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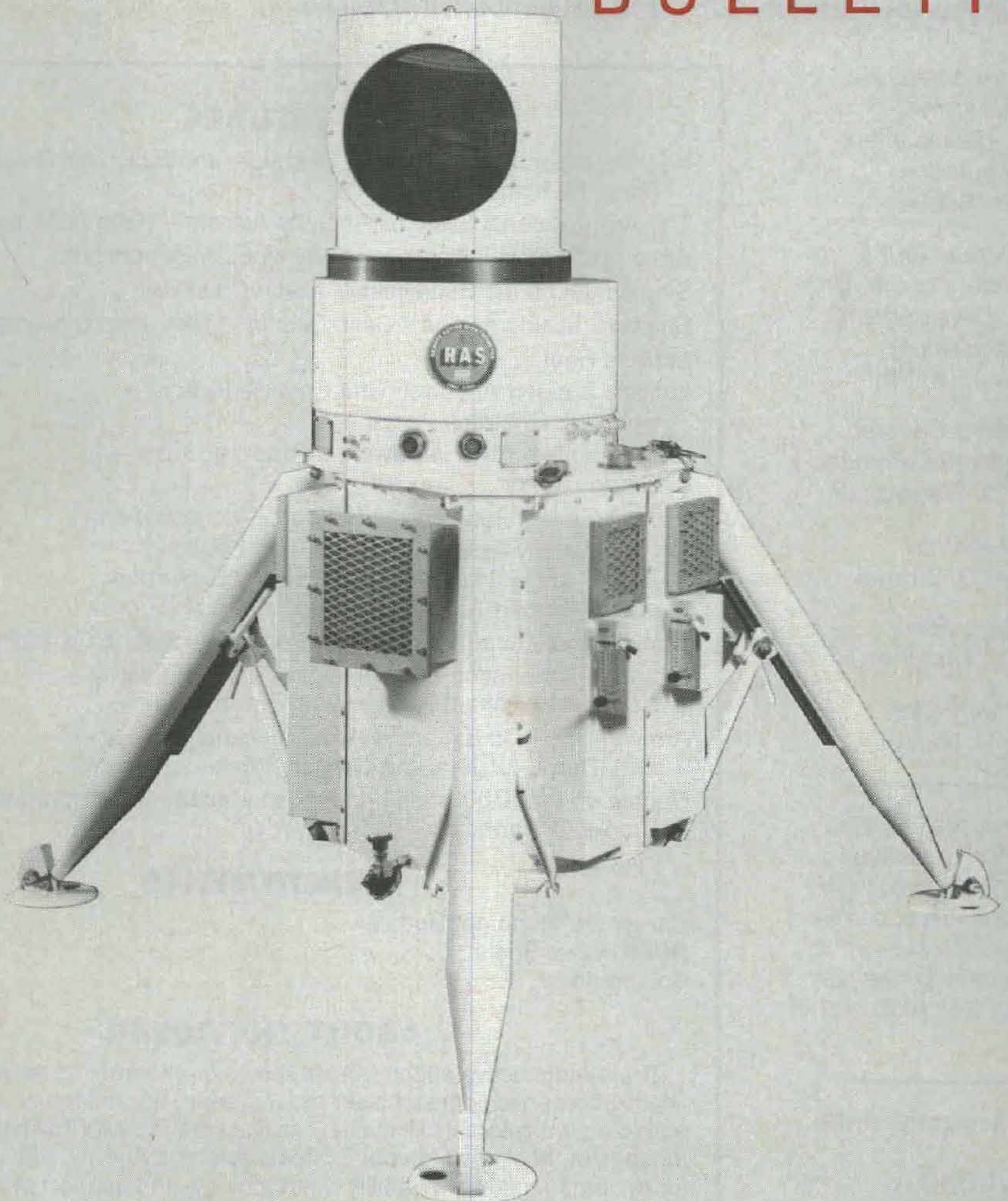

CHEMICAL/BIOLOGICAL AGENT DETECTION

ARMY
Research
Development
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RD&A

PB 70-89-1

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PROFESSIONAL BULLETIN OF THE RDA COMMUNITY

This medium is approved for the official dissemination of material designed to keep individuals within the Army knowledgeable of current and emerging developments within their areas of expertise for the purpose of enhancing their professional development.

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FEATURES

DEPARTMENTS

ABOUT THE COVER

The remote active spectrometer shown on the front cover was the Army's first experimental compact laser radar system. It is related to a feature article on toxic agent detection. Photo by Ruth Hawks, APG, MD. The back cover shows the logo of the Army Materiel Systems Analysis Activity, AMC's lead activity for systems analysis, reliability methodology, and support of Army studies.

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By Diane M. Kotras

NEW DETECTION APPROACHES FOR CHEMICAL AND BIOLOGICAL DEFENSE

Introduction

The military threat posed by chemical and biological agents is marked with the ease in which they can be produced. Standard chemical processing technology has expanded to allow for large-scale production that is both economical and efficient. Commercial pesticide plants and pharmaceutical production facilities bear witness to this trend. Corresponding large-scale production of chemical and biological warfare agents would be a relatively easy process.

In addition to the classical chemical threat, emerging biotechnologies have compounded the biological threat considerably. Protein engineering, fermentation and gene cloning provide opportunities for more diverse threat agents. Viruses and bacteria, in particular, can be rendered more lethal by genetic engineering techniques, and many toxins can now be mass-produced.

Although the 1972 Biological and Toxin Weapons Convention bans the development, production and stockpiling of biological agents and toxins for hostile purposes, neither the types nor the quantities of these materials are specified. Moreover, the treaty permits research, production and modification of a biological agent or toxin for declared prophylactic, protective and other peaceful purposes.

With no verification provisions included in the convention, the agents produced or modified could be used militarily or covertly with antagonistic intent. The shortcomings of the treaty render it vulnerable to broad and adverse interpretations of provisions that would otherwise minimize the risk of hostile use of biological agents and toxins. Given the political reality of an unverifiable convention and the dynamic menace of chemical and biological agents, a strong defense posture is necessary to counter a diversifying threat.

The use of chemical and biological warfare agents in international conflicts must also be incorporated in the threat assessment. It has been widely reported that chemical weapons have been used extensively in Afghanistan by the Soviet Union, in the Iran-Iraq war and in Angola. Toxins have also reportedly been used in Laos and Kampuchea.

While the use of such weapons has aroused some international indignation, little action has been taken to curb the use of these agents. Yet, the number of countries possessing a chemical and biological weapons capability continues to grow. Together, these observed trends indicate changing attitudes towards the deployment and use of these weapons. They gauge the tolerance of such aggression and underscore the expanding chemical and biological threat.

The U.S. chemical and biological defensive program must constantly keep pace with ever-shifting political trends and emerging new technologies that may be applied to adversarial materials and their delivery systems. This pursuit must be balanced with the demand for provisional solutions to immediate problems. Stopgap measures cannot detract, however, from the overall advancement of the program.

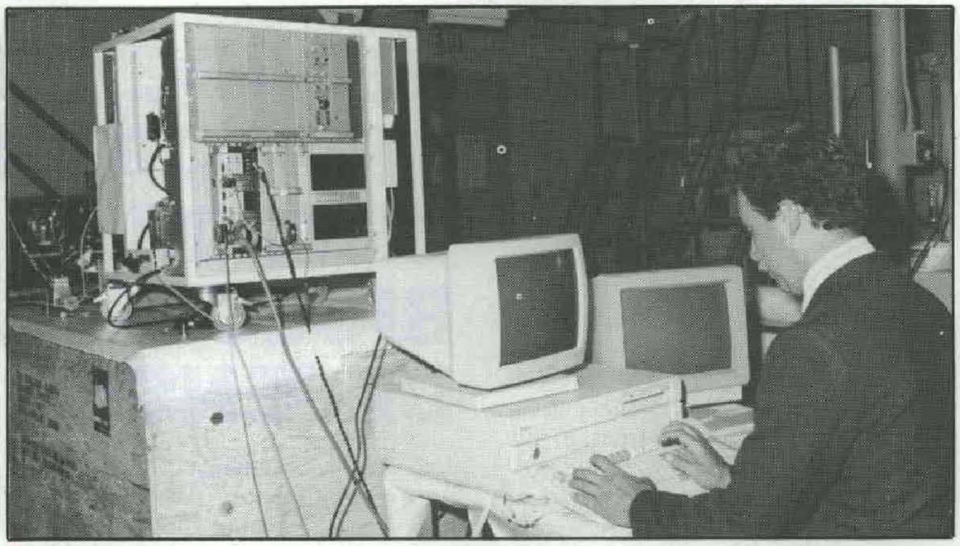
Chemical and biological defense R&D encompasses detection, physical protection and decontamination. In supporting these objectives, the program must respond to significant defense challenges. Detection is particularly encumbered by exacting and complex requirements necessary for effective battlefield operation.

Successful physical protection and decontamination are predicated on accurate detection capabilities. Detectors, for instance, must be capable of identifying a broad spectrum of chemical and biological agents having incredibly diverse physical, chemical and biological characteristics. They must also exhibit high sensitivity and specificity along with a quick response time under rigorous battlefield conditions.

Master Plan

Recognizing these defense challenges, the U.S. Army Chemical, Research, Development, and Engineering Center (CRDEC) and the U.S. Army Chemical School developed a reconnaissance, detection and identification master plan. This plan serves as a strategy for acquisition of point and standoff detectors. It is based on battlefield-driven information needs and the appropriate technologies available to address them. Three agent detector-sensor systems were targeted in the plan because of their versatility, high sensitivity and quick response time. These devices are the chemical and biological mass spectrometer, the biochemical detector system and the laser standoff detection system. They constitute the three major technology thrusts of CRDEC's chemical and biological detection initiative.

The technologies are being concurrently pursued because of their inherent capabilities as well as discrete intended applications. No single technology can fulfill all the desired performance criteria in every combat scenario. Each one, however, possesses distinct advantages. The mass spectrometer, for example, has been identified as the foremost method for specific identification of known and unknown agents. It allows for unique characterization of chemical and biological agents and other toxic but non-warfare agents that may be present on the battlefield. The microsensor-based bio-chemical detector is most amenable to miniaturization for tactical operations and for such specialized applications as in-place filter, garment and contamina-



Dr. William Lagna, a physical scientist at CRDEC, enters data into the chemical and biological mass spectrometer computer. The device has potential for applications to environmental monitoring, medical diagnostics and industrial process control.

tion monitors. For standoff detection, laser radar is the most promising technology because of the ability to perform look-ahead and scanning reconnaissance. In concert, these technologies strive to satisfy chemical and biological battlefield information needs.

Mass Spectrometer

The chemical and biological mass spectrometer was identified by the master plan as the next generation point detector for reconnaissance and fixed site applications. It is designed to detect, identify and determine concentrations of threat materials that are present in the air as vapors, aerosols or liquid droplets. The device, now in exploratory development, is intended for man-portable field deployment and will be capable of 24 to 72 hour unattended missions.

A systems engineering approach has been taken to develop and integrate components of the mass spectrometer for sample acquisition and pretreatment, ionization, mass analysis, ion detection, signal processing and data display. These components have been assembled in a prototype detector comprising the mass analyzer module, the aerosol collection and sampler module and the computer-power module. This modular format was created to accommodate technology advances in detection as well as changes in the chemical and biological threat.

The mass spectrometer's proficiency will be demonstrated using a variety of chemical agents and model biological materials. While mass spectrometry makes detection of chemical agents fast and easy, biological agents present a more formidable challenge. As they typically exceed the molecular weight range of most conventional mass spectrometers, these biomaterials must be broken down into compounds that are readily recognized by the device. Pyrolysis mass spectrometry allows for such analysis. Using this approach, complex materials are heated in a controlled manner. This results in characteristic chemical signatures easily analyzed by the spectrometer. These signatures are then compared with a large data base of known chemical signatures to identify the material.

Designed to operate in a nuclear, biological and chemical (NBC) environment, the new mass spectrometer is intended to replace the German mass spectrometer (GEMS) currently used in the Fuchs NBC reconnaissance vehicle. The new design will provide for ease of decontamination and future incorporation of nuclear hardened components.

The system will detect, identify and monitor chemical and biological agent contamination while on the move. It will be portable for dismounted operations and for use as a point alarm at fixed sites, such as air bases and aboard ships. It may also be used in airborne operations and for low mobility combat service support.

Because of enhanced detection capabilities and reduced size, the mass spectrometer surpasses the GEMS in application and deployment possibilities. For instance, the GEMS can only detect chemicals whereas the new mass spectrometer can detect chemicals, biologicals, toxins and polymers. Moreover, it can identify over 120,000 compounds with substantially higher selectivity than the German MS. The device will take no more than 15 seconds to detect the presence of any threat material as compared to one minute for the GEMS. Identification of the threat material and quantitative determination of the concentration will occur within two minutes.

The new mass spectrometer will occupy less that four cubic feet and weigh only 40 pounds, an order of magnitude less than the GEMS. In addition, the device will auto-tune, auto-calibrate, and self-diagnose. Last July, the first demonstration model was delivered to the Army. Its capabilities will not only benefit military applications, but will enhance medical, environmental and systems process monitoring as well.

Biochemical Detector

Perhaps the most challenging endeavor in the area of detection is the development of an extremely lightweight, automatic detector that will be adaptable to changes in technology and the threat. The master plan identified the need for such a system to sample, detect and classify chemical and biological hazards in air and surfaces. The bio-chemical detector is envisioned to meet these objectives.

CRDEC is currently applying emerging microsensor technologies to develop a modular, mini-detector. Once completed, it will provide continuous, automatic air-sampling over a 24-hour period and will be capable of detecting a wide variety of chemical and biological materials in the air. The detector is principally intended to serve as a tactical point alarm.

In addition to visual and audible alarms, the system will indicate the agent class and determine the concentration level of the detected material. All data will be transmitted to a battlefield information network for dissemination.

The biochemical detector comprises sample acquisition, as well as sample, sensing and signal processing elements. The system is designed to be compact and lightweight. Upon completion, the detector will occupy one cubic foot of space and weigh about 10 pounds. Three state-of-the-art electronic approaches to detection will be incorporated into the device. The fiber optic waveguide, the light-modulated silicon sensor and the miniature electrochemical detector are the candidate technologies being evaluated for eventual use in the device. Together, these methods will allow for the detection of nerve agents, blister agents, pathogens and toxins.

The fiber optic waveguide is an electro-optical approach to point detection. It comprises a thin quartz rod coated with enzymes, antibodies or biological receptor molecules specific for certain threat agents or classes of agents. Upon surface contact, the chemical and biological threat material will displace fluorescent analogues from the coated quartz rod or compete with the fluorescent analogue for a limited amount of binding sites.

At the quartz-sample interface, light penetrates a short distance into the sample and excites the fluorescent probes. The 100 nanometer field of excitation permits an effective partitioning of surface-bound fluorophores from those which are free in solution. This separation allows for analytical measurements of the analyte (agent material) in picogram quantities.

The silicon sensor is a microsensor-based method for detecting chemical and biological threat compounds. It is a light-modulated silicon device containing a 25 mm 2 planar silicon wafer with a silicon oxide-nitride layer on the surface. When alternating current is applied to an infrared light emitting diode, a photocurrent is produced that is dependent on the surface chemical potential. Changes in pH level or redox potential are reflected in the magnitude of the photocurrent illumination of the diode. The silicon surface layer can be readily adapted to include acetylcholinesterase-based assays for the detection of chemical nerve agents, as well as enzyme-labelled immunoassays and receptor-based assays for detection of biological threat materials.

The miniature electrochemical detector operates via a differential pulse voltammeter in an electrochemical cell. Direct electrochemical oxidation of the chemical agent produces an electric signal. This device is readily applicable to the detection of blister agents such as mustard and lewisite. Work is also underway to modify the approach so that nerve agents may be detected.

These and other technologies form the basis for the miniaturized biochemical detector. Together they hold promise for threat agent detection in combat. Following their integration in a hand-held, portable device, they will be used in highly mobile combat and combat support operations and contamination monitoring.

Laser Radar

Standoff detection capabilities are necessary for fixed-site chemical defense, ground and air reconnaissance and contamination avoidance. The master plan identified laser radar as having the most potential in detecting chemical vapors, aerosols, liquids on surfaces and agent rains. Specifically, two types of radar were addressed — differential scattering for aerosol rain and surface contamination detection, and differential absorption for vapor detection. Combined, both technologies provide for detection of chemical aerosols and agent rains by their unique spectral backscatter patterns. They may also afford a basis for early warning of chemical attacks.

While infrared (IR) laser radar systems are employed for the detection of chemical agents, a corresponding ultraviolet system using laser-induced fluorescence is being developed to detect biological clouds. The IR system interprets data in several ways. Via topographic reflection, different IR frequencies are transmitted and detected by their topographic return. If chemical clouds are present, they will selectively absorb some of the IR frequencies, thus allowing for their detection as well as determination of concentration and path length.

Aerosol backscatter laser radar employs lasers with greater intensity. Following transmission of different IR frequencies, ambient atmospheric aerosols reflect the IR signals back to the detector. The returned signals are gate-timed for range resolution. Vapor concentrations and ranges can then be calculated for anything in the laser radar path.

Agent backscatter laser radar works in a similar fashion. If chemical agent aerosols or rains are present, they can be detected by the particular frequencies that are backscattered to the detector. Surface reflection permits the detection of chemical agent on soil, foliage or equipment surfaces via interpretation of select IR frequencies that are backscattered by the agent material.

In 1985, both laser radar systems were incorporated into a demonstration model. It comprised two CO_2 transverse excited atmospheric laser transmitters, an optical receiver, and control, signal processing and diagnostic equipment. A corresponding airborne system was also designed to operate in a twin-engine plane. Both systems have undergone extensive testing at Dugway Proving Ground. The ground-based system detected chemical clouds at distances up to seven kilometers, while the airborne system detected chemical clouds at the same distance downwind from the vapor source.

In 1986, the differential absorption laser radar was reduced in size. This compact, lightweight system served as a remote active spectrometer for the detection of chemical agents from a standoff position. It was the first step taken to reduce the size of the system without compromising the operational capabilities. It is anticipated that future laser radar applications will involve detection from helicopters and remotely piloted vehicles.

Conclusion

The technologies being developed represent a new generation of chemical and biological agent field detectors. Their development is in response to the demand for increased operational capabilities on the battlefield. They will continue to be refined to accommodate future changes in the threat as well as new battlefield requirements.

DIANE M. KOTRAS is a physical scientist at the U.S. Army Chemical Research, Development and Engineering Center.

THE ARMY MATERIEL SYSTEMS ANALYSIS ACTIVITY

By Keith A. Myers

Introduction

The U.S. Army Materiel Systems Analysis Activity (AMSAA) at Aberdeen Proving Ground, MD, has a challenging mission that covers the whole life cycle of a variety of Army materiel. The AMSAA mission begins early in the materiel acquisition process, during the requirements and technology base phase, and continues through to the operation and support phase (Figure 1). Central to this mission is the AMSAA responsibility to perform technical test design and independent continuous evaluation for almost all Army systems requiring evaluation. Evaluated systems range from the very large, such as the the M1A1 Abrams tank and the Forward Area Air Defense System, to the 9mm pistol, which has generated congressional interest far beyond its size and budget. Overall, this responsibility entails evaluation of about 145 main systems and subsystems and consumes about one third of the technical effort of the AMSAA work force.

Another key facet of AMSAA's mission is the development of evaluation methodologies and the preparation and dissemination of item-level system performance estimates for various Army sponsored studies carried out by the U.S. Army Concepts Analysis Agency, the U.S. Army Training and Doctrine Command (TRADOC), and other governmental agencies and their contractors. We generate or coordinate the development of estimates and methodologies for the full range of Army item-level systems, e.g., tanks, helicopters, combat net radios.

Depending on customer needs, the item-level characterization task might vary from the straightforward calculation of probability of kill versus range of engagement for a single system to the wholesale provision of data for all the U.S. and threat systems to be played in a Cost and Operational Effectiveness Analysis (COEA) or combat simulation.

