DECOMMISSIONING UNIT COST DATA

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ABSTRACT

The Rocky Flats Closure Site (Site) is in the process of stabilizing residual nuclear materials, decommissioning nuclear facilities, and remediating environmental media. A number of contaminated facilities have been decommissioned, including one building, Building 779, that contained gloveboxes used for plutonium process development but did little actual plutonium processing. The actual costs incurred to decommission this facility formed much of the basis or standards used to estimate the decommissioning of the remaining plutonium-processing buildings.

Recent decommissioning activities in the first actual production facility, Building 771, implemented a number of process and procedural improvements. These include methods for handling plutonium-contaminated equipment, including size reduction, decontamination, and waste packaging, as well as management improvements to streamline planning and work control. These improvements resulted in a safer working environment and reduced project cost, as demonstrated in the overall project efficiency. The topic of this paper is the analysis of how this improved efficiency is reflected in recent unit costs for activities specific to the decommissioning of plutonium facilities. This analysis will allow the Site to quantify the impacts on future Rocky Flats decommissioning activities, and to develop data for planning and cost estimating the decommissioning of future facilities.

The paper discusses the methods used to collect and arrange the project data from the individual work areas within Building 771. Regression and data correlation techniques were used to quantify values for different types of decommissioning activities. The discussion includes the approach to identify and allocate overall project support, waste management, and Site support costs based on the overall Site and project costs to provide a "burdened" unit cost. The paper ultimately provides a unit cost basis that can be used to support cost estimates for decommissioning at other facilities with similar equipment and labor costs. It also provides techniques for extracting information from limited data using extrapolation and interpolation techniques.

The conclusion of the work is that unit cost and labor information can be collected from estimate and cost control data for an active decommissioning project. Additionally, that data can be used as the basis for future estimates, and to evaluate on-going productivity and areas for improvement in project efficiency.

INTRODUCTION

The physical approach, and thus the cost, used to decommission contaminated facilities varies with the activities that were conducted in the individual facility and the types and kind of contamination present. Plutonium handling and processing facilities constitute a significant element of decommissioning scope that the Department of Energy must address as it cleans up the weapons complex. Plutonium facilities are characterized by gloveboxes, and in some cases contaminated rooms (e.g. "canyons"), which collectively contain the processing equipment and protect workers from the contamination associated with the work. The interiors of these gloveboxes and rooms were designed to become contaminated with levels of plutonium on the order of grams (or curies) per square foot, while maintaining the exteriors at pico-curie levels. A dedicated exhaust system that constantly maintains the interior of the glovebox or room at a negative pressure differential with respect to the occupied spaces is also necessary to contain the plutonium contamination in the gloveboxes and rooms. The interior of this ventilation exhaust system was also designed to become highly contaminated. The process equipment, gloveboxes, and primary exhaust system (referred to as the "Zone 1" system at Rocky Flats) represent the primary decommissioning challenge and the majority of the costs for the closure of the plutonium facilities and in fact the whole of the Rocky Flats Site (Site).

The general approach to decommissioning a plutonium facility is to initially remove selected non-contaminated or lightly contaminated materials and equipment. This material is removed both from the areas immediately surrounding the gloveboxes and process equipment to allow access, and from adjacent rooms to provide room for supplies, waste packaging, size reduction, and logistical support. Gloveboxes and other process equipment such as piping, tanks, and ducts are then dismantled and packaged, either in their original location or at a size reduction facility located in a separate section of the building, where contamination spread may be better controlled. Specially trained crews (at Rocky Flats we use retrained process operators directly employed by Kaiser-Hill) typically remove most or all of the gloveboxes and supporting equipment from a given area, and then move to another area as required by the overall project plan. These areas then become available for other, less trained building-trades crews to complete the removal of less-contaminated materials prior to the demolition of the structure.

The challenge of developing accurate cost data correlated to the materials removed may be approached a number of ways. Time studies may be used to identify the time that a given crew works on specific equipment. This method has the advantage of directly connecting the activities with the work, but is relatively labor intensive and may miss ancillary costs associated with training or costs incurred by the significant number of support personnel used in the nuclear field. Another approach is to utilize accounting and project control data to identify the costs associated with activities. While this approach is more comprehensive (all costs must roll up to the project total); it's ability to distinguish costs by material type or by specific glovebox is dependent on the resolution of the original estimate and the cost charging structure. In particular, the decommissioning operational personnel and management are more interested in physical work and in the safety and operational issues associated with their day-to-day job. There has been reluctance accept a more detailed cost collection and accounting structure with greater detail than that required for adequate project control. This reluctance, while understandable, has made it impossible to directly correlate actual labor and cost data to parameters directly related to individual gloveboxes or pieces of equipment.

We decided to look at approaches that had the potential to extract unit cost data from the Set and Project actual cost data available. We investigated two general approaches – applying regression techniques to extract unit rates from overall actual direct labor hours from all of the completed Sets, and extract labor rates from the actual labor hours for a single Set using the time-phased earned value data.

The remainder of the paper begins with a Background section discussing relevant aspects of the 771 Project. The methods of analysis and results each of the two approaches are then discussed in detail. A discussion of the approach to determine the values of the factors relating direct labor to total project cost follows. Finally, a section on Lessons Learned and overall Conclusions are presented.

BACKGROUND

Kaiser-Hill Company LLC (Kaiser-Hill) has the prime contract for the Rocky Flats Closure Project. The project duration is from February of 2000 with completion scheduled for December of 2006. The Rocky Flats Closure Project has been subdivided into six "Projects," four of which are principally concerned with decommissioning each of the four major plutonium facilities. The 771 Project involves the equipment dismantlement, structural decontamination, and demolition of Buildings 771, 774, and some of the smaller adjacent structures, and is integrated with the environmental restoration of the soil under and surrounding the building.

