The Decontamination, Decommissioning, and Demolition of Loss-of-Fluid Test Reactor at the Idaho National Laboratory Site

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ABSTRACT

In October 2006, CH2M-WG Idaho completed the decontamination, decommissioning and demolition of the Loss-of-Fluid Test (LOFT) facility. The 30-year-old research reactor, located at the Idaho National Laboratory site, posed significant challenges involving regulations governing the demolition of a historical facility, as well as worker safety issues associated with the removal of the reactor's domed structure.

The LOFT facility was located at the west end of Test Area North (TAN), built in the 1950s to support the government's aircraft nuclear propulsion program. When President Kennedy cancelled the nuclear propulsion program in 1961, TAN began to host various other activities. The LOFT reactor became part of the new mission. The LOFT facility, constructed between 1965 and 1975, was a scaled-down version of a commercial pressurized water reactor. Its design allowed engineers, scientists, and operators to create or re-create loss-of-fluid accidents (reactor fuel meltdowns) under controlled conditions. The LOFT dome provided containment for a relatively small, mobile test reactor that was moved into and out of the facility on a railroad car. The dome was roughly 21 meters (70 feet) in diameter and 30 meters (98 feet) in height. The Nuclear Regulatory Commission received the results from the accident tests and incorporated the data into commercial reactor operating codes. The facility conducted 38 experiments, including several small loss-of-coolant experiments designed to simulate events such as the accident that occurred at Three Mile Island in Pennsylvania, before the LOFT facility was closed.

Through formal survey and research, the LOFT facility was determined to be a DOE Signature Property, as defined by the "INEEL Cultural Resource Management Plan," and thus eligible for inclusion in the National Register of Historic Places. Decontamination and decommissioning (D&D) of the facility constituted an adverse effect on the historic property that required resolution through the contractor (CH2M-WG Idaho), the U.S. Department of Energy, the Idaho State Historic Preservation Office (SHPO), and the Advisory Council on Historic Preservation.

The project team identified multiple hazards that would result if conventional techniques were used to demolish the dome. The physical structure of the vessel containment facility reached 30 meters (98 feet) above grade, presenting significant worker safety hazards created by hoisting and rigging activities. The dome also included a polar crane, 19 meters (62 feet) above grade, that posed similar hazards to workers. The need to work on significantly elevated surfaces, and the thickness of the dome walls—30 millimeters (1-3/16 inches) of carbon steel—would prove difficult with traditional arc plasma cutting tools. The dome's proximity to operating facilities with equipment sensitive to vibration added to the demolition challenges.

To address cultural resource issues, the project team engaged all parties in negotiations and in mapping a path foreword. Open and frequent communication resulted in a Memorandum of Agreement, with stipulations that mitigated the adverse affects of the intended demolition action.

The unique mitigating actions resulted in a favorable agreement being signed and issued. To mitigate hazards posed by the height of the facility, the project team had to abandon traditional D&D techniques and employ other methods to complete demolition safely. A different approach and a change in demolition sequence resulted in the safe and efficient removal of the one-of-a-kind containment facility. The approach reduced the use of aerial lifts, aboveground size reduction, and dangerous hoisting and rigging activities that could pose significant hazards to workers.

INTRODUCTION

In October 2006, CH2M-WG Idaho (CWI) completed the decontamination, decommissioning and demolition of the Loss-of-Fluid Test (LOFT) facility at the Idaho National Laboratory (INL) site (see Fig. 1). The 30-year-old research reactor posed significant challenges involving regulations governing the demolition of a historical facility and also safety issues associated with the removal of the reactor's domed structure.

