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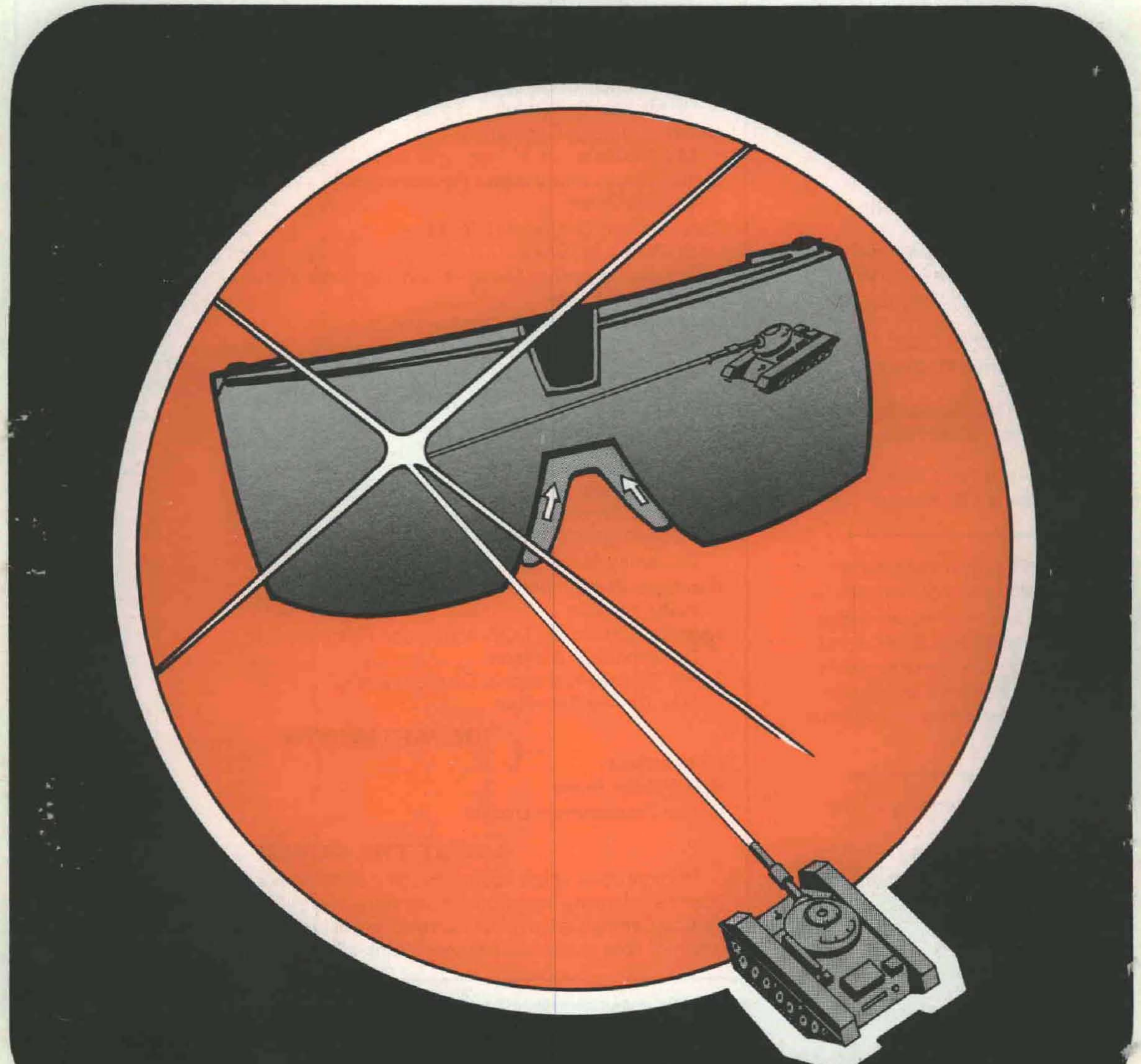

Army Laser Protection Program

ARMY
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RD&A

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FEATURES

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ABOUT THE COVER

The front cover article addresses some of the Army's efforts to protect soldiers from the potentially hazardous effects of low-energy lasers. The Infantry Fighting Vehicle Composite Hull shown on back cover is related to an article on the field repair of fiber-reinforced polymer matrix composite materials.

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THE ARMY LASER PROTECTION PROGRAM

Protecting Combat Soldiers from Potential Hazards of Laser-Inflicted Eye Injuries

By Dr. John H. Brand and MAJ Tony L. Dedmond

Introduction

Low-energy lasers used as target designators and rangefinders are the target acquisition system aids of today's battlefield, and their applications are growing in number. However, these lasers are currently a threat to soldiers, optics, and electro-optics. Laser protection is now, and will continue to be, a major survivability issue in weapons development.

Lasers in War

The laser was invented in 1960 and since then has been proliferated. In recent years the laser has found a place on the modern battlefield. The number of lasers being used by the world's armed forces is estimated to be in the tens of thousands. The principal military uses of lasers are in fire control systems — either as rangefinders or as target designators. These lasers can also dazzle sensors or blind soldiers at short ranges or at longer ranges, if viewed through magnifying optics, such as binoculars or tank sights. The great utility of lasers in combat is their instantaneous effect after trigger pull (laser beams travel at the speed of light) and their very small beam spread. The same attributes that make the laser useful in combat, as a weapon, cause major safety concerns in training.

What Is a Laser?

The laser was invented before most of the soldiers and some of the leaders in today's Army were born. When most people think of lasers they think Star Wars (Luke Skywalkers' light saber) or Star Trek ("Phasers to stun, Spock!"). That concept of a laser is not accurate. A laser is merely a device that transforms chemical or electrical energy into a precisely controllable beam of light. Laser is an acronym for Light Amplification by the Stimulated Emission of Radiation. Lasers have been built that use gas as the light amplifying medium,

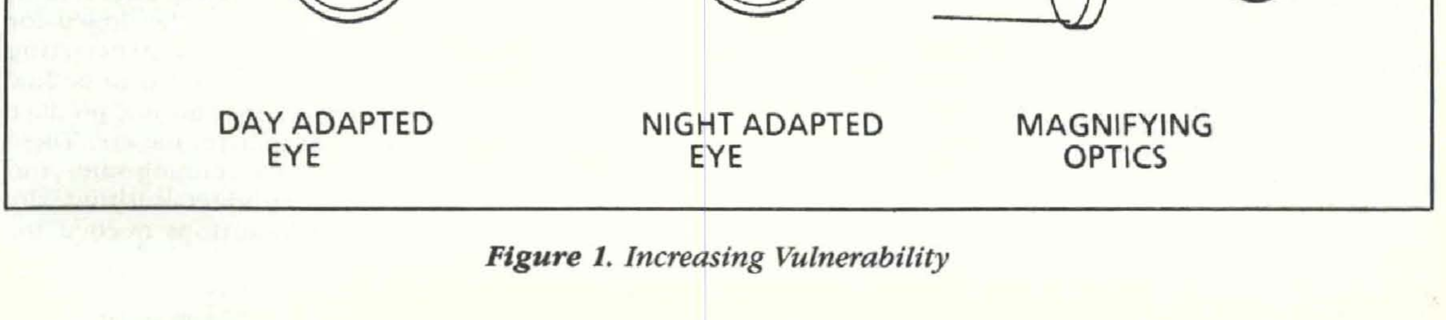


***Figure 1.** Increasing Vulnerability*

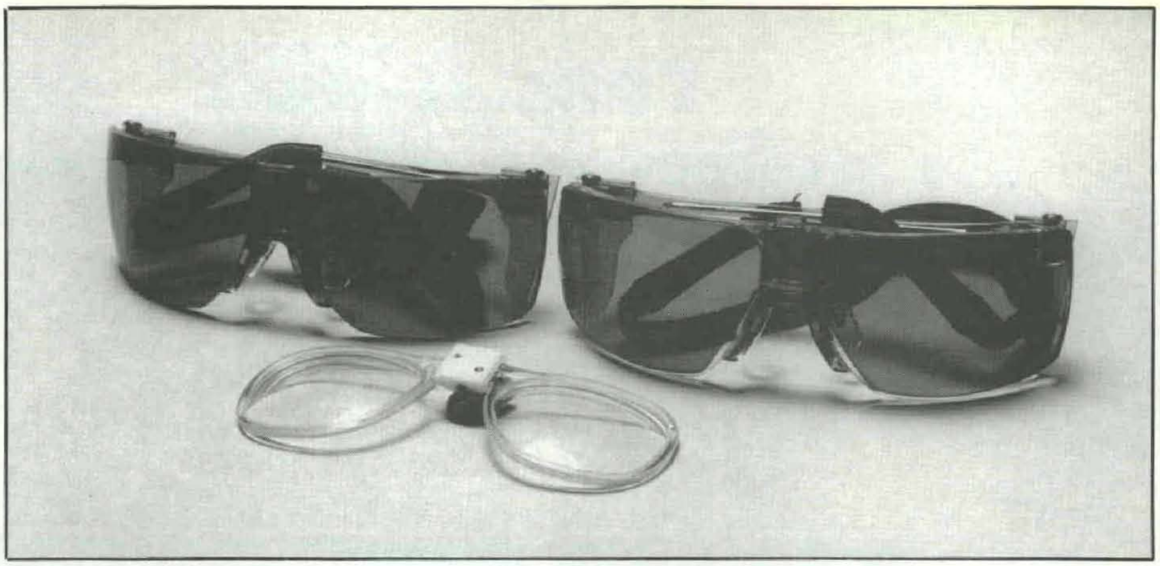


Figure 2. Ballistic and Laser Protective Spectacles. *The spectacles on the left are ballistic sunglasses only, not laser protected spectacles. The spectacles on the right are clear ballistic spectacles with the clip-on laser filter. The corrective lenses are in the center. They clip inside either the clear or sunglass spectacles.*

others use crystals or glasses, and some playful physicists have even built a laser using a popular gelatin dessert!

Some lasers produce a great deal of light, but most military lasers actually produce very little average light power. For instance, a laser designator powerful enough to cause severe eye injury at a few hundred meters actually produces only about two watts of usable light power — about one third as much as a child's night light. Other lasers can weld or cut hard metals, and some, such as the ones under consideration for the Strategic Defense Initiative (SDI) can melt holes in rockets at great distances. The SDI lasers are anything but portable, so we will concentrate on why a comparatively weak and relatively lightweight device, such as a laser rangefinder, can cause injury.

A typical military laser consists of a mechanism for transforming electrical power into light energy, storing and transforming it into an extremely intense pulse of light only a few billionths of second long, and an extremely precise optical system to direct the pulse to the distant point.

The pulse of light, when it arrives at a target several kilometers away, makes a very bright spot. Once the light comes out of the laser, the turbulent, dusty, smoky battlefield atmosphere has the effect of weakening the beam and spreading it out until the spot is a meter or so in diameter when it reaches the target. If your eye happens to be looking directly at a laser beam when the beam hits (intrabeam viewing), the light is concentrated into a small spot on the lightsensitive inner surface of the eye (the retina), and eye injury may occur.

If the eye is adapted to night conditions with the pupil expanded to gather as much light as possible, the eye is more susceptible to injury than it is in the daylight. If the soldier is using a telescope to see better, the telescope will gather and concentrate still more light into the eye, making the eye injury problem much worse (see Figure 1).

Laser Eye Injury

If the laser emits visible light, the victim will see an extremely intense flash of colored light. The flash can be so intense that it leaves an after-image, just like the image left when a flash camera goes off close to one's face. The after-image can persist for seconds or minutes, rendering the soldier temporarily blinded. This temporary or "flash" blinding can occur with no permanent injury whatsoever. The problem in combat may not be the temporary loss of vision itself, but the inability to perform key tasks for those lost seconds or minutes. Good examples are pilots flying nap-of-the-earth who cannot see for 15 seconds, and tank gunners who may not be able to see well enough to defend themselves against the opposing force.

Some eye injuries last longer and cause more damage, in a manner very similar to a sunburn on the arm. Sometimes healing of the retina is complete and no scars remain. At other times, the healing may be complete but the lesions might cause very minor blind spots that are not noticed by the injured soldier. If more energy gets into the eye, a permanent burn may occur on the retina, and the blindspot may be large enough to be noticeable. Since the retina does not have pain sensors, the only way to notice laser injury is by the loss of vision. Laser eye surgeons report that patients undergoing laser surgery on the retina may report a sensation, but the sensation is not pain.

If enough energy gets into the eye, a small hole can be burned through the back of the retina into the blood vessels that supply the retina, leading to bleeding inside the eye. These injuries may heal in time, and doctors are developing new ways to treat them. People almost never completely lose their vision from this type of injury, but a soldier would be combat-ineffective for a period and would suffer some permanent vision loss.

Certain types of lasers produce light that is absorbed in the outer layer of the eye, producing an immediate intense pain and damage that may take a long time to heal. These lasers create beams of light that are invisible. An example of this type of laser is the carbon dioxide laser. The carbon dioxide lasers being developed for use as smoke and fog penetrating rangefinders are intended to be low power devices that do not produce enough light to harm the eye. These lasers will make training safer and possible to conduct without the extensive precautions needed for existing systems.

The new "eye-safe" laser rangefinders will not harm troops, but larger versions of the same kind of laser could. These larger lasers are cumbersome; but, if anyone can identify a military advantage in their use, they are commercially available. Fortunately, even glass or plastic eyeglasses, visors, or sun, wind, and dust goggles completely block light from carbon dioxide lasers.

The physical effect of eye injuries on individual soldiers can be devastating, but the psychological effects may be even greater. If a combat vehicle crew member is blinded while using an optical sight, another soldier will hesitate to use the same device. This may give the enemy the time to destroy both vehicle and crew. The fear can be fueled by ignorance or reduced with training and information about available protective measures.

Training

A considerable amount of training material on lasers is now available: the Army schools have several videotapes available, a Training and Doctrine Command (TRADOC) Special Text, and documents produced by various agencies. Some of the materials available include:

A Combined Arms Training Activity Special Text 1-1, Directed Energy Warfare Awareness Training, Nov. 25, 1987; an Armor School videotape, "Directed Energy Awarness Training," AO515-87-006; videotape 707533 DA TF (VT) 8-6379, "B-LPS. . . For Your Eyes," produced by Walter Reed Army Institute of Research and distributed by Tobyhanna Army Depot; and a Navy videotape "Lasers in Military Operations," Part I, program 803562DN. The Navy tape is primarily oriented to a fixed wing aircrew and is available from the U.S. Army Audiovisual Information Center, Tobyhanna Army Depot.

In addition to the various training materials listed above, there are common sense solutions that can be used by soldiers to prevent or reduce their susceptibility to eye injury. These include treating lasers like any other direct fire weapon — do not point lasers at fellow soldiers or look into lasers being pointed by fellow soldiers. Always assume that the laser is in operation and dangerous.

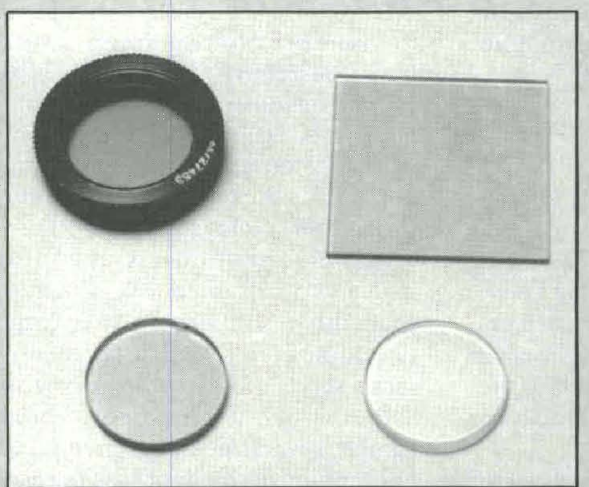
TYPES OF LASER FILTERS

Materiel solutions to laser survivability involve various types of light filters. Filters are familiar to everyone who owns a pair of sunglasses. Most sunglasses block light of all colors almost equally well, rather than making the world look colored. Sunglasses provide little real protection to lasers. Laser filters, however, are designed to allow as much light as possible to pass through — except the color that includes the laser light. Fortunately, filter technology for scientific and industrial users is so well developed that there are many filters available.

The usefulness of the laser in industry is such that an enormous array of protective and control measures are standard engineering art. There are only a few basic filter types in wide use, however, and only some of those are rugged or versatile enough to be used in military systems (see Figure).

The most widely used filter for military applications is the absorption filter. It works by absorbing a large amount of light at some color. It may be made of glass or plastic and may be any color. An example is the clip-on laser filter issued with the laser rangefinder on the M60A3 (see Figure, top left). It is a blue green glass that absorbs the red light from ruby lasers (such as the M60A3 rangefinder) or the invisible near-infrared light from lasers such as the neodymium doped yttrium aluminum garnet (ND: YAG) rangefinders on the M-1 series tanks. Of course, it will protect only if it is used. If it has been lost or the gunner does not wish to view the world through a blue glass, he must be willing to accept the risk of catastrophic eye damage in return. These filters are similar to commercial laser goggles the Army issues for laser eye protection where extremely high levels of protection are needed. A commercial absorption filter is also shown (Figure, top right).

Another filter type is the interference filter. The interference filter works by the same general principles that produce the rainbow from a film of oil on water. An interference filter reflects light of a given very narrow range of colors that includes the target laser color. The filter will look like a colored mirror that changes colors depending on the angle at which the light strikes it. These filters are also called dichroic mirrors. The advantage of this filter is that it only reflects a little of the light you need to see with, but nearly all the undesirable light. The disadvantage is that if the light strikes the filter too far off its design angle, most of the laser light goes on through. Interference filters are often used as coatings applied to absorption filters (see Figure, bottom items). The combination is primarily used in optical systems, where the angle at which the light hits the filter is controlled.



On the top, left to right, an M60A3 clip-on filter and a commercial absorption filter are shown. Shown on the bottom are two Optical Improvement Program filters.

When performing reconnaissance of a laser-equipped foe, always check the area out first with the naked eye before using magnifying optics. Use Forward Looking Infra Red (FLIR) or image intensifier (night vision goggles) devices whenever possible — these devices will intercept the light and prevent eye injury. *Do not* rely on sunglasses. Good ones will block about 90 percent of all light, including the light from most lasers. This reduction may give soldiers an edge — but usually not enough to prevent some degree of injury. In contrast, laser protective goggles are not usually considered useful unless they block 99.99 percent or more of the light from the laser they were designed to protect against — but unfortunately they usually do not block much of the light from other lasers.

As mentioned previously, most kinds of lasers that can attack the outer layer of the eye are blocked by ordinary clear glass or plastic. Every other kind of laser produces light that goes right through ordinary glasses and visors.

These tips can be complemented by sound use of laser protected equipment.

Army Protective Measures

The Army began a program in 1984 at the direction of the vice chief of staff and the under secretary of the Army to protect soldiers and crew members from the effects of low energy lasers. This program, the Optical Improvement Program, addressed the problem of soldier eye injury when using direct view optics. Direct view optics can be magnifying or unity gain, and are most often used in the front-line area of the battlefield.

The Optical Improvement Program is resulting in the fielding of major Army tactical systems with optical devices that are protected against the lasers in common military use today. These optical systems contain filters that are extremely efficient against lasers. Sometimes benefits in addition to protection are gained; the new binoculars not only have laser filters, but they are less expensive than the binoculars they replace.

Concern continues to grow about the laser hazard. Increasing reports have surfaced about lasers being used against our ships and aircraft by Eastern Bloc countries (*Soviet Military Power*, 1987, pp. 112-113).

Protection has long been provided by off-the-shelf commercial goggles designed for laboratory and laser range safety. These commercial goggles interfere with vision too much to be used as tactical protection devices. The Army needed something better for field use. This requirement led to development of a protective spectacle that lessens the chances of injuries to the eye from lasers and from most shell fragments and debris. These problems were solved when the surgeon general and the project manager for clothing and individual equipment, Army Materiel Command, began fielding Ballistic and Laser Protective Spectacles (BLPS) to the Army and Marine Corps last year.

The Army is now issuing the BLPS to soldiers in high priority units. The BLPS are intended to be worn by individual soldiers day and night in both training and combat. When worn, the BLPS will provide the same high level of fragment protection afforded by the ballistic lens developed for the standard sun, wind, and dust goggles ("Rommel Goggles"). The polycarbonate ballistic lens reduces the probability of eye injury from fragments by around 50 percent.

In training and maintenance situations, the BLPS are effective as safety glasses and could prevent many of the eye injuries that occur each year. The key is they ***must be worn*** to be useful, and the Army has attempted to make that as easy as possible.

Steps have been taken with the BLPS to ensure that prescription glass wearers have a corrective insert which clips to the main ballistic protection frame. A laser filter against the most common laser designators and rangefinders clips on as an outsert to the ballistic protection frame (see Figure 2).

Aviators can afford less visual disturbance and can tolerate less light loss than other soldiers, so the Army is developing jointly with the other services a series of laser-protective visors. These visors will be used to protect against several possible enemy lasers and minimize the light loss necessary to provide this protection. Different visors will be used during day and night operations, to maximize protection during both periods.

As a general rule, the most effective protection for the eye from lasers is a night vision system. The system may be destroyed or damaged by powerful lasers, but the eye itself will be safe. Most image intensifiers (night vision goggles and "starlight scopes") also can detect the presence of most visible and near IR lasers, allowing soldiers to engage the laser itself as a target.

Most battlefield lasers are either determining the range for a tank main gun or artillery or designating for a guided missile soon to follow. In both cases, only a few seconds are available to cope with the munition or the gunner. These few seconds are provided when the above protective measures are used.

Another family of lasers exists which cannot damage eyes at tactical ranges, but can shine into thermal night sights and "white out" displays or cause sensor damage. As a result, the Army is fielding thermal night sights with a filter wheel that will prevent this particular laser from harming the FLIR and allow the gunner time to engage the laser and eliminate the source of the jamming.

Both the Optical Improvement Program and the Ballistic and Laser Protective Spectacles are extremely effective against the lasers being used today. To address where laser technology is headed, a new research program, the Advanced Laser Protection Program, has been initiated to develop protection against the hazards which may appear tomorrow.

