THE NASA PLUM BROOK REACTOR FACILITY DECOMMISSIONING: STATUS AND LESSONS LEARNED

K. M. Peecook
NASA Glenn Research Center

ABSTRACT

The NASA Plum Brook Reactor Facility is currently being decommissioned. This 60 MW test reactor operated from 1961 to 1973, at which time it was shut down, all fuel was shipped offsite, and the balance of plant was placed in safe dry storage until 2001, when pre-decommissioning efforts were begun. Full decommissioning efforts began in 2002, and the project is on track to make its goal of NRC license termination by the end of 2007. This paper is intended to give a brief history of the plant, describe the current status of the decommissioning activities, and provide the major lessons learned so far.

INTRODUCTION

The National Aeronautics and Space Administration’s (NASA) Glenn Research Center’s (GRC) Plum Brook Reactor Facility (PBRF) consisted of a main 60 MW pressurized water reactor (NRC license # TR-3), a 100 KW pool type Mock-Up Reactor (NRC license # R-93), seven hot cells, and assorted laboratory and support buildings. See Figure 1, an aerial view of the facility. The reactor site was located on the northern edge of what would eventually become the 26 square kilometers Plum Brook Station. It was designed to provide material and fuel testing capability for the nuclear aircraft program, and construction began in 1958.

Fig. 1. NASA’s Plum Brook Reactor facility – circa 1987

The future of the facility looked uncertain when in 1961, just months before initial criticality, the nuclear aircraft program was cancelled by President Kennedy. Fortunately the emergence of a nuclear rocket program shortly thereafter gave the plant a new objective. A cutaway view of the reactor tank and core is shown in Figure 2. Full power operations totaling 98,000 MW-days were conducted from 1963 to 1973, when the facility was shut down due to NASA budget cuts and the lack of continued support for the nuclear rocket program. The reactor fuel was sent off site for reprocessing, and the rest of the facility was placed in a safe, dry storage condition over a six month period. It remained in this condition for 29 years.

PBRF's last "possess-but-not-operate" license expired in 1997. NASA's original intent in the mid 90's was to request an extension of that license while Ohio worked toward opening the Mid-West Compact waste site. The combination of the decision by the compact not to pursue opening a site, and questions raised by the Nuclear Regulatory Commission (NRC) while reviewing the extension request prompted NASA to decide to decommission the PBRF. NASA formally submitted its plan to the NRC in December 1999, and received approval in March 2002. NASA's goal is to complete clean up of the site to unrestricted use levels, and achieve license termination by the end of 2007 with the major buildings left standing. Once license termination is achieved for both licenses all remaining structures will be demolished to 1 meter below grade, and the remaining 11 hectare site will be restored to a greenfield condition. The site will remain under NASA's control as part of the buffer area for the remaining active, non-nuclear test facilities at Plum Brook Station.

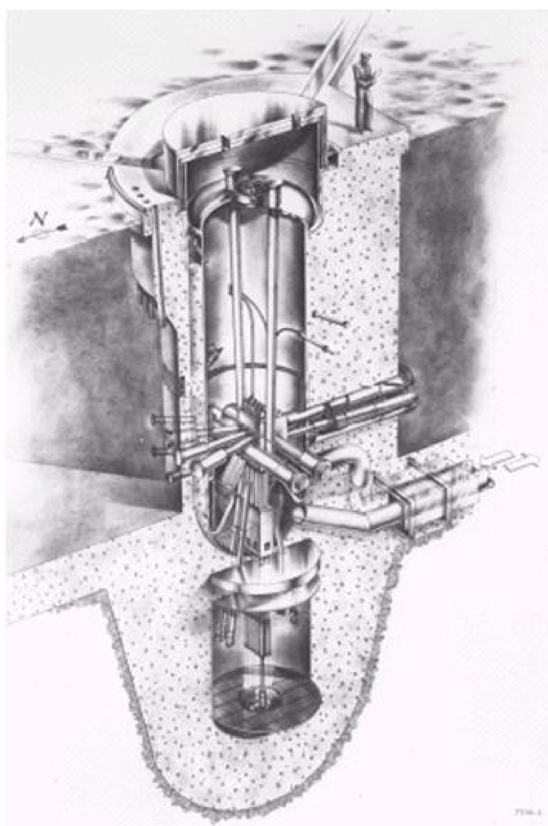

Fig. 2. Cutaway view of the Plum Brook Reactor

A somewhat unique part of NASA’s decommissioning effort has been documenting the history of the PBRF. Reference 1 is an overview of the history of PBRF, and Reference 2 is a historical documentary film. In addition, a more formal scholarly book is currently being written. Finally, an archivist went through over 200 boxes worth of documents from the reactor’s operating days. These records, including all test reports, were sorted, preserved, and catalogued to allow easy access during the decommissioning, and for future researchers.

