ENVIRONMENTAL MANAGEMENT SCIENCE PROGRAM RESEARCH PROJECTS TO IMPROVE DECONTAMINATION AND DECOMMISIONING OF U.S. DEPARTMENT OF ENERGY FACILITIES

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ABSTRACT

This paper describes fourteen basic science projects aimed at solving decontamination and decommissioning (D&D) problems within the U.S. Department of Energy (DOE). Funded by the Environmental Science Management Program (EMSP), these research projects address D&D problems where basic science is needed to expand knowledge and develop solutions to help DOE meet its cleanup milestones.

EMSP uses directed solicitations targeted at identified Environmental Management (EM) needs to ensure that research results are directly applicable to DOE's EM problems. The program then helps transition the projects from basic to applied research by identifying end-users and coordinating proof-of-principle field tests. EMSP recently funded fourteen D&D research projects through the directed solicitation process. These research projects will be discussed, including description, current status, and potential impact. Through targeted research and proof-of-principle tests, it is hoped that EMSP's fourteen D&D basic research projects will directly impact and provide solutions to DOE's D&D problems.

INTRODUCTION

The U.S. Department of Energy (DOE) Environmental Management Science Program (EMSP) uses directed solicitations to ensure that its research projects address DOE's most important EM problems. Areas where new tools are needed are defined by the DOE sites and by independent studies. Based on this information, EMSP issues solicitations and awards research grants targeted at solving these problems. This approach ensures that the research conducted will be directly applicable to DOE site needs.

Although various methods exist to perform decontamination and decommissioning (D&D) work within the DOE, these methods are often cumbersome and labor intensive, increasing radiation dose, schedule, and cost. New technologies and approaches are needed to decommission the large number of surplus, contaminated DOE facilities at a reasonable cost. In some cases, the scientific knowledge and technologies needed to solve these problems do not exist, and additional research is necessary.

As part of the need definition and solicitation process for EMSP's D&D program, the National Academy of Science (NAS) performed an independent study that revealed three primary D&D need areas for DOE:

- Characterization of contaminated materials
- Decontamination of equipment and facilities
- Remote intelligent systems to improve worker safety.

In 2001, EMSP sent a targeted solicitation and awarded thirteen research grants aimed at solving these D&D problems. The duration of the research grants is three years, with the possibility of renewal if results are promising. One project was renewed in 1998, bringing the total number of current EMSP D&D projects to fourteen. These projects are conducting research in areas where basic science knowledge is needed to develop solutions that will help DOE complete its required cleanup. The ongoing research, which ranges from working to understand the methods of transport of contaminants in concrete to developing improved autonomous robots, has the potential to impact D&D at DOE sites by providing information and tools to improve the way D&D is done. These projects, along with the Principal Investigator and institution conducting the work, are listed in Table I. A brief synopsis of each project is included in the Characterization, Decontamination, and Remote Systems sections of this paper. Additional information on each project, including contact information for the Principal Investigators, can be found under the project database tab on the EMSP website at: http://emsp.em.doe.gov/

Table I. Current EMSP D&D Research Projects.

Project Number	Project Title	Principal Investigator	Lead Organization
82773	Contaminant-Organic Complexes: Their Structure and Energetics in Surface Decontamination Processes	Dr. Calvin C. Ainsworth	PNNL
82803	Novel Laser Albation Technology for Surface Decontamination	Dr. Winston Chen	ORNL
82807	Physico-Chemical Dynamics of Nanoparticle Formation during Laser Decontamination	Dr. Mengdawn Cheng	ORNL
82873	Design and Sensor-Based Control for Hyper-Redundant Mechanisms	Dr. Howard M. Choset	Carnegie Mellon University
82749	Field Portable Microchip Analyzer for Airborne and Surface Toxic Metal Contaminants	Dr. Greg Collins	Naval Research Laboratory
82797	Image-Based Visual Servoing for Robotic Systems: A Nonlinear Lyapunov-Based Control Approach	Dr. Warren Dixon	ORNL
82723	Remote Manipulation for D&D Exhibiting Tele-Autonomy and Tele-Collaboration	Dr. Thomas Ewing and Dr. Young S. Park	ANL
82810	Hybrid Actuators for Enhanced Automation in D&D Systems Tasks	Dr. John Jansen	ORNL
73835	Atmospheric-Pressure Plasma Cleaning of Contaminated Surfaces	Dr. Robert F. Hicks	UCLA
82794	Multi-Optimization Criteria-Based Robot Behavioral Adaptability and Motion Planning	Dr. Francois G. Pin	ORNL
82715	Development of Biodegradable Isosaccharinate-Containing Foams for Decontamination of Actinides: Thermodynamic and Kinetic Reactions between Isosaccharinate and Actinides on Metal and Concrete Surfaces	Dr. Dhanpat Rai	PNNL
82799	Bio-Chemo-Opto-Mechanical (BioCOM) Sensors for Real-Time Characterization	Dr.Thomas Thundat	ORNL
82784	Assessing the State and Distribution of Radionuclide Contamination in Concrete: An Experimental and Modeling Study of the Dynamics of Contamination	Dr. Brian E. Viani	LLNL
82792	Alternative Ionization Methods for Particle Mass Spectrometry	Dr. William B. Whitten	ORNL