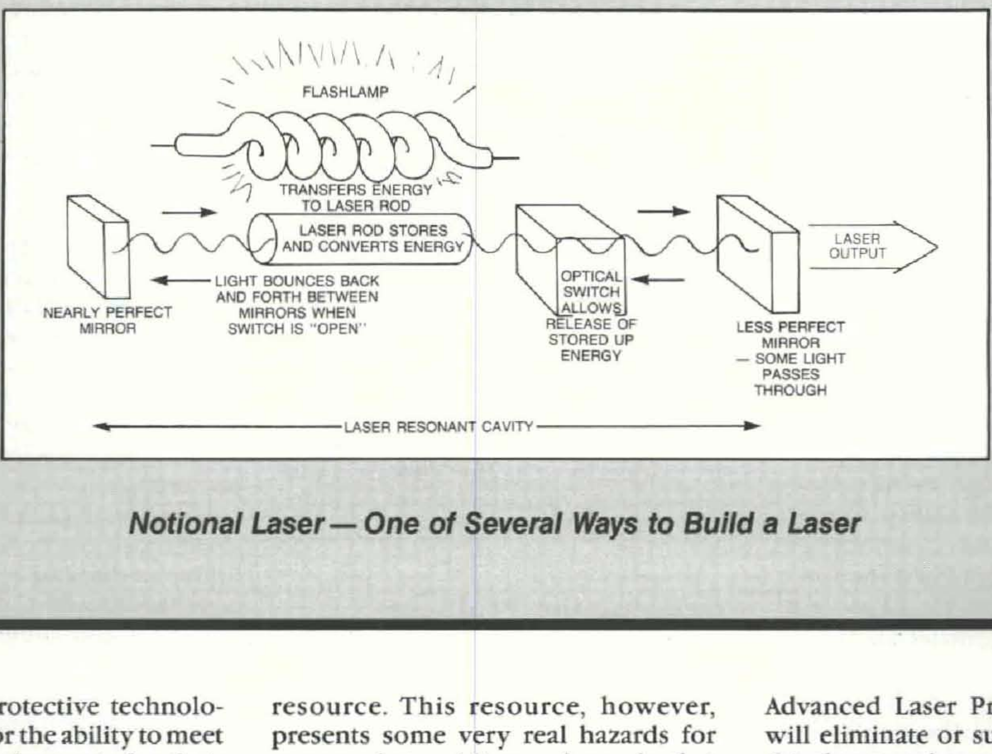
Future Laser Protection

Any laser eye protection can be defeated, given enough effort and money. The way to defeat a given laser protection device is to use light of a different "color" or to build a more powerful laser. There are now several very promising approaches to future laser protection which will not be dependent on either color or power. The Army is working in a joint cooperative program with the Defense Advanced Research Projects Agency and the other services to develop these advanced laser protection techniques.

This effort, part of the Advanced Laser Protection Program, is a five year

Inside a Laser

A typical military laser consists of a flashlamp similar to the electronic flash unit in a camera, a crystal or glass rod to store the light energy from the flashlamp and release the energy in the desired form, and a very precise optical system to get the light out of the laser. One part of the system is an optical container called a resonant cavity, with an optical switch. The laser rod sits in the resonant cavity. The switch is like a door that allows the light to pass through only when the controlling electronics are turned on. The resonant cavity allows the light to bounce back and forth until most of the stored energy from the laser rod is turned into a very intense beam of light of a single color. This requires many passes back and forth inside the cavity. At some point the light is dumped out of the cavity and into a telescope like arrangement which directs the light into a very narrow "rod" of light a few meters long. Thus, the light energy is very concentrated — the laser only shines for a few billionths of a second — and is very precisely directed. A great deal of light comes out of the laser at one time, and it does not spread out very much as it travels through space on its way to the target (see Figure).



Notional Laser — One of Several Ways to Build a Laser

plan to identify protective technologies, screen them for the ability to meet the protection requirements for their intended applications, and incorporate the best into proof-of-principle demonstrators. The focus is on developing and evaluating promising concepts, discarding ideas that cannot be of use in the near future, shifting resources into the successful concepts, and incorporating those concepts that can meet the protection requirements into testable hardware.

Summary

The laser obviously offers great potential as a future battlefield resource. This resource, however, presents some very real hazards for our combat soldiers — hazards that must be addressed. Hopefully, the Advanced Laser Protection Program will eliminate or substantially reduce this threat and provide the protection our troops deserve.

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MAJ TONY L. DEDMOND is a 1972 graduate of the U.S. Military Academy and is assigned to the Survivability Management Office of the U.S. Army Laboratory Command where he has been the focal point for the Army Laser Protection Program for the past four years.

Planning for the Future...

FIELD REPAIR OF COMPOSITE MATERIALS IN ARMY SERVICE

By Dr. Michael S. Sennett

Recently, an Air Force F-16 fighter required a minor repair to the tail section. Before the repair could be completed, several layers of paint had to be removed, requiring 225 man-hours of hand sanding. The reason? The tail is made of a fiber-reinforced composite material and traditional paint stripping methods cannot be used on it.

This episode illustrates the kind of problems that arise when new materials are put into service without adequate consideration for how they will be maintained in the field.

Fiber-reinforced polymer matrix composite materials are being increasingly employed in military vehicles and hardware, and have become key to the Army's drive to lighten the force. The rapid development of systems utilizing composite materials has, to some extent, outpaced the development of technology for the maintenance and repair of these materials. This threatens the readiness and maintainability of systems that contain composite materials and, as such, is an issue of vital importance.

Field repair of composites is a subtopic of the overall issue of composite repair. Composite field repair is not a well defined term, at least in Army usage, and this is true in part because the Army has very little composite material currently in service. The major critical use of composites is in components of helicopters, most notably rotor blades on certain models, and these structures are not readily repaired in a field environment.

As the lead laboratory for harnessing new materials technology for the Army, the U.S. Army Materials Technology Laboratory (MTL) is developing prototype systems incorporating composite materials such as the Infantry Fighting Vehicle composite turret and hull. This underscores the pressing need for an expanded awareness of and capability for field repair of composites within the Army. The objectives of this article are to identify the Army's needs in this critical area of materials technology and to recommend ways to meet them.

Defining the Problem

The definition of field repair varies greatly, depending upon the system or vehicle being addressed and the conditions under which it is used and serviced. To the Air Force, field repair means servicing an aircraft at a forward air base, complete with hangars, repair shops, electricity, material storage facilities and trained technicians. Similarly, Naval field repair is primarily the maintenance and repair of aircraft on aircraft carriers. While slightly more restrictive than the Air Force environment, many facilities are available to the personnel performing the repairs.

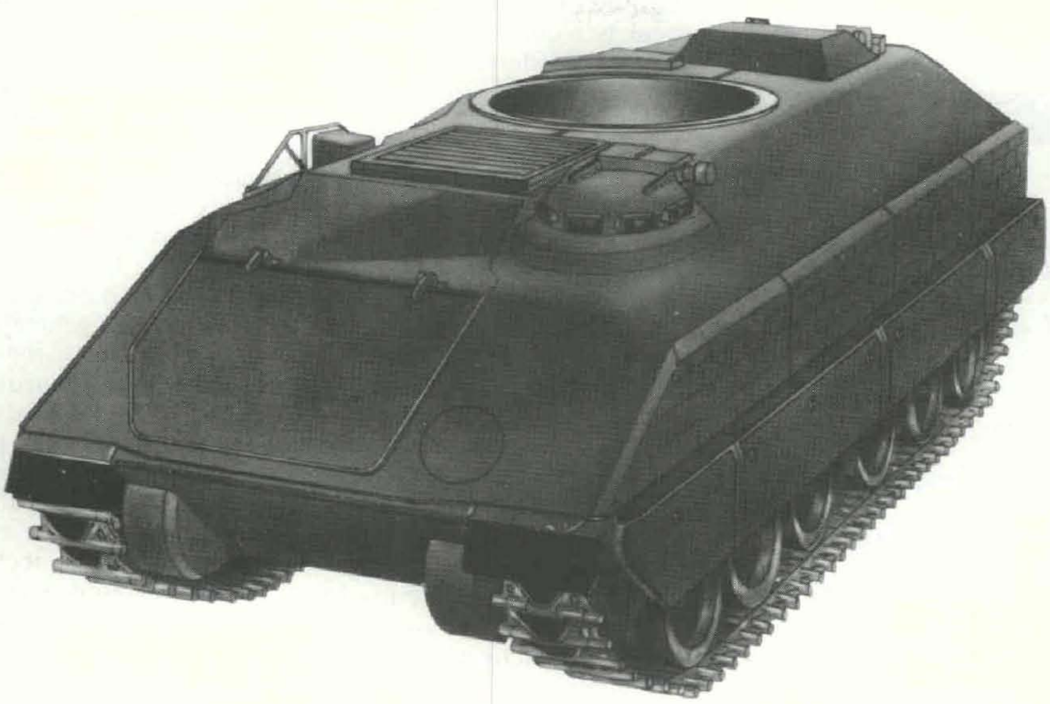
In Army applications, field repair may be expected to have a much more literal meaning, especially for ground vehicles employing composite armor. In the Army field environment, extensive facilities will not be available for fabricating repairs. This sets very stringent requirements for any proposed repair technique. The Army may also be expected to employ composite materials in a much wider variety of applications than the other services, which deal mainly with composites on fixed wing aircraft.

Potential Army applications include hardened attack tactical shelters, howitzers, cargo containers, tactical structures (lightweight bridging), armor and structural components of ground vehicles and aircraft. Each of these applications may impose unique requirements on repair processes and materials.

The Army requirement for composite field repair can be defined as the level of repair that can be performed by the vehicle or system crew using only the materials and equipment that can be carried along while performing their mission. The repair must allow continuation of the mission or at least allow evacuation of the vehicle or system to a rear area.

The issues that must be addressed in developing a strategy for field repair of composites in Army materiel are materials, expertise, equipment and system design.

- Materials: What adhesives or structural materials are currently available? What storage stability may be expected under wide ranging conditions of temperature and humidity? What are the properties (service limits) of the finished repair (and what is actually required)? What hazards (toxicity or others) are associated with a given material?



Composite IFV Hull Technology Demonstrator

The MTL Composite Hull Technology Demonstration is proving the feasibility of molding a hull of advanced thick composite (reinforced plastic) which can be used in an armored combat vehicle that meets the severe ballistic and structural performance requirements with lighter weight. Referenced to metal hulls, benefits are:

- 25% WEIGHT REDUCTION in full structure and armor weight, equal ballistics
- ENHANCED CREW SURVIVABILITY - No spall (metal fragment projectiles); improved resistance to Mine Blast and Reactive Armor Detonation.
- NOISE AND VIBRATION REDUCED BY 5-10 DB in crew compartment
- REDUCED MANUFACTURING COSTS - Estimated 20% lower cost of fabricating hull structure, because molding large sections reduces machining/joining
- REDUCED LIFE CYCLE COSTS from increased fatigue strength and elimination of corrosion and weld problems in metal hulls

The next generation of fighting vehicles will require protection from increased ballistic threats, which translates to increases in gross vehicle weight. This materials technology can minimize weight growth while meeting required protection.

The Army would benefit from establishing a central organization similar to those of the other services, responsible for coordinating composite repair R&D within the Army and with the Air Force and Navy.

• Expertise: How sensitive is the repair technique to the level of expertise of the personnel performing the repair?

• Equipment: What specialized equipment is required to perform a given repair procedure? What are the power requirements of the proposed technique?

• System Design: Can the structure of the vehicle or system in question be adequately restored to service using techniques and materials available to field personnel?

Ideally, a single material or kit could effectively repair all composite materials in Army service and restore the system to near original levels of performance with a minimum of expertise required to apply the repair. The materials making up this kit would have a storage stability of at least one year at temperatures up to 100 degrees Fahrenheit.

Unfortunately, materials currently used for composite repair are usually system specific, require a high level of training to apply properly, are sensitive to storage conditions and restore only a fraction of the system's original performance. They are typically not adaptable to composite field repair as it is defined here.

DOD Programs

Each branch of the military addresses the issue of composite repair independently. Both formal and informal avenues for information exchange between the services exist, but no one agency oversees these programs for all of DOD.

The Navy and Air Force both have well developed composite repair programs that include field repair as it is defined by these services. These efforts were born of necessity, as both services have significant amounts of composite material in critical applications on fielded systems.

The Navy and Air Force composite repair R&D efforts are centralized at specific laboratories (Naval Air Development Center, Warminster, PA, and Wright Aeronautical Laboratories, Dayton, OH) that interact with the logistics activities that put the technology into practice (Naval Air Depots and Air Logistics Centers). R&D activities are also carried out at the depots and the central laboratory helps ensure adequate communication between all the organizations involved.

The Navy and Air Force R&D programs are large and dierse. All aspects of composite repair are being addressed, including non-destructive inspection of damaged parts, development of repair methods for specific structures and types of damage, adhesive development, and training of maintenance personnel.

In contrast to the other services, the Army has no centralized approach to composite field repair. Field repair technology is being developed on an ad-hoc basis, generally as low level adjunct projects to the development of specific systems. Furthermore, there is very little composite field repair development work being done by Army research facilities. These observations refer specifically to field repair and not to higher level repair or remanufacturing techniques which tend to be somewhat better defined and therefore more easily addressed.

Requirements and Recommendations

The Army now uses or is in the process of developing major systems utilizing fiber-reinforced polymer matrix composite materials in the following areas: aviation (helicopters); armor (Infantry Fighting Vehicles); shelters (hardened attack tactical shelters); personnel protection (Kevlar helmet, vest); artillery (howitzer carriage); ground vehicles (truck bodies); and tactical structures (lightweight bridging). Except for aviation, none of these systems' field repair requirements are being directly addressed by R&D programs outside the Army. Unfortunately, these requirements are also not being adequately addressed within the Army.

The Air Force and Navy composite repair programs are mainly directed at depot level processes and do not directly address field repair in Army terms. In spite of this, their repair needs sometimes overlap with the Army's, particularly in the area of materials.

Virtually all repair strategies for composite materials involve adhesive bonding, and the stability and performance requirements for the adhesives used are quite similar from one application to another. The Navy and the Air Force have ongoing programs to develop such materials, and the results should be valuable to the Army. Although less applicable to Army field repair requirements, some of the specific repair techniques and equipment developed by the other services could conceivably be adapted to Army applications.

The Army would benefit from establishing a central organization similar to those of the other services, responsible for coordinating composite repair R&D within the Army and with the Air Force and Navy. The principal benefit of centralization is efficiency.

Currently, individual commodity commands are responsible for developing general field repair (or battle damage repair) technology for Army systems. This decentralized approach has the advantage of allowing the organization most familiar with a given system to address its repair needs. However, this setup undoubtedly results in the re-invention of various generic repair techniques by several organizations. In addition, one organization or another may not acquire the best solution to a given repair problem if communication between the commands is insufficient.

A central composites repair organization could be expected to work with the commands to meet their needs and would ensure that all Army users of composite materials have access to the same level of repair technology. This organization would have several tasks.

First, it would need to define repair requirements. For each vehicle or system, a requirement for repairability of the composite components must be set. It must detail the most demanding conditions under which a repair will have to be performed and the minimum performance that the repaired item will be expected to deliver. This set of standards will be governed in most cases by the materials and equipment that can be made available to do the job. These standards would have to be determined in cooperation with the commodity command responsible for the system in question.

A set of repairability goals should be set also, to provide a target for R&D efforts to improve the repairability of the system. The standards should be updated periodically to take advantage of new technology as it becomes available.

Because most Army systems that promise to incorporate large amounts of composite material are still in development, their designs can be modified to ensure that the structures are repairable.

The Army also needs to develop an active and ongoing technology capture/transfer function to acquire existing composite repair technology in an efficient manner and to keep abreast of continuing developments in the other services and in industry. This same organization could perform the R&D functions required to evaluate the potential of technology developed elsewhere to meet Army needs. They would then transfer the technology to the commodity commands for implementation.

Because most Army systems that promise to incorporate large amounts of composite material are sill in development, their designs can be modified to ensure that the structures are repairable. This may mean building in structural redundancy or configuring main structural elements of composite components so that damage and subsequent repair are anticipated and provided for.

This burden should fall squarely on the contractors designing and manufacturing Army materiel, and this goal should be aggressively pursued by procurement officials throughout the Army. Manufacturers should demonstrate repairability and include the complete specification of materials, equipment and techniques, along with experimental data to authenticate the repair strategies.

The composite repair organization could be consulted by the procuring organization to provide expert advice and facilities to evaluate contractors' proposed repair techniques. (One of the Naval air depots is now performing this function for repair techniques proposed by Grumman Corp. for the V-22 VTOL aircraft).

Finally, the proposed composite repair organization would be expected to carry out R&D efforts directed at Army specific systems, to develop repair techniques where none exist, and to advance the state of the art of existing techniques.

Conclusions

The Army does not have a systematic approach to the problem of field repair of fiber-reinforced polymer matrix composite materials, and would benefit by having a central organization to deal with the issue. The need to develop such a capability is critical, since neglect of this area may lead to reduced performance and loss of readiness in Army systems. The time to act is now, before the lack of composite field repair expertise impacts operational capabilities.

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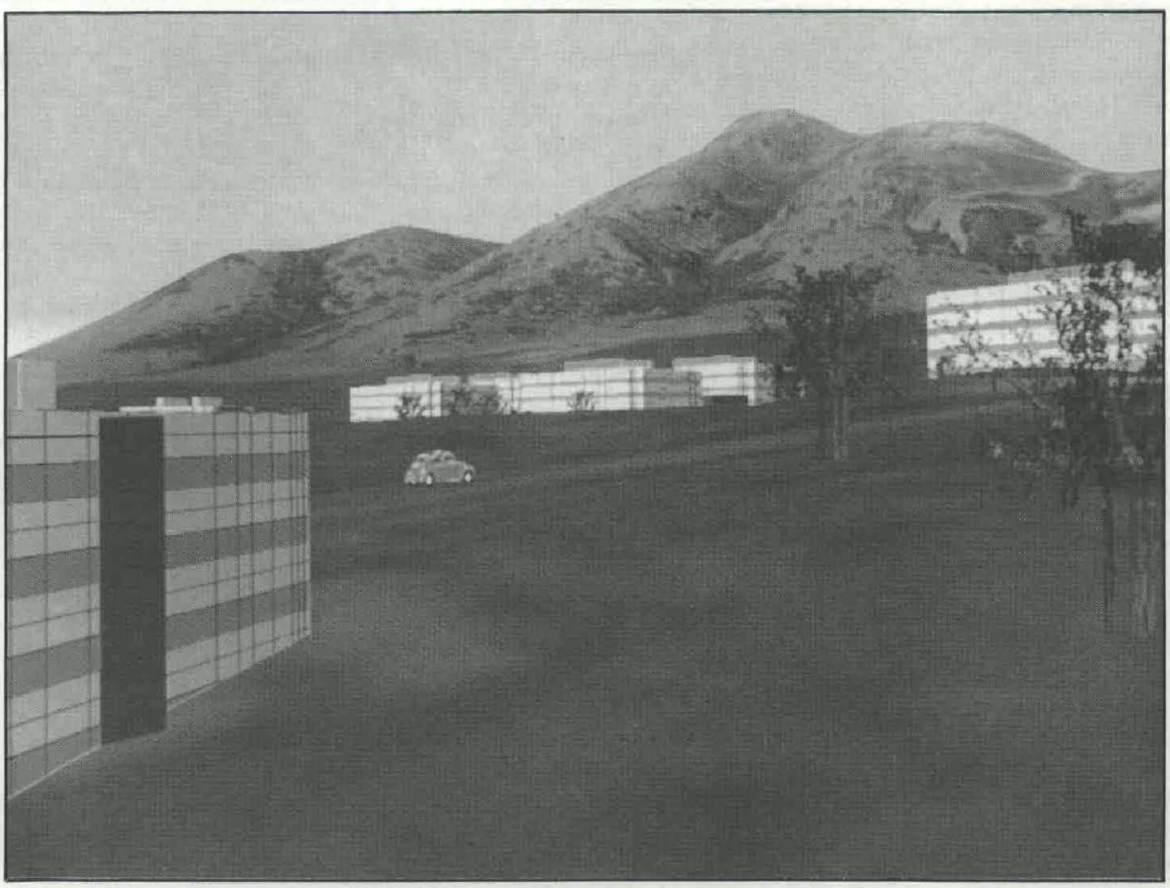
COMPUTER IMAGE GENERATION

By Mark K. Ross

Being a commander on a modern battlefield means making quick decisions in a complicated and chaotic environment. Currently, to assist in making those decisions, commanders use two-dimensional maps covered with numerous mylar overlays. The lines, grids and symbols on these maps take time and skill to interpret.

Now picture the commander sitting down to a computer monitor. On the screen is a realistic, three-dimensional depiction of the battlefield terrain. There are trees that look like trees, roads that look like roads and buildings that look like buildings.

Using joysticks, the commander can "fly" through these scenes. He can go high up to get a bird's-eye view of the scene, or move down to get a close-up look at the terrain. The scenes can show both the position of his troops and the known locations of the enemy. In addition to showing all the traditional data from map overlays — like obstacles, vegetation and roadways — environmental conditions like fog, smoke, haze and snow are shown.



This CIG image, of a site near Denver, CO, was made by using aerial imagery draped over a U.S. Geological Survey Digital Elevation Model. The buildings, trees and vehicle are 3-D solid models that were added separately.

Making this scenario a reality is one of the goals of the Computer Image Generation (CIG) project at the U.S. Army Engineer Topographic Laboratories (USAETL), Fort Belvoir, VA. "What we're trying to do for the Army is allow the battlefield commander to see and understand the complex battlefield environment," said Leila Herrmann, CIG project engineer.

USAETL is developing CIG capabilities for various military tasks, such as mission planning, battlefield management and training.

According to Laslo Greczy, chief of USAETL's Display Technology Branch, CIG can be seen as a sophisticated 3-D graphic processor. "Instead of generating 2-D overlays that go on a standard 2-D topographic map, there are 3-D scenes with all the mobility, environmental effects and intelligence information built into the scene," Greczy said.

With these 3-D scenes, the commander can "fly" or "drive" through the model to make his assessments. "They will look realistic, so he won't have to do the interpretation one has to do when using graphic overlays and paper maps," Greczy said.

These images are different from the video arcade machines which give the appearance of 3-D fly throughs. CIG uses real data of the terrain — real images, not imaginary ones.