BACKGROUND

In 1949, the government established the National Reactor Testing Station, known today as the INL site. The Idaho desert provided an isolated location where prototype nuclear reactors could be designed, built, and tested. Over the years, 52 "first of a kind" reactors were constructed at the INL site. [1]

In May 2005, CWI undertook the Idaho Cleanup Project (ICP) contract to perform safe, environmental cleanup of the INL site, which has been contaminated with waste generated from World War II–era conventional weapons testing, government-owned research and defense reactors, laboratory research, and defense missions at U.S. Department of Energy (DOE) sites. The 7-year, $2.9 billion cleanup project, funded through the DOE's Office of Environmental

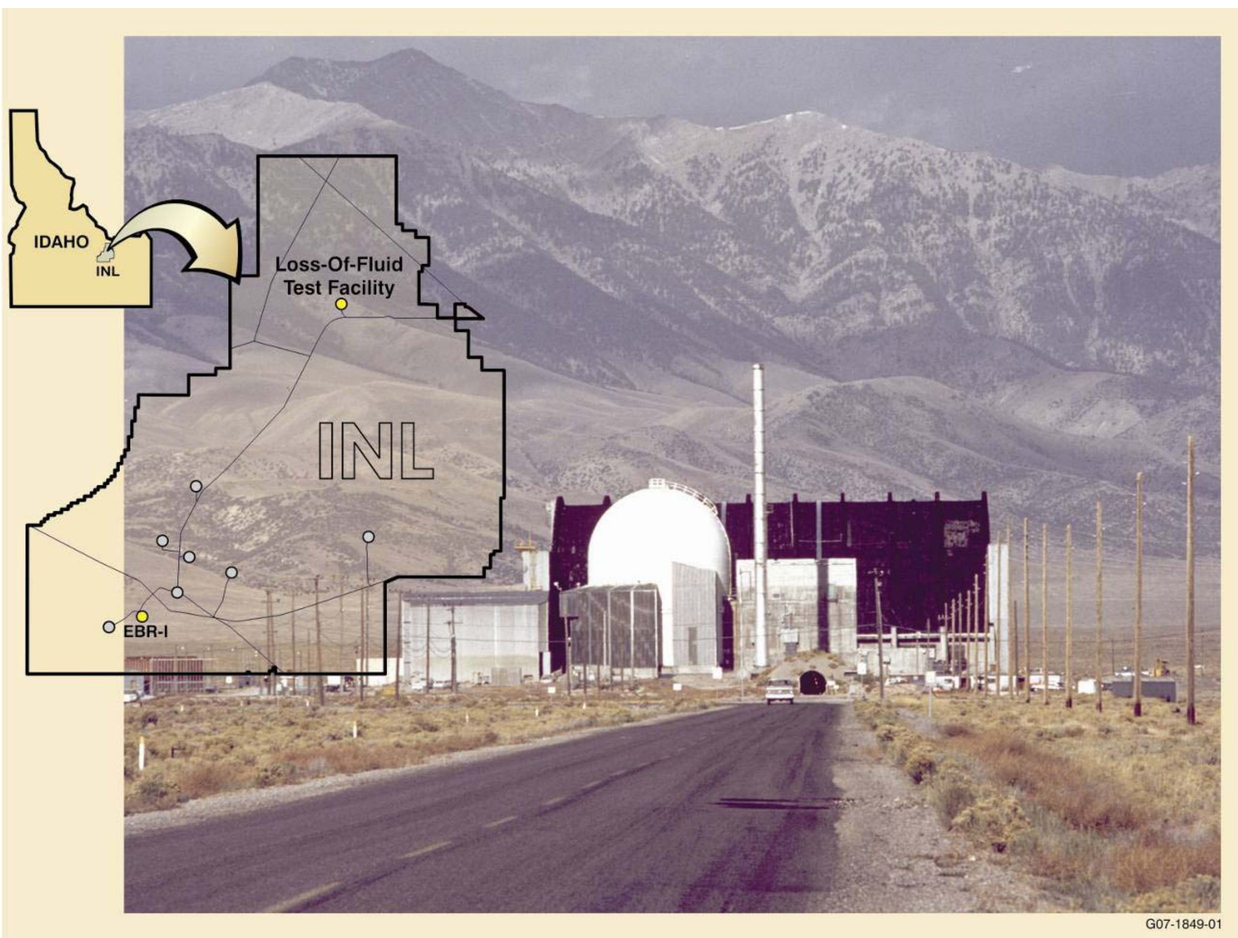

Fig. 1. Loss of Fluid Test reactor, once located on the Idaho National Laboratory site, played a critical role in nuclear energy research.