To give the customer a sound understanding of the system's predicted performance, item-level data packages for a typical system usually address both capabilities and limitations in all major areas, such as target acquisition; firepower (e.g., combat hit and kill probabilities); mobility; command and control (e.g., probability of a successful communication link); survivability; reliability; and countermeasure susceptibility.

The AMSAA mission also supports the other services. All the services — Army, Navy, Air Force, and Marine Corps — benefit from the manuals produced by the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME). This group, which AMSAA administers as the executive agent, develops joint service approved effectiveness estimates and weaponeering manuals that are in everyday use within the analytical and operational communities of all the services.

Systems must be supported to be effective on the battlefield. In response to this need, we have developed a logistics and readiness analysis capability to complement the activity's traditional emphasis on firepower analysis. This capability directly serves the needs of the U.S. Army Materiel Command (AMC), and we are often called upon to run special logistics and readiness studies for TRADOC and Headquarters Department of the Army (HQDA). In addition, we maintain cognizance of and contribute to the improvement of the performance of fielded equipment through our participation in Ammunition Stockpile Reliability Programs, Fielded Systems Reviews, Materiel Readiness Reviews, Sample Data Collection efforts, Field Exercise Data Collection (FEDC) efforts, field surveys and visits, and Battlefield Damage Assessment and Repair (BDAR) efforts (Figure 1).

All our efforts at AMSAA are geared to provide timely information to support AMC and Army decisions on materiel

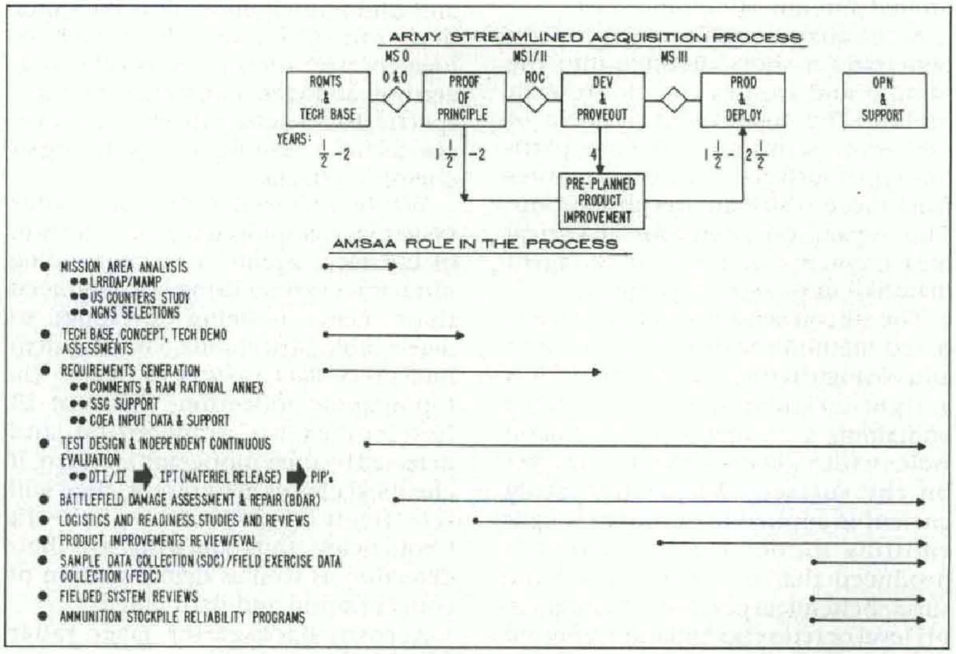


Figure 1.
AMSAA's Role in the Materiel Acquisition Process

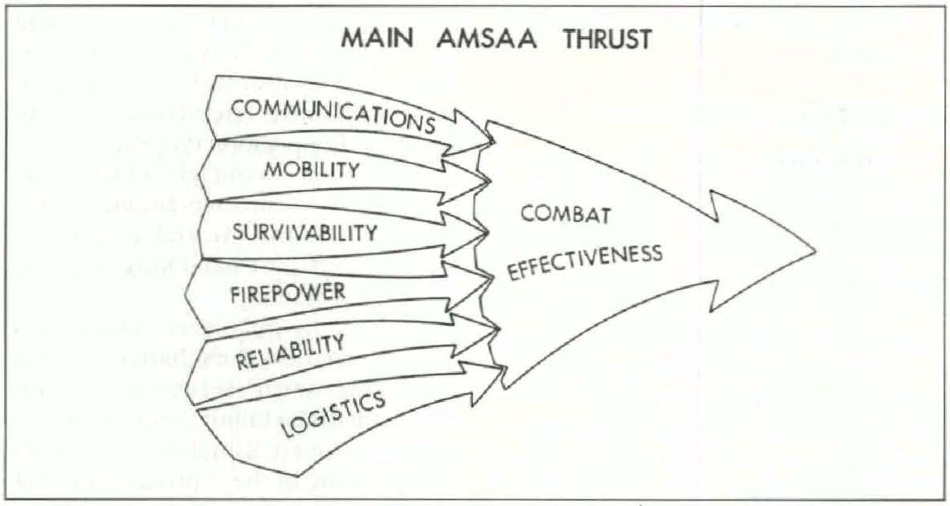


Figure 2.
AMSAA Thrust Across the Mission Areas Improves Combat Effectiveness on the Battleground

acquisition, material support, resource management, and other selected issues. Over the years, we have matured to a "full service" analytical organization with the capability to analyze equipment from all mission areas from a perspective that addresses as appropriate, command, control, and communications (C3); mobility; survivability; firepower; reliability; and logistics (Figure 2). Using this capability, we are able to establish a system's overall combat potential or contribution.

As AMC's lead organization for system analysis, support to Army studies, and reliability, availability, and maintainability (RAM) methodology, AMSAA has developed a broad corporate expertise and experience. Consequently, we are often called upon to conduct, in addition to a continuous evaluation mission for selected conceptual, developmental, and fielded materiel systems, a variety of ad hoc studies, analyses, and assessments in support of project managers, major subordinate commands, other major commands (within and outside the Continental U.S.), HQ AMC, and HQDA.

Methodologies

New evaluation methodologies are being developed at AMSAA to meet changing times and special needs. Some of the first Army COEAs were performed by AMSAA. We continued to support TRADOC in this area until TRADOC established its own systems analysis activity in the mid-1970s. We have developed a number of duel, small-unit and higher level combat models. At one time, we had the only usable division-level interactive war game, DIVLEV, within the Army. In one of DIVLEV's major applications, gamers came to AMSAA from several North Atlantic Treaty Organization (NATO) countries, and along with their TRADOC sponsors, executed an important anti-artillery study to determine means to strengthen NATO's defense of Europe.

During the mid-1970s, we developed the first Army model to evaluate the impact of C 3 factors on artillery force effectiveness. On its initial application, this model, called the Artillery Force Simulation Model, was used by AMSAA to analyze the Army artillery tactical fire control computer.

Within the last several years, AMSAA, aided by the integration of the Inventory Research Office and the Logistics Study Office into its ranks, has expanded its role in the logistics, readiness, and resource management areas. Our efforts in this arena continue to grow in depth and complexity. We are bringing high-quality analysis to bear on these problems with excellent results. For example, provisioning models like the Selected Essential Item Stockage for Availability Method and level-of-repair models such as the Optimum Supply and Maintenance Model are routinely used to evaluate Integrated Logistical Support (ILS) concepts.

Combat Sustainability

Combat sustainability is also being improved for today's soldier by an integrated program conducted, supervised, and/or monitored by AMSAA analysts. This program includes the development of policy, procedures, and primers for BDAR; validation of Army Spare Component Requirements for Combat methodologies by live-fire tests; development of new algorithms which include the effects of wartime losses caused by enemy and non-enemy actions in the computation of Authorized Stockage Lists and War reserves; and the analysis of FEDC data leading to the prediction of wartime reliability failures.

Resource Management

In the resource management area, the success of AMSAA's early 1980s Logistics Unit Productivity Study has resulted in the Army institutionalizing the effort at the TRADOC centers and schools under the aegis of the Logistics Unit Productivity Studies Program. The initial AMSAA study, conducted for the deputy chief of staff for logistics (DCSLOG), is a good example of the many ad hoc efforts conducted by AMSAA over the years to help Army decision makers.

Faced with a logistics force manpower ceiling and increased workload, the DCSLOG gave AMSAA carte blanche to evaluate all ways to improve logistical force effectiveness short of increasing actual force size. Working in close cooperation with the DCSLOG Staff, we were able to demonstrate in tests various changes in organization, doctrine, and equipment that significantly improved the productivity of the company-level logistics units under evaluation. These measures, many of which the Army adopted, were developed after careful analysis and consideration of both foreign and domestic military and industrial logistical practices for work simplification, manpower allocation, and equipment modernization.

Mission Area Analysis

Force modernization is vital to the Army and the other services. The AMSAA recognizes this by vigorously supporting efforts to develop effective research, development, and acquisition policy for new Army equipment. Our participation in the biennial Mission Area Materiel Plan, ongoing studies of U.S. materiel counters to Soviet modernization, and U.S. Army Laboratory Command Next Generation and Notional System selection exercises are three principal ways we help shape policy across the mission areas (Figure 1). In addition, there are many occasions like the AMC/TRADOC "Why 3" Radio Study where AMSAA becomes intimately involved in examining the options for RDA policy for a specific mission area. This study was conducted in the mid-1980s to satisfy the concerns of the under secretary of the Army, pertaining to the need for a new communications system.

The under secretary requested an analysis that compared the performance and cost of communication architectures that included the system with alternative architectures that excluded the system. The study results not only satisfied the under secretary's needs, but also pointed out the need for improved communications system survivability.

Joint Service Efforts

In the early 1960s, gross inconsistencies among weapons effectiveness estimates produced by the Air Force, Navy, and Defense Intelligence Agency led to the formation of what is now called the JTCG/ME. The JTCG/ME has helped remedy the data inconsistency problems of the 1960s by preparing and disseminating Joint Munition Effectiveness Manuals that provide a joint-service approved source of estimates of the effects of air-to-surface, surface-to-surface, and anti-air (air-to-air and surface-to-air) weapon systems.

Overall direction to the JTCG/ME program is provided by a joint-service steering committee chaired by the AMSAA director. A small group in AMSAA provides the day-to-day executive agent administration of the program, which involves 300 plus personnel (civilian, military and contractor) in the preparation and revision of the manuals. The manuals are now in routine use throughout the free world. Weaponeers and other military personnel use them to select that mix of weapons, munitions and delivery conditions that best meets the objectives of the mission and analysts use them as a basis for their studies and war games.

Continuous Evaluation

As mentioned earlier, our technical test design and independent continuous evaluation role is central to our efforts to support the materiel acquisition process (Figure 1). This role goes beyond a mere determination of whether or not specifications are met by the system. Instead, we strive to portray to the decision makers the military significance of the performance level achieved. In many instances we are able to show that a shortfall is not significant enough to adversely affect military utility. For example, during the 1970s we recommended fielding of an improved-low-to-medium air defense system that had failed to demonstrate specified levels of lethality. We did so because other factors, such as survivability and supportability, coupled with the fact that the system was two to three times more lethal than the existing system indicated that it was in the best interest of the Army to deploy it even though it didn't reach its goals.

The continuous evaluation role also provides a program of work that keeps us involved in all the actions leading to the development, production, and deployment of major materiel items. It also has synergistic effects with respect to AMSAA's systems analysis mission because problems frequently arise during the acquisition process that require new methodologies and/or effectiveness evaluations to point the way to their solution. An example is the development of a methodology for projecting the growth in reliability of developmental systems. This arose out of a need to treat the evolutionary maturation of a system design whereby the system improves over time as problems are identified and fixed. This methodology is now available to all the services in the Department of Defense Handbook on Reliability Growth Management prepared by AMSAA in the early 1980s.

International Activities

The AMSAA is also active in the exchange of ideas and analyses with our counterparts in friendly foreign governments. Our personnel are the U.S. leaders or the associate technical project officers for many data exchange agreements. We also provide the U.S. National Leader for Panel W-6 (Generic Weapons System Effectiveness) of the Technical Cooperation Program (TTCP). This program encourages a broad dialogue on defense matters among its five-member nations: Australia, Canada, New Zealand, the United Kingdom, and the United States.

At the individual level, AMSAA has had international exchange analyst programs with selected foreign governments including Australia, Israel, and the United Kingdom. Personnel participating in these programs gain a better perspective of the analytical practices and philosophies of the host organization as well as an appreciation of the customs and traditions of the host nation.

Conclusion

In 1988, AMSAA celebrated its 20th anniversary. We have come a long way from our firepower oriented post-World War II origins at the Ballistic Research Laboratory and continue to grow in capability. Our mission has expanded from the prediction of weapon effects to an all service mission that encompasses the analysis of the full range of Army materiel systems, RAM problems, and logistical/resource management issues. We take pride in our role as the Army's lead technical evaluator of new materiel before and after it is fielded to the soldier and look forward to even more significant contributions to the Army as we enter our third decade.

KEITH A. MYERS has been the director of AMSAA since July 1, 1981. He graduated from Auburn University in 1953 with a B.S. degree in mathematics and has continued his education with graduate studies in mathematics and statistics at the University of Delaware. He chairs the JTCG/ME, acts as the U.S. National Leader of the TTCP Panel W6, and regularly participates on many other national and international working and advisory groups.

ARMY COULD COST INITIATIVE

By Maxwell E. Westmoreland

Could-Cost Philosophy

There is an ultimate cost for every type of contract. This cost usually reflects the best business arrangement available at the time of contract award. Each party seeks to minimize financial risks. The customer seeks the minimum price, and the supplier seeks to cover his anticipated costs, plus a reasonable level of profit. A compromise is usually reached where each party gives up some portion of what they seek in order to reach a business agreement. The invariable result is that no contract value really reflects an absolute minimum cost. Non-value added costs are always present. These costs contribute nothing to the actual value of the product. They are the consequence of the desire by both parties to minimize financial risks. For example, the customer may require detailed tests and inspections to assure the supplier is complying with the specifications. The supplier may have inefficient processes which generate scrap and rework, and he wants to assure these costs are passed on to the customer to avoid having to pay them out of profit dollars.

The "could-cost" value of a contract is that cost which could be achieved if the non-value added government requirements are removed, and the contractor non-value added work is eliminated. Achieving the "could-cost" value will require a fundamental change in current government/industry business methods. Both parties must critically examine requirements and operations, and must jointly develop innovative solutions to business and technical issues that are barriers to needed changes.

The potential payoffs of could-cost are high. The DOD faces stiff competition for defense dollars with other pressing national needs. Within DOD, the military departments are vying for their fair share of a constrained defense budget. The Army's ability to buy what it needs for force modernization will be severely hampered by a declining budget that is not offset by greater buying power for the defense dollar. The savings from elimination of non-value added costs can be applied to sustaining procurement levels to support force modernization needs. This is where effective could-cost efforts on all Army development and acquisition programs can make a difference.

Could-Cost Experiments

In mid-December 1987, Dr. Robert Costello, the under secretary of defense for acquisition, requested that the Services undertake trial could-cost programs. The purpose of these trials is to conduct experiments with oversight at a sufficiently high management level so that experience gained from both government and industry participants can be used as the basis to institutionalize change to a better way of doing business. The real objective is not solely the saving of dollars on these experimental programs, but the use of the knowledge gained to leverage the could-cost concept throughout all Army contracts.

The Army experiments were selected to sample the full range of business opportunities where could-cost payoffs might result. Two production efforts were selected. These are the FMC facility at San Jose, CA, where the Bradley Fighting Vehicle and the M113 Personnel Carrier are produced, and the McDonnell Douglas production facility for the Apache Helicopter at Mesa, AZ. These facilities were selected because the contracts are sole source, they are dedicated to production on Army programs, the annual value of the production exceeds $150 million, and three years of production remains to be completed.

The Advanced Anti-Tank Weapon System — Medium (AAWS-M) was selected to provide experience on a development program. The fourth effort involves government-owned, contractor-operated (GOCO) Army Ammunition Plants (AAPs). This effort is intended to provide experience on how well the government and the AAP operating contractors can improve efficiency and business practices to reduce costs.

This article is based on the experience gained in implementing these experiments. It discusses how to approach could-cost in the acquisition environment, what elements of could-cost should be addressed by a contractor, how could-cost can be contractually applied, and what types of incentives can be used to motivate contractor achievement of could-cost objectives. A second article is planned for the May-June 1989 issue of this bulletin on results being achieved on the individual experimental programs.

Acquisition Strategy

There are certain basic factors to consider in applying the could-cost philosophy in any acquisition program. Customer requirements and producer incentives are key to the success of any could-cost program. Non-value added requirements must be removed from the documents that formally communicate our (government) needs to the producer. The system specifications, request for proposal and the contract must be devoid of all but what we need. Non-value added requirements can cause inefficiency in a contractor's operations while providing nothing of real value to the government.

While there are a number of measures by the procuring activities to scrub requirements to the bare bones, it is unreasonable to expect that the government possesses sufficient knowledge to know exactly what does and what does not add avoidable costs to a contractor's operations. As a matter of logic, it would also be unreasonable to insist the contractor remove non-value added costs where the basis of some of those costs are government requirements.

As noted earlier, the other element of non-value added costs are those contractor operations that are inherently inefficient and add costs that are avoidable. These operations are an integral part of the contractor's business and therefore the costs associated with them are allowable and rightly find their way into the cost of doing business with that contractor. The root cause for the continued use of these inefficient operations is usually lack of sufficient incentive to reduce the cost base upon which a determination/estimation of a reasonable profit is made. What then must be done to provide sufficient incentive to eliminate inefficiencies in contractor operations that are non-value added contributors?

Could-cost must be formally incorporated into contracts to have any significant impact on cost or price. The contractual vehicle must be structured so that there is an incentive of sufficient worth so that the process of reduction of non-value added costs continues throughout the acquisition. The methods for doing this differ for current and future contracts, as will be discussed later in this article.

Sharing could-cost savings with the contractor is essential to protect the contractor's profit level. Profits are popularly viewed and negotiated as a percentage of estimated costs. Thus, if the contract cost base is reduced, then gross profits are also reduced. If a contractor improves efficiency and reduces non-value added costs on a contract, the increased profit level he will enjoy on the instant contract will not usually make up for the profits lost on future work (other contracts or annual options that are renegotiated). Under this situation, there is no financial motivation for the contractor to reduce the contract cost base through improved efficiency. This applies to both cost and fixed price type contracts, and quickly becomes evident when attempts are made to remove non-value added costs from current contracts. The response to this dilemma is to provide financial incentives for the contractor, which are designed to protect profit levels while efficiencies shrink the cost base for those profits. Any system of acquisition that discourages rather than promotes the continual search for improved efficiency has a foundation that is flawed.

This incentive argument might appear to some to be contrary to the basis of fair and equal treatment for all under current government procurement policies. In other words, should a more efficient contractor get a better return on his efforts than one who is less efficient? Under current business practices, non-value added costs will invariably be present as contracting parties seek to minimize financial risks. From the customer's perspective, it would appear to be a good business practice to reward the supplier to eliminate these costs, rather than incur them from contract to succeeding contract. The cost of the reward will be less than that of continuing to incur the non-value added costs, since both the customer and supplier are sharing the savings. The customer will realize a net savings over the alternative of doing nothing.

Once could-cost is applied to a contractual effort, measures must be taken to assure the gains are carried forth to succeeding contracts. Nothing of long term significance will be gained by applying could-cost to the current contract and then reverting to the old practices on the succeeding contracts with the same contractor or with other contractors. Continuous improvements should be sought from contract to succeeding contract to ultimately drive out all non-value added costs. Incentives should also be built into succeeding contracts to assure continued contractor motivation to further reduce non-value added costs.

