Environmental Cleanup of the Nation's Former Nuclear Weapons Sites:

Unprecedented Public-Private Challenges at the Largest Facilities

By

Henry Mayer, Josephine Faass, Michael Greenberg and David Lewis

CRESP Center for Social and Economics Issues

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Authors

Henry Mayer, Ph.D., is Executive Director of the National Center for Neighborhood and Brownfields Redevelopment, at Rutgers University. Dr. Mayer has extensive experience in the corporate, academic, and government arenas, with a focus the past ten years on the complex environmental, infrastructure, and financial issues associated with the redevelopment of many of the country′s older and former industrialized cities. Dr. Mayer is a member of CRESP, a five University consortium that works with the Department of Energy on the cleanup and reuse of its former nuclear weapons sites.

Josephine Faass, is Ph.D. Graduate Assistant in the National Center for Neighborhood and Brownfields Redevelopment, and currently examining the status of cleanup and natural resource damage issues at the Department of Energy's largest former nuclear weapons sites.

Michael R. Greenberg, Ph.D., is a Professor, the Associate Dean for Faculty at the Edward J. Bloustein School of Planning & Public Policy, and Director of the National Center for Neighborhood and Brownfields Redevelopment. Dr. Greenberg has focused on urbanization, industrialization, and environmental health policy issues for many years, and contributed more than 475 publications to both scientific and public interest journals. He has received career research achievement awards from the Society for Risk Analysis and the American Association of American Geographers, and awards from the USEPA and the American Public Health Association for education and research. Dr. Greenberg is a Management Board Member of CRESP, and the CRESP Chair of the Public Policy, Economic, Social Impacts, and Land Use Planning Center of Excellence.

David Lewis, Ph.D., is an Assistant Professor in the Department of Geography and Planning at the University at Albany. Lewis' research interests have focused on the intersection of innovation and regional development, business incubation, and sustainable development. His research has catalyzed interest from policy-makers from the local to global scale including the Japanese Ministry of Industry and Trade, U.S. Departments of Commerce and Energy, the States of New York and New Jersey and a variety of counties and communities across the country. Currently, he is working on developing a regional approach to rural economic development through asset mapping and developing methodologies for regional fiscal impact analysis.

Abstract

In 1994 the U.S. Department of Energy initiated a contract reform program intended to strengthen oversight capabilities, and to encourage the creation of contract and incentive structures which would effectively facilitate the treatment of onsite contamination and waste. The remediation and disposal of these legacy wastes is the core of the Department's environmental management mission (GAO, 2003). Despite a concerted effort toward achieving the goals of the reform, progress has been slow. Many projects continue to necessitate cost and time extensions, above those originally agreed upon. Although the Department instituted an accelerated cleanup program in 2002, promising to shave some $50 billion and 35 years from its earlier cost and schedule projections, there have been delays in critical project areas which call into question the attainability of the proposed reductions (GAO, 2005). Numerous explanations have been offered as to why achieving these goals has proven so difficult; many of which have concluded that flawed contracting practices are to blame. This article concludes that the root of the problem is much deeper and that the organizational criticisms aimed at the DOE are as much a legacy as the waste itself. Although the focus of this paper is on large former nuclear weapons sites, these types of contracting and organizational issues are often found at other government and private complex hazardous waste sites.

Introduction

Since the inception of the Manhattan Engineering Project that produced the world's first nuclear weapons, a virtually unique public-private partnership has evolved in the United States in an attempt to overcome the challenges in managing the complex tasks and uncertainties associated with nuclear weapons and their legacy. Beginning with construction and operation of the first production facilities at Hanford and Oak Ridge in the 1940s, the federal government has relied on the private sector to provide the engineering and management expertise required to make these programs a success. The private sector role has changed over the years so as to adapt to and support the needs of the Atomic Energy Commission (AEC), and its successor the U. S. Department of Energy (DOE). In the early 1990s, that role expanded to include the environmental cleanup of the nation's Cold War nuclear waste legacy.

Currently, almost 90 percent of the DOE′s annual budget of $21 billion is paid to private and public sector contractors, and of this amount, $16.2 billion is used to manage and operate 28 major sites (GAO, 2002b and 2003). In the United States, only NASA has a similarly high proportion of government contract work. Although the DOE, and its predecessor the AEC, were able to successfully avail themselves of private sector expertise and resources in the development and production of nuclear weapons during the 1950s and 1960s, more recent contracting processes related to remediation have come under criticism for being inefficient (GAO, 2001, 1999, 1998a; Figura, 1999) due to the under utilization of more innovative technologies that reduce costs and environmental hazards (GAO, 1999) and excessive cost overruns for major capital projects (GAO, 2001, 2000a; Figura, 1999). Further, the DOE has also been criticized for misalignment of contract incentives with organizational goals (GAO, 1998a, 1998b, 2001), over-indemnifying the contractors (GAO, 1993 and 1996), failure to sufficiently protect worker safety and the environment (Kaltenheuser, 1999), and insufficient oversight of contractors (GAO, 2001, 1999). While similar criticisms have been voiced with regard to the remediation efforts undertaken as part of the Superfund program, as well as those conducted by the Defense Department and others, they are most strongly associated with cleanup work done at DOE sites.