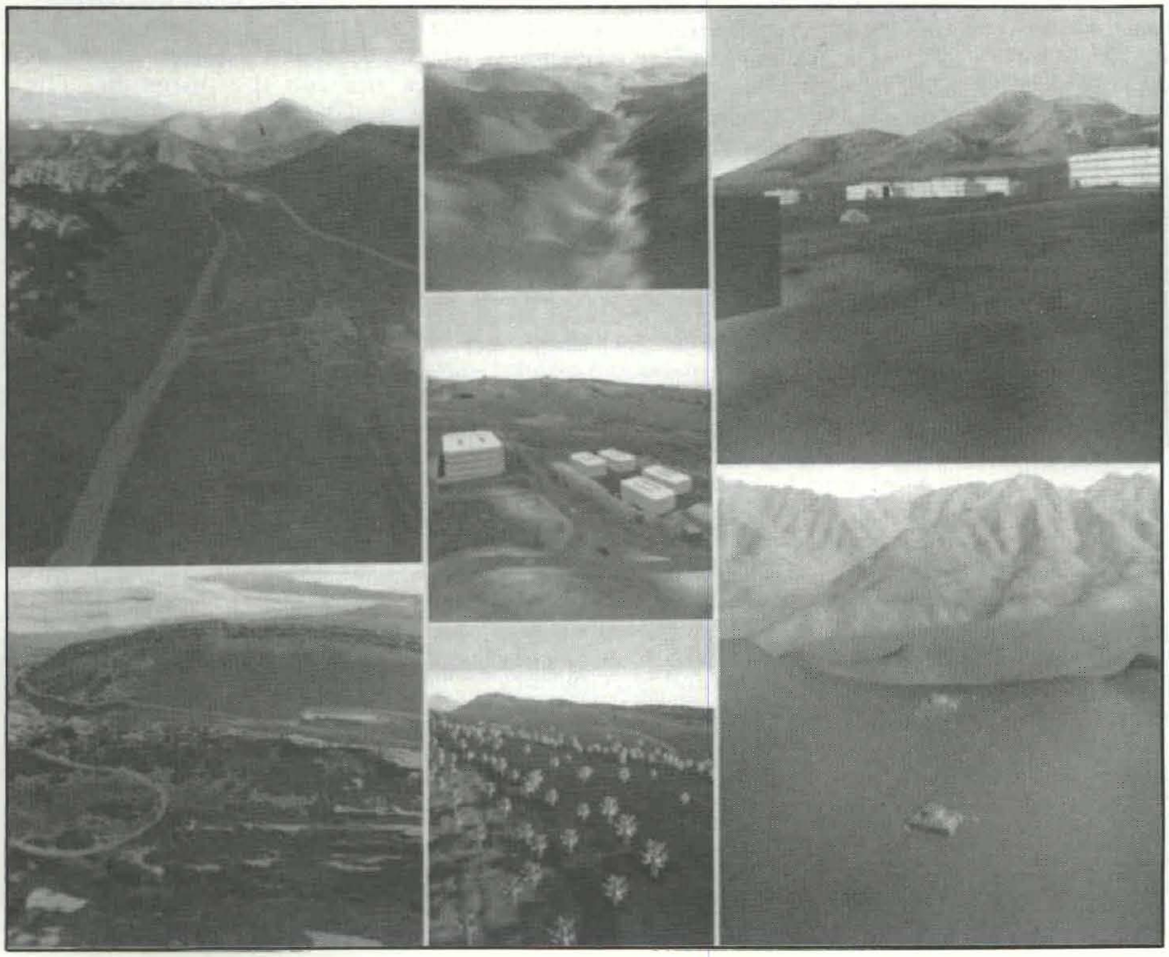
CIG isn't conceived of as a standalone capability, but one which will be incorporated into other Army developmental programs. One likely system is USAETL's Digital Topographic Support System (DTSS). DTSS is being designed to generate and manipulate digital topographic products in the field. Presently, the CIG and DTSS developers are working to come up with specific functional requirements for CIG in the DTSS.

"In a sense, the same generic scene-generation capabilities that apply to the DTSS could apply to other future systems; though, the systems might use CIG differently," Greczy said. He explained that one system might focus more toward the intelligence assets, while another might be more interested in how individual units will maneuver in the field. "The scene generation process will be the same, but it will be tailored for the systems' applications."

Work on the CIG program began in the early 1980s. That is when the Defense Advanced Research Projects Agency (DARPA) initiated an early concept development contract to Boeing Aerospace to develop depth buffer algorithms. This is a technique for determining how much of an object in a computer scene is visible from a particular viewpoint.

Based on that early work, DARPA, assisted by USAETL, continued with a second phase of the contract with Boeing to implement the depth buffer algorithms into a software system as a proof of concept. That contract was concluded in 1984.

DARPA awarded a development contract to Boeing for developing three visual scene generation systems in December 1984. In September 1987, a software system was delivered to USAETL, now a co-sponsor of the CIG project along with the U.S. Army Missile Command (MICOM), Redstone Arsenal, AL. The software system permits generation of images strictly in a



This is a montage of CIG images created using U.S. Geological Survey Digital Elevation Models and Landsat data. The trees, buildings, and vehicles are 3-D models which were added.

software environment. Each image takes anywhere from three to 15 minutes to generate.

The other two systems delivered as a result of the Boeing contract were two real-time visual systems — one to USAETL and one to MICOM. Both were delivered in January 1989. "Basically, the real-time visual systems do the same thing the USAETL software system does, except they do it in the hardware and are capable of generating images at up to 30 frames per second," Greczy said.

"So, instead of taking from three to 15 minutes to generate an image, as the software system does, the real-time hardware takes the same data base and generates it as fast as a 30th of a second," Greczy said. This capability allows the operator to use joysticks to simulate "flying" or "driving" through the data base exactly as if in an aircraft or a tank.

The visual realism that is depicted in those images is dependent to a large degree on what is used to construct the data base. A variety of different types of data can be used to make CIG data bases.

Elevation data, like Defense Mapping Agency (DMA) Digital Terrain Elevation Data, can be used to create a simple 3-D representation of the terrain. Various feature data, like DMA Digital Feature Analysis Data; satellite imagery, like Landsat or SPOT imagery; and aerial photography can be added to give more realistic representations.

"One of the more unique characteristics is the versatility in the data base — the types of data sources we can bring in," Herrmann said.

The current configuration of the CIG software system is controlled by a super mini-computer supported by several 300 megabyte disk drives and other standard system peripherals. A digitizing table is directly linked to the system for adding data. Both high- and low-resolution monitors also are part of the system. There are modeling work stations where 3-D solids models can be created from engineering drawings, plans and side views. They can be used to create scale models of various vehicles and other objects to be placed in the scenes.

Along with these components and the software system, there are the three racks of hardware that were delivered in January that make up the real-time visual system. "There are some hardware dependencies in the input/output processes, but the application code is all written in standard Fortran 77," Greczy said.

When fielded with other Army systems, CIG will provide rapid and realistic depictions of the battlefield, including weather, intelligence and maneuver data.

"What basically happens is we develop the CIG data base on the software system using the elevation data, and then we can add feature data or bring in aerial photographs or other imagery. The data base is then converted to the real-time hardware system. Once it's there, you can sit in front of the monitor and use the joysticks to fly right through the area," Greczy said.

The CIG system also is capable of recording images directly onto optical discs and video tapes. This can be valuable as a mission rehearsal tool, giving participants both familiarity with the terrain and training for operations before actual missions.

This technology is being used in the U.S. Army Communications-Electronics Command (CECOM) Sandtable project. The original project plan was to use a huge sandtable model that would have been a representation of the terrain for the VII Corps area of Germany. CECOM wanted to show a layout of various friendly and threat sensors, weapons systems and other intelligence assets on the sandtable. It would have required building a realistic miniature landscape, duplicating the terrain, forests, buildings and other features.

"When they really looked at doing this, they found it was going to be expensive to construct and maintain these terrain boards, and they would be inflexible in terms of being updated," Greczy said.

"Also, in showing it to different people, you can't very well carry a huge sandtable around with you. A video concept came about and grew out of that," Herrmann said.

USAETL demonstrated to CECOM the work they were doing in image generation and some work private companies were doing with video disc map backgrounds. "Between the two concepts, we were able to come up with an approach that will show exactly what they wanted to show, only electronically," Greczy said. "We'll build the VII Corps area the same way as they would with a terrain board, but we'll build it with digital data. Instead of building little miniature models of trees and tanks, we'll build those same models in software and represent them in the CIG scenes."

One of USAETL's major tasks in developing CIG technology is to answer the questions about the Army's CIG requirement — what does the Army need? What level of detail does the commander need? For instance, a helicopter pilot would need much less detailed information than a tank commander, but the area of coverage for the helicopter pilot would be much greater. Does the battlefield commander need the dynamic motion capability in real time that gives the illusion of fluid movement, or will static scenes generated every couple of seconds satisfy his requirement? Working with various program managers and the U.S. Army Training and Doctrine Command, USAETL researchers are working at getting answers to these questions.

USAETL scientists also are working to make the system more userfriendly. Herrmann said the system now requires a technical expert to generate the data bases and run the programs. The amount of detail contained in the CIG scenes correlates to the amount of expertise needed to generate the scenes — the more detail, the more expertise needed. Making the system easier to operate will speed training and make it possible for more operators to use the system.

When fielded with other Army systems, CIG will provide rapid and realistic depictions of the battlefield, including weather, intelligence and maneuver data. Mission planning and rehearsal will be greatly enhanced, and new opportunities for troop training in the computer-simulated battlefield will be available. And USAETL is still only beginning to see the numerous possibilities for using CIG.

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BIOTECHNOLOGY AND VACCINE DEVELOPMENT

Protecting Soldiers from Naturally Occurring Infectious Disease Threats

By Charles Dasey

The latest advances in biotechnology are being used by the U.S. Army Medical Research and Development Command to provide increased protection to soldiers in future deployments and on future battlefields. The new methods promise increased protection from naturally occurring infectious disease threats such as malaria, from septic shock caused by bacterial infection of battlefield wounds, and from biological and chemical weapons used by an adversary.

The Defense Department defines biotechnology as "any technique that uses living organisms or part of organisms to make or modify products, to improve plants, or to develop microorganisms for specific uses." Technologies specifically included in the definition and in military medical research programs are recombinant DNA, hybridomas and monoclonal antibodies, and novel bioprocess techniques.

The Army has long had a major interest in tropical medicine because of the traditional threat of infectious diseases to mobilizing or deploying military forces. Military historians cite Biblical and classical references to outbreaks of infectious diseases crippling armies. Modern armies have the same susceptibility to infectious diseases. During the early stages of the Vietnam conflict, U.S. soldiers suffered malaria at a rate of almost 1,000 new cases per month.

Malaria has had a devastating impact on military campaigns throughout history, and continues to be a major threat to personnel deployed in tropical and subtropical regions. Drug resistance by malaria parasites compounds the problem.

When a mosquito bites a soldier and injects malaria sporozoites into the soldier's blood, they circulate through the blood and reproduce in the liver. From the liver, new parasites are released into the bloodstream, infect red blood cells, and release new parasites (merozoites) from infected cells to attack more blood cells, causing the recurring fever, chills and malaise of malaria.

Researchers at the Walter Reed Army Institute of Research (WRAIR), led by COL Jeffrey Chulay, MC, have targeted the sporozoite stages of Plasmodium falciparum and Plasmodium vivax, the two most serious strains of malaria.

The malaria vaccine team has selected several approaches to the problem of malaria immunization, based on the stages of malaria infection and the life cycle of the parasites.

In 1984, investigators at the WRAIR isolated the gene responsible for producing malaria sporozoite coat (circumsporozoite) proteins. The antigenic coat proteins are the key to stimulating immunity to malaria in the sporozoite stage.

Using synthetic peptide and recombinant DNA methods, highly purified antigens can be produced in large quantities and administered as a vaccine. The DNA segment that codes for the coat protein is detached from the rest of the sporozoite DNA and inserted into the DNA of a common bacterium. As the bacteria grow in culture, they manufacture the coat protein, which can then be separated from its bacterial host, and purified.

The purified protein contains a sequence of peptides (components of proteins) which stimulate the formation, by the soldiers immune system, of antibodies, which neutralize the sporozoites that reach the liver. The sequence of peptides has been tested in both animals and people as a malaria vaccine. One volunteer was totally protected from disease challenge. In other volunteers, the immune response was not sufficient to protect against disease.

After a prototype vaccine was tested in 1987, an improved version was tried in 1988. In 1989, a third candidate has been tested in volunteers, this one incorporating a new adjuvant, or non-specific immune-enhancing additive, with a resulting level of immunity three times higher than the first candidate.

The second target of attack is the parasite as it develops in the liver. Cytotoxic (foreign cell-killing) blood cells that kill developing liver stage parasites are of primary importance at this point. Stimulation of this kind of immunity requires a different kind of vaccination.

Investigators at the WRAIR showed that mice immunized with a recombinant vaccine-strain salmonella bacteria, containing the circumsporozoite protein gene of a mouse malaria (P. Berghei), did not develop antibodies to sporozoites like the vaccine described but were strongly protected against challenge. The recombinant bacteria grew in the liver, where they stimulated cytotoxic blood cells by attaching the circumsporozoite protein to other antigens recognized by the mouse immune system. Vaccination similar to this could be practical in people. Other proteins that may be involved in immunity against liver stages are also being investigated.

Once parasites grow in the liver, they cycle from red blood cell to red blood cell, causing the disease symptoms and pathology of malaria. The blood cycle includes many points for immune attacks. If properly designed, attacks at several points at once may be superior to a single approach in their lethal effects on the parasites.

When malaria parasites infect red blood cells, they cause a substance called sequestrin to appear on the red cell surface. Sequestrin acts like glue, causing the red cell to stick to the endothelial cells (which line the blood vessels). This is a mechanism by which the malaria parasites hide (sequester) themselves in their victim, insuring a continuing presence and infection. This mechanism is one of the reasons why Plasmodium falciparum is so severe. Infected red cells clog the blood vessels in the brain, causing cerebral malaria. Similar adherence to circulating cells and other elements of blood stimulate other processes that contribute to the disease.

Walter Reed investigators discovered a surface protein on endothelial cells, platelets and white blood cells, which allows adherence of infected red cells to these host cells. The protein, called CD36, circulating in the blood stream, can block and even reverse adherence. This could lead to a vaccine that could cause red cells containing malaria parasites to lose their grip on endothelial cells and be swept into the spleen, where cytotoxic cells can destroy them. WRAIR investigators have a patent pending on the process of using CD36 to reverse red cell binding.

Infected red blood cells release merozoites, smaller malaria parasites, which invade more red cells to sustain the blood stage infection. Merozoites can be clumped with antibody, forming "immune clustered merozoites" or ICM, that die before invading the next red cell. Merozoite surface proteins stimulate formation of antibodies, then attach to them, eventually forming a cluster. WRAIR investigators have a patent pending for their work in identifying the antigens involved in the cross-linking. They have another patent pending for their identification of an erthrocyte binding antigen which has been cloned and used to immunize mice by blocking the attachment of merozoites to red blood cells.

Walter Reed investigators discovered a surface protein of endothelial cells, platelets and white blood cells, which allows adherence of infected red cells to these host cells.

The persistent and pervasive threat of malaria is not the only infectious disease problem that threatens U.S. forces in overseas deployments. U.S. military personnel, limited to immunity to the diseases naturally occurring in the U.S., have no defenses against the foreign diseases occurring in the areas to which they are deployed. Army medical researchers also have the mission to protect soldiers against these exotic disease threats, and are using advanced methods to develop vaccines and diagnostic methods.

Through recombinant vaccines, Army researchers are using genetic engineering to find new and better protection against infectious diseases. Major emphasis is on the development of polyvalent vaccines using vectors such as the viruses, vaccinia, adenovirus, baculovirus, and, as described above for malaria, the bacteria, salmonella.

The development of medical countermeasures to disease has historically been a long process, requiring 12 to 14 years. Today, biotechnology offers the potential for reducing the total time required by 4 to 5 years.

According to Joel Dalrymple, Ph.D., Virology Division, U.S. Army Medical Research Institute of Infectious Diseases, Fort Detrick, MD, most vaccines in use today were developed by continuously passing vaccine candidate virus through animals until attenuated strains of the infectious organisms appeared. Attenuated strains stimulate immunity but do not cause disease. The classical development of attenuated vaccines requires extended propagation to allow for mutation, with few predictors of how long this will take, and no good measures of attenuation for some diseases. Another drawback is that there is always the chance than an attenuated mutant can revert to virulence.

Genetic engineering improves the process in two dramatic ways. The first is to identify genetic changes in the mutant virus, and clone the mutants that work most effectively as vaccines.

Another way is to identify portions of the virus genome that control the parts of the organism (such as the malaria circumsporozoite protein) responsible for stimulating immunity, and insert them in vector organisms. The experimental malaria vaccines were vectored in E. coli bacteria and in salmonella. Other recombinant vaccine vectors include vaccinia, adenovirus and baculovirus.

Dr. Dalrymple and colleagues identified the part of the Ribonucleic Acid (RNA) of the Rift Valley fever virus responsible for protective immunogens of the virus. They have inserted it in baculovirus, a virus which grows in insects, then used cultures of moth cells to produce the protective antigens, which were then tested in laboratory animals, and proven effective against disease challenge.

Vaccinia virus has been used as a vector for both Rift Valley fever virus and Hantaan virus gene segments. Both recombinant vaccines have protected laboratory animals against disease after challenge with virus.

Army contractors are applying recombinant DNA technology to the development of militarily significant diagnostics. They are developing identification and diagnosis kits using monoclonal antibodies and nucleic acid probes for use by soldiers in the field.

Investigators at WRAIR and at the U.S. Army Medical Research Institute of Infectious Diseases are working with the latest diagnostic technology, called polymerase chain reaction (PCR). This method can detect a single DNA molecule of a specified type in a test tube sample containing millions of other, unrelated DNA molecules.

A mixture of nucleotide bases, or primers, the building blocks of DNA, and the enzyme polymerease are added to the sample. A chemical procedure causes the double-stranded DNA molecule to split into single strands. In the presence of polymerase, the bases attach to the single strands in the chemically correct places, replacing the separated strand, and producing two new double-stranded molecules. Thus, one molecule becomes two, these are split again to form four single strands, and so on. The geometric progression (chain reaction) of recombination results in a million-fold amplification of the single molecule in about three hours.

This diagnostic capability will facilitate rapid diagnosis of diseases such as malaria and leishmaniasis, which may occur when very few parasites are circulating in the blood stream. Work is in progress to develop practical, field-applicable methods for PCR-based diagnosis of malaria and other infectious diseases of military importance.

Biotechnology is also being applied to the protection of soldiers from dangerous complications of wound infections, and from the threat of chemical weapons.

Biotechnology is also being applied to the protection of soldiers from dangerous complications of wound infections, and from the threat of chemical weapons.

COL Jerald J. Sadoff, MC, of the WRAIR, and colleagues from Stanford University Medical School and the School of Medicine, University of California, San Diego, have developed a human monoclonal antibody to protect against septic shock resulting from bacterial infections.

Septic shock occurs as a result of battlefield trauma, burns, and surgery when bacteria enter the bloodstream. A toxic component of the bacterial cell wall, lipopolysaccharide, interacts with the immune system, causing the patient to go into shock and organ failure. The condition is fatal in up to 70 per cent of cases.

Sadoff and his colleagues used a mutant of E. coli bacteria to produce antibodies to the toxic substance. A vaccine was made from the mutant bacterial cells, and successfully immunized animals and humans in tests. Serum taken from immunized humans was used to prevent septic shock in volunteer post-surgical patients in intensive care wards. A monoclonal antibody was produced when a cell with desired antibody properties was fused with an endlessly reproducing tumor cell, resulting in a hybridoma. This hybridoma can be grown indefinitely outside the body and produces monoclonal antibodies. The monoclonal antibody has also proved effective, and is now in clinical trials. The monolconal antibody lasts for a short period of time; an experimental synthetic vaccine which promises to produce long lasting protection will also be tested.

Significant reductions in mortality from septic shock were achieved in clinical trials. A successful vaccine could be used in all military personnel in anticipation of combat because of the high risk of injury and subsequent septic shock.

COL Sadoff has also made important early progress in new methods of protecting soldiers from chemical warfare agents. Soldiers are currently protected from chemical threats by Military Operational Protective Posture (MOPP) IV, the thick hood, boots and overgarments worn by soldiers when a chemical threat is perceived, and by drugs that serve as pretreatments and as therapies for use after exposure. Sadoff's work with chemical agent protection allows the Army to conceive of vaccinating soldiers against these deadly weapons.

Sadoff and his colleagues inactivated molecules of the nerve agent soman by modifying its molecular structure, with the same goal as virologists modifying viruses through attenuation. The modified soman molecules did not harm laboratory mice, but they did induce the animals to form antibodies to soman. When blood cells from these animals were used to make hybridomas producing monoclonal antibody as described above, laboratory mice treated with this monoclonal antibody were completely unaffected by a dose of soman comparable to that which soldiers would encounter in a chemical attack.

The road from protected mice to protected soldiers is long, and full of scientific regulatory hurdles. However, the soman monoclonal antibody, the monoclonal antibody for bacterial infection, the diagnostic tests and the recombinant vaccines indicate tremendous possibilities in the realm of biotechnology for future life-saving medical products.

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CATALYSTS AND CHEMICAL DEFENSE

Researching the Use of Catalysts for Protection from Chemical Weapons

By Dr. Robert W. Shaw

Background

More than half a century has passed since the first full scale use of chemical weapons. Since World War I, these weapons have existed mostly as threats and have not been used. Recently, however, chemical weapons were used in the Iran-Iraq war and there is evidence elsewhere for the proliferation of chemical weapons industries.

The Army is the lead service for chemical defense efforts and a crucial element of these efforts is protection. This article describes recent research on use of catalysts for protection against chemical weapons. Interestingly, some other chemical agents — pesticides, herbicides — are related to chemical weapons and this research may lead to important methods for destroying these other toxic materials as well. (I will refer to all of these toxic molecules as "agents" and capitalize the elements that act as catalysts.

In the past, people have used simple adsorptive trapping to clean air of agents. Charcoal is a good adsorbent and, in filters and canisters, can be very effective. Adsorbents are passive means of removal — the agents are simply held on the adsorbent and may be released by heat or by other preferentially adsorbed molecules if they come to displace and release the agent. The "residual life" — how much longer the adsorbent will work before it becomes exhausted — is difficult to determine. Because of these disadvantages, we seek an active means of protection by which the agents will be destroyed — chemically changed into relatively harmless materials.

Many of the industrial chemicals on which our technological society depends come from chemical reactions in which molecules are broken and rearranged. For example, in petroleum cracking, large molecules in crude oil are broken down to form smaller ones (gasoline) suitable for burning in an automobile engine. These and many other processes in the chemical industry use catalysts to increase the yields of desirable products.

A catalyst provides an environment in which a chemical reaction can occur more easily, faster and with less energy. Without catalysts many reactions would be much too slow to be useful. In a chemical reaction, molecules change shape, break apart, combine with other molecules, etc. We can think of these changes in molecules occurring along a "reaction path." The catalyst makes new paths accessible to the molecules. Along these new paths the molecules may react more quickly and require less input energy.

The catalyst is used over and over: the molecules move to the catalyst, react, and move on, freeing the catalyst to assist more molecules to react. An unfortunate example is the catalytic activity of the Chlorine atoms from freons that pollute our atmosphere and assist the destruction of ozone. The Chlorine atoms are not used up in this reaction when an ozone molecule is destroyed; instead, the Chlorine is released to catalyze destruction of other ozone molecules. Similarly, the catalyst in a car exhaust system remains active through cycle after cycle of exhaust gas reactions. I will briefly discuss automotive catalysts because they provide a good introduction to the use of catalysts for chemical defense.

Automotive Catalysts

The widespread use of catalysts to reduce air pollution began in the late 1970s. Faced with requirements to limit the amount of carbon monoxide and unburnt fuel coming from automobiles, the manufacturers developed catalysts to assist burning (oxidation) in the exhaust stream. These catalysts used the metal elements Platinum and Palladium. At the beginning of the 1980s, automobiles were also required to limit the amount of nitrogen oxides emitted by removing oxygen (reduction). We needn't concern ourselves with the chemical meanings of oxidation and reduction here; it is enough to say that the catalyst assists the addition of oxygen to carbon monoxide and unburned fuel and the removal of oxygen from nitrogen oxides, both at the same time. Obviously, this new requirement greatly increased the demand on catalyst designers.