Elements of Could-Cost

Although could-cost can apply to any type of contract, the experiments focus on hardware development and production as areas with the greatest potential for significant savings. In a development program, the contractor should consider the following elements:

• **Challenging Technical Requirements.** Government system development requirements may specify capabilities that require solutions which push the technological state-of-the-art. Technically complex and costly designs may be required to meet the outer boundaries of the system's performance envelope. In these cases, a large portion of development cost may be needed to achieve a modest increase in performance. Giving up a small capability increase may still result in a system which is responsive to the user's needs. Contractors should be encouraged to challenge requirements that fit this category.

• **Challenging the Request for Proposal Requirements That Do Not Add Value.** Some examples of these requirements are detailed specifications, specification tiering, data requirements and "boiler plate" provisions. Although the government reviews of the request for proposal may remove some non-value added requirements, contractors should look hard at this category.

• **Enhancing Design Practices.** This area could be the most fruitful for generating savings in a development program. Use of concurrent engineering would include all the functional disciplines in the design effort at the outset and should eliminate the need for many design iterations and reviews. The utilization of variability reduction and design for producibility techniques can optimize a design for cost effective production. These techniques can also improve management and engineering productivity in the design process. Other areas for consideration are exercising tight configuration control, reducing or consolidating testing, using standard parts, using commercially proven practices, and streamlining the decision and review processes.

The acquisition strategy itself can complement could-cost efforts on a development program when that strategy calls for the system developer to be the initial producer. This provides the opportunity to carry forth the could-cost philosophy from development to production with the same contractor. It also permits the integration of incentives for could-cost in development with those for production to provide for greater contractor motivation.

Could-cost elements for a production program include overhead reduction, requirements streamlining, reducing the cost of quality, and improving labor efficiency.

Areas to address in overhead for trimming the cost of operations include marketing departments, office space, use of utilities, fringe benefits, bid and proposal effort, contracting out services, indirect labor pools, and all other allowable overhead charges.

Requirements streamlining encompasses efforts to eliminate non-value added product requirements; unnecessary specifications, standards and data items; boiler plate and special provisions; tiering of specifications and standards; and unnecessary and inefficient testing.

Reducing the cost of quality is potentially the greatest area of savings on a production program. Elements that should be addressed in this area

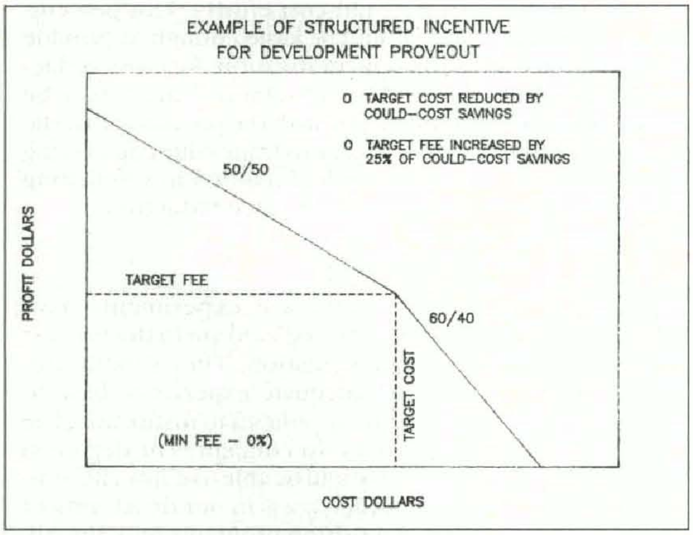


Figure 1.

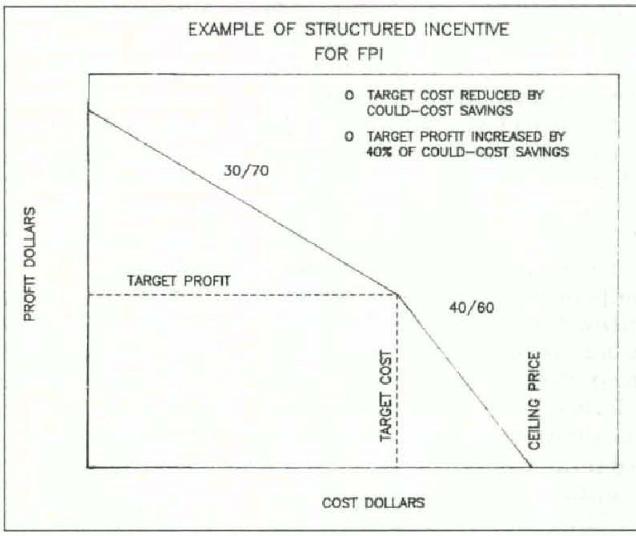


Figure 2.

include eliminating the causes of waivers, increasing manufacturing yields, reducing audits, reducing parts shortages, using process controls, reducing design changes, reducing scrap and rework, controlling and improving vendor quality, reducing work in process, increasing inventory turns, and improving the effectiveness of corrective actions.

Improving labor efficiency involves reducing the size of program offices and increasing the productivity of engineering support and manufacturing labor.

Another important aspect to consider in a could-cost effort on both development and production programs is that the prime contractor must involve the subcontractors in the effort. The majority of program costs are often spread among the subcontractors. The prime contractor should use techniques with the subcontractors similar to those discussed in this article. In addition, some promising areas for primes to pursue include reducing the number of suppliers and concurrently increasing volume for the remaining suppliers, improving supplier quality and requiring wider use of process control by suppliers, expanding the use of sole source suppliers for long term quality and stability, and combining test requirements with supplier tests.

Contractual Application

Appropriate contractual arrangements are needed to assure that the full benefits of could-cost reductions will accrue to both the government and the contractor. For a contract already awarded, some means must be used to interject could-cost efforts into the on-going contractual effort in a way which does not disrupt contractor performance. The method developed for the experiments at FMC and McDonnell-Douglas Helicopter was to execute a parallel, stand-alone could-cost agreement. The on-going contract serves as the baseline for any could-cost adjustments ultimately negotiated under the terms of the stand-alone agreement. This agreement should be in the form of a business arrangement which specifies general terms and conditions, a sharing arrangement for savings generated; and, for each candidate could-cost effort to be incorporated in the agreement, specification of the scope on each effort, the estimated savings, the schedule for negotiating the details, where the efforts will be applied (the on-going contract, future contracts, or both), and the planned effective dates.

To develop the could-cost agreement, the government and the contractor have to undertake a joint effort to identify and review potential areas for evaluation. All of the could-cost elements previously discussed should be examined. The contractor then proposes a list of candidates for evaluation. After government review, the contractor is advised which candidates appear to have merit for further development. The contractor then selects his preferred candidates and develops a detailed scope of work and a rough order of magnitude of savings anticipated to result from each effort. The government decides which candidates are viable, and these are included as annexes to the could-cost agreement. If implementation of a candidate requires a waiver of regulations, the government obtains this waiver prior to inclusion of the candidate in the agreement. Each individual candidate is then negotiated according to the schedule stipulated in the agreement annex covering that candidate. This process should be executed carefully, since inclusion of the candidates is expected to result in a cost savings for sharing with the contractor.

A different approach is taken for contracts yet to be awarded. In these cases, could-cost provisions can be integrated into the contracting process at the outset and can be considered in the contract award process (source selection). The method described here was developed from the AAWS-M experiment. A requirement for the submission of a separate could-cost proposal, in addition to the submission of a fully responsive proposal, is included in the request for proposal. In the separate could-cost proposal, the contractor proposes a program based on his recommended changes to the provisions of the request for proposal. He must be able to demonstrate that his proposed changes would provide a more cost effective approach and, at the same time, not violate procurement laws nor compromise mission essential requirements. Further, he must show a clear benefit for each proposed change, and separately price each change as a selectable option.

The cost realism of the could-cost proposal is evaluated to establish whether or not the selectable options of the proposal are credible enough for incorporation in the contract. The proposal is not "scored" or considered as a "go/no-go" factor in source selection. Discussions would be held with offerors whose could-cost proposals were considered marginally responsive. In a competitive environment, contractors will most likely provide good, realistic could-cost proposals to maintain their responsive competitive posture.

Given that the could-cost selectable options are included in the contract, these options would be negotiated in detail within 90 days after contract award. Their not-less-than cost will trigger a reduction in the contract price or target cost, depending on whether the contract is cost or fixed-price. The contract price/target cost would then be reduced by the amount of the savings resulting from the could-cost option.

The contractor should also be required to execute could-cost agreements with his subcontractors. Provision should be made in the contract which allows the submission of additional could-cost proposals at any time during contract execution. Provisions should also be made to financially reward the contractor for achieving could-cost savings. Methods to do this are discussed in the next section.

Contractor Incentives

The need for providing adequate incentives for the contractor to reduce non-value added costs has already been discussed. The incentive methods used will depend upon the type of program and the type of contract. For a development program with a cost type contract, incentive methods which should be considered are the structured incentive on cost, award fees on program elements and the value engineering clause.

• **Structured Incentive on Cost.** Figure 1 illustrates a structured incentive which could be used for a development proveout effort. This is representative of the structured incentive envisioned for the development proveout phase of the AAWS-M experiment. In this case, the contract target cost is reduced by the savings negotiated for the could-cost proposal options once these options are exercised. The target fee is then increased by an amount equal to 25 percent of the could-cost savings. This gives the contractor the potential to earn more fee if he does not exceed the adjusted target cost. At the same time, he can earn additional fee amounting to 50 percent of every dollar his actual cost comes in under the adjusted target cost. If his actual cost exceeds the adjusted target cost, he pays 40 percent of the overrun up to the point where all his earnable fee is consumed; thereafter the government assumes the cost overrun.

• **Award Fees on Program Elements.** The government may place special emphasis on the successful performance of some element of the program. For a development effort, emphasis may be placed on design-to-cost, design-to-operational-support cost, or design for producibility for their ultimate impact on future production and support costs. These type efforts would be prime candidates for award fees. The award fee provisions are usually structured to permit continuing government evaluation during contractor program execution, thus providing an additional management tool for potentially high risk areas.

• **Value Engineering (VE) Clause.** This clause would be beneficial to the contractor to share in collateral savings from his value engineering proposals, and to provide a contractual mechanism for sharing savings where the sharing period would extend beyond the current contract.

For a production program with a fixed price incentive contract, a structured incentive on cost and the value engineering clause could be used. Figure 2 illustrates a structured incentive similar to that envisioned for the limited production phase of the AAWS-M experiment. The concept is the same as the structured incentive for development proveout, with the exception that the share ratios and the target fee percentage increase due to could-cost savings are greater. This recognizes the increased risk for the contractor in achieving cost reductions in a production environment. The target profit would be increased by 40 percent of the could-cost savings, and the contractor share of savings under the adjusted target cost would be 70 percent. The contractor's share of any overrun over target cost up to the ceiling price would be 60 percent. The argument for the VE clause is the same as previously discussed for the development proveout case.

For a production program with a firm fixed price contract, the contractor should be allowed to retain a percentage of the contract price reduction resulting from could-cost efforts. This percentage should be large enough to provide sufficient motivation for cost reduction. The VE clause could also be applied, but with the provision that the price reductions from value engineering would not be included in calculating the could-cost price reduction.

Summary

The could-cost experiments have been structured, and are in the process of implementation. They should provide an adequate experience base to derive Army policies to institutionalize the could-cost concept. The degree to which we will be able to eliminate non-value added costs in our development and acquisition programs will directly depend on how well we and our supporting industries can improve the processes by which we do business. In this light, the could-cost concept is entirely compatible with the continuous process improvement philosophy of total quality management. Unless underlying process improvement is achieved by the Army and its contractors, could-cost gains will undoubtedly be superficial and short-lived. Continuous process improvement must become the way we do business.

Acknowledgments

The material for this article has been developed by the many people at all levels within the Army acquisition community and supporting contractors involved with could-cost experiments. Robert Black, Darold Griffin, Seymour Lorber, and John Jury (retired) have provided invaluable leadership and guidance for the experimental efforts. Finally, LTC Richard Horne provided editorial assistance and helpful comments on the organization of the material.

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SINGLE FUEL ON THE BATTLEFIELD

By Austin Chadwick

Introduction

A "single fuel on the battlefield" is well on its way to realization.

The United States and the other members of the North Atlantic Treaty Organization (NATO) are steadily working toward the goal of combat fuel standardization. In fact, "single fuel on the battlefield" stands among the top 10 projects of the NATO Military Agency for Standardization.

In the vanguard for the Department of Defense (DOD) is the single fuel on the battlefield initiative. Since the U.S. Army Belvoir Research, Development and Engineering Center (BRDEC) has DOD lead responsibility for ground fuels technology, the center has been a focal point in planning and implementing the research and demonstration phases leading to fuel standardization.

The key is the use of kerosene-type aviation turbine fuel (JP-8) in both aircraft and all ground vehicles and equipment that run on diesel fuel. The Fuels and Lubricants Division within the Directorate for Materials, Fuels and Lubricants at BRDEC with support from its dedicated contractor-operated Belvoir Fuels and Lubricants Research Facility was the key player in deeming JP-8 fuel acceptable as an alternative to diesel fuel, through exhaustive system and engine evaluations.

The center is also developing a comprehensive combat fuels data base. Because it promises an array of benefits, the single fuel concept has maintained a high priority and emphasis within BRDEC's fuels and lubricants field of endeavor.

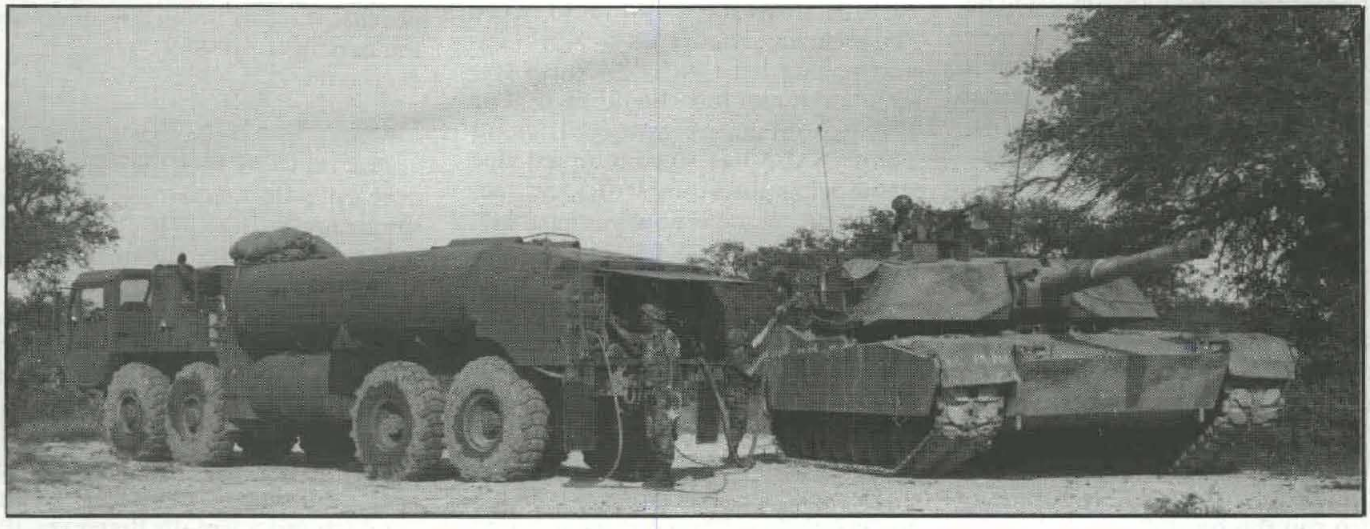
Standardization will, obviously, simplify military fuel use. This in turn, will increase fuel availability near potential combat locations. The initial focus is on the NATO theater with other areas to follow.

JP-8 as the standard combat fuel will impact tremendously through a wide range of Army operations, and those of other services and allies. Flexibility will be enhanced. The logistical and supply burden that is compounded in dispensing, transporting and storing multiple fuels for air and land forces will be decreased. Vehicle operational readiness — reliability, durability and low-temperature operability — will improve, and maintenance will be reduced. What's more, with the concept of "one-fuel forward" comes the capability to refuel aircraft in forward areas with the same refueler used for ground vehicles, which is a significant combat multiplier.

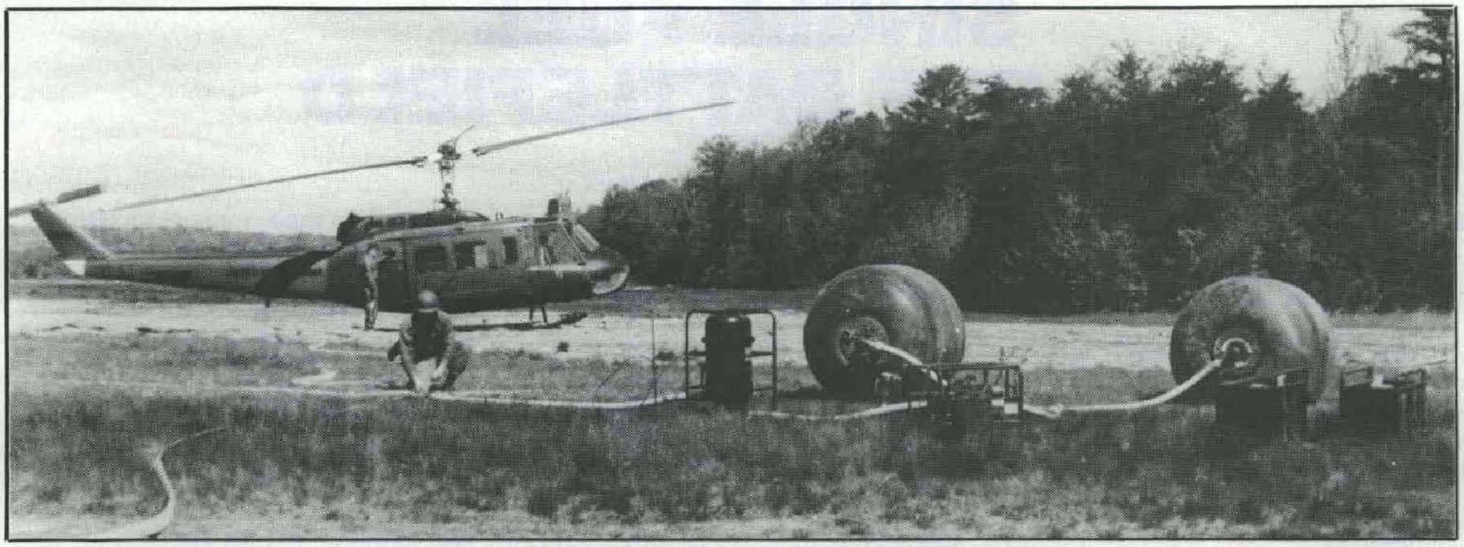
The intention is not that JP-8 become the primary design fuel for diesel engines, but that those engines be able to operate satisfactorily on JP-8 as well as diesel fuel. The changeover from diesel and JP-4 aviation fuel to JP-8 will occur as NATO war reserve stocks are used up in the next few years. No conversion is envisioned to take place in the continental United States (CONUS).

Fuels

The "single fuel on the battlefield" is designated as JP-8, which is interchanged by the allies under NATO Code No. F-34. It can be used not only in aircraft, but also in all diesel-engine-driven ground vehicles and equipment. A couple of other fuels are essentially identical.



With "one-fuel forward," the same refueling truck can service ground vehicles and aircraft in forward areas, a significant combat multiplier.



Storing, transporting, and dispensing a single fuel will help alleviate the logistical and supply burden on the battlefield.

Commercial JET A-1 differs from JP-8 only in that it does not contain three additives required in JP-8: the fuel system icing inhibitor, corrosion inhibitor, and static-dissipator additive. JET A-1 is the worldwide standard for commercial airlines, except in the United States, where JET A is the principal fuel. JET A-1 differs from JET A only in its freeze-point requirement.

JP-5, also a kerosene-type fuel and very similar to JP-8, requires a slightly higher flash point than JP-8. It's used in sea-based aircraft.

Military fuels that ultimately will be phased-out are JP-4 and automotive gasoline. JP-4 is a naphtha-based aviation turbine fuel. It was formerly the NATO standard aircraft fuel. However, it is not acceptable as an alternate fuel in diesel-fueled equipment. And JP-8 is safer to handle.