In response to these criticisms, in 1994 DOE initiated a contract reform program intended to strengthen oversight capabilities and to encourage the creation of contract and incentive structures, which would effectively facilitate the remediation and disposal of legacy wastes (GAO, 2003). Despite a concerted effort toward achieving the goals of the reform, progress has been slow. Many projects continue to necessitate cost and time extensions, above those originally agreed upon. Although the Department instituted an accelerated cleanup program in 2002, promising to shave some $50 billion and 35 years from its earlier cost and schedule projections, complicating factors have already caused delays in critical project areas and call into question the attainability of the proposed reductions (GAO, 2005). Many explanations have been offered as to why addressing the contamination and waste issues present at various sites across the country's former nuclear weapons sites has proven so difficult, with most concluding that flawed contracting practices are to blame.

This article presents data that suggests that the root of the problem is much deeper and that the organizational criticisms aimed at the DOE are as much a legacy as the waste itself. It begins with a failure on the part of the federal government to fully recognize that in its push to develop and manufacture a storehouse of ever more powerful nuclear weapons after World War II, it had created a veritable soup of high level and mixed hazardous wastes that had never before been encountered. Because of the need for strict security and secrecy, only a handful of scientists and engineers had an understanding of the waste streams created, and few, if any, had focused on how they might react over time in the places where they had been dumped or stored, or what more sustainable remediation solutions might be necessary in the future.

With the end of the Cold War, the DOE was faced with the need to address huge quantities of legacy nuclear wastes spread across more than two dozen major sites and many smaller ones (over 100 in total) located in multiple states in every region of the country. Initially, the Department turned to the same private contractors that had been operating these research and production facilities for technical and managerial remediation expertise. This decision was based in part on their perceived familiarity with the production facilities and waste streams created, but also on the need to maintain security and secrecy about the nation's bomb-making processes. National defense concerns were raised regarding the potential of an analysis of residual wastes divulging weapon design and production process secrets. Although logical in concept, this approach had the effect of limiting the quantity and quality of available scientific and engineering expertise to those organizations and individuals who had built and operated the nuclear reactors and other weapons production facilities, the same individuals who had left the sites in their highly contaminated condition.

An urgency and further complexity was added through the numerous cleanup agreements that the DOE entered into with State governments. Most required the DOE to achieve specific legally enforceable cleanup schedule milestones, and many required that radioactive wastes be removed and shipped to more permanent repositories in another state (GAO, 2002a; Blumenthal, 2005). At the time these agreements were made, methods for treating the largest quantities and most complex waste forms were only in the earliest stages of research, and a permanent geological depository for high-level waste was only in the design stage and its final location was still a matter of much congressional debate.

Nearly fifteen years and $90 billion into its remedial action campaign, results are mixed. Work at the Rocky Flats, Fernald and Miamisburg-Mound sites are nearing early completion at or below budget. Yet the large high-level waste vitrification projects at Hanford and Savannah River, the tank waste removal at Hanford and the transuranic (TRU) waste removal at Idaho National Laboratory are years behind initial schedules and billions over budget. The objective of this article is to examine why these differences in outcome may be occurring, and what roles the contract form versus technical uncertainties are playing at the various sites.

The article is divided into four sections. The first discusses contract theory and the roles of uncertainty and financial risk; the second looks at the history of the DOE's contracting practices; the third section includes several case studies related to the Department's successes and failures associated with contracts awarded since 2000; and the final section summarizes the findings and offers several possible paths for improving results.

Contract Theory

The analysis that follows is centered on uncertainty and risk. While integral to understanding the subject at hand, these terms are used extensively and in widely divergent contexts. Therefore they may take on slightly different meanings for different people. For this reason, a brief introduction to these concepts as they relate to contract theory and to the DOE's contract reform effort is provided here. The notion of financial risk allocation between principle and agent, an important, though likely less familiar tenet of contract theory, is also discussed.

Uncertainty is said to occur when the amount of information needed to perform a given task is greater than that which is possessed. Its presence during contract formulation makes the accurate prediction of the probabilities associated with a set of outcomes problematic (Kollveit et al., 2004). Due to the nature of the work, both external and internal uncertainty are often hallmarks of the DOE’s environmental management projects and are usually more prevalent at larger sites exemplified by complex contamination and waste concerns. Sources of external uncertainty, which is said to result from factors beyond the project’s scope, include future congressional budgetary allocations and the need for regulators, such as the U.S. Environmental Protection Agency, to reach a final decision regarding the cleanup standards that must be attained at each site (GAO, 1999). Internal uncertainty, which can originate from a project’s goals, technical concept, or from the organization’s own competence, is also prevalent (Kollveit et al., 2004). The unclear composition of many of the contaminants to be addressed and the frequent need to develop new technologies to accomplish cleanups, translate into a lack of internal information that can significantly impact project outcomes (GAO, 1999).

In terms of contract design, risk is associated with the ramifications (both positive and negative) of possible events, and is said to exist "in situations where each outcome has a known probability of occurrence" (Kollveit et al., 2004). This element of risk is often present in contracted work, including that occurring across the U.S. nuclear weapons complex. The outcomes associated with various risks may impact project costs, but because their likelihood of occurrence is known in advance, they can be accounted for in the planning process. An event involving the exposure of a worker to radioactivity above allowable levels during the remediation of a waste storage tank is an example of a project-related risk. This is because task-specific procedures in combination with established health and safety practices, largely determine the likelihood of such an accident occurring. The ramifications related to both the health effects and any associated legal and monetary penalties could be predicted in advance.

