

Using 3-D Modeling to Improve the Efficiency for Removing Plutonium Processing Equipment From Gloveboxes at the Plutonium Finishing Plant

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

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Using 3-D Modeling to Improve the Efficiency for Removing Plutonium Processing Equipment from Gloveboxes at the Plutonium Finishing Plant

By

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Introduction

The Plutonium Finishing Plant at the Department of Energy's Hanford Site in southeastern Washington State began operations in 1949 to process plutonium and plutonium products. Its primary mission was to produce plutonium metal, fabricate weapons parts, and stabilize reactive materials. These operations, and subsequent activities, were performed in production lines, consisting primarily of hundreds of gloveboxes. Over the years, these gloveboxes and attendant processes have been continuously modified. The plant is currently inactive and Fluor Hanford has been tasked with cleaning out contaminated equipment and gloveboxes from the facility so it can be demolished in the near future. Approximately 100 gloveboxes at PFP have been cleaned out in the past four years and about 90 gloveboxes remain to be cleaned out. Because specific commitment dates for this work have been established with the State of Washington and other entities, it is important to adopt work practices that increase the safety and speed of this effort.

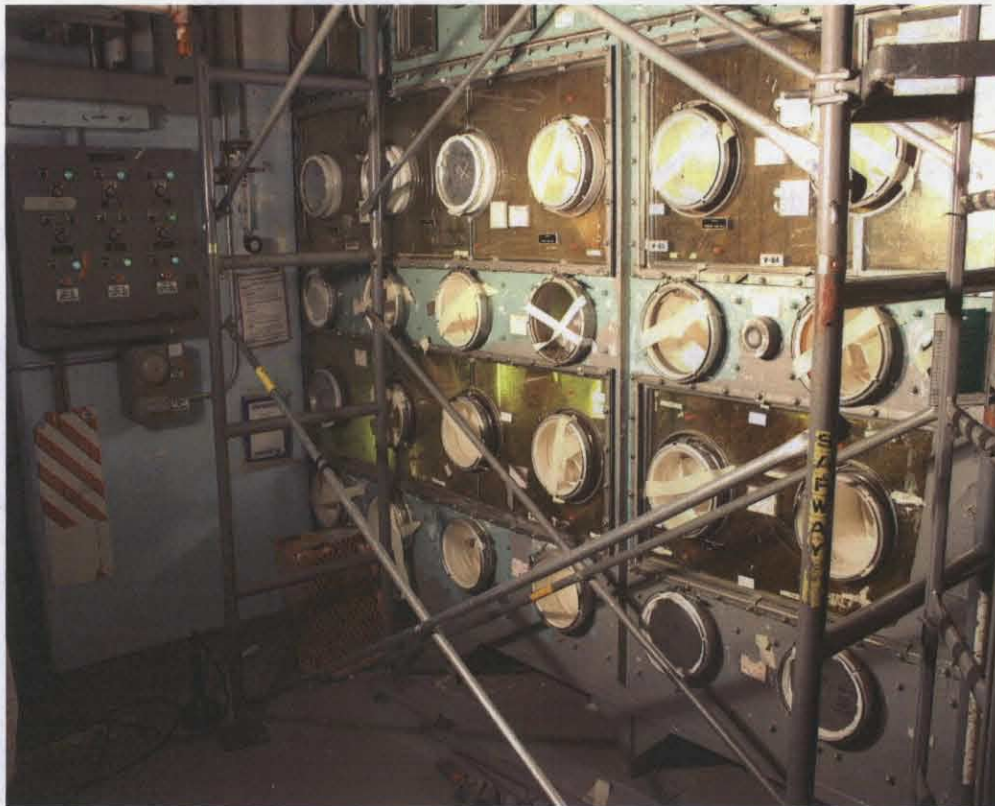
The most recent work practice to be adopted by Fluor Hanford D&D workers is the use of 3-D models to make the process of cleaning out the radioactive gloveboxes more efficient. The use of 3-D models has significantly improved the work-planning process by giving workers a clear image of glovebox construction and composition, which in turn is used to determine cleanout methods and work sequences. The 3-D visual products also enhance safety by enabling workers to more easily identify hazards and implement controls. Further, the ability to identify and target the removal of radiological material early in the D&D process provides substantial dose reduction for the workers.