Building 771 was one of the original facilities at the Rocky Flats Site, constructed in 1952 to handle all of the plutonium purification and weapons fabrication. Building 774 was constructed at the same time to treat the liquid wastes generated in Building 771. The combined footprint of the buildings is 147,000 square feet. Although weapons fabrication operations were subsequently relocated, the plutonium purification activities remained active until the Site was shut down in 1989. The operations in the Building 771 gloveboxes and tanks used concentrated plutonium-containing solids and solutions, nitric acid, hydrochloric acid, and plutonium fluoride; and also included residue incineration, grinding and vapor extraction among many operations used to process concentrated radionuclides.

During the course of operations there was a major fire, numerous spills (within the building), and removal and replacement of numerous pieces of equipment. The ventilation system was upgraded several times to support new safety standards and process requirements. Operations were suspended in 1989, and the principle activity for a number of years thereafter was "Deactivation," which was the removal of hold-up, residues, and classified items left over from operations, and stabilization of plutonium nitrate solutions. Deactivation, which is now essentially complete, has recently been proceeding in parallel with decommissioning to remove residual process liquids from, and then removing the piping connecting the tanks and gloveboxes. This scope that in other projects might be considered decommissioning was estimated and tracked separately. In 1999 decommissioning began, including the removal and size reduction of gloveboxes, tanks, duct, equipment, and the remaining piping systems.

The decommissioning work is subdivided into generally three kinds of work: (1) removal of highly contaminated equipment (>2,000 disintegrations per minute [dpm]) that is done under relatively rigorous controls by Kaiser-Hill crews, (2) removal of less contaminated equipment (<2,000 dpm) and some interior walls, and decontamination of structural surfaces done as fixed-price contract by building trades crews; and (3) structural demolition as fixed-price contracts, typically in conjunction with environmental restoration. The work is delineated by physical location in the building – into "Sets" of work for scope to remove and packaging of specific pieces of highly-contaminated equipment, and into "Areas" of work for the scope to remove the remaining less-contaminated equipment and decontaminate the structure to an unconditional release status. In this building there are a total of 47 Sets and 13 Areas, with 19 Sets and 1 Area complete as of October 2001. Again, it should be emphasized that the location of the Sets of equipment and the Areas are typically co-located in the building, although there may be several Sets within the portion of the building covered by one area. The major difference is what is to be done and by whom.

All of the estimates, budgets, and cost collection are organized under the project work breakdown structure. The management of decommissioning activities (work packages, planning, project control, single foreman responsibility, etc.) occurs primarily at the Set level, although schedules, earned value reporting and (to some extent) cost accounting extend to a lower level. The Set and Area scope includes the majority of the direct decommissioning craft labor, although there is some waste packaging and floor management costs included. Most of the engineering costs, for work package development and support, are also included in the Set or Area scope. The remaining direct costs including most of the in-building waste management, supplies, laundry, health and safety, surveillance and maintenance, and project management have separate budgets and cost collection structures.

Kaiser-Hill project accounting is based on costs rolling up from a system of charge numbers tied to the project work breakdown structure, which collect direct labor hours (and costs) for direct Kaiser-Hill employees (including the floor labor for the Sets), and costs for subcontracted labor, supplies, and expenses. Labor hours are tracked by the week in which the work occurred, and costs by the month in which the invoice was paid and/or accrued. The weekly labor hour entries identify the worker name, craft, Site organization, and entry straight time or overtime designation. Resolution of costs or hours more accurately by date, while theoretically possible, is impractical.

For the 771 Project decommissioning activities, individual charge numbers below the Set level were assigned for Set planning and six execution charge number "suffixes": size reduction, and for the removal of gloveboxes, pipe, duct, tanks, and "balance." The "balance" equipment included electrical, utilities, and less contaminated equipment that had to be removed for accessibility. The work crew at the size reduction facility typically charges to the Set size reduction charge number as items from the Set are brought there and size reduced. The work crew in the Set area (i.e. the "in-room" activities) typically charges to the remaining Set charge numbers based on the work done on a given day. In-room work crews typically work on one Set until complete, then move to another Set.

The choice was made not to collect labor and cost to an "equipment item" level, e.g. by glovebox or other individual piece of equipment, although the total Set glovebox removal costs could in principle be segregated from the total Set tank or total Set pipe removal costs by charge number. Although there are charge numbers based on media type, neither the Site's accounting system or the Project's management approach facilitated accurate collection of costs below the Set level, except for the glovebox size reduction which was done by a different crew. Problems include crews simultaneously working on different charge numbers, different gloveboxes, and sometimes different Sets while charging one number; delineation between Set sub-elements being poorly defined, and no procedure for checking the allocation of hours between charge numbers on a daily or weekly basis.

The 771 Project's decommissioning estimate evolved as an integral part of the planning process. Set work was estimated using the "POWERTool" estimating software, a system developed by Polestar, Inc. for the DOE to estimate decommissioning projects, and used in various forms at Rocky Flats, Hanford, and other sites. The 771 Project team's estimating method collected key data by Set, including such specific items as electrical panels (standard sizes), piping length, number of internal glovebox components, and glovebox internal area to be decontaminated. The team also created work-specific "derived" data related to how the team expected the work to be performed, including rigging or scaffolding set ups, linear feet of cut during glovebox size reduction, and soft-sided containment erection and removal. Unit rates derived from build-up of detailed task elements or from anecdotal experience from concurrent decommissioning activities in Building 779 were used to populate "work units". The work unit output included hours (by craft) and various materials and labor costs. By combining the Set data with the appropriate work units, POWERTool generated the hours and costs which then rolled up first to the "task" level (e.g. "Remove Utilities" or "Place Gloveboxes In-Service") and then to the overall Set level.

