# ADVANTAGES, DISADVANTAGES, AND LESSONS LEARNED FROM MULTI-REACTOR DECOMMISSIONING PROJECTS

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## ABSTRACT

This paper discusses the Reactor Interim Safe Storage (ISS) Project within the decommissioning projects at the Hanford Site and reviews the lessons learned from performing four large reactor decommissioning projects sequentially. The advantages and disadvantages of this multi-reactor decommissioning project are highlighted.

## INTRODUCTION

The decommissioning of four of the nine retired plutonium-production reactors within the Columbia River Corridor at the U.S. Department of Energy's (DOE's) Hanford Site in Richland, Washington–, as multi-reactor ISS projects is the focus of this paper (Fig. 1). A *National Environmental Policy Act of 1969* Record of Decision directed that these reactors be maintained in safe storage for up to 75 years, with ultimate one-piece removal of the graphite block cores to a disposal site on the plateau in the central part of the Hanford Site. The 75-year ISS concept was first implemented at C Reactor in 1995. In 1998, ISS of C Reactor was completed, and planning was initiated to implement ISS at the DR and F Reactors. The D and H Reactors were added in 2000.

The scope of each ISS activity for the Environmental Restoration Contractor (ERC) is to remove all ancillary and support structures around the reinforced-concrete secondary shield walls, seal all openings, place a new safe storage enclosure (SSE) roof on the reactor facilities, and install lighting and a monitoring system in the remaining structure.