Traditional Work Method for Planning and Executing Glovebox Cleanout

The conventional work-planning process for cleaning out gloveboxes involved a team with representatives from a variety of disciplines: operations, maintenance, engineering, nuclear and industrial safety, health physics, and work-planning organizations. Specific criteria stipulated the amount of internal equipment and loose debris that would be removed, as well as the internal piping that would be sealed.

Most of the information used to plan cleanout work and produce work instructions came from drawings, photographs, and field inspections of the gloveboxes. However, these sources of information provided only a limited amount of usable information.

- The glovebox drawings typically consisted of a large quantity of individual sheets that gave numerous details of individually installed equipment. These drawings tended to provide a very poor overall representation of the glovebox configuration. The drawings of individual components did not routinely show the fully assembled system and the installed spacing between multiple components and the glovebox. Due to the numerous drawing sheets involved for each box, it was very difficult for the D&D worker to get a clear and accurate representation of what was actually installed in the gloveboxes.
- Because the drawings had not been consistently updated during the decades of operation, additional effort was required to confirm actual field conditions. The field inspections were of limited use, however, because many glovebox windows were very discolored and even painted over, making it very difficult to see in to identify and confirm internal components. At this point, the gloveboxes had no internal lighting, thus compounding the problem.



Photograph of the outside of PFP glovebox 227S. The ability to look into gloveboxes during field inspections was limited by the discolored glass, the outer steel walls of the glovebox and often paint or crazing on the polycarbonate windows. Leaded or layered glass would also distort the sizing of components inside the glovebox.

The lack of a clear picture of contents and configuration required that unknown conditions be factored into work instructions and the actual field work processes. Broad contingency plans were required to accommodate uncertainties. Work stoppages to resolve issues caused by unknown or unforeseen conditions were a common concern, and gaining consensus of the work-planning team members on work sequences and methods was also a challenge.



Photograph taken through PFP glovebox 227S window showing internal equipment and debris. Objects were often difficult to see and identify.

Identifying hazards and implementing controls are core functions of the Integrated Safety Management System (ISMS) used by Fluor at the Hanford site. Work was evaluated and planned using the best information available to the planning team before the start of work. Although controls and restrictions were implemented for safely performing work, overall efficiency was hampered by accounting for uncertain conditions. Work would frequently have to be put on hold while unanticipated problems and conditions were re-evaluated. Because of the uncertainties of what the craft would encounter in the gloveboxes once work started, it was necessary to transfer a large number of tools, nuts, bolts and other items of various sizes into the boxes to safely accommodate possible work requirements.

Improved Method for Planning Work and Doing Work in the Field

The task of cleaning out the radioactive gloveboxes at PFP is now benefiting from the use of 3-D modeling. The 3-D models and images that can be easily manipulated and viewed by the crafts, engineers and planners has reduced the uncertainties of configuration and enhanced the ability to plan, visualize and perform the required work. Workers are now able to measure the size, placement and clearances for assembled and installed components and develop paths for removing those components. The 3-D model has been

used to test work sequences and disassembly plans for large components, allowing the most efficient process to be chosen.

The 3-D models have also been used to identify the sizes of bolts and nuts, weld attachments that would require cutting, and other equipment needs for size reduction of equipment in the glovebox. Once the tooling requirements were determined, glove port covers with power, instrumentation, and pneumatic and/or hydraulic pass through adapters were identified and designed. This process allowed all the tooling and adapters to be available inside the glovebox at the start of the job. By not having to stage unnecessary parts and tools in the gloveboxes, the amount of transuranic waste created during D&D was minimized.

