

WM '02 Conference, February 24–28, 2002, Tucson, AZ

## **REVIEW OF INDUSTRIES AND GOVERNMENT AGENCIES FOR TECHNOLOGIES APPLICABLE TO DEACTIVATION AND DECOMMISSIONING OF NUCLEAR WEAPONS FACILITIES**

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### **ABSTRACT**

The Deactivation and Decommissioning Focus Area's (DDFA's) mission is to develop, demonstrate, and deploy improved deactivation and decommissioning (D&D) technologies. This mission requires that emphasis be continually placed on identifying technologies currently employed or under development in other nuclear as well as nonnuclear industries and government agencies. In support of DDFA efforts to clean up the U.S. Department of Energy's (DOE's) radiologically contaminated surplus facilities using technologies that improve worker safety, reduce costs, and accelerate cleanup schedules, a study was conducted to identify innovative technologies developed for use in nonnuclear arenas that are appropriate for D&D applications.

Industry selection was based on the anticipated potential for technology transfer from an industry or government agency to D&D applications. Current D&D needs were sorted according to problem area, national priority (as determined by the DOE Environmental Management program), and technical response (technologies suggested for potential deployment to meet specific site needs) to gain a better understanding of the types of technical needs represented in the DDFA and to ensure that the industry search would focus on today's most relevant D&D problems.

Based on need prioritization, it was concluded that target industries for technology transfer should specifically relate to one or more of the following D&D technical needs: 1) dust and particulate control and air pollutant monitoring and mitigation for worker safety; 2) D&D support, including data management systems and temporary utilities; 3) decontamination of coatings and surface contaminants; 4) robotic equipment for size reduction, sampling, retrieval, and investigation; 5) waste sorting, packaging, and tracking; and 6) improved size reduction and cutting technologies, including underwater applications. Selection priority was assigned to industries with the greatest likelihood of employing technologies with potential to reduce D&D costs or cleanup schedules or feasibility to meet specific D&D needs that currently have no technical response or identified solution. Industries selected for investigation included mining; wrecking, demolition, sandblasting, and excavation; construction; petrochemical; oil and gas; plumbing and sanitary services; adhesives and sealants; paints and coatings; manufacturing; aeronautical and nautical; diving and search and rescue; and shipbuilding and repair and oceanography. Government agencies selected for investigation included the U.S. Navy; the Department of Transportation and highway/bridge construction and maintenance; the U.S. Department of Agriculture and the U.S. Forest Service; the National Oceanic and Atmospheric Administration; the National Aeronautics and Space Administration; the Central Intelligence Agency, National Security Agency, and Department of Defense; and the U.S. Environmental Protection Agency.

An assortment of commercially available technologies as well as technologies that are currently in stages of development or demonstration were identified as potential candidates for D&D activities. In general, the technologies that were identified during the search of federal agencies and industry were found to be no more innovative or advanced than the technologies already identified by the DDFA. This indicates that the DDFA is fulfilling its mission to promote and use the latest technological innovations to attain closure of contaminated DOE sites. The results of this study serve to ensure that DOE continues to develop, demonstrate, and deploy the latest innovations. To achieve this, sixty technologies found during the search are recommended for investigation of potentially new solutions to one or more DDFA needs.

## **INTRODUCTION**

The mission of the U.S. Department of Energy (DOE) Deactivation and Decommissioning Focus Area (DDFA) is to develop, demonstrate, and deploy technologies that improve worker safety, reduce costs, and accelerate schedules in the deactivation and decommissioning (D&D) of the DOE nuclear weapons complex. While some emphasis is placed on basic scientific research, the cornerstone of DDFA's success is a series of large-scale demonstration and deployment projects and accelerated site technology deployments. A majority of D&D site needs are being met through the deployment of innovative technologies, but there is still a need to further reduce costs, accelerate cleanup schedules, and better protect workers. There are also needs that will not be met by technologies currently available to DDFA. The development of new technologies is costly and time-consuming, making the transfer of technologies from the private sector or other government agencies an appealing option for reducing costs while accelerating schedules.

In the private sector, needs drive innovation in technology. While D&D site needs are often complicated by the involvement of radioactive material, many of the needs for D&D technologies are similar to those in other industries. For instance, demolition of a concrete wall with surface radionuclide contamination may employ the same technology as is used in the commercial nonnuclear demolition industry. The objective, therefore, is to identify those technology innovations in the private sector that may also apply to D&D of nuclear facilities.

Because there are many vehicles for technology transfer across the country, it is difficult for any one agency to keep up to date with all of the emerging technologies. Substantial time could easily be spent following the innovations of a single industry that invests significantly in research and development (R&D). This search, therefore, sought to achieve a preliminary investigation of a broad range of industries instead of a thorough investigation of a few.

## **METHODS**

### **Literature Search**

A literature search was conducted to identify activities similar in scope to this study in order to avoid duplicating previous efforts designed to investigate industry for technologies relevant to D&D activities. The literature review was limited to an Internet search of on-line databases, libraries, technology exchange conference literature (i.e., Spectrum 2000, National Association for Industrial Technology, and the Technology Information Exchange), and federal laboratory research. The literature search identified numerous instances in which technologies used in the private sector were developed for application in other industries; however, no comparable comprehensive industry review was found.

### **Characterization of D&D Needs**

In an effort to focus the industry and technology search on solving today's most relevant D&D problems, the properties of 2001 site D&D needs were evaluated and assigned priority in the search effort. Technology needs were characterized by their representative D&D problem area (e.g., characterization, decontamination, size reduction), national priority, and technical response (technologies proposed as potential solutions to site needs). The Deactivation and Decommissioning Information System (DDIS) was used to categorize and enumerate technology needs based on these criteria. DDIS is a searchable database used by DDFA for responding to D&D site needs. It allows the user to sort D&D needs by various criteria (e.g., field office, problem area, etc.), identify potential technical solutions for each need, and review the technical response.

DDIS currently contains 190 FY01 D&D science and technology need statements. Because each need statement can encompass multiple technical needs, when each need is separated by problem area, the total number of needs reaches 263. The needs for characterization represent the largest portion of the D&D needs, with 21% of the total (Figure 1). Decontamination needs follow with 17%; material disposition and health and safety each represent 16% of all D&D needs; 15% fall under dismantlement, demolition, or size reduction; 8% call for robotic equipment (i.e.,

arm/manipulators, crawlers, and platforms); and 6% are for D&D support (generally computer software and facility maintenance technologies).