An estimate breakdown for a typical Set is shown in Table I, with the "task" in gray and the work units supporting that "task" given below. For purposes of earned value tracking, work elements in the second and third columns were associated with glovebox charge numbers, those in the first columns associated with non-glovebox charge numbers.

As it became time to track decommissioning progress, a system to collect earned value was defined based on the baseline cost estimate. The schedule activities were also developed during the planning process. Work package development and the project control earned value system was structured around major pieces of equipment, typically gloveboxes. The estimate elements that were associated with all gloveboxes were distributed across the gloveboxes, typically based on glovebox surface area. The estimate elements not associated with gloveboxes were distributed as much as possible to other large pieces of equipment, gloveboxes, or specific areas to create distinct scope elements that could be evaluated for earned value (percent complete) on a weekly basis for progress reporting. Thus the earned value system maintained the integrity of the estimate structure at the Set and Subset levels, but the connection to the estimate at the work unit level was less exact.

In 2000, we made an initial attempt to correlate the direct hours for the decommissioning activities by charge number in three completed Sets, with very scattered results. We were able to identify a number of potential causes for this scatter, including non-uniformity of gloveboxes (e.g. differences in dimensions or contamination levels), poor time charging practices, and estimating inconsistencies. A decision was made to perform a more detailed analysis in an attempt to obtain more consistent labor hour productivity by activity, and costs per unit.

Two approaches were used. The Completed Set Multiple Regression Approach took advantage of the fact that there are now more completed Sets available – currently twelve with cost and estimate data that appear reasonably complete and consistent. It uses multiple regression techniques to compare estimated quantities of glovebox volume, duct surface area, tank volume, and Set footprint to determine unit rates for each.

The Single-Set Earned Value Comparison Approach makes use of original estimate and project control data derived from scheduling and earned value determination to more closely compare the glovebox and other material removal costs with their quantities and characteristics. It subdivides the worker hours by activities that were conducted over time to yield initial data on the efforts that were expended on those activities. It then assesses the quality of that data.

Table I – Typical Building 771 Decommissioning Estimate Elements

Non-Glovebox Subsets	Glovebox Subsets	
Utility Removal	**Place Gloveboxes In-Service**	**Erect Soft-Sided Containment**
Systems # Isolations	Certify/Prep # Glovebox	SSCs # Setups
#Panels/Conduit – ft.	Change # Windows	
Rigging # Setups	Change # Gloves	
Scaffold # Setups		
Ext LL Equip	**Internal GB Equip**	**Separate Gloveboxes**
Proc Pipe # Setups	# Vessels/Racks	Scaffold # Setups
Rigging # Setups	# Unique Components	Rigging # Setups
Scaffold # Setups	Debris	Cutting – ft. of cut
# Component Size Reduction		Wrapping/Packaging
Wrapping/Packaging		Area # Decons
Ext Pipe/TRU Equip	**Glovebox Decontamination**	**Size Reduction**
Systems # Isolations	Gloveboxes - # wipes	Scaffold # Setups
Process Pipe – ft.		Rigging # Setups
Scaffold # Setups		Cutting – ft. of cut
		Wrapping/Packaging
		Area # Decons
Duct/Misc. Equipment	**Apply Fixatives**	**Structural Support Removal**
Duct – ft. of cut	# Gloveboxes	Structural Support # Removals
GB Overheat	**Perform SCO Survey**	**Remove SSC**
# Glovebox Sections	# Gloveboxes	SSCs # Removed
Recover Area	**Remove from Vent**	
Fixed per Set	Systems # Isolations	
	Process Pipe – ft.	
	# Sleeves	

COMPLETED SET MULTIPLE REGRESSION APPROACH

Method of Analysis

The concept for this approach was to identify labor hours by decommissioning activity by first collecting estimate "metrics," i.e. raw data such as cubic feet of gloveboxes or tanks or linear feet of pipe from building walk-down and take-off data, for each completed Set. We also collected the overall Set actual direct hours. With a sufficient number of completed Sets with varying metrics, a "multiple regression" algorithm may be applied to determine the coefficients that, when multiplied by the individual metric quantities and summed by Set, result in the best fit. The use of this method came partially as a by-product of the work accomplished by our group on waste generation estimates.

Of the fourteen completed Sets, only the most recent twelve had labor hours that could be segregated by charge number and discipline to isolate the direct labor (Kaiser-Hill craftsmen and foremen) from the planning and support labor. We recognized that it would be impossible to use all of the work units in a regression, and that some intermediate-level metrics would need to be defined. Instead of "length of cut" data for gloveboxes we used glovebox volume. Similarly, tank and duct data were changed from "length of cut" to tank volume and duct surface area (i.e. similar to sheetmetal takeoffs), respectively. A direct translation for Low-Level Equipment, Utility Removals and Pipe was too complicated, and the Set footprint, i.e. the rooms or floorspace covered by the Set tanks, gloveboxes and other equipment, was identified as a simple way of representing those work elements.

A number of trial regressions were performed using various combinations of these and other metrics and actual data, such as substituting glovebox surface area for volume, adding piping data, and comparing selected metrics against sub-groupings of the actual costs such as just size reduction. Based on the results of these trials, the final metrics used were the standing volume of glovebox (segregated between those gloveboxes size reduced as TRU and those decontaminated for disposal as LLW), duct surface area, tank volume, and the Set footprint area.