Developing a 3-D model involves the designer gathering and incorporating information from several sources. Multiple drawings, design-change documents, and informal historical sketches are collected as the primary sources for structural content and dimensions. Current and past photographs, both internal and external, are used as visual and supplemental aids. Field inspections and measurements focus on confirming the existing conditions of the glovebox and validating any configuration assumptions made from drawings and photographs. Finally, the 3-D model is constructed.

The modeling software used for this effort is a parametric solid modeler. During the modeling process the designer is able to apply physical and dimensional properties to each piece of equipment and place them in the model in their exact relation to the other components. This approach results in a part and assembly model having exact dimensions. The program is also able to provide weights for, and the centers of gravity of components, enabling faster and better planning for removing equipment. The software package automatically produces requested drawing views based on the model. With very little effort, the designer can provide a variety of plans, details, elevations and sections of the glovebox for review. The model used to produce the drawings is tied to the drawings, and any changes made to the model automatically update the associated drawings. This linkage makes it very easy to illustrate progress of the D&D effort and provide a drawing of the current "state of the glovebox" at any time.

The availability of a single 3-D model incorporating a variety of configuration sources provided the multi-disciplined planning team with an integrated, more accurate depiction of the glovebox. The team could then more easily determine the best ways to access internal equipment for decontamination, disassembly, size reduction, and removal. Clearances could readily be determined for identifying and positioning cutting tools. Lifting and rigging points could also be determined and the order of equipment removal established. Alternate work methods could be more readily identified and considered to resolve personnel safety issues.

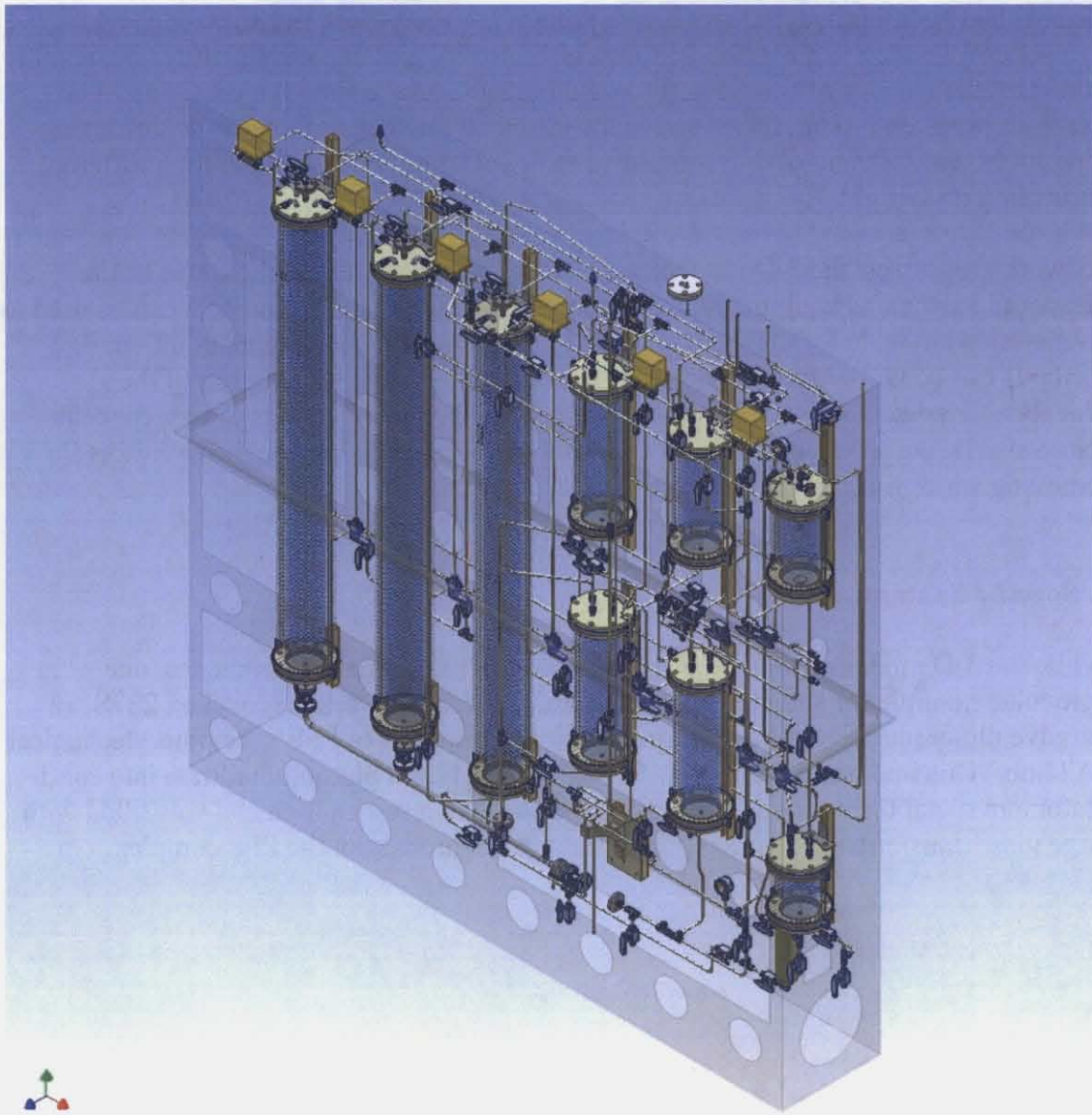
The teams would often focus on removing the highly radioactive materials or unsafe components (e.g., glass, chemicals, transfer lines) from the glovebox using pathways shown in the 3-D model. Removing the source term early in the process would significantly reduce total worker dose and exposure during glovebox cleanout. Once the