Management, focuses equally on reducing risks to workers, the public, and the environment, and on protecting the Snake River Plain Aquifer, the sole drinking water source for more than 300,000 residents of eastern Idaho.

To achieve its 2012 cleanup commitments, CWI will treat 3,785,000 liters (1,000,000 gallons) of sodium-bearing waste; remove targeted transuranic waste from the subsurface disposal area; and demolish more than 200 nuclear and nonnuclear structures, including reactors, spent nuclear fuel storage basins, and laboratories used for radioactive experiments.

The LOFT facility was located at the west end of Test Area North (TAN), built in the 1950s to support the government's aircraft nuclear propulsion program. When President Kennedy cancelled the nuclear propulsion program in 1961, TAN began to host various other activities. [2] The LOFT reactor became part of the new mission. The LOFT facility, constructed between 1965 and 1975, was a scaled-down version of a commercial pressurized water reactor. Its design allowed engineers, scientists, and operators to create or re-create loss-of-fluid accidents (reactor fuel meltdowns) under controlled conditions. The LOFT dome provided containment for a relatively small, mobile test reactor that was moved into and out of the facility on a railroad car. The dome was about 21 meters (70 feet) in diameter and 30 meters (98 feet) high. The Nuclear Regulatory Commission received the results from the accident tests and incorporated the data into commercial operating codes for reactors. The facility conducted 38 experiments, including several small loss-of-coolant experiments designed to simulate the type of accident that occurred at Three Mile Island in Pennsylvania, before the LOFT facility was closed. [3]

When DOE's focus turned to the cleanup of legacy waste from past operations, the LOFT facility was determined "high risk" and included in the cleanup scope.

AUTHORIZATION TO REMOVE A HISTORICALLY SIGNIFICANT FACILITY

In 1991, the Idaho State Historic Preservation Office (SHPO) recognized the facility as being among the most significant places on the INL site. Then in 2004, the facility was determined through formal survey and research to be a DOE Signature Property, as defined by the "INEEL Cultural Resource Management Plan," and thus eligible for inclusion in the National Register of Historic Places. [4] According to the plan, cultural resources may be standing structures, buildings, or objects that are more than 50 years old, of exceptional importance as deemed through their association with momentous events (e.g., Cold War, reactor testing, World War II), or embody significant workmanship and design. A Signature Property, as determined by DOE, denotes historically important properties across the Complex or those with tourism potential. [1]

The proposed D&D of the facility constituted an adverse effect on the historic property, requiring resolution among the contractor (CWI), the U.S. Department of Energy, the Idaho SHPO, and the Advisory Council on Historic Preservation. The SHPO initially requested an evaluation of the possibility of cleaning up (decontaminating) and preserving the facility for possible tours, allowing it to remain a more permanent structure, but this was deemed infeasible from a safety and economic perspective.

To satisfy the cleanup responsibilities of DOE and CWI and the cultural resources protection responsibilities of SHPO and the Council, the parties entered into a Memorandum of Agreement (MOA). The MOA was designed to capture and appropriately recognize the historic importance of the unique facility, yet to allow movement forward to achieve the DOE's objectives of safely cleaning up legacy waste at INL. The MOA included unique mitigation actions designed not only to capture the history of the LOFT facility but also to establish processes and programs to ensure that future culturally sensitive facilities are properly managed.

