KEY CONSIDERATIONS FOR COST EFFECTIVE D&D OF NUCLEAR FACILITIES

Thomas A. (Tom) Baillieul
U.S. Department of Energy
Columbus Environmental
Management Project
555 Metro Place North, Suite 415
Dublin, OH 43017

Leonard F. (Len) Ermold
Battelle Memorial Institute
D&D Operations
505 King Avenue, Office 11-1-121
Columbus, OH 43201

ABSTRACT

Since 1989 the Department of Energy and Battelle Memorial Institute have pursued, under a cost sharing arrangement, the Decontamination and Decommissioning (D&D) of Battelle owned facilities located in central Ohio that were used for nuclear research and development dating back to 1942. Decontamination of eleven buildings has been successfully performed, with a twelfth building scheduled to be completed by the end of 1997. Three additional buildings—a hot cell facility, deactivated reactor, and critical assembly and radiochemistry laboratory building—remain to be completed. The total cost of the Battelle effort is estimated as approximately $290 million, and a recently completed re-engineering evaluation has identified in excess of $30 million in potential savings for the remaining approximately $130 million effort.

The D&D effort provides significant challenges: widely varying contamination levels; inaccessible areas for decontamination, survey, and release; effects on ongoing research operations; and multiple facility types (foundry, metalworking, laboratory, hot cell, etc.). Contamination includes uranium and thorium, mixed fission products, transuranic elements and activation products from nuclear power plant fuel. As in most D&D activities, the scope of effort was not well defined initially, and contingency planning to accommodate the unknown together with a focus on selected key cost reduction considerations were essential to a cost effective D&D process. The Battelle experience has identified six key cost reduction considerations. They are:

- Selecting the correct timing and level of characterization
- Understanding, early on, various facility end state costs
- Achieving the optimum balance between D&D and waste disposal costs
- Selecting the low cost decon technology
- Reducing life cycle cost to the extent possible
- Balancing personnel exposure and critical path work

Each of these key cost reduction considerations and their application in the D&D of Battelle nuclear facilities are discussed together with lessons learned through experience with the D&D process.

BACKGROUND/INTRODUCTION

Between 1942 and the mid 1980's Battelle Memorial Institute (BMI) performed nuclear research activities for the federal government and commercial organizations at two locations: King Avenue Facilities located in a residential area in Columbus, Ohio adjacent to Ohio State University; and West Jefferson Facilities located approximately 15 miles west of downtown Columbus, Ohio. The West Jefferson Site is bounded by Big Darby Creek, a National Scenic and state protected river on the east, and farm lands to the west, south and north. Immediately east of Big Darby Creek are a Girl Scout camp and several residential neighborhoods, all within ½ mile of the site. The King Avenue facilities (Figure 1) included a foundry; machine shop; metal working, engineering, and materials buildings; and metallurgical and chemistry laboratories. A research reactor, hot cells, and critical assembly and radiochemistry laboratories are among the West Jefferson facilities (Figure 2). BMI nuclear related research work included fuel element fabrication, nuclear reactor material development, nuclear material reprocessing and recovery, fabrication methodology development such as hot isostatic pressure bonding, and radiochemistry studies.

In the mid 1980's, the decision was made to discontinue nuclear material research at the BMI Columbus facilities. The Battelle Columbus Laboratories Decommissioning Project (BCLDP) was formed to decontaminate radiologically contaminated facilities, or parts thereof, in a safe, environmentally sound and cost effective manner, and return the facilities to Battelle in a condition suitable for use without radiological restriction. Contamination included uranium and thorium, mixed fission products, transuranic elements and activation products from nuclear power plant fuel. Nine King Avenue Facilities and six West Jefferson Facilities were included in the BCLDP and a 90/10 cost share arrangement between the Department of Energy (DOE)/BMI was established.

Figure 1. King Avenue facilities located in a residential area north of downtown Columbus.