The Decommissioning Team

The PBRF reactors are the only ones NASA will ever need to decommission, and as a result NASA decided that there was no value in building up a large contingent of knowledgeable full time NASA decommissioning personnel. Instead NASA opted to team with another government agency that would handle all the contracting and directly oversee the actions of the prime and sub contractors.

NASA entered into a Memorandum of Understanding (Space Act Agreement) with the United States Army Corps of Engineers (USACE) to perform contract management of the decommissioning. USACE in turn brought in Montgomery Watson Harza (MWH), who was already under contract to USACE as one of their Total Environmental Restoration Contractors (TERC). As such, MWH is the prime contractor, and has assembled the in-house talent and a team of subcontractors that is performing the actual decommissioning work. This team includes Mota Corporation for general decommissioning and decontamination activities, Wachs Technical Services for reactor internals removal and reactor tank segmentation, Toltest Incorporated for asbestos remediation and heavy equipment operation, Bartlett Nuclear Incorporated for radiation protection technicians, and other selected subcontractors for specific needs. Local contractors and workers have been used where possible.

Even with this arrangement NASA, as the licensee, remains solely responsible to the NRC for ensuring that all decommissioning activities are carried out safely, and that all license conditions are adhered to. To accomplish this NASA put together a team. It is made up of several NASA engineers, technical specialists from Argonne National Lab, an administrative staff, and a small group of field technicians under direct contract to NASA. For its public relation efforts NASA hired FOCUS Group Risk and Strategic Communications Consultants. With this team NASA is able to provide the necessary oversight for the decommissioning and license compliance.

Status

Decommissioning activities are in full swing across the site. The team is well along on the removal of fixed equipment from all the buildings in the facility. The reactor tank originally held the largest portion of the source term, chiefly in the form of tritium bound up in the beryllium reflector pieces, as well as activated stainless steel components. The reactor internals were removed (including the core box, multiple beam and sample tubes, the control rods, and the flow divider structure) and the segmentation of the reactor tank is complete. The area in the plant with the second highest concentration of source term was the Hot Dry Storage (HDS) vault, a large, 8 meter deep vault with a 1.8 meter thick concrete roof. This area contained legacy control rods, hardware for inserting experiments into the reactor, and the first generation of beryllium reflector plates that had cracked while in service in the reactor. HDS is now completely empty, as are the Hot Cells that are located in front of the vault. The entire 100 KW MUR, its control room, and all associated hardware have been completely removed.

Next to the Reactor Building is the Primary Pump House, a monolithic two story concrete structure which contained, in separate vaults accessible only through the roof, the three reactor pumps, two primary to secondary heat exchangers, and ion exchangers. This equipment has all been removed, and decontamination of the remaining empty building is underway.

The PBRF skyline has also seen some changes. The 57 meter tall signature 'double water tower' was dropped using controlled explosive charges, and was then size reduced using track mounted shears. The 27 meter tall facility gas exhaust stack was taken down in a less exciting manner, using a large crane to pick up and gently lay down the stack, which was then sliced up. Several lesser structures have also been eliminated. When operational the reactor had one experiment loop that operated at liquid helium temperatures. To support that there was a large compressor building and a gas handling yard, complete with bottle farm. All of those structures have been removed down to their concrete slabs foundations. Two other small steel buildings have been removed, and most of the water treatment plant precipitator has been removed. Two large 34.5 KVA transformers were surveyed out for free release elsewhere at Plum Brook Station, and all the other remaining transformers have also been removed.

Fixed equipment removal is nearing completion in all the other support buildings. Major equipment that has been removed includes the two story tall liquid waste evaporator from the Waste Handling Building, all of the ventilation plenums, piping, and filter banks in the Fan House, all of the hoods, counters, and other miscellaneous equipment from the Reactor Office Laboratory Building. This last building also had a room-sized mass spectrometer that was internally contaminated with mercury. The Service Equipment Building has had all switch gear, air compressors, diesel generators, water treatment equipment, and large boilers removed.