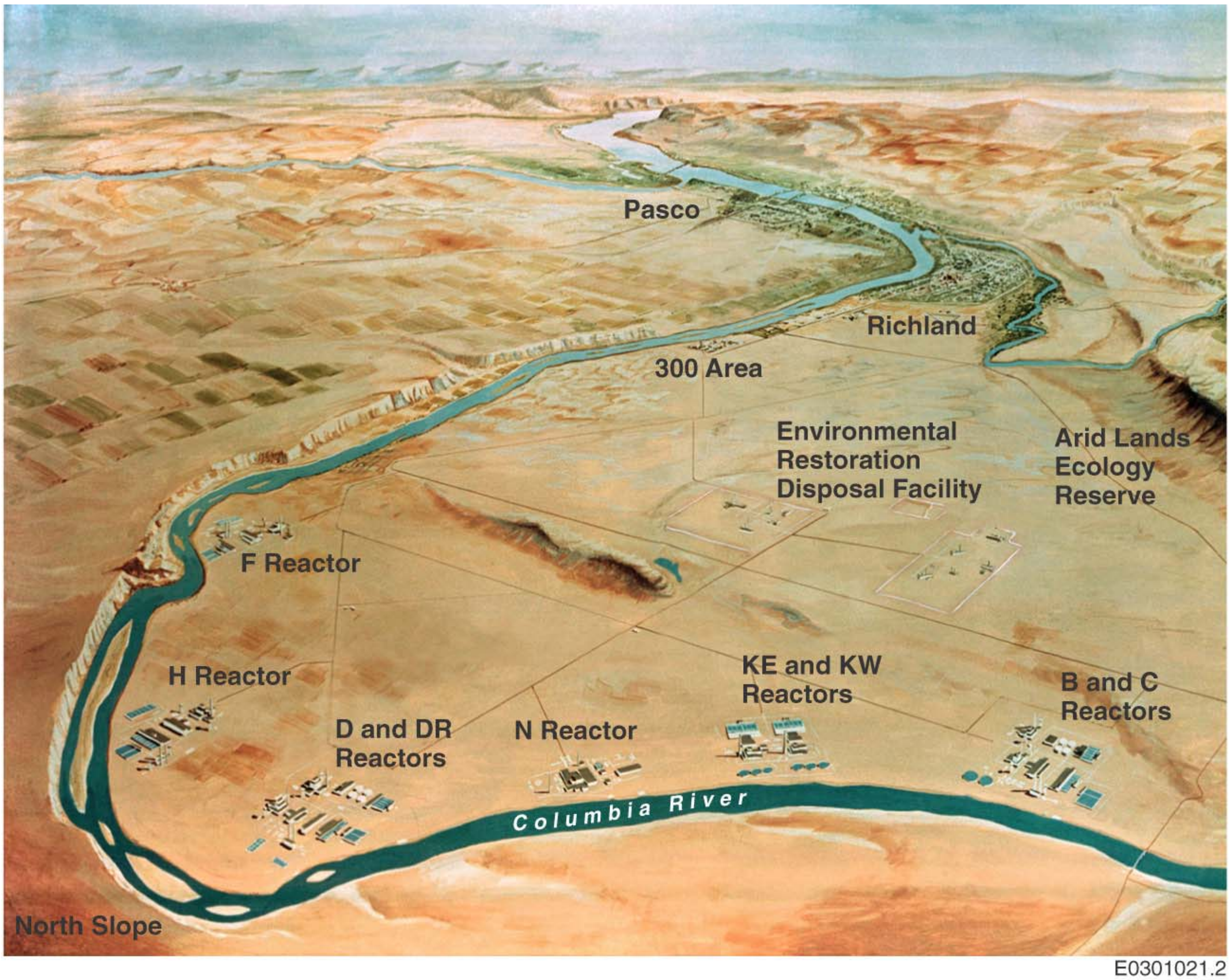


**Fig. 1. Columbia River Corridor with Nine Reactors**

## CURRENT STATUS

The current status (as of December 2002) of the four reactors (see Fig 2) is as follows:

- C Reactor has been sealed since 1998, and no abnormalities have been noted by the remote monitoring system. The first inspection entry at the reactor in November 2002 went as planned.

- DR Reactor work is complete, and the building will be sealed by March 2003.

- F Reactor footprint reduction demolition work has been completed, and the design of the new roof structure and systems in underway. Demolition of the upper reactor area is anticipated to begin in February 2003, following by construction of the new roof by October 2003.

- D Reactor footprint reduction demolition work has been completed, and efforts are underway to award a contract for the design/construction for the new roof and systems.

- H Reactor demolition work is progressing, and fuel storage basin cleanout will continue during most of 2003.


**Fig. 2. Current Status of Reactor ISS Work**

## ENGINEERING AND PLANNING

Because the engineering and planning for the last four reactors was performed in groups of two, significant savings and efficiencies were realized in the following areas:

- **Regulatory and Safety Documentation –** The consistency between regulatory and safety document development and approval was evident. The regulatory documentation (i.e., engineering evaluation and cost analysis, removal action work plan, and sampling and analysis plan) were developed by Bechtel Hanford, Inc. and CH2M Hill Hanford, Inc. (an integrated subcontractor) in 1998 for the F and DR Reactors and in 2000 for the D and H Reactors. Lessons learned from the first two years of the DR and F projects were incorporated into the D and H Reactor documents. Programmatic and regulatory procedures for these documents had changed only slightly in the two years that had lapsed between the preparation cycles of the two efforts. In addition, the same authors were available to further streamline document preparation.

- **Scope and Schedule Development –** Combining scoping survey and schedule development processes for the two sets of reactors were more consistently applied than if the processes had been performed separately using different people over time. Because scope and schedule development were performed together, lessons learned from the first set could be applied to the second.

  In addition, engineering and support efforts were also minimized by this approach. Craft and engineering staff who had performed site walkdowns of the first two reactors were available two years later to complete the walkdowns for the second set. The result was an abbreviated inspection only addressing the remaining engineering questions.

- **Characterization Sampling and Waste Disposal –** The efficiency of the characterization sampling and waste disposal activities increased as a result of work on the two reactors in parallel. Data quality objectives/sampling and analysis planning, waste characterization, and as low as reasonably achievable planning levels of effort were reduced by applying lessons learned from F and DR Reactors to the work at D to H Reactors.

## DEMOLITION

Craft utilization and demolition equipment utilization and maintenance are areas demonstrating the benefits and difficulties of sharing these critical resources while working on multiple-reactor projects.