The following specific mitigation actions were included:

- Hire a professionally qualified historian to conduct or oversee the development, implementation, and completion of the actions included in the MOA.
- Edit and reprint 2,000 copies of *Proving the Principle: A History of the Idaho National Engineering and Environmental Laboratory, 1949–1999,* and make copies available to the general public and to the Museum of Idaho in Idaho Falls, ID.
- Establish a scholarship for study of cultural resource–related disciplines (i.e., archaeology, history, archiving) related to the history or prehistory of southeastern Idaho and the Snake River Plain.
- Publish several Historic American Building Survey/Historic American Engineering Record reports in compact disc and hard copy formats, and distribute them to the general public. The reports were to be designed to capture the history of INL's Signature Properties.
- Install interpretive signage throughout the Idaho Falls area, with verbiage determined through discussion with the Idaho SHPO, National Park Service, Shoshone-Bannock Tribes, and other stakeholders. [4]

On October 17, 2005, all parties signed the MOA, allowing D&D to proceed.

In addition to the stipulations described above, CWI recognized the historic importance of the shielded locomotive that transported the mobile reactor into and out of the containment facility during various testing evolutions. An initiative was launched to determine the possibility of relocating and preserving the critical piece of equipment, which had been used in support of 38 nuclear reactor experiments. Negotiations with the Idaho SHPO resulted in approval to relocate and display the locomotive at the Registered National Landmark at the INL. CWI successfully implemented a plan to decontaminate and move the locomotive from its moth-balled location at TAN, 56 kilometers (35 miles) south to its new home. The locomotive has joined Experimental Breeder Reactor-I (EBR-I) and the prototype of the nuclear powered aircraft engine, now on display at this landmark (see Fig.2).

The 16,450-kilogram (362,000 pound) locomotive was designed to protect its engineer from radiation and was a crucial part of the Aircraft Nuclear Propulsion program of the 1950s. As part of the program, prototype reactor-powered jet engines were moved on four-rail tracks a distance of 2.4 kilometers (1.5 miles) to a test area. The mobile reactor required a new safety philosophy: shield the people, not the reactor. The locomotive was shielded with lead to protect the engineer and had a double-paned, oil-filled window in front that was nearly 1.2 meters (4 feet) thick.

When the LOFT reactor was brought online, the locomotive again was used to transport the reactor from the LOFT facility to the TAN Hot Shop for examination.

To move the locomotive, a four-point gantry system lifted the heavily shielded engine high enough for a transporter to be rolled beneath it for the 45-minute trip to EBR-I. The 272-metric-ton (300-ton) gantry system was erected at TAN, then disassembled, moved, and reassembled at EBR-I to take the locomotive off the transporter and place it in its permanent home.