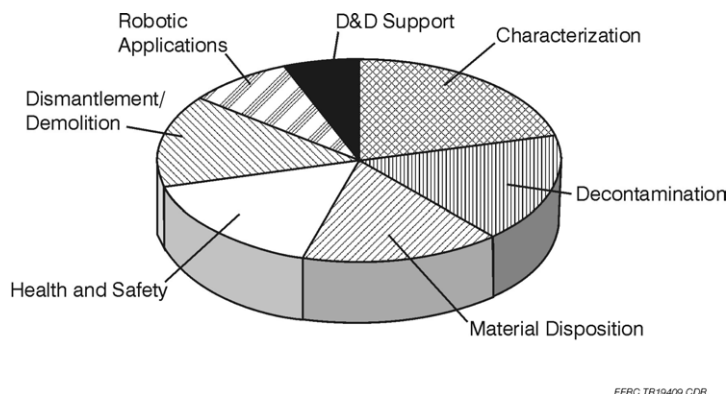


Fig. 1. D&D needs sorted according to problem area, represented as percent of total needs.

The breakdown of technology needs by D&D problem area was the initial step taken in creating a preliminary list of industries most applicable to solving D&D needs. Needs were subsequently separated within each problem area by the media of concern (e.g., concrete, pipes, tanks) and the remediation objective (e.g., packaging, sorting, cutting) or contaminant type (e.g., tritium, beta/gamma, beryllium). Needs were also sorted according to national priority (high – critical to success, medium – provides substantial benefit, or low – provides significant benefit), as identified by the Environmental Management (EM) Program, and the known technologies that could be employed in those situations.

Of the 56 needs for characterization, nearly two-thirds require technologies capable of characterizing radionuclide-contaminated materials, and one-quarter of those needs are of high national priority. One-third of the characterization needs require remote application. Although the number of needs for characterization is greater than any other problem area, only two of the 56 characterization needs have no identified potential solution, which means that technologies have been identified that may meet all but two of the needs for characterization.

In contrast, one-quarter of the needs for health and safety have no identified solution. The majority of health- and safety-related needs fall under dust and particulate control (51% of total health and safety needs) and work area monitoring (24% of total needs), which includes facility surveillance and monitoring of alpha, beta, and gamma release. Half of the needs for dust and particulate control are of high national priority.

D&D needs for decontamination primarily relate to the removal of coatings and surface or fixed contaminants from a variety of material types. One-fifth of the needs call for technologies that can be remotely applied. Twenty-two percent are of high national priority, and 17% have no identified solution. A number of the needs for decontamination can also be classified as material disposition (e.g., recycling of metal debris). These needs make up 33% of the total material disposition needs. The remaining, nonrecycling needs include such objectives as sorting, packaging, tracking, and compaction. Twelve percent of the needs for material disposition currently have no identified solution.

Needs for dismantlement and demolition include both mechanical- and thermal-cutting techniques among others used for size reduction. One-half of the needs for dismantlement and demolition will require technologies with remote capabilities. While nearly one-quarter of the needs are of high national priority, only four have no identified technical solution.

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There are currently 51 needs, primarily for size reduction, characterization, and decontamination, that will require the remote deployment of a technology, but only 22 needs that specifically call for robotic equipment (i.e., arms/manipulators, vehicles/crawlers, and platforms). Of the 22 needs for robotic equipment, five are of high national priority.

The needs that do not fall under any other problem area generally fall into D&D support. D&D support includes the needs for temporary utilities (e.g., power and ventilation) and computer software (e.g., database management). Although D&D support has the fewest needs of any problem area, nearly one-quarter of the needs have no identified solution.

Industry selection priority was based on the industry's potential ability to meet D&D needs. Based on the information obtained through need characterization, it was concluded that industries should specifically relate to one or more of the following D&D technical needs: 1) dust and particulate control and air pollutant monitoring and mitigation for worker safety; 2) D&D support, including data management systems and temporary utilities; 3) decontamination of coatings and surface contaminants; 4) robotic equipment for size reduction, sampling, retrieval, and investigation; 5) waste sorting, packaging, and tracking; and 6) improved size reduction and cutting technologies, including underwater applications.

### Industry Selection

A comprehensive list of industry sectors with potential to meet priority D&D needs through technology transfer was compiled using the Standard Industrial Classification (SIC) Index. A detailed description of each industry can be found at [www.osha.gov/oshstats/sicser.html](http://www.osha.gov/oshstats/sicser.html).

Upon revision of the preliminary group of industries selected, numerous government agencies were added, forming an industry/agency search list thought to have the greatest potential for identifying D&D-related technologies. The following list of industries and agencies includes the type of technologies sought within each group as potential solutions to D&D needs:

**Mining:** remotely operated equipment, safety equipment, and dust/particulate control and mitigation

**Wrecking, demolition, sandblasting, and excavation:** dust/particulate control, cutting technologies, sorting/segregating equipment, and remotely operated equipment

**Construction:** advanced sealants, paint, roofing material for facilities maintenance, radon monitoring, and heavy construction equipment

**Petrochemical:** lubricants

**Oil and gas:** subsurface and underwater technologies and pipe inspection

**Plumbing and sanitary services:** pipe inspection and remote robotics

**Adhesives, sealants, paints, and coatings:** removable fixatives, electrostatic coatings, powder coatings, and spraying systems

**Manufacturing:** robotics and CO/CO<sub>2</sub> and diesel particulate mitigation systems

**Aeronautical and nautical:** guidance systems, remote sensing, and virtual reality

**Diving and search and rescue:** underwater cutting technologies

**Ship building and repair, oceanography, and U.S. Navy:** underwater cutting technologies and remote robotics used in deep-sea exploration

**Department of Transportation (DOT) and highway/bridge construction and maintenance:** demolition equipment, nondestructive examination of structural integrity, dust/particulate control, and underwater cutting techniques

**National Oceanic and Atmospheric Administration (NOAA):** sensor technology

**U.S. Department of Agriculture (USDA) and U.S. Forest Service:** advanced engineering in developing autonomous vehicle systems and sensor technology

**National Aeronautics and Space Administration (NASA):** telerobotics, nondestructive examination, and sensors

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**Central Intelligence Agency (CIA), National Security Agency (NSA), and Department of Defense (DOD):** sensor and surveillance technologies

**Environmental Protection Agency (EPA):** decontamination technologies, separations, and vegetative covers

## **Technology Search**

An Internet search was conducted for each industry or government agency to identify D&D-applicable technologies. The search included a review of on-line resources, including databases and libraries, technology exchange conference literature (i.e., Spectrum 2000, National Association for Industrial Technology, and the Technology Information Exchange), technology vendors, professional organizations, industry journals, federal laboratories, government agency Web sites, the DDFA Vendor Link, the National Institute of Standards and Technology (NIST), and various technology transfer sites, including the National Technology Transfer Center and the Federal Laboratory Consortium (FLC) for Technology Transfer. The on-line search of industries proved much more difficult than the review of government. Unlike government agencies, in which technologies were often easily identified in agency technology databases and links, industry technologies were generally identified through lengthy searches of industry- and technology-specific vendors, journals, and professional organizations.

