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Progress and Future Direction for the Interim Safe Storage and Disposal of Hanford High-Level Waste

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PROGRESS AND FUTURE DIRECTION FOR THE INTERIM SAFE STORAGE AND DISPOSAL OF HANFORD HIGH-LEVEL WASTE

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ABSTRACT

This paper describes the progress made at the largest environmental cleanup program in the United States. Substantial advances in methods to start interim safe storage of Hanford Site high-level wastes, waste characterization to support both safety- and disposal-related information needs, and proceeding with cost-effective disposal by the U.S. Department of Energy (DOE) and its Hanford Site contractors, have been realized. Challenges facing the Tank Waste Remediation System (TWRS) Program, which is charged with the dual and parallel missions of interim safe storage and disposal of the high-level tank waste stored at the Hanford Site, are described.

In these times of budget austerity, implementing an ongoing program that combines technical excellence and cost effectiveness is the near-term challenge. The technical initiatives and progress described in this paper are made more cost effective by DOE's focus on work force productivity improvement, reduction of overhead costs, and reduction, integration and simplification of DOE regulations and operations requirements to more closely model those used in the private sector.

I. INTRODUCTION

The federal government established the Hanford Site in south central Washington State near the city of Richland in 1943 to produce plutonium for national defense. The Hanford Site occupies approximately 1,450 square kilometers (560 square miles) of land north of Richland. The production mission ended in 1988, thus shifting the Hanford Site mission to waste management, environmental restoration, and disposal of radioactive, hazardous, and mixed waste.

These wastes are presently stored in 2.08E+05-L (55,000-gal) to 4.16E+06-L (1,100,000-gal) low-carbon-steel-lined tanks. There are 149 single-shell and 28 double-shell radioactive waste underground storage tanks, as well as approximately 40 smaller inactive miscellaneous underground storage tanks. In addition, the TWRS mission includes disposal of 1,929 cesium and strontium capsules created as part of waste management efforts, should the capsules be declared wastes.

Tank waste was a byproduct of the production of plutonium and other defense-related materials. From 1944 to 1990, four different major chemical processing facilities at the Hanford Site processed irradiated (spent) fuel from defense reactors to separate and recover plutonium for weapons production. As new and improved processes were developed, the processing efficiency improved and the waste compositions sent to the tanks for storage changed both chemically and radiologically. The earliest separation processes (e.g., bismuth phosphate coprecipitation) carried out in T Plant (1944-1956) and B Plant (1945-1952) recovered only plutonium. All remaining dissolved fuel elements, including uranium, were sent to the tanks as alkaline waste. Later processes, such as the Reduction Oxidation Plant process (REDOX) and Plutonium Uranium Extraction (PUREX) flowsheets were also developed to recover uranium, which was then recycled back into making reactor fuel. The process of purification of both plutonium (Z Plant) and uranium (U Plant) also led to the creation of waste streams which, after neutralization to a pH >10, were added to the tanks.

Most processes associated with plutonium recovery from spent fuel involved dissolving the material in nitric acid. After extensive acid side chemical separations to recover plutonium, uranium, and often neptunium, the waste streams were made alkaline by addition of sodium hydroxide and/or calcium carbonate prior to their transfer to the low-carbon-steel waste tanks. The process of making waste alkaline produced large quantities of metal oxyhydroxides, which, along with solids from the bismuth phosphate process, formed the sludge found in the bottom of the tanks. The waste composition in tanks was complicated further by the recovery of uranium by sluicing during 1952-1958. The waste was made alkaline to prevent corrosion of the low-carbon-steel tanks, thereby introducing large volumes of sodium nitrate and other sodium salts into the waste tanks. Sodium nickel ferrocyanide was added to 20 of the tanks during the 1950s in order to precipitate solids and create additional space in the tanks.

To increase useful storage capacity, volume reduction methods (e.g., in-tank and external evaporation), and recovery of heat-producing cesium and strontium in B Plant (1968-1985), were carried out. The concentration of the originally soluble sodium-salt-rich waste led to the production of the saltcake that is often found overlying the sludge waste in the tanks. Most of the hazardous chemicals and radionuclides are found in the sludge. Only radio-cesium, -iodine and -technetium are significantly soluble in alkaline salt solutions.