CHARACTERIZATION

Field Portable Microchip Analyzer for Airborne and Surface Toxic Metal Contaminants (1)

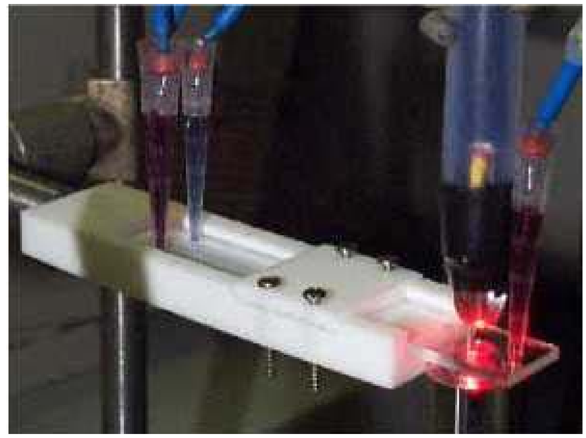

Fig 1. The "Laboratory-on-a-Chip" can be used for real-time detection of hazardous waste metal ions in the field.

The Naval Research Laboratory is developing a portable, capillary electrophoresis microchip capable of sensitively and rapidly monitoring hazardous waste metal ions in the field. The microchip, nicknamed "Laboratory-on-a-Chip," consists of a pattern of channels etched into a small glass slide that is thermally bonded to a cover plate to define the liquid pathways. Through the chip geometry, the contaminant is mixed with a "dye" solution that binds chemically to the contaminant metal ion being measured. Capillary electrophoretic forces are used to transport the sample solution down the microchannel and separate the individual components for sensitive detection. The system has been proven on UO^{22+}(VI), as well as on Co, V, Ni, Cu, Fe, Mn, and Cd. The research team is working on different assay techniques for other metal ions, including Be^{2+}, Cr^{6+}, Hg^{2+}, Pb^{2+}, Co^{2+}, Ni^{2+}, Cs^{+}, and Sr^{2+}. In addition, the researchers are expanding the system to enable the measurement of multiple metal ions simultaneously by putting multiple microchannels in parallel on the same microchip. Because the electrophoretic mobilities of metal ions are similar enough to make separations difficult, an auxiliary ligand that binds chemically to the contaminant is added to the separation medium to increase separation selectivity. The researchers are also expanding the capability to include solids by using chemical extraction techniques to bring the metals into solution, and then applying the extract to separation and measurement with the microchip. This work will result in a field-portable microchip sensor capable of identifying numerous radioactive and hazardous waste metal ions simultaneously.

Assessing the State and Distribution of Radionuclide Contamination in Concrete: An Experimental and Modeling Study of the Dynamics of Contamination (2)

This project is aimed at developing a better understanding of how radionuclides bind to and penetrate concrete, and at developing a more accurate predictive capability of these processes. The results will help evaluate decontamination approaches and may lead to development of new decontamination methods. The project team is performing laboratory tests with Portland Cement containing granite and quartz aggregate, and trace amounts of uranium and neptunium. The results will be analyzed using X-ray adsorption spectroscopy, radioanalytical, and microscopic methods to show speciation, including distribution, redox activity, and aging. The results of these tests will be compared with analysis of aged samples of cores taken from the DOE Rocky Flats site. The laboratory data will be used as input to the model, which will predict the depth, chemical form, and association of contaminants in concrete. The model and simulations will include fractures and heterogeneity, such as that caused by aggregate in concrete. Once complete, the project team hopes to provide a predictive model that captures the physical and chemical processes that control contamination distribution and binding in concrete. This model and the project data can be used as a tool to develop better ways to remove contaminants from concrete.