The BMI Decommissioning Plan, approved by the U.S. Nuclear Regulatory Commission (NRC) in December 1993, calls for completion of decommissioning activities by October 2000; the current planned estimate to complete is between 2002 to 2005 dependent on funding. Three of the West Jefferson buildings and nearly all of the King Avenue main complex effort have been completed at a cost through the end of September 1997 of approximately \$160 million. The remaining effort involves primarily West Jefferson North buildings consisting of a Hot Cell, with a calculated 6,000 curies of activity, a Critical Assembly and Analytical Laboratory, and a Research Reactor. The reactor was defueled and partially dismantled in 1975. Cost to complete the project is estimated at approximately \$130 million. Total expected personnel exposure has been calculated as 500 person rem over the project lifetime. Volumes of existing plus generated radioactive waste are estimated at approximately 600,000 ft^3, including approximately 13,000 ft^3 transuranic waste (TRU). Almost 200,000 ft^3 of contaminated material was dispositioned through the end of FY97 with an actual disposal volume of approximately 100,000 ft^3. King Avenue areas requiring decon increased 54% between July, 1994 and April, 1997 from 67,000 ft^2 to 103,000 ft^2. These increases have been accommodated without significant changes in expected project funding due to aggressive application of the key cost effective D&D considerations discussed herein.

BCLDP functions include Material/Equipment Removal, Characterization, Decontamination, Certification/Release, and Restoration Settlement. The major project operational goals are to: (1) Minimize potentially adverse environmental, safety, and health impacts; (2) Minimize waste generation and costs; (3) Minimize project and other personnel radiation exposure; and (4) Minimize disruptions to Battelle's ongoing research activities.

Figure 2. West nuclear material research facilities.

The experience to date and planning for the remaining effort have identified six key cost reduction considerations that are essential to a cost-effective D&D process. They are:

- Selecting the correct timing and level of characterization
- Understanding, early on, various facility end state costs
- Achieving the optimum balance between D&D and waste disposal costs
- Selecting the low cost decon technology
- Reducing life cycle cost to the extent possible
- Balancing personnel exposure and critical path work.

Each of these key cost reduction considerations and their application in the D&D of Battelle nuclear facilities are discussed together with lessons learned through experience with the D&D process. Relative to successful utilization of the key cost reduction considerations, it should be understood that the requisite skills, knowledge, creativity, and experience of the individuals, and the synergy of the project team will greatly influence the ultimate level of success.

KEY COST REDUCTION CONSIDERATIONS

Selecting the Correct Timing and Level of Characterization

The characterization process for a facility that is to be released and restored generally involves five specific survey types: background; scoping; characterization; remediation; and final status release. In performing the surveys it is important to select the proper instrumentation for the radionuclides of interest. Background surveys are performed to enable net residual activity to be determined from total radiation or radioactivity levels. Such surveys may have to be repeated on a regular basis as remediation proceeds, especially for highly contaminated facilities where movement of radioactive materials can change background levels. Scoping surveys provide a preliminary assessment of site conditions, relative to guideline values, and initial guidance in classification of the site into specific areas both for decontamination planning and radiation protection purposes. These surveys may be limited by lack of access to all facility areas. Characterization surveys are performed to more precisely define the extent and magnitude of contamination. Remediation control surveys are used to monitor effectiveness of the decontamination effort as the decontamination process is in progress. Final status surveys provide data to demonstrate that all radiological parameters (total surface activity, exposure rate, removable surface activity, and radionuclide concentrations) satisfy the established guideline values and conditions. Once the BCLDP has satisfactorily completed final status surveys, an Independent Verification Contractor (IVC) is contracted to independently validate the results. The BCLDP works closely with the IVC to define common instrumentation and calibration standards. Synchronizing survey approaches with the IVC reduced their time on site and saved the project approximately $300,000.