The single-shell tanks were taken out of active service in 1980, and no new waste has been added to these tanks since then. Sixty-seven of these tanks are assumed or confirmed leakers. Removal of drainable liquid by saltwell pumping (interim stabilization), waste sampling in support of characterization, installation of new monitoring equipment, and/or any mitigation or remediation deemed necessary to assure interim safe storage of the waste, are the only significant intrusive activities into these tanks. Drainable liquid removed from the single-shell tanks, as well as dilute waste resulting from decontamination of production facilities, is added to the double-shell tanks after due consideration of waste compatibility concerns. There are approximately 2.12E+08 L (55 Mgal) of waste in the TWRS single- and double-shell tank system.

II. THE TWRS MISSION

The TWRS Program is the largest environmental cleanup program in the United States. The TWRS mission is to place all tanks in an interim safe storage condition and prepare for long-term disposal of tank waste.

A. TWRS Mission-Related Activities

TWRS mission-related activities include:

1. Continuation of the current program of tank monitoring and maintenance, including any enhancements needed to assure interim safe storage of waste (see the discussion of controlled, clean, and stable below);

2. Resolution of safety issues related to interim safe storage and/or disposal of the waste in the tanks;

3. Removal and transfer of pumpable liquids from single-shell tanks by saltwell pumping (interim stabilization);

4. Performance of waste and tank characterization to the extent needed either to resolve tank safety issues or to support safe retrieval, transfer, processing (pretreatment) and disposal of the waste;

5. Continuation of receipt and storage of newly generated waste in double-shell tanks; and

6. Concentration of waste to the maximum extent safely practical in the 242-A Evaporator.

These activities ensure that the tank contents and the tank farms themselves are maintained in a controlled, clean, and stable mode until the waste is retrieved and processed for disposal.

In addition, major resources are being expended to:

1. Develop and apply systems engineering to assure integration of the overall TWRS mission activities;

2. Prepare for phased waste retrieval, treatment and waste vitrification efforts that form DOE's first major step in demonstrating waste disposal using private sector resources (privatization);

3. Achieve an integrated and responsive safety authorization basis to assure continued safe operation of the tank farms as the mission changes from storage to disposal; and

4. Analyze tank waste through effective sampling and phenomenological understanding for the basis of

mitigation, addition of tank controls or safety issue resolution.

The remainder of this paper will highlight recent achievements in resolving tank waste safety issues, progress toward putting the tank farms into a controlled, clean and stable mode, and transition to an operating mode in which privatization is a key factor.

B. Progress Made in FY 95-96 and Planned in FY 97

As described below, DOE and its management and operations contractor, Westinghouse Hanford Company (WHC), have made significant progress in meeting mission objectives.

1. Key Progress in 1995

- Eliminated the need for six new 3.78E+06-L (1-Mgal) high-level waste tanks by using a strategy for resolving the safety issues using existing tanks, fostering waste minimization and accelerating waste volume reduction by efficient concentration of dilute waste streams from facility generators. By canceling a project that called for six new tanks, $385 million in costs was avoided.

- Completed the first cross-site transfer of wastes since 1989; 1.70E+06 L (450,000 gal) was transferred 7 miles to facilitate volume reduction of dilute waste stored in the 200 West Area. Success required exacting engineering and testing as well as successful collaboration with regulators.

- The volume of high-level waste was reduced by more than 7.57E+06 L (2 Mgal) by evaporation, freeing up space to receive wastes generated by the cleanup and ultimate decommissioning of unneeded production facilities.

- Improved the safety of high-level waste tanks by completing installation of standard hydrogen detectors in all flammable gas safety issue tanks, and new thermocouple trees in tanks that had received ferrocyanide-containing (fuel-rich) waste.

- Reduced radioactive surface area contamination by 92,900 m^2 (1 million ft^2), fostering our goal of bringing the tank farms into a controlled, clean and stable mode.

- Interim stabilized 7 single-shell tanks containing high-level waste by pumping out drainable liquids to the double-shell tanks. Such action, in keeping with our regulatory agreements, reduces the chances for significant release of high-level waste to the tank farm environment should the older single-shell tanks develop a leak. 115 of 149 single-shell tanks are now interim stabilized.