- **Asbestos and Liquid Removal –** When the ISS projects were originally planned, the ERC used a craft personnel called a decontamination and decommissioning (D&D) worker, which is analogous to a construction laborer. At that time, D&D workers were assigned to each reactor site and would be used for all decommissioning activities. The D&D workers removed all asbestos, drilled and checked systems for liquids, and removed de-energized electrical systems and components. Based on a recent labor arbitration decision, individual crafts must now perform many of these tasks. Insulators must remove asbestos pipe insulation, pipe fitters must remove piping, and electricians must remove electrical systems. Accordingly, this decision has led to craft resource issues and conflicts within the work force.

  The hands-on removal work is performed at various times throughout the project and does not warrant the assignment of a full staff of insulators, pipe fitters, and electricians at each reactor. In addition, the overall labor rates of these journeyman crafts are much higher than the labor rates for D&D workers.

  To implement this outcome of the labor arbitration decision, the project schedules had to be integrated to a much higher degree, resulting in decreased overall efficiency. Minor issues at one site were addressed by either rescheduling work at other sites requiring the same critical resource, or by relocating the craft and addressing the issue when the craft became available. Both of these options were used, depending on overall project priorities and the extent of potential delays at each reactor.

- **Hazardous Material Removal –** Prior to demolition, all loose hazardous materials are removed from the structure. By characterizing and disposing materials from several similar facilities in sequence, the lessons learned from one facility were readily applied to another facility. For example, the ERC has established an array of paint sampling information as to color, source, lead content, polychlorinated biphenyl content, etc. In many cases, the compiled data precludes the need for additional paint sampling within other facilities in the Hanford Site's 100 Areas. The cost savings (e.g., sampling labor, analytical costs, etc.) are a direct result of conducting D&D in a phased, sequential approach.

  Other examples of efficiencies include the disposal and/or recycle of hazardous materials. For instance, a single oil processing contract was put in place for all of the oils from all four reactor facilities, thereby eliminating the cost of securing multiple individual contracts.

- **Equipment Scheduling –** Scarce or unique equipment poses some of the same problems that scarce or unique personnel resources present. The ERC uses five large, track-mounted excavators to perform the majority of the demolition work on the project. Initially, the project schedules sequenced the used of this equipment from site to site and allowed for the logical progression of demolition at various sites. This plan has worked well and has allowed equipment to be efficiently and productively employed.

  However, when a problem is encountered at one site (e.g., when a floor is significantly thicker than shown on as-built drawings), equipment needs (e.g., type, duration, etc.) can change dramatically. These problems have at times caused the need for mitigation plans that have included extended equipment use, resulting in equipment maintenance being delayed and/or additional corrective maintenance.

- **Schedule Delays and Ripple Effect –** Schedule delays caused at a reactor site where the anomaly occurs are clear. A less obvious, but more far-reaching impact is the ripple effect that these problems have had on the overall multi-reactor project. For example, when a crew encounters a problem at H Reactor and they are scheduled to be elsewhere to finalize a pre-demolition task at D Reactor, a "daisy-chain delay" results. Not only do these two tasks become delayed, but the demolition equipment that was to subsequently begin at D Reactor must either be redirected or remain idle until the needed pre-requisite work can be accomplished. Similarly, if discrete equipment requires extensive unplanned maintenance, the resulting ripple effects can affect the schedule at all four reactors within a matter of weeks.

  A significant advantage of having four reactors in various stages of decommissioning is that by redirecting personnel or equipment among sites, the effective operations of the total project can usually be maintained.

- **Preparation Work, Segmentation, and Demolition –** Through the course of planning and executing four reactor projects with similar scopes, the physical performance of sequential work has steadily improved. The corporate knowledge from one facility is used on the next facility to increase overall efficiency. Demolition techniques and operator experience are transferred from one site to another on a frequent, real-time basis. As the operators and equipment are moved from site to site, the lessons learned at the worker level are carried as corporate knowledge of the people actually doing the work.

- **Waste Loadout/Disposal –** Lessons learned in waste characterization, segregation, segmentation, and loadout are also transferred from site to site and applied based on the workers accumulating knowledge and experience in similar areas and with similar materials. Waste container management is an example of increased expertise in regard to workers and management because of repetitive issues encountered at the sequential sites.