DOD has targeted the year 2010 to stop stocking, storing, and issuing gasoline overseas. This will be accomplished by no longer acquiring new equipment using gasoline, unless that equipment is intended for CONUS use only. Army force modernization is accelerating the shift from gasoline- to diesel-engine-driven equipment, which can run on JP-8.

In addition, gas turbine engines can use JP-8. They were first developed on kerosene and so can easily accommodate turbine fuels.

History

A number of important milestones have marked the way toward a single fuel on the battlefield. Several of the most important ones follow.

The idea to convert from JP-4 to JP-8 for all land based NATO aircraft originated in 1975. It was based on greater commercial availability, enhanced safety, extended operating range, and improved interoperability.

In late 1981, JP-8 and JP-5 were found very useful in the field fix to the Abrams Tank in Germany. The M1 and other gas-turbine-powered equipment were experiencing serious cold-weather fuel-waxing problems with F-54, the NATO standard diesel fuel. Blending JP-8 or JP-5 into the diesel lowered its cloud point. NATO has since adopted this winterizing procedure with great success as this blend is now interchanged as NATO Code No. F-65.

By 1985, testing had confirmed the feasibility of replacing the NATO standard diesel fuel F-54 with JP-8. U.S. Army regulations reflected the acceptability of JP-8 as an alternate to diesel in January 1987. During that same time frame, NATO ministers ratified the agreement to convert from JP-4 (F-40) to JP-8 (F-34). The conversion of all U.S. land-based aircraft in NATO has been completed.

A key DOD document was issued in March 1988. DOD Directive 4130.3, Fuel Standardization, specifies JP-8 as the primary fuel for overseas land-based air and ground forces when approved by the unified commander. In NATO, draft STANAG (standardization agreement) 4362, "Fuel Requirements in Future Ground Equipment," parallels the DOD directive. The draft STANAG was developed in October 1987 and is now being coordinated for ratification and promulgation.

The next big step forward is a year-long demonstration of JP-8 in vehicles and equipment. It's slated to begin in early 1989 at Fort Bliss, TX. It will provide the data needed to document the benefits of JP-8.

Benefits

The move to JP-8 will benefit not only operations and logistics but also the related hardware itself.

JP-8 is more refined than diesel fuel. Diesel tends to plug fuel filters and leave deposits in injector nozzles, which degrades fuel consumption and impacts the operational readiness posture of our ground fleet. JP-8 does not. Cold-weather starting is faster with JP-8 than diesel, which reduces excess fuel consumption during engine cranking and warm-up. Better yet, JP-8 is presently more than six percent cheaper than diesel.

JP-8 greatly lowers emissions in diesel engines and will significantly reduce fuel-related corrosion. What's more, JP-8 contains low levels of sulfur, and combusts more completely than diesel. This will decrease engine wear and significantly reduce lubricating oil contamination, which leads to less wear in oil-wetted engine parts such as piston rings and cylinders. Clear reductions in fuel-related maintenance will naturally result.

A technical problem being resolved involves smoke; JP-8 produces too little and poor smoke in on-board vehicle smoke generators. There's a retrofit plan for the Vehicle Engine Exhaust Smoke System (VEESS) in the works, as well as simple hardware modifications and smoke-enhancing additives.

It's important to note there's no danger of starting a fire with JP-8 in a smoke generator, as has been erroneously reported. JP-8 is a "low volatility" fuel and not hazardous.

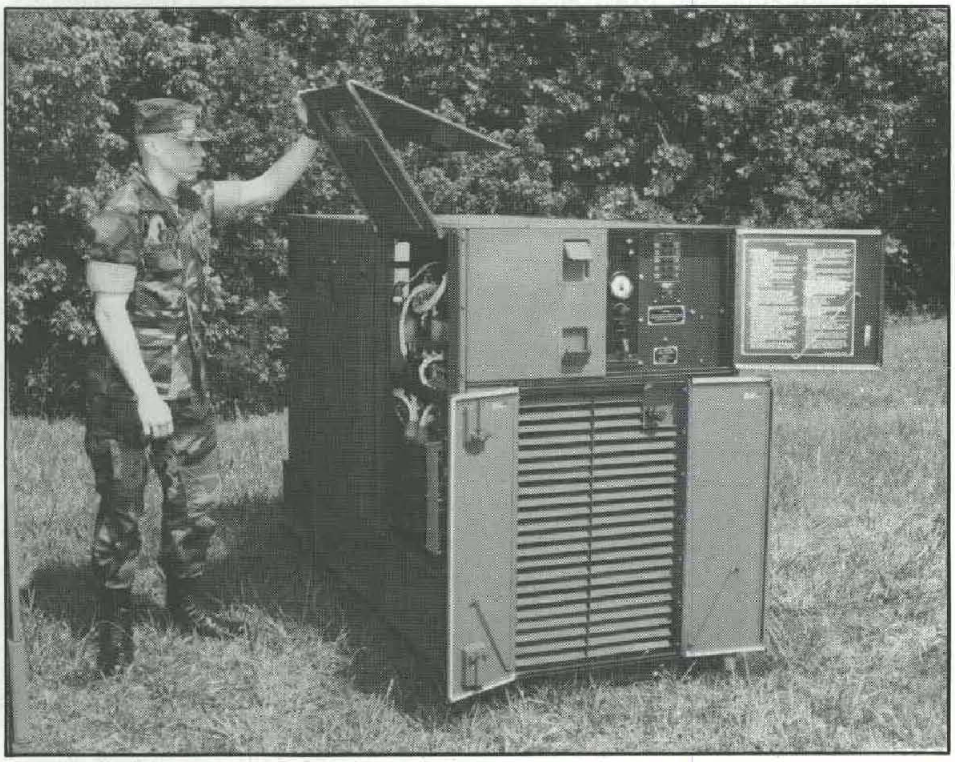
Demonstration

A key part of the effort to establish a good statistical data base for JP-8 is scheduled to begin in January or February 1989. A year-long demonstration will be conducted at Fort Bliss, TX, using a representative mix of combat, tactical, and soldier-support vehicles and equipment. Fort Bliss was chosen in order to place maximum stress on the fuel. The statistics gathered there will help establish the full extent of how well the efficiencies of JP-8 in cooler weather carry over into a hot environment.

Extensive data will be carefully gathered on performance in actual field environments. Since the single-fuel initiative has such far-reaching consequences, this demonstration has been coordinated with, and supported by, a large number of interested commands and agencies.

Execution and monitoring will be funded and largely handled by BRDEC and their contractor-operated Belvoir Fuels and Lubricants Research Facility at Southwest Research Institute, located in San Antonio, TX.

The demonstration program is timely. In reality, the Army and other military services are responding to the series of events that, in effect, mandate the use of JP-8 for diesel-powered equipment in Germany in the near future. This conversion will occur in FY91 or possibly sooner, depending on how quickly DF-2/F-54 stocks are depleted.



The use of JP-8 is the key to combat fuel standardization. It can power both aircraft and all ground vehicles and equipment that run on diesel fuel, such as generators.

The program will demonstrate and document the advantages of JP-8 that result from improvements in engine efficiency and maintenance benefits. A big monetary plus will be lower outlays for repair parts. The Fort Bliss activities will go a long way in determining just how much can be saved with JP-8.

The protocols to quantify conclusions have been established in several similar demonstrations. Like methodology was successfully used on Army evaluations of unleaded gasoline and gasohol (a blend of 10 percent ethyl alcohol in gasoline), and in a DOD demonstration of methanol-fueled administrative vehicles.

Conclusion

DOD Directive 4140.3 states that "fuel is a critical combat resource." The "single fuel on the battlefield" initiative will contribute greatly to the most effective marshaling of that resource. AirLand Battlefield commanders will be the first and primary beneficiaries, gaining flexibility and enhanced logistics supportability.

The single-fuel on the battlefield is a concept whose time is coming. Ratified agreements and the depletion of war reserve stocks of DF-2, along with the phase-out of gasoline, ensure that in NATO. Southern Command plans conversion to JP-5 in ground and air equipment no later than FY90. Central Command has begun storing JET A-1 for aircraft, and will study ground requirements conversion to JET A-1. Pacific Command plans a phase-in to JP-8 shortly.

JP-4 is well along on its way to conversion overseas, and the diesels will be overtaken in NATO in a couple of years. In about 20 years, gasoline will have been eliminated from DOD storage in foreign countries. At that point, JP-8 will have achieved its inevitable status as the "single fuel on the battlefield."

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SOFTWARE TESTING AND TEST CASE DESIGN

By CPT John D. Burke

Introduction

Senior Army leadership is being asked to allocate funds in terms of people versus equipment, research and development versus sustainment, and new versus enhanced hardware. In this regard, one of the greatest returns on investment is in functional and operational improvements in existing software which resides on current and in future hardware systems. Since the overall investment in Mission Critical Computer Resources (MCCR) is expected to be $30 billion by 1990, the test and evaluation effort applied to MCCR should be commensurate with the procurement cost.

One of the highest and earliest payoffs in establishing and preserving functional upgrades or development of new software is through a comprehensive and timely testing of software before distribution. A fault found during development is only two percent to five percent of the cost to fix this fault if found after release.

Software Development Methodology

The most common representation of the development sequence in MCCR is the "Waterfall" model developed by Dr. Barry Boehm. This model has been replicated in a number of software development publications, including DOD Standard 2167. An illustration of the "Waterfall" model is shown in Figure A. This depiction of product refinement shows events as successive and dependent upon completion of the earlier stages. An incorrect assumption is that testing begins after the software has been coded. Following this pattern, especially in a schedule dependent development effort, test failure will inevitably result in program slippage.

A different approach which incorporates the same elements as the Waterfall model but is more effective in producing software with higher reliability and less schedule risk, is the "Hourglass" model. It is shown in Figure B. The principal difference between the two models is that the Hourglass model reflects the iterative progress of defining functions and test criteria.

Requirements Analysis and Test Case Design

Successful software programs begin with a clear understanding and definition of functions and tasks of the software the user expects available for their application. These user requirements may be in the form of a description of current operations, future functions, or embellishments to existing software systems. Without a firm definition of the expected functions, any software produced is unlikely to support the end use objective.

Once the software requirements are known in general, specific subfunctions are determined which will

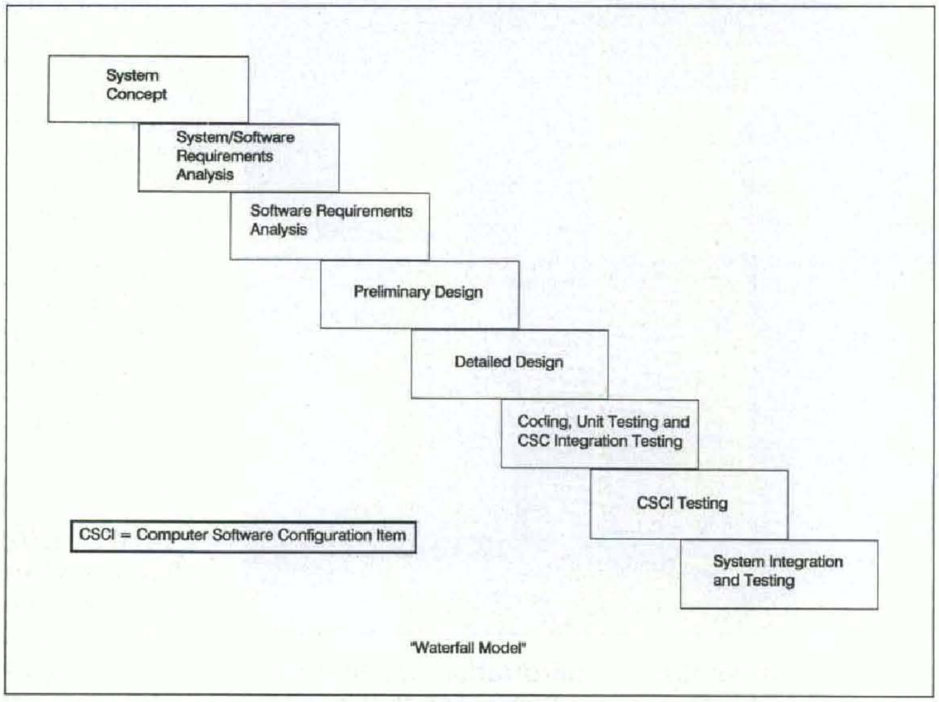

Figure A.

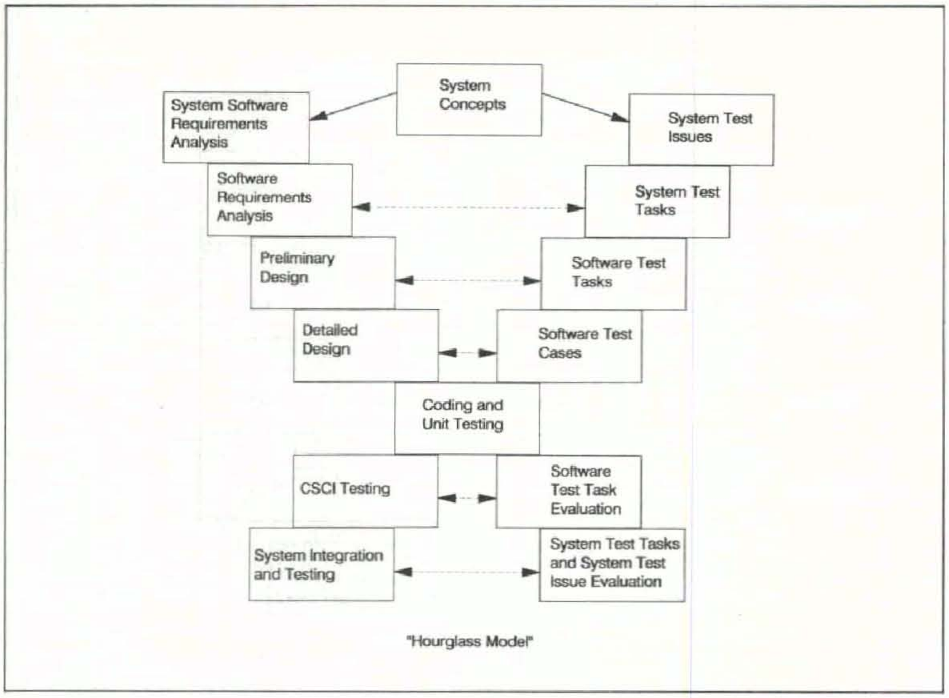

Figure B.

generate overall test criteria. As the sub-functions or tasks are refined in even greater detail, test cases are then created to evaluate and test these detailed functional requirements. In the extreme sense, the greatest degree of functional detail results in a one-for-one correlation with test cases. However, this is neither practical nor efficient. A general rule is for the test cases to be in one level of detail greater than the functional definition they are applied against.

Just as sub-tasks support tasks so will test cases support overall test criteria. This building block approach to functional requirements and test criteria results in several positive benefits:

- Coding is deferred until executable code, as opposed to program design language, can be tied directly to a specific function or task.
- The concurrent development of test cases establishes boundaries for system solution space through system definition and attributes.
- Since the programmer and analyst do not have to develop test cases after the fact, unit and module testing is done faster and more completely.

Software Testing Management

Overall software test management begins with a clear functional description of the system requirements and the specific software portion of the system's capabilities. The functional description of the system operational mission is usually found in the Required Operational Capabilities (ROC). Specific hardware and software capabilities are then defined in the system technical specification.

Based on the ROC and technical specification, initial test management begins by identifying functional requirements and developing test issues and criteria. This analysis forms the basis of the technical and operational independent evaluation plans. Each critical issue parallels a particular system function and the criteria necessary to determine if that function has been met. From these independent evaluation plans, the ROC, and the technical specification, the software developer can begin to develop test cases and sub-functional tasks.

To determine whether the software developer has met the requirements for the system, the tester and evaluator will perform verification and validation testing. Verification consists of proving whether the software performs in a technically correct fashion. In other words, does the code do what the engineering design planned? Validation is the evaluation of the software to determine if the product is a viable solution to the stated problem (requirement). Verification and validation are mutually dependent activities which build upon each other until the entire software system is accepted.

The extent of verification and validation testing is usually somewhat subjective. The more complex and diverse a system, the more likely that the role of the developing contractor will diminish and the actual formal verification and validation testing will be the responsibility of an independent verification and validation tester. In smaller projects where the objective software system can be limited in scope and duration, the government may perform the formal verification and validation function.

Software Test Case Identification

A software test case is the execution of a particular function or sub-function of the developed software system to assure that this function performs within performance parameters in the evaluation plan. As such, each test case should be correlated to one or more specific functions.

Within each function the logical subset becomes functional tasks. These tasks are represented in the software hierarchy as units. A combination of units to perform a specific function are known as modules. As modules are linked together and integrated, this becomes the computer software configuration item (CSCI); which generally is a specific product to be delivered by the developing contractor.

The goal of the software engineer is to map out each functional requirement and the corresponding test case to verify and validate each task. An example of the Function-Test Case matrix is shown in Figure C. As the software items are generated, the developer can then test to the corresponding test case and evaluate both software product schedule progress and identify basic functional areas that have been met. One other aspect of this function-task-test case matrix is that the requisite "hooks" between the tasks and test cases can be seen.

Complexity and Structure

Development of software test cases cannot begin until the "shape" of the objective software program has been identified. This identification includes the type of language used, the operating environment, hardware, user interface and a host of other factors. Each of these has a direct impact on the software tester since the software test cases, as well as the software, must be developed within these design parameters.

Assuming the software test is designed to evaluate the product for acceptance, one of the first criteria for test case development is whether we are interested in system functionality ("black-box") or in the design and maintenance of the software ("white-box"). One criteria is whether the system is mission critical such as avionics or target acquisition, or at the other extreme will be for general purpose, administrative use.

System functionality testing (validation) alone is certainly much faster, less complicated and resource intensive. However, it also has a corresponding lack of visibility into software development and maintainability. Thus, MCCR are initially tested at least at the module level (verification) and once technically certified, are then functionally validated.

Practical limits on the extent of unit and module testing must be set early since the ability to test each line and path of executable code is often impossible. Even a small program with 25 decision points (IF-THEN-ELSE) could approach 100 million control paths. This clearly is infeasible to test. Therefore, some functional testing must occur in lieu of perfect verification tests.

Other considerations include whether the software system will be interactive or batch, real time, data base management, or communications. The skill and capabilities of the intended user and operating environment are also evaluated.

Software Test Case Design

Each software product will have a specific software test case portfolio applied to it. However, a few generalities can be made in the development of software test cases.

White Box Testing

White box testing is the analysis and evaluation of the program design and execution to determine technical accuracy and correctness. Several techniques have been identified as standard practices in conducting white box testing. These are examined in Pressman's book, *Software Engineering — A Practitioners Approach*.

Basis path testing is a method of defining a basis set of execution paths. The objective of basis path testing is to exercise all of the executable code at least once during the test. Several techniques exist to develop the basis path: flow graph notation, cyclomatic complexity, and graph matrices.

Flow graph notation is a means of representing the control flow of the program. The principal advantage of flow graph notation is ease of use and ability to quickly capture the basic program design.

Cyclomatic complexity is the index of logical complexity of a software product. This index or metric is important in determining the number of logic paths in the program and the number of tests which must be run to guarantee execution of all program statements.

Graph matrices complement flow graph notation and show the control flow as a square matrix (even rows and columns).

Loop testing is a second method of evaluating program execution where numerous loops are embedded in the program structure. These loops may be nested, concatenated, or unstructured (GO TO statements). Loop testing is especially valuable in testing the loop parameters and array boundaries.

	Function A		Function B	
	Sub-Function AA	Sub-Function AB	Sub-Function BA	Sub-Function BB
Task 1	TC1 AA_4	TC2 AA_2	TC1 BA_2 , BA_3	TC3 BB_2
Task 2	TC1 AB_1	TC2	TC4 BA_1	TC4 BB_1
Task 3	TC1 BB_3	TC3 AB_4	TC2 BA_1	TC3 AA_1
Task 4	TC3 AA_1	TC2	TC1 BB_4	TC3 BA_4

TC = Test Case
Small Block = Test Case Used for Task and Function
Large Block = Other Affected Sub-Functions and Tasks

"Function - Test Case Matrix"

Figure C.