## **RESULTS AND DISCUSSION**

### **Technology Search Overview**

The Internet sites of various federal agencies and industries were searched to find technologies that have been developed under the auspices of their programs that might meet DDFA needs. Each of the entities searched is discussed in the following sections.

#### ***Federal Agencies***

##### ***Army Corps of Engineers***

The U.S. Army Corps of Engineers (USACE) is made up of military and civilian engineers, scientists, and other specialists whose mission is to provide quality, responsive engineering services to the nation, including 1) planning, designing, building, and operating water resources and other civil works projects; 2) designing and managing the construction of military facilities for the U.S. Army and Air Force; and 3) providing design and construction management support for other defense and federal agencies. Working with EPA, DOD, and various contractors, USACE has developed a wide range of technologies. The technologies that were determined during the search to be the most relevant to D&D applications include safe and cost-effective removal of lead-based paint from a variety of material surfaces, automated robotic inspection of tanks and pipes, and remote monitoring and nondestructive evaluation of facility structural integrity. Periodic monitoring of the USACE Web site could result in new technologies that can be applied to D&D activities.

##### ***Central Intelligence Agency/National Security Administration/Department of Defense***

The Web sites of these agencies were searched in an effort to find various surveillance and detection equipment. Research in this area is understandably not discussed in detail, and the search was abandoned when it became apparent that computer network security was the only type of detection technique described on-line.

##### ***Department of Agriculture and Forest Service***

USDA sponsors research in crop profiling, forestry, food and nutrition, and statistical reports dealing primarily with agricultural data. Equipment and instrumentation are generally not developed during many of the USDA-sponsored projects, and as a result, few technologies were found during the search that could be applied to DDFA needs.

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#### *Department of Transportation*

DOT is made up of numerous organizations; the one most closely related to D&D is the Federal Highway Administration (FHWA). FHWA is responsible for assisting states in the construction and improvement of the national highway system, urban and rural roads, and bridges. FHWA also manages a comprehensive research, development, and technology program, which focuses on improving the safety, efficiency, and operation of the national highway system. Research is conducted in the areas of environment, human factors, pavements, safety, structures, and intelligent transportation systems. The research found to be the most relevant to D&D applications is in the area of nondestructive examination methods used to determine structural integrity of roads and bridges.

#### *Department of Commerce/National Institute of Standards and Technology*

NIST is a nonregulatory federal agency within the Commerce Department's Technology Administration. NIST technologies, measurements, and standards help U.S. industries invent and manufacture superior products reliably, ensure a fair marketplace for consumers and businesses, and promote acceptance of U.S. products in foreign markets. NIST focuses on the most critical and emerging needs of industry, including health care, information technology, manufacturing, construction, communications, and the automotive industries, among others. A number of NIST technologies were identified in this search as being applicable to D&D needs, including optics, imaging, and virtual reality. NIST has also developed many D&D-appropriate technologies for construction, which were identified in the search of the construction industry.

#### *Department of Energy DDFA Vendor Links*

The DDFA Vendor Links Web site was searched for technologies not currently available in DDIS but with the potential to meet D&D needs. The technologies identified fall under the areas of robotics, monitoring, and nondestructive examination of structures and equipment.

#### *Environmental Protection Agency*

The mission of EPA is to protect human health and safeguard the natural environment—air, water, and land—upon which life depends. Numerous offices within EPA function to develop, demonstrate, and deploy technologies for these purposes. EPA's Office of Research and Development is responsible for the development, direction, and conduct of a national environmental research, development, and demonstration program in health and risk assessment, health effects, engineering and technology, processes and effects, acid rain deposition, and monitoring systems. The EPA Technology and Innovation Office is responsible for advancing the use of innovative technologies for characterization and remediation of waste sites, soils, and groundwater. The Clean Air Technology Center serves as a resource on all areas of emerging and existing air pollution prevention and control technologies and provides public access to data and information on their use, effectiveness, and cost. The majority of technologies identified in this search are part of the Small Business Innovative Research Program under the Office of Research and Development and relate primarily to air pollution monitoring and mitigation. The technologies that were found to be the most applicable to D&D needs include air-cleaning and pollution prevention devices, leak detection instrumentation, and emissions monitors. Periodic review of EPA's available technologies should offer new, D&D-appropriate technologies.

#### *Federal Laboratory Consortium for Technology Transfer*

The FLC for Technology Transfer was organized to promote and strengthen technology transfer nationwide. More than 700 federal laboratories and centers and their parent departments and agencies are members of FLC. This search focused primarily on identifying potential D&D-related technologies that are available for licensing. The types of technologies that were found include compact generators, material and/or surface defect detectors, liquid sensors, air pollution monitors, telerobotics, surveillance techniques, in-ground imaging, and laser technologies.

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#### *National Aeronautics and Space Administration*

NASA is arguably the federal government's premiere R&D entity. There are six strategic technology areas on which NASA's research efforts are currently focused: advanced miniaturization, intelligent systems, compact sensors and instruments, self-sustaining human support, deep-space systems, and intelligent synthesis environment. One of NASA's primary aims is to form partnerships with private industry to commercialize the many technologies that have been developed. Many of the technologies that have been developed are applicable to D&D activities, including advanced alloy processing, robotics, sensors, imaging technologies, cleaning techniques, wireless communications subsystems, and nonintrusive structural integrity testing. Given the large number of technologies that are currently available as well as those that are likely to be made available in the future, frequent review of the NASA Web site is recommended for identifying additional technologies that can be applied to the D&D activities.