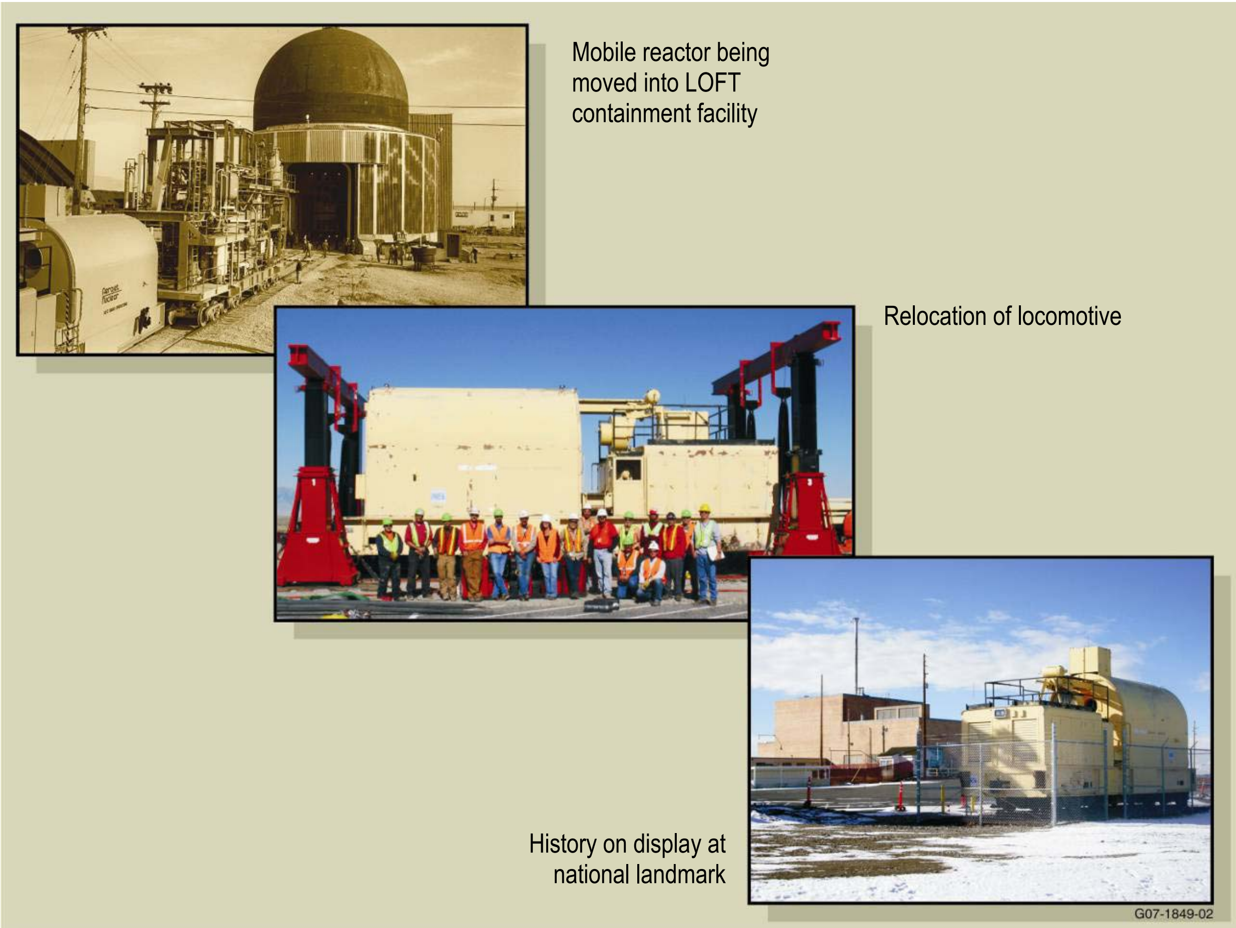

Fig. 2. The shielded locomotive used to move the mobile reactor into and out of the containment facility is now on display at the site national landmark facility.

Completion and implementation of the MOA, coupled with moving the locomotive to a permanent display, has allowed CWI to satisfy competing demands successfully and to proceed with decommissioning and removal of obsolete facilities to accommodate new missions at the site.

Demolition of the LOFT Facility

An analysis of the technical challenges and safety hazards was conducted to evaluate and determine the most effective demolition method for the LOFT facility. The height and geometry of the containment vessel created difficult access to the upper, center part of the dome. Typical high afternoon winds exacerbated the hazards associated with the use of aerial lifts. The thick steel materials used to construct the dome limited methods of cutting and size reduction. The option of hoisting and rigging dome sections down was considered too hazardous and an unacceptable approach because of the complex geometry of differing sections and the windy conditions. Contamination on the inner parts of the upper dome posed additional hazards. The dome could not be demolished until the interior circular polar crane was removed, and the crane had high levels of lead paint and was also highly contaminated. The awkward geometry made cutting and dropping or lowering the crane within the dome very dangerous. The entire demolition project was to take place near a vibration-sensitive operating facility and under much public scrutiny.

Facility Description

To demolish the imposing LOFT containment vessel structure (CV) safely, many unique challenges were faced and overcome. The CV was structurally attached to former support facilities and stood near an operating facility. The Control and Equipment Building (TAN-630) to the west was connected by concrete tunnels to the still operating Special Manufacturing Capability (SMC) facility. This area contained the control room with the entire facility covered with 2 meters (6.5 feet) of shielding soil and an emergency escape tunnel. To the north, the four-story emergency core cooling system building (TAN-650) supported a 73-metric-ton (80-ton), 17-meter (56-foot)-long tank on the top level. The facility was heavily reinforced for shielding and to support the tank weight. To the north and east, numerous basement areas contained off-gas and support equipment.