  For example, obtaining the appropriate number of containers at the correct site was identified as a significant problem. A management decision was made to funnel all available containers to the site with the greatest need. Meanwhile, other sites stockpiled waste and waited for their turn in sequence. In addition to alleviating the inefficiency of insufficient containers at a particular site, the efficiency of demolition, waste handling, and shipping processes also improved. This resulted from the ability of the site team to focus on a single task (e.g., waste handling) rather than dividing their efforts between several tasks.

## DESIGN/CONSTRUCTION SUBCONTRACTING

Because these activities are involved in completing the final product, SSE, design/construction work was performed by a subcontractor with a defined scope of work at multiple reactors. The efficiencies gained by awarding one subcontract for the similar scope for multiple reactors is an example of how multiple site work can be used effectively to reduce cost.

- **C Reactor SSE –** C Reactor was the first ISS project. The SSE for the reactor was designed by a subcontractor and was then implemented by both the ERC team and another subcontractor. This contracting arrangement led to many revisions and claims for changes between ERC and the two subcontractors. Other delays and interferences occurred as the two groups (ERC and the builder) attempted to accomplish their respective scopes. Some significant technical/installation problems occurred, but the ERC and the subcontractor worked through these issues to complete the project on time. The approximate cost of the demolition within/above the shield walls and the installation of the SSE roof was approximately $2.7 million.

  Two significant lessons learned resulted during the C Reactor SSE project. Having the ERC craft and construction crafts working side by side was difficult to manage. It increased the potential of impacting the subcontractors work and provided potential grounds for claims. The design/construction interface also provided opportunities for design claims and field delays.

- **DR and F Reactors SSE –** Because the SSE roofs were to be installed in sequence, the design construction for the DR and F Reactors SSE was awarded as one subcontract in order to gain efficiencies. This approach addressed one of the lessons learned from C Reactor to award a design/construct subcontract that would require the subcontractor to manage the design/build interface. The ERC team provided only a conceptual design of the final structure. Another innovation for this project was to schedule subcontractor activities to begin after all of the ERC’s work was completed. Although design problems still occurred using this approach, the field work was never impacted by ERC work activities, and any design omissions or as-found condition problems were managed within the subcontractor’s organization and were invisible to the project.

  A number of problems were experienced during the design and installation of the SSE roofs for the DR and F Reactors. Many of these problems stemmed from the subcontract designer being remote to the site location. Overall subcontractor inexperience with heavy steel renovations to old industrial buildings was also an issue. Exacerbating the situation was the lack of clarity of some of the specification language, as well as design engineers with many years of nuclear power plant experience reviewing an industrial structure. The gap between expectations and performance was significant in some cases.

  The total cost for the design and installation of the DR and F Reactor SSE structures will be approximately $4.4 million. The DR Reactor was completed in September 2002 (see Fig 3), and F Reactor should be completed by September 2003. This represents approximate $500,000 savings per reactor when compared to the cost of the C Reactor SSE.

  One change to the sequencing of subcontractors was anticipated and addressed in the SSE subcontract. This allowed the subcontractor to mobilize at another reactor based on delays at the F Reactor fuel storage basin. This clause allowed the ERC to demobilize and remobilize the subcontractor at a cost that had previously been agreed upon.


**Fig. 3. DR Roof – Construction**

- **D Reactor SSE Plans –** The D Reactor SSE subcontract strategy is very similar to the strategy used at DR and F Reactors in that it will be a design/build subcontract implemented after all of the worked performed by the ERC is complete. Both the C and DR Reactor SSE designs will be offered to the bidders as acceptable examples, with the successful bidder selecting the final shape of the roofline. By using recent experience from the DR and F Reactor subcontract and reworking to the specifications and scope of work to address every change request from the subcontractor, the subcontract package will continue to improve. This subcontract is scheduled to be awarded in May 2003, with design completed by September 2003, followed by mobilization in October 2003.

- **H Reactor SSE Plans –** The strategy for the H Reactor SSE construction depends on the lessons that are learned from the D Reactor SSE experience. Options include in-house design adaptation of one of the previous designs, followed by either a build subcontract or by continuation of the design/build approach that was used for the DR, F, and D Reactors.

## SITE RESTORATION AND CLOSEOUT

The sites are being closed out under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* process, which includes the advantages of dealing with regulators on the closure of multiple sites within a short timeframe. Discussions with regulators regarding compliance issues are expedited when a larger cleanup scope can be included in one discussion. Broad cross-cutting issues can be resolved at one time rather than being revisited repetitively.