Allocation of Financial Risk

Unlike some project-specific types of risk, the allocation of financial risk is a ubiquitous element in contract design and forms the underpinnings of much of the existing theory on the subject. During the formulation of any agreement, there is a mutual understanding that regardless of the specific terms selected, there will always remain the possibility that the contractor will be unable to accomplish the desired tasks within the allotted time and cost budgets (Umanath et al., 1996). The decision as to how much of the resulting cost overrun should be assumed by each party in the event of such a variance is often thought to be a significant determining factor in the contract's overall effectiveness (Keisler et al, 2004; Ward & Chapman, 1995; Scherer, 1964; Barron, 1972).

When viewed from the perspective of either the principle or the agent, financial risk allocation is something of a conceptual hybrid, incorporating elements of both “risk” and “uncertainty” as they are understood more generally. Each party has some prior expectation as to the likelihood that cost or time excesses will occur. This expectation however, is formed through a combination of factors over which they can exert control, and an estimate of possible outcomes related to the elements controlled by the other party. The chance that additional costs will be incurred as a result of one's own actions therefore, is akin to risk, because there exists a basis upon which to make predictions. Uncertainty results because there is no way to reliably predict the likelihood of overruns occurring as a result of elements under the other party's control (Umanath et al., 1996).

Theory holds that to the extent that the contractor is asked to assume less than the optimal amount of financial risk, their motivation to stay within budget and to abide by various other constraints is lessened. Should they be allocated too much risk, however, they will likely increase their compensatory requirements, so as to provide a kind of financial buffer against unexpected events. This additional price is often dubbed a “risk premium” and can vary greatly in magnitude dependent upon the nature of the work and the level of risk aversion of the contractor (Keisler et al, 2004; Ward & Chapman, 1995).

Contract Structures

Many different contract structures have been developed to accommodate the need for various levels of uncertainty and financial risk allocation. Fixed price contracts lie at one end of the spectrum and force the contractor to assume total responsibility for potential cost overruns. Cost plus fixed fee contracts, which put the burden squarely on the shoulders of the contracting agency, form the other extreme. The risk gradient between fixed price and cost plus structures is made up of various types of incentive contracts, a design under which a fraction of the risk is assumed by each of the parties, rather than allocated in its entirety to one or the other (Scherer, 1964). Since settling on performance based incentive contracts as the design of choice for conducting environmental management projects, the derivation of effective criteria has been one of the DOE's top priorities. The conception of these elements is critically important because they determine not only the degree of financial risk sharing, but the nature of the compensation available, which is the primary mechanism whereby the client motivates the contractor to work towards achieving their objectives (Ward & Chapman, 1995).

During contract formulation, the elements of risk, uncertainty and financial risk allocation must all be considered, yet the ease with which each can be effectively accommodated by any one design varies. By its very nature, uncertainty is the attribute whose ultimate impacts on project success are most difficult to predict in advance. While the Department's current conception of performance-based incentive contracts for accomplishing its environmental remediation and management projects appears effective with regard to smaller, less complex sites, it has not proven a satisfactory methodology for addressing the larger and more complicated cleanups. This differential success is likely due to the fact that the latter category of undertakings is fundamentally different than the former as they entail higher levels of uncertainty and require longer timeframes to reach completion.

History of DOE's Contracting Practices

Prior to enactment of the Government and Performance Results Act of 1993 (GAO, 1996 and 1998c), DOE used cost-plus Management and Operations (M&O) contracts to conduct work at its major facilities. Under these arrangements, the contractor was repaid all of its expenses, plus some negotiated profit margin in the form of either a fixed percentage of total costs or a fixed dollar amount (Feldman et al, 2002). In addition to these predetermined earnings, an incentive award was usually granted in recognition of the contractor's ability to meet general performance expectations (GAO 2002b and 2003).

The M&O structure is an example of a cost plus fixed fee contract design. In general, it is thought that because the client must pay only for the labor, materials and other inputs necessary to complete the project, they are effectively spared the possibly higher contract price that might result from pre-specifying project costs. However, such an arrangement often weakens the contractor's incentive to perform their duties in the most cost effective manner, as doing so produces no reward, and failure to do so, no penalty (Scherer, 1964). In general, the use of cost-plus contracts is advisable in instances where uncertainty is high or when the project has not been completely specified, and when the client, not the contractor, has control over the efficiency and effectiveness of the work and the associated risks (Ward & Chapman, 1995).

The M&O structure was born out of the unique characteristics of national defense contracting. The highly uncertain nature of the advanced technology being supplied, combined with the large capital requirements and tendency towards rapid obsolescence that characterized many DOE projects, made contractors reluctant to assume the potentially substantial financial risk associated with changes in scope or project failure. The fact that the DOE was the only buyer for the technology under development meant that the contractor could anticipate no additional profits through sales to other parties, further underscoring the need to provide them with a buffer from financial risk. Firms working under these M&O agreements enjoyed a great deal of autonomy, their statements of work were broadly defined and they were subjected to minimal oversight. Contracts were often not awarded competitively, but were instead arranged through bilateral negotiations, and what competition did exist between firms was largely centered on technological designs and capabilities. These conditions provided contractors with little incentive to minimize expenditures or time frames (Cummins, 1977). While concerns were voiced as to the efficiency of this contracting mechanism, the DOE utilized it until the mid-1990s to manage its cleanup program.

Projects conducted under these cost-plus contracts were often characterized by substantial price increases and time extensions above those initially agreed upon. These outcomes drew harsh criticism from the Government Accounting Office (GAO), the DOE's Office of Inspector General (OIG), Congress and various stakeholder groups, and figured heavily in the Department's decision to undertake a massive contract reform effort in 1994. Conceived as a holistic redesign, the reform was focused on strengthening contracting and management practices. Accountability was to become a hallmark of all projects and the selection of appropriate contract designs, the use of competitive bidding, and the creation of proper performance measures and incentives, were chosen as the mechanisms through which this would be accomplished (GAO, 2002b and 2003).