#### *National Oceanic and Atmospheric Administration*

NOAA performs research that usually involves satellite tracking and imaging. As such, the techniques that are available are not applicable to D&D activities, with the exception of a satellite-based interferometer. It is unlikely that NOAA will be a source of applicable D&D technologies in the future.

#### ***Industries***

##### *Adhesives and Sealants/Paints and Coatings*

The adhesive/sealant/coatings industry was searched both for 1) removable coatings that could be used to temporarily seal contamination to a surface to prevent its spread during D&D activities and 2) innovative sealant/coating application methods and equipment. Many types of strippable coatings were found. A few novel nozzle designs and specially engineered spraying systems were also identified. It is not likely that many new technologies or products that can be used during D&D activities will be found by future investigation of this industry.

##### *Construction*

The construction industry is continuously working to improve the safety, quality, schedule, and cost-effectiveness of projects through research and implementation of innovative technologies. Recent innovations in the industry relate to automating construction processes with electronic access to databases, three dimensional (3-D) as-built models, methods of retrofitting equipment to reduce particulate emissions, cranes, radon monitoring, wireless communication systems, Web-based data analysis, real-time part tracking, and leak detection systems. Many of the technologies available to the construction industry are applicable to D&D.

##### *Diving*

The diving industry was investigated for its underwater technologies, most of which were also found when searching other industries (i.e., shipbuilding, oil and gas exploration) and will be discussed in those sections. However, an underwater communications system was found with the potential for application to D&D activities.

##### *Manufacturing*

The manufacturing industry was searched for its air pollution mitigation, dust control, and surface cleaning/preparation technologies. A number of technologies are available in the manufacturing industry, among others, for removing indoor air pollutants. There are a large number of filtration systems and fume exhaust removal systems available on the market. Innovations in this area are primarily found in EPA technology development projects. The types of indoor air cleaners commonly used in industry today include electrostatic, media filtration, staged filters, and fume removal systems. There are many different surface preparation techniques used by the manufacturing

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industry that could be applied to D&D, including plasma and laser cutting of materials, surface blasting using nut shells or nanocomposites, fluidized-bed paint stripping, laser cleaning, high-pressure water cleaning, and heat cleaning. It may be appropriate to monitor specific subsets of the manufacturing industry for future D&D-applicable technologies.

#### *Petrochemical*

A very rudimentary search was performed to locate state-of-the-art lubricants that could be used in rotating equipment (such as compressors) during D&D activities. All of the petrochemical companies offer a variety of lubricants for this application. When specific information about the compressors or other equipment is known, a more thorough search could be undertaken.

#### *Mining*

A study conducted between March 2000 and July 2000 by the Rand Science and Technology Policy Institute indicated that technology innovation in the mining industry is likely to be characterized for the foreseeable future by slow but steady incremental improvements.<sup>1</sup> Innovations requiring significant private-sector R&D expenditures are likely to be viewed as too costly and speculative. As a result, many of the technological innovations adopted in the mining industry come from other sectors such as construction or automotive industries. Technologies critical to mine productivity include information and communications technologies for process optimization, remote control and automation, operations and maintenance, and unit operations capabilities. Because a number of these technology innovations could have potential in the D&D arena, close attention should be paid to any mining R&D in the future. While there may be potential to develop cutting, drilling, and excavating technologies for D&D applications, this survey placed little emphasis on these areas, concentrating instead on dust control and concrete-fracturing technologies, for which numerous D&D-applicable technologies exist.

#### *Oil and Gas Exploration/Plumbing and Sanitary Services*

The search of the oil and gas exploration and the plumbing and sanitary services industries was performed in an effort to identify innovative technologies for remote and nondestructive pipeline inspection. A number of technologies were identified, few of which appear to be as advanced as those already employed in D&D applications. The sanitary services industry typically uses basic push-cable technologies for remote viewing of pipeline clogs and corrosion, while more advanced technologies include Inukton's robotic crawlers with basic pan-and-tilt cameras, which are currently available in DDIS. Offshore oil and gas exploration uses somewhat more advanced crawlers and "pigs" mounted with various video cameras and sensors to survey and inspect pipeline interiors. Other technologies include sonar profiling of liquid-filled pipelines and tanks.

#### *Radiological Detection and Monitoring*

The ability to detect and monitor low-level radioactivity is useful in D&D activities. A cursory search of vendor sites offering low-level radioactivity detection and monitoring capabilities was performed. Because this was a preliminary look at the industry, additional searching could be performed if DDFA determines that there is substantial need for radiological detection and monitoring technologies that are currently unknown to the EM Program.

#### *Shipbuilding and Repair (including U.S. Navy)*

The shipbuilding industry includes many activities ranging from hull repair, ship design, and fabrication to plumbing, application of coatings, removal of coatings, and engine work. The primary focus of this search was for technologies that could be used to dismantle equipment that is at least partly submerged. Several technologies are used commercially, including those also used for D&D of nuclear facilities—underwater plasma cutting and oxyacetylene and oxygasoline torches—and a number of underwater thermal cutting rods not currently in DDIS.

## Technology Selection

In general, the technologies that were identified during the search of federal agencies and industry were found to be no more innovative or advanced than the technologies already identified by DDFA as offering potential solutions to the site needs. Results show that 59 of the technologies found during the search offer potentially new solutions to one or more DDFA needs. These technologies are listed and briefly summarized in Table I.

Table I. Innovative Technologies Identified in Reviewed Industries and Government Agencies That Offer a Potential Solution to D&D Needs