Alternative Ionization Methods for Particle Mass Spectrometry (3)

This research team is developing ionization techniques to enhance the capability of real-time mass spectrometry of individual airborne particles. The researchers have developed an apparatus for aerosol analysis based on laser ablation ion trap mass spectrometry. It is extremely sensitive for low ionization potential (IP) substances, such as uranium, but less sensitive for high IP substances, like mercury, as the ions interact through charge exchange with the laser ablation plume. In addition, it is highly matrix dependent for all substances. To improve sensitivity for high IP substances and decrease matrix sensitivity for all substances, the researchers are exploring using resonance ionization together with laser ablation. In this approach, a resonance laser will be used after most of the collisions from the initial laser ablation plume have occurred, which should allow re-ionization of the neutrals and detection of the high IP substances. Because the laser must be tuned to the particular substance being detected, the sensitivity and level of information gathered will be very high for that item – with the drawback that it will not work on a large range of materials simultaneously.

In another approach, the research team is exploring glow discharge ionization to decrease matrix sensitivity for all substances. This approach will be able to detect a broader range of substances, but perhaps with less sensitivity. The glow discharge creates a plasma so that the increased charge exchanges should ionize some neutrals and allow them to be detected. In addition to actinides, the team is working to develop methods to detect mercury, 99Tc, and PCBs. This research should result in improved sensitivity for trace substances and allow detection of contaminants in micro particle samples on an individual particle basis. This will lead to a compact, real-time, extremely sensitive monitor for airborne particles, including actinides, mercury, 99Tc, and PCBs. The technology could be used for real time detection of these substances during decontamination operations, significantly increasing worker safety. The monitor could also be used to obtain contamination versus depth information in drilling, or as a perimeter monitor for airborne contamination.

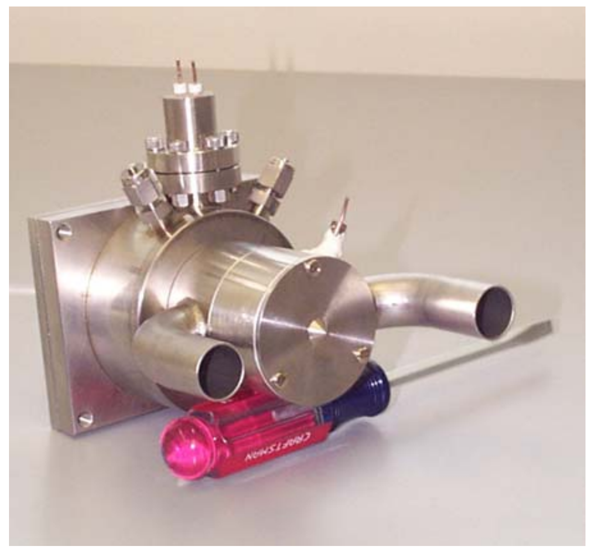

Fig 2. The Alternative Ionization Methods for Particle Mass Spectrometry project is aimed at identification of target species on an individual particle basis using this atmospheric pressure inlet system and quadrupole ion guide for the mass spectrometer.

Physico-Chemical Dynamics of Nanoparticle Formation During Laser Decontamination (4)

This research team is using a pulsed, Laser-Induced Plasma (LIP) for decontamination and characterization of heavy metals and radionuclides, and is investigating the formation and growth dynamics of nanoparticles produced by these processes. Knowledge about nanoparticle formation will enable development and optimization of a system for simultaneous characterization (using time-resolved aerosol spectrometry and differential mobility analysis) and decontamination (using LIP).

Project tasks include obtaining baseline data (size, shape, distribution, and chemical composition), developing advanced particle detection instrumentation, and developing a computer simulation model. In the first year, the researchers are studying how laser characteristics affect the formation and growth dynamics of heavy metal and radionuclide nanoparticles. The research team is studying real-time particle chemistry with a time-resolved aerosol spectrometry system in tests that will include laboratory-produced and ORNL field samples. In addition, the researchers are developing a model to simulate formation and growth of nanoparticles produced by LIP processes. This knowledge will enable design of improved D&D methods that protect workers from airborne heavy metals and radionuclides in the nanometer size range, which easily penetrates human lungs and most respiratory protection equipment.

