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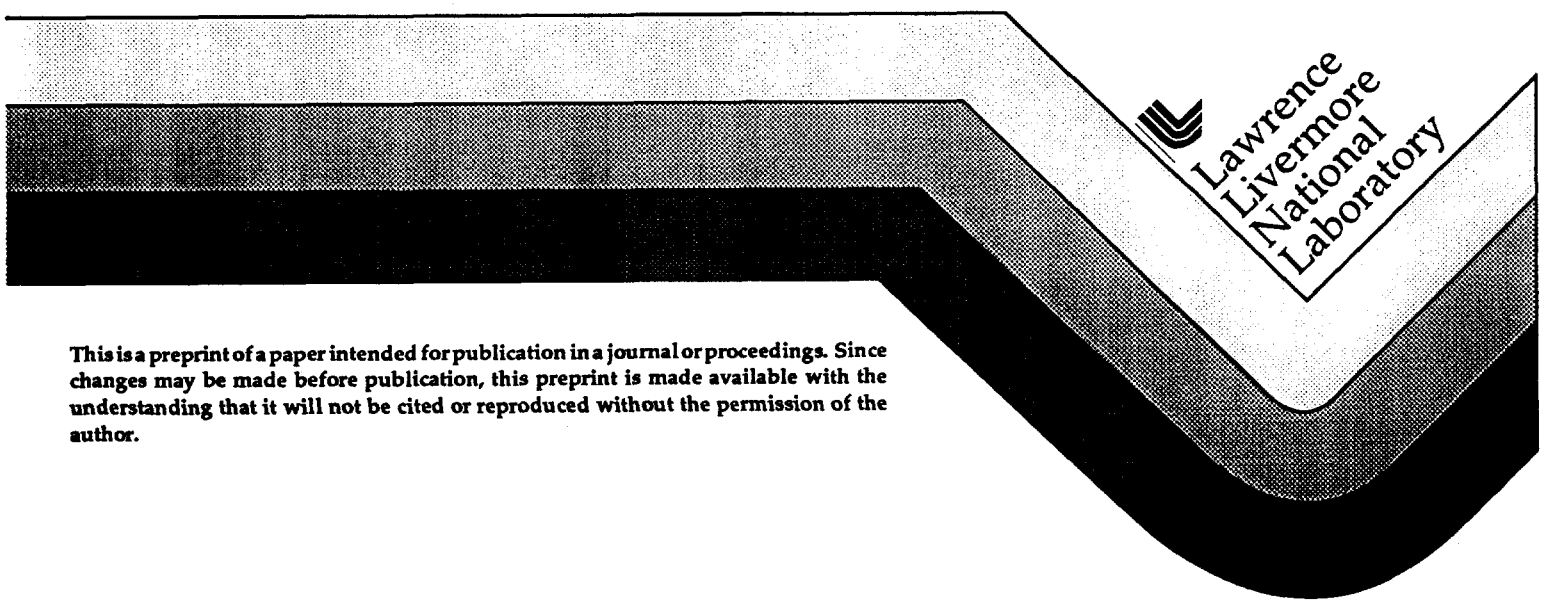

Addressing Nuclear and Hostile Environmental Challenges with Intelligent Automation

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Introduction

Lawrence Livermore National Laboratory (LLNL) has developed and continues to develop solutions to address the challenges associated with nuclear and hostile environments. The nuclear challenge and, in general, most hostile environments present unique conditions requiring new approaches and techniques. Solutions used in controlled or conventional environments are limited in the highly volatile nuclear environment. Engineers at LLNL have been actively involved in finding unique and creative intelligent automation solutions. We have made significant advances in automation control theory, nuclear material handling processes, robotics systems, and sensors technology.

Pushing the Edge on Automation Controls

Nuclear and hostile environments present challenges to controlling hardware and processes in the environment. Any approach must be sure not to radically disturb the environment. Current work at LLNL involves the development of advanced tele-operation controls. Telerobotics, or shared control of a manipulator by an operator and a computer, provides the flexibility needed to match task complexity. The work involved integrating key tools to (1) make a robust telerobotic system that operates at speeds and reliability levels acceptable to waste handling operators and (2) to demonstrate an efficient operator interface that minimizes the amount of special training and skills needed by the operator.