Armed with a newly defined approach that stressed accountability and results, the DOE began to make use of contract designs that would, it hoped, be more effective at inducing desirable contractor behavior and project outcomes than the cost-plus contracts of years past. A privatization initiative was started in 1995, the goal of which was to enable the DOE to behave more like a private entity, in order to reduce the cost and duration of cleanups. This was to be accomplished through the use of competitively bid fixed price contracts (Keisler, 2004).

The fixed-price contract design most closely resembles familiar market transactions in that the contractor agrees to deliver a set of specified services for a predetermined price. Once agreed upon, the price remains the same regardless of the difference between the actual and anticipated costs of fulfilling the contract. Thus, the contractor alone assumes responsibility for the financial risk associated with the project. (Scherer, 1964) This structure is thought most effective in instances where there is little or no uncertainty associated with the project, and when the contractor has control over the its effectiveness, efficiency and the risks involved in its completion, and can therefore make accurate time and cost predictions. When uncertainty is high, however, a contractor may demand a substantial risk premium before agreeing to perform the work for a fixed price. This inflated price acts as a sort of insurance should costs exceed anticipated levels. If expenditures escalate so substantially as to threaten profits, the contractor will likely (and logically) attempt to curtail their losses through renegotiation or other means whereby they can pass some of the burden back to the client (Ward & Chapman, 1995).

A total of eight DOE privatization contracts were negotiated through 1998, the largest of which was the Hanford high level waste project that was to cost $6.9 billion (GAO, 2000a) The proposed scope of work at the Hanford site involved significant levels of uncertainty and necessitated the development of new waste removal and disposal technologies, factors which should have signaled that a fixed-price structure was not an appropriate choice. The Department was forced to abandon the contract when almost one year into the endeavor, and after having developed much of the needed technology, the price estimate submitted by the contractor for the next stage of work was more than double the amount initially agreed upon (Keisler, 2004).

In the wake of major problems on similar large-scale privatization efforts at its Savannah River, Hanford and Idaho facilities (GAO, 2000a, 2000b), the DOE came under renewed criticism regarding its contract practices in 2000. In testimony before a House Sub-Committee the GAO reported that this approach had yielded little in terms of cost savings, keeping projects on schedule, or improving contractor performance. The GAO identified the DOE's seemingly indiscriminate use of this contract structure as fundamentally flawed and cited its use of fixed-price contracts for projects ranging from laundry services to the remediation of high level wastes, as evidence of this practice. In keeping with existing contract theory, they concluded that while fixed price contracts would be an appropriate choice for projects characterized by low levels of uncertainty, they were wholly inappropriate for use in instances where uncertainty was high (GAO, 2002b and 2003). The U.S. Army Corps of Engineers contracting guidance echoes this sentiment, stating that fixed-price contracts are not the best vehicle for complex radioactive waste cleanup projects, because they can have significant uncertainties, including undefined amounts and concentrations of contaminants (GAO, 2000a).

Reducing Uncertainty

As a means of possibly overcoming many of these uncertainties, the DOE developed the Streamlined Approach for Environmental Restoration (SAFER) (DOE 1993). In 1994 and 1995, the SAFER methodology was pilot-tested on contaminated areas at Oak Ridge National Laboratory, Hanford, Savannah River and Mound sites. The goal was to streamline the process and focus project planning and scoping of the remedial investigation/feasibility study (RI/FS) phase, as a means of overcoming the high degree of uncertainty that exits with limited characterization data at environmental restoration sites. The pilot projects demonstrated that DOE, U.S. Environmental Protection Agency, and State personnel could work together to reduce the time lines and costs associated with various remediation projects. However, consensus building, a crucial part of SAFER, was found to be a sometimes frustrating and time consuming process, and thus in conflict with the desire to get results quickly. Concern was expressed in the DOE's 1995 pilot project report that regulators might be unwilling to continue to invest significant time up front in the scoping and characterization stages of the response, if it was not translated into faster remediation. "For SAFER to be successful in the long run, there must be resistance to the ever-present urge to take shortcuts in the scoping process" - Harry Boston, Lockheed Martin (DOE, 1995 p8).

Incentive Based Contracts

Performance-based incentive contracts were first used by the DOE in the mid-1990s and soon became the primary instrument through which cleanup projects are managed across the weapons complex. Incentive contracts are essentially a structured system of rewards and penalties, and work on the premise that a contractor will tailor their work so as to earn the former, while avoiding the latter. The selection of particular incentives and penalties effectively dictates the level of financial risk sharing between parties. Appropriate performance measures and goals must be simple, quantifiable, readily verified by the client and structured so as to induce the contractor to produce the desired results. Incentive contracts can be a promising mechanism for inducing the desired behavior on the part of a contractor, however, they are perhaps most appropriate when the client has a sound idea of potential project costs and where uncertainties exist, but are not so prevalent as to warrant a completely flexible cost ceiling (Ward & Chapman, 1995).