2. Progress in 1996

- Issued, for public review and comment, the EIS for disposal of Hanford high-level wastes. When supported by a Record of Decision, this document will serve as the road map for the disposal of waste contained in the Tank Farm system.

- Will award contracts to private companies for the initial work leading to the design, construction and operation of commercial demonstration facilities to treat and immobilize Hanford Site tank waste.

- Complete resolution of the Hanford Site high-level waste ferrocyanide safety issue. A large quantity of sample data and studies of waste energetics and aging, coupled with extensive modeling efforts, has provided the technical safety basis for resolving this safety issue.

- Finalize plans and install equipment needed to resolve the high heat safety issue in tank 241-C-106 by removing the majority of the heat-bearing solids to a double-shell tank better designed for storing such waste. Completion of this effort in 1997 will allow DOE and its contractor to stop adding cooling water to this high-heat single-shell tank, reducing potential releases of waste to the environment should this tank start to leak.

- Received the state-of-the-art high-level liquid waste transport cask. This heavily shielded 3,785-L (1,000-gal) trailer-truck-mounted container provides a rapidly deployable alternative means of transporting liquid high-level waste in the event single-shell tank leakage is detected.

- Increased the productivity and quality of high-level waste tank characterization by developing and implementing improved sampling and analysis equipment and methods. In 1996, we will take 45 rotary-mode and 12 push-mode full-depth core samples from the waste tanks, and issue 21 tank characterization reports. These tasks are part of a strategy that supports reaching agreement with the Defense Nuclear Facilities Safety Board (DNFSB) on revision of the DOE implementation plan for DNFSB Recommendation 93-5.

- Completed interim stabilization of six additional single-shell tanks by pumping drainable liquids to the newer double-shell tanks.

- Reduce the high-level waste volume by an additional 3.03E+06 L (800,000 gal) by evaporation.

- Achieved a controlled, clean, and stable condition for two or three single-shell tank farms.

3. Planned Progress in 1997

- Resolve the high heat safety issue by removing the high-heat waste from single-shell tank 241-C-106 to double-shell tank 241-AY-102.

- Resolve the organic safety issue by demonstrating a thorough understanding of the reactive behavior of waste constituents or by providing mitigative measures.

- Complete all Secretarial initiatives on the Hanford Site waste tanks. (36 of the 44 issues have been resolved.)

- Issue an approved Hanford Site tank farm final safety analysis report that will define the safety basis for the tank farm system and implement the necessary safety controls in the field.

- Complete necessary actions so that at least two or three additional single-shell tank farms are transitioned to a "controlled, clean and stable" condition with ensuing reduced operating and maintenance costs.

- Complete interim stabilization of 14 additional single-shell tanks by pumping drainable liquids to the newer double-shell tanks.

- Conduct demonstration test of double-shell tank mixer-pump-based retrieval and sludge washing systems in tank 241-AZ-101 to support privatized tank waste treatment and immobilization commercial demonstrations.

- Issue final TWRS environmental impact statement and associated record-of-decision that will define the plan for retrieving, treating, immobilizing and disposing of Hanford Site tank wastes.

III. PROGRESS IN RESOLVING THE TANK WASTE SAFETY ISSUES

Of four major safety issues (flammable gas, ferrocyanide, organics in the tank, and high heat), two are essentially closed. Concern that waste tanks have the potential for releasing high-level radioactive wastes to the environment resulted in the passing of Public Law 101-510, section 3137, "Safety Measures for Waste Tanks at Hanford Nuclear Reservation," also known as the Wyden Amendment, in 1990. In response, DOE developed a set of criteria to identify tanks with potential safety concerns as "Watch List" tanks. There are currently 54 Watch List tanks, with 10 tanks listed in more than one of four different categories based on the specific safety concerns described below.

Detailed evaluation of tank contents and behavior, starting in 1989, resulted in the following safety issues.

1. Flammable Gas Issue - Twenty-five of the stored single- and double-shell waste tanks were generating, storing, and releasing hydrogen in quantities that might lead to flammable gas concentrations above the safety margin of 25% of the lower flammability limit. Recent measurements have shown that changes in atmospheric pressure may cause changes in liquid levels in some of these and other waste tanks. These changes may indicate that a greater amount of gas is stored in the waste than

previously believed, and 25 additional tanks may be added to the Flammable Gas Watch List until this issue is resolved. Screening of all waste tanks for potential flammable gas accumulation is in progress.