Bio-Chemo-Opto-Mechanical (BioCOM) Sensors for Real-Time Characterization (5)

In this project, the research team is developing bio-chemo-opto-mechanical (BioCOM) sensors for technetium, mercury, uranium, and beryllium in solution that can be used for real-time analysis in the field. The sensors consist of an array of micro-machined silicon cantilevers containing embedded deformable diffraction gratings functionalized with chemically selective coatings. Adsorption of specific molecules on the cantilever array leads to bending, which changes the diffraction of light resulting in a change of color. This simple design makes it easy and inexpensive to manufacture and easy to use in the field for high sensitivity simultaneous measurement of many analytes using a single microchip. The project approach includes: (1) design and development of coatings to make selective sensors; (2) design and fabrication of a test chip and optical detection system; and (3) design, development, and testing of a field test prototype sensor. Work is underway on design and fabrication of the deformable diffraction grating chips and on development of a system to electronically record the diffraction patterns as a function of time. In addition, studies of the surface chemistry needed to create surfaces that will link to the contaminant molecule are underway. This research will result in a miniature sensor for real-time detection of contaminants in field operations.

DECONTAMINATION

Development of Biodegradable Isosaccharinate-Containing Foams for Decontamination of Actinides: Thermodynamic and Kinetic Reactions Between Isosaccharinate and Actinides on Metal and Concrete Surfaces (6)

This project team is developing an Isosaccarinate (ISA)-containing biodegradable foam to remove plutonium from steel and concrete. ISA is a degradation product of cellulose that binds strongly with plutonium. Because ISA is biodegradable, it will result in a more environmentally acceptable, non-mixed, secondary waste stream. The research team plans to study the effect of pH and common ions (sodium, calcium) on the speciation and thermodynamic reactions of ISA over large variations in pH and large concentrations of sodium and calcium. This data will help understand how ISA binds with actinides, and over what conditions the binding will be most effective. Next, the researchers will study the thermodynamic and kinetic reactions between ISA/iron and ISA/plutonium to understand how iron and plutonium will compete for ISA bonds, thus increasing understanding of how effective ISA will be for decontaminating plutonium from steel. Lastly, the researchers plan to study how plutonium binds with concrete and steel, and test the ISA-containing foam to see how well it decontaminates these surfaces. Preliminary studies using NpO2 showed that ISA strongly complexes NpO2 over a large range of pH, so it is expected that it will perform similarly for plutonium. Once completed, the biodegradable ISA-containing foam can be used to decontaminate plutonium from concrete and steel surfaces in a more environmentally friendly way.

Contaminant-Organic Complexes: Their Structure and Energetics in Surface Decontamination Processes (7)

This project team is using microbially produced chelates (siderophores) to remove actinides from oxidized steel and iron. These siderophores, which are less corrosive than the acids commonly used, remove contaminants from under oxidation layers, as well as from corrosion pits and cracks. Siderophores have a high binding affinity to iron and actinides, so contaminants are bound to the cleaning agent, reducing secondary contamination. Tests on oxidized samples aged over one year have shown that the ability of these chelates to solubilize and remove actinides is not affected by aging. The structure and bonding of siderophores and their functional moieties, and how these change with chemical environment, are being studies using molecular spectroscopy (Fourier Transform Infrared Spectroscopy, Raman, X-ray Adsorption Spectroscopy). The team is also using a molecular modeling system to select the optimum siderophore structure. This research will result in an actinide decontamination method that removes contaminants effectively from oxidized metal with little secondary waste. Removal of actinides from oxidized layers, pits, and cracks will allow cleaning of metal that would otherwise have been disposed of as HLW so that it can be disposed of as LLW or non-contaminated metal at a much lower cost.

Atmospheric-Pressure Plasma Cleaning of Contaminated Surfaces (8)

This research team is developing a decontamination method using an atmospheric-pressure plasma to remove transuranic contamination with little secondary waste. The system will remove actinides from metal and concrete surfaces. In this process, fluorine atoms carried in a plasma gas attract and bond to actinides, volatilizing the actinides and allowing them to be collected by a vacuum system. The system generates little secondary waste (only the vacuum system filter). The technology has been demonstrated in the laboratory using tantalum as a surrogate for plutonium and has also been demonstrated to remove depleted uranium from metal surfaces. Currently, work is being done to determine etch rates for uranium. The expected cleaning rate is approximately ½ square foot per minute down to a couple of microns depth. Decontamination with this technique could be used to remove TRU elements from items such as gloveboxes, so the waste can be re-classified as LLW and disposed of at a much lower cost. This low-energy, low-temperature, low-pressure, mobile process can be taken into the field for decontamination of TRU contaminated equipment. It can also be used to routinely decontaminate TRU contaminated gloveboxes and hoods to reduce the radiation exposure to workers using this equipment.