The challenge faced by the Department in structuring effective performance-based incentive contracts has proven to be quite daunting. As with any environmental management contract, the remediation goals to be accomplished under the scope of work must be adequately defined. While an obvious necessity, this process is not always a straightforward one owing to the fact that a variety of federal and state laws may apply and because of the Department's obligation to accommodate the desires of a variety of stakeholders, who may have contrasting opinions and visions for the future of the site. Once the scope of work has been agreed upon, the DOE must create a system of performance measures capable of ensuring that the contractor meets or exceeds these goals. In order to be effective, the contractor has to have a reasonable opportunity of accomplishing each task within the budgetary and time constraints provided, and still able to earn a profit.

Despite efforts to tie a greater proportion of a contractor's fees to its achieving specific project objectives, the DOE's choice of performance measures in its earliest contracts often rewarded the contractor for work only partially completed. The GAO found that DOE failed to focus on high-priority outcomes and did not adequately correlate fee amounts with a task's difficulty. They also concluded that the Department's tendency to loosen performance requirements over the life of a contract served to significantly undermine their effectiveness. In response, the DOE provided anecdotal evidence demonstrating the success of its performance contracts, to which the GAO answered in kind, citing specific failures. Because the Department had not engaged in any sort of systematic monitoring of contractor performance or documented the completion of tasks with regard to certain contract stipulations, the GAO conducted an informal analysis to determine the general impacts of the reform. Their conclusion, while subject to a series of caveats, was that the proportion of projects experiencing significant delays and cost overruns was higher in 2001 than it had been in 1996 (GAO, 2002b and 2003).

In 2001, the DOE conducted an internal top-to-bottom review of their environmental management program. A report issued the following year found that of the 114 sites that had required remedial actions at the program's inception 12 years prior, some 74 had been successfully concluded. The magnitude of this accomplishment was diminished however, by the conclusions that these cleanups had been the smallest and least complex, and that "the remaining large sites present enormous challenges." In order to complete all of the projects it had planned, DOE estimated that the total expenditures required could reach as high as $300 billion, with the final site achieving closure as late as 2070 (DOE, 2002).

The Department acknowledged that the current approach, which was characterized by significant time and cost extensions for the completion of these large cleanups, put in jeopardy both human and environmental health. In what can only be described as a complete break with conventional bureaucratic wisdom, the reviews came to the unsettling conclusion that should the status quo remain unchallenged, the DOE's cleanup and closure goals might never be attained. Flawed contracting practices were identified as one of the major factors to be addressed. A variety of actions, including improvements to the contract solicitation process, increasing contractual clarity, focusing incentives on the achievement of end points, and embracing a more explicit consideration of project-specific risks, were recommended (DOE, 2002).

Accelerated Cleanup Initiative

Soon after, DOE initiated an accelerated cleanup initiative, intended to implement the suggestions that came out of the top-to-bottom review. In March 2003, it declared that its new strategy, which involved the use of 16 "gold chart metrics" to track environmental risk reduction and an earned value management system to gauge contractor performance, would shave approximately $50 billion and 35 years from its 2001 estimates. Progress toward completing cleanup activities would be tracked, on a site by site level, through metrics such as quantities of waste disposed, number of high level waste (HLW) tanks closed, and number of buildings demolished. Projected savings were tied largely to a series of proposed performance enhancements, including projected cost and time reductions made possible by improvements in a new form of performance-based contracting (GAO, 2005).

The GAO review found that the DOE was close to, on, or ahead of the accelerated cleanup plan for 13 of its 16 gold chart metrics. However, it was falling behind schedule for the most costly and challenging of these tasks. The closure of HLW tanks and disposal of their contents had proven particularly problematic. Some of the technologies for treating a portion of the tank waste at Hanford are not fully tested, and plans to send certain types of tank waste at the Idaho site to the Waste Isolation Pilot Plant (WIPP) in New Mexico have not been approved by the State of New Mexico or the USEPA. Savannah River, which initiated a HLW vitrification process in 1996, had not eliminated any liquid waste and was some 3 million gallons behind schedule as of March 2005, because it is still developing its waste separations technology and lacks operational treatment facilities for processing the wastes. GAO questioned the Department's ability to achieve its proposed cost and time reductions, noting that the cleanup of a single site (Rocky Flats) had accounted for a major portion of the initiative's success thus far. Their doubts were further underscored by the fact that roughly half of the $50 billion reduction promised three years prior had been tied to anticipated progress with regard to these three major cleanup projects (GAO, 2005).

The Stewardship Challenge

Much of the nation's legacy waste will be treated in-situ and covered with earthen and other impermeable barriers, or relocated to long-term containment facilities on the site. The uncertainties in contracting for long-term stewardship include technological choices, determining safe levels of residual waste, unforeseen complications regarding the containment of waste, and preventing public exposure for decades or centuries, among others. Incorporating these future stewardship requirements into DOE cleanup contracts has proven to be difficult, because of the strong focus on reducing current risk to workers and the public. In response, the DOE established the Office of Legacy Management in 2004 to assume long-term responsibility for those sites where cleanup had been completed, and where no ongoing defense or science related missions were continuing.

Case Studies

In the fifteen years since the end of the Cold War and ensuing shut down of the nation's nuclear weapons testing and materials production facilities, the DOE has employed a wide range of contract structures to develop and manage the cleanup and disposal of its radioactive and other hazardous legacy wastes. The following three case studies examine and compare the status and expected outcomes of recent performance-based fixed price contracts awarded for the environmental cleanup of the Rocky Flats and Mound-Miamisburg sites and cost plus contracts awarded for the retrieval and treatment of 55 million gallons of high level tank wastes at the Hanford site. The first two represent relatively simple site remediation projects where the new contract form and improved contract management processes have significantly reduced the final cost and cleanup timeline. The last is an example of the much more complex projects that have experienced serious cost and time schedule overruns.