Black Box Testing

Black box testing is a test technique used with white box testing to perform input-output analysis of functional performance. Pressman also provides an excellent encapsulation of black box testing. He asserts that this test area is designed to uncover incorrect or missing functions, interface errors, errors in data structure, performance errors, and system start-up or shut-down errors. Techniques used for black box testing are:

- Equivalence partitioning involves breaking up the program by some pre-selected criteria such as a type of input (records, control commands, file update), certain values, comparison of inputs, or logical paths based on true or false (Boolean) conditions.
- Boundary value analysis (BVA) is a second test method which is used with equivalence partitioning to analyze the output domain of the program's functional performance parameters.
- Data validation testing is a fairly simple technique to test interactive systems which are dependent upon the user to input data into the program.

The goal of every test, whether hardware or software, is to assure the test director that the Computer Software Configuration Item meets the stated performance criteria.

These tests are designed to identify when incorrect input will force unplanned execution within the system.

An example of white and black box testing can be seen in a software program routine designed to perform a function of comparing data input with communications system sampling rates to determine successful data block transmission.

The validation (black box) of the requirement is demonstrated by the input of the subject block (equivalence partitioning), acceptance for size (boundary value), and correct parity (data validation). The verification (white box) portion of this test compares the transmission time against the known sampling rate (flow graph), and the flow and error checking of the data to its output file (cyclomatic complexity). The limited scope of this program function reduces the required amount of detailed analysis. However, hundreds of these sub-functions are used to control a real-time communications system. The interactions between program tasks and the requisite test cases can be shown in a function-test case matrix.

The creation of software test cases is actually an iterative process beginning with an analysis of the basic program design, determining the complexity of the program, identifying a set of logic paths, and then preparing test cases which will exercise each path in the basis set. As test cases are formed for each function, an entire software product set of test cases will emerge to represent the verification of the software engineering, and the validation of user requirements.

Software Testing and Test Integration

In creating the program plan to develop and test the software configuration item, several considerations must be kept in the forefront. These include test schedule, resources, control, and conduct.

Test schedule is entirely dependent upon the development techniques and quality control placed upon the software development team. When adequate requirements analysis, preliminary and detailed design, and preliminary (informal) testing have been done and problems corrected, the actual formal test is relatively easy and short. When this is not the case, then test schedules often mirror development schedules.

Test resources should be identified as an integral part of the software product cost estimates. Using the Hourglass method of software development, corresponding tests are related to module or unit delivery and thus can be both scheduled and resourced. In addition, provisions must be made for additional personnel such as independent verification and validation testers, and formal government on-site evaluators.

Test control and conduct is essential in the evaluation of the software product. Using the Function-Task-Test matrix shown earlier, the test manager can see not only what has been tested, but also what has not. This clear division of the test scope is invaluable where formal testing is required, but a complete product is not available. Thus, specific tasks which fail in earlier tests can be retested, at the test director's discretion, in later tests. Of course, full product acceptance should require all functions and tasks to be successfully tested.

Conclusion

The goal of every test, whether hardware or software, is to assure the test director that the Computer Software Configuration Item meets the stated performance criteria. However, tests are only indicative of what was tested, it cannot (except in the most simple programs) prove that no errors exist. The software tester must focus on the most important parts of the software product. These are a sound and thorough requirements analysis, identification of functions and tasks, building test case criteria, and developing representative and applicable test cases for verification and validation.

Comprehensive software development folders and test reports, to include unit and module tests, will greatly facilitate future software maintenance and product upgrades.

Today's Army uses software in nearly all modern weapon systems. Although the repair and sustainment of hardware is well defined, the maintenance of software is a difficult and often unrecognized problem until something catastrophic occurs. Through the use of effective and thorough software testing techniques the weapon system product manager is able to field a system with a high level of confidence that it will perform as designed.

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ACHILLES HEEL

The following editorial, which we believe will be of interest to our readers, is provided courtesy AVIATION WEEK & SPACE TECHNOLOGY.

The challenge of managing computer software development for weapons systems is not receiving enough attention from U.S. military leaders.

Whether potential enemies are deterred or battles are won or lost will depend increasingly in the future on complex computer software. The operation of everything from F-16s to ICBMs depends on software to control functions of these major weapons systems.

In the U.S. military procurement establishment and in aerospace/defense companies, efforts to manage increasingly complex software development programs are falling far short of what is needed. The situation can best be described as one in which companies are struggling to get this year's software product out the door while worrying about the requirements of the next generation.

The procurement establishment is undoubtedly more comfortable dealing with hardware than software. Bending metal is something U.S. industry knows how to do well. But software has more to do with bending ideas, and the process is difficult to manage. One of the biggest difficulties in understanding the software discipline is that it is not very disciplined yet, but rather an amalgam of art and science. The rapidly growing software engineering ranks at major aerospace companies and government laboratories are just as likely to be populated by former music majors and linguists as engineers.

To develop a million lines of software code, or 5-10 million lines contemplated for use in some advanced weapons systems, requires a team of hundreds of people developing portions of the whole. Coordinating and managing construction of numerous interlocking software modules is a major challenge.

ABSTRACT WORLD OF SOFTWARE

Procurement practices that work for hardware do not work as well in the abstract world of software, and the procurement community should be using innovative approaches to software development. The focus should be first and foremost on careful, up-front systems engineering work. To execute a product in the abstract, it is imperative that the objective be well defined and understood.

A systems engineering approach examines the requirement and works through various hardware and software options to define a system that meets the need. This step comes before the first line of software code is generated or the first piece of computer hardware is acquired.

At this point, rapid prototyping and frequent interaction between the end user and the contractor are in order.

However, the biggest deficiency in military software programs is not the specification process. It is the lack of software experience and talent in the military itself. The report of the Defense Science Board Task Force on military software, issued last year, points out that the number of software-qualified military officers has been essentially constant over the past decade, despite exponential growth in software.

This expertise is being spread ever more thinly over more and more software procurement activities. The Defense Dept. purchased $9 billion worth of mission-critical software in 1985 and expects to purchase as much as $30 billion in 1990. If the trend continues, it seems that the U.S. military's appetite for software will eventually exceed its ability to procure and maintain computer programs.

INVESTMENT IN TRAINING

The military needs a growing cadre of software experts rather than a cadre that has not grown in a decade. The Defense Dept. should be investing heavily in software training programs for officers involved in procurement. Programs the Defense Dept. has already created to foster development of software are helping, but often create as many problems as they solve.

For example, it made good sense to invent the Ada computer language to handle the special needs of U.S. weapons systems. But by starting from scratch, the Defense Dept. positioned itself out of step with the mainstream of software development. Just finding people qualified to work in Ada is difficult, and many large aerospace firms are hiring recent college graduates and giving them a crash course in Ada before assigning them to classified programs.

Flexibility is software's strong suit, allowing the military to make changes in how a weapon system functions, even after it is fielded. But flexibility also allows for changes to be made for the sake of change. Additional features are constantly being added to the software of deployed weapons systems, driving the cost of so-called software maintenance through the roof.

If making needless changes is less than desirable, making changes in a hurry during a conflict is imperative if software is to help U.S. forces prevail.

Traditionally, armies have had combat engineers to build makeshift bridges, ports and even airfields in a hurry. But where is the U.S. corps of software engineers that can fix a key software module quickly so the next airstrike can account for an unexpected SAM threat? Do the armed services expect contractor personnel to volunteer for duty on the front lines? Clearly some minimal level of expertise is needed in the field and on board ship to make sure that weapons systems programs can accommodate unexpected circumstances.

Obviously, there is too much riding on software and too little expertise in the military to deal with it. Computer literacy, as it turns out, may be as important in future conflicts as knowing how to fire a rifle or fly a plane.

LOGISTIC SUPPORT ANALYSIS AND COST REDUCTION

By Robert J. Orendas

Introduction

The goal of every logistician involved in the acquisition of military end items should be to do his part to provide the soldier in the field with the best equipment possible at the lowest cost to the government. When faced with dwindling financial resources, that goal becomes more difficult, but is none-the-less attainable.

To assist in the accomplishment of his mission, the logistician must avail himself of every tool and asset at his disposal. One of his basic tools, and perhaps the most effective, is the Logistic Support Analysis (LSA) process and its attendant Logistic Support Analysis Record (LSAR).

The LSA process is used by integrated logistic support (ILS) management to provide a continuous dialogue between designers and logisticians. The LSA causes design engineers to evaluate the proposed design against manpower constraints, operational and logistic support requirements, and other limiting factors. These evaluations may be accomplished through the application of varied techniques, ranging from logistics analysis, parametric estimates, and trade-off analysis, to the use of mathematical techniques for projecting life cycle operating and support costs.

The LSA is also used when making repair versus throw away decisions and when determining the optimum level of repair. To summarize, LSA provides a system to identify, define, analyze, quantify, and process logistics support requirements for materiel acquisition programs. The LSAR consists of selected data from LSA tasks pertaining to an acquisition program.

Benefits

The benefits attained through the use of LSA/LSAR are both tangible and intangible. In either case, the final result is generally an enhanced product, produced at a lower life cycle cost, which is more easily supported and maintained by the soldier, whether in training or combat.

Tangible benefits are commonly expressed in terms of dollars saved and may be used to measure the effectiveness of the applied LSA effort. Identification of tangible benefits is accomplished with relative ease for they readily equate to dollar savings. Exploitation of significant cost avoidances is very desirable due to the high visibility they engender. This is seen far too infrequently in government contracts which, unfortunately, are too often noted for their highly publicized cost overruns.

Intangible benefits are not always easily identified as they are subjective in nature and their cost or cost savings cannot be readily projected in the form of actual dollar amounts. The intangible benefits resulting from the application of LSA tasks and subtasks, are frequently found as a result of the iterative nature of the process and the inter-relationship among the LSA tasks. Several examples of intangible benefits achieved during a selected acquisition program will be addressed later in this article.

Though intangible benefits are considered to be non-equatable to dollars, they tend to have a significant impact upon tangible benefit. This facet is especially significant when intangibles resulting from LSA/LSAR products lead to design influence decisions, which affect the original design, and in turn, may create highly visible cost avoidances. It is from this viewpoint, that the complimentary nature and interdependency of tangible and intangible benefits become evident.

SINCGARS

To provide further insight as to the role that LSA/LSAR may play in the derivation of cost benefits during any acquisition process, the Single Channel Ground/Airborne Radio System (SINCGARS) program has been selected to provide specific examples. All of the tangible benefits which will be addressed were identified through the application of basic LSA/LSAR efforts and resulted in a total projected cost avoidance of nearly $75 million. The savings realized were a direct result of conscientious and determined efforts made by program management team members who identified program deficiencies and proposed improvements and recommendations.

As a result, the SINCGARS is a well developed, state-of-the-art family of radios that is highly reliable, easily maintained, and operationally effective under all field conditions which are reasonably expected to be encountered during both peacetime and wartime scenarios.

Tangible Benefits

The judicious application of the LSA/LSAR process yielded tangible cost savings of nearly $75 million without jeopardizing or comprising the integrity of the final product. A major portion of these savings occurred as a result of a decision to use existing military

TANGIBLE COST AVOIDANCE AND LOGISTIC SUPPORT ANALYSIS COST DATA

COST REDUCTION ITEM	ORIGINAL COST	REVISED COST	SAVINGS
1. BATTERY CHANGE	$1,433.400 M	$1,361.730 M	$71.670 M
2. REDUCED MODULE PULLER RQMNTS	$ 0.354 M	$ 0.158 M	$ 0.196 M
3. CHANGE IN MAINT CONCEPT	$ 7.800 M	$ 6.732 M	$ 1.068 M
4. AVOIDANCE OF TPS DEVELOPMENT COSTS BY ILS PLANNING	$ 6.688 M	$ 3.644 M	$ 3.044 M
5. SAVINGS REALIZED BY IN-HOUSE ORLA	$ 0.066 M	$ 0.000 M	$ 0.066 M
TOTALS:	$1,448.242 M	$1,372.264 M	$75.978 M

LOGISTIC SUPPORT ANALYSIS COSTS:

CONTRACTUAL COSTS :	$0.480 M
PRODUCTION COSTS :	$0.814 M
ADMINISTRATIVE COSTS:	$0.785 M
TOTAL LSA/LSAR COSTS :	$2.079 M

The data presented was sourced from documents produced during the period 1978 through 1986, and is projected for a 20 year life cycle.

Figure 1.

standard batteries in place of system unique batteries. That decision necessitated a change in the design of the proposed battery case. However, since the required change was made during the early stages of the contract, the costs of redesign were held to an absolute minimum. Tangible savings realized by this action were nearly $72 million over the life cycle of the SINCGARS.

Analysis of changes in electronic counter-counter measures doctrine resulted in a decision to change a Line Replaceable Unit (LRU) to a module. That decision, in turn, led to a change in the maintenance concept, which then allowed for a reduction in test equipment requirements, thereby generating a cost avoidance estimated to be approximately $240,000.

Under the original design concept, each individual SINCGARS was to be fielded complete with module pullers. Upon system review, it was determined that the required module pullers need not be fielded below direct support level, thereby providing for a significant reduction in the total quantities originally recognized as being required. The reduced requirement yielded an estimated cost avoidance of approximately $196,000.

An Optimum Repair Level Analysis (ORLA) was conducted in house using the Optimum Supply and Maintenance Model (OSAMM). This action eliminated the cost of contracting for the requirement and provided a cost avoidance of approximately $66,000. Data obtained through ORLA established maintenance allocations and assisted in the identification of shortcomings in depot test manpower data loading.

These four examples demonstrate how LSA/LSAR may lead to tangible savings. Several more initiatives involving this system acquisition could be discussed. However, these were chosen as representative examples. Similar situations can be found in other acquisition programs, such as the T-700 and T-800 aircraft engines, the Multiple Launch Rocket System, and the Bradley Fighting Vehicle. Figure 1 provides complete cost savings data associated with the SINCGARS program.

Intangible Benefits

Significant intangible cost savings may also be attributed to the LSA process. Dollar savings for these costs cannot be readily determined as they are generally subjective in nature, and are not amenable to definitive cost projections. During the full scale development phase of the SINCGARS acquisition, several issues that produced intangible benefits were identified.

ILS Decisions

The original design imposed a requirement to perform voltage checks, using a voltmeter, to determine if DC voltage from the vehicle power source was being applied to the vehicular mounted SINCGARS. That requirement was eliminated when power source indicator sensors were added to the system and mounted on the front panel of the radio. This resulted in a reduction of man-hours, savings which cannot be determined in this case.

The original design provided for a number of different sizes and types of fasteners. This necessitated the use of an excessive number of different tools, some of which were non-standard. Analysis of this design requirement ultimately resulted in the standardization of fasteners needed and the elimination of some special tool requirements. No cost avoidance has been calculated for these applications.

Maintainability Demonstration

Review of the Tool and Test Equipment Requirements list revealed a shortage of tools required to support the system at intermediate direct support level maintenance facilities. Some tools were not contained in existing tool kits but were subsequently identified and added to the requirements list and selected tool kits prior to fielding.

Review and analysis of LSA/LSAR data identified certain high failure rate items which were subsequently replaced by modules which provide for quick and easy replacement. Cost avoidance is considered to be intangible for these accepted changes as the principal savings are realized as a reduction in manhours lost by units in the field, which may then be used for other purposes.

ILS Planning

Initiation of LSA/LSAR at the earliest stages of ILS planning allowed for the early identification of special test equipment, identified a lack of internal contractor coordination, led to the early formulation of a production delivery plan, impacted upon the Source Selection Evaluation, generated numerous items for negotiation prior to contract award, and highlighted several other actions which might have been overlooked had full use of available LSA/LSAR data not been made. These actions all produced intangible benefits.

Level of Repair Analysis

The ORLA, which was conducted in house, resulted in the attainment of intangible savings by allowing government employees to modify the Source, Maintenance and Recovery, and Financial Inventory Accounting (FIA) codes, thus eliminating what would have been a contractual requirement.

Data Acquisition Decision

Data made available through LSA/LSAR proved to be very useful in the selection of test objectives for the maintenance demonstration. LSA/LSAR also provided the source of data for the development of technical manuals and the repair parts and special tools list. These items are considered to be intangible benefits.

The tangible benefits, generated as a result of the application of the LSA process to the SINCGARS program, were over $75 million.

Design Influence Decisions

Although this area of LSA/LSAR is frequently considered to be an intangible, it is actually an uncosted tangible which produces the most significant cost avoidances. Intangibles derived from design influence decisions applied to the acquisition of the SINCGARS include: enhancement of maintenance improvement programs by analyzing LSA/LSAR data; a reduction in the number of interconnect devices, required as a result of being able to identify electrically identical but physically different items; and, the use of LSA/LSAR data generated during the development of the surface use radio system was applied during the development of the airborne and securable remote control radios. This provided for a commonality of parts and modules within the SINCGARS family, thereby enhancing the supportability of the entire system. Other changes or improvements which were generated as a result of LSA/LSAR cannot be addressed at this time due to space limitations.

Summary

The tangible benefits, generated as a result of the application of the LSA process to the SINCGARS program, were over $75 million. The cost of the LSA/LSAR process involved in achieving this savings, while also providing information necessary to determine the military manpower and skills requirements, technical manuals, provisioning data, and significant impact on every aspect of logistics support, was slightly over $2 million.

One may state that several of the issues discussed are common sense. However, one must recognize that LSA/LSAR provides a structured means of positive identification of real or potential problem areas, thus protecting against the randomness of the application of common sense. It is a well structured tool which enhances the program manager's decision making process.

If the LSA/LSAR process had been more vigorously applied during the concept or demonstration and validation phases in the acquisition of the SINCGARS, the redesign effort during the full scale development phase would have been unnecessary.

The availability of a standard military battery meeting engineering requirements, should have been recognized much sooner, if data generated during early analysis of applicable LSA tasks had been more thoroughly evaluated at the proper time.

Proper and complete data analysis should be the concern of the ILS management team members from the time of their first meeting throughout the acquisition maturation process. If full use of the LSA/LSAR process is made during the acquisition of new materiel and equipment the government will receive a greater return on its investment.

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FIRST COMPLETE AIPS HARDWARE TO UNDERGO TESTS

By George Taylor

The U.S. Army Tank-Automotive Command's (TACOM) long-term program to develop an advanced propulsion system for future heavy combat vehicles will reach an important milestone in 1989 with the beginning of testing of the first complete system hardware by Cummins Engine Co. and General Electric.

The program is known as the Advanced Integrated Propulsion System (AIPS). Cummins and GE were among six competitors which submitted AIPS technical proposals for evaluation by TACOM in 1984 at the end of the initial study phase of the program.

In 1984, TACOM selected the Cummins and GE concepts and awarded each firm a five-year contract, with an option for a two-year extension, to develop hardware and demonstrate concept feasibility. The Cummins concept uses a diesel engine coupled to a seven-speed automatic transmission, while GE's uses a turbine engine and a six-speed automatic transmission.

The AIPS program differs from past developmental efforts in two ways. First, the engine, transmission and related components are being developed as an integrated system rather than as separate items. The purpose of this approach is twofold. It is intended to ensure that all components, and functions such as diagnostics, are properly integrated for maximum performance and efficiency. Also, it is aimed at achieving more efficient packaging of components to minimize vehicle space requirements, thereby making it possible to reduce hull length.

The other unusual aspect about the AIPS program is that one of its main objectives is to have competition throughout much of the research and development process.

The engine in the Cummins concept, designated the XAV-28, is a 1682-cubic-inch turbocharged V-12 diesel that falls within the 1500 horsepower class. Though smaller than the 1790-cubic-inch V-12 which powers M60-series tanks, it is highly turbocharged and is thus able to develop approximately twice as much horsepower.

One of the key differences between this engine and present-day diesels is that it uses advanced heat-resistant alloys in the pistons and cylinder heads. Another important difference is that the XAV-28 is cooled by oil rather than water.