Tanks with a potential for flammable gas release have been placed under stringent administrative control while their potential for flammable gas release is being evaluated. Tank 241-SY-101, the tank that periodically released the greatest quantity of gas, occasionally filling the headspace with hydrogen above the flammable limit, was safety mitigated by installation of a mixer pump. The periodic operation of the mixer pump allows stored gases to be released in a manner that poses no risk from flammability concerns. Gas monitors and other instrumentation have been put on all Flammable Gas Watch List and suspect tanks to gather information on gas storage and release behavior. Information is being gathered to determine the specific mechanisms of gas storage and release to better evaluate the risk from stored flammable gases, aid in their control and mitigation and better avoid creating such tanks in the future.

Results of extensive tank monitoring and surveillance show that most of the tanks on the Flammable Gas Safety Watch List pose little potential for exceeding 25% of the lower flammability limits for generated gases, or if such gas accumulation potential exists, it can be mitigated by installing a low-flow ventilation system on the tank.

2. Organic Safety Issue - Twenty single-shell tanks contain organic materials in the presence of excess sodium nitrate and sodium nitrite oxidizing agents. This situation could lead to a potential propagating reaction, with ensuing release of radioactive and hazardous materials to the environment, if the waste were dried and heated to threshold temperatures above 200 °C.

Radiolytically or chemically induced waste aging processes have destroyed or significantly lowered the energy content of a vast majority of organic materials added to the tanks. Therefore, conditions exist that do not create the potential for a propagating reaction in even a dry tank.

Furthermore, the exploration of waste species energetics, waste species solubility, and waste tank chemistry are demonstrating that the organic-rich tanks contain a sufficient amount of moisture to preclude a risk from propagation under even the bounding "worst case" accident scenario. A combination of experimental work and waste characterization is continuing to provide data to substantiate these findings of waste safety.

3. Ferrocyanide Safety Issue - Eighteen single-shell tanks contain sodium nickel ferrocyanide, which could similarly pose a threat of a propagating reaction, if the waste were dried and heated above 250 °C. Ferrocyanide-based deflagration represents the bounding "worst case" accident scenario previously identified in the Hanford Environmental Impact Statement.

Current conditions for storing ferrocyanide waste at the Hanford Site (passively ventilated underground tanks) foster the retention of moisture and the passive dissipation of nuclear decay heat. Decay heat loads are known to decrease with time, and tank samples and laboratory studies indicate that ferrocyanides have degraded over the four decades of storage history. Therefore, hazards posed by uncontrolled exothermic reactions are expected to further diminish with continued storage time. Recent aging studies have shown that the combined effects of temperature, radiation, and pH during 38 years or more of storage would have destroyed most of the ferrocyanide originally added to the tanks. Because of new core and analytical sampling effectiveness, sample results through full depth of FeCN tanks have shown Fe $<$ 8 weight percent. This type of confirmation of phenomenological basis exemplifies the need for sampling. The resultant sludge is too dilute to support a sustained reaction, even if dried out and heated to ignition temperatures.

4. High Heat Safety Issue - One single-shell tank (241-C-106) contains sufficient heat-producing radio-strontium that it requires addition of cooling water to prevent tank failure from structural damage, if the tank temperature is allowed outside of the safe operating criteria.

As was stated in the previous sections, this issue will be mitigated by removing the strontium-rich sludge to a double-shell tank, one that by design is able to deal with the heat load.

IV. PROGRESS TOWARD PLACING THE HANFORD SITE SINGLE-SHELL TANK FARMS INTO A CONTROLLED, CLEAN, AND STABLE MODE

For the first time in the 50-year history of the tanks at the Hanford Site, a tank farm of six tanks was designated "controlled, clean and stable" on December 3, 1995. Congressman Doc Hastings and the public were allowed to enter the farm to observe this new state. An essential element of the strategy for meeting the TWRS mission is achieving a controlled, clean, and stable condition in the Hanford Site tank farms. This strategy is essential in achieving an interim, safe, low-cost status until retrieval and disposal operations commence.

The definitions of controlled, clean, and stable are:

1. Controlled: a) All necessary (as determined by safety analysis) active and passive safety systems are in place; b) Any safety issues related to interim safe storage and/or disposal of the waste stored in Watch List tanks are resolved; and c) All controls necessary to meet risk acceptance criteria for current operations are in place.