FEDERAL AGENCIES
U.S. Army Corps of Engineers
<ul style="list-style-type: none"> <li>• <b>Blastox</b> is an abrasive blast chemical stabilizer admixture that has application in lead-based paint removal on wood and steel structures. It is commercially available and potentially applicable to D&amp;D needs for lead-based paint removal.</li> <li>• <b>Fury</b> is an automated underground tank inspection system equipped with inspection sensors, cameras, and surface-cleaning devices and is capable of fitting through openings as small as four inches in diameter. Fury is commercially available.</li> <li>• <b>In situ vitrification for removal of lead-based paint</b> is a method in which molten glass is applied by oxyacetylene thermal spray equipment to remove a layer of lead oxide from painted steel surfaces. This form of in situ vitrification has been successfully demonstrated and may be applicable to D&amp;D needs for lead-based paint removal.</li> <li>• <b>Lead-based paint abatement using microwaves</b> is a lead-based removal method that uses microwaves to heat contaminated surfaces coated with microwave-coupling compounds which causes the paint to debond from the surface for easy removal. This method has been successfully demonstrated on wood surfaces.</li> <li>• <b>Neptune</b> is a tethered robot used to inspect for leaks in buried or submerged structures. It is equipped with ultrasonic transducers that continuously test the structural integrity of the vessel.</li> <li>• <b>Pneu-Worm</b> is a pipe corrosion inspection crawler that is currently in development for inside inspection of 2-inch-diameter pipes. The crawler can travel vertically and negotiate multiple 90-degree bends and is equipped with an optical video probe, allowing visual inspection.</li> <li>• <b>PreTox</b> is used for lead-based paint removal and stabilization. It is commercially available and has potential to meet D&amp;D needs for lead-based paint removal. PreTox includes PreTox 2000 Fast Dry Abrasive Blast Pretreatment, PreTox 2000DM Paint Protectant, and PreTox 7000 Paint Stripper.</li> <li>• <b>Wireless remote structural integrity monitoring</b> is a system capable of collecting structural integrity data and sending it via cellular modem to any remote location. It has been installed by USACE and is applicable to remote monitoring of structural integrity.</li> </ul>
DDFA Vendor Links
<ul style="list-style-type: none"> <li>• <b>OSCAR</b> is a versatile track-driven working retrieval platform that utilizes a practical design that enables technicians to remotely position tooling in obscure, high-dose areas. OSCAR is commercially available.</li> <li>• <b>ReTRIEVR (Revolving Turret Reeled Cable Incremental Link Extending Vacuuming Robot System)</b> that can efficiently vacuum or pump waste from confined-space tanks and silos. ReTRIEVR combines an extended segmented-link platform with an industrial master-slave robot on the platform end, capable of holding a vacuuming tube and/or a series of mining tools. A single operator remotely operates ReTRIEVR via a computer graphic simulation.</li> <li>• <b>RPIMS (Radiation Protection Integrated Monitoring System)</b> is a commercially available system that provides remote viewing, dose monitoring, and wired or wireless audio communications to unlimited work locations through a fiber optic network.</li> </ul>

- **SPIDER (Service Piping Inspection and Debris Removal System)** is capable of performing video inspections of piping systems and removing potentially damaging debris. SPIDER automatically collapses and expands to fit its surroundings. It is commercially available for use.
- **SUPER-SAM (Segmented-Articulated-Manipulator)** is a commercially available large SAM that can be used for search and retrieval of parts from inaccessible areas.

#### U.S. Environmental Protection Agency

- **Environmental monitoring compact Raman LIDAR system** uses a short-range ultraviolet Raman light detection and ranging (LIDAR) system for detecting automobile emissions. The compact LIDAR system is currently in development.
- **Handheld laser-based sensor for remote detection of gas leaks** employs tunable diode laser absorption spectroscopy in which the sensor is capable of measuring the amount of target gas along the line of sight transmitted by the laser beam without the use of any special retroreflective materials. The system, which is currently in development, does not need to be immersed in the gas leak and has the capability of detecting leaks from 20 m with a response time of less than 1 second.
- **New NO<sub>x</sub>, HC, and small-particle filter with a regeneration-in-place capability for stationary diesel-engine applications** is a capture and destroy technology in which NO<sub>x</sub> is captured and then recycled back to the diesel engine where it is destroyed. The system is currently in development for indoor diesel exhaust mitigation.
- **Novel catalytic air cleaner for removal of volatile organic compounds (VOCs) and particulates from indoor air** is a catalytic air filtration element utilizing an open-cell foam substrate coated with a mixed-metal oxide electrolyte/metal catalyst system for the complete conversion of VOCs near room temperature and under high-flow-rate conditions. This technology is currently under development for removal of indoor air pollutants.
- **Photocatalytic Adsorption-Integrated-Reaction (AIR) cleaner for indoor air pollution control** uses AIR technology to destroy VOCs and other gaseous indoor air contaminants at ambient temperatures with compact units and at low cost.
- **Real-time calibrated microwave plasma multimetals emissions monitor** uses continuously sustained microwave plasma for monitoring trace metals in stack exhaust. It is currently under development but has potential application to beryllium monitoring in D&D facilities.

#### Federal Laboratory Consortium for Technology Transfer

- **Acoustic emission linear pulse holography** technology images defects in a structure as the defect propagates. Signals and timing information are transferred to a computer for reconstruction of synthetic linear holographic images. This technology is available for licensing from Pacific Northwest National Laboratory (PNNL) and has potential D&D application for nondestructive monitoring of defects in tanks, vessels, or buildings.
- **All gas-phase iodine laser** creates its light by combining nitrogen chloride and atomic iodine. It was designed to be more versatile and lighter weight than earlier chemical oxygen iodine lasers, and because it is a purely gas-phase reaction laser, it has a built-in heat rejection exhaust. The all gas-phase iodine laser is available for licensing from the Air Force Research Laboratory (AFRL).
- **Compact generator technology**, available for licensing from AFRL, offers improved reliability; better fuel economy; and reduced logistics, operation, and maintenance costs compared to current systems.
- **Electro-optic liquid sensor** detects and measures liquid present in soil, sand, cement, and other porous materials and can serve either as a meter of water content or leak detector for underground storage tanks. The electro-optic liquid sensor is currently available for licensing from PNNL.
- **Fiber laser** uses electricity as its power source rather than the chemical reactions that fuel chemical lasers. AFRL developed the fiber laser for use as a laser weapon. It is commercially available for licensing.

- **Ground-penetrating holographic (GPH) system** generates high-resolution, 3-D images of buried material in real time. GPH is available for licensing from PNNL and may be applicable to detecting buried wastes at DOE's nuclear weapons complex.
- **Smart Paint** is paint with microencapsulated dyes that outline a fatigue crack in a bridge or other highway structure as the crack forms and propagates. Smart paint is available for licensing from the National Science Foundation and may be used to nondestructively monitor defects in buildings and other structures.
- **Telerobot for site characterization** can perform geophysical, radiological, and chemical surveys of hazardous waste burial sites. The Telerobot is a small, self-propelled, largely nonmetallic/nonferrous survey vehicle that transports several types of sensors that can detect buried objects and materials. The Telerobot is available for licensing from PNNL and has potential D&D application in the characterization of buried wastes.
- **Through-the-wall surveillance (TWS)** is a technology that is currently available for licensing from AFRL for monitoring individuals shielded behind walls. TWS uses a variety of existing sensor technologies, combining specific data from each for a better image. It may be applicable to remote viewing in D&D activities.
- **Ultrasonic sensor to detect gases and particulates** is a handheld instrument capable of accurately detecting and quantifying levels of trace gases and particulate matter in air with real-time monitoring. It is available for licensing from Argonne National Laboratory.