"The same oil that is used to lubricate the engine is pumped through the engine where necessary to cool it," explained Dr. Richard Munt, TACOM RDE Center AIPS program manager. "The oil travels through a heat exchanger to reject heat just as water does in a conventional system." The oil is a special high-temperature diesel oil that can run hotter than other types of diesel oils.

According to Charles Raffa, RDE Center diesel team leader, the advantage of these differences is that the amount of heat rejected to the cooling system is substantially reduced and easier to transfer to the atmosphere. Consequently, the cooling system is much more compact. Thus, the 240 horsepower normally required to run cooling fans in a 1500-horsepower-class diesel tank engine has been cut in half.

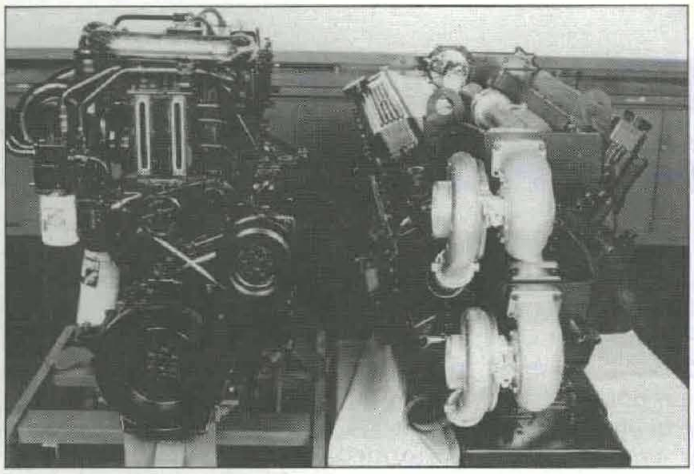
Raffa added that fuel economy is also improved because at the same fuel flow more power is available to move the vehicle. He also said that fuel economy is further improved by the high-pressure, electronically controlled fuel-injection system and variable geometry turbocharging system. He said the overall result is a 1500-horsepower-class diesel engine with its transmission and cooling system in the same volume occupied by the 750-horsepower M60 tank engine without its transmission.

Comparing it to the M1 Abrams, Raffa said the AIPS propulsion system develops 10 percent more sprocket power than that of the M1 in about 60 percent of the M1 propulsion system volume.

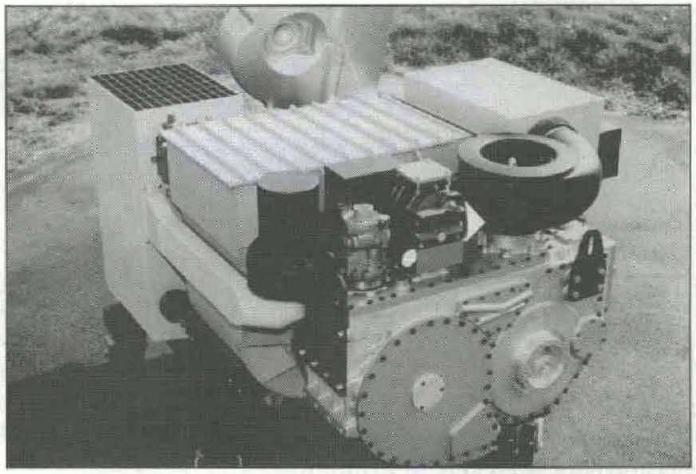
GE's turbine is also in the 1500-horsepower class, and is thus similar in power output to the AGT-1500 turbine that powers M1-series tanks. But unlike the M1 power plant, the GE turbine, called the LV-100, features an improved design that enables it to operate at a significantly higher internal temperature.

The most important benefit in raising the temperature is that it results in substantially reduced air consumption. "One problem with a turbine engine," according to Eugene Danielson, RDE Center turbine specialist, "is that it breathes a lot of air. This means the air cleaner in the M1 has to be large because a tank has to be able to operate in a dusty environment.

"The GE engine is not a lot smaller than the AGT-1500," he added. "It's hard to make a turbine engine much smaller. But you can make it smaller in the sense of designing it to breath



The engine from the Diesel AIPS candidate at 1500 hp (right). Alongside conventional diesel at 440 hp (left). Note similar size of the two engines.



Full-scale mockup of the Turbine-Powered AIPS candidate. It is 62 inches long, compared to 120 inches for the M1 Propulsion System.

less air. When you do this, you can make the air cleaner and associated duct work smaller and thus reduce space requirements."

Noting that turbines have traditionally had poorer fuel economy than diesels, Munt said the increased temperature in the GE turbine, and improvements in the turbo machinery efficiency at low power, result in improved fuel economy which may prove to be competitive with that of a conventional diesel.

In both the Cummins and GE AIPS concepts, the transmission is approximately 10-15 percent smaller in physical volume than the M1 gearbox and features seven and six gear ranges respectively (versus four in the M1). Both have a torque converter that reduces the transmission cooling requirement and improves efficiency. A torque converter is a hydraulic unit that provides slippage between an engine and an automatic transmission to act as a variable-ratio coupling during low-speed operation. This slippage generates heat which must be dissipated through the vehicle cooling system to prevent the transmission from overheating.

RDE Center transmission specialist Frank Margrif explained that since the Cummins and GE AIPS transmissions have additional gear ranges, the torque converter can lock up at all vehicle speeds above three miles per hour. Thus, for the most part there is no slippage, which means the cooling system can be smaller because the transmission cooling requirement is greatly reduced. He added that the reduction in slippage results in better fuel economy.

Munt said another significant advance is the level of diagnostics in the AIPS concepts. "This push in diagnostic capability arose," he explained, "from experience with previous tanks, where we learned that a sizable fraction of the cost of ownership is attributable to service and overhaul of the power packs. Unfortunately," he continued, "history has shown that a great deal of that expense could have been avoided by better initial diagnosis of the failures. Inadequate diagnosis had led to unnecessary repeats of failures and, more significantly, to unnecessary depot visits and overhauls of essentially satisfactory hardware."

Munt said that the increased diagnostic capability is attributable in part to the opportunities afforded by the "clean-sheet-of-paper" integrated systems approach. He said that with many diagnostic sensing requirements satisfied by electronic hardware already required to control the power pack, additional cost due to dedicated diagnostic sensors is minimized. Furthermore, the clean-sheet-of-paper approach allows physically embedded sensors to extract information that is otherwise unattainable. For example, the Cummins diesel engine has three internal position sensors which allow the determination of instantaneous torque level and crankshaft end play. These sensors, in conjunction with other sensors located elsewhere in and on the engine, will permit the identification of a failure of any specific cylinder and its cause.

According to Munt, Cummins and GE will use the upcoming hardware tests — expected to last about one year — to determine what, if any, problems may be present in their systems and make necessary corrections. Then, under terms of the contracts, the firms will each provide a demonstrator system for use in a 50-hour test.

Munt said current plans call for the testing of one system to take place at TACOM and the other to be performed at the contractor's facilities under TACOM's supervision. Following these tests, which are scheduled for completion in July 1990, one of the two concepts will be selected for further development. Plans are now being formulated for demonstration of the AIPS in TACOM's Advanced Transition Technology Demonstrator vehicle. This is a test bed intended to show the integration potential of the various technologies anticipated for future combat vehicles, such as propulsion, gun and fire control, track and suspension, VETRONICS (vehicle electronics) and armor.

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FOCUSING INTEGRATED LOGISTIC SUPPORT

By John E. Peer

Integrated Logistic Support (ILS) encompasses anywhere from nine to 12 functional areas or elements depending on which DOD or service regulation is used. The diversity of the ILS elements, coupled with the self-inflicted confusion over what functional elements are considered part of ILS, has to a certain extent weakened and fragmented the ILS program.

What is needed is a focusing of the ILS program that is clear and understandable to not only the logistics community, but also the design and management communities as well. This article will establish the keys for refocusing the ILS effort and will identify some tools for tracking its success.

The objectives of ILS are twofold: design for support, and design of support. Two simple objectives, but what do they mean? What do they mean to the logistician, the designer, or the project manager? How are the objectives achieved? How do we measure achievement of the objective?

ILS Design for Support

Let's look at the first objective, design for support. From a logistician's point of view it means that each ILS functional element should be considered as part of the design process in order to minimize the support of the system/end item. That is an objective that is easily stated but very rarely quantified or accomplished. The problem is that minimizing support is a difficult concept to present to the designer and hence sell to the project manager. What is needed are clear design objectives like those depicted in Figure 1.

The top objective is to design a system so that it is discarded at failure. Eliminating the need to repair an item reduces significantly the support burden. While such a design goal is possible for small end items it is not realistic for large weapon systems. However, repair versus discard decisions for each assembly and component that comprises a system can be made.

The decision to repair versus discard is easily quantifiable in terms of the cost of the item versus cost to repair; guidelines a designer can understand. Designing for discard would naturally include designing for modularity and modular replacement. Optimizing modules in terms of size, functions, and cost of components will result in more items that can be discarded and if not discarded then modular replacement reduces the maintenance burden.

If an end item must be maintained, then the next few objectives should be considered from a design standpoint. The use of high reliability parts reduces the number of times an item must be repaired. If it fails, built in test equipment (BITE) or integrated diagnostics provides for the best mode of determining when a failure has occurred that requires a maintenance action to be performed. If BITE can't be designed in, then standard test points/connections for external test equipment becomes the next design criteria.

Having covered the design approaches for avoiding the need to perform maintenance and when a failure occurs how to detect it, the next objectives address how to design for ease of maintenance. Knowing which items that must be replaced or repaired establishes the design criteria for which items must be accessible and the identification of access panels and the positioning of components and assemblies. Likewise, the use of quick disconnect

ILS OBJECTIVE

DESIGN FOR SUPPORT:

- DISCARD AT FAILURE
- MODULAR REPLACEMENT
- HIGH RELIABILITY PARTS
- BITE/INTEGRATED DIAGNOSTICS/STANDARD TMDE
- STANDARD TEST POINTS
- ACCESSIBILITY
- QUICK RELEASE FASTENERS
- STANDARD PARTS
- SIMPLICITY (FEWER PARTS)
- LIFTING POINTS FOR TRANSPORTABILITY
- REDUCED WEIGHT/CUBE
- SOLDIER/MACHINE INTERFACE

Figure 1

ILS OBJECTIVE

DESIGN OF SUPPORT:

- REDUCE NUMBER OF PARTS
- REDUCE NUMBER OF REPARABLES
- REDUCE REQUIREMENT FOR COMMON TOOLS/TMDE
- ELIMINATE SPECIAL TOOLS, TMDE, & SKILL RQMTS
- REDUCE MANPOWER
- REDUCE SKILLS REQUIRED
- REDUCE TRAINING COURSE LENGTHS
- REDUCE TRAINING DEVICES
- INCREASE MODES OF TRANSPORTATION
- REDUCE NUMBER OF TECH MANUAL PAGES

Figure 2

ILS KEYS TO SUCCESS

- EARLY PLANNING VIA FRONT-END LSA
- SOUND ILS RFP/CONTRACTS
- COMPREHENSIVE PROGRAM REVIEWS
- LOGISTICS TESTING
- POST DEPLOYMENT ASSESSMENTS

Figure 3

fasteners shortens the time to access and thus replace or repair an item.

Use of standard parts reduces the numbers of different parts and can have the added affect of reducing the numbers and types of tools needed to support the end item. It can also simplify the end item's complexity in terms of the sheer numbers of components that comprise the end item.

Designing for transportability is an often overlooked objective that is not addressed until the end item is built and ready to be shipped. Lifting points, weight and overall size of the end item must be considered on the design drawing board in order to ensure the end item's future transportability.

The last, but not least design for support objective involves the man-machine interface, the human factors considerations, if you will. Each system must be designed with the operator and maintainer in mind. Design criteria in terms of human physical dimensions, visual perpetuity, and physical/mental limitations are well documented in human factors engineering handbooks and human performance studies. Knowing the limitations of the target audience (i.e., the operator and maintainer) before designing the end item certainly helps to design the equipment to meet the capabilities of the soldier.

If the logistician, along with the designer, applies the design for support objectives to the design of a new system (or uses them as the criteria for choosing an off-the-shelf item), then ILS is well on its way to being accomplished.

ILS Design of Support

Design for support is but one piece of the design puzzle that a designer and project manager must deal with. The other piece, that tends to be a bigger piece, is the design for performance objectives. While an equal balance is the logistician's goal, there are times when performance objectives are met at the expense of support objectives. This results in a less than optimum end item from a support standpoint. Under these circumstances, the design of support objectives become critical to the support of the end item.

Figure 2 lists the design of support objectives. The first objectives involve reducing the total number of parts and reparables that comprise the end item. Such reductions lower cataloging, inventory, and pipeline costs, and the

ILS DESIGN FOR SUPPORT SCORECARD

SYSTEM NAME ______________________

FACTOR	BASELINE SYSTEM	NEW SYSTEM
SYSTEM MTBF		
NUMBER OF PARTS		
NUMBER OF REPARABLES		
NUMBER OF SPECIAL TOOLS		
NUMBER OF COMMON TOOLS		
NUMBER OF COMMON TMDE		
NUMBER OF SPECIAL TMDE		
NUMBER OF PERSONNEL		
NUMBER OF DIFFERENT SKILLS		
TOTAL LENGTH OF TRAINING COURSES		
NUMBER OF TRAINING DEVICES		
TRANSPORTATION MODES		
NUMBER OF TM PAGES		

Figure 4

number of types of maintenance actions and its attendant logistics tail (e.g., tools, TMDE, TM pages, skills, etc.).

Reduction/consolidation of common tools/TMDE needed to perform maintenance simplifies the maintenance actions, as does the elimination of any special tools/TMDE. Achievement of these objectives has a direct affect on reducing the need for existing skills, eliminating the need for special skills, and reducing manpower requirements and reducing the number of TM pages. For the latter objective, initiatives to automate TMs as an integral part of the hardware is an additional realistic approach to achieving this objective.

Reducing the length of training courses is a function of reducing skill levels, number of reparables, and by designing training courses around multiple, common skills. Similarly, the same can be said for reducing the number of training devices. Although, the need for training devices is also a function of how economical it is to use the end item itself for training versus a training device and its logistics tail.

Finally, a system that can be transported by many modes (ground, air, rail, ship, etc.) offers the logistician the choice of the most economical mode for any given mission and point in time rather than being limited to a single mode that may be costly or worse not available at all due to higher priorities.

ILS Keys to Success

Designing for support and the design of support objectives can only be achieved through successful project management of the entire effort beginning at day one. Figure 3 provides the simple programmatic keys that should be followed to insure ILS success. By focusing on each of these keys on a day-to-day basis, the objectives of ILS can be met. Failure to accomplish the self-explanatory keys will surely result in a less than adequate ILS program and less than optimum design and support structure.

Measuring Accomplishment of ILS Objectives

Determining whether or not a design/acquisition effort has achieved the ILS objectives can be difficult if measurement is based on "minimizing the support structure." How does the logistician or the project manager know when he has accomplished the ILS goals and what does he measure it against? Perhaps the way to measure achievement is to compare ILS for the new system with ILS requirements of the predecessor system or a baseline system.

Figure 4 provides a scorecard that can be used to measure whether or not the ILS objectives have been met. The key to the scorecard is the establishment of predecessor or baseline system parameters. In other words, what is the ILS status of the old system and is the new system doing any better? If it isn't, then project management must ask the question, "Why are we developing a new system?" If the answer is that performance is so much better with the new system, then the question still remains can we afford the support cost for it.

Establishing the baseline parameters ties into the programmatic keys to success by using the up-front LSA efforts in the area of comparative analysis. Accomplishing the LSA comparative analysis establishes the baseline system parameters that can then be used as the scorecard values.

Going down the list of the Figure 4 parameters, it is obvious for most which direction the new system values should go (e.g., number of reparables should go down, number of tools should go down, reliability should go up, etc.). For some, like training devices, the direction is not so obvious. For example, an increase in training devices could significantly reduce training course lengths and avoid costly use of the end item. Thus, an increase is beneficial. Suffice to say, explanations where necessary would increase the utility of the scorecard.

Summary

The ILS design for support objectives provide the logistician with quantifiable parameters that the design community can understand and the project manager can defend when requesting funds and considering tradeoffs between performance and support. The ILS design of support objectives provide the logistician with quantifiable parameters that should be placed on every development effort in addition to the design and support constraints. Taken together these objectives focus the efforts of the ILS, design and project management communities on developing a supportable system that is maintained at minimum operating and support costs.

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By Dr. William H. van der Schalie, Henry S. Gardner, and Dr. Robert A Finch

ON-SITE TOXICITY ASSESSMENTS FOR ARMY FACILITIES

Evaluating the toxicity of surface and groundwaters

Introduction

Increasingly large expenditures of funds are being required for the identification and remediation of surface and groundwater contamination at Army facilities. It has been estimated that the Department of Defense has 400-800 hazardous waste sites that will require $5-10 billion for remediation over the next 10 years. Many of these sites contain complex mixtures of chemicals and an estimated 35 percent contain military-unique materials.

The Army has at least 22 hazardous waste sites on the National Priority List established under the Comprehensive Environmental Compensation and Liability Act (as amended by the Superfund Amendments and Reauthorization Act). DOD also operates 500-700 domestic and 100-200 industrial wastewater treatment plants in the continental United States.

The actual cost of treatment required for contaminated water or wastewater depends upon the degree of clean-up required, and this frequently is based largely upon toxicity estimates. Toxicity is usually determined by comparing the concentrations of individual chemical constituents in water or wastewater with available data on toxicity to mammals.

Unfortunately, there may be little or no toxicity data on many of the compounds present in the contaminated water. Even when toxicity data are available, their application to a specific contaminated water may be difficult because of interactions among chemicals present in complex mixtures and large variations in the concentrations of chemicals over time. When faced with such uncertainty, target concentrations for clean-up are usually set using generous (and very costly) safety factors.

One way to reduce high costs associated with treatment of contaminated aquatic media would be to obtain direct, on-site measurements of toxicity using traditional mammalian test species. This approach is not practical from a technical standpoint and would be very costly if used.

With support from the U.S. Army Corps of Engineers and the U.S. Army Medical Research and Development Command,the U.S. Army Biomedical Research and Development Laboratory (USABRDL) has been working for several years on an alternative approach: the development of fast, relatively inexpensive non-mammalian toxicity assessment techniques that can be used not only in the laboratory but also at Army field sites having potentially contaminated water or wastewater.

There is precedence for using biological end points for evaluating (and regulating) toxicity: aquatic toxicity tests of wastewater effluents have been made an integral part of the federal Clean Water Act of 1987.

Test Methods

Non-mammalian testing techniques being evaluated at USABRDL have been developed with the goal of improving toxicity estimates to protect both man and the aquatic environment. To facilitate using these techniques at Army facilities, we have concentrated on test procedures that can be conducted in an on-site biomonitoring facility. As shown in Table 1, there are four test systems presently under development.

Fish Carcinogenicity Test

The use of fish in carcinogenicity evaluations has been suggested based on the sensitivity of many fish species to known mammalian carcinogens. For example, a small fish, the Japanese medaka, has developed tumors in as little as six weeks following a one-hour exposure to only a few parts per million of the mammalian carcinogen methylazoxymethanol acetate. Fish carcinogenicity tests are quite inexpensive relative to mammalian tests.

The on-site carcinogenicity test system uses medaka hatched in the laboratory. Medaka are easily bred in the laboratory, and hundreds of eggs can be obtained daily on a year-round basis. Two groups of medaka are tested at the on-site biomonitoring facility. One group has been previously exposed at the laboratory to a known carcinogen at a concentration that should not, by itself, induce tumors. The second group has not been exposed to carcinogens. Both groups of fish are then taken on-site and exposed to several concentrations of the water or wastewater to be tested. Using this approach, the potential of chemicals in the water to act either as complete carcinogens or as carcinogen promoters can be determined. The length of on-site exposure can vary, but 13 weeks is recommended, followed by transfer to the laboratory for an additional 13 weeks of holding. Medaka are examined periodically and the incidence of tumors is determined.