The multiple regression analysis was conducted using the imbedded Microsoft Excel "linest" function. This function specifies the constants (A, B, C, …) for an equation of the form A*X + B*Y + C*Z … = W, where X, Y, Z … represent the metrics and W the estimated labor hours. The constants are those that provide the best linear fit for the raw data provided, in this case the metrics and the actual labor for the completed Sets. Ideally, these constants should approximate the factor for labor hours per metric for a stand-alone activity such as removing a glovebox. However, the constants do not represent a direct comparison between metric quantities and hours worked such as could be derived from accurate cost collection for that activity. They only represent the labor hours that may be mathematically attributed to the metric within the context of all of the decommissioning work. The "linest" function also returns various indications of the validity of the correlation, the most useful being the correlation coefficient, R^2. A value of R^2 of 1.0 would represent perfectly collinear data; a value of 0.0 completely random data.

Results

After several trial regressions, we determined that the best fit was the data shown in Table II, and also shown graphically in Figure 1.

Table II – Multiple Regression of Completed Set Data

Set	**GB-TRU**	**GB-LL**	**Duct**	**Tanks**	**Area**	**Actual**	**Estimated**
Units	Ft^3	Ft^3	Ft^2	m^3	Ft^2	Hours	Hours
7	416	0	0	0	561	15,605	6,004
12	420	0	0	0	588	9,411	6,123
27	362	0	0	194	637	8,036	9,430
38	2,209	781	1,615	5	3538	43,453	43,455
43	90	1,355	420	82	1530	24,149	19,830
46	1,327	0	0	0	2940	15,241	22,406
60	216	108	0	0	1551	16,999	7,651
65	0	1,070	332	0	502	7,371	11,653
67	1,256	0	514	62	880	17,339	17,939
68	133	444	791	92	1656	5,799	13,280
69	825	216	1,143	133	1780	25,174	20,343
72	0	0	3,345	0	0	5,992	5,898
Total	7,255	3,974	8,160	567	16,163	194,570	184,012
Constants (Hours/Unit)	10.62	9.018	1.76323	19.494	2.8252	0	

The first item we examined in the analysis of the regression data was the R^2 value, which at 0.72 was relatively high. Examining Figure 1, which is merely the plot of the two right-most columns of Table II, shows the clustering of the data. In an attempt to see if the regression was dominated by Set 38 (the point in the upper right corner of Figure 1), the regression was re-run without the data from that Set, and the constants returned from the regression were almost the same.

Another basis for using this group of metrics was that the constants were all positive and seemed to be reasonably close to what would be expected as factors for these activities. Other combinations of metrics and charge numbers sometimes yielded situations with negative constants. This could be interpreted as the more pipe that a Set contained, the fewer labor hours needed to complete the Set, which is not consistent with real situations. While judging regression accuracy based on preconceived expectations is inappropriate by itself, it is clear that the gloveboxes are the greatest portion of the effort in this work, and constants that are either negative or suggest that, for instance, piping was the greatest labor contributor are of little use.

SINGLE-SET EARNED VALUE COMPARISON APPROACH

Method of Analysis

The concept for this approach was to correlate labor hours to decommissioning activities by first to using the earned value data over time to assign the direct labor hours to specific gloveboxes or other media. The earned value data and the labor hours were both available for each week. The earned value system separated the work performed among individual gloveboxes and also among the non-glovebox work activities. Specific work on one glovebox and many of the other activities at this level of resolution was most often done sequentially, and completed in at most a few weeks. If the earned value accurately reflected the labor expended, then the fraction of the weekly labor on a given glovebox should have been equal to the fraction of the weekly earned value assigned to that glovebox.

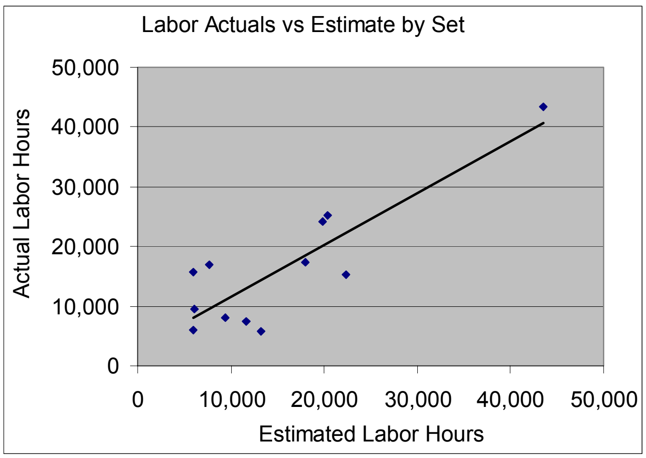

Fig. 1 – Scatter Plot of Actual Hours vs. Estimated Hours

The intended product of the analysis was unit rates based on the discriminating characteristics of the gloveboxes and equipment. For example, if a specific glovebox was lightly contaminated it might not be size reduced, but disposed of as low-level waste in a larger container. By collecting the data on a number of such gloveboxes across several Sets we could develop an average unit rate (direct labor and/or cost) for some metric (i.e. glovebox volume or surface area) to remove a lightly contaminated glovebox. That unit rate should be different than the unit rate for a glovebox that would require extensive decontamination to be dispositioned as low-level waste, or for a glovebox size reduced and dispositioned as transuranic waste.