Decommissioning has generated three main waste streams. The first is Class B and C Low Level Radiological Waste (LLRW), principally from the reactor and the HDS vault. Six shipments of Class B and C waste (approximately 3.7 PBq total) were sent in casks by truck to the Barnwell disposal facility in South Carolina. This stream should now be complete. The second stream is Class A LLRW. As of November 2004 over 2,300 metric tons of material, including a large amount of asbestos, have been sent to Envirocare in Utah. It is anticipated that up to another 5,900 metric tons of material, including concrete and soil, and nearly 450 metric tons of lead remain to be packaged and sent. Finally, approximately 340 metric tons of scrap metal from unimpacted areas of the plant have been released from the site for recycling.

Dry Removal of the Reactor Internals and Tank

A unique approach was used for the removal of the reactor internals and reactor tank segmentation. All of this work was done dry. The decision was made to go this way after analyzing the impact of the reactor tank having been maintained in a dry storage mode under a nitrogen purge for the past 30 years. Activity levels had dropped considerably (nearly six

Cobalt-60 half lives had passed), there was some question as to the watertight integrity of the various seals around the control rods at the bottom of the tank, and there was no existing on-site water purification system for maintaining the required clarity of the water during cutting operations.

The original planned approach was to remove and dispose of the three 18 metric ton shrapnel shields from the top of the vessel and the reactor vessel head, and then install a shielded work platform over the top plane of the reactor tank. Initial unshielded dose rates in this area were in the range of 11.0 mSv/hour. After an ALARA analysis showed that dose rates on the shielded platform would have been 0.5 mSv/hr, it was decided that this plan would result in too much accumulated dose, and an alternate approach was developed. A 2.5 meter diameter hole was cut in the top portion of each shrapnel shield, and all three were then reinstalled following the removal of the reactor vessel head. The reinstalled shield walls provided shielding to the workers on the concrete walkway around the top of the reactor tank, while the holes provided plenty of access to the vessel. With the vessel head removed and the modified shields in place the general area dose rates in the work area averaged 20 µSv/hour.