Although this test was intended primarily for predicting mammalian toxicity, monitoring the survival, reproduction, and growth of medaka could also provide useful data on the chronic toxicity of the water tested to aquatic organisms.

Fish/Amphibian Developmental Toxicity Test

Embryos of both the medaka and the African clawed frog have been used to screen chemicals for their potential as developmental toxicants. These aquatic embryos are small (only a few millimeters in diameter) and are well suited for use in on-site toxicity assessments. Tests in several laboratories have shown that, in general, there is a good correlation between the results of studies with chemicals that are developmental toxicants in aquatic organisms and those that cause analogous effects in mammals.

The on-site developmental toxicity test is initiated by exposing newly fertilized embryos to the aqueous test material through the period of organogenesis and hatching. Test length varies from 96 hours for the African clawed frog to about 12 days for the medaka. After the exposure, the effects on survival, growth, and the incidence of developmental abnormalities are used to determine whether or not the water tested can be considered to be developmentally toxic.

Automated Fish Acute Toxicity Monitor

In this USABRDL-developed system, a small computer monitors changes in the ventilatory patterns of fish that are indicative of developing toxic conditions in the water. Fish ventilatory patterns are sensed as electrical signals that are detected by electrodes placed in water with the fish. From these signals, the computer can determine the ventilatory rate, the depth of the ventilatory movements, the gill purge (or "cough") rate, and whole body movement rate. The computer determines whether the fish in either group are showing abnormal patterns indicative of toxic water conditions. If toxicity is found, the computer can immediately notify appropriate personnel.

A variety of toxicity monitoring systems using aquatic organisms are presently being used in Europe and South Africa. In the United States, two systems that monitor fish ventilatory rates have been tested at Radford Army Ammunition Plant and Pine Bluff Arsenal. The toxicity monitor developed at USABRDL represents a significant improvement over these systems because of its use of multiple endpoints to detect toxicity.

Another advantage of the USABRDL monitor is that it includes simultaneous computerized reading of physicochemical data that can aide in the interpretation of any abnormal responses indicated by the fish.

Aquatic Microcosm Test

Predictions of the environmental effects of water or wastewater have

Table 1. Proposed On-Site Toxicity Assessment Techniques

Proposed Technique	To Predict:	Applications
Fish Carcinogenicity Test	Human carcinogenicity	Monitoring groundwater contamination
	Chronic toxicity to aquatic organisms	Monitoring wastewater treatment plant effluent
Fish/Amphibian Developmental Toxicity Test	Human developmental toxicity	Monitoring groundwater contamination
Automated Fish Acute Toxicity Monitor	Human acute toxicity	Monitor drinking water for toxicants
	Toxicity to aquatic organisms	Monitor wastewater treatment plant effluent for toxic spills
Aquatic Microcosm Test	Aquatic ecosystem-level toxicity	Monitor wastewater treatment plant effluent for effects on aquatic communities.

generally been based on toxicity tests with single species of aquatic organisms, but single species tests cannot measure potential ecosystem-level toxicant effects on such parameters as predator-prey relationships, nutrient cycling, productivity, or decomposition. To improve on single species toxicity estimates and to provide continuous monitoring of chronic toxicity with a minimum of effort, we have chosen a protozoan microcosm system developed by Cairns and Pratt. In this system, naturally-occurring protozoan species in clean water ecosystems are allowed to colonize polyurethane foam (PF) substrates for several days. The colonized substrates are then placed in tanks containing barren, uncolonized substrates, through which the water or wastewater flows.

The ability of protozoans to colonize the barren PF substrates over a 14-21 day period is limited by the toxicity of the water. Although it originally was necessary to identify and count the number of colonizing protozoan species in order to complete the test, there are a number of promising alternative endpoints (such as certain enzyme levels) that appear nearly as sensitive to toxicant effects as changes in protozoan species numbers.

The protozoan microcosm test has many advantages. Indigenous protozoan species are used and data collection is relatively easy and inexpensive. The test can measure ecosystem-level effects as reflected in protozoan community dynamics, and toxicant sensitivity is comparable to both chronic toxic levels from single species tests and in-stream effects observed in field studies of benthic macroinvertebrates.

Application of Test Methods to On-Site Toxicity Assessment

Testing of the on-site toxicity assessment concept has recently been initiated at an Army wastewater treatment plant. Test systems presently being evaluated include the automated fish monitor for detection of acute toxicity, the fish carcinogenicity test, and the amphibian developmental toxicity test. These systems were installed in a 24-foot mobile biomonitoring facility located at the wastewater treatment plant. Dechlorinated wastewater effluent and river water are pumped to the facility for use in testing.

In the carcinogenicity test, groups of medaka are exposed to both the effluent and to clean dilution water for 13 weeks, then transferred into clean water for an additional 13 weeks to allow for any potential tumor development. In addition to monitoring waste effluents, this carcinogenicity test can be used for evaluating surface water, contaminated groundwater, or hazardous waste leachates. This test could also be used for evaluating reductions in the concentrations of toxic chemicals afforded by treatment or remediation efforts, since the carcinogenic responses of fish exposed to water or wastewater both before and after treatment could be evaluated. Test results could also be compared among several contaminated sites to provide guidance concerning the priortization of clean-up activites.

The automated fish acute toxicity monitor is also being evaluated at the on-site biomonitoring facility by exposing computer-monitored fish (bluegills) to simulated spills of toxic materials. Additional development of this system should permit continuous, on-line evaluation of toxic changes in water or wastewater at Army sites. The acute toxicity monitor should be most useful where the detection of rapidly changing water or wastewater conditions is of primary importance. Examples include monitoring an industrial wastewater discharge for chemical spills, checking the toxicity of water taken into water treatment plants, and monitoring for sudden changes in the operation of treatment facilities used in remediation efforts at hazardous waste sites (e.g. contaminant breakthrough of activated carbon used to remove organic materials from groundwater).

Future Plans

Additional validation is required before the proposed test methods will be accepted for routine use by regulatory authorities. A key issue is extrapolation, not only from non-mammalian species to man but also from one set of aquatic organisms to another, when the monitoring goal is aquatic environmental protection. We are addressing these issues through our planned in-house and extramural research efforts.

Collaborative research efforts with government agencies must be an integral part of our overall program. Several federal agencies, including the U.S. Environmental Protection Agency, the National Cancer Institute, and the Agency for Toxic Substances and Disease Registry (ATSDR), have shown considerable interest in the use of biological toxicity test methods, particularly in the development of the fish carcinogenicity test. A recent National Academy of Sciences workshop sponsored by ATSDR entitled "Animals as Monitors of Environmental Hazards" included our presentation of the on-site toxicity assessment work.

In the near future, we will be locating a mobile biomonitoring facility at a DOD site to demonstrate its use in evaluating the toxicity of both a contaminated groundwater and an industrial waste effluent. We also will be exploring the use of non-mammalian species for testing other toxicological end points, including neurotoxicity and immunotoxicity.

On-site toxicity assessment techniques can provide direct and cost-effective evaluations of the toxicity of both surface and groundwaters. More realistic estimates of toxicity at Army sites can help ensure that any remedial actions are appropriate to the degree of hazard involved. This is an important consideration, given the high cost to the Army of cleaning up contaminated aquatic resources.

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MANUFACTURING TECHNOLOGY

By Stephen V. Balint

A major initiative of the Department of Defense (DOD) is the advancement of the concept of total quality management (TQM) throughout all DOD operations. Simply stated, the purpose of TQM is to generate an environment within which people continually strive to improve their products, processes and performance as judged by their customers.

The defense acquisition life cycle has many complex processes which contribute to the ultimate goal of providing the soldier with the ability to fight and win. However, when considering the production phase of that life cycle, one of the principal tools for improving performance is manufacturing technology.

Manufacturing technology is defined in DODI 4200.15 (May 1985, Manufacturing Technology Program) as "Information that is, will, or may be used to define, monitor or control processes and equipment used to manufacture or remanufacture DOD materiel." In practical terms, it is the application of science and engineering to the problems of manufacturing in order to increase quality of the end product, worker safety and the competitiveness of the U.S. industrial base and decrease the cost of production and ownership of materiel. The reference to "manufacture or remanufacture" emphasizes the fact that the Army mission includes the repair and overhaul of equipment at depots and arsenals as well as manufacture of new equipment at both contractor and government owned facilities.

Manufacturing technology (MANTECH) projects are funded through the Army research, development, test, and evaluation (RDTE) appropriation, and are coordinated and tracked by the Office of the Secretary of Defense (OSD) as a tri-Service effort. DOD policy is to rely on the private sector to decide which technologies should be pursued, make the necessary investment, and develop the processes and equipment to improve the manufacturing capability of the U.S. industrial base.

DOD MANTECH funds are intended to fill the gap in situations where (a) "seed money" from DOD can lead to significant advances in technology, (b) industry cannot or will not commit to the investment of funds, or (c) applications are unique to in-house industrial facilities.

The Army effort to prepare for and execute the production phase of the weapon system life cycle is not limited to the MANTECH program. There are manufacturing science programs within the basic and exploratory research programs (6.1 and 6.2) of the laboratories with manufacturing technology and producibility receiving increased emphasis in the technology base program as a whole.

During the engineering development phase, producibility of the design and planning for production are supported with RDTE funds under the producibility engineering and planning program. In the production phase, procurement appropriation funds are set aside to support engineering tasks required to resolve design, documentation or manufacturing shortfalls.

The current status and future direction of the Army MANTECH program has been shaped by significant decisions in the past five years by both Army management and the Congress. Although the MANTECH program was funded prior to FY83 from the procurement appropriation, Congressional direction resulted in a change of funding source to the RDTE appropriation starting in FY83 and continuing to the present.

During Fiscal Years 1987 and 1988, the Army's program was restricted to in-house operations (Army owned manufacturing plants, arsenals and depots). However, on Aug. 31, 1988, the under secretary of the Army issued guidance which permitted the Army Materiel Command (AMC) to resume sponsoring MANTECH projects for weapon systems applications at contractor owned facilities.

The key to the Army MANTECH program in FY89 and beyond is the concept of focusing resources to a small set of technology thrust areas. The Army initiative utilizes the same definition in DODI 4200.15 for a thrust area, "A set of manufacturing technology projects intended to achieve some overall, unified purpose." The technologies selected for thrust areas will present serious issues/problems, in terms of cost and quality, in the manufacture of Army systems, and will have the potential for making a significant impact on national manufacturing goals and the U.S. industrial base.

While the basic unit of the program will continue to be the individual MANTECH project, the thrust area approach will integrate projects from two perspectives. First, related projects will be coordinated horizontally to resolve large problems and achieve overall objectives by attacking them from several different aspects and by several different organizations. Second, a thrust area will seek vertical integration of projects with different relative technological maturity:

- Applications which may be required for immediate implementation with perhaps a rebuild/overhaul operation at a depot or arsenal,
- Projects which address cost drivers or technological opportunities for equipment just starting production, and
- Projects may also be initiated in synchronization with emerging technology base results to promote the tools and processes necessary to implement those results into long range plans for production.

The technology thrust areas will be selected from proposals prepared by the AMC major subordinate commands (MSC) in conjunction with private industry and academia. Highest priority for funding will go to thrust areas which exhibit the greatest potential for the following:

- High leverage of Army funds through cooperation with other services, other government agencies, industry and academic institutions;
- Opportunities to establish microfactories; and
- Significant impact on Army programs and U.S. industrial base.

The concept of leveraged funds is of particular importance considering the limited amount of MANTECH funds that are available and the large number of organizations that are actively pursuing advances in manufacturing technology. Duplication of effort is unaffordable, but more importantly, establishing technological advances that will make a significant difference in manufacturing capability is an expensive process. The "Force Multiplier" effect of several organizations pooling resources for a common objective can insure that Army funds derive the benefits needed for Army systems.

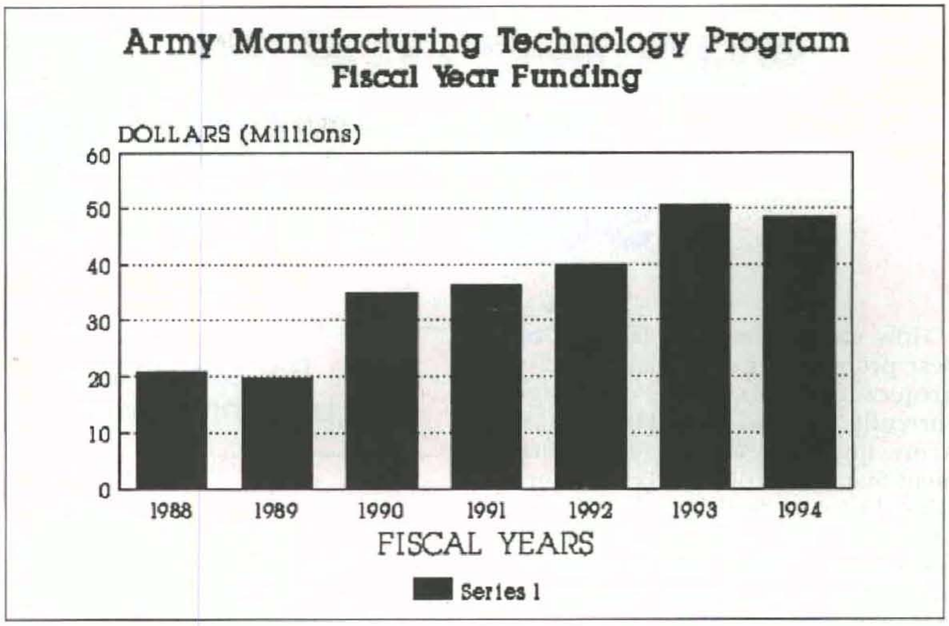
The micro-factory is envisioned as a cooperative effort among several kinds of organizations with owners/producers of equipment and processes providing prototypes or existing equipment to a government controlled site for free use in solving production problems or for analytical experimentation. The owners would benefit from the feedback and technical reports generated in the micro-factory and the publicity of their capabilities within the industrial community.

Once established, the micro-factory would serve as a center of excellence for working out problems in that technology thrust area. MANTECH funding would be limited to the engineering support required for the experiments and not major capital investment. However, the key element of a successful technology thrust area is the potential for establishing a "World Class" capability and making a difference to Army production and the U.S. industrial base.

The AMC MSCs were briefed initially on the concept through a video conference on Aug. 25, 1988. A second conference on Sept. 16, 1988 allowed each MSC to share their ideas for thrust areas with the rest of the AMC community. This initial coordination is important because the MSC selected as a thrust area manager may sponsor projects to be executed by other MSCs. It is the thrust area manager's task to integrate projects, balance resource allocations and achieve the overall technical objectives.

Implementation of this concept is based upon the thrust area proposals mentioned above. Each proposal addresses the following:

- Definition — a brief description of the thrust area.
- Objectives — specific results against which progress can be measured.
- Impact — Potential benefits to the Army and U.S. industrial base.
- Justification — Why this area can become a "World Class" capability.
- Issues — Technology gaps to be filled.
- Projects — Breakdown of specific technical investments.



- Leverage Potential — which organizations can help in attaining objectives through cooperation/exploitation.
- Micro-factory potential.
- Resources — Funds required from the MANTECH program, existing resources that can be redirected, parallel efforts of other organizations that can be synchronized.
- Management — Thrust area manager, members of an advisory steering group, and reporting chain within the MSC.

Some expected MANTECH thrust areas include: soldering (on going), adhesive bonding techniques (on going), optics manufacturing (on going), composite materials processes, heavy plate welding, microelectronics, energetic materials manufacture, machining/material removal, chemical defense materials, and volatile organic compounds.

The Army program remains linked to the other Services and OSD through the Manufacturing Technology Advisory Group (MTAG) and designated OSD reporting procedures. It is expected that the thrust areas will align with one or more technical subgroups of the MTAG for coordination with other DOD efforts and inclusion of industry inputs to program direction and evaluation.

Fiscal Year 1989 is a year of transition for the Army MANTECH program. Projects which cannot be supported in future years will be identified and phased out in the most cost effective manner.

The FY90 program will reflect the full implementation of the thrust area concept. High payoff projects which do not fit under a thrust area will continue to be supported as part of the MANTECH program as single issue projects, but will compete harder for a smaller source of funds.

RDTE funding for MANTECH, documented in the FY 90-94 POM, is shown on the accompanying graph. OSD incentives may add funds starting in FY90 as explained earlier. Full implementation of the thrust area effort may yield the kind of results which will add $50M per year in the ensuing years.

In summary, the direction of the Army MANTECH program recognizes the limited amount of funding available and thus looks for opportunities to leverage those funds with cooperative ventures in order to develop a few world class technology capabilities. Cooperation between vendors of equipment and processes and manufacturers with "seed money" and guidance from the Army can result in experimental micro-factories that can be utilized to advance the state-of-the-art and solve near term production problems.

In earlier years, the Army had the largest funding support among the Services for MANTECH programs. Successful development of world class technologies will build support for similar funding levels in the future.

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PROJECTILE PENETRATION HIGH PRESSURE SOIL TEST FACILITY

By Dr. Behzad Rohani and Lee Ann Tidwell

How can U.S. military facilities be best protected against high-velocity projectiles? This is the challenge currently being addressed by the U.S. Army Engineer Waterways Experiment Station's Projectile Penetration/High Pressure Soil Test Facility in Vicksburg, MS. This unique facility houses an 83mm ballistic range developed especially to investigate anti-penetration shielding techniques employing geologic and man-made materials. These techniques are being tested against a wide variety of projectile threats.

The ballistic range consists of an 83mm gas or solid propellant launcher, a mount to support and align the launcher, a blast tank, a sabot separator system, a drift tube assembly and a target tank (see Figure 1).

The 83mm "gun" has the capability of launching various sizes and weights of projectiles at a variety of velocities. Velocities greater than 0.4 kilometers per second are achieved with a breech assembly using powder propellants. A gas chamber can be attached to achieve lower velocities.

The 10.9-meter-long launch tube is equipped with piezoelectric pressure transducers to monitor gas pressure within the bore. At the downstream end of the launch tube, a vent section extends into the blast tank. It allows the projectile to pass freely while the accelerating gas charge expands laterally through a series of large ports cut in the tube wall. The effect of the vent section is to terminate projectile acceleration and muzzle the sound. The tank contains two central baffles used to break up large gas flow and is equipped with a ventilation system to remove the explosive gas after the test.

Down stream of the blast tank is a sabot separator system consisting of a gasdynamic tube and impact tank. Sabots are thrust transmitting carriers that are positioned around smaller projectiles to allow their firing in the 83mm launch tube. The gasdynamic tube is an extension of the launch tube; provisions have been made to seal each end of this tube.

