand Against the Rush to Reopen and Unsafe WIPP," March 23, 2016, http://nukewatch.org/importantdocs/resources/Stand_Against_Rush_To_Re-Open_Unsafe_WIPP.pdf.

materials from the State of South Carolina equal to the amount of defense plutonium or defense plutonium materials transferred to the State of South Carolina after April 15, 2002.

## Table 2. Defense Nuclear Nonproliferation Appropriations FY2007-FY2016 and FY2017 Request

(in $ thousands)

| | FY07 | FY08 | FY09 | FY10 | FY11 | FY12 | FY13 | FY14 Enacted | FY14 Repro-gram[a] | FY15 | FY16 | FY17 request |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Fissile Materials Disposition** | 470,062 | 66,235 | 41,774 | 701,900 | 802,198 | 685,386 | 663,754 | 526,057 | 585,300 | 430,000 | 426,584 | 413,833 |
| **U.S. Surplus Materials Disposition** | 470,062 | 66,235 | 40,774 | 700,900 | 802,173 | 684,386 | 662,832 | 526,057 | 585,300 | 311,125 | 86,584 | 143,833 |
| U.S. Pu Disposition | 57,415 | 0 | 0 | 91,659 | 200,400 | 205,632 | 189,480 | 157,557 | 157,557 | 60,000 | 54,504 | 107,833 |
| U.S. Uranium Disposition | 86,898 | 66,235 | 39,274 | 34,691 | 25,985 | 26,000 | 23,958 | 25,000 | 25,000 | 25,000 | 31,080 | 35,000 |
| Supporting Activities | 14,960 | 0 | 1,500 | 312 | 0 | 0 | 0 | 0 | 0 | 0 | 1,000 | 1,000 |
| Construct. | 310,789 | 0 | 0 | 574,238 | 575,788 | 452,754 | 449,394 | 343,500 | 402,743 | 345.000 | | |
| *MOX Fuel Fab* | 262,500 | 0 | 0 | 504,238 | 501.788 | 435,172 | 400,990 | 343,500 | 402,743 | 345,000 | 340,000 | 270,000 |
| *Pit Dis.* | 32,789 | 0 | 0 | 0 | 17.000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Waste Solid.* | 15,500 | 0 | 0 | 70,000 | 57.000 | 17,582 | 48,404 | 0 | 0 | 0 | 0 | 0 |
| **Russian Materials Disposition** | 0 | 0 | 1,000 | 1,000 | 25 | 1,000 | 922 | 0 | 0 | 0 | 0 | 0 |

**Source:** CRS-compiled information from DOE annual budget requests to Congress, H.Rept. 112-118, and S.Rept. 112-75.

a. Reflects a reprogramming of $59,242,760 from FY2013 International Material Protection and Cooperation funding to Fissile Material Disposition in FY2014.

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