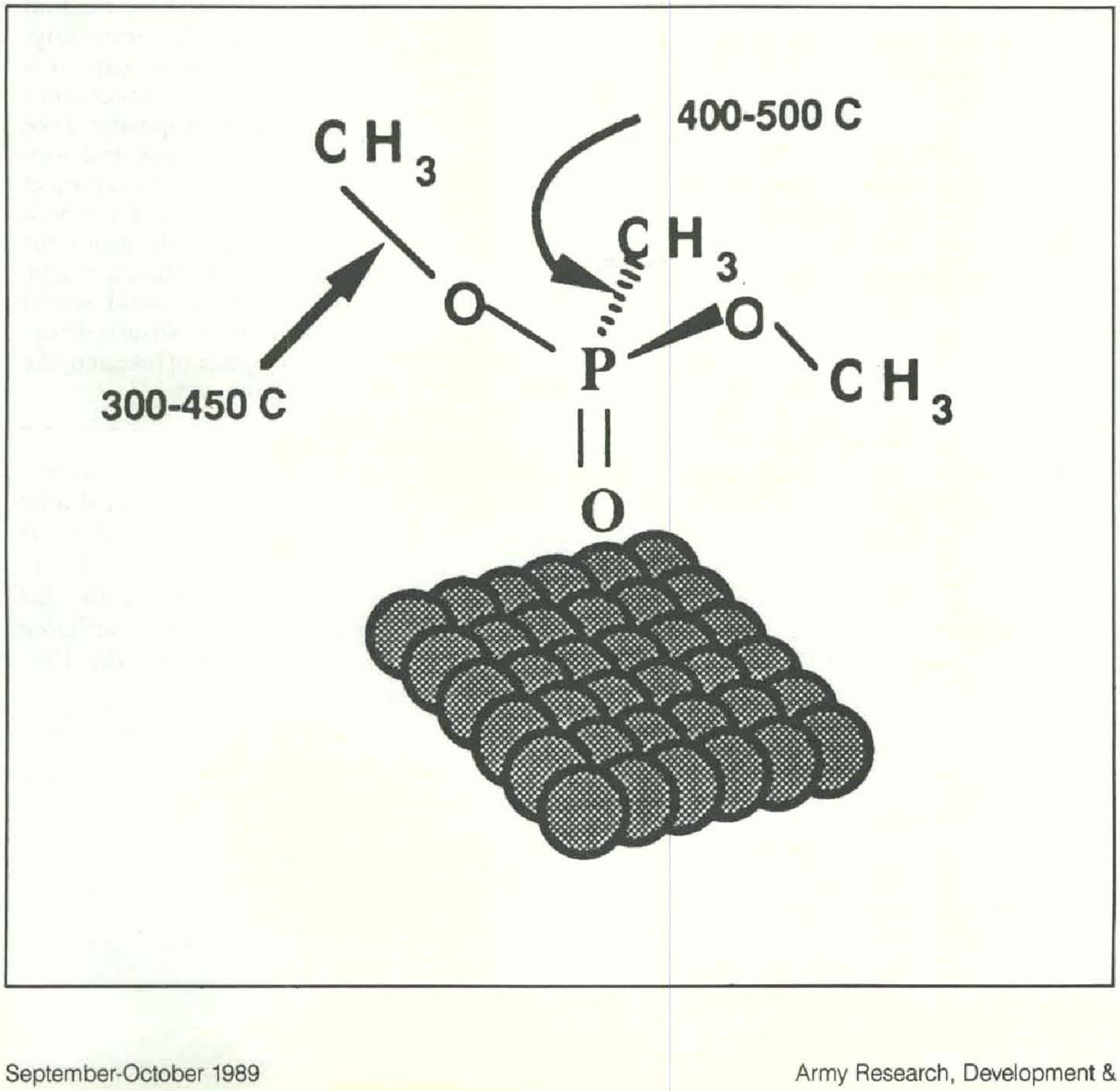
The new catalysts use the element Rhodium for nitrogen oxide reduction, Platinum and Palladium for carbon monoxide and unburned fuel oxidation, and other elements (e.g., Cerium, Lanthanum, Nickel, Iron) as additives to improve catalyst performance. Even the material these elements are deposited on contributes to catalyst performance. The operation of these catalysts also depends on engine and fuel characteristics; they are very sensitive to the fuel/air ratio in the engine and can be poisoned by lead in the fuel.

Other elements can also poison catalysts. Sulfur, for example, can be a potent catalyst poison and may be present in automotive fuels and lubricants. However, the sulfur is present in low enough concentration and the chemical reaction conditions are such that the catalyst is not poisoned. Even the small amount of sulfur present puts additional requirements on the catalysts because reduced sulfur compounds smell bad. So catalyst designers have sought catalyst formulations and operating conditions that will suppress reduction of sulfur.

When these automotive catalysts were first used, their chemistry was not understood, but the enormous commercial market drove a large, Edisonian (trial and error) development effort. Of course, there is no large commercial market for chemical defense catalysts. Therefore, we must use basic research that leads to a better understanding of the chemistry involved and, in turn, to provide cost effective guidance for development.

Chemical Defense

The agent molecules used as chemical weapons have relatively large amounts of catalyst poisoning atoms — phosphorous, sulfur, chlorine. These atoms make the development



Part of the reaction pathway for the destruction of an agent simulant on a Platinum catalyst surface. The arrows show where and at what temperatures the molecule breaks (research at University of Texas — Austin).

of effective agent catalysts particularly difficult. Clearly we must understand how these elements and the molecules that contain them behave on a catalyst surface. This is because it is the microscopic structure of the catalyst surface that provides the assisting environment for the desired reactions of the agents.

Fortunately, since its beginning about 20 years ago, a true scientific revolution has taken place in our understanding of chemical reactions on surfaces. This revolution began with the development of new experimental methods to prepare and maintain clean surfaces and to analyze substances on those surfaces. These new methods and the understanding that has emerged from their use has made possible a wide range of now critical technologies (especially solid state electronics). Catalysis is only one example of the application of basic research on surfaces.

Surprisingly, not much research or engineering development has been done on the catalyzed reactions of agent molecules or their simulants. An excellent summary by C. C. Hsu and J. V. Pistritto, (Air Purification by Catalysis — A Literature Survey; CRDEC-SP-84014, October 1984) was presented at the 1983 CRDEC Scientific Conference on Chemical Defense Research. Much of the later work is reported in the proceedings of subsequent CRDEC conferences, especially by Weller et al of the State University of New York at Buffalo and by Lester et al of Signal Research Center. Both of these groups were supported by CRDEC. The approach of much of this work was to adapt automotive catalysts for agents and the results were very promising: in some operating conditions, relatively high concentrations of agents were destroyed with an efficiency exceeding 99 percent.

For the past decade, the Army Research Office has been supporting basic research on reactions of molecules on well characterized surfaces at CalTech, the University of Texas and the University of Pittsburgh. In most cases the molecules studied had structural similarities to toxic agent molecules and contained the atoms that normally poison catalysts. This work has explored how the molecules attach to the catalyst surface and how they break apart — alone and in the presence of other molecules such as oxygen and water.

How the molecule decomposes depends largely on how it first becomes attached to the surface. This attachment was the topic of study at CalTech. Scientists at Texas and Pittsburgh have pursued this earlier work and explored how and at what temperatures the molecules react. Understanding these processes is critical to the successful development of a catalyst because we seek a reaction pathway that will not leave poisoning atoms behind to spoil the function of the catalyst.

In 1986 we judged that significant progress had been made by workers at university, industrial and Army labs on reactions of agent-like molecules on catalysts. We asked a small number of distinguished experts on chemical reactions on surfaces to survey the current state of understanding and to make recommendations for future research. That group met for one week of intensive study during which they were briefed by active research workers from the Army and from industry; they also had access to the scientific literature — both published and in internal reports. That study produced the report, "Catalytic Destruction of Organic Heteroatom Compounds" (J. M. White, J. G. Ekerdt, K. L. Klabunde, J. R. Shapley, and J. T. Yates, U.S. Army Research Office Technical Report, Nov 1986, NTIS No. AD-A174 367). An abbreviated version, appropriate for the open scientific literature, was also published by the same authors (*Journal of Physical Chemistry*, 1988, 92, 6182-6188).

Three separate research projects, supported by the Army, have grown directly from the research recommendations in those reports. Scientists at Kansas State University are studying the use of Metal Oxides for toxic molecule destruction. Work is beginning at the University of Texas on the surface chemistry of molecules similar to mustard agent — especially difficult to destroy. And in a striking breakthrough, workers at the University of Pittsburgh have shown that Molybdenum, in the presence of oxygen, is a true catalyst for the destruction of a nerve gas simulant. In these reactions, the molecules are broken down on the Molybdenum surface and then move on without leaving any catalyst-poisoning atoms behind. This indicates that the catalyst can be used repeatedly. A patent on this work is pending.

These experiments are difficult and require specialized basic research equipment. They point the way, however, for exploratory development and, perhaps, to engineering development of useful applications. Already, workers at CRDEC, in cooperation with the University of Pittsburgh, are planning to study the use of Molybdenum catalysts. If these trials give more positive evidence for catalytic destruction of agents, workers can begin to study other requirements for the production of catalytic devices: low pressure drop, thermal stability, low temperature operation, etc.

Summary

The research described in this article shows that the catalytic method for agent destruction is promising. Further work will show whether it is economically viable or whether other approaches may be superior. Like other research carried out and supported by the Army, it seeks to protect the soldier; but this particular research also has important implications for civilians who may be threatened by agents and for the general social problems of hazardous waste destruction. In this whole area of research, the Army is leading the way.

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Introduction

In the three previous issues of Army RD&A Bulletin, the topic of item-level weapons analysis was introduced and then illustrated with methods used in vulnerability/lethality and predictive signature analyses. Of all applications, the vulnerability and signature methods are the most heavily exploited by the weapons modeling community; nevertheless the possibilities and potential impact of this class of modeling goes far beyond these two disciplines. In this article, a brief summary will be made of other item-level applications which have been developed to date. Finally, some of the possibilities and issues connected with growing utilization of item-level modeling will be discussed.

Item Level Weapons Modeling . . .

LOOKING TO THE FUTURE

By Dr. Paul H. Deitz

Other Applications

• **Weights and Moments of Inertia**: As noted previously, when a target description is assembled, both the geometric shapes (internal as well as external) are fully defined. In addition, each geometric entity of the

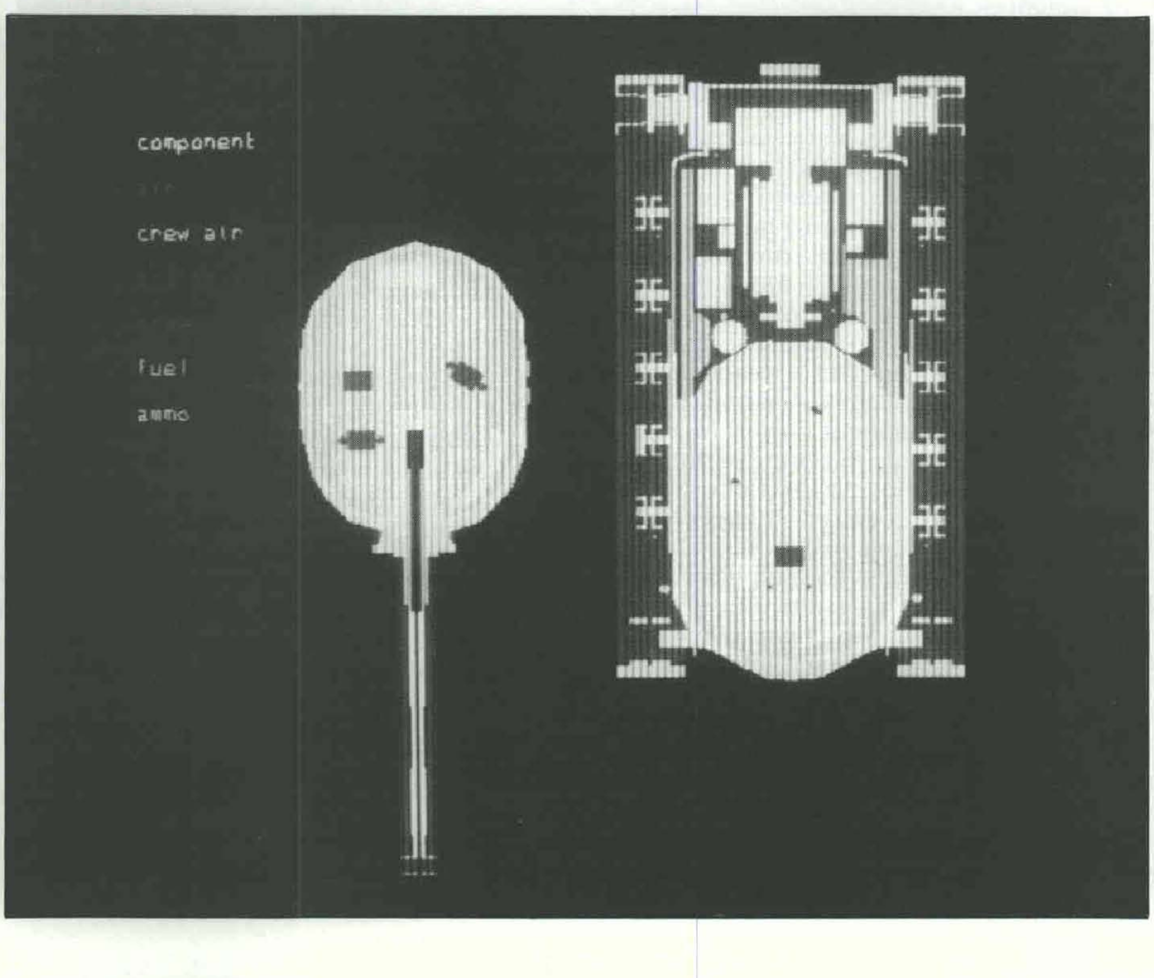

Figure 1.

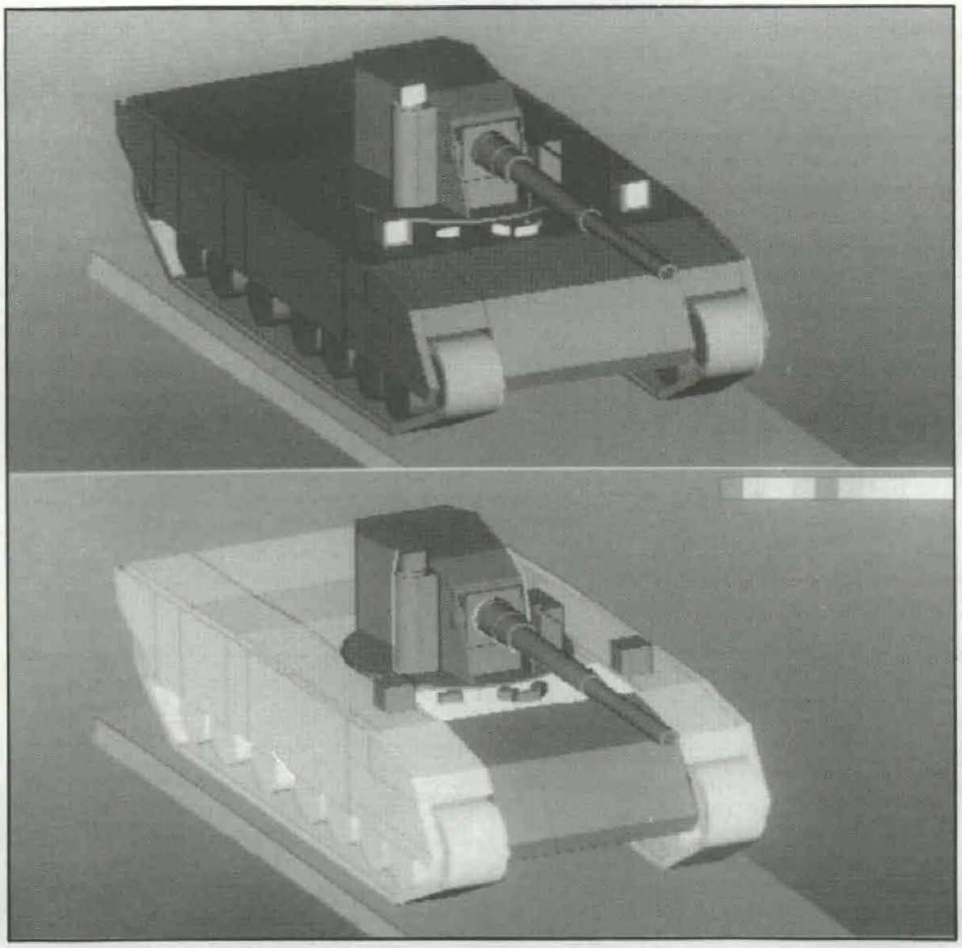

Figure 2.

description is assigned a unique name to which specific material properties are related. For the task of weight estimation, the material density of each component or part is linked to the geometry.

By firing mathematical rays in a tight grid and viewing groups of these rays, the composition of a target can be seen in high resolution. Figure 1 illustrates this process in which a 1 inch by 1 inch matrix of rays was fired through the front of a heavy tank target description. Groups of rays in horizontal sections were then extracted for individual viewing. Two are shown; the various gray levels (normally rendered in color) indicate the specific target materials (armor, ammunition, fuel, crew, air, etc.). If the material density information used for viewing is integrated over all rays in a given section, the weight of the target is derived for that particular 1-inch thickness. If all sections are added, the weight of the entire system is estimated.

Such a process is important in many stages of weapons system evaluation. In all military systems, whether conceptual or fielded, air or ground, weight is a critical constraint.

By similar methods, the center-of-mass and the moments-of-inertia (MOI) of a system can be estimated as well. The MOI are a measure of the torques required to change the rotational rate of a mechanical assembly.

The U.S. Army Ballistic Research Laboratory (BRL) computer aided design (CAD) tools have been used, for example, to estimate the baseline weight of an M60, and then the change in weight for various configurations of applique armor. In addition, MOI calculations were performed with the applique layouts in order to estimate the required changes in the turret slewing hydraulics. These methods have also seen application to problems such as estimation of vehicle overturning moments due to nuclear (air) blast wave and a howitzer undergoing firing cycles.

• **Neutron Transport**: When a nuclear weapon is detonated, several threats to equipment and personnel exist. Among these is nuclear radiation. Using a computer code developed at Oak Ridge National Laboratory, the initial radiation output from a nuclear weapon can be tracked from the point of detonation to a region within a military vehicle.

A number of years ago this code was used to estimate the neutron dosage just below the driver's hatch in a concept vehicle. Called the Tank Test Bed, one particular configuration is illustrated in the upper half of Figure 2. In this study, the total radiation dose reaching the driver's head was calculated while monitoring the specific exterior portions of the vehicle through which the radiation leaked. In the lower half of Figure 2 the image shading has been adjusted according to the magnitude of neutron flux. Higher neutron flux surfaces are show in lighter shades.

• **Structural/Acoustic Analysis**: Structural integrity is an important issue in the design, analysis and testing of military items. It is clearly a central issue for both fixed and rotary-wing aircraft; in the past it has not been an issue for heavy tanks, but now has taken on

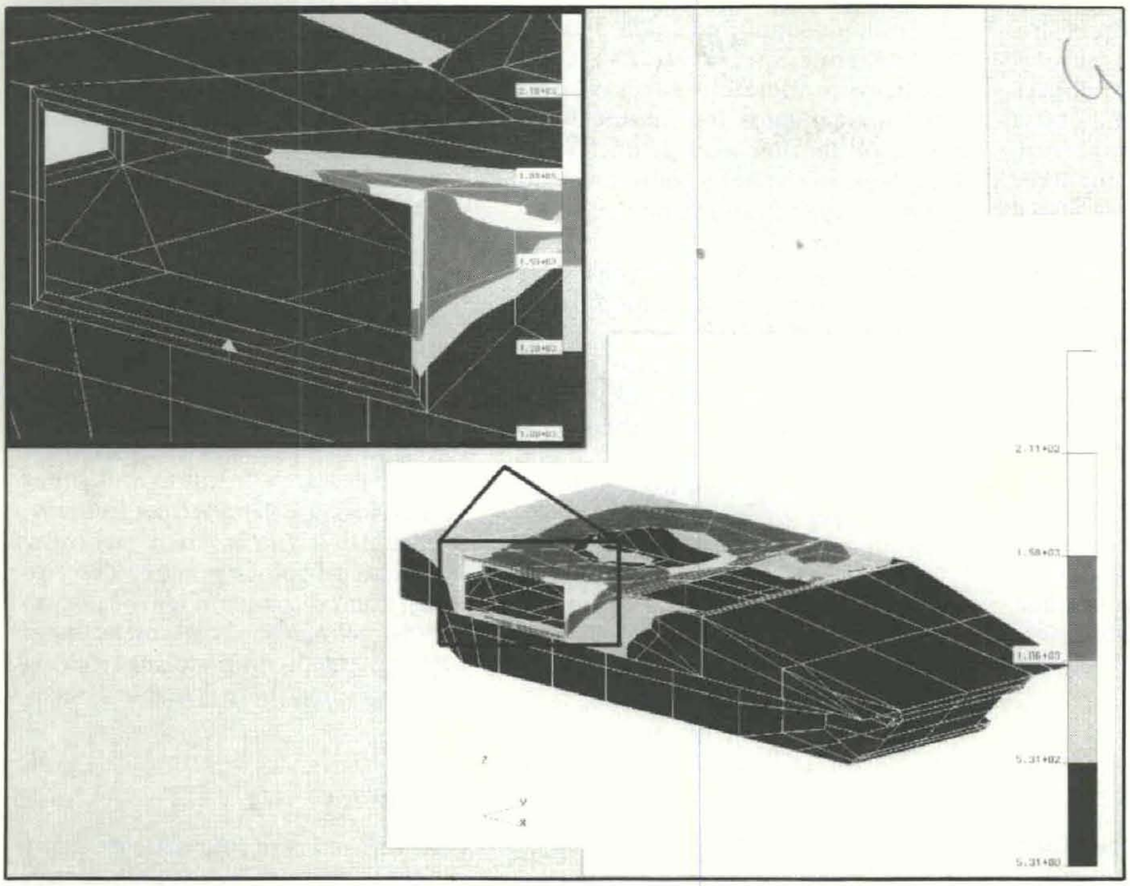

Figure 3.

increasing importance with lighter fighting vehicles, particularly as the use of explosive applique armor has been considered.

A baseline calculation is often employed to yield the so-called "static case" in which a steady force is applied to a portion of a vehicle. Such a pilot study was performed using a chassis design for a Mobile Protected Gun System (MPGS). The BRL-CAD geometry assembled for vulnerability analysis was translated into the CAD format of a commercial finite-element preprocessor. Inside this modeler, the chassis was subdivided into discrete elements and then passed to a finite-element code where a steady force corresponding to the turret weight was applied to the region of the turret ring. Figure 3 shows the von Mises stresses calculated over the chassis. The results reveal a conservative design, far below the levels at which plastic deformation begins.

The same finite-element medium can be used for other classes of calculations. One study involved calculating the natural harmonic frequencies of this chassis design together with the amplitudes of oscillation. Such results can be important in reducing harmonic resonances which can affect vehicle mobility; they relate as well to the acoustic signature of the vehicle.