- **Closeout Verification Package (CVP) Efficiencies –** The CVPs are documents prepared to show compliance with the predetermined cleanup standards or to demonstrate when, where, or how deviations exist in complying with these standards. By covering more than one reactor at a time, significant benefits are realized. The preparation of these documents requires significant effort and the expertise of scientists, statisticians, health physicists, and engineers with a broad range of capabilities. Mobilizing these resources to perform a closeout is difficult at best. Therefore, once assembled, preparing two or more verification packages in sequence has obvious benefits.

- **CVP Regulator Efficiencies –** As multiple CVP documents prepared at one time introduce efficiency into the process, presenting these packages to the regulators in a short timeframe is also advantageous. If issues are resolved on the first package, subsequent packages can then be revised accordingly.

- **ISS Project Closeouts and Transition to Long-Term Surveillance –** The historical and planning information in Table I shows how the ISS activities are planned to be closed out in order to take advantage of the efficiencies that have been noted.

Table I. Completion of ISS Projects at Hanford

| Facility | SSE Roof Installation | CVP | Surveillance and Maintenance Plan Implemented |
|---|---|---|---|
| C Reactor SSE | 1997-98 | 1998 | 1998 |
| DR Reactor SSE | 2002 | 2003 | 2003 |
| F Reactor SSE | 2003 | 2004 | 2003 |
| D Reactor SEE | 2004 | 2003 | 2004 |
| H Reactor SSE | 2004 | 2005 | 2005 |

## SYNOPSIS/RECOMMENDATIONS

A summary of the advantages and disadvantages of the multiple-reactor ISS projects discussed in this paper is presented in Table II.

Table II. Advantages/Disadvantages of Multiple Reactor Decommissioning Work

| Process | Advantages | Disadvantages |
|---|---|---|
| Engineering and planning | Excellent consistency in approach, estimating and scheduling of the project work. Efficiency in staff utilization after a good process is established. | This could be resource limited based on the number of qualified decommissioning engineers that are available. |
| Regulatory interfaces for project planning documentation | Issues are resolved once, rather than every few years possibly with a different person with a different perspective. Consistency in approach and expectations regarding regulatory interpretation is achieved. | Regulator may not have time or responsibility to regarding issues that may arise five to seven years in the future. |

Table II. Advantages/Disadvantages of Multiple Reactor Decommissioning Work

| Process | Advantages | Disadvantages |
|---|---|---|
| Public interface for project planning documentation | Issues are resolved once, rather than every few years possibly with a different group of people with a different perspective. | On rare occasions, the massive amount of information overwhelms the public. |
| Craft utilization | Efficiency in staff utilization after a good process is established. Familiarity with the facilities increases as project work moves between similar facilities. | When a problem is encountered at one site, the ripple effect will affect all of the sites without aggressive and decisive management action. |
| Demolition equipment | Individual operator's technique and expertise increases as they move from site to site. Equipment utilization rates increase with proper scheduling. | When a problem is encountered at one site, the ripple effect can affect all of the sites. More difficult to find "natural" downtimes to perform extensive preventive maintenance. |
| SSE design and construction | Lessons learned regarding subcontracts/subcontractors are immediately applied to the next subcontract. Lower cost for multiple SSEs in one contract. | |
| Regulatory interface for closeout documents | Issues are resolved once, rather than every few years possibly with a different person with a different perspective. Consistency in approach and expectations as to regulatory interpretation. | |

- **Recommendations –** When possible, scheduling similar facilities for sequential decommissioning has significant advantages and allows for increased process efficiencies within the decommissioning project organization as the team looks for better ways to perform the work. These efficiencies and advantages can, however, be tempered by some notable disadvantages. Through aggressive and anticipatory project management, these disadvantages may be overcome or minimized to produce favorable results.

When the current ISS Project (after the C Reactor ISS pilot project) was initiated in 1998, the ERC team committed to the DOE to cocoon four reactors for the price and schedule of three. Five years later, the ERC team is well on the way to fulfilling that commitment.