THE NATIONAL ACADEMIES
REPORT IN BRIEF

Soldier Protective Clothing and Equipment:
Feasibility of Chemical Testing Using a Fully Articulated Robotic Mannequin

The U.S. Department of Defense (DOD) is moving toward the day when human-like mannequins can be used to test the equipment that protects military personnel from exposure to hazardous chemical agents. Unfortunately, current technology can't produce a robot small enough to meet U.S. standards and still include all necessary system components (including power, control, sensors, perspiration, respiration), nor can it produce robots that are untethered and move like humans. However, DOD can make progress by setting priorities among system components, improving guidance for proposing contactors, and considering a complementary test approach with simulants and real-time sensing.

As part of the continued need to protect soldiers in environments where they are exposed to chemical-warfare agents, the effectiveness of individual protection equipment must be ensured by testing. However, carrying out tests with human subjects presents numerous challenges. A wide array of humanoid robots and mannequins are increasingly used in national-security applications. Over the years, human-size thermal mannequins have been used to test military garments, and there is growing interest in making mannequins more human-like by adding motion to permit more advanced testing capabilities (such as needed to perform Man-in-Simulant Testing shown in Figure 1). This report addresses the feasibility of developing an advanced humanoid robot—a PETMAN system—to enhance the testing of chemical-warfare individual protective equipment in the United States.

FIGURE 1 Man-in-Simulant Test exercises in the chamber. The PETMAN system is required to perform the same set of exercises as the soldiers shown. SOURCE: Charles Walker, U.S. Army Dugway Proving Ground.

Although most of the PETMAN system requirements taken independently are technically feasible, fulfilling all of U.S. Department of Defense, Joint Program Executive Office for Chemical and Biological Defense, Joint Project Manager, Nuclear, Biological and Chemical Contamination Avoidance, Product Director, Test Equipment, Strategy, and Support (PD TESS) requirements in a single PETMAN (especially one that is not tethered) is not currently possible.

A substantial effort will be needed to move from current mannequin systems, to the type of system described in the PETMAN requirements document. This report addresses the feasibility of meeting the major design challenges of the PETMAN system requirements on the basis of currently available technology. This includes a detailed consideration of human-physiology simulation, the mannequin under ensemble sensing conditions, robotic design, architecture and materials of the PETMAN skin, an integrated PETMAN system, and a complementary approach to PETMAN. As a PETMAN system is developed, three major recommendations should be

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taken into consideration: priority setting among PETMAN requirements, contractor qualifications, and a complementary option to a PETMAN system.

Priority Setting Among PETMAN Requirements

Although the Defense Department's PD TESS indicated that an exercise was being done to set priorities among the PETMAN requirements, the results of that exercise were not available to inform this study. With that in mind, the panel recommends that, because integrating all the current objective requirements is a major challenge, the sponsor should set priorities for the PETMAN requirements according to the program objectives. Additionally, a phased approach to the development of the system should be used, with the high-risk challenges identified in the study addressed first. Achievable objectives can then be decided upon according to the priorities set.

Contractor Qualifications

The development of a PETMAN system is a large undertaking for any organization. The development of individual components—in particular the robotics capability—will require considerable resources and expertise. The high level of expertise needed for both the robotics and the simulation may be beyond the means of a single group. Therefore, the study concludes that an interdisciplinary approach be taken, and that the primary contractor should have demonstrated capability in systems integration. Additionally, a workshop should be organized to inform the proposing groups fully of the objective and threshold requirements. The invitation list should include system integrators and developers and suppliers of component technologies for the mannequin, materials, and sensors.

PETMAN systems include real-time chemical agent sensing capability to detect whether chemical agents can penetrate individual protection equipment while the following realistic human test conditions are simulated:

Body temperature and perspiration: moisture-permeable fabric or metal shell covers surface and transfers body-temperature water from the mannequin core through tiny pores connected to hose-and-valve system

Respiration: mechanical lung system simulates breathing movement of chest and possibly respiratory gas movement

Skin: moisture-permeable fabric simulates the feel of skin, but has ability to protect mannequin circuits and systems from exposure to chemical agents

Mobility: Robotic capability driven by electric or pneumatic motors inside mannequin

Current requirements for a PETMAN System

- Is compatible with individual protective equipment.
- Is not tethered.
- Uses mostly off-the-shelf technology and can be decontaminated.
- Operates continuously for 12-24 hours.
- Tests for agent in real time.
- Simulates human physiology.
- Is compatible with test-chamber conditions.
- Is compatible with Man-in-Simulant Test exercises.
- Has human-like articulation and construction.

A Complementary Approach

The current man-in-simulant test (MIST) protocol evaluates individual protection equipment on soldiers rather than mannequins, and this offers the benefit of testing the effects of actual human movements and physiologic conditions. However, one of the major shortcomings of MIST is its method of chemical agent sensing. However, some technologies are sufficiently mature to support construction of a whole-body suit for a human—a sensor-integrated body suit—outfitted for real-time sensing of chemicals, body temperature, heart rate, cardiographic characteristics, and humidity without the need for a tether. The study recommends that a sensor-integrated body suit be considered as a complement to the proposed PETMAN system. This approach would prove more cost efficient, as it has been shown that recreating human-like movement, respiration, perspiration, and body proportions will be difficult and expensive.

This brief was prepared by the National Research Council based on a report by the Committee on Full-System Testing and Evaluation of Personal Protection Equipment Ensembles. The report was sponsored by the Department of Defense. For more information, contact the Board on Chemical Sciences and Technology at (202) 334-2156 or visit http://dels.nas.edu/bcst. Copies of *Soldier Protective Clothing and Equipment: Feasibility of Chemical Testing Using a Fully Articulated Robotic Mannequin* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; www.nap.edu.