hazards had been limited, the sequence of removing equipment and size-reducing components inside the glovebox was optimized for the expertise and skills of the team to minimize the number of people in the contaminated areas around the glovebox. For example, work on piping, tubes, and tanks would be the focus of one work shift using pipefitters, and tasks involving equipment removal would be scheduled for a different shift using millwrights.

As work progresses, the 3-D models can also be updated to reflect the status of the cleanout. Further, as equipment is disassembled and removed, the models can be used as communication tools for the work team and management. Planning assumptions and methods can be verified as the model shows changes in the configuration of the glovebox. Updated 3-D models can be used during pre-job meetings to sequence the removal and size reduction work for the work shift and to determine the pathways for removing waste from the glovebox.

A Specific Example

While the 3-D modeling method has been used at PFP for many gloveboxes, one particular example for showing the best features for D&D work is glovebox 227S – a massive plutonium nitrate liquid transfer unit that was part of PFP's Remote Mechanical "A" line. This line was installed in 1951 to convert liquid plutonium nitrate into solid plutonium metal for weapons. The glovebox stood two stories high and was filled with large glass transfer tanks that fed plutonium nitrate throughout the PFP complex.



This figure is a 3-D model of the internal equipment of plutonium nitrate liquid transfer glovebox 227S at PFP. The vessels inside are glass transfer tanks.