Rocky Flats

The Rocky Flats site is 10.31 square miles (6500 acres) in size and located 15 miles northwest of Denver, Colorado. The production of nuclear weapons components began there in 1952 and all but ceased in 1989, when the remediation of the environmental legacy began in earnest (Hanson, 1993; DOE, 2000b). Manufacturing and waste management practices had resulted in varying levels of contamination across the facility, some of which extends beyond the site's boundaries. In early 2000, the DOE and Kaiser-Hill Company completed negotiations on a contract to manage the final cleanup of this major former nuclear weapons production site. A "target schedule" date of December 16, 2006, was established for contract completion. However, the Rocky Flats agreement was unique in that the termination date was not hard and fast, rather the contract was to remain in effect until the site could be closed.

The Kaiser-Hill Contract was written as a performance-based agreement and links financial incentives to the contractor's ability to meet predetermined time and fixed cost schedules. Completing the contract by December 16, 2006, and at a total targeted cost of $3.963 billion, would earn Kaiser-Hill a total incentive fee of $355 million (DOE 2000). To the extent that it achieves completion of the contract before that date, and/or at an actual cost less than the target amount, it can earn a total incentive fee of as much as $460 million. The contractor would be entitled to a much lower incentive fee if total actual costs significantly exceed the nearly $4 billion target cost. The only explicit time-related penalty in the contract appears to be a $20 million reduction in the contract's total target fee if closure is achieved on or after March 31, 2008 (DOE 2000). The penalty is much steeper for cost overruns, which are inherently linked to time extensions, as expenditures continue to accumulate during periods of delay. Should significant cost overruns occur, penalties could reduce the incentive fee to as little as $150 million.

The contractual scope of work is relatively simple – remove and ship weapons grade plutonium to a safer permanent off-site DOE facility, and demolish and dispose of all of the 805 former weapons production and administrative buildings on the site. There were virtually no contaminated groundwater, on-site waste treatment or long-term HLW containment issues with which to contend. The only inherent uncertainty stemmed from questions about how the contractor would remove some of the most hazardous residual wastes from several large building interiors prior to their being demolished and disposed of, and whether they would encounter any radioactive or hazardous contaminants under the buildings once they were removed. Kaiser-Hill was given the freedom to schedule demolition work so as to minimize time and cost, rather than being required to first remove those that might represent the greatest potential human or ecological risk. It was also permitted to use caps to contain low levels of plutonium and other hazardous materials in soils. Final land use had been determined in advance and while the majority of the site was to be turned over to the Department of Interior for use as a wildlife refuge, the small former central production area, where some contamination would remain *in situ*, was to stay in DOE hands in perpetuity,.

The closure of Rocky Flats will mark the contract's completion, however, continued monitoring, restriction of site access and other measures will likely continue for years to come. The National Research Council (NRC 2000) recommended several years ago "that, to address the risks and uncertainties of LTS [long-term stewardship], a systematic approach to cleanup be developed in which contaminant reduction, contaminant isolation, and stewardship are considered in an integrated and complementary fashion." In a departure from this way of thinking however, the Rocky

Flats contract does not stipulate that the contractor make the site ready for the commencement of LTS activities, in fact there is no reason for the contractor to connect its short-term assignments to long-term stewardship. This arrangement reflects DOE-environmental management's (EM) approach to contract management, which continues to treat long-term stewardship as a separate activity that will occur sometime in the future after cleanup of the site has been completed.

In early October 2005, Kaiser-Hill pronounced the cleanup of the Rocky Flats site officially complete - almost 15 months ahead of schedule. The work must still be reviewed and approved by DOE, EPA and state health officials, but should approval be granted, the Rocky Flats cleanup will have been accomplished at a substantial time and cost savings compared to initial estimates of as much as $36 billion and 70 years (Hartman, 2005; McGuire, 2005).

Miamisburg - Mound

The Mound facility was constructed in 1946 on a hilly 306-acre site in Miamisburg, Ohio. Operations began two years later with the development, manufacturing and evaluation of explosive components for the nuclear defense stockpile. Beginning in 1954, the facility was used for the development of radioisotopic thermoelectric generators (RTGs), which act as a power and heat source for deep space missions such as Galileo, Ulysses and Cassini (DOE, 2003a). At the end of the Cold War, production operations ceased at the Mound facility, and the DOE initiated efforts to cleanup the site, with the goal of returning it to the community for commercial and industrial reuse.

A cost-plus Operation and Maintenance (O&M) contract for site remediation and closure was issued in 1997. Significant increases in the estimated date and cost of the project completion caused the DOE to cancel that contract in 2002 and issue a request for proposals (RFP) built around the fixed cost-plus incentive structure used at Rocky Flats. In a departure from the design used at the Colorado site, however, the Department used a competitive bidding process. A completion date of September 30, 2006 was stipulated, as was the condition that total project costs and incentives could not exceed $367 million.

The incentive structure stipulated for the Mound contract consisted of rewards for early completion and penalties for delays, which formed a greater percentage of the contract's total value than they had at Rocky Flats. Where the Rocky Flats contract limited the penalty for delay in project completion to $20 million and did not become effective until 108 days after the target date, the Mound contract structure included a penalty of $3.4 million per month and began immediately, amounting to a maximum reduction of $20.4 million. The magnitude of the potential penalties relative to the contract's total value was nearly twelve times greater under the Miamisburg contract than at Rocky Flats (6.0 percent, as compared to about 0.5 percent).