• **High-Energy Laser**: In the 15 years prior to 1984, many high-energy laser experiments were carried out; these tests established an effects data base for lasers of various wavelengths (primarily 10.6 and 3.8 microns) and wave shapes (pulsed and continuous). During the same time, vulnerability tests were conducted to establish component damage thresholds, particularly for those utilized in optical systems, missiles and aircraft. The information gathered in this testing has been used to assemble a laser-damage effects model. BRL-CAD target descriptions, giving the three-dimensional geometry and material definitions, serve as part of the input. This information is combined with illumination dwell times and damage thresholds to compute likelihood of component degradation/target destruction.

• **High-Powered Microwave (HPM)**: HPM weaponry is currently in the exploratory research stage. The coupling of microwave energy to the components of a target is an extremely complicated, non-separable problem. Linkage can occur via "front-door" avenues, such as through antennae which are designed to collect low power microwave signals, or through "back-door" channels, such as cracks and seams in the outer vehicle skin. These potential channels and their unavoidable interplay result in the need to analyze systems as a whole in order to achieve reliable target kill assessments.

A goal for HPM is development of a computer-based methodology which uses the standard BRL-CAD target models (perhaps with some augmentation) in the assessment of target vulnerability. The development of a computer model has been contracted for and the first-stage deliverables are under review.

• **X-Ray Simulation**: Recently, an extension was made to the BRL-CAD environment to simulate the behavior of X-rays in materials. The radiation source can be placed at an arbitrary point in space. A series of rays are then extended through the object for which the simulation is to be performed. The material attributes assigned to the regions of the object can be related to actual X-ray absorption. Thus, the energies emerging at the far side of an object can be calculated and then transformed according to the efficiencies typical of film detection. Images have been derived for a number of objects including portions of heavy tanks. Such techniques may be of aid in the interpretation of experimental X-rays normally taken in armor penetration studies or other non-invasive tests.

The techniques described here and in the previous articles represent current methods of high-resolution item-level modeling. By inference, many other kinds of applications can be supported, limited only by the imagination of the analyst.

Future Issues

Currently, the Army Materiel Command (AMC) has a renewed interest in CAD. A charter for an AMC Functional Coordinating Group for Computer Aided Design-Engineering (CAD-E) was approved on Feb. 24, 1989. The CAD-E Group is directed to make a strategic assessment of AMC CAD-E efforts, evaluate the feasibility of a standard CAD-E system and determine how such a system would be maintained.

One problematic issue involves the extent to which standards should be imposed on a particular community of users. Without some standards, interchange of data may become difficult or impossible.

The plethora of ways in which geometry can be represented is in fact the reason solid geometric data generated by one commercial modeling system generally cannot be used by another vendor's system. Sometimes the basic geometric constraints used in one system simply cannot be handed over to another due to mathematical constraints.

Another typical incompatibility arises because most vendors choose to keep the nature and format of their data base inaccessible to the user. This is a commercial strategy referred to by some as "vendor lock in." The government-supported Initial Graphics Exchange Specifications (IGES) has been moderately successful at defining standards for sharing wire-frame (or drafting-level) geometry but is unlikely to provide a common meta-language specification for the solid-modeling world.

The approach taken in the BRL-CAD environment has been to modularize those parts of the software in which the mathematical definitions of 3-D shapes play a role. Tools have been developed so that as new mathematical forms are required, they can be added easily at these key sections of code. All other parts of the environment, including interfaces to applications codes, remain unchanged.

The first foray into using BRL-CAD as an Army standard begins now with the Heavy Force Modernization (HFM) thrust. The objective of HFM is to provide the Army with the optimum ground-vehicle fleet in the year 2004; nearly 30 vehicle types are included. All vendors will be required by contract to submit geometric and material descriptions of vehicle designs in the BRL-CAD format and to provide updates at six-month intervals.

On the other hand, with too many standards, technical innovation can be stifled. Such a situation could arise in a future weapons procurement if both a solid-modeling requirement and the new DOD Computer-Aided Acquisition and Logistics Support (CALS) system are applied.

CALS is a laudable interservice effort to provide standards for computer-aided design drawings, text formatting, graphics and pictures. However, since solid geometric data is a complete form of specification as opposed to blueprint-level specification, the former is not derivable from the latter. If the latter were defined to be the primary deliverable under a government contract, it might well preclude the use of the more advanced technology. These and related issues will provide interesting challenges as the electronic age advances.

In a time of shrinking resources, the maintenance of BRL-CAD software and related data bases is receiving increasing attention. At least three aspects are involved.

- The CAD package itself has been distributed to over 450 computer sites. Code and documentation must be written and distributed, bug-fixes performed, and extensions made as new capabilities are sought.
- Various inhouse applications codes (vulnerability, signature, etc.) must be maintained, extended, and distributed within a growing community of users. Also, codes developed by outside users need to be brought in, examined, and sometimes installed for inhouse production use.
- Among the community of target-description providers such as BRL, Denver Research Institute and other contractors (see *Army RD&A Bulletin, March-April 1989*), there are now hundreds of military target descriptions, domestic and foreign, in a shareable format. Mechanisms must be found and implemented for storing, sharing and upgrading these valuable assets.

Summary

In this series of four articles, many modern computer-based methods have been described in support of high-resolution item-level weapons modeling. Without doubt, these methods will enjoy increasing use throughout government and industry. This exploitation is possible because of a number of factors including the establishment of rigorous algorithms, the uniform support provided by modern computer software environments, and the power and low cost of today's computer hardware.

The development of these tools is due to the efforts of many scientists and analysts; it is significant that a major portion of these modern analytic methods owe their existence to Army-sponsored and staffed research.

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EVOLUTION OF THE ROBOTIC COMBAT VEHICLE

By MAJ Ricky Lynch
and Gerald R. Lane

Introduction

Unmanned systems can be used to augment manned forces in the accomplishment of their military mission. The technology to develop and field unmanned systems for military applications has been pursued for quite some time. The purpose of this article is to describe the efforts underway in the pursuit of one particular application of unmanned systems technology — that of the robotic combat vehicle (RCV). The RCV program is a joint effort between the U.S. Army Tank-Automotive Command (TACOM) and the U.S. Army Armor School to develop a robotic vehicle for military applications.

What is a robotic combat vehicle? First, let's start with a definition of the ultimate system: A robotic combat vehicle is a system of unmanned ground vehicles capable of military combat, combat support or combat service support operations that has a very high degree of autonomous operations capability. The system consists of a manned robotic command center (RCC) and numerous unmanned robotic vehicles (RVs).

Ideally, all the human operator in the robotic command center has to do with the ultimate version of an RCV is to tell the robotic vehicles (either via key board entries or voice command) to travel from point A to point B and when they get there to perform a specific military mission (antiarmor, recon, resupply, decoy, etc.). This definition, to those at all versed in the technology of unmanned ground vehicles, is the "mark on the wall." It provides for focused effort in basic research and early on user tests and proof of principle demonstrations.

The Need for RCVs

A question that must be answered up front is: Does the U.S. Army need an RCV? If the answer to that question is NO, then all work should be stopped and the money currently being used to develop the RCV should be channeled elsewhere. We believe the answer to that question is an emphatic YES.

We in the U.S. Army are working under a capped force structure that is in danger of becoming even smaller. At the same time, the recognized threat is continuing to build its forces, both quantitatively and qualitatively. RCVs could be used to augment our manned ground forces.

One could conceive of many potential military applications for an RCV. A unit commander could choose to use his unmanned systems for high risk missions and in contaminated areas, thus freeing him of the concern for loss of human life. If the RCVs are effective enough, the commander could mass his robotic vehicles and use them in an economy of force role to free his manned forces to maneuver as a mobile reserve.

The question becomes "When will we field RCVs?" That's the $64,000 question, that can also be translated as "When will robotic vehicle technology be good enough to field RCVs of sufficient combat effectiveness that they are of use to field units?" The answer is "We're not sure." This article will address the evolution of RCVs, where we have been and where we are going.

Concept Based Requirements System

Under the U.S. Army's Concept Based Requirements System (CBRS), the first step in the process should be the development of operational concepts for the use of RCVs. These operational concepts will "set the stage" for the future development of RCVs by roughly defining the desired characteristics and the operational environment for the systems.

Numerous draft concepts are being circulated throughout the Army. We would like to highlight two potential ones. The first, entitled the Multi-dimensional Concept (MDC), uses RCVs (in conjunction with other unmanned systems) in an economy of force role to free maneuver forces to execute maneuver doctrine better.

The second concept, the Robotic Wingman, provides for an antiarmor RCV that could act as the wingman for a manned tank. This unmanned

Advances in machine vision are important for autonomous mobility and also for robotic control of mission modules.

wingman could then be used in high risk situations such as leading the attack or in stay behind missions without concern for loss of life. Once these draft operational concepts are matured, the developer then takes them and defines the specific technological requirements on which to base his future work.

Functions

The first question the developer must answer is: Technically, what must the system be able to do? The RCV, like other combat systems, must perform basic combat functions to achieve effectiveness on the battlefield. Five key functions are required: move, shoot, communicate, survive, and be supportable.

In order to achieve required levels of effectiveness for each function in unmanned RCV systems, critical technologies must be advanced to enable the RCV to effectively engage opposing forces or perform other combat missions as effectively as manned systems.

Basic technological areas necessary to field RCVs include mobility, intelligence, sensors, communications, command and control, platform development and mission modules. Advances in artificial intelligence, machine vision, microelectronics, parallel processors and low bandwidth communications feed the above technology areas, making unmanned RCVs feasible.

Autonomous Mobility

Autonomous mobility is what separates an RCV from teleoperated systems. The RCV is "smart enough" to traverse from point A to point B under its own control. This is no easy task — especially on a battlefield. The RCV cannot simply follow a digital data base to get from A to B. Obstacles not reflected in the data base can easily stop the RCV in its tracks.

Advances in autonomous mobility are currently being spearheaded by the Defense Advanced Research Projects Agency's (DARPA) Autonomous Land Vehicle Program (ALV) and are critical to the Army RCV program. The autonomous mobility advances from the ALV offer the potential to achieve multiple vehicle control. A human operator no longer has to control the robotic vehicle continuously. With a certain degree of autonomous mobility on the part of the robotic vehicles, he can "control" the movements of numerous RVs simultaneously.

Advances in machine vision are important for autonomous mobility and also for robotic control of mission modules. For an antiarmor RCV, automatic target tracking, aided target, and ultimately automatic target recognition will be required. Machine vision is also required to facilitate other RCV variants, such as control of automatic refueler arms and grippers.

Computer Enhancements

While advances in autonomous mobility are being made under the ALV program, opportunities exist to advance RCV mobility through computer enhancements. One such program is Computer Aided Remote Driving (CARD). The CARD program can provide the RCV commander the capability to manage multiple RCVs and/or communicate through a low bandwidth communication system. CARD, through a stereo vision display located in the RCC, allows an RCV driver to predrive a path. This is accomplished by using a cursor to designate a three dimensional path in a stereo display. The RCV will then follow the path through to completion. This technology, unlike autonomous mobility, makes use of human intelligence versus machine intelligence, but still does not require continuous human control.

Communication is critical. A low-bandwidth communications link between the RCC and the robotic vehicles is an operational imperative. The use of a fiber optic cable, coupled with available bandwidth, when multiple systems are operating, necessitate the development of a low bandwidth communications system. This is a priority area needing resolution before the Army can consider fielding a robust system capable of performing combat missions.

Early on user tests and proof of principle demonstrations are critical in the evolution of RCVs. The Army's first attempt at an integrated technology demonstration was performed under the joint DARPA/Army Advanced Ground Vehicle Technology (AGVT) program.

The purpose of the AGVT program was to demonstrate the application of the DARPA ALV technology integrated into a combat vehicle performing a reconnaissance mission. General Dynamics Land Systems (GDLS) and FMC Corp. were selected to develop the robotic vehicles for these demonstrations. The demonstrations showed the military potential of such systems. During the demonstrations, the robotic vehicles were able to autonomously follow a road at speeds up to 10 kph. In addition, the same vehicles could be teleoperated at operational speeds.

In the fall of 1987, three variants of robotic vehicles (the GDLS and FMC versions and an additional one developed by GM Delco) were brought to the Armor School for a Concept Evaluation Program (CEP). It was imperative to put "soldiers in the drivers seats" to determine the effectiveness of the current version of robotic vehicles and to highlight specific soldier-machine interface issues. The results of this CEP have been published and are available under the Defense Technical Information Center system. Based on the results of the CEP, the user can now refine the operational concepts for the use of RCVs and the developer can ensure that the results of the CEP are incorporated into future developmental efforts.

So that's where we are today. In terms of CBRS, we have articulated draft concepts for the use of RCVs and have developed some hardware for early on user tests and proof of principle demonstrations. Where do we go from here?

The U.S. Army Tank-Automotive Command (TACOM) has focused its RCV program to assist the user community in understanding the capabilities, benefits, and limitations of robotic systems. The principal hardware program currently ongoing at TACOM is the development of the Robotic Command Center.

We are still trying to answer the question: When will robotic vehicle technology be good enough for military missions? The next opportunity for such an evaluation will be in late FY90 when RCC development is complete and becomes available for government tests.

The RCC has been designed with a standardized communication protocol which will maximize its interoperability with other RCVs including the Army Laboratory Command Joint Test Vehicle program, the Marine Corps teleoperated vehicle and potential other RCVs. The FY90 and FY91 evaluations will be the first ones that address force multiplication through multiple vehicle control.

Multi-vehicle control will be accomplished by the RCC crew managing and controlling up to four RCVs with only two operators and a commander. These initial demonstrations are not expected to prove the concept of multi vehicle control but will begin a systematic evolution of technologies required to field an RCV platoon with a single command center. Such an evolution of RCC and RCV is dependent on parallel technology development.

Critical to the multiple vehicle command and control capability is the DARPA ALV program. Continued progress is needed in autonomous mobility to advance the capability to control multiple RCVs. Unfortunately, the ALV program is beginning to lose budget support. Current ALV system integration responsibilities are receiving minimum funding with emphasis being placed on supporting research. ALV technology is essential to the RCC program and also key to follow-on Advanced Ground Vehicle Technology programs.

To accomplish the task of advancing the technologies, a cooperative effort between DOD organizations, industry and academia is required. A robotics master plan is currently being drafted by AMC for the Department of the Army. In August 1988, the first of a continuing series of expert subgroup meetings was held as part of the ongoing Robotic Vehicle Working Group. The expert subgroups will be assigned separate technology areas that correspond with the critical technology shortfalls for development of the RCV.

Obstacles

What we have described is the current plan for the evolution of robotic combat vehicles from our perspective. In an ideal world, this plan would continue on track and the soldier would have truly robotic vehicles for use at the earliest possible date. We do not live in an ideal world, however. Obstacles are encountered on a daily basis.

First and foremost, the most severe obstacle is the constrained budget environment in which we work. Money is limited, and must be wisely spent to ensure accelerated development. Wise decisions on the use of limited funds can only be made in an environment where there is a focused effort.

What does the Army need most in terms of RCVs? Does it need a robotic tank killer, a robotic decoy, a robotic artillery vehicle, or what? All variants are good ideas, but what is the best idea? This is a tough decision, but one that has to be made in order to ensure a focused effort. The user community must come forward in a unified voice to state specific requirements for robotic vehicles.

The next killer for RCV development is the tendency to "mortage our future." Everything cannot be near term. If we simply wanted teleoperated vehicles for military missions we could buy "off the shelf" hardware. Teleoperated vehicles have been available for 50 years. Today, teleoperated vehicles compete with truly robotic vehicles for the limited funds in the robotic arena. This delays basic developmental efforts in support of RCVs. If the Army doesn't invest in basic R&D for RCVs now, we will never have truly robotic vehicles. Industry doesn't need a vehicle capable of going cross country at 45kph autonomously and hence will not invest in research in this area.

The third killer in the development of RCVs is the tendency to pursue "pet rock programs" and the "not invented here" syndrome. Pet rock programs are those that are being pursued with limited or no user support, with marginal potential application to military missions. The not invented here syndrome causes us to spend limited R&D dollars on our own programs simply because we want to find the answer ourselves. We don't want to buy off the shelf technology simply because "we didn't invent it." These are both killers, that can cause a significant waste of funds, and of which we are all guilty to various degrees.

Again, tough decisions have to be made. Not all programs can be funded. The perfect analogy is the garden. An astute gardener plants a lot of seeds early in the growing season, and then plucks away those that are not doing as well and fertilizers and nurtures those that show promise.

Conclusion

Robotic vehicles, RCVs if you will, are important to the future of the U.S. Army. They have the potential of allowing us to commit systems on the battlefield that can augment manned forces without a significant increase in force structure. With focused effort, and wise expenditure of funds, we can develop these systems and field them for the soldier at the earliest possible time.

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COMBAT STRESS

A Major Threat to Victory on the Battlefield

Introduction

The Army's research, development and acquisition community represents a diverse area of professional interests and a vast range of products designed to support Army readiness requirements. In publicizing RD&A accomplishments, it is easy to overlook the fact that scientific information represents a valuable component of RD&A contributions to combat readiness. While not as glamorous as some of our military hardware, information is an important RD&A product.

This article highlights contributions made by one of the Army's medical R&D laboratories. The focus is the production of information about a major threat to victory on the battlefield — combat stress.

The prevention and treatment of casualties that result from combat stress are critical readiness issues. Historically, these casualties have been important sources of wartime personnel losses and, when effectively treated, a valuable source of combat replacements. Walter Reed Army Institute of Research (WRAIR) scientists have a long history of interest and scientific accomplishment in areas that relate to combat stress. In recent years these research efforts have expanded to include the influence of organizational, family, and community factors on the prevention and treatment of combat stress reactions.

Past Experience and Combat Stress

The simplest description of the soldier who becomes a casualty as a result of combat stress (what the Army now calls "battle fatigue") is an individual who, in a combat environment, loses the ability to function adequately as a soldier. While the symptoms may cover a wide range of dysfunctions (cognitive, emotional, physical, and/or behavioral), the defining aspect is the soldier's psychologically induced inability to perform his military duties for a length of time sufficient to endanger himself, his fellow soldiers, and/or the unit mission.

In World War I, these casualties were initially attributed to "shell shock" and suspected neurological injury. As time went on, however, it became clear that these symptoms existed even in soldiers not exposed to artillery fire. By World War II, common descriptions of combat stress reactions focused on excessive exposure to the demands of combat. These soldiers were described as victims of "combat fatigue" and "combat exhaustion." Every soldier was thought to have his own breaking point and all soldiers would eventually break down if they remained exposed to combat beyond some finite point.

In the Korean conflict and later the Vietnam War, rotation policies were put in place to limit the individual's degree of exposure to the stress of combat. While the incidence of classical combat stress reactions was reduced, other forms of dysfunctional behavior (primarily substance abuse) were noted and evidence of delayed stress reactions in soldiers who participated in these conflicts has now become an important concern.

The 1973 Arab-Israeli War and the 1982 Lebanon conflict vividly demonstrate the impact of brief intense stress on casualty rates. While the 1973 Israeli rates of stress casualties to wounded were 30:100 and the 1982 rates were 20:100, combat units subjected to prolonged, heavy fire had stress casualty rates as high as 86:100. Both of these wars also provide a distinction between chronic stress (lengthy exposure to the physical and psychological strain of war) and acute combat stress (the shock of intense, highly lethal combat). These wars clearly demonstrate that given the right set of individual, unit, and situational circumstances, combat stress reactions can result in a soldier becoming a battle fatigue casualty within days, if not hours, of combat exposure.

Lessons from World War II, Korea, Vietnam, and the Israeli Wars demonstrate that various factors, including personal and family morale, unit relationships, and leadership, can have an important influence on the rate of combat stress casualties. History also demonstrates that both the unit's and the medical system's response to stress symptoms, and the corresponding management of identified battle fatigue casualties, can have a tremendous effect on the recovery process and the likelihood of a soldier's timely return to his unit. This is critically important because on a future battlefield our stress casualties may be our only source of available replacements.

Recent Achievements

WRAIR's current combat stress research covers a broad spectrum of laboratory and field studies and represents work performed at WRAIR and at two of WRAIR's special activities (U.S Army Medical Research Unit-Europe

By James A. Martin and LTC Frederick J. Manning

and Fort Bragg, NC). The institute's research program is three-pronged, looking at sources of stress, consequences of stress, and countermeasures to prevent, moderate, and/or treat the effects of stress. In most cases individual research projects encompass multiple aspects of this model. For the sake of simplicity, this description of recent achievements does not attempt to highlight results in the context of this model.

Since 1985, WRAIR has supported the HQDA ODCSPER study of the Army's implementation of the Unit Manning System (UMS) and the associated unit replacement program called COHORT. Analysis from the ongoing UMS evaluation suggests that horizontal cohesion scores drop for all soldiers as the number of months they are in their company increases. This appears to be due to the waning of the high expectations that soldiers bring with them from basic training. However, compared with the small number of junior enlisted soldiers who remained in conventional units over a similar 24 month period, COHORT soldiers retain higher horizontal cohesion scores. Likewise, largely because of their common initial training experience, COHORT soldiers with less than six months in their units display higher cohesion scores than equally new soldiers in control units. Horizontal cohesion at any point in time is, along with confidence in NCOs, a significant predictor of junior enlisted soldiers' willingness to go to war with their small unit.

Part of WRAIR's UMS research involves an evaluation of the development of light infantry units. Results from this research suggest that the policies used to implement the light concept were sound, but that the units involved did not fully achieve the objectives set for them because the behavior of commanders and leaders often functions at cross purposes to policy.

Data from WWII suggest that the soldier who arrives at a new unit with a buddy or as part of a small group has a better adjustment and in combat, a higher likelihood of initial survival than the soldier who arrives alone. A related UMS study of replacement practices demonstrates this adjustment effect even in highly cohesive combat units. This study also suggests problems in the way some unit leaders deal with new arrivals.

Interview and observational data show that COHORT soldiers have no difficulty integrating and socializing small, preformed groups of new soldiers (COHORT packages). Data show that many NCOs and officers do not involve themselves in the integration process and many leaders are resistant to the concept of keeping newly arriving soldiers together in preestablished groups. Their natural tendency is to "fill spaces with faces" without regard to the new soldiers' need for psychological support during the transition period.

Our research suggests that the optimal size for group replacement in a combat arms line company is four to eight soldiers per platoon. Results also indicate that keeping small groups of replacements together provides a powerful and inexpensive technique to reduce stress and ensure a soldier's rapid acceptance into the combat team.

WRAIR's broad range of family-focused studies provide an example of the military relevance of the social-psychological aspects of stress. Families are important to medical readiness for three reasons. First, we know that more than half of our deployable soldiers are married. Secondly, we know that family issues are important sources of life stress, as well as life satisfaction. Finally, we know that all stress is cumulative. The soldier deploys to combat carrying pre-existing stress burdens onto the battlefield.

In WRAIR's ongoing study of the Army's implementation of the Unit Manning System, WRAIR scientists have demonstrated that social support from other unit wives acts as an important buffer against the stress associated with husband absence. They have also shown that a wife's attitude about the leadership in her husband's unit has a direct impact on his morale.