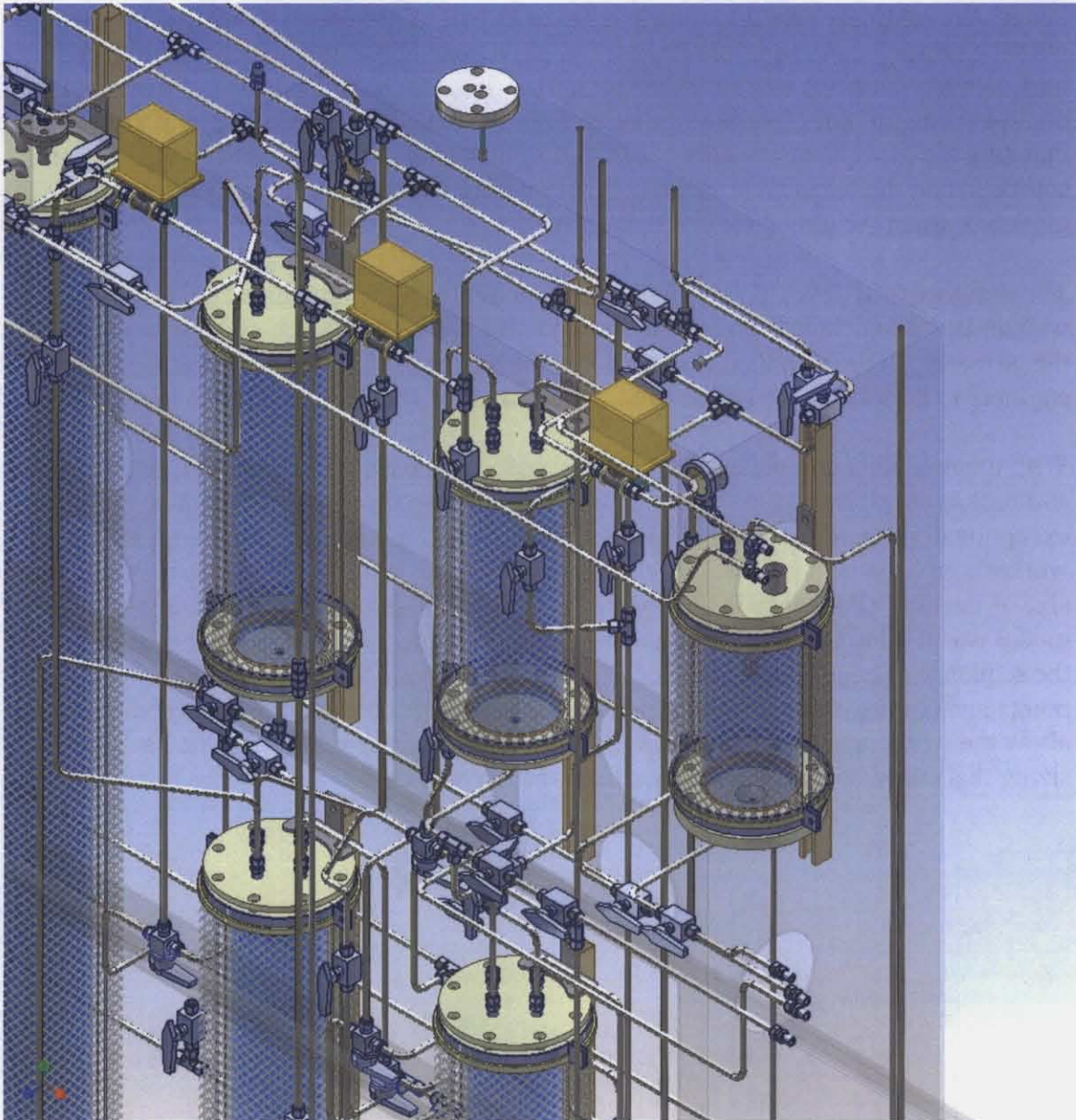
The first step in the modeling process was to establish the boundary for removing equipment from this specific glovebox. Acid lines, transfer lines, electrical power and instrumentation wiring and connections to other gloveboxes were identified, and isolation points were established. All the remaining components inside this isolated boundary and inside the glovebox where to be capped, isolated, removed, size reduced, packaged and then sealed out from the glovebox as transuranic waste.

The designer collected the drawings, component manuals, photographs, parts lists, and piping and instrument diagrams for the original glovebox construction and the many subsequent modifications. After reviewing the drawings and other documents, the designer conducted a field review of the glovebox to determine if all the modifications to the glovebox had been found. Over the years, transfer lines, control wiring and other

items were routinely added to the gloveboxes as part of projects not directly associated with the original configuration of the 227S glovebox. Those connections were traced back to their source(s) so a complete set of drawings could be identified. Power and control wiring in older facilities are often found to have been added or modified without updating the glovebox drawings. For those systems, all wiring was traced back to the source(s) and the wires were tagged. Power wiring was always air gapped from the glovebox when the glovebox was deactivated.