#### National Aeronautics and Space Administration

- **Advanced alloy processing improves saw blades** is a heat-treating process developed by NASA and the USDA Forest Products Laboratory that is used to reduce residual stresses in nickel-based superalloys, permitting the manufacture of thin, wobble-free saw blades. It could be used in D&D applications where precise cuts using thin saw blades are required.
- **Buried-object locating and tracking system** is a proximate object locating and tracking technology that can accurately detect buried objects when surveys, records, or surface markers are not available. It is available for licensing and commercialization from the NASA Johnson Space Center and could be used in the detection of pipelines or sumps that are not clearly mapped.
- **Compact dextrous robotic hand** was developed by the NASA Johnson Space Center and is available for commercialization. It functionally simulates a human hand while maintaining mobility, dexterity, and precision during grasping and release motions and could be applied to D&D remote dismantlement and/or retrieval activities in hazardous environments.
- **Fiber-optic high-temperature sensor system** is compact, robust, and highly reliable and can measure temperatures in harsh environments accurately and with high precision. Available for commercialization, it was developed by NASA and SENTEC Corporation and could be applied to harsh-environment temperature control during D&D activities.
- **Imaging technology** developed by NASA consists of custom-engineered, visual-data acquisition systems that can combine high-speed motion picture, high-speed video, multispectral, digital, and still images in a manner that makes them more easily manipulated, reduced, and analyzed. The technology is currently available and has application in nondestructive materials testing and remote collection of images in hostile environments during D&D activities.
- **Method and apparatus for indicating disbonds in joint regions** is a NASA-developed technology that consists of a simple ultrasonic device to acoustically inspect disbonds at joints. It is available for commercialization and could be used during D&D for nonintrusive structural integrity testing.
- **Space-age vacuum cleaning** techniques developed by NASA and the California Institute of Technology remove debris more effectively than current vacuum systems. The technology could be used as a part of cleanup and dust control during and after D&D activities.
- **Surface Defect Analyzer** was developed at NASA to provide an accurate, in-the-field method of evaluating the physical dimensions of surface flaws, defects, and damage on critical surfaces. The technology could be applied to nondestructive, remote analysis of surfaces during D&D activities.

- **Ultrasonic nondestructive evaluation** rapidly determines material elastic stiffness constants and evaluates the characteristics of material (metallic or composite) flaws that affect these constants. The technology could be used for the nondestructive evaluation of the structural integrity (or degree of damage) of piping, tanks, etc.
- **Wireless communications headset subsystem to enhance signaling** permits the interfacing of any commercial off-the-shelf wireless headset and any communications equipment that requires signaling that is not provided by the headset. A NASA-developed technology that is ready for commercialization, this technology could provide clear communication in hazardous situations during D&D activities.

#### National Institute of Standards and Technology

- **Capillary Optics technology** is based on the use of bent capillaries to focus and control x-rays and neutrons over broad angles and energy ranges with high efficiency. The technology is commercially available for improved x-ray instrumentation for nondestructive evaluation.

#### INDUSTRIES

##### Construction

- **Digital Hardhat** enables dispersed users to capture and communicate multimedia field data to collaboratively solve problems and share information. The system uses a pen-based computer to collect information (text, sound, video, and images) and communicate by video teleconferencing between remote locations. Field tests were conducted by USACE in 1998. Digital Hardhat could potentially allow D&D site employees to communicate problems in the field to off-site personnel or field personnel at other sites.
- **E-PERM radon monitor** is used to measure radon and thoron concentrations in indoor and outdoor air and is commercially available.
- **NIST Construction Automation Initiative** includes research in the areas of sensors for real-time construction site metrology, wide-band telemetry and data acquisition, virtual site simulation and object representation, global-positioning satellites, fanning lasers, non-line-of-sight surveying systems, and construction robotics. Technologies are currently in development at NIST's National Construction Automation Testbed and are potentially applicable to monitoring the status of D&D operations and data transfer.
- **Radio Communication System (RS65i)** is a handheld radio system that is easily adapted to extreme work conditions. The throat mic can be used with any type of face mask with breathing apparatus, encapsulated suits, or respirators. The RS65i is commercially available.
- **Radio Frequency Identification (RFID) Tag** is used by the construction industry for the receipt and tracking of pipe supports at the job site. RFID does not require line-of-site or direct contact between the reader and the tag, automatically identifies locations and tracks assets, and allows read/write capabilities to the tag.
- **RADON-check** is a portable instrument capable of rapidly, accurately, and continuously determining individual radon and thoron progeny concentrations in air, additionally resolving these into referentially bronchially deposited ultrafine and attached aerosol size ranges. RADON-check is commercially available for the determination of personnel radon exposure.
- **Real-time construction component tracking system** integrates field sensors, portable computers, wireless communication, and real-time kinematic global position equipment. Items are tagged with bar codes or radio frequency transponders (RFID), from which encoded information is scanned directly into a portable computer and wirelessly relayed to a remote project database. The tracking system used in the construction industry has potential D&D application to tracking packaged wastes.
- **Retrofit of big dig equipment with oxidation catalysts and particulate filters** has been done in the construction industry to reduce diesel emissions. Equipment such as front-end loaders, backhoes, cranes, and excavators have been retrofitted with oxidation catalysts, particulate filters, or both for diesel reductions up to 95%.