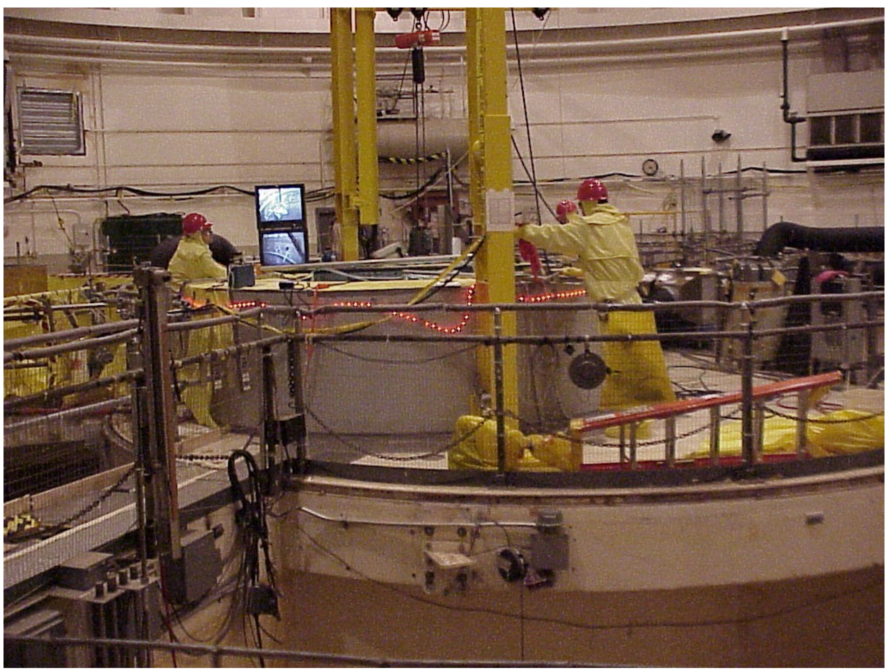

Fig. 3. Workers segmenting reactor internals from behind shrapnel shields

Workers from Wachs Technical Services then performed the disassembly of the reactor internals using standard tooling on 8 meter long poles which they manipulated from behind the shields with 90 degree reach rods. The poles were suspended from jib cranes attached to the shrapnel shield outer wall. Specialty tools were also designed and used, such as an air driven device that clamped and cradled the beryllium reflector pieces during removal. The workers watched the action of the tools on monitors that displayed the view from multiple in-tank cameras (Figure 3). All of this work was practiced first on a wooden simulator that allowed the workers to get the feel of 'working blind'. Fittingly, the final training of the workers and checkout of the tooling was done by using the planned approach to disassemble the 100 KW Mock-Up Reactor. The combination of these two dry run sessions allowed the workers to develop an impressive ability to efficiently perform the segmentation work, to shake out in advance any issues with the way the tooling was designed, and to work out the necessary camera support. Between the reactor internals and the tank walls the total amount of material removed was 36 metric tons of steel and aluminum, with a cumulative activity level of 2.3 PBq. The single hottest item removed, a section of control rod, was 16 mSv/hr on contact. The total dose for performing the work was 127 person mSv. This is 20 % of the projected dose had the work platform approach been used.

New Immobilizing Compound

A new immobilizing compound was developed for Duratek by Locktite to enable the disposal of beryllium pieces from the PBRF site. Large plates of beryllium were used as reflectors around the reactor core during operations, and as a result had become embrittled and, more importantly, saturated with tritium. The plates had a beryllium oxide coating that helped seal them. The concern was that if they were not immobilized during shipment that they could break, or even shatter. This could potentially result in a sizeable release of tritium. The problem with the standard approach of using grout as an immobilizing agent was that grout is alkaline and the beryllium oxide coating was slightly acidic. There appeared to be the potential for the grout to react with the coating, again possibly resulting in the release of tritium.

Locktite developed the solution in the form of a two part epoxy that was injected into the cask liners once all of the material to be disposed of was in place. The two component chemicals were pumped from their respective containers and combined in a mixing nozzle. The resulting mix was discharged into the liner, where it flowed like water, filling all voids. The material then set up in 24 hours into a hard, rubber like consistency. It gave off virtually no heat during the curing phase, had no expansion, was neutral in its pH, and its use required no protective equipment to be worn. As a bonus, it knocked down radiation levels on the surface of the liner by almost a factor of 10.

Challenges Remaining

While the overwhelming majority of the radioactive source term has successfully been removed from site, several challenges remain for the project. Soil remediation is scheduled to begin in May of 2005. Current estimates are that approximately 4,080 metric tons of soil will end up being removed from the site. Since the water table in the area is extremely high, averaging less than 2 meters below grade, it is anticipated that dewatering of the excavations will be required, even with a dry year. NASA is currently working with the Ohio Environmental Protection Agency (OEPA) to allow the post monitoring discharge of groundwater to an offsite open ditch, the same path currently permitted for discharging groundwater removed from site by 13 active sumps in the PBRF buildings.

As a research reactor PBRF used the seven hot cells for performing all post-irradiation testing on the materials being tested. The best approach for decontamination of those structures, with their 1.5 meter thick concrete walls, stainless steel liners, and interconnecting conduit and pneumatic tubing, remains under evaluation. Two options have been proposed – decontamination of the structures to a point that will meet Derived Concentration Guide Lines (DCGLs), or the physical removal of the entire structure without decon. A comparative cost analysis of the two approaches will be performed using data from the trial decontamination of Hot Cell #7.

The project is just beginning to deal with the issue of embedded piping. For our purposes this includes only piping that is greater than 1 meter below grade and is encased in concrete. There is a significant amount of such piping ranging from 10 centimeter drain lines to 61 centimeter primary piping. Where this pipe is only embedded in a few centimeters of concrete it will likely be dug out. In some cases, however, the pipe is beneath many meters of concrete, or the effort of removing it would seriously threaten the structural integrity of the building. The planned approach in this situation is to survey, decontaminate to below the DCGL levels, resurvey to prove this, and then fill the pipes with grout after NRC approval is granted.

The PBRF has an extensive network of quadrants and canals. They are 8 meters deep, and during operation were filled with water. The water provided shielding as irradiated experiments and spent fuel were moved around the plant on a remote operated, rail mounted cart at the bottom of the canals. The walls of the quadrants and canals were ‘wallpapered’ with fiberglass sheeting, and then painted with epoxy paint. The good news is that these surfaces are in good condition, and core sampling has shown the combination was successful in limiting the penetration of contamination into the concrete. The recently discovered bad news is that the mastic used to apply the fiberglass in the first place contained asbestos. This means that those areas that require scabbling will have the added requirement of needing the work to be done by certified asbestos abatement workers, and it may mean that areas that do not require scabbling for radiological reasons may still require asbestos removal.