Finally, research conducted by WRAIR's Medical Research Unit in West Germany demonstrates that the vast majority of adolescent family members makes a successful adaptation to overseas life. In addition, this research highlights a number of actions that facilitate adolescent adjustment, including arranging family moves as close to the start of the school year as possible to insure that the adolescent has an opportunity to initiate new peer relationships as soon after the move as possible.

At WRAIR's Fort Bragg, NC field research unit, scientists have examined an array of duty stressors experienced by our rapid deployment forces. This research focuses at the small unit level and involves a significant command consultation component. A primary topic of research this year has been "burnout," diminished individual and unit level functioning as a result of perceived excessive duty demands and corresponding difficulties meeting personal and family responsibilities. This research has identified a number of unit practices that contribute to burnout, and WRAIR's consultation with unit commanders has demonstrated the value of eliminating unnecessary duty requirements and moderating the impact of others, especially requirements unique to the rapid deployment mission. One of these issues, the importance of a predictable duty schedule for personal and family well-being, supports similar findings in WRAIR's UMS research.

As a result of our 1985-1986 study of the air crash at Gander, Newfoundland, Canada where 248 members of the 101st Air Mobile Division perished, WRAIR has continued the development of a traumatic stress research program. WRAIR's current research suggests that many of the Gander Survival Assistance Officers (SAO) experienced a delayed negative impact associated with their helper role (both physical symptoms and psychological distress). Research data also suggest that interpersonal support from duty supervisors, family, and friends has an important moderating effect on the stress associated with SAO duties.

This year WRAIR was able to begin building a network of relationships with other federal and civilian institutions interested in the social-psychological aspects of disaster and traumatic loss. In addition, WRAIR has established program objectives that include: developing doctrinal principles and effective medical and leadership practices to manage the effects of traumatic stress in military units and communities, and to effect the reconstitution of units that have suffered traumatic losses. Twelve related projects are now in varying stages of development, ranging from an effort to develop a model for grief leadership to the study of ways to moderate the psychological impact on soldiers whose duties require them to handle human remains after incidents of traumatic death in combat or a disaster.

WRAIR's neuroscience research has also complemented the social-psychological study of combat stress issues. For example, WRAIR scientists have found a very useful natural laboratory for examining stress as a function of military duty, as well as the effects of stress on military performance. The "laboratory" is the Soldier of the Month Board, a rigorous, structured interview before a panel of senior noncommissioned officers that tests, among other things, a soldier's knowledge of job-related subjects.

While the number of subjects tested is small, WRAIR scientists have demonstrated that a psychosocial stressor can rapidly activate physiological and biochemical indices of arousal in healthy young males. Among other findings, the board's competitive oral exam elicits significant increases in heart rate and plasma levels of stress-related hormones and peptides. Most importantly, WRAIR scientists believe that they have found a simple, militarily relevant model suitable for studying not only endocrine and cardiovascular responses to psychological stress, but for the study of immune responses to stress as well.

During any mobilization, soldiers are subjected to various physical and psychological stressors for prolonged periods of time. This typically causes impaired immune host defenses which result in increased susceptibility to infectious diseases and, consequently, personnel losses and decreased unit effectiveness. The mechanisms by which adaptation to stress affects immune function are unknown. WRAIR's efforts to obtain this knowledge should allow the development of pharmacologic strategies to prevent or treat threat-induced immunocompromise.

This year WRAIR scientists also demonstrated that the anterior pituitary stress-responsive hormone prolactin is vital in the maintenance of normal immune function. Prolactin prevents immunosuppression resulting from chronic stress and appears to be a potent counter-regulatory hormone opposing the effects of glucocorticoids on immune function. Plans are now underway to move from current animal tests to tests of human subjects at extreme risk for secondary immunosuppression.

Finally, WRAIR scientists have continued to study ways to sustain soldier effectiveness in the face of operational stress. Multiple factors contribute to operational stress. Recent factors examined by WRAIR scientists include the effects of brief and fragmented sleep or no sleep, episodic and continuous mental and physical stress, and individual vulnerability to operational demands.

WRAIR is conducting field studies of continuous operations to determine the degree to which sleep is restricted and fragmented in actual operational settings. WRAIR scientists are also pursuing studies of behavioral and pharmacological ways to increase the recuperative value of sleep during continuous operations.

Initial data collected during field training exercises at the National Training Center and the Ranger School indicate that soldiers sleep when they have the opportunity, but that demands of the mission and "friction" of operations restrict these opportunities. Even when sleep is possible, poor sleep habits (e.g. sleeping sitting up in a jeep, near a radio etc.,) and inadequate sleep discipline (lack of encouragement to sleep by command) limit the duration and continuity, and hence the recuperative value of the sleep obtained.

These studies have also demonstrated that it is the problem of brief and fragmented sleep, rather than total sleep deprivation, that characterizes continuous operations. It is soldiers with command and control responsibilities, including unit leaders, who are more likely to be sleep deprived during continuous operations. Those whose responsibilities will be most negatively affected by lack of sleep are typically those who actually obtain the least sleep.

Summary

WRAIR's research into the causes, consequences, and moderators of combat stress reactions covers a broad range of scientific effort and it continues to produce an even broader range of information of value to Army planners, policy makers, program managers, and most importantly, unit leaders.

Combat stress is a major threat to success on any modern battlefield. Understanding the causes, consequences, and methods of moderating combat stress are critical readiness issues. WRAIR's accomplishments in this area continue to be a major contribution to a trained and ready Army. They also illustrate the critical importance of information as an RD&A product contributing to our Army's success on future battlefields.

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LABCOM SPONSORS TECHNOLOGY SYMPOSIUM

By Dave Davison

More than 500 people from all levels of the Army, Department of Defense, Congress, the Office of the President, and the media got a first-hand look at the technology of the future battlefield at a technology symposium June 6-8 at Aberdeen Proving Ground, MD.

"Army Science and Technology for a Strong America" was the theme for the symposium which featured more than 80 exhibits and demonstrations. It was sponsored by the U.S. Army Laboratory Command (LABCOM), a major subordinate command of the Army Materiel Command (AMC).

"The LABCOM Technology Symposium was a tremendous success," said BG Malcolm R. O'Neill, LABCOM commander. "There is no doubt that we got our message across — the Army in-house labs are alive and well and leading the way in the development of new technologies which will give our present and future soldiers the advantage on the battlefield."

Scientists and engineers from LABCOM's seven laboratories demonstrated the capabilities of a broad spectrum of the Army's newest technologies. These included robotics, composite materials, lasers, smart weapons system, radars, information and signal processing, advanced electronics, flat panel displays, advanced computing, atmospheric effects, and human factors engineering. There were also demonstrations of vulnerability and lethality assessments.

Also exhibited were a number of joint service programs and cooperative laboratory efforts including teleoperated robotic vehicles, a joint Army/Marine Corps initiative; and the AirLand Battle Management Program, a joint Army/ Defense Advanced Research Projects Agency program to develop decision aids for corps and division commanders and their staffs.

A representative sampling of exhibits and demonstrations at the symposium ranged from robotics to composites and from signal processing to countermeasures.

• Remotely driven robotic vehicles included the Soldier/Robot Interface Program (SRIP) vehicle, a laboratory tool for evaluation of potential military applications of telerobotics. LABCOM also displayed its Tech-Base Enhancement for Autonomous Machines (TEAM), a four-lab cooperative project which addresses critical battlefield issues of a telerobotic weapons platform.

TEAM exhibits included the Robotic Drive Control package, a microprocessor-based system which can control the steering, throttle, brake, transmission and transfer case thereby transforming standard vehicles into robotic vehicles; and the Automatic Target Acquisition System, designed for ground-based robotic platforms, as part of an unmanned anti-tank weapon system being developed for use in areas known to be contaminated, mined or otherwise life-threatening.

• A composite hull of advanced thick composite for use in armored combat vehicles that meets the severe ballistic and structural performance requirements with lighter weight.

• Smart munitions included the Anti-Personnel/Vehicle Radar, a short range radar for vehicle/personnel detection; the Frequency Modulated Continuous Wave Sensor which detects targets such as tanks, airplanes and helicopters; and Sense and Destroy Armor capable of detecting vehicular targets at close range.

• Mini-Moving Target Indicator Surveillance Radar for Unmanned Aerial Vehicles is a radar sensor weighing less than 110 pounds packaged to fit mid-sized UAV's. It provides high performance target detection, location and tracking of moving ground vehicles and low-flying helicopters.

• The Information Processor Test Bed, housed in an S-250 shelter mounted on a Commercial Utility Cargo Vehicle, collects, processes and disseminates time-critical combat information on the battlefield.

• VHSIC (Very High Speed Integrated Circuits) and MIMIC (Microwave Millimeter Wave Monolithic Integrated Circuits) technology insertion. Both are DOD tri-service initiatives.

Also demonstrated were new field capabilities developed under the AMC-FAST (Field Assistance in Science and Technology) program. AMC-FAST focuses AMC resources to rapidly idenify and solve field Army technical problems through technology demonstrators.

Among the demonstrations were a limp-home capability for the M1/M1A1 Abrams Tank developed for use in emergency conditions; an auxiliary power unit to provide emergency power to the M1A1 Abrams Tank; a vehicle navigation aid for a wide variety of vehicles to help the soldier know where he is on the battlefield; and the Individual Soldier Operated Personal Acoustic Detection System which combines acoustics and fluidics to amplify sounds and extend the soldiers listening range during perimeter defense.

"One of LABCOM's greatest challenges is to help America remain competitive as we move into the 1990s and prepare for the 21st Century," O'Neill said. "The technology symposium was a unique occasion in which participants had the opportunity to learn what the Army Materiel Command's corporate laboratories are doing to meet today's challenges in science and technology."

Through the symposium, the first sponsored by LABCOM, the command hopes to promote better understanding of the laboratories' technology activities, to demonstrate the laboratories' products and capabilities and to build interest within the military community in using the laboratories' services.

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EXPERIMENTAL TRUCK ENTERS SECOND PHASE

By George Taylor

The U.S. Army Tank-Automotive Command (TACOM) and General Motors are now in the second phase of a joint program to demonstrate the feasibility of using advanced technology in future Army tactical trucks to make them lighter and improve performance and mobility.

Phase 2 began last October, when the command awarded GM a contract to build an Advanced Technology Transition Demonstrator (ATTD) 5-ton truck. GM will build the vehicle on the chassis of an existing M939-series 5-ton truck. Most of the other major components, however, will be different from those used in the standard vehicle and will represent the latest advances in technology.

It will be the second such vehicle to be built for the program. During Phase 1, GM, using different components than those planned for the Phase 2 truck, fabricated the first demonstrator on a military 5-ton truck chassis. (See Advanced Technology for Future Trucks, *Army RD&A Bulletin*, July-August 1987.) It was completed in January 1988. Since then, it has undergone mobility tests at the Waterways Experiment Station (WES), Vicksburg, MS, and 4,000 miles of performance and mobility tests at Aberdeen Proving Ground, MD.

The objectives of the program are to demonstrate enhanced mobility and propulsion, and to upgrade future-generation tactical-vehicle specifications.

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A unique feature of the Phase 2 truck will be Rockwell International-developed, fully independent suspension axles instead of the solid-axle design commonly used in the driving axles of most trucks and passenger cars. In such a system, the differential at the center of the axle, which distributes power to the wheels, is anchored to the frame of the vehicle. The axle shaft on each side of the differential has a bell joint that allows the wheel at the opposite end to move up and down independently as the vehicle encounters bumps.

"A fully independent suspension system offers advantages over the solid-axle design," explained Milan Mekari, in charge of the truck demonstrator program in TACOM's RDE Center. "One of these is that it permits increased vehicle ground clearance, because the differential — which remains stationary and thus requires no space for upward movement when the wheels hit a bump — can be mounted higher in the vehicle.

"An independent suspension," he continued, "also provides an improved ride, less cab vibration and better mobility because only the wheel that encounters a bump moves upward. The other wheels stay on the ground and continue to drive the vehicle."

The differential will further enhance vehicle mobility by providing improved traction on mud, snow and ice. It is an advanced limited-slip differential with a minimum torque-biasing ratio of 8:1.

Like the limited-slip differentials in some cars and trucks, the truck demonstrator version automatically shifts the driving torque away from a slipping wheel and transfers it to the opposite wheels. But unlike the conventional design, which applies equal torque to both wheels, it multiplies the torque being transferred to the non-slipping wheel by eight times the amount originally applied to the slipping wheel.

The truck's engine will be a 6.6 liter, 6-cylinder Caterpillar diesel. Its displacement is less than that of the 8.3-liter, 6-cylinder diesel that powers the standard M939A2 5-ton truck. Yet, the new engine develops 290 horsepower, 50 horsepower more than the larger engine. Mekari said there are two reasons for the significant horsepower increase. First, the engine has electronic controls that provide near optimum fuel-injection timing for maximum thermal efficiency. Also, it is equipped with an improved fuel-injection system and turbocharger which deliver fuel and air to the cylinders at pressures some 50 percent above traditional levels.

The engine will be equipped with an experimental self-cleaning air-filtration system, developed by Donaldson Corp., in which vibration is used to remove dust from the filter element. The element is connected to an electrically driven vibration mechanism which periodically shakes it when the dust buildup on the element's surface begins to restrict the airflow to the engine. As the element shakes rapidly, the dislodged dust particles fall into a duct that is connected to the engine's exhaust system, and are scavenged via the tailpipe.

The filtration system will have a dust detector that will warn the driver if excess dust particles should get past the filter element and enter the engine.

The engine will also include three features to make cold-weather starting easier. One of these is an air-driven starter motor, which weighs less than the traditional electric motor yet produces higher torque and cranking speed in cold temperatures. It also means a reduction in the number of batteries from the four required in the standard 5-ton truck to one for the ATTD.

The other two cold-starting aids are a diesel-fuel-fired intake-manifold flame heater that will preheat the incoming air and an in-line electric heater to warm the fuel.

The truck will use a unique radiator design now being developed by Beltran Associates of Brooklyn, NY. It does not use the traditional one-piece mesh radiator core. Instead, it has a core consisting of a series of vertically mounted pipes. The pipes radiate or reject excess engine heat through fins like those used in baseboard heat pipes. Each pipe is partially filled with water or other fluid and hermetically sealed. Its lower end is then inserted into a hole in the top of a rectangular-shaped engine-coolant tank and sealed in place to prevent coolant leakage.

In operation, hot coolant flowing from the engine into the tank touches the ends of the pipes and transfers heat to them. This converts the liquids in the bottom of the pipes to steam. As the steam rises, the heat travels along the entire length of the pipes and is dissipated by the engine's cooling fan.

"The nice thing about this design," said Mekari, "is that if some of the pipes get damaged, the vehicle can still run because the other pipes are not affected and can continue to cool the engine."

The truck will have a Detroit Diesel Allison six-speed, electronically controlled automatic transmission whose design is unique. Unlike conventional all-wheel-drive designs, in which the transmission and transfer case are separate items, this one combines them into a single unit that requires less space and is easier to maintain. Also, the transfer case provides full-time all-wheel drive.

Another feature of the truck will be an experimental version of the Army's Vetronics (vehicle electronics) concept now under development. Planned for introduction in the 1990s, Vetronics is a system design with common hardware and software modules that will support both combat and tactical vehicles. It will use multiplex wiring to simplify the complex vehicle wiring harnesses now in use and integrate many of the control and display functions, thereby improving crew efficiency and combat effectiveness.

The truck will have a Detroit Diesel Allison six-speed, electronically controlled automatic transmission whose design is unique.

Plans also call for extensive use of composite body components throughout the ATTD to reduce vehicle weight and improve corrosion protection.

Mekari said the Phase 2 ATTD truck will be ready for testing in December 1990, at which time it will undergo mobility and performance tests at WES and Aberdeen like those of its Phase 1 counterpart. The tests are expected to last about nine months.

TACOM is also testing two antilock brake systems — one being developed by Westinghouse Air Brake Co. and the other by Bendix Corp. — on the Phase 1 truck.

When the upcoming tests are completed, TACOM hopes to test other new or improved components on a third ATTD truck, which will be a High Mobility Multipurpose Wheeled Vehicle.

GEORGE TAYLOR is a technical writer-editor for the Army Tank-Automotive Command. He holds a bachelor's degree in journalism and a master's degree in communications from Michigan State University.

THE MANPRINT METRIC IN TESTING AND EVALUATION

By Dr. James C. Geddie

The ultimate goal of the Manpower and Personnel Integration (MANPRINT) program is to influence system design so that Army fielded systems provide the required performance at the minimum total life cycle cost. This includes all expenses associated with acquisition and use of the system from initial concept to disposal.

For systems recently fielded by the Army and for those still in development, the life cycle cost projections for a system typically show only about 20 percent of the total cost to be absorbed by research, development, and acquisition costs. Operation, maintenance, and other support costs absorb the remaining 80 percent. This later 80 percent is heavily weighted with "people costs" to include trainers, operators, maintainers, and others.

Thus, Army planners now understand that greater emphasis on developing systems that have an effective and efficient soldier-machine interface — even at the expense of increasing the up-front acquisition costs — promises soldier-machine systems with enhanced total life cycle cost effectiveness.

Before discussing MANPRINT testing and evaluation, it is important to clarify some important aspects of the relationships among the six MANPRINT domains. Of the six MANPRINT domains, human factors engineering is unique among them in that, while it clearly belongs with the others in any list of domains to be considered in integrating human requirements into system design, it is the only domain that offers a direct way to influence hardware design.

The system engineering requirements generated by the MANPRINT domains result in human engineering specifications as design inputs. In attaining the MANPRINT goal, considerations involving the MANPRINT domains either affect the requirements of some other MANPRINT domain or they affect system engineering via human engineering design of the system's hardware. Human engineering design is the only way in which they can affect anything other than the MANPRINT domains themselves. For example, if a given human task is not being performed quickly or accurately enough to support system performance requirements, the system design change required to correct the shortcoming can address either the human or the machine side of the human-machine interface.

If a hardware change is selected as the solution, we are dealing with a human engineering design change. However, if the shortcoming is addressed via the human side of the interface, the change involves either the number or the characteristics of the people who perform the task, or their training, thus impacting on the manpower, personnel, or training requirements of the system.

Soldier-Machine Systems Versus Hardware

The increased emphasis on the soldier-machine interface within the engineering design process as emphasized by the MANPRINT program, is not a sudden change (see Figure 1). Instead, it has been a gradual one related to an emphasis on developing total systems. This is in contrast to developing separate hardware, training, software, logistic support, technical documentation, and facilities and later combining them into an effective system. This metamorphosis is by no means complete. There are many members of the acquisition community who still say "system" when what they really mean is "hardware."

At first encounter, the difference between the two concepts may seem somewhat superficial, but it has fundamental implications for the way in which the Army develops new combat systems. It also has some profound consequences for testing and evaluating developmental systems (see Figure 2).

During development, the systems approach requires that many players get into the process right at the beginning. The materiel developer, the combat developer, the trainer, the logistician, and several others must participate in defining goals, requirements, and limitations for the system.

Unlike the somewhat fragmented approach to development just mentioned, the systems approach requires that each player participate in a tradeoff process. In this process, all participants make an attempt to arrive at a cost-effective means of acquiring a new combat capability. For example a tradeoff which might be negotiated is a choice between: a hardware design that is high in acquisition costs but imposes human performance and skill requirements that are cheap to acquire and maintain, versus a hardware design

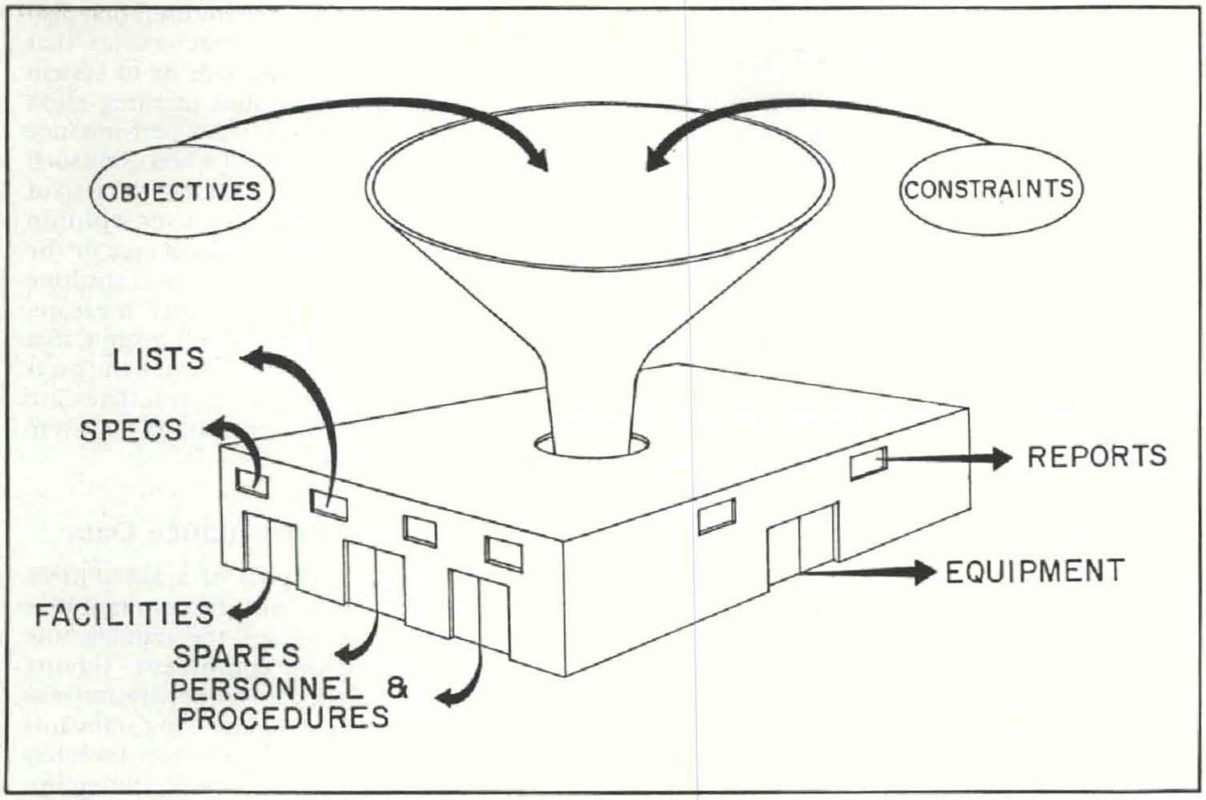
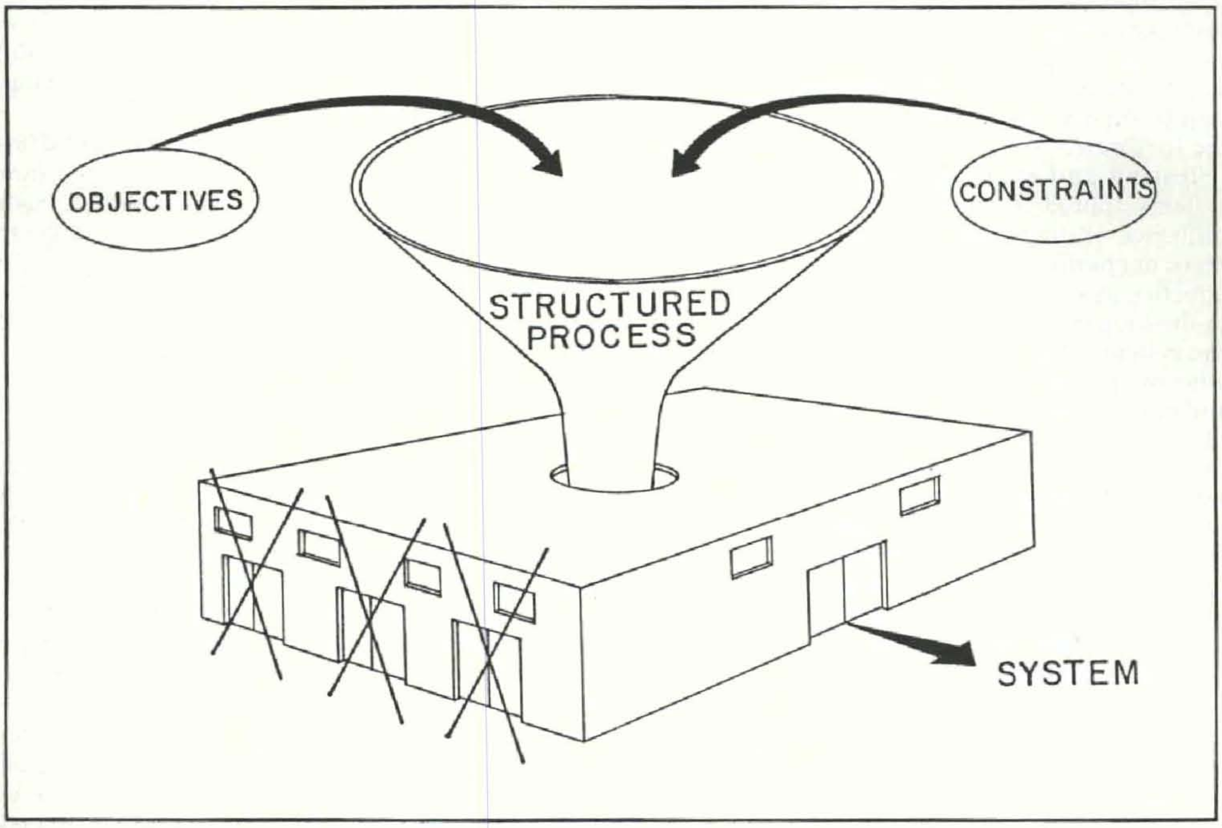


Figure 1. Traditional Approach

Figure 2. System Engineering Approach



that is lower in acquisition costs but requires human performance and skills that may be very costly to acquire and maintain. Based on the available cost predictions, the alternative meeting the system goals at the lowest life cycle cost could be selected. Now, what does all of this have to do with MANPRINT testing and evaluation?