2. Clean: a) Surface contamination areas are cleaned and reduced to radiological control areas or even less controls; b) Unused contaminated equipment is removed from the tank farm; and c) Reusable equipment is stored if not in use.

3. Stable: a) Pumpable liquids from single-shell tanks are removed by saltwell pumping (interim stabilization); and b) All penetrations where liquids could intrude into the tanks are sealed.

A. Strategy for Achieving a Controlled, Clean, and Stable Tank Farm Environment

The controlled, clean, and stable strategy has the following four missions:

1. Provide Safe Storage Prior to Retrieval - This task includes updating safety analyses, and specifying necessary engineering design features and operational and administrative controls.

2. Reduce Worker Exposure to Hazards - Every time a worker enters a tank farm, or operates equipment in or near a tank, there is some level of potential exposure to radiological and chemical hazards. Controlled, clean, and stable reduces worker exposure to these hazards.

3. Maintain Compliance with Regulatory Requirements - The Hanford Site Tank Farms are regulated as a treatment, storage and disposal facility, with associated permits and closure agreements in compliance with regulatory requirements. All interim storage activities must be performed in a manner to assure current and continued future compliance with regulatory requirements.

4. Reduce the Tank Farm "Mortgage" - The "mortgage" is the current operational cost to monitor the tanks and their waste. This task is currently a labor-intensive effort that includes a large number of tank farms and tank entries. The controlled, clean, and stable condition significantly reduces this "mortgage."

B. Planned Upgrades in Support of Controlled, Clean, and Stable

Focused tank farm upgrades are planned to improve the reliability of safety-related systems, minimize onsite health and safety hazards, improve the regulatory compliance of tank farm support systems, and put the tank farms into a controlled, stable work environment until disposal is completed. The following upgrades are planned.

- Instrumentation such as automatic tank data gathering equipment, management control systems, and closed-circuit television monitoring will be upgraded or added to minimize personnel exposure and to provide more accurate data for tank status assessment.

- Tank ventilation systems will be upgraded to replace outdated ventilation systems.

- Electrical systems will be upgraded to meet capacity needs for both routine monitoring and to support retrieval, as well as to comply with the current upgraded electrical codes.

- Piping systems will be upgraded to enable transfer of liquid or waste slurries from the decontamination and decommissioning of other selected Hanford Site facilities to the tank waste system.

V. CHARACTERIZATION OF TANK WASTES

Another essential element of the strategy to achieve the TWRS mission is the characterization of tank wastes. "Characterization" is understanding the chemical, physical, and radiological properties of the waste to the extent necessary to ensure safe storage, interim operation, and ultimate disposition of the waste.

Five sampling methods are currently used to gather information on tank wastes: 1) Grab sampling of supernatant liquids for laboratory analysis; 2) Vapor sampling for both on-line and laboratory analysis; 3) Core sampling of solid wastes using core sampling systems designed to drill or push into the waste to retrieve segments that are about 2.5 cm (1 in.) in diameter and 50 cm (19 in.) long; 4) Auger sampling of the top 40 cm (16 in.) of waste in the tanks; and 5) In situ measurement of the void volumes in the waste and the viscosity of the waste.

To address the challenge of safely characterizing the waste tanks and to bring focus to the program, the TWRS Tank Characterization Project was formed in February 1995. The Characterization Project accomplished the following tasks during 1995.

- Two new rotary core sampling trucks were deployed.
- Key improvements were made to the drilling equipment and the drill bits to make them more compatible with the type of waste being drilled and to improve sample recovery. These improvements resulted in sample recovery increases from an average of 20% to over 90%.
- A new X-ray imaging system was deployed for use in the field to determine the amount and type of waste in the sampler.
- A Tank Waste Characterization Basis document was issued that: 1) established a prioritization basis for sampling that integrates known safety and disposal programmatic needs; and 2) defined the key waste tanks to be sampled based on grouping tanks into similar categories and selecting tanks to answer specific safety questions.
- Four core sampling crews were trained and certified.
- Data quality objectives were issued for the five primary sampling needs: safety program; retrieval, pretreatment, and disposal program; waste compatibility; historical model evaluation; and privatization waste characterization.
- Analytical laboratories were upgraded, and the goal throughput of five analytical equivalent units was achieved in October 1995 for the first time.