Decommissioning has resulted in one additional waste stream for which a permanent disposal path is still needed. Starting in 1961 seven stainless steel clad cadmium rods were used as the first generation control rods in the reactor. After a few years of operation they were successfully replaced by pure stainless steel rods, and the ‘used’ rods were put in the PBRF Hot Dry Storage vault. After 40 years of storage the activity level in the rods still qualifies them as Class C LLRW. Since they contain cadmium, even though it is completely clad in stainless steel, the rods are considered a mixed waste by the South Carolina Department of Health and Environmental Control and are therefore not acceptable for disposal at Barnwell. Another disposal pathway considered was through the existing USACE contract with Envirocare of Utah. Envirocare can accept mixed waste, however they cannot accept waste above Class A LLRW. At this point no viable commercially available permanent disposal option has been identified. As an interim solution NASA plans to transfer possession of the rods to an existing NRC materials license for which GRC is also the licensee. GRC includes both the Lewis Field site in Cleveland, Ohio and the Plum Brook Station site in Sandusky. A heavy concrete storage container is being procured and installed to safely store the rods. The rods will be removed from the PBRF licensed area, but will not leave NASA property. NASA will continue to pursue a permanent disposal path, but without further impact to the decommissioning.

Finally, the project has made enough progress with the removal of fixed equipment that it will soon be time in many areas of the plant to move fully over to decontamination and Final Status Survey (FSS) activities. The project has submitted its FSS Plan to the NRC, and is awaiting the results of its review. In the meantime we are working out the administrative and engineering controls we will need to have in place to allow FSS to go forward in some areas of the site while other areas are still undergoing remediation.

Lessons Learned

Characterization Data is Key

Prior to the start of the decommissioning NASA personnel reviewed other decommissioning projects for lessons learned. One that came through loud and clear was the need for early and complete characterization of the site. NASA believed it had that information in the form of several site wide surveys that had been done through the years. It turned out that based on changes over time in both sensitivity of instruments and the list of isotopes of interest to the regulators that significant additional characterization was necessary. We could identify MARSSIM Class 1 areas, but more information was needed to classify areas as Class 2 or 3. Every decommissioning will eventually require complete characterization data, including subsurface data, and the earlier a project has the characterization data, the better.

One somewhat surprising finding from characterization was that the ditch that was used as the monitored discharge path for process water during plant operations was cleaner than expected. At the same time, rather large areas (several hundred square meters) of the flat ground above the bank of the ditch was found to be lightly contaminated. Discussions with retired site maintenance workers indicate that the likely cause was the dredging of the ditch over the years since 1973, when the plant ceased operations. Silt was removed along with plant material from the ditch and was spread out where the contamination was found. While outside the PBRF fence line, all of this area is still within the Owner Controlled Area.

'As Builts' Sometimes Are Not

Another lesson we heard from other sites was that as-built drawings are not completely trustworthy, especially at a research reactor. Even though it was known that great efforts were made to keep drawings redlined during plant operations, NASA decided to take this advice seriously.

A few differences from the as-builts have been found. Lead shielding and asbestos insulation were discovered in areas where it could not be seen prior to the removal of fixed equipment, but it was not shown on the drawings of the area. Another example was the fact that the top of the reactor tank had a welded flange that extended well into the concrete bioshield. As with the asbestos and lead this flange could not be seen until other components had been removed, and it did not show up on any of the plant drawings (or construction photographs). This discovery required changes be made to the planned approach for reactor tank segmentation which was already underway.

One precaution that was taken was the successful use of the 'cold and dark' approach to power on site, where all legacy electrical wiring was air gapped and only newly installed, clearly marked and easily visible wiring is energized.

Find the Retirees

It is extremely important for a facility that has been shut down for so long to find an effective means to draw on the corporate knowledge of those who once worked at the facility. NASA was fortunate in that there were retirees still living in the area who originally operated, and in some cases built, the plant. Over a dozen retirees, with specific areas of knowledge based on where they worked during the operating years, have been brought back as subcontractors to NASA. Most are only interested in limited, part time employment, but they have been invaluable in finding documentation in the legacy records (Where is the file that shows what is inside that piece of experimental equipment?), providing explanations for why something in the plant was configured the way it was (What the heck was this thing used for?), explaining and providing training on the overall operations history (Why would this isotope be found in this location?, How were these systems actually used?), and in general acting as an inspiration to those of us working at PBRF today to maintain their original high standard and do the job right. They have also turned into wonderful ambassadors of the project for the broader community – showing up consistently at all public events and lending credibility to NASA's efforts.