<ul style="list-style-type: none"> <li>• <b>Robocrane</b> was developed for large-scale manufacturing, bridge construction, shipbuilding and undersea configurations using cable control. The system provides rigid support and precise maneuverability of large loads, remote positions of tools, and is capable of high lift-to-weight ratio and resistance to environmental perturbations.</li> <li>• <b>SoundPrint (continuous acoustic monitoring for structures)</b> allows continuous monitoring of entire structures. Sensors mounted on the structure detect acoustic energy released when a prestressed wire breaks. SoundPrint is commercially available.</li> </ul>
<b>Manufacturing/Surface Cleaning and Preparation</b>
<ul style="list-style-type: none"> <li>• <b>Jet Blast Cleaning Media</b> is a blast-cleaning technique in which walnut and pecan shells serve as the abrasive. The nut shells are of medium abrasiveness and can remove dirt and oils from surfaces without causing damage to the surfaces. The technology is commercially available from Dennis Dawson Company and could be used to clean the surfaces of equipment such as engines and compressors as well as walls, floors, ceilings, etc., during D&amp;D activities.</li> <li>• <b>Magic® Nanocomposite Blast Coating Removal System</b> is another blast-cleaning method. The nanocomposite material is a composite abrasive media made of blended amino thermoset resin and reinforcing fiber. It is said to perform up to four times faster than traditional plastic media blast products. This commercially available technology (from U.S. Technology Corporation) could be used for cleaning of surfaces during D&amp;D operation.</li> </ul>
<b>Mining</b>
<ul style="list-style-type: none"> <li>• <b>Controlled Foam Injection (CFI)</b> is a proprietary and patent-protected technique used to fracture rock and concrete by injecting foam into a predrilled hole. CFI is commercially available and has potential D&amp;D application to demolition of concrete structures and removal of concrete from around concrete-encased equipment.</li> <li>• <b>Rotary atomizer</b> produces a spray of water, which covers 30 linear meters by using a spinning head to produce millions of microscopic water droplets, creating a fine mist, which is effective at suppressing dust. The rotary atomizer is commercially available.</li> <li>• <b>SureStrike rock breaker</b> uses a modular impact hammer, which can attach to conventional front-end loaders or excavators and can be applied to breakage of oversized concrete materials. SureStrike is commercially available and has many potential uses in D&amp;D.</li> <li>• <b>Ultrasonic fogger</b> is a commercially available technology to control dust by producing a very dense fog of 1–10-micron-size water droplets, which blanket the dust source and keep the dust particles from becoming airborne.</li> </ul>
<b>Miscellaneous</b>
<ul style="list-style-type: none"> <li>• <b>Belgoprocess wallshaver</b> is a diamond-tipped drum system used for decontamination of concrete walls. The wallshaver is powered by a remote-controlled hydroelectric power pack and has a dust control cover for connection to a dust extraction system. The wallshaver is commercially available and has potential to solve D&amp;D needs for surface coating removal.</li> <li>• <b>Easily Manipulated Mechanical Armature (EMMA)</b> is a remotely operated, cable-driven serpentine arm with long reach and considerable dexterity. When equipped with an end effector such as a scarifier and waste-transfer device, the system is able to remove hardened waste from tank bottoms. EMMA was demonstrated as part of the Hanford Tanks Initiative Project and may be applicable to D&amp;D tank waste heel retrieval needs, as may several other retrieval technologies commonly used by the Tanks Focus Area.</li> <li>• <b>LEADX®</b> is a commercially available heavy metal scavenger, applicable to paint removal, soil remediation, and waste sludge remediation.</li> <li>• <b>PCB concrete cleaning</b> is a service that offers a nondestructive process for removing polychlorinated biphenyls (PCBs) from concrete by removing oil, grease, and other petroleum hydrocarbons from concrete surfaces and deep inside porous materials.</li> </ul>

<ul style="list-style-type: none"> <li>• <b>TUFF100A Portable Alpha Probe</b> uses patented Tuff-Tector® sensor technology to deliver a lightweight, accurate, and reliable detection instrument. It is more efficient than conventional scintillation-based survey probes, and environmentally rugged to physical and chemical abuse. TUFF100A is commercially available and has potential application as an alpha contamination monitor for D&amp;D activities.</li> </ul>
<b>Oil and Gas Exploration/Plumbing and Sanitary Services</b>
<ul style="list-style-type: none"> <li>• <b>Sonar profiling of liquid-filled pipelines</b> is performed in the offshore oil and gas industry as well as in plumbing and sanitary services to inspect pipe interiors when full of liquid or submerged. The technique could also be used to inspect tank interiors during D&amp;D activities. It is commercially available.</li> </ul>
<b>Shipbuilding</b>
<ul style="list-style-type: none"> <li>• <b>M2000 Robotic Paint Stripper</b> consists of an automated robotic device that can be magnetized to a metal surface such as part of a ship, a set of high-pressure jet streams, and a controller that helps the robot navigate along the ship's surface. The water is filtered and reused, while the paint residue is collected. The M2000 is commercially available for stripping paint from metal surfaces.</li> <li>• <b>Magmafusion® Torch and Underwater Cutting Rods</b> consist of thermal cutting rods that can be used underwater to cut, gouge, and pierce metal, refractory, rock, and many other materials. The tubes are bendable for all-position access. The rods are commercially available from different vendors, including Broco Underwater, Woodtech U.K., Aqua Tech Dive Center, and Magnum Manufacturing Incorporated and are used during shipbuilding. The rods could be used to cut tanks and piping underwater during D&amp;D activities.</li> </ul>

### Technologies Recommended for Demonstration and/or Deployment

A number of commercially available technologies have been identified as potential candidates for immediate deployment. This group includes the lead-based paint stabilization and removal technologies Blastox, PreTox, and LEADX®; CFI and SureStrike rock breaker for concrete demolition; ultrasonic fogger and rotary atomizer for dust control; and the Magmafusion® cutting/welding torch.

Blastox, PreTox, and LEADX®, although similar to contaminant stabilizers currently available in DDIS, have the potential to meet D&D needs for lead-based paint removal and may result in cost reductions when used in conjunction with current paint removal techniques. Blastox is an additive used for the stabilization of abrasive blast wastes resulting from removal of lead-based paint on wood and steel structures. It can be used in conjunction with wet or dry abrasive blasting systems and is available from TDJ Group, Inc. PreTox is commercially available from NexTec, Inc., in the form of a fast-dry abrasive blast pretreatment (PreTox 2000FD), a paint stripper (PreTox 7000), or a protectant for demolition (PreTox 2000DM). PreTox 2000FD is a single component, temporary overcoating applied to a lead-based paint-coated surface as part of surface preparation to render lead-based paint nonhazardous. It can be applied by brush, roller, or mechanical spray and is compatible with most removal methods, including wet and dry abrasive blasting, sponge abrasives, power tools, recyclable abrasives, and water jetting. PreTox 7000 is a chemical paint stripper designed to remove multiple layers of lead-based paint with one application. It can be applied by brush, roller, trowel, putty knife, or mechanical spray equipment and is compatible with hand-scraping and water removal methods. PreTox 2000DM is a single- component coating applied over lead-based paint-coated surfaces prior to demolition, keeping the paint intact during the demolition process. LEADX® is a patented heavy metals scavenger applicable to paint removal, soil remediation, and industrial waste/sludge remediation. Immediate molecular bonding between LEADX® is applied dry or wet and is typically applied with blasting media. LEADX® is commercially available from the Proactive Applied Solutions Corporation.