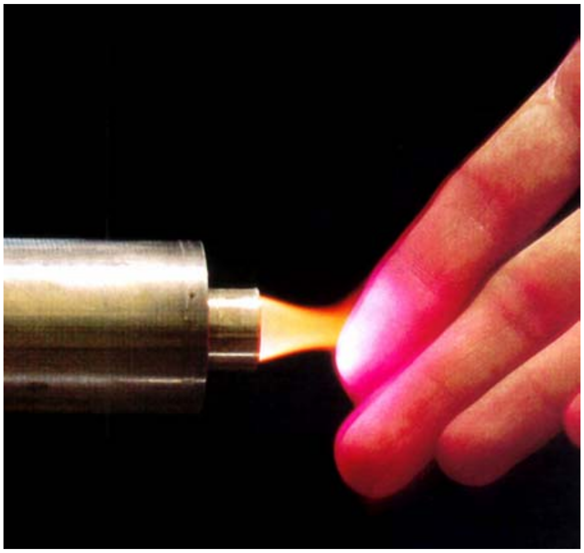

Fig 3. The Atmospheric-Pressure Plasma Cleaning system will remove actinides from items like gloveboxes during D&D activities.

Novel Laser Ablation Technology for Surface Decontamination (9)

In this project, the research team is investigating a surface decontamination process using laser ablation with the surface to be decontaminated immersed in liquid. The evaporated contaminants are confined to the liquid so secondary contamination and the risks of airborne contamination are eliminated. The team has developed an apparatus for Laser Ablation Decontamination in a Liquid (LADIL), and the researchers are now working to understand the basic physical processes of laser ablation on a solid-liquid interface. The researchers are working with different laser systems to find the optimum wavelength and power for laser ablation in liquid. This data will be used to increase the efficiency of using LADIL to clean contaminated surfaces. Initial tests show that the system formed micro-droplets with an average radius of 5 to 10 micrometers. Particles in this colloidal solution can be detected by observing light scattering in the solution, and particle size measured with an optical microscope. From the density of the particles in solution and the average particle size, it is possible to estimate the amount of material removed from the test surface. Preliminary tests using a benign painted surface showed that the amount of paint removed from the surface matches the estimated amount of material in solution. The system resulting from this research could be used for decontamination of many surfaces in a way that contains airborne contamination and increases worker safety. In addition, many DOE sites have fuel pools requiring deactivation with highly contaminated "bathtub rings" around the top edge. Lowering the water level for decontamination can allow these contaminants to become airborne, often at an unacceptable safety risk. Using LADIL, these "bathtub rings" could be decontaminated in place while containing the contaminants and avoiding releases of airborne contamination.

REMOTE SYSTEMS

Design and Sensor-Based Control For Hyper-Redundant Mechanisms (10)

This project team is developing a multi-degree-of-freedom "snake" robot that can thread through tightly packed volumes, inspect pipes, and enter small spaces. This articulated probe, or hyper-redundant mechanism, will be able to maneuver in a variety of ways, just like its biological counterparts, and will have many degrees of freedom to give it a wide range of capabilities. Existing snake type robots have lacked either the control system or strength to lift the robot's own weight – both of these are areas are being addressed by this project. The project tasks include mechanism design, path planning and control, and sensor integration. In mechanism design, one challenge is to make the probe small enough to fit into small spaces, but strong enough to lift itself in 3 dimensions. In the first year of this project, the research team has designed, built, and tested a six joint mechanism that is fixed at one end. Tests show one joint has the strength to "cantilever lift" all 6 joints. The researchers plan to develop control algorithms that allow the robot to navigate in unknown three-dimensional spaces with control modes that range from tele-operation to full autonomy. The tele-operation mode will use a joystick to direct the "head" of the snake, and a path planner to coordinate the internal degrees of freedom of the snake to allow the forward motion. The result of this project will be a snake robot that can thread through tightly packed volumes, and undefined three-dimensional spaces, such as reactor vessels, collecting samples or transmitting images from remote locations inaccessible by conventional robots and people. It will allow inspection with still and video pictures (to form a virtual presence for the remote user and to document the internal conditions of the facility), and sample collection from areas too small or too hazardous for human entry. For homeland security, it could be used as a remote sensor to detect biological or radioactive contamination in buildings that have been contaminated by terrorist activities. The snake robot will be minimally invasive, avoiding the cost of dismantling to make larger entry ports, and also avoiding worker entry and the associated cost and dose to workers.