The CV stood 30 meter (98 feet) high with a diameter of 21 meters (69 feet). The 19-meter (62-foot)-high cylindrical section was constructed of 30-millimeter (1-3/16-inch) carbon steel and the 10.5-meter (34-foot)-high hemispherical dome of 16-millimeter (5/8-inch) carbon steel. The weight of the CV destined for demolition above the operating floor was estimated at 855 metric tons (942 tons). The CV consisted of the hemispherical top shell (90 metric tons, [100 tons]), the cylindrical shell (305 metric tons [336 tons]), the railroad door (173 metric tons [190 tons]), the door frame assembly (196 metric tons [215 tons]), and the polar crane assemble (90 metric ton [100 tons]).

A circular (polar) crane assembly with lead-based paint was at the 19-meter (62-foot) level. The crane and the upper, inner surfaces of the CV dome were radiologically contaminated and had PBS (polymeric barrier system) spray applied as a fixant prior to demolition. PBS is a nontoxic, water-based solution that forms an impermeable barrier between hazardous or contaminated materials and the environment. Lower, more accessible, areas had previously been decontaminated to safe levels.

Facility Isolation and Preparatory Activities

All utility, process, life safety, and electrical feeds were isolated from the CV. The connecting concrete tunnels to SMC were saw-cut to create a clean break and permanently sealed with concrete bulkheads. Asbestos insulation was removed from piping and pipe penetrations. Two boilers with asbestos fire brick were removed and disposed of. Hazardous materials were removed from the control room and segregated. The lower containment area and sumps were filled with 1,150 cubic meters (1,504 cubic yards) of low-strength grout to create a solid monolith. Shielding soil was removed from TAN-630 and stockpiled for use as ramps and basement backfill. Track hoes with processor and hammer attachments were used to demolish support buildings. Soil ramps were built to reach high areas of TAN-650. All basement walls were lowered by .91 meters (3 feet) following the removal of equipment, conduit, and piping. Bulldozers pulled the large tank off the TAN-650 building. The adjacent cleared areas were then backfilled with soil to completely physically isolate the CV.

Demolition Approach

The physical nature of the CV created many hazards with removal, such as personnel working on elevated surfaces, significant hoisting and rigging evolutions, material size reduction for proper waste disposal, control of contamination, high winds affecting exterior aerial work, and awkward angles for reaching the inner polar crane for controlled removal. Demolition took place only 57 meters (187 feet) away from the operating SMC facility, which is sensitive to vibration.

Standard D&D methods were evaluated to determine the most desirable approach for demolishing the CV. Explosive demolition of the entire CV was considered, but the amount of pre-crippling and the resulting air blast and vibration effects on the adjacent facility were deemed unacceptable. Use of a processor to cut down the CV was investigated, but height and the shell thickness for the processor shears proved to be limiting factors. The resulting cuts would be rough and uneven, and make transport of the pieces to the waste disposal facility difficult. The use of cutting torches and an internal polar crane was a feasible option, but safe access to the crane was prohibitive. Accessing the top of the CV dome to make the initial cuts was risky with respect to fall protection from aerial lift in wind and the air blast of the falling sections. Radiological contamination on the inner part of upper dome required additional personal protective equipment for torch cutting. Hazards posed by the protective equipment were heat stress, reduced productivity, and obstructed vision.

Because the task at hand was complex and unique, a performance specification subcontract, highlighting all constraints and challenges, was prepared allowing for innovative technical approaches by specialized bidders. A best-value award was made based on technical approach, safety record, experience, key personnel, cost, and proposed schedule.

To mitigate hazards posed by the height of the physical structure, the project team employed a composite approach of the options previously evaluated. Explosives were used to remove the interior polar crane and top part of the dome, but traditional methods (processors, hot-cutting) were used on the lower parts of the facility (see Fig. 3).