In general, the number and extent of surveys should be kept to a minimum to satisfy their intended purpose. Performing more than a bare minimum of pre-final status surveys, particularly for areas whose characteristics may potentially be changed by subsequent decontamination activities, simply results in additional surveys and costs. For example, the BCLDP plans to reduce the number and extent of characterization surveys to be performed for West Jefferson North buildings, compared to those performed for King Avenue buildings, for an estimated savings of $200,000 out of a previously planned $1.6 million. The BCLDP carefully divides buildings into affected areas (locations for which evidence exists concerning the potential for contamination) and adjacent areas, and chooses statistical populations to minimize the number of readings which will satisfy the NUREG 5849 criteria. Surveys should flow from areas whose decontamination could potentially contaminate other areas, e.g., ceiling areas, to those less likely to spread contamination, e.g., floor areas. Proper sequencing of area decontamination can also reduce the costs associated with preventing the spread of some contamination to other areas, particularly those that will require subsequent decontamination. Finally, effective integration of the health physics and characterization functions will reduce overall project costs by eliminating redundancy and improving resource utilization.

Understanding, Early on, Various Facility End State Costs

There are several possible facility end states, such as greenfield, brownfield, restored to the original pre-contamination condition, and restored to a different condition. A restored facility end state will normally increase decontamination costs compared to those associated with a removed or demolished facility end state. Drain lines and other difficult to access areas requiring decontamination can be accessed much more readily during the demolition process, thereby decreasing decontamination costs. When significant facility modifications will be required to enable a future utilization of the facility, it may be more cost effective, overall, to demolish the existing facility and build a new facility, rather than to "surgically" decontaminate the older facility and then restore it to accommodate a new mission. This is especially true for facilities whose initial design was specific to a particular past mission which is not compatible with a new future mission.

Decontamination and decommissioning always involves unknowns. Any project estimate should include a contingency fund to handle the likely discovery of additional contamination. This becomes most significant where the final state for a site includes preservation of facilities for re-use without radiological restrictions. This is the case for buildings at Battelle's King Avenue site - and is mirrored by economic re-development efforts at DOE sites around the country. Discovery of contamination around buried drains or underlying foundations can require very significant remediation efforts. In some cases special engineered supports are needed to keep the structure stable until excavations can be back filled.

The original BCLDP end state for the West Jefferson North facilities was to free release restored facilities. Evaluation of alternate end states concluded that pursuit of a decontamination/demolition/green field approach at the West Jefferson North site for BCLDP could reduce project costs and/or future costs to DOE and Battelle. The evaluation recognized that a final cost difference between the decontamination/restoration, and decontamination/demolition/green field approaches could not be determined until (1) a refined definition of restoration needs is available late in the decontamination process, and (2) the cost savings achievable due to decontamination with a demolition/green field end state versus decontamination with a restored end state could be established. However, estimates are that the demolition/green field costs will be less than the restoration costs associated with return of the decontaminated buildings to their precontamination functional use. It was also concluded that the decontamination costs will be less for a demolition/green field versus restored end state. For example, an end state which includes removal of buildings is much more forgiving of incomplete knowledge of contamination levels. In this case, hard to get at contamination can be removed relatively easily as demolition progresses. More contaminated drain segments than anticipated are not a major consideration when all drain lines are to be removed after the building has been razed. Also, a demolition/green field end state reduces significantly the potential for subsequent liability with attendant cost ramifications to both DOE and Battelle since facility demolition and removal would not leave areas that are masked or hidden where contamination may be left (Figure 3).

Figure 3. Trench digging with a track-hoe to uncover buried drain lines within a building.

If a once contaminated building is removed completely, the chance of discovering additional contamination is significantly reduced.

Even in the case of a restored end state, many situations will arise in which the cost of decontamination will exceed the cost of disposition of building material as waste followed by replacement. For example, during the D&D of King Avenue Building # 2 it was concluded that removal and replacement of the existing roof and partial supporting structures would be more cost effective than decontamination of the roof and supporting structures in place. Also, during the D&D of King Avenue Building # 3 it was decided to demolish interior walls rather than pursue the labor intense decontamination of the two sides of each wall, resulting in a savings of over $125,000. In the Building # 3 situation, wall removal was particularly advantageous because Battelle wanted to gut the interior anyway and wall restoration was not necessary.

Achieving the Optimum Balance Between D&D and Waste Disposal Costs

Seeking the optimum balance between D&D costs and waste disposal costs as well as minimizing waste disposal costs has been a continuing BCLDP effort. Relative to waste disposal costs, the BCLDP DOE Project Office in October 1993 was the first DOE EM-40 project to receive an exemption from portions of DOE Order 5820.2A, Radioactive Waste Management Requirements, enabling use of a commercial waste disposal site. This practice resulted in $2 million savings the first year and subsequent savings of $350,000 per year in disposal costs compared with the previous disposal option.