Multi-Optimization Criteria-Based Robot Behavioral Adaptability and Motion Planning (11)

In this project, the researchers are developing a novel "generic" code for robots that is independent of the optimization criteria, constraints, or type of robot, and allows for real time, on-the-fly adaptability to changes in any of these areas. The approach uses a new optimization-based resolution of under-specified systems of algebraic equations with constraints. The resulting generic code will allow a transformation from task space (3-D world) to joint space (motors) that allows real time robot behavior adaptations to changes in task objectives, constraints, or kinematics configuration. Typically, the control code for robots is specific to a particular task and set of constraints. Any change in the task objectives (such as precision, strength, or torque), constraints (obstacles, joint limits, etc), or robot configuration (type of joints, mobile platform, manipulator, etc.) requires a change in the code. This limits the flexibility of robots and makes it very difficult to use them for widely varying, complex tasks such as those in found in DOE. The single code being developed by this project provides for the general solution of under-specified systems of algebraic equations that is suitable for solving inverse kinematics of robots, and is useable for all types of robots with no limitations on number of joints or number of task-space variables. In addition, it can adapt in real time to changes in number and type of constraints, task objectives, and kinematics configuration.

The first development step has been successfully completed, which allows automatic generation of the matrices that represent under-specified equations. This means that the same code will work on different robots and will resolve the equations independent of the constraints. The next step is to combine this with an equation solver that makes the transformation from task to joint space. Lastly, the code will be tested on existing ORNL robots to verify its effectiveness.

Hybrid Actuators for Enhanced Automation in D&D Systems Tasks (12)

In this project, researchers are developing hybrid actuators that combine the strength of hydraulic actuators with the precision of electric actuators. These new actuators will enable transition from tele-operated to more fully autonomous robotic systems. Most current robotic systems that require high payload capabilities use hydraulic actuators, which generally leak, are non-linear and time-varying in operation, and require high maintenance. These features lead to poor controllability that impacts accuracy and speed of response for robotic systems. This work seeks to improve the mechanical performance of manipulators by using a new type of piezoelectric ceramic material as the basis for a new type of actuator. The first step is to understand the science and performance of the new type of piezoelectric ceramic. The next step is to study design issues of a hybrid actuator. Lastly, the system will be modeled to verify its potential performance. An experimental setup is in place, and the researchers are collecting data on the piezoelectric ceramic. Models of the piezoelectric crystal and mechanical pump are almost completed. The purpose of the simulation is to see if the power densities needed are achievable based on measured values of piezoelectric materials. Once completed, the hybrid actuators will enable a transition to more autonomous control of robotic systems for D&D because the actuators will perform with better control, more reliability, and less maintenance than existing systems.

Remote Manipulation for D&D Exhibiting Tele-Autonomy and Tele-Collaboration (13)

This project team is developing a novel control system for the Dual Arm Work Platform (DAWP). The DAWP is a two-arm, tele-robotic manipulator system that was demonstrated and used extensively (over 2000 hours) during D&D of the CP-5 reactor at Argonne National Laboratory. Use of the DAWP was successful, reducing cost and effort by a factor of two, but during the demonstration, the project team realized that improvements could be made that would increase its effectiveness significantly. This project is aimed at making and demonstrating those improvements. The effort is three-fold, including (1) a new control architecture and software, (2) a new hand controller, and (3) new sensors for shape discrimination and distance information. The new control architecture is developing a "virtual fixture" that is defined mathematically and bounds the workspace for specific tasks, and that works in tandem with the new hand controller. The virtual fixture defines the workplace and paths for the manipulator interactively with the controller. If the user moves the manipulator to an "edge" of the control-system-defined workspace, the user feels physical resistance; then, as the user moves the manipulator, it moves along the contour of the defined workspace. The contours are defined by the software and physically felt by the user through the software during operation. This will give increased accuracy, speed, and repeatability. For instance, if a circular saw is making a cut and binds, it is normally difficult to remove the blade and place it in the exact same place to finish the cut. With the virtual

Fig 4. An innovative control system will enable the Dual Arm Work Platform to complete D&D activities more quickly with increased accuracy.

workspace, the defined workspace might be a truncated funnel shape that would help guide the tool back to the exact same location. A new hand controller is being designed and built that reacts to the software and allows the user to feel the bounded areas from the software. Lastly, the team plans to install new sensors to provide distance and shape information to the control system. The results of this research will be tested and demonstrated on the DAWP, which can then be deployed on D&D tasks. Use of the manipulators on the DAWP will be more accurate and quick, and will allow much greater control by the user, enabling it to perform many more tasks. Once proven on the DAWP, the control system can be adapted for use on other robotic systems throughout DOE, increasing their efficiency and capabilities to perform complex tele-operated tasks during facilities D&D.