The polar crane supports were weakened at key pre-engineered structural locations at the ends where the crane was attached to the dome. Linear-shaped explosive charges were then placed at the weakened areas to facilitate the final removal of equipment. This permitted workers to cripple the crane under safe conditions.

The team used horizontal stitch cutting to weaken the dome 3 meters (10 feet) below the top. Eight 3.7-meter (12-foot)-long cuts with 20-centimeter (8-inch)-diameter holes at each end were burned using a magnesium oxide long-arm lance. Three-meter (10-foot)-wide spacing was left between cuts to support the dome. The pre-crippling was determined to not exceed a demand-to-capacity ratio of 1.0, using a 3-second gust wind speed of 112 kph (70 mph), exposure Category C, and an importance factor of 1.0 prior to intentional collapse. Linear-shaped explosive charges were placed on the inside of the remaining material at the circumference near the top of the dome. Conveyor belting was attached with rebar wire on the exterior of the dome covering the explosive cut areas to control risk from flying debris. Seismographs were installed at four locations around adjacent facilities to determine peak particle velocity and to measure air blast forces.

The polar crane and dome structure charges were set off simultaneously, felling the crane and severing the top of the dome. By placing the charges inside the dome to minimize flying debris, the severed dome was lifted, then shifted slightly, hanging up partially within the cylinder. Two followup cuts with an oxy-propane torch were completed, and the 46-metric-ton (51-ton) dome safely dropped within the cylinder of the containment vessel (see Fig. 3). Vibration and air-overpressure readings were below the calculated limits.