Set 38 was selected for the first evaluation because it contained a number of different types of gloveboxes, and was a relatively large Set with a duration of over one year, and is the only Set that we have analyzed to date. Development of the labor data by week was relatively straightforward. All craft crew and supervisor hours, whether straight time or overtime, was collected from the Site accounting system. Hours that were direct-charged by technical support were removed. The only readily identified source of error was in monthly adjustments, which for a few weeks represented a significant portion of the total weekly labor. The result was the Set labor hours from the week of March 5, 2000 through the week of August 26, 2001 for each of the six Set 38 execution charge numbers. These were subsequently summarized into size reduction and glovebox (which contained all the Set 38 in-room work) since the other charge numbers labor data was too sparse to correlate with earned value data, and probably was not representative of the work performed. Days of down-time were identified from the schedule data, and subtracted from the labor data. This information was included as a separate item in the roll-up.

The earned value (in dollars) was arranged approximately by "task" (see Table I) and then further divided into glovebox or other area/grouping. The earned value data was available in a number of separate sheets that rolled up to the total estimated value for the Set. Since it could be related back to the estimate, the earned value could be manipulated to isolate a variety of work elements that could not be directly identified in the charge numbers. Individual glovebox volumes and surface areas, and tank volumes, were also available independent of the estimate.

Analysis of the size reduction scope was relatively straightforward, since there were a limited number of gloveboxes and activities, and it could be compared to a credible charge number breakout. The work on individual gloveboxes was also very sequential since there is typically only one glovebox in a size reduction facility at a time. The size reduction grouping of glovebox earned value was compared with the size reduction charge number labor hours, the hours per glovebox for each week were determined, and summed to determine the total hours per glovebox. Since the relevant metrics (glovebox volume and surface area) was readily available, the comparisons could be made directly. The comparison of this data against the glovebox volumes and surface areas is discussed in the Results section.

The remaining groupings of earned value for in-room activities were compared with the sum of the remaining charge number labor hours. The earned value was grouped in several ways. One grouping segregated the earned value for the piping, duct, balance, and glovebox earned value, and then subdivided the glovebox earned value by the glovebox categories in Table I, thus grouping by "task" or kind of work. The glovebox earned value was separately subdivided by individual glovebox, i.e. by "equipment item".

The labor hours were then allocated to the piping, duct, balance or glovebox elements, and then to each glovebox (cut one way) or "task" (cut the other) grouping based on the fraction of the earned value attributed to that glovebox or grouping in the given week. Once the hours for each week and for each grouping were determined, they were summed to provide the total hours per glovebox or hours per "task" for in-room Set work. The comparison of this data against the glovebox volumes and surface areas is discussed in the Results section.

The analysis then identified the ratio of the labor hours per dollar of earned value. A large variation in this ratio among the "task" types could mask glovebox differences, and preclude the use of the approach to discriminate between glovebox types. There was considerable variation, indicating that the estimates were low compared to the effort that it was taking to perform some "tasks," and high compared to the effort required for others. The variation of the ratio appeared to be overwhelming the ability to distinguish the variation of effort between the different types of gloveboxes, the intent of the analysis, and also increasing the scatter of the glovebox of similar types.

In an effort to improve discrimination between gloveboxes, the labor hour per dollar of earned value ratio was normalized across the "tasks." That is, if the labor hours to achieve $1,000 for earned value were higher for glovebox decontamination than for applying fixatives, the earned value of decontamination was increased and that for applying fixatives was decreased for the whole Set until the ratios were equal. The direct result of this was to increase or decrease the earned values of the "task" types, leaving the overall total the same. This resulted in a significant improvement in correlation of glovebox data. The labor hours by glovebox for each week were then summed to give a total for each glovebox, and also for the other overall estimate elements (overall duct, pipe, tank, and balance elements).

One confounding effect that was identified was the lag between when the work is performed and the date that the earned value is taken. An algorithm was developed that allowed the averaging across the previous two, three, or four weeks prior to then the earned value was taken for a particular activity, and an analysis was conducted based on an improvement in correlation. Another problem was that there were a few weeks where there was either earned value taken and no actual labor hours charged, or actual labor hours charged and no earned value taken. This was merely the most extreme example of weeks where the earned value and the actual labor hours charged did not correlate well. There was no way to correct for this problem, and it appears to be a significant contributor to the scatter of the data.

Results

The labor hours required to size reduce each glovebox was plotted against the in-place glovebox metrics in Figure 2, Panels 1 and 2. Initial data for the gloveboxes is shown as dark diamonds. As the data was examined further it was observed that the three extreme points represented three of four gloveboxes that were size reduced over a four-week period. A second plot of the same data adjusted based on schedule data from the four-week period is shown as light squares, and results in a significant damping of the extreme points. This analysis included only the gloveboxes in Set 38B and Set 38C. The Set 38A and Set 38D gloveboxes were either essentially clean (gloves never installed) or clean enough to be size reduced without using the Size Reduction facility. The equations and correlation coefficients are shown.