Image-Based Visual Servoing for Robotic Systems: A Nonlinear, Lyupanov-Based Control Approach (14)

This research team is working to develop a new approach to visual servoing that adapts for the unknown camera calibration parameters (focal length, scaling factors, camera position, and orientation) and the physical parameters of the robotic system (mass, inertia, friction). The researchers are using non-linear, Lyupanov-based control techniques to enable robotic systems to extract information from high-speed cameras and other sensors (e.g., laser-based depth sensors, joint encoders) and use the information in the feedback loop of an actuator level control algorithm. This feedback will allow increased accuracy, in spite of the fact that the cameras are not calibrated and the workplace is undefined. The result will be increased accuracy, autonomy, and robustness for robotic operations. These improvements will allow more tasks to be performed remotely with increased autonomy, removing workers from hazardous situations.

CONCLUSION

This research has the potential to greatly impact how DOE performs D&D activities on its facilities, enabling D&D work to be done with reduced cost, accelerated schedules, and increased safety. Current EMSP-funded D&D projects address characterization with research, including development of a real-time, hazardous metal sensor for field use – a "lab-on-a-chip", improved understanding of how contaminants bind to and penetrate concrete, study of alternative ionization methods for particle mass spectrometry to allow real-time individual particle detection, development of a method for simultaneous laser-based decontamination and characterization, and development of micro-cantilevers to make a diffraction grating-based bio-chemo-opto-mechanical miniature field-deployable sensor. Decontamination will be improved through development of biodegradable isosaccharinate-containing foams to remove actinides, use of siderophores to remove actinides from oxidized metal, an atmospheric-pressure plasma system to remove actinides, and a laser ablation in liquid method to clean contaminated surfaces while reducing airborne contamination. Remote systems improvements will be seen through development of a multi-degree-of-freedom snake robot to investigate tight spaces that cannot be entered by conventional robots or humans; development of a "generic" code that is independent of the constraints, robot configuration, or task objectives and will enable robots to perform complex sequences of tasks; development of a hybrid hydraulic/electric actuator to improve robot performance and allow transfer to autonomous robots; development of an improved interactive control system for tele-operated robots that will increase repeatability and precision; and a new approach to visual servoing that accommodates for camera calibration issues, allowing for more accuracy and increased autonomy in robotic operations. Through this research, EMSP is conducting basic science to increase knowledge and develop technologies and improved methods that will directly impact and provide solutions to DOE's D&D problems.

REFERENCES

1. Collins, Dr. Greg E., and Gang Deng (June 2002). *Metal Ion Analysis Using Near-Infrared Dyes and the "Laboratory-on-a-Chip."* Project 82749: 2001-2002 Progress Report. U.S. Department of Energy EMSP Webpage. http://emsp.em.doe.gov/portfolio/multisearch.asp [EMSP Problem Area: Deactivation and Decommissioning].

2. Viani, Dr. Brian E. (October 2002). *Assessing the State and Distribution of Radionuclide Contamination in Concrete: An Experimental and Modeling Study of the Dynamics of Contamination*. Project 82784: 2001-2002 Progress Report. U.S. Department of Energy EMSP Webpage. http://emsp.em.doe.gov/portfolio/multisearch.asp [EMSP Problem Area: Deactivation and Decommissioning].

3. Whitten, Dr. William B., and Peter T. A. Reilly (June 2002). *Alternative Ionization Methods for Particle Mass Spectrometry*. Project 82792: 2001-2002 Progress Report. U.S. Department of Energy EMSP Webpage. http://emsp.em.doe.gov/portfolio/multisearch.asp [EMSP Problem Area: Deactivation and Decommissioning].