Relative to the disposition of suspect transuranic (TRU) waste, the BCLDP is pursuing a bath process to decontaminate highly contaminated equipment and material, either presently in storage or generated during D&D efforts, to achieve free release status or a reduced cost waste disposal form. Chemical decontamination of the waste will reduce characterization costs due to the change from a mostly heterogeneous to a mostly homogeneous waste form, and also reduce waste disposal costs by converting the waste to a less expensive disposal type. An initial demonstration of this concept has been performed and a pre-production program is under way to substantiate the level of cost reduction achievable (Figure 4). At the present time waste packaging and disposal costs for 10,000 ft³ of TRU waste are estimated to be approximately $22.7 million, and it is expected that a savings of roughly $7 million is achievable by chemical decontamination of the waste.

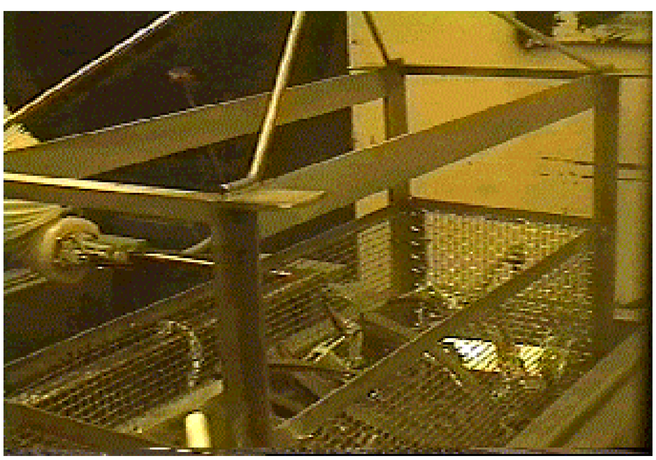

Figure 4. Basket rinse during waste decontamination demo.

In pursuit of the optimum balance between D&D and waste disposal costs, floor drain lines containing both radioactive and RCRA heavy metal contamination as sludge and scale were honed and decontaminated to reduce the volume of radioactive mixed waste. Pipe joints sealed with poured lead were broken and the lead removed and radiologically released. Fluorescent light bulbs, mercury vapor light bulbs and vacuum tubes were also radiologically released. Through separation, the BCLDP reduced the volume of potential radioactive mixed waste by approximately 3,200 ft³ in calendar year 1996 saving an estimated $3.4 million in radioactive mixed waste treatment and disposal costs.

To the extent possible, waste minimization is integrated throughout the project (Figure 5). Waste management staff are involved in the planning for each decontamination activity and review each work instruction. Likely waste types are identified before they are generated through a careful program of characterization and laboratory analysis. Sorting and control of all waste begins at the site of generation. Decontamination crews are trained to recognize and segregate waste items based on classification to meet processing and eventual disposal requirements. Documentation associated with each waste container also begins at the point of generation. In this way the handling of, and exposure to, contaminated items is minimized. Volume reduction through incineration, super-compaction, and metal remelting is employed as a key means of reducing waste shipments and disposal costs. Finally alternate disposal options are maintained to assure continuity of access, and to allow waste to be shipped for the least costly interment based on its specific characteristics.

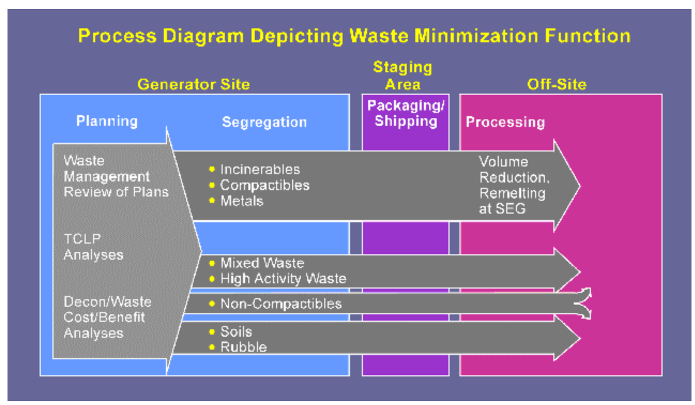

Figure 5. Waste minimization is built into every element of the BCLDP.