The designer then developed a detailed 3-D model from the drawings and the field walkdown. The detailed model was shown to the D&D work team assigned to clean out the glovebox. The team then walked down the glovebox with the designer and the engineer to be sure all the key information needed for D&D was available in the model.

With the modeling complete, the planning phase for the isolation, removal, size reduction and packaging phase began. Working on plutonium-processing equipment is exceptionally hazardous work. Releases of very small amounts of plutonium into the worker's environment have substantial impacts. These risks, combined with weight and size of the nine glass tanks inside the 227S glovebox required detailed planning. The model was used to identify the connection points for the tanks to the glovebox, determine the sequence of cage and equipment removal from around the tanks, establish lifting points and pathways for lowering the tanks safely to the bottom of the glovebox, and allow the workers to simulate different tube lengths to determine the waste package sizing that could be safely sealed out from the glovebox.



This figure is a close-up view of the 3-D model for glovebox 227S at PFP. Detailed images of equipment helped workers as they planned their approach and removed equipment from the glovebox.

With the D&D sequence and concepts developed, the detailed tooling, materials, lifting system designs, and special waste containers were all designed and added to the model. The model was then configured to show the work sequence for use in team training and pre-job briefings.

The 3-D model enabled the team to prepare all the tooling and materials ahead of time and allowed the workers to clearly “see” the equipment inside the glovebox during the planning effort.

The modeling of the 227S glovebox was one of the early tests of the value of 3-D models in D&D. As the teams continued to use the model, they were able to reduce the time to

clean out a glovebox by more than 50%. This efficiency came as a result of both the benefits from using the 3-D modeling in the planning process and the improved skills of the D&D workers. The shorter cleanout time is very important as the PFP D&D effort moves to the older, high-dose-rate gloveboxes. Better prepared workers and more efficient processes yield a faster cleanout and less dose to the workers.

Summary of Advantages for Using 3-D Modeling

The 3-D modeling approach to glovebox cleanout at has resulted in numerous advantages:

- **Shorter Planning Process.** The 3-D model provided planning team members with very clear images of glovebox structure and contents. This improved their understanding of the workscope and resulted in more precise work plans produced in less time.
- **Less Radioactive Waste Generated.** The model is exact and shows the sizes of connections and equipment. Therefore, only the minimum amount and sizes of equipment and miscellaneous items such as nuts and bolts to support D&D work have to be staged in the gloveboxes. Because the gloveboxes are internally contaminated, this significantly reduced the amount of additional items that eventually have to be bagged out and disposed of as transuranic waste
- **Hazards More Readily Recognized.** Clear 3-D images improved the planning team's ability to identify safety concerns and hazards up front that may have in the past gone unrecognized. Awareness of the risks has eliminated the work being interrupted during the actual cleanout process to deal with problems not previously recognized.
- **Lower Radiation Dose Rates.** The planning team has been able to develop a work plan that adequately lays out the steps required for the most efficient cleanout. As a result, fewer employees have had to be placed on the job and the amount of time the crafts are actually working in a contaminated environment – with attendant dose rates – has been cut significantly.
- **Better Workflow.** By clearly seeing the placement of equipment in the gloveboxes, the workers have been able to identify pick points, hoisting and rigging requirements and specialty tools before field work begins. This eliminated work stoppages that were previously experienced.
- **Less Cost and Shorter Duration.** The use of 3-D modeling has significantly decreased the time needed to clean out a glovebox. In turn, this has produced a significant cost savings and has resulted in a large increase in the amount of work the project can perform within a set budget and schedule.
- **Enhanced Safety Program.** For many years, PFP has carried STAR status in the Department of Energy's Voluntary Protection Program. The use of 3-D modeling at PFP so impressed the evaluation team during the last re-qualification that it was listed twice in the resulting report and critique as being one of PFP's best practices.