These changes in procurement and contract structure as compared to those used in Rocky Flats, created a stronger relationship between the successful completion of the work and eligibility for financial incentives, led to a more transparent selection process, and succeeded in attracting competitive proposals from three experienced contracting teams. The winning bid included a maximum total contract cost of $314.3 million (nearly $53 million less than the maximum allowable amount) and promised project completion six months earlier than required (DOE, 2003b).

Here again, the scope of work was relatively straightforward. The new owners either scheduled each building on the site for demolition and disposal, or cleanup for industrial reuse. The only uncertainty for the contractor was in the exact location of equipment, clothing and other contaminated waste materials that had been dumped in various ditches and then covered over in earlier years. The risks and costs were not so much related to removing these materials once located, as in the need to have workers possibly involved in deep excavation work and related accidents. The project is currently scheduled for completion in early 2006, and will represent the DOE's first successful transition of a former weapons site to private sector reuse.

Hanford High Level Waste Retrieval and Treatment

DOE's Hanford site, a plutonium production complex that contains nine nuclear reactors, occupies some 586 square miles in southeastern Washington State. The site was one of two created to fulfill the Manhattan Project's mission of engineering the world's first nuclear weapon. In 1998, the DOE established the Office of River Protection to retrieve, treat and dispose of 55 million gallons of highly toxic, high-level radioactive waste stored in 177 underground tanks located within seven miles of the Columbia River. Under a 1989 Tri-Party Agreement between the DOE, the EPA and the Washington State Department of Ecology, firm milestones were established for completing retrieval of the waste from 149 single-shell tanks. The first requires the DOE to remove about 6.6 millions gallons of waste in the 16 tanks located in Hanford's C-Tank Farm by the end of Fiscal Year 2006. Originally estimated by the contractor CH2M Hill Hanford to be completed at a cost of $90 million, this initial phase is already at least five months behind schedule and $125 million over budget (DOE, 2005).

A recent audit by the DOE's Office of Inspector General found that "The Department had not based its retrieval plan schedule and cost estimates on prior experience and current characterization data or taken timely action to ensure that resources are available to meet the established schedule" (DOE, 2005 p2). Recent retrieval operations have been beset with numerous problems. Waste removal in one tank, for example, was stopped within 5 minutes due to clogging of the equipment, and not restarted until 5 months later. Delays in schedule and increased labor costs were caused by the need for workers to begin using supplied air systems to combat exposure to tank vapors. These problems and cost overruns raise serious doubts regarding the Department's ability to remove all wastes from the single-shell tanks by 2018, as required under the Tri-Party Agreement.

Waste Treatment

Once removed from the tanks, the waste must be treated and then disposed of in a permanent geological containment facility. The Department began designing a vitrification plant to treat the waste in 1991, but abandoned the plan in 1993 after spending $418 million because the resulting design was too small to treat all of the waste in an acceptable time frame. In addition, the plant would have been operational before retrieval of the tank wastes had been perfected. In 1995 DOE turned to a fixed price privatization contract structure to design, finance, build and operate the waste treatment facilities. The first project phase was intended to treat 10 percent of the waste at a cost of $3.2 billion, but by 2000 the cost had escalated to more than $14 billion.

The DOE cancelled this contract after spending about $300 million, and in 2000 awarded a new $4.3 billion cost-plus contract to Bechtel to complete the design and construction of the treatment plant. In the first phase, about 10 percent of the wastes by volume, and about 25 percent of total radioactivity, would be separated into high and low activity waste portions, and then each would be vitrified in its own treatment facility. The high level vitrified portion would then be sent to a permanent geological containment facility (Yucca Mountain) and the low level portion would be disposed of in a facility to be constructed on the Hanford site. The proposed vitrification plants were intended to complete treatment of this first 10 percent by 2018, after which their treatment capacities would be expanded so as to allow processing of the remaining 90 percent by 2046 – well past the regulatory deadline of completing the retrieval and treatment of all tank wastes by 2028. The total cost for retrieval, treatment and disposal using this approach was estimated to be $56 billion over the project life (Stang, 2000; GAO, 2004).

This saga of changes in project direction continued in 2002, when the Department announced that it was implementing an accelerated approach that would allow it to meet its regulatory deadline of 2028 and save $20 billion. This announcement came about 2 years after Bechtel had begun to design, build and test the treatment facilities required under the previous approach, and before a revised contract had been negotiated. In April 2003 the DOE increased the amount of the design and construction contract by a third to $5.7 billion, to reflect the added production capacity requirements, contractor performance problems, additional design and revisions to cost estimates.

Much of the performance problems were related to the decision to use a "fast-track" process, where much of the design, technology development and construction activities are carried out simultaneously. In several instances construction was outpacing design (GAO, 2004, 2005). These problems are strikingly similar to those encountered in the ill-fated design and construction of the in-tank precipitation (ITP) project at the DOE's large Savannah River Site in the 1990s. Started in 1983, the project was to be completed in five years at a cost of $32 million. After numerous delays and costs spiraling toward $500 million, DOE suspended the project in 1998 because it would not work safely (GAO, 2000b). "DOE and the contractor encountered delays in starting up the ITP facility because they had begun construction before the design of the process was completed (p 2) … The ITP project was managed on a fast-track schedule – concurrent design and construction – with an emphasis on pushing ahead in the belief that the problems could be solved later (p 10)."