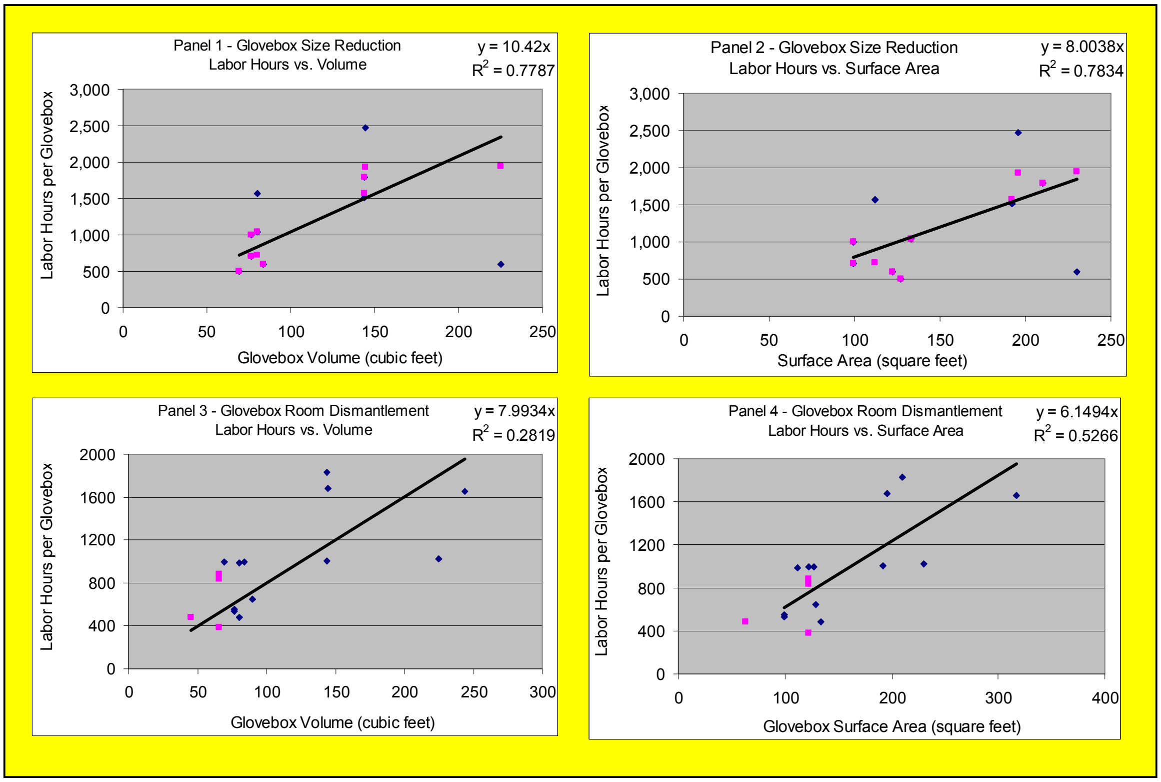

Fig. 2 – Size Reduction and In-Room Glovebox Evaluation

The labor hours required to perform all of the in-room Set work for each glovebox was plotted against the glovebox metrics in Figure 2, Panels 3 and 4. The data on glovebox earned value for the in-room work is spread over a much longer period than the data for size reduction, and subdivided into different estimate elements making correlation much more difficult. The correlation was particularly bad before October, 2000. The data in the dark diamonds represents the glovebox groups 38C and 38D, which were more contaminated and proceeded on to size reduction. The light squares were glovebox group 38D, which were more lightly contaminated and size reduced in place.

The impact of the normalization process on the hours by major work element is shown in Figure 3.

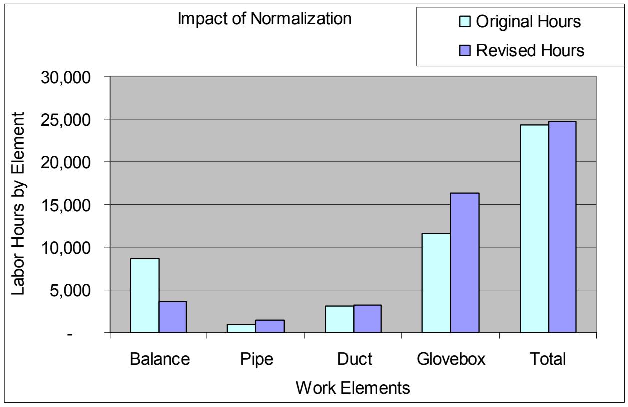

Fig. 3 – Impact of Normalization on Different Work Elements

The net impact at the highest level was that the hours assigned to the "balance" scope decreased and the hours assigned to the glovebox scope increased, reflecting the overestimating of the "balance" activities.

After the work "types" were normalized, the labor hours by glovebox were computed (as shown in Figure 2). To identify which gloveboxes required above or below average effort, the individual gloveboxes labor hours were divided by their earned value (i.e. estimated cost) and normalize to the Set average. Figure 4 shows the result.