Facility Infrastructure

An important consideration for a facility that has been shut down for an extended period is that a sizeable and time consuming effort will likely be required to restore cranes and other infrastructure to a safe, operable condition. PBRF had a total of five 18 metric ton cranes, and numerous smaller cranes whose operation has proven necessary to support the decommissioning. Unfortunately, virtually no effort had been made to maintain them for the previous 30 years. A total of $500,000 and 18 months was required to get them all working and requalified. Most of this work was able to be completed while the NRC was reviewing the Decommissioning Plan, so the impact on the decommissioning schedule was minimal. Any similar facility may also need to budget time and money for repairing the infrastructure they identify as needed to support decommissioning.

The Importance of Community Relations

NASA made a conscious decision early on to have an extensive community relations program. Although NASA has active non-nuclear test facilities at Plum Brook Station, the local community had little sense of what went on 'behind the fence', and even less idea that a mothballed reactor was located there. Even before the Decommissioning Plan was submitted NASA developed a Community Relations Plan outlining the many ways it intended to both inform and get input from the community regarding our decommissioning efforts. An important part of NASA's community involvement efforts was establishing a Community Work Group prior to the start of decommissioning. That group has continued to meet quarterly since October 1999. Six annual Community Information Sessions have been held to date for the general public, there have been several media briefings, and there was even a media tour early in the project. A quarterly newsletter is been produced; numerous fact sheets were prepared, and even a newspaper supplement that went to over 30,000 local households. There is a also a 24 hour, toll free information line (1-800-260-3838), and a website (www.grc.nasa.gov/www/pbrf). Though not regulatorily required these efforts have produced a pool of positive public good will for NASA from its near neighbors. All of this effort is seen as having been a good investment. The overwhelming response from the public has been that since we are being so open, there must not be anything to worry about, and as a result we have had no community resistance. In fact, NASA has been called a ‘good neighbor’ by several local media outlets.

Work Early and Often With Your Regulators

Early and consistent contact with all regulators has been a big help to NASA. Besides the NRC NASA has been working with the Ohio Environmental Protection Agency (OEPA) and the Ohio Department of Health, Bureau of Radiation Protection, which regulates nuclear activities for the state of Ohio. All regulators were invited to a ‘partnering session’ early on in the decommissioning planning process, and were able to make clear what issues were of concern to them, how they wanted them addressed, and how and how often they wanted to be kept informed on the progress of the decommissioning. Knowing the regulators’ needs early on has allowed NASA to keep all parties properly informed, and has allowed us to better plan for such things as lead time required for various permits.

As an example of what has come from good relations with regulators, NASA has been able to work with OEPA and has received approval for an innovative approach to disposing of the estimated 7,500 cubic meters of Construction and Demolition Debris (C&DD) that will result from the post-license demolition of the main buildings. One of the remaining below grade structures will be the lower half of the containment vessel, a 2.54 centimeter thick steel tank that is 30 meters diameter and extends 16 meters below grade. OEPA has given NASA permission to place all material that would be classed as C&DD into the containment vessel which will then be capped (approximately 4 meters below grade). This arrangement will act as a disposal cell. Based on this unique physical arrangement and its one time use OEPA will not require NASA to obtain a C&DD landfill license. This approach will save NASA the time and cost of separating C&DD material from clean hard fill, and from shipping it for disposal at an offsite C&DD landfill.

CONCLUSIONS

The NASA Plum Brook Reactor Facility was on the nuclear frontier, and after a long twilight, the final chapter in its story is being written. Much of the work is completed, including the removal of over 2,300 metric tons of radioactive material. The source term on site has been reduced over 97%, with the removal of the reactor internals, most of the reactor tank, and the material that was stored in the Hot Cells and the Hot Dry Storage vault. The project continues to deal with challenges as the work moves forward. Through all of this some valuable lessons have been learned, and in some cases relearned. The transition from the removal of equipment to structural decontamination and Final Site Survey will be taking place over the next several months. NASA and the project team expect to continue their successful efforts to complete the decommissioning in a safe manner, and achieve license termination by 2007.

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