Implication for Performance Measurement

Once the focus of attention shifts from "materiel" to "system," the business of testing and evaluation becomes quite different from testing of materiel alone. In component level and even in subsystem level testing, hardware functions are exercised in a way in which any human function is assumed to have a probability of 1.0 of being correctly performed the first time and every time. The concern in this type of testing is nothing more than "Did the hardware work as expected?" The assumption is explicit that failures due to human error are not chargeable to the hardware design.

An implicit (and probably wrong) assumption of this approach is that the manpower, personnel, and training resources available when the system is fielded will be capable of meeting whatever human performance requirements have been built into the hardware.

Testing and evaluation under a systems approach acknowledges the influence of the human operator and his or her performance on total system effectiveness and reliability. Soldier-in-the-loop testing attempts to exercise the system using a sample of soldiers who, by aptitude, training, experience, and physical characteristics, are typical of the average user. An attempt is made to control the variation in this soldier sample by using selection criteria or at least to account for it with demographic data. Within available test resources, system functions are exercised over a representative sample of the conditions (terrain, weather, visibility, and others) that are anticipated when using the system in training and in combat.

In the interest of efficiency in using test resources, human performance testing is often conducted as a part of testing for other aspects of the system's performance. For example, in testing a vehicular system, data on critical driving tasks might be collected on the same exercises used to test reliability or durability of the vehicle.

MANPRINT Test Data

Whether MANPRINT data are collected in a separate test or during testing of some other aspect of performance, there are basically three kinds of information that will be collected. These are engineering measurements, user opinion, and human performance data. Each has its own role in the evaluation and will be treated separately.

Engineering Measurements

When the project management office or the prime contractor on a system begins to plan for MANPRINT testing and evaluation, they usually consider engineering measurements first. When establishing the system's goals, requirements, and limitations, applicable military standards and specifications should be cited by the government as design standards to be met. Requirements documents may also specify military handbooks and other sources of guidance for use in hardware design. In general, engineering measurements are the data used to evaluate compliance with these requirements. The required data may often be collected without participation of the human component of the system and may address requirements in such areas as: size; weight; lighting level; noise level; crew workspace layout; ingress and egress provisions; temperature; vibration; display brightness, legibility, and labeling; and control placement and force requirements.

User Opinion

This second category of information is gathered from test participants, test control personnel, and observers. It is used to learn about those characteristics of the system that might not be revealed by engineering measurements. It is generally accepted that troops will not function at optimum effectiveness with equipment they dislike or mistrust, thus limiting system performance.

Obviously, the most direct way to find out how a user feels about the equipment is to ask his opinion. User insights may sometimes suggest improvements in hardware design or in operating procedures that compliance checking would not reveal.

Problems reported by users may also identify system characteristics that point to health hazards or to system safety problems, thus meriting close scrutiny during human performance testing. It is important when using such information not to fall into the trap of accepting subjective user opinion regarding system performance or the user's own performance as a substitute for objective performance measurement. In addition, don't assume that system characteristics which the users don't like necessarily translate into degraded soldier-machine system performance.

Human Performance Data

The overall goal of a MANPRINT program is to ensure compatibility among the soldier, the training, the tasks, and the equipment. Having compared the hardware characteristics against human engineering standards and having trained a sample of soldiers and elicited opinions of the equipment and training, the remaining task in determining whether the MANPRINT goal has been met, is exercising mission-critical soldier tasks and collecting and analyzing performance data on those tasks.

Collection of data must be based on a review of the human performance requirements associated with the system. If the performance requirements have been properly specified in the requirements documents and a usable task analysis is available, a good start has already been made on identifying tasks on which to collect human performance data.

Other inputs to the task selection process should include technical manuals and training materials used in training test participants. The list of selected tasks should have as its highest priority those tasks whose performance defines an outer limit on total system performance (e.g., in a tank system — loading, laying, and firing the gun).

There are two basic measurements used in human performance testing: human performance time and error rate. For each task exercised and measured in the test, both kinds of data must be collected on each event. The reason for insisting that both measures be made of each event is that for most tasks, performance time and error rate can be traded off one for the other.

The priorities with which the test participant approaches any task can radically affect whether he emphasizes speed of performance at the expense of accuracy or conversely, accuracy at the expense of speed. For some tasks, the trade-off function itself may be more important than either data point alone in affecting both design changes and operational doctrine for the system.

The analysis of these data should first compare achieved performance against the performance goals established in the system requirements documents. If the system's front-end analyses have been thorough enough to define criteria for task performance, then they also define the test criteria.

In the case of systems for which the criteria have not been stated, the performance data are used in predicting what the performance in the field will be. The question of "How good is good enough?" then gets a post hoc answer, but at least the decision of whether to accept a system can be an informed one, based on knowledge about currently achieved performance.

Another use, perhaps a more important one, for these data is identifying areas in which human engineering design improvements have a high potential payoff in terms of reducing "people costs" or improving the system's performance. If, for example, the data show an unexpectedly long performance time for one of a series of sequentially performed tasks, then that task would be identified as a priority candidate for improvement in the hardware associated with it or the procedures for performing it.

Consideration might also be given to machine aiding or to automating part or all of the task's performance. The costs of these alternatives would be compared to the costs associated with attempting to improve task performance by setting higher soldier selection criteria or by investing in more training on that task.

MANPRINT Evaluation

The bottom line for a MANPRINT evaluation of a soldier-machine system is reached when the evaluator answers the question "So what?" for each test issue. The specifications and standards against which we evaluate engineering measurements should be met. Their criteria have been developed from experience with many past systems, and meeting those criteria improves the probability of acquiring an effective and efficient soldier-machine system. However, meeting those requirements does not by itself assure that this has been achieved, nor does failure to meet one or more of the criteria guarantee an unsuccessful system.

Likewise, the user's feelings and attitudes toward the system are important. The Army has demonstrated too many times that a system that is not liked or trusted by the users has little chance of operational success. However, we must remember that there is not a one-to-one correspondence between equipment characteristics about which users complain and equipment characteristics that can be shown to degrade their performance or total system performance.

In competitive testing, soldiers often state a preference for an equipment design with which their performance is worse than with a less liked competitor. There is a lesson we must acknowledge from this reversal: although test participants will readily express their feelings about how well they like a system, and are seldom reluctant to evaluate their and the system's performance, regardless of how precisely and accurately we might measure those feelings and attitudes, they have (at least in my small sample of opportunities to compare them with objective performance data) been observed to have no consistent relationship to objectively measured performance.

The indications from engineering measurements and from user input are important in a system evaluation. They should influence the selection of tasks for human performance testing. Obviously, if an equipment characteristic clearly violates a human engineering standard or users feel that it significantly degrades their performance, then that characteristic merits closer examination. But the system, the human factors profession and technical area, and the MANPRINT program are all done a disservice when we attempt to evaluate system performance or human performance as one of its components without objectively measuring that performance.

The risk to the system is simply that our evaluation may be wrong, and we end up "fixing something that isn't broken." We might also accept a system with design errors that reduce system performance without our even knowing that performance has been reduced. The long-term damage to MANPRINT or to any other program that attempts to integrate "people considerations" into system development may be much more significant.

We are continually challenged to document the value of human engineering and related disciplines to system design. When we justify decisions to change (or not to change) a system's design based on a prediction of performance consequences, then base those predictions on anything less than hard performance data, both our credibility and future acceptance of MANPRINT inputs are jeopardized.

Put a bit more colloquially, if we want to know whether the materiel design has complied with the system specification and with applicable criteria in the standards, engineering measurements are appropriate; if we want to know whether the user likes it, user opinion is appropriate; but if we want to know how well the humans in the system perform, and how their performance relates to total system performance, there is no defensible substitute for human-performance measurement. That, I submit, is as close as we can get to having a MANPRINT metric.

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CONTRACTOR PERFORMANCE CERTIFICATION

By Paul Levesque

Encouraging Contractor Participation in Total Quality Management

In the spring of 1988, the Department of Defense launched a new quality enhancement effort known as Total Quality Management. The goal of TQM, which is based on the theories of noted quality consultant Dr. W. Edwards Deming, is to get the best possible weapons, equipment and ammunition into the hands of American service members at the lowest possible cost.

While TQM's goal may be laudable, it will always remain out of reach unless it is shared by contractors in the private sector who produce most defense-related items.

Fear not, quality fans: There's at least one program in place specifically designed to encourage the growth of quality enhancement efforts and modern management techniques among contractors who do business with the Army. It's known as the contractor performance certification program, or CP2 for short.

CP2 is a combined initiative of the U.S. Army Materiel Command, the Defense Logistics Agency, and the Army's contractors. One organization within the Army Materiel Command, the U.S. Army Armament, Munitions, and Chemical Command, has taken the lead in working toward the program's goals.

AMCCOM's participation in CP2 is critical because the command manages the development, procurement, maintenance and transportation of conventional ammunition for all services, not just the Army. Its responsibilities also encompass artillery pieces, air defense systems, machine guns, and other weapons that launch ammunition, any related test and maintenance equipment, and chemical protective gear. Currently commanded by MG Marvin D. Brailsford, AMCCOM is headquartered at Rock Island Arsenal, IL.

The contractors that produce the aforementioned items have been invited by AMCCOM to take part in CP2. Those accepting the invitation can eventually be certified in recognition of their efforts to reduce costs and upgrade product quality. In turn, the contractors promise to make a continuous effort to improve quality and productivity.

Because of the commitment to quality demonstrated by CP2-certified contractors, the number of government quality assurance representatives assigned to their plants is reduced. (QA reps are stationed in contractor plants, either permanently or on a rotating basis, to assure that

AMCCOM's participation in CP2 is critical because the command manages the development, procurement, maintenance, and transportation of conventional ammunition for all services, not just the Army.

Companies who wish to gain CP2 certification must go through an auditing process, to assure that they have a viable quality enhancement program in place and a long-term corporate commitment to quality.

production and quality goals are being met.)

Command CP2 coordinator Ralph Wunder, who serves as a branch chief in the Product Assurance Directorate at AMCCOM Headquarters, noted that the program initially stemmed from a desire on the part of contractors to reduce the government presence in their plants.

"Using CP2 in this way can benefit the government as well as contractors," Wunder said. "We can use our resources more wisely by concentrating our QA reps where they are needed, rather than using them at contractors with good quality track records."

Nevertheless, Wunder stressed that reducing the number of government employees stationed in contractor plants was not the main goal of CP2, nor its main source of mutual benefits.

"CP2's objective is to spread the message of TQM by spotlighting our quality producers and letting them know that their efforts in this area are appreciated," Wunder remarked. "The program has also helped open up whole new lines of communication and understanding."

According to Wunder, participation in CP2 is strictly voluntary and entirely extra-contractual: In other words, taking part in the program leads to no changes in the scope of work or price of a particular contract. Nor does CP2 certification give companies any direct advantage in bidding on future contracts.

"However, if CP2 can help a company become more productive and efficient," Wunder remarked, "then that company obviously has a better chance of being the low, responsive bidder when other contracts are let."

While CP2 contractors may see a reduction in the number of QA reps in their plants, Wunder emphasized that this government presence was by no means eliminated. He pointed out that the government reserved the right to perform unannounced in-plant inspections and to return a full staff of QA reps to a plant if it feels a contractor's quality performance has deteriorated.

Companies who wish to gain CP2 certification must go through an auditing process, to assure that they have a viable quality enhancement program in place and a long-term corporate commitment to quality. Thus far, only one contractor has passed its audit and been certified under CP2. About 25 others are currently being audited and are vying for certification, and some of them are very close to achieving it.

To date, AMCCOM's one and only CP2-certified contractor is Harley-Davidson Inc. The well-known motorcycle maker also produces MK82 bomb bodies for the Army at its plant in York, PA.

According to Wunder, Harley-Davidson gained certification quickly because its TQM program was much further advanced than that of any other contractor who applied for CP2. Yet, despite Harley-Davidson's reputation for quality, the company waited more than a year after their initial application before gaining CP2 certification. Wunder remarked that the wait for other companies will probably be much longer.

"That's because the audit we perform is very detailed and very thorough," Wunder explained. "This benefits the company being audited, though, because they get a real good look at where their management and quality systems stand."

CP2 auditors research a lot of different technical and managerial areas, but one thing they do look for everywhere is a sincere corporate commitment to quality.

"It's not enough just to hang posters in your factory stating how important quality is," Wunder said. "We expect to find attention to quality at all levels of an organization. If it's not there, then that company won't be certified."

Auditors discuss their findings in detail with company representatives, and Wunder noted that these talks had already led to better cooperation and understanding between AMCCOM and its contractors.

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FROM INDUSTRY

APPLYING TQM TO THE DOD ACQUISITION PROCESS

By Dr. Richard A. Stimson

Editor's Note: The following article reflects the views of the author and should not be interpreted as the official position or policy of the Department of the Army or any of its agencies.

The new leadership in the Pentagon is placing a high priority on improving the acquisition process. Many members of Congress feel that reforms advocated by the Packard Commission and the Goldwater Nichols legislation in 1986 have fallen between the cracks. David Packard, former deputy secretary of defense, has stated in Congressional testimony that, "One could do just as good a job...in awarding the major contracts by putting the names of qualified bidders on the wall and throwing darts." (*Washington Post*, July 31, 1988)

The Department of Defense (DOD) has launched a number of new initiatives to improve the acquisition process. One such initiative is designed to significantly improve the quality of contractor produced goods and services. Total Quality Management (TQM) is its name, and the principles upon which it is built parallel the quality improvement approach now being applied in the private sector based on the teachings of quality gurus such as Deming and Juran.

The TQM approach provides the mechanism to improve the acquisition process, but it is not necessarily a foregone conclusion that it will. It depends on whether DOD can transform philosophy to practice. Deming preaches that the practice of awarding business on the basis of price should cease. Instead, reliance should be placed on meaningful measures of quality, along with price. Suppliers should be eliminated that can not qualify with statistical evidence of quality. The highest possible efficiency, and hence the lowest overall cost, is achieved when a supplier's system is under statistical control and capable of producing within specification requirements (Deming's 14 points).

It may appear that TQM is contradictory to an acquisition process that places heavy emphasis on competition and awarding contracts to the lowest responsible bidder. This article takes the position that TQM and competition in contracting are not contradictory. In fact, application of the TQM philosophy to the acquisition process can not only improve the process, but accomplish the improvement without changing the acquisition rules.

This is not to say that using a TQM philosophy will be easy. The key is in not following a regulatory, rule oriented approach to implementing TQM. There are already over 4,000 laws and 30,000 pages of regulations issued by 79 offices that regulate the acquisition process. More rules are not needed. TQM is a management philosophy, not a set of rules or requirements. It provides a basis for sensible use of existing rules, regulations, and requirements.

It is not comforting to observe that some early contractual applications of TQM are requiring its implementation as a set of requirements added to all other typical contractual requirements. No attempt has been made to harmonize TQM with other requirements such as quality assurance (Mil-Q-9858), reliability, value engineering, design to cost producibility and other similar factors. The net effect is that costly new requirements are added to the contract with no reduction in the older established requirements. This is not the underlying philosophy of TQM.

TQM Philosophy

TQM builds on many existing management approaches, tools and techniques. What is different about TQM is a new focus on applying these practices from the perspective of a unique blend of Japanese and American management approaches. The essential features (according to David Garvin, *Managing Quality*, Boston: The Free Press, 1988) are: involvement of all functions, involvement of all employees, strong customer orientation, and a philosophy of continuous improvement.

These four elements must be supported by active involvement of top executives, managerial leadership, use of statistical tools, extensive training, and an environment that fosters teamwork. The involvement of all functions in improving quality of output can be traced to the work of Armond Feigenbaum of General Electric in the early 1950s and is referred to as "Total Quality Control (TQC)" or "Company Wide Quality Control." (Armond Feigenbaum, "Total Quality Control," *Harvard Business Review*, November-December, 1956.)

With regard to the acquisition process, the new philosophy suggests that an improved relationship among requirements developers, specifications writers, engineers, and contracting officials is needed if the acquisition process is to be improved. A team concept, which emphasizes coordination and cooperation among its members rather than a strict functional orientation, possibly encouraged by collocation of key functional experts, is an example of an application of this approach.

The involvement of all employees — management and professionals — seeking improvement and taking responsibility for his or her work is a key philosophy. This envisions transitioning from "fire fighting" to focusing on and improving the processes by which acquisition tasks are accomplished. Building on the cross-functional perspective, professionals can provide the ideas for process improvement and managers can see that the acquisition process is changed to reflect the improvement ideas.

With TQM, quality is defined from the customer's point of view and the "voice of the customer" is deployed throughout the organization. In the current acquisition process, the customer's needs are easily distorted as the interpretation of needs flow through various functional organizations and are ultimately translated into contract specifications. The specification becomes the critical link to inform the contractor of what the true DOD requirements really are. The correct translation of the customer's (user's) needs into contract requirements is critical to the process. The quality characteristic of "conformance to requirements" is meaningless without requirements that represent DOD's true needs. Also, the socialeconomic customer must be considered. Government contracts must satisfy both kinds of needs. At times, the needs of the military customer and the social-economic customer may seem at odds with each other. The use of TQM practices can harmonize the requirements of each.

A philosophy of continuous improvement is the last key feature. A high priority is placed on small incremental improvements as contrasted with major innovations. TQM is viewed from the perspective of a long term commitment as contrasted with a project approach focused on major changes which most likely can not be implemented because radical changes generate too much opposition.

Acquisition Process Viewed as a Barrier

On Dec. 16-17, 1987 a workshop was held in Washington, DC to review the DOD TQM initiative and to identify barriers to implementation. The workshop was jointly sponsored by the DOD, the National Security Industrial Association (NSIA), and the Aerospace Industry Association (AIA). The author was an organizer and co-chairman of the workshop. Approximately 100 experts on defense issues related to TQM were invited to attend. Workshop planners intentionally invited an equal number of DOD and industry representatives. Industry attendees were invited by the quality committees of each industrial association. DOD attendees were chosen by the individual services and the Office of the Under Secretary of Defense for Acquisition. Each service was given a quota of spaces to fill.

During the workshop, the attendees were divided into subgroups. Special attention was given to mixing the groups so that each had representation from industry and each service and agency. The most significant barriers to TQM implementation were identified as:

- The need for a clear definition of TQM
- The requirement for a single, consistent DOD approach
- The appropriate contractual application of TQM
- The total commitment from both DOD and industry
- The use of incentives to encourage the new behaviors
- The need for training in the new philosophy and tools

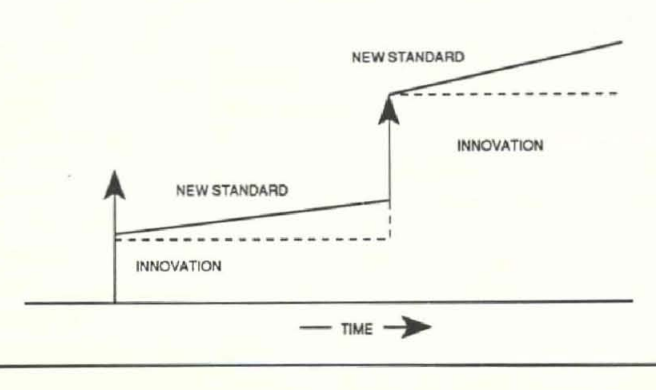
These results indicate that improving the acquisition process is critical to successful implementation of TQM.

A TQM Approach to Improve the Acquisition Process

An underlying assumption of using TQM to improve the acquisition process is that competition is a central theme now and will be in the future, and "set-aside" contracts for special needs in our society such as small business and minority firms, will continue to meet the needs of the social-economic customer. The real issue is that the price tag alone should not be the basis for contract award.

David Packard, in Congressional testimony, stated that past performance should be the main standard for contract award and he endorsed the Air Force "past-performance initiative" (*Aviation Week and Space Technology*, Aug. 8, 1988, p. 78).

PURSUE CONTINUOUS IMPROVEMENT STRATEGY



This Air Force initiative is designed to place more emphasis on a contractor's track record in source selection. In June of last year, the Air Force began compiling a data base that includes more than 650 evaluations of contractor performance throughout the Air Force Systems Command. More than 85 contractors are involved.