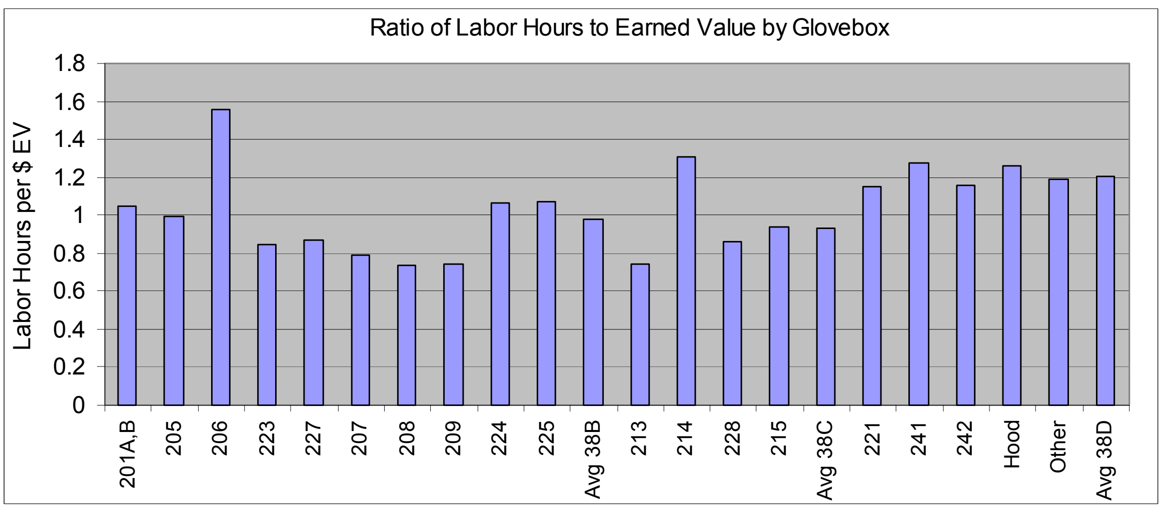

Fig. 4 – Analysis of Glovebox Actual Labor vs. Estimate

In this plot, the greater the ratio of labor hours to dollars of earned value, the greater the effort to decommission the glovebox over that estimated. The results show no clear trend, except that the group 38D gloveboxes that required no subsequent separate size reduction did require more in-room labor. We are continuing to investigate the differences in the gloveboxes to identify the characteristics that result in the individual differences.

Table III – Comparison of Results between the Overall Completed Sets and Single Set Approaches

Multiple Regression Approach				Single Set Approach		
	Regressed				Derived	
	Set 38 Hrs	Factors			Set 38 Hrs	Factors
GB – TRU (cubic feet)	23,462	10.6		GB - Room	16,989	5.7
GB - LL (cubic feet)	7,045	9.0		GB - SR	15,346	10.1
Subtotal GB	30,507	19.6		Subtotal GB	32,335	15.8
Duct (square feet)	2,848	1.8		Duct	3,362	2.1
Area (square feet)	9,996	2.8		Balance	3,840	1.1
Pipe (linear feet)				Pipe	1,576	0.85
TRU Tanks (cubic meters)	104	19.5		Tanks	18	3.6
Lost Time					2,322	
Total	43,455				43,453	

Comparison of Results

The results of the Multiple Regression and the Single Set approaches are compared in Table III.

The table shows reasonable comparison for the regressed and derived values. Although the glovebox data could not be compared at the lowest level (i.e. by factor, because the Multiple Regression approach did not yield good results when size reduction was introduced as a variable), the results at the subtotal level are similar. However, a TRU glovebox would likely need both in-room effort and size reduction (5.7 + 10.1 = 15.8 hours/cubic foot) while a LL glovebox should need just in-room effort. Viewed that way, the Multiple Regression TRU factor would be 67% of the Single Set TRU factor, and the Multiple Regression LL factor would be 160% of the Single Set equivalent. The values for the duct are very close; those between the area and the balance and pipe are similar, but again are difficult to compare directly since the metrics are different. Tank values provided by the Multiple Regression approach are probably more reliable since the Set 38 tank data was so sparse, although neither is very robust. It should be noted that in most cases the tanks are raschig-ring filled tanks used to store plutonium nitrate solutions.

Overall, both methods had significant scatter, but show initial promise. The fact that the glovebox subtotal is so close is encouraging; we hope that by collecting more data or reconfiguring existing data we will be able to reconcile the differences of the lower-level factors. The Single Set approach yielded more detailed information in a form that could be used more directly by cost estimators, and is believed to be more reliable. The agreement between the slope in Figure 2 and the overall averages suggests good correlation. Although it required much more effort to develop, it should be more useful for detailed estimates because it can differentiate between size reduction and other glovebox activities at a lower level of detail. However, if the work methods change or the scope of the effort is significantly different from Set 38, the factors might in fact be less accurate. The Multiple Regression approach factors might be more appropriate for conceptual-level estimates and as a check of the more detailed data, and required much less effort to develop.

RELATIONSHIP OF DIRECT LABOR TO TOTAL PROJECT COST

Once the analysis determined the direct labor hours for disposition of the gloveboxes and other equipment associated with the Sets, a similar analysis assigned first costs to the labor hours, and then indirect costs to the unit rate. These indirect rates included waste management, supplies, and project management, among other expenditures. The results would be an overall rate that could be used for cost estimates of similar facilities.

An analysis was conducted to identify the portion of the overall project costs that would apply to the glovebox metric. The costs for the project were collected on a monthly basis and correlated to the activities occurring in the relevant Sets. The monthly costs were divided into general project management and related overall project costs (including building surveillance and maintenance), direct deactivation, direct decommissioning, decommissioning support, and support services. The support services grouping includes technical support, waste support, security, and special projects. The indirect costs were pro rated by direct labor element (deactivation systems and decommissioning Sets) to determine the "build-up" cost per direct labor hour for the relevant Sets. This factor was then applied to the direct labor hour per metric.

It is important to discuss what the "build-up" costs contain, and to distinguish them from overhead costs. The analysis intentionally used an extremely restrictive definition of direct labor hours, defining them as productive hours spent within the controlled area to perform direct decommissioning work on equipment. Labor hours expended for training and when the job was shut down were not included in the direct hour total. The "build-up" costs thus contain all other project costs, although not Site overhead costs such as central engineering and accounting – costs that on commercial projects might be considered G&A. Set non-direct labor includes the engineering to develop work packages and job down time. In apportioning the general and the waste categories, the analysis considered only the other decommissioning and deactivation costs to be direct costs. All other project costs were non-direct. Thus, hourly workers in the same room but doing waste packaging and certification were not considered direct labor. These other project costs included most of the materials and supplies, small tools, costs for the size reduction facilities, engineering, authorization basis support, laundry, direct management, planning and regulatory support, and training. It also included the surveillance and maintenance costs, i.e. the costs to maintain nuclear facility systems operating at an adequate level of surety.