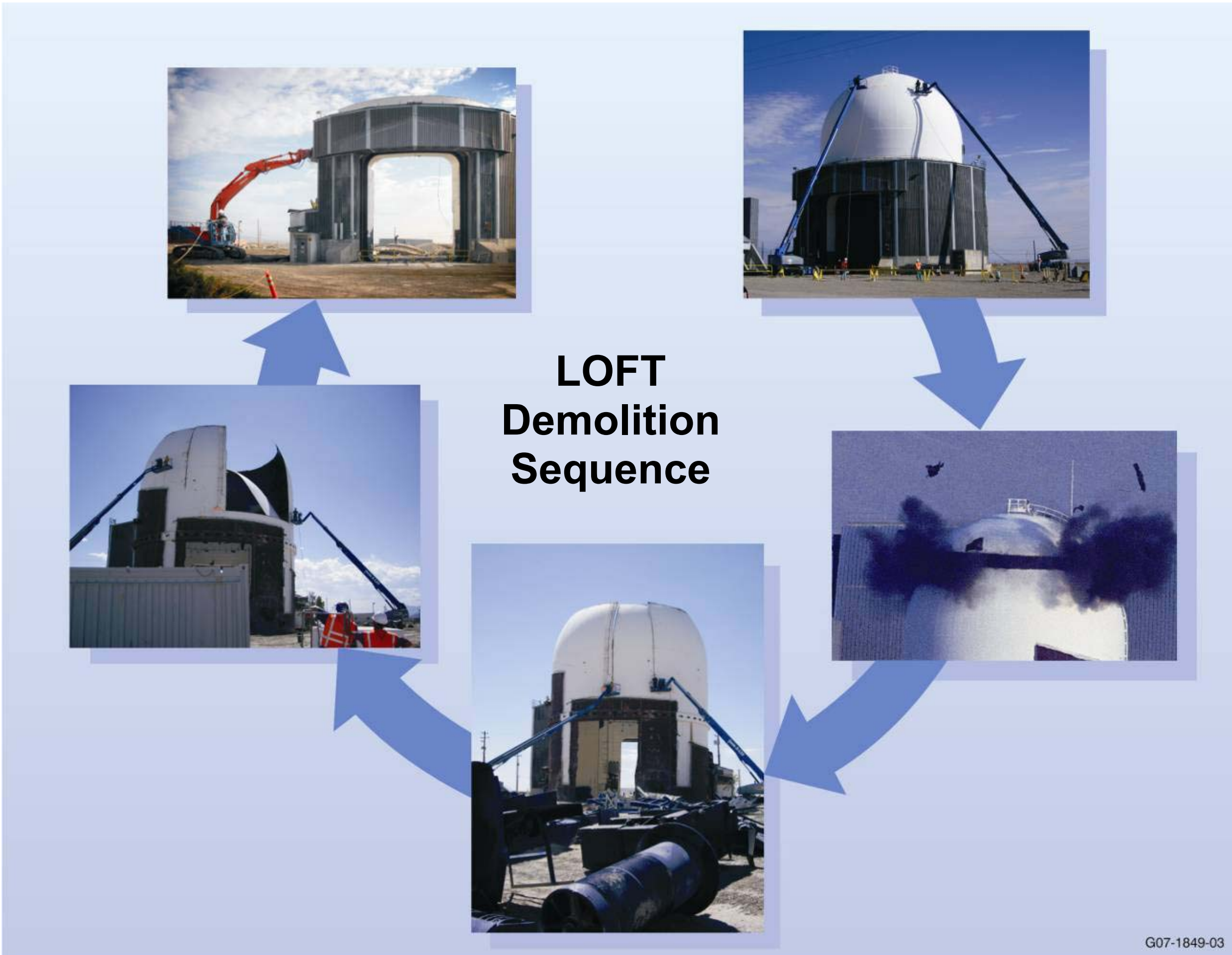

Fig. 3. CWI used a combination of demolition techniques to protect workers and nearby facilities.

The remaining parts of the structure could then be felled using controlled hot cutting methods, taking advantage of the eccentrically loaded, overhanging sections to fall safely to the ground, again, within the cylinder of the containment vessel. These sections were sized to be handled by equipment on the ground, which minimized later size reduction to meet the disposal facility's waste acceptance criteria. Explosive and demolition experts worked with a knowledgeable, onsite team to develop the safe, effective D&D strategy.

A comprehensive management self-assessment was performed before proceeding with the explosive task. A detailed timeline was prepared, and all effected parties participated in the planning, work package development, and subsequent approval. Evacuations, road blocks, and countdown protocol were developed and agreed upon before explosives arrived onsite.

CONCLUSION

Demolition of the LOFT facility was a significant success from many aspects. It was the first major historically significant facility completed under the new CWI contract (see Fig. 4). The contract listed the structure as one of nine high-risk facilities at INL that CWI is to dispose of between May 2005 and September 2012.

The following critical metrics were used to demonstrate the success of this demolition project:

- Outstanding safety record for the entire duration of the project:
  - zero recordable injuries
  - zero lost-time injuries
  - five first aid cases
- Demolition of a 7,000-square-meter (75,300-square-foot) high-risk facility
- Disposition of more than 12,230 cubic meters (16,000 cubic yards) of waste
- Placement of a historically significant locomotive on permanent display to educate future generations
- Completion of more than 1 year ahead of schedule and at a significant cost saving; major contribution to an over all ICP D&D Project Cost Performance Index of 1.48 ($34,100,000) and Schedule Performance Index of 1.23 ($20,100,000)
- Elimination of ongoing surveillance and maintenance costs, freeing funds for use on other risk-reduction activities

Fig. 4. D&D crews on the Idaho Cleanup Project used unique D&D techniques to deliver the LOFT demolition safely while preserving a historically significant part of the reactor development era.

REFERENCES

[1] *Idaho National Laboratory Site Cultural Resource Management Plan*, DOE/ID-10997, U.S. Department of Energy Idaho Operations Office (2004)
[2] Department of Energy News Release, *Agencies Sign Record of Decision for Cleanup of Test Area North,* (1999).
[3] *Test Area North* Fact Sheet, Idaho National Engineering and Environmental Laboratory.
[4] Memorandum of Agreement between United States Department of Energy, Idaho Operations Office, and the Idaho State Historic Preservation Office, (2005).