4. Cheng, Dr. Meng-dawn, and Dr. Da-Ren Chen (June 2002). *Physico-Chemical Dynamics of Nanoparticle Formation during Laser Decontamination*. Project 82807: 2001-2002 Progress Report. U.S. Department of Energy EMSP Webpage. http://emsp.em.doe.gov/portfolio/multisearch.asp [EMSP Problem Area: Deactivation and Decommissioning].

5. Thundat, Dr.Thomas G. Dr. Arunava Majumbar, Dr. Dian Blake, and Dr. Hai-Feng Ji (June 2002). *Bio-Chemo-Opto-Mechanical (BioCOM) Sensors for Real-Time Characterization*. Project 82799: 2001-2002 Progress Report. U.S. Department of Energy EMSP Webpage. http://emsp.em.doe.gov/portfolio/multisearch.asp [EMSP Problem Area: Deactivation and Decommissioning].

6. Rai, Dr. Dhanpat, Dr. Linfeng Rao, and Dr. Robert C. Moore (June 2002). *Development of Biodegradable Isosaccharinate-Containing Foams for Decontamination of Actinides: Thermodynamic and Kinetic Reactions between Isosaccharinate and Actinides on Metal and Concrete Surfaces*. Project 82715: 2001-2002 Progress Report. U.S. Department of Energy EMSP Webpage. http://emsp.em.doe.gov/portfolio/multisearch.asp [EMSP Problem Area: Deactivation and Decommissioning].

7. Ainsworth, Dr. Calvin C., Benjamin P. Hay, Samual J. Traina, and Satish C. B. Myneni (June 2002). *Contaminant-Organic Complexes: Their Structure and Energetics in Surface Decontamination Processes*. Project 82773: 2001-2002 Progress Report. U.S. Department of Energy EMSP Webpage. http://emsp.em.doe.gov/portfolio/multisearch.asp [EMSP Problem Area: Deactivation and Decommissioning].

8. Hicks, Dr. Robert F., Hans W. Herrman, Xiawan Yang, Maryam Moravej, and Gregory R. Mowling. (June 2002). *Atmospheric-Pressure Plasma Cleaning of Contaminated Surfaces*. Project 73835: 2001-2002 Progress Report. U.S. Department of Energy EMSP Webpage. http://emsp.em.doe.gov/portfolio/multisearch.asp [EMSP Problem Area: Deactivation and Decommissioning].

9. Chen, Dr. Chung H. (June 2002). *Novel Laser Albation Technology for Surface Decontamination. Project 82803: 2001-2002 Progress Report*. U.S. Department of Energy EMSP Webpage. http://emsp.em.doe.gov/portfolio/multisearch.asp [EMSP Problem Area: Deactivation and Decommissioning].

10. Choset, Dr. Howard M. (October 2002). *Design and Sensor-Based Control for Hyper-Redundant Mechanisms*. Project 82873: 2001-2002 Progress Report. U.S. Department of Energy EMSP Webpage. http://emsp.em.doe.gov/portfolio/multisearch.asp [EMSP Problem Area: Deactivation and Decommissioning].

11. Pin, Dr. Francois G. (June 2002). *Multi-Optimization Criteria-Based Robot Behavioral Adaptability and Motion Planning*. Project 82794: 2001-2002 Progress Report. U.S. Department of Energy EMSP Webpage. http://emsp.em.doe.gov/portfolio/multisearch.asp [EMSP Problem Area: Deactivation and Decommissioning].

12. Jansen, Dr. John F. (June 2002). *Hybrid Actuators for Enhanced Automation in D&D Systems Tasks*. Project 82810: 2001-2002 Progress Report. U.S. Department of Energy EMSP Webpage. http://emsp.em.doe.gov/portfolio/multisearch.asp [EMSP Problem Area: Deactivation and Decommissioning].

13. Ewing, Dr. Thomas, and Dr. Young S. Park (June 2002). *Remote Manipulation for D&D Exhibiting Tele-Autonomy and Tele-Collaboration*. Project 82723: 2001-2002 Progress Report. U.S. Department of Energy EMSP Webpage. http://emsp.em.doe.gov/portfolio/multisearch.asp [EMSP Problem Area: Deactivation and Decommissioning].

14. Dixon, Dr. Warren E. (June 2002). *Image-Based Visual Servoing for Robotic Systems: A Nonlinear Lyapunov-Based Control Approach*. Project 82797: 2001-2002 Progress Report. U.S. Department of Energy EMSP Webpage. http://emsp.em.doe.gov/portfolio/multisearch.asp [EMSP Problem Area: Deactivation and Decommissioning].