Cost/benefit analyses are incorporated into the plans for decontamination, balancing the volume of material which will be packaged for disposal against the cost to decontaminate buildings and materials. To date the project has "free released" for reuse and recycle over 400,000 ft³ of "clean" material and has dispositioned almost 200,000 ft³ of low-level waste.

An important consideration in optimizing the balance between D&D costs and waste disposal costs is to minimize commingling of waste types. For example, in evaluating the cost merits of D&D followed by restoration versus demolition followed by greenfield or new construction, the need to avoid commingling of waste will, in many cases, lead to the conclusion that D&D of the facility to free release followed by demolition is the most cost effective approach as compared to demolition preceded by minimal or no D&D. This was found to be the case for one of the West Jefferson North facilities.

Selecting the Low Cost Decon Technology

Equipment capital investment, waste generation, staging requirements, safety and labor involved in applying any particular decon technology are major considerations in selection of the low cost decon technique for a particular situation. The BCLDP has and will continue to evaluate the various available decon technologies seeking at each point to use the most overall cost effective one consistent with both anticipated decon and waste disposal costs. For example, in conjunction with the King Avenue Building # 2 decontamination effort, the cost effectiveness of decontamination and reuse of roof support material versus disposal and replacement with new material was evaluated and it was concluded that disposal without decon was the cost effective path. Also, the project has found that the maturity of new technology and equipment should be carefully evaluated, considering factors such as setup time and reliability, since a basic proven approach may be more cost effective. The recently issued DOE Decommissioning Benchmarking Study Final report has been useful in ensuring that the BCLDP is using the most cost effective approach in nearly every situation. It is presently planned that the initial portion of the West Jefferson North decon effort will proceed using the low cost vacuum grit blasting decon technology employed in the King Avenue effort (Figure 6). As the decon effort proceeds, the use of other alternate low cost technologies will be assessed on a continuing basis.

Figure 6. Vacu-blaster operation.

Reducing Life Cycle Cost to the Extent Possible

A recently completed, DOE requested, rethinking and re-engineering of the approach to completing the BCLDP confirmed, once again, that the funding profile is the single most significant factor in minimizing project life cycle costs. In particular, the re- engineering evaluation concluded that the BCLDP could be completed three years earlier at a savings in excess of $20 million. The savings resulted from use of a five-year flat funding profile when compared to a proposed eight year funding profile that used a flat funding profile equal to approximately half of the five year funding profile for the first five years, and then roughly tripled the previous funding level during the last three years for a total project unescalated cost of $116.2 million. The optimum funding profile is defined as the most efficient ratio of workers to support costs, given the physical limitations of the area to be remediated and the need to balance radiation exposure.

At the present time, West Jefferson surveillance and maintenance costs are approximately $1.5 million per year. The eight year funding profile does not support major high radiation decontamination work until the FY03 time frame. The five year funding profile increases near term funding and allows major high radiation decontamination work to begin much earlier in the project effort and reduces the needed time period for inspection and maintenance as a specific directly costed effort. It was concluded that $1.0 million to $1.4 million of direct surveillance and maintenance costs per year could be saved during the FY98 through FY02 time frame if the funding profile during that period was raised to the five year profile level, resulting in a project cost savings of $5 to $7 million.

Figure 7. Hot cell access area is cleared by workers wearing bubble suits.

Each year a project remains in existence it will incur certain costs of simply being in business that would no longer be necessary if the project was complete. Many of these "business expenses" are relatively independent of the rate at which project work is completed. Examples are:

- Project Reporting - Weekly, Monthly Reports including budget, cost, variance analysis
- Contract Administration
- Community/Institutional Relations
- Regulatory Compliance/Oversight
- Quality Assurance/Audit/Assessment
- Emergency Preparedness
- Records Management
- Training Infrastructure
- Project Management Infrastructure
- Environmental Monitoring and Reporting.