The SureStrike rock breaker (SureStrike International, Inc.) and CFI (Applied Geodynamics, Inc.) technologies are used in the mining and demolition industries and may have potential to meet D&D needs for concrete demolition. The SureStrike rock breaker is a competitor to explosives, drop balls, drop crosses, and hydraulic hammers or moils. The modular impact hammer attaches to conventional front-end loaders or excavators and can be applied to

breakage of oversized materials such as concrete bridge pilings or equipment pedestals. Its potential D&D application may be breaking and rubbleizing equipment pedestals and heavy reinforced concrete foundations and demolition of reinforced underground structures that have been exposed by excavation. CFI has similar applications, but uses high-pressure foam to initiate, pressurize, and propagate controlled fracturing. A hole must be drilled to the desired depth before the foam can be injected. The hardware can be mounted on an articulated boom, with the percussive drill and foam injection barrel comounted for automated and near-continuous demolition. CFI can be used in close proximity to personnel, sensitive structures, and equipment. The potential D&D applications for CFI may be expanded to include controlled removal of concrete around concrete-encased piping and equipment and demolition of thick concrete walls.

The ultrasonic fogger and rotary atomizer are also commonly used in the mining and demolition industries as methods for controlling dust. The ultrasonic fogger, available from Dust Solutions, Inc., produces a very dense fog of 1–10-micron-size water droplets which blanket the dust source and keep the dust particles from becoming airborne. The fogger is an air-driven acoustic oscillator capable of fogging liquids by passing them through a field of high-frequency sound waves. The rotary atomizer, available from Probe Industries Ltd. in the United Kingdom, also creates a fine mist for effective dust suppression. It produces a spray of water, which covers 30 linear meters by using a spinning head to produce millions of microscopic water droplets. Both technologies have potential D&D application for controlling and capturing dust during demolition activities. Because both systems rely on agglomeration to capture dust with microscopic water droplets, the amount of secondary waste is minimal.

Magmafusion® is an amphibious (above and underwater) cutting/welding torch that uses consumable rods and oxygen (no gasoline or acetylene tanks required). It is applicable to ferrous, nonferrous, and refractory (concrete, rock, etc.) materials and is touted as being able to cut or pierce thicker materials at a considerably faster rate than the oxyacetylene, air carbon arc, and plasma arc systems. Its potential D&D applications include underwater dismantlement of fuel storage racks, pool reactor components, and possible controlled removal of concrete around concrete-encased piping and equipment. Although Magmafusion® is commercially available, extension of remote deployment methods for the oxygasoline torch or plasma torch to Magmafusion® may require development.

A number of commercially available inspection and retrieval robotic systems were also identified as having potential application to D&D and are recommended for further evaluation and demonstration. A search of the DDFA Vendor Link revealed several robotic technologies developed by Framatome that currently are not in DDIS. These technologies include a ReTRIEVR system, Super-SAM, and SPIDER system. ReTRIEVR is capable of effectively vacuuming or pumping waste from confined-space tanks and silos. It combines an extended segmented-link platform with an industrial master-slave robot on the platform end, which features a six degree-of-freedom dexterous master-slave robotic arm, capable of holding a vacuuming tube and/or a series of mining tools. ReTRIEVR is controlled by a single operator via computer graphic simulation. Super-SAM is based on a series of discs strung together on cables. Cable tension is controlled by pneumatic, electric, or hydraulic actuators located on the arm's mounting end. The working channels in the manipulator arm protect sensor and tool cables. With regard to D&D-related activities, Super-SAM has the capability of searching for and retrieving parts in inaccessible areas. SPIDER also performs video inspections, but is also capable of removing potentially damaging debris. SPIDER operates in air or underwater and can travel through 14- to 36-inch-diameter piping by expanding or collapsing to fit its surroundings. The system is equipped with a camera system, vacuum head, and pneumatic grippers for inspection and retrieval activities.

Framatome has also developed a RPIMS that provides remote viewing, dose monitoring, and wired or wireless audio communications to unlimited work locations through a fiber optic network. RPIMS has the capability to display up to 16 camera views simultaneously on one large-screen monitor. The video signal can display dosimetry information while adjustable audible and visual alarms alert the technician to changing radiological conditions. Each of the Framatome technologies is recommended for further investigation and inclusion in DDIS. An assortment of D&D-applicable technologies that have been demonstrated or deployed but are not yet commercially available are recommended for further evaluation. There were also several technologies uncovered in the industry search that are

WM '02 Conference, February 24–28, 2002, Tucson, AZ

currently in development. It is recommended that these technologies also be investigated further for potential D&D application.

## **CONCLUSIONS**

The purpose of reviewing industries and government agencies for D&D-applicable technologies was twofold. It was intended, first, to identify D&D-related technology innovations in nonnuclear industries and government agencies and, second, to build a database of contact information and search sources so that in future technology investigations, industry/agency innovations could be routinely and readily identified. This effort focused on a broad array of industries and government agencies, through which numerous technologies with potential application to D&D were identified. The following conclusions were drawn for this effort:

- DDFA is fulfilling its mission to promote and use the latest technological innovations to attain closure of contaminated DOE sites.
- Industries and government agencies identified as having the greatest potential to meet D&D needs through technology transfer and recommended for future review include mining, construction, shipbuilding and repair, U.S. Navy, USACE, NASA, and EPA.
- Industries and government agencies identified as less likely to provide D&D-applicable technologies at reduced cost or with potential to accelerate the cleanup schedule or reduce worker safety risks include CIA, NSA, USDA, NOAA, and plumbing and sanitary services.
- Many technologies employed in the private sector that are considered state of the art in their respective industry are not improvements over technologies available to DDFA. However, as industries increase investments in R&D, there is greater likelihood for developing innovative technologies suitable for transfer to DDFA.

## **REFERENCES**

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