These changes resulted in a ten-fold increase in the number of core samples taken during CY 1995 compared to CY 1994. This was particularly important for the full-length core samples where 49 core samples were obtained in 1995 compared to 5 core samples during CY 1994. Sample loads through the analytical laboratory more than doubled. Finally, by the end of CY 1995, 116 of the 177 underground storage tanks had been sampled using one of the five sampling methods listed above.

A. Improvements in Characterization Capabilities Planned for Out Years

1. Deploy a core sampling system capable of retaining gas in the core samples and then analyzing those samples for the gases that are trapped in the waste.

2. Deploy a cone penetrometer system for in situ measurements of rheological properties of the waste and moisture content (using a neutron moisture probe). The cone penetrometer includes a Raman spectroscopy system capable of in-place speciation.

3. Deploy a surface moisture measurement system capable of measuring the moisture content of surface wastes within the tanks up to 2 m (6 ft) off-center below the 10-cm (4-in.) tank risers into the tank headspace.

4. Deploy a light duty utility arm capable of robotic operations over 3 m (10 ft) off-center in the headspace below 30-cm (12-in.) risers into the tanks. This system will provide significant flexibility for inspection, sampling, gripping, and cutting operations in the tanks.

5. Redesign some of the core sampling equipment to allow rotary sampling (necessary to retrieve samples from very hard wastes) from tanks that could potentially contain explosive mixtures of gases within the waste.

VI. SUPPORT OF DOE PRIVATIZATION EFFORTS

In September 1995, DOE announced its intent to "privatize" the disposal part of the tank waste remediation program. The idea was to turn cleanup of Hanford Site tank waste over to private companies that would do the design work and pay construction costs without federal appropriations. The companies would then be paid for the waste they produced. The privatization would be done in two phases: 1) design and construction of waste treatment and immobilization facilities for a small fraction of the waste (6-13%), followed by; 2) design and construction of waste retrieval, treatment, and immobilization facilities for the bulk of the waste. Characteristics of the two (2) phases are summarized in Table 1. During Phase I, waste retrieval would be performed by the existing Site contractor.

A draft request for proposal (RFP) was issued for comment in November 1995, and a final RFP released in February 1996 for the first phase. In August 1996, up to three companies will be selected for more in-depth design work. Each company will design a prototype plant to treat and immobilize the low-level radioactive waste fraction stored in selected tanks. Bidders will have the option of adding a prototype plant to vitrify (in glass) high-level radioactive waste. In February 1998, DOE will select the best bidders' proposals to build the waste plants, with hot operations to begin by December 2002. It is possible that a third plant to vitrify high-level wastes will be authorized for the same time period.

DOE's goal is for the two prototype plants to process 13,200 tons (~3%) of waste in the first 2-1/2 years and another 24,200 tons (~5-6%) in the second 2-1/2 years.

As the first phase nears completion, DOE will issue an RFP to build two larger low-level waste vitrification plants, plus a full-scale high-level waste vitrification plant. The second phase bidding process will be open to any company interested, not to just the successful Phase 1 bidders. Construction of the larger second-phase low-level waste plants is scheduled to begin in 2008. The second-phase high-level waste plant is to begin operating in 2010, and the low-level waste plants are to start in 2011. All Hanford Site liquid radioactive wastes are to be immobilized by 2028.

Table 1. Privatization Approach

Phase I: Waste Treatment and Immobilization Demonstration, ~6 - 13% of Waste	Phase II: Waste Retrieval, Treatment, and Immobilization Production, ~87 - 94% of Waste
- Low-level waste fraction plus option for high-level waste fraction	- All remaining tank waste plus potentially cesium and strontium capsules
- Three preliminary design contracts; two vendors selected to design, construct, and operate two competitive facilities	- Two vendors selected to design, construct, and operate two competitive facilities
- Schedule - Select two vendors 1998 - Hot Start-up 2002 - Complete demo phase 2011 - Complete D&D/RCRA Closure 2013	- Schedule: - Select two vendors 2005 - Hot start-up 2011 - Complete single-shell tank retrieval 2018 - Complete immobilization 2028

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