It was concluded that savings of approximately $0.8 million to 1.5 million in labor and $0.5 million in environmental monitoring per year would result for each year that the BCLDP was completed early. Assuming that the project is funded in a manner that would allow it to complete at the end of F 02 instead FY05 there would result a cost savings to the total project cost of $4 million to $6 million. Additional savings would also occur to DOE since the Columbus Office could be closed three years early and personnel assigned to other efforts.

The eight year funding profile provides for a low level of staffing through the end of FY02 followed by a major increase in funding in FY03 that will support a large increase in personnel. The large ramp up in personnel that the eight year profile provides for in FY03 will, however, increase project training costs over those associated with a more uniform funding profile and also provides a much reduced return on training investment, due to the larger number of trained personnel working on the project a shorter period of time. Also, the large staffing levels necessitated by the eight year profile will impede cost effective utilization of physical facility and equipment capabilities. It was concluded that a 10% cost savings, or at least $10 million, would result due to the more effective utilization of resource and facility capabilities associated with the five year funding profile.

Another important consideration in minimizing life cycle costs is project organization structure. Throughout the project life cycle, the project organization structure has been assessed and, as appropriate, changed to accommodate changes in project focus as well as to improve personnel utilization and minimize the effort associated with various functions. In this vein the BCLDP remediation and waste management organizations were combined to enable more complete personnel utilization and reduce waste handling activities. Management span needs to be continually assessed and changed to appropriately leverage the capabilities of project personnel. Cross-training of project personnel is used by the BCLDP to enable effective resource utilization as a result of changing needs during the various project phases. In the case of BCLDP, a flattening of the organization in late 1994 saved approximately $300,000 annually; additional organizational changes made in early 1997 and effective resource utilization are expected to reduce project costs and improve productivity by roughly $400,000 per year.

Balancing Personal Exposure and Critical Path Work

D&D of facilities involving moderate to high level dose exposure necessitates the rotation of personnel from work in high radiation areas to work in low radiation areas to balance individual dose rates while providing for effective resource utilization. For example, it is anticipated that the West Jefferson North work will involve 3-hour work segments consisting of, on the average, either 20 mrem or 10 mrem of exposure (Figure 7). If individual personnel exposures are to be restricted to less than 2 rem per year, then a weekly exposure limit of approximately 40 mrem would apply. If an hour suitup and an hour unsuit time are added to a three-hour work segment, then an individual would receive their 40 mrem exposure in ten hours with two 20-mrem work segments and in twenty hours with four 10-mrem work segments. For the two 20-mrem work segment case, an additional thirty hours per week of low to no exposure work would be necessary to enable cost effective resource utilization. Twenty hours of low to no exposure work would be required for the four 10 mrem segment exposure case.

BCLDP work at the King Avenue facilities has involved minimal exposure while the West Jefferson North effort has been calculated to involve up to 500 person rem exposure. Current estimates are that the West Jefferson North activities will involve 68,000 hours of 20 mrem exposure per three-hour work segment effort and 93,000 hours of 10 mrem per three-hour work segment effort that will need to be balanced with low or no exposure work to obtain effective resource utilization. Balancing of exposure and resource utilization will, in certain situations, limit the approach that can be taken in sequencing work.

CONCLUSIONS/RECOMMENDATIONS

Cost effective D&D of nuclear facilities necessitates the application and balancing of different considerations for a variety of situations that will or could be encountered. Up front planning, an early determination of the most cost effective approach to the desired end, and involvement of experienced personnel will greatly increase the probability of success. The key considerations discussed in this paper have been found to provide areas of focus and to stimulate the continuing effort to reduce costs and achieve the desired end. Because of this it is recommended that D&D project performance be periodically reviewed relative to the key considerations discussed here. As with any non-routine project effort, and many if not most D&D efforts fall into this category, the creativity, experience and synergy of the project team will greatly influence the final result. These factors have enabled the BCLDP to accommodate a 54% increase in the originally planned King Avenue effort while providing approximate on-schedule completions within established budgets.