Key elements that contributed to robust tele-operation include the following:

- A truly seamless transfer between tele-operation and autonomous operations.
- A major advance in whole-arm to whole-workcell collision avoidance that is operational during all moves.
- Force-compliant arm behavior.
- A real-time collision-free path-planner.

The operator interface demonstrates key elements including a force-reflecting hand controller that provides operator inputs in a novel hybrid position/rate mode, a speaker-independent natural-language-based voice-recognition system, and a reconfigurable graphics and video display system. The control system is currently being used to integrate and control a six-degree-of-freedom manipulator and force-reflecting master controller in a waste sorting demonstration cell.

Optimizing Nuclear Material Handling Processes

LLNL is an acknowledged leader in glove-box and hot-cell special nuclear materials processing. To improve safety, reduce the costs of processing, and improve productivity, LLNL integrated robotics and automation into previously conducted manual operations. This system eliminates the radiation-exposure hazards of glove-box materials processing, and has the added benefit of substantially reducing waste generation.

Glove-box and hot-cell environments impose stringent operating requirements on robotics and automation systems. The robotics system was hardened for operations in hostile environments. LLNL and the robot vendor selected materials of construction for radiation tolerance and operation in dry, inert environments. In addition, protective covers, seals, and lubricants can be used for operation in dry, chemically hazardous, and dusty environments. Modularity reduces size and weight for handling robot components in a glove-box during maintenance. We used special, remote engineering features for aligning, handling, and fastening components. LLNL engineers have developed and continue to

develop advanced handling approaches that allow efficient and safe processing of material without putting personnel at risk.

Advancing Robotics Systems

Significant work is being done in the area of robotics. Because of their robustness, capacities, and versatility, robotics systems provide an increasingly viable solution to problems the nuclear environment.

Since the late 1970s, LLNL has developed remotely controlled mobile robotic systems. LLNL's mobile robots are unique because of the way we have coupled and integrated the mobile platforms' abilities, such as their environmental and radiation hardening, sensing of nuclear materials, and specialized articulated end effectors. We either design hardened mobile systems for accident responses, or adapt a commercial vehicle, adding navigation, control, locomotion technologies, and site characterization sensors. In a more recent application, LLNL's engineers have designed an innovative and inexpensive all-terrain vehicle. With its low center of gravity, this vehicle can cross treacherous terrain with sensors for detecting, dislodging, and detonating mines or other ordnance, or for detecting hazardous wastes or toxins. Using modular control architectures, diverse sensor packages, and mobile systems that go can anywhere, we readily develop remotely controlled mobile systems.

Developing Sensors Technology

Recent innovative sensors development at LLNL has focused on the increasing importance of identifying and categorizing types of materials in the nuclear environment. Our sensor developments also enable robotics and automated systems to adjust to rapid changes in unstructured and hostile environments. Our advanced control algorithms take and use the information gathered by suites of sensors as the foundation upon which to base their intelligent decision making. Advanced image analysis and three-dimensional vision

data algorithms have been developed to interface with existing automation hardware, thus providing a complete intelligent solution.

Significant advances have also recently been made in the simultaneous use of non-destructive evaluation (NDE) technologies as the input sensing systems to provide data for automated intelligent decision making. We have merged the simultaneous output of many sensors and interpreted the resulting data (with fuzzy logic and neural network algorithms) to classify materials. NDE technologies are optimal for identifying materials, determining volumes, and detecting minimal limits. This is particularly important in real-time applications for manufacturing process and assembly-line monitoring, for inspecting and gauging precision alignments and tolerances, and for investigating the contents of sealed hazardous materials containers. Researchers at LLNL have developed sophisticated, automated process-control platforms that integrate sensor packages with automated, real-time data collection. The resulting computerized systems for environmental monitoring and site characterization are easily transportable and rapidly deployable.

Summary

In many of these areas, LLNL has been pushing the envelope of traditional technologies as well as building off of state-of-the-art commercial technologies to provide integrated system solutions to nuclear- and hostile-environment challenges. We believe the answer lies in the integration of comprehensive application engineering with innovative technology development.

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