The Set 38 estimate was collected as a percentage of the total decommissioning earned value during the period that it was being worked, and this data was correlated with the overall costs by category and earned value of direct labor activities being conducted at the same time, between April, 2000 and August, 2001. The results are shown in Table IV.

Table IV – Set 38 and 771 Project Cost Data

Direct Labor		Other Direct Costs (ODCs)	
General PM/S&M/Project Hours	367,539	General PM/S&M/Project Costs	14,226,869
Direct Deactivation	185,753	Direct Deactivation	9,537,104
Direct Decommissioning	198,396	Direct Decommissioning	6,420,258
Decommissioning Project Support	5,896	Decommissioning Project Support	7,118,813
General Project Support (Waste, etc.)	213,108	General Project Support (Waste, etc.)	17,569,636
Total Labor	970,693	Total ODCs	54,872,681
Direct Set 38 Labor Hours	41,131	Direct Set 38 ODCs, $	484,886
Lost Time	2,322		
Buildup Labor, hours assigned to Set 38		Buildup ODCs, $ assigned to Set 38	
Set Non-Directs	1,935	Direct Set 38 ODCs	484,886
General Non-Directs	43,425	General ODCs	1,680,921
Decommissioning Non-Directs	1,349	Decommissioning ODCs	4,019,459
Waste Non-Directs	25,179	Waste ODCs	2,075,873
Total	71,888	Total	8,261,139
Buildup Labor $/Set 38 Hours		Buildup ODCs, $/Set 38 Hours	
Set Non-Directs	2.18	Direct Set 38 ODCs	11.16
General Non-Directs	43.27	General ODCs	38.68
Decommissioning Non-Directs	1.52	Decommissioning ODCs	92.50
Waste Non-Directs	22.99	Waste ODCs	47.77
Total	69.97	Total	190.12

Combining the overall data and the unit rates, the costs for the given metrics identified from the 771 Project can be determined. The unit costs are summarized in Table V.

Table V – Unit Cost By Metric

Unit Metric	Labor Hrs	Direct Cost	Build-up Cost	Total Cost
GB - In-room (cubic ft.)	5.68	$221	$1,402	$1,624
GB - Size Red. (cubic ft.)	10.13	$394	$2,501	$2,895
Duct (square ft.)	2.08	$81	$514	$595
Balance (square ft.)	1.09	$42	$269	$312
Piping (linear ft.)	0.852	$33	$210	$244
Tanks (cubic meter)	19.5	$759	$4,815	$5,574

CONCLUSIONS AND FUTURE WORK

The work performed in this effort establishes an initial basis on which to develop more accurate estimate factors. The analysis of the 771 Project data, and in particular the Set 38 data, was successful in developing a set of quantitative cost and labor unit rates for the decommissioning of gloveboxes, and in quantifying the higher-effort gloveboxes from the lower-effort gloveboxes. The rates are based on actual data, and are the best information currently available. The method was able to develop values for the non-glovebox costs in the absence of accurate charge number data. Finally, the analysis provided non-direct costs that could be applied to the glovebox metrics.

The multiple regression approach gave higher-level data, which should improve as more Sets are completed. In particular, we intend to examine smaller groupings of like Sets, such as those functionally connected with tanks, and determine if we can achieve greater discrimination of different metrics with that method. While the approach may never satisfactorily develop the level of resolution to support detailed estimating, it is certainly valuable in evaluating distinctions between Sets and as a check of the more detailed data.

The use of earned value data to determine labor rates provided detailed rates with a degree of internal consistency. We still need to complete additional Sets to ensure consistency and reduce the data scatter. We have not yet achieved one of the initial objectives of using the data to classify the gloveboxes into types (e.g. standard 2 X 3 X 8 foot vs. oversize or by contamination level) that could be used in a more refined estimating approach.

One of the systematic problems identified for Set 38 was the problem with worker mis-charging, particularly for the non-glovebox activities (e.g. pipe, duct) and particularly before October 2000. There was also some charging to the wrong Sets, and it was difficult to clearly identify non-productive hours (e.g. training) that would be charged to the actual work other than anecdotal data on shutdown periods. Some revisions to the charge code structure and training to allow the individual pieces or types of equipment would significantly improve the data quality. A preliminary review of the distribution of the charge number data for other more recent Sets appears to indicate better charge number compliance, which should give us a better ability to derive unit rates.

A second problem was that in the restructuring of the estimate both during a rebaselining effort and in the development of the earned value data, some of the resolution of the original estimate was lost, or, in the case of the duct, the actual data had to be recreated. The data supporting the non-glovebox work was difficult to correlate with the work both because of vagueness in both the estimate and earned value data. A significant lesson learned out of this is that it is advisable that estimates always correlate back to tangible items of equipment, since Sets will be reorganized as work is better defined, earned value is taken by equipment piece, and not all equipment in a given category (e.g. gloveboxes) is the same.

Some areas in which additional efforts are intended over the next several months are in analyzing additional Sets. The first purpose is to analyze additional gloveboxes, and other data, specifically tanks, that was under-represented in Set 38. Additionally, the 771 Project is beginning to aggressively decontaminate gloveboxes, which will reduce the transuranic waste and the size reduction effort for a given glovebox, and thus should significantly reduce costs. Some of Sets with gloveboxes that were originally intended for size reduction have been decontaminated and can be analyzed. We intend to use these methods to develop this data.

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