The strategy is to use a performance risk-analysis group to develop risk assessments for source selection officials based on the data base. Contractors will be ranked by risk in each category — low, medium, and high risk — and then factored into the source selection process (*Aviation Week and Space Technology*, Dec. 12, 1988, p. 37)

My own assessment is that this looks good in theory, but in practice could become a nightmare to administer. Some problems with it are: maintaining a current data base, maintaining continuity of risk assessment, and assuring that "apples" are compared to "apples" and not to "oranges." It is also questionable whether this system will survive a protest from a designated high risk supplier.

Instead of the past performance approach, I suggest a strategy that builds on existing practices, but with a TQM perspective. For purposes of illustrating this strategy, two classes of customer contract types will be used: major weapon systems and major subsystems/negotiated type contracts; and vendors or small subcontractors/fixed priced-sealed bid type contracts.

Major Weapon System Application

Selection:

• Use criteria such as technical performance, schedule, and cost as before. All of these criteria can be improved if the contractor applies TQM. Companies using TQM as a management philosophy will see their performance improve, cycle time decrease, and costs decline. DOD does not need to apply a specific TQM contract provision which would lead to increased contractor overhead.

Contract Management:

• Motivate contractors to allow them to share in the decreased costs resulting from TQM. Therefore, provide gainsharing as an incentive to pursue TQM. Many forms of contract incentives exist, e.g. award fees. If all the savings from TQM flow to the DOD, contractor profitability would suffer. The desirable outcome is a win-win situation in which DOD contract costs decrease at the same time as contractor profits increase. This is the essence of a TQM outcome.

• Conduct selective assessments (not the excessive, duplicate audits now in vogue) to review TQM application, e.g. management philosophy with respect to TQM attentiveness to quality, handling of quality complaints, manufacturing methods, use of statistical process control, and trend and dispersion of quality over time. The criteria used for the Malcom Baldridge National Quality Award could be tailored and used for this purpose.

Vendors Application Selection:

• Use receiving inspection to gather quality data and eliminate from consideration vendors that do not meet quality specifications.

• Use engineering departments in conjunction with purchasing to review statistical data and make the selection.

Contract Management:

• Devote time and resources to pursue continuous quality improvement for approved vendors. This includes providing training for small and/or disadvantaged vendors.

• Use receiving inspections less as policemen than as consultants to vendors to foster continuous improvement.

• Require new vendors to pass rigorous 100 percent inspection tests. As evidence from data justifies less inspection, statistical sampling and/or Just-In-Time (JIT) techniques can be used.

• Identify problem vendors through "hit lists." Vendors with chronic problems are dropped from further consideration. More detail could be provided, but this should be sufficient to give the reader an awareness of how TQM can be applied to the acquisition process. Much of it can be implemented with existing practices and no new rules or regulations are needed.

Acquisition Streamlining

One additional important point is a reminder that the TQM philosophy is driven by customer requirements. In DOD contracts, this is stated explicitly in the specifications provided. It is critical to the TQM process that these requirements be understood and reflected accurately in the specifications.

Norman Augustine, CEO of the Martin Marietta Corp., in a recent article (*Fortune*, Dec. 5, 1988, p. 219) contrasts the two page specification for the Wright Brothers airplane with one contractor's bid for a new aircraft that weighted 24,927 pounds. All too often DOD specifications contain excessive or conflicting requirements. The DOD Acquisition Streamlining Initiative (DODD 5000.43) is designed to provide accurate and concise specifications that reflect true DOD requirements.

Only a total quality approach, not a one dimensional approach, will be truly effective. However, it must be streamlined to the special features of the acquisition-contractor/vendor, buying agency and commodity. A combination of existing techniques brought together into mutually reinforcing practices can do the trick.

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TACOM gets HMMWV Robots

Two robotized High Mobility Multipurpose Wheeled Vehicles (HMMWVs) will help U.S. Army Tank-Automotive Command (TACOM) RDE Center engineers evaluate new robotic vehicle technology aimed at improving troop survivability.

The modified vehicles, which were prepared for TACOM by Kaman Sciences of Colorado Springs, CO, use the same power-train components as their standard counterparts. However, they have each been outfitted with a control system that enables an operator to drive them and perform tasks from a remote-control station.

Each HMMWV will be equipped with two-way communications equipment to handle remote-control signals, as well as a computer to interpret the signals and several computer-controlled actuators that control acceleration, braking, steering and gear-shifting.

One piece of technology to be evaluated by TACOM RDE Center engineers will be a reconnaissance mission module specifically designed for robotic-vehicle applications. The module is the result of a Small Business Innovative Research (SBIR) project with Odetics Inc. of Anaheim, CA.

Plans call for mounting this module atop one of the HMMWVs. The module will contain a camera with a zoom lens that provides the operator with images of the scene surrounding the vehicle, a laser range finder for obtaining range information and a high-resolution camera with a telescopic lens for obtaining detailed image information.

Also included in the module will be an infrared sensor for use in night observation. With such a sensor, it is possible to determine the presence of objects by measuring the various levels of infrared (heat) emissions in the surrounding environment. These emissions are always present, but their intensity depends upon their source. For example, the level produced by a nearby vehicle with its engine running would be much different than that of a tree or a hillside.

Two of the unique capabilities to be provided by the module will be the ability to transmit scenery information at a low data rate and the ability to detect a moving object within the scenery.

A control station for remotely controlling the HMMWVs is being built by FMC Corp. It is a console that will be approximately four feet long, three feet high and three feet wide. With these dimensions, it can be used as a developmental and testing tool in the laboratory or be operated as a mobile unit in a truck or trailer. This unit will allow an operator to control robotic vehicles in a teleoperation mode.

The control station will include an operator's control panel, radio communications equipment and a central computer that will generate the signals needed to control the HMMWVs. It will also have three TV monitors. One of these will provide the operator with a view of where the vehicles are traveling. The second unit will be a high-resolution graphics monitor that will display vehicle status information such as engine temperature and oil pressure. The remaining monitor will provide reconnaissance data.

This modified HMMWV has a control system that lets an operator drive it and do tasks from a remote-control station.

"What is nice about the system," said the RDE Center's John Hertrich, "is that it is extremely flexible. It is reprogrammable, so we will be able to test whatever mission hardware and new technology we want to put on the HMMWVs."

Hertrich said the HMMWVs will remain at TACOM for approximately one year for integration of vehicle subsystems and development of control software. They will then be used in exercises designed to help engineers evaluate the technology for potential use in robot vehicles for other missions.

In addition to aiding in technology evaluations, the vehicles will be shipped to Fort Knox, KY in the fall of 1990, where they will be used in tests of a larger, more sophisticated Robotic Command Center (RCC) now being designed and built for TACOM by FMC Corp.

The RCC will be a module that will mount on the chassis of an XM975 Roland vehicle. This is an M109-series howitzer chassis that was modified during the late 1970s for use as a carrier for the French- and German-developed Roland surface-to-air missile system. The module will carry a three-man crew — a commander and two robot operators. An additional crew member will drive the module carrier vehicle.

The module will have two robot driver's stations that will permit each operator to control two robots simultaneously. It will also have a commander's station which will have all the capabilities of the driver's stations, plus additional equipment to allow the commander to perform route planning.

Hertrich said that when the RCC arrives, plans call for outfitting the HMMWVs with additional hardware that will enable them to operate in a variety of advanced remote-control vehicle mobility modes.

The preceding article was written by George Taylor, a technical writer-editor for the Army Tank-Automotive Command.

JUNIOR OFFICER PROFESSIONAL DEVELOPMENT

By MAJ Denise Bachman

While in the Officer Basic Course, most young lieutenants, have visions of working in a field unit as a platoon leader or possibly the company executive. Anxiously, you look forward to hearing from PERSCOM regarding that initial assignment. Finally, you receive notification of an assignment not to a field unit, but to an Army Materiel Command (AMC) research and development center. For some, there is an initial sigh of relief with the thought that at least I may be able to put my college technical degree to good use. For others, the feeling is disappointment at not being able to work with soldiers and gain first hand troop leading experience. What, if any, are the career concerns and obstacles for a junior officer with an initial assignment at AMC?

Questions that immediately come to mind are what will I do in an R&D center and how will I apply the skills acquired in the Officer Basic Course. More importantly, however, is the thought of how this AMC assignment will affect my overall career development.

At the U.S. Army Chemical Research, Development and Engineering Center (CRDEC) at Aberdeen Proving Ground, MD, as in all units throughout AMC, great emphasis is placed on reinforcing skills acquired by the officer both in college and in the Basic Officer Course, as well as building upon those skills through the Junior Officer Professional Development (JOPD) Program. JOPD was established in 1985 pursuant to AMC Pamphlet 350-1. In the past three years, CRDEC has implemented a dynamic and viable professional development model designed to better prepare junior officers for future assignments.

JOPD uses several approaches to achieve the goals set out by AMC Pamphlet 350-1. First of all, lieutenants and captains are placed in development categories, Category I if they have not attended their Officer Advanced Course and Category II if they have completed the Officer Advanced Course. Training is then tailored to the needs of these different categories of participants.

The keystone of JOPD is hands-on technical proficiency training. Each month, a four to eight hour class is scheduled by the JOPD training coordinator, encompassing level II Military Qualification Skills (MQS), unit survival skills (property book accountability, maintenance, classified document accountability and writing proficiency), as well as materiel acquisition management (MAM) training. The headquarters and headquarters company monitors training and maintains a record on each officer.

Another avenue for professional growth offered by JOPD is the opportunity for young officers to participate in the Active Army Affiliation Program. This program gives junior officers an opportunity to be assigned for a period of 6-8 weeks with an active Army unit, normally in conjunction with a major exercise such as those conducted at the National Training Center. To date, five CRDEC officers have participated in the program. Two officers trained at Fort Polk with the 45th Chemical Battalion and three trained with the 4th Chemical Battalion (Provisional) at Fort Carson, CO.

Because of funding constraints, not everyone can be sent TDY to an active duty Army unit. Another option for the officer is to pursue, as a counterpart to the Active Army Affiliation Program, the Reserve and National Guard Affiliation Program. In this option, the junior officer spends one year with a unit and is required to attend one weekend drill per quarter and the unit's two weeks of active duty training. CRDEC junior officers normally serve as chemical advisors and assist the unit in developing specialized training programs and SOPs. Since the Reserve/NG program was initiated, there have been six CRDEC officers who have participated.

Another facet of the JOPD program involves rotational assignments. During their tour with CRDEC, junior officers receive multiple assignments that challenge and expand their capabilities. Category I officers are identified for a rotational assignment every 15 to 18 months and Category II officers every 24 months. The command encourages the officers to rotate into a different phase of the R&D process by selecting varied assignments in designated laboratories and project management offices. In addition, direct troop experience is available through an assignment with the Technical Escort Unit, located at the Edgewood area of Aberdeen Proving Ground. The CRDEC Technical Escort Unit provides worldwide joint service capability for the technical escort and disposal of hazardous chemical agent ammunition as well as supplying an emergency response capability for chemical accidents and incidents.

As part of JOPD, the CRDEC headquarters and head quarters company conducts a three day field training exercise each year. This realistic training helps the junior officers maintain proficiency and build upon skills obtained during the Officer Basic Course. Senior captains act as evaluators and trainers and instruct the junior officers and enlisted personnel on a variety of field subjects to qualify them in officer MQSII skills or enlisted common tasks.

To conduct a realistic field training exercise of this magnitude, many logistical barriers must be overcome since the CRDEC Table of Distribution and Allowances does not authorize unit weapons, masks and other necessary field gear. Through a cooperative effort, equipment is borrowed from surrounding active duty units from the Aberdeen Proving Ground and Fort Meade areas as well as the National Guard. The National Guard also provides transportation support.

AMC is committed to grooming all assigned junior officers through well designed junior officer professional development programs like the one at CRDEC. Ensuring that officers remain branch qualified, and that they are well prepared for future assignments is one of the highest command priorities.

Professional (continued)

In summary, an AMC R&D center assignment offers a multitude of challenging opportunities. Today's young officers are able to learn materiel development and become familiar with acquisition programs that are without precedent in technical sophistication and complexity. At the same time, through JOPD, they are able to maintain the basic troop leading skills needed to remain current with their fellow junior officers.

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Materiel Acquisition Management Survey

In the last issue of *Army RD&A Bulletin*, we presented selected demograhic data drawn from the recently completed occupational survey of MAM officers. This issue covers the section of the survey which dealt with officer opinions and impressions of the MAM program.

Following are responses to selected questions:

How have acquisition assignments affected your career advancement?

Greatly limited	—	6%
Somewhat limited	—	19%
Neither enhanced nor limited	—	39%
Somewhat enhanced	—	25%
Greatly enhanced	—	11%

Extent current assignment provides an opportunity to utilize and develop your MAM skills?

Very small extent	—	7%
Small extent	—	7%
Some extent	—	28%
Large extent	—	30%
Very large extent	—	28%

Extent current assignment provides opportunity to perform duties commensurate with your rank?

Very small extent	—	5%
Small extent	—	6%
Some extent	—	20%
Large extent	—	36%
Very large extent	—	33%

Should PM selection be considered equivalent to Battalion/Brigade command selection?

Yes	—	60%
No	—	34%
Don't know	—	6%

By rank:

	YES	NO	DON'T KNOW
CPT	61	27	12
MAJ	64	31	5
LTC	58	37	5
COL	48	48	4

Should the Army establish an acquisition track with separate promotion/selection boards?

Yes	—	54%
No	—	34%
Don't know	—	12%

By rank:

	YES	NO	DON'T KNOW
CPT	52	31	17
MAJ	55	32	13
LTC	60	31	9
COL	42	50	8

Should the Army open the MAM program to reserve officers?

Yes	—	41%
No	—	33%
Don't Know	—	26%

How useful was the MAM Course (of those who have attended)?

Not very useful	—	3%
Moderately useful	—	28%
Very useful	—	42%
Extremely useful	—	27%

How useful was the Program Managers Course (of those who have attended)?

Not very useful	—	1%
Moderately useful	—	12%
Very useful	—	32%
Extremely useful	—	55%

Should PMC be a MEL-4 equivalent school (of those who have attended)?

Yes, without modification	—	26%
Yes, if modified	—	36%
No	—	38%

The write-in questions at the end of the survey provided good feedback on a number of important issues. The results of two of the write-in questions follow:

Survey (continued)

How would you improve the DOD materiel acquisition process?

Top five responses:

1. Streamline process/paperwork	15%
2. Eliminate/reduce bureaucracy	8%
3. Eliminate/reduce congressional involvement/politics	7%
4. Stabilize funding process	7%
5. Give PM more authority	5%

How would you improve the MAM Program? Top five responses:

1. Make MAM a separate career track (branch)	13%
2. Ensure better promotion potential-equal with command (i.e. separate promotion board)	9%
3. Give MAM more prestige — positive publicity	8%
4. Assign to MAM earlier in career (like Air Force)	6%
5. Make troop/MAM assignments equal (PM/BN command should be equivalent)	6%

MAM 6T Promotions to Colonel—FY89

The results of the FY 89 promotion board to colonel show that the Army average select rate of first time considered officers was 40.5 percent. The board results also show that the first time considered select rate for officers awarded 6T skill identifiers, was 58.5 percent. Figures below summarize first time considered selection rates by branch and skill 6T:

OVERALL

BRANCH	FTC/EL	FTC/SEL	PERCENT
CM	16	11	68.7
OD	80	48	60.0
TC	52	27	51.9
SC	80	40	50.0
AR	96	46	47.9
AD	69	32	46.3
FA	132	56	42.4
AG	60	24	40.0
EN	73	29	39.7
IN	213	84	39.4
QM	66	24	36.3
AV	198	55	27.7
MI	119	34	28.5
MP	35	15	42.8
SF	27	10	37.0
FI	16	5	31.2
TOTALS	**1332**	**540**	**40.5**

SKILL 6T

BRANCH	FTC/EL	FTC/SEL	PERCENT
CM	3	3	100.0
OD	21	14	66.6
TC	3	1	33.3
SC	10	7	70.0
AR	1	0	0.0
AD	5	3	60.0
FA	4	3	75.0
AG	0	0	N/A
EN	3	2	66.6
IN	3	1	33.3
QM	5	3	60.0
AV	10	4	40.0
MI	1	0	0.0
MP	1	0	0.0
SF	0	0	N/A
FI	0	0	N/A
TOTALS	**70**	**41**	**58.5**

Seventy-one (71) percent of officers selected were certified acquisition managers (under current certification guidelines) and 85 percent were legitimate 6T participants with average MAM experience of two plus years.

Acquisition Management Career Program

The Army has announced its intent to establish an Acquisition Management Career Program designed to improve development, training and retention within the total acquisition work force. The concept was approved on Feb 8, 1989 by Under Secretary of the Army Michael P. W. Stone, formally establishing the Acquisition Management Mission Cluster Group (AMMCG) Career Program.

The objective of the career program is to develop a pool of qualified military and civilian personnel to fill designated critical acquisition management positions responsible for the full range of functions in the materiel life cycle. In addition, the program will provide oversight for the development of current and future acquisition managers.

In establishing the Acquisition Mission Cluster Group, the under secretary created an Executive Board with responsibility for the selection, development, training and retention of acquisition managers for positions in program executive offices, program management and select matrix support command organizations. The Executive Board will provide the executive level review for the acquisition management portion of the Logistics and Acquisition Management Program (LOGAMP) and the Materiel Acquisition Management (MAM) Program.

The Executive Board for the career program is composed of the Army Acquisition Executive (AAE)-chairman and functional chief; assistant secretary of the Army (manpower and reserve affairs); commanding general of the Army Materiel Command; commanding general of the Information Systems Command; director of information systems for command, control, communications and computers; deputy chief of staff for logistics; comptroller of the Army; chief of engineers; and the assistant secretary of the Army (research, development and acquisition) deputy for program evaluation, who will act as executive secretary and also serve as the AAE's representative to the LOGAMP Management Board and MAM Proponency Committee. The intent is for the Board and the membership to implement an Army-wide program through planned career development to staff critical acquisition positions.

The functions of the Acquisition Management Mission Cluster Group Board are:

- Provide advice and recommendations on acquisition personnel career development policy and management matters and their implementation in select portions of the LOGAMP and MAM Programs.
- Review the acquisition management training and career development process and recommend methods to integrate that process across the participating career programs and functional areas.
- Review career progression across the acquisition community and recommend ways to achieve a more structured approach.
- Review select portions of the LOGAMP/MAM Programs and provide recommendations to ensure an appropriate interface in establishing a Competitive Development Group.
- Identify career development patterns and professional development issues and recommend improvements when necessary.
- Review individual training and educational requirements for entry into the Competitive Development Group and provide recommendations as appropriate.
- Establish the selection criteria for entry into the Competitive Development Group.
- Review the funding levels necessary to support the career development program and recommend alternative strategies as appropriate.
- Review and evaluate Affirmative Action/EO/EEO Action Plans/Progress.

Though the implementation process for the program has been slow, this has been deliberate awaiting the recommendations of the Defense Management Review (DMR). A working group, chaired by Stephen R. Burdt, executive secretary to the AMMCG, developed guidelines necessary to provide the organizational concepts for managing the integration of the LOGAMP and MAM programs which will form the basis for future referral of candidates to be managed by the Acquisition Mission Cluster Group.

Membership on the working group consists of representatives for each of the Executive Board members. The working group meets on a monthly basis and is working closely with the DMR Task Force to refine the concept to satisfy the recommendations and provide support during development of an Army plan to meet DMR objectives.

We will continue to keep you apprised of progress through periodic updates in this bulletin.

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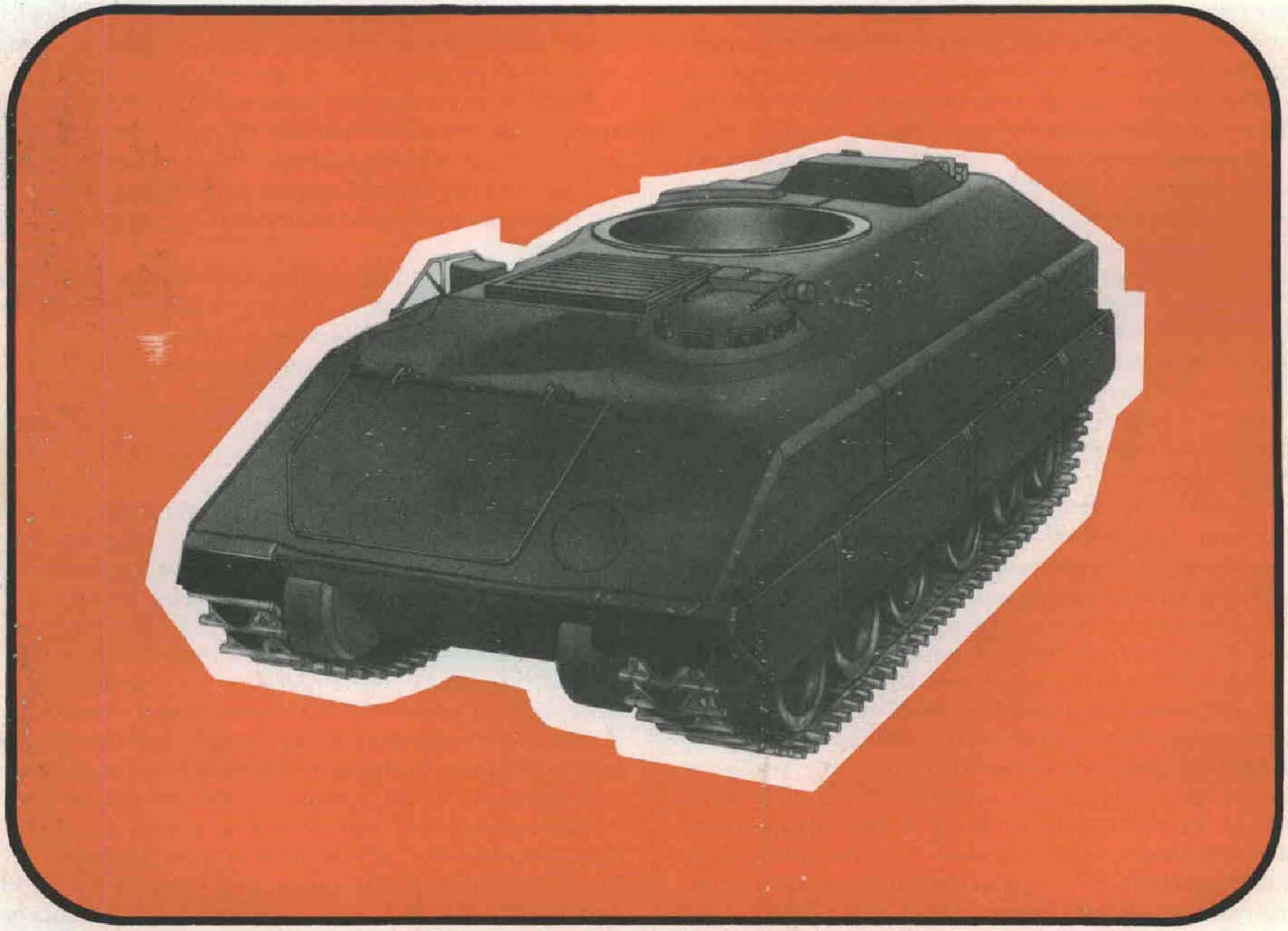

REPAIR OF COMPOSITE MATERIALS