The DOE provided an additional 16 months in the revised contract for designing and building the newly configured facilities, but in order to retain the 2011 startup date it shortened the period for testing the plant to ensure that it would work properly under full operating loads. In addition, it assumed that 60 percent of the low activity waste portion would be treated in some alternative fashion that would not require it to significantly enlarge the vitrification plant already well into design and initial construction.

A recent report by the U.S. Army Corps of Engineers (Army, 2005) found that cost and schedule problems are continuing. In January 2005 the DOE requested Bechtel to develop a high confidence level estimate of total project cost to completion under two funding scenarios – unconstrained funding and constrained funding of $690 million a year. They responded in April with an estimated total project cost of $8.348 billion and schedule completion date of July 2015 under the constrained funding scenario. About one-third of the large increase over the $5.7 billion contract value was attributed to changes in design and construction caused by changes in predicted ground motion associated with possible seismic activity. Other large cost adjustments were related to use of a more accurate bottom-up approach for estimating engineering costs and increases in construction material and labor costs, and not to contract scope changes.   The Army's review of Bechtel's revised costs estimates found them often lacking in detail and/or having inconsistencies between individual schedules and final cost estimates. More importantly, it believes that risks in the commissioning assumptions could add substantial costs and further delays to the facilities' operational startup. In total, Bechtel's latest cost estimates may be understated by as much as $1.3 billion and project completion may be delayed beyond the revised 2015 date (Army, 2005).

Other Project Risks

Looming in the background are at least three issues that could potentially cause further delays and significant costs to this high level tank waste retrieval and treatment project. The first is that the separation of tank wastes into high and low activity components, and follow-on separate treatment and disposal pathways, is reliant on the DOE having the authority to reclassify the low activity portion as waste incidental to reprocessing, and thus not subject to more stringent high-level waste treatment and disposal in a permanent geological repository. A Federal District Court in Idaho ruled in 2003 that DOE did not have such authority. An Appeals Court reversed this decision in 2005, but only on the basis that the issue was not ripe for litigation. Congress amended the Nuclear Waste Policy Act the same year to permit DOE to reclassify wastes at its Savannah River and Idaho National Laboratory sites, but not at Hanford. Not resolving this issue in DOE's favor in the next several years could add tens of billions of dollars to the project's cost and delay completion to the former 2046 deadline (GAO, 2004).

Meeting the 2028 completion date and holding treatment plant construction costs to even the revised amount of $9.6 billion amount, requires using alternative technologies to treat 60 percent of the low activity waste. The DOE is relying heavily on the assumption that bulk vitrification will succeed, even though its effectiveness has not been fully tested. A pilot test facility is under construction, but the size and treatment capacity of a full-scale plant cannot be confirmed until testing is completed (GAO, 2004).

Lastly, the DOE has not as yet devised and implemented an efficient method of removing the wastes from the tanks, and it is still unclear if they will be able to remove all of the waste and if not, what portion may remain that will require further treatment or containment (DOE, 2005).

Discussion

From the perspective of public-private partnerships the types of sites that make up the U.S. nuclear weapons complex can be divided into two categories. “Simple” sites are ones where an end state has been identified and is generally agreed upon by regulators and stakeholders. These simple sites tend to be those that are small in size, hosted a limited number of activities during their active lifetimes and have relatively minor amounts of waste and contamination. After experimenting with different contract mechanisms, it appears to us that the DOE has found an approach that works. Although not perfect, it will accomplish its goal of accelerating the cleanup of these sites at a significantly reduced cost.

“Complex” sites do not have a clear end state, there are uncertainties related to proposed cleanup technologies and end states, and the time frames associated with the remediation process are quite long. Sites that are large in size, were the location of multiple activities, and are now characterized by large amounts and types of waste and environmental contamination can be classified as complex. These sites are legal, environmental and economic nightmares for the Department and for taxpayers, alike. The major lesson learned from these sites is that even in taking actions to address a perceived crisis situation, the often-lengthy life cycles of hazardous products cannot be ignored. Plans for the treatment and disposal of wastes generated as part of research and development activities should be incorporated into each project's conception. Had such steps been taken 60 years ago, the outcomes described in this paper could have been prevented. Second-guessing what was done over a half a century ago however, will not solve the dilemma at these sites. Rather, political recognition that these complex radioactive and hazardous waste cleanup problems are, in many instances, not going to be solved within the time frames dictated by the tri-party agreements is a necessary first step.

Recognition of the need for more flexible time schedules should be followed by the redesign of site cleanup programs and categorizing tasks according to their levels of complexity and priority. Once organized in this fashion, appropriate contract structures can be selected for accomplishing each type of undertaking. Those having little uncertainty regarding waste characteristics, remedial technology and end state condition should move ahead quickly and make use of designs, including performance based incentive agreements, which have proven effective under such circumstances. Work on more complex tasks with uncertain or incomplete disposal pathways should be delayed until uncertainties can be reduced to a manageable level and a workable, cost effective and sustainable remediation strategy can be implemented. While these issues are being resolved, the site should utilize interim measures to contain and protect these hazardous materials against terrorism, natural hazards and other events (Greenberg et al, 2005). When a sustainable strategy has been developed, the project tasks should be matched with the most appropriate contract structures as informed by contract theory and the Department's own past experiences.

Although the focus of this paper has been on the DOE's largest and most complex former nuclear weapons sites, these recommended paths forward should be appropriate to addressing the similar contracting and organizational issues are often found at other government and private complex hazardous waste sites.

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