Figure 1. The Ballistic Facility

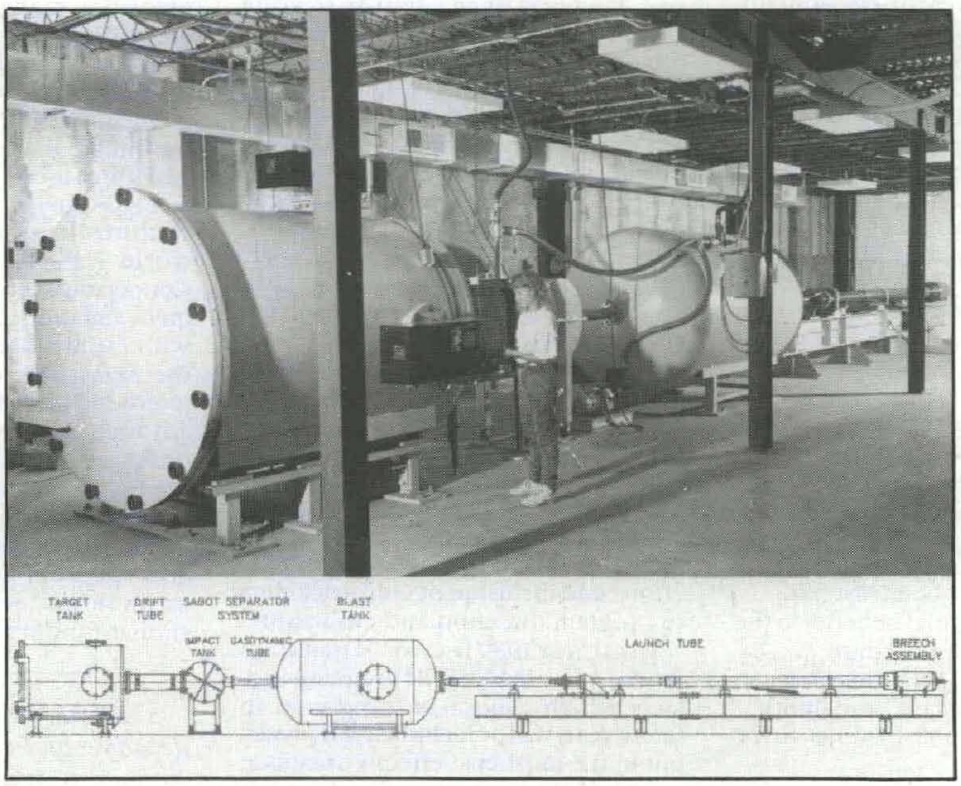

Figure 2.
A "new" projectile next to a post-test or "used" projectile

In range operation, the gasdynamic tube can be operated at atmospheric pressure while the launch tube is operated under a vacuum. More extensive separation tasks are accomplished by either pressurizing the gasdynamic tube with air at levels up to 0.2 megapascals or replacing the air with a high molecular weight gas. The sabot impact tank is used to intercept and pulverize oncoming sabots while allowing projectiles to pass through the drift tube and into the target tank unimpeded.

A major measurement resource of the range consists of a Hall Intervalometer System, which is located alongside the drift tube. It is used to determine projectile orientation and velocity. A pair of shadowgrams from orthogonal viewing angles are recorded by a streak camera as the projectile passes each of two stations along the drift tube. These two orientation measurements are used to determine the velocity and yaw rate of a projectile in free flight with enough accuracy to determine projectile orientation at impact within plus-or-minus one degree. Velocities can be measured within 0.2 percent.

The target tank for the enclosed ballistic range is a massive steel cylinder large enough to accommodate a three-cubic-meter target. Horizontal and vertical window ports are located in the tank's side wall that provide access for a pair of dual-pass shadowgraph units. These cameras take simultaneous orthogonal pairs of pictures of oncoming projectiles in the target tank. These pictures are also used to determine projectile orientation just prior to impact.

WES's extensive capability and experience in the design and fabrication of large targets constructed from either geologic or man-made materials under laboratory controlled conditions provides outstanding support to the facility. Because of this experience in material handling and processing, targets can be reproduced to very close tolerances, thereby reducing target variability.

The facility is also supported by a unique material testing laboratory capable of conducting dynamic, high pressure tests on the wide range of materials of interest in projectile penetration experiments. Strength and compressibility can be measured at pressures reaching 600 megapascals and at loading times as fast as three milliseconds. Coupled with a strong numerical modeling capability, an analytical assessment can be made of each experiment, relating target response to projectile penetration.

The penetration test range is supporting hardened structure survivability research sponsored by the Corps of Engineers under an RDT&E work unit entitled "Shielding Methodology to Defeat Advanced Kinetic Energy Weapons." The objective of the investigation is to devise effective shielding concepts for protection of fixed military facilities against high-velocity penetrating munitions. The current test program involves the firing of one-fifth-scale models of a 1,600-pound armor-piercing projectile into protective overlays at impact velocities ranging from 0.38 to 0.76 kilometers per second.

A series of one-tenth-scale tests were previously conducted to evaluate the effectiveness of various protective overlay concepts and determine the optimum design. Based on those results, a relatively simple design was developed. It consists of three layers of loose basalt boulders overlying a 60-centimeter-thick layer of smaller boulders whose voids are filled with a 69-megapascal grout. A corrugated steel container is used as a form for the burster slab and to contain the loose boulders during placement in the target tank.

The subscale projectiles and sabots for these tests were fabricated at WES. Figure 2 shows a "new" projectile next to a post-test or "used" projectile. The damaged projectile had been launched into the boulder target at 0.78 kilometers per second. It was found after the test laying horizontally at a depth of approximately one caliber into the burster slab after smashing through three boulders and being turned by the boulders prior to impact with the slab. It is clear from the figure that the projectile did not survive the impact.

The results of this test program have already led to a better understanding of projectile interaction with boulder overlays. Future design manuals for protection of our military facilities against high-velocity projectiles will be based on the results gained from this program and the contribution of the WES Projectile Penetration/High Pressure Soil Test Facility.

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LEE ANN TIDWELL is the project engineer for the experimental portion of the "Shielding Methodology to Defeat Advanced Kinetic Energy Weapons" work unit. She holds a B.S. in civil engineering from the University of Mississippi.

ARMY INITIATIVES IN EXPERT SYSTEM MAINTENANCE AIDS

By COL Don L. Bullock and Gregory Winter

Introduction

Very High Speed Integrated Circuit devices, infrared systems, turbine engines, and other advanced technologies have been incorporated into Army weapons systems to reduce system weight, increase functionality and firepower, and increase the soldier's ability to sense and locate targets. At the same time, they increase testing complexity and tax the soldier's ability to maintain the system. To offset these complications, the Army is investigating new technologies to provide simpler, cost-effective alternatives for maintaining weapons system readiness.

The U.S. Army's Office of Test, Measurement, and Diagnostic Equipment (PM-TMDE) evaluates new equipment, methods, and technologies for maintaining Army weapons systems. PM-TMDE is currently supporting three efforts to investigate one such new technology, the expert system, for its ability to improve maintenance at all levels, especially the organizational or unit level.

A practical application spawned by artificial intelligence research, expert systems are software tools that essentially encode the problem-solving abilities of a human expert as IF-THEN rules or 'heuristics' in a specially designed data base called a knowledge base. It is hoped that these new tools will be able to reduce the time and resources needed to diagnose a weapons system by bringing the knowledge of human experts to the aid of the technician or mechanic.

Time Management

Although weapons systems are completely tested, repaired, and sometimes overhauled at the depot level, system readiness is affected most by the efficiency of the front-line mechanic. In the forward area, to get the tank rolling or the helicopter back in the air, the mechanic must evaluate the entire system and identify failed Line Replaceable Units (LRUs) by making a series of maintenance decisions quickly, accurately, and with as little equipment as possible.

The mechanic's efficiency, his ability to perform the task in the shortest time possible, is a function of the ability to manage his time and resources. Therefore, the forward area soldier's greatest problem is not lack of resources but time management. Time management is critical to ensure that the soldier uses the right resources at the right time. Simply giving the mechanic as many resources as possible not only increases testing complexity, but increases the amount of time required to use those resources.

In other words, the repair technician in the forward area has all the resources needed to diagnose the system including automatic test equipment (ATE), technical manuals, and built-in-test (BIT). Yet, the real task facing the soldier is to use the right equipment and procedures without having to read through volumes of technical data. The soldier must also be able to analyze BIT responses quickly and accurately in order to not only find faulty LRUs but to distinguish false alarms from actual failures. Finally, in order to minimize actual test time, the soldier must be able to evaluate system symptoms and decide which key functional tests to run instead of running an entire complement of time-consuming parametric tests.

Another increasingly burdensome task facing forward area mechanics and technicians is the training needed to test new and constantly changing weapons systems. With increasing electronic and electro-mechanical complexity, soldiers find themselves spending more time in the classroom and less time in the field.

New Technology

The key to successful maintenance time management on the battlefield is to provide the technician or mechanic with an expert advisor. Obviously, design engineers, production test technicians, or system training specialists can not be deployed with every weapons system to every forward area site. However, their knowledge and expertise can be captured and brought to the field by developing a knowledge base and an expert system for the weapons system.

The Office of PM-TMDE explores new technologies which can complement existing test methods, minimize manpower resources, and decrease the skill levels necessary for troubleshooting. Knowledge-based or expert systems are a promising new technology with the potential to provide that much needed expert in the forward area and to solve the time management problems described above.

Expert System Tools

As the name implies, expert systems contain the knowledge of human experts in specific fields, along with the reasoning rules they use to manipulate their knowledge and arrive at conclusions. Given this capability, expert systems can serve as assistants to novices, giving suggestions and instructions, and asking questions for data input.

Expert systems differ from conventional software in their ability to perform symbolic parallel processing in order to reason about knowledge, as opposed to the sequential execution of instructions found in conventional programs. In this way, competing hypotheses can be considered simultaneously, weights can be assigned to different alternatives, and recommendations may be made based on these.

Expert systems are comprised of knowledge represented as heuristics (rules of thumb) derived from experts based upon the way they reason about a specific problem. These rules reside in a knowledge base and are "fired" by an inference engine which tests the rules to determine whether they are true or false. It continues to fire rules until a conclusion or solution has been found or all rules regarding the problem have been tested. In the latter case, a best recommendation based on the knowledge possessed will be given.

Expert systems exhibit several advantages over other diagnostic methods. First, Expert systems can often reach a conclusion identifying a faulty LRU in less time and with less information than deterministic test methods. This is possible since they use "rules-of-thumb" rather than simple yes-no fault trees (like a test program set) to reach a conclusion.

Second, unlike other test methods, expert systems can learn from past experience and supplement their knowledge base by adding new rules or altering weights assigned to existing rules. Third, facilities can be provided to explain the inferences made at any point in the operation in order to better the operator's understanding as to why tests are being performed. This last capability can reduce or eliminate the need for unwieldy volumes of technical data since instructions and graphics may be incorporated into these explanation facilities.

Expert systems are not expected to replace conventional diagnostic methods since total non-intrusive testing is not possible considering the complexity of today's weapons systems. Identification of subtle or complex failures will still require BIT or ATE. The potential for expert systems lies in their ability to complement other diagnostic methods, minimize intrusive testing, and improve the time management of the soldier's diagnostic decisions.

Most importantly, expert systems provide a means of structuring functional testing in the field. Functional testing is a strategy that focuses on verifying system performance by emulating its operational environment and observing its intended functions. The goal is to isolate to a single faulty LRU. On the other hand, parametric testing involves exercising and measuring exact input/output parameters to isolate to the piece part location of the failure.

Parametric testing is necessary for the depot and some intermediate level testing, but, at the Unit level, goes beyond the requirement to isolate to the faulty LRU. Therefore, functional testing represents the most efficient approach for diagnostic decision making in the forward area. Expert systems can be used to tell the technician which critical functional tests to run out of all possible diagnostic procedures thereby reducing the time actually spent in testing the system.

The PM-TMDE Evaluation Program

In order to evaluate this new technology and to verify the concept of functional testing, the Army's PM-TMDE Office is evaluating three benchmark efforts. These efforts were selected to demonstrate the potential benefits of expert systems to both diagnose system failures and to provide an effective interactive user interface. To ensure a comprehensive evaluation, the results of these efforts are being compared against those for conventional test methods and are being verified using actual field technicians.

Diagnostic Improvement Program

Under PM-TMDE support, the Land Systems Division of General Dynamics (GDLS) kicked off an M1 Tank Diagnostics Improvement Program in November 1987. This continuing program is a coordinated effort involving PM-TMDE, PM-TANKS, and the Army Training and Doctrine Command.

The existing unit level diagnostic methodology calls for the use of ATE and an automatic test probe. This methodology is applied to the M1 Stabilization Subsystem which has an unusually high density of electronic and electro-mechanical components prone to misdiagnosis and lengthy analysis cycles. Therefore, specific goals of the effort are to demonstrate the viability of non-intrusive testing and to decrease troubleshooting time by a factor of 50 percent.

The task was to use a portable, military computer capable of supporting a prototype expert system to be developed by General Dynamics for the M1 Stabilization System. This prototype would then undergo validation over several months utilizing an M1 tank. The system would then be customized to perform system diagnostics, minimize intrusive testing, and maximize the soldier's own experience and capabilities. The system must support multi-experienced technicians and be employable without tank modification.

For this effort, the Contact Test Set (CTS), developed as part of the Intermediate Forward Area Test Equipment (IFTE), was targeted as the host computer. The prototype expert system, developed and ported by GDLS onto the CTS, provides a dual approach to diagnostics with both a functional checkout program for novice users and a menu-driven system for more experienced technicians. The checkout program performs a purely functional test and requires minimal understanding of the tank operation.

The GDLS expert system CTS has demonstrated significant advantages over conventional ATE. For example, test times for the CTS average four times faster than the existing ATE. Moreover, the CTS requires only 68 pounds compared to 422 for the ATE system. Most importantly, the GDLS expert system requires no hard copy maintenance documentation, whereas the existing method requires 5,230 pages in seven volumes to document all maintenance procedures.

As part of the development process, the prototype underwent a user evaluation at Fort Knox in July 1988. With no contractor support or previous training, field technicians used the system for the first time on an M1 tank with failures in the Stabilization Subsystem. As expected, the technicians were able to diagnose the majority of failures and in less time than conventional ATE. Moreover, the system was shown to perform all non-intrusive testing before resorting to intrusive tests with the ATE and ATE probe. In the latter case, the system provided the technician with detailed graphics and instructions for connecting all jumpers, probe connections, removal actions.

However, difficulties in understanding explanations or graphics led to the definition of new ways to improve the user interface by redefining vocabulary, providing additional help facilities, and streamlining diagnostic procedures. These areas are now being developed by GDLS and may also lead to the development of new training modules specifically geared to the first time user.

HAIDEX/Firefinder

PM-TMDE is also supporting the development of a knowledge-based diagnostic system for the HMP-3637A computer of the AN/TPQ-36,37 Firefinder radar system. Currently under development by the Ground Systems Group at Hughes, the system employs a causal model approach to diagnosis. The inference engine for the prototype is the Hughes HAIDEX (Hughes AI Diagnostic Expert) hosted on a Symbolics computer.

The Firefinder computer is an LRU in the radar system containing extensive BITE to assist technicians in diagnosing problems to a faulty card group. While the BIT is effective for most faults, complex failures beyond its capability occur. These failures, including multiple faults or wiring opens/shorts, are detectable but require experts for effective diagnosis and, though infrequent, can lead to significant system downtime. The HAIDEX Firefinder Expert System is targeted specifically for these kinds of faults.

The HAIDEX Firefinder knowledge base consists of a model of the system structure, functional descriptions of the system's circuit elements, and the interrelationships between elements. The knowledge base also contains details of normal system operating values. BIT results are used to initially steer the diagnosis toward the general area of the malfunction. Knowledge of system connectivity and normal operating conditions is then used with a logic state analyzer to locate the specific malfunction.

Development of the prototype expert system began in October 1987 and was verified at Hughes with a validation demonstration in December 1988. Results of the validation have been promising so far with average fault isolation times as much as four times faster than expert technicians. Deployment of the system to the Sacramento Army Depot will begin in the first quarter of 1989.

The increased complexity of Army weapons systems has led to a reassessment of traditional diagnostic methods and equipment.

AH-64 APACHE

McDonnell Douglas Helicopter Co. has developed a prototype expert system called the Intelligent Fault Locator (IFL) to fault isolate four subsystems on the AH-64 Apache: the auxiliary power unit, fuel system, communications and navigation avionics, and flight control system. Although the system was developed independently of PM-TMDE initiatives, PM-TMDE is evaluating the effort to rehost the IFL on the CTS for its ability to support functional testing at the unit level.

For the IFL, McDonnell Douglas developed a probabilistic knowledge base using component reliability data. After being advised of a fault symptom by the technician, the IFL accesses a system-specific knowledge base. If this does not isolate to a single cause, the IFL accesses the probabilistic base to break the ambiguity. If the IFL is still unsuccessful, it will access the general knowledge base. If the IFL is still unable to isolate the fault, it will actuate the simulation module.

The simulation module models the failure of one or more components until it matches the given symptoms. At the time of the first demonstration, the IFL contained over 2,000 production rules which produced a 75 percent accuracy in identifying failures in single LRUs. Additional testing with the system will add new production rules and is expected to improve the accuracy and efficiency of the system.

PM-TMDE is considering the requirements for integrating the 1553 Manchester bus controller software on the CTS, developed under PM-TMDE support, with the IFL software into a single CTS-based portable maintenance aid (PMA). This combination promises to yield significant savings in the time and resources needed to test the Apache helicopter.

Conclusions

The increased complexity of Army weapons systems has led to a reassessment of traditional diagnostic methods and equipment. Expert systems are a new type of technology with the potential for enhancing weapons system diagnosis by improving time management for the field technician. Benchmark efforts to evaluate this potential have provided promising results; in all cases, Expert system-based PMAs have reduced the time to perform diagnostic tests, reduced the weight and size of diagnostic equipment, and eliminated associated hardcopy documentation.

Much remains to be demonstrated before expert systems can be considered a viable supplement to existing diagnostic equipment. Expert systems must be shown to be adaptable so that applications can be customized for different systems without redeveloping the knowledge base or inference engine. Moreover, a means of verifying the logic of customized expert systems must be determined to ensure that repeatable results are obtained for the multitude of potential failures in a weapons system.

In short, the Army plans on continued development and evaluation of this new technology on a non-trivial basis to determine not only its capabilities and benefits, but its limitations as well.

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By Brooks O. Bartholow

UPDATE ON THE ACQUISITION INFORMATION MANAGEMENT PROGRAM

Introduction

On Sept. 14, 1988, the Army Major Automated Information System Review Council (MAISRC) approved the formal establishment of the Acquisition Information Management (AIM) Program. The program had been initiated in February 1987 by the assistant secretary of the Army for RDA and the deputy chief of staff for RDA (DCSRDA), with the concurrence of the under secretary of the Army. Initially called the Research, Development and Acquisition Information Network, the program was renamed "AIM" in June 1987.

The AIM Program was created to address two basic objectives. First, AIM is a key part of the Army strategy for implementing the new acquisition executive structure. It will provide Army leadership with a common, classified, real-time (as appropriate), integrated research, development, and acquisition data base network that is interactive and immediately accessible to all users. At the same time, it will insure that the data in the network is collected, reviewed, validated, controlled, and submitted on time to support Army-wide RDA information management needs. From a systems view, AIM will integrate existing and approved new acquisition information systems. From a management view, AIM will provide the information needed to support decision makers, managers, executives, the Office of the Secretary of Defense, and Congress.

Second, AIM will continue HQDA's effort to define the information structure required to support the Army. That is, the AIM Program will develop the detailed information model for the information process related to "acquisition" in the HQDA Information Model. Taken together, these two broad objectives define the AIM Program responsibilities for information management in the Army acquisition community.

Background and Organizations

To achieve these objectives, the assistant secretary of the Army for RDA, in his memorandum of June 1987, appointed LTG Jerry Max Bunyard as the first Army executive agent for RDA information. LTG Bunyard, then the assistant DCSRDA, retained that responsibility when he became DCG for RDA at AMC. Planning for AIM was initiated by a special task force, reporting to LTG Bunyard. Management of the program has now been formalized by establishing the AIM Program Office and the product manager for AIM as shown in Figure 1.

The AIM Office is the functional proponent for the AIM Program. As such, it has overall responsibility for definition and analysis of functional requirements, definition and coordination of data and policy architectures, coordination for development of information systems and analysis tools for the RDA community, and orchestration of data collection and information production and delivery process.

The AIM PM is the systems developer and is responsible for undertaking those tasks that, when implemented, will enable the architectural objectives and specifications developed and defined by the AIM Office to be achieved. Those responsibilities include designing, developing and implementing the AIM communications network; developing an integrated environment for access and transfer of acquisition information; engineering data process and information control systems; and designing and developing selected applications and operating systems.

Need for AIM

The Army acquisition community is large, complex and geographically dispersed. It includes the Army acquisition executive, the Army Staff, major commands/program executive officers (PEOs), program/project/product managers (PMs), schools, major subordinate commands, etc. It manages direct annual appropriations averaging $20 billion for research, development, testing, evaluation, production, and services for materiel/weapon systems. To operate effectively, the acquisition community requires a myriad of acquisition information to support decisions, directly affecting national security.

The Army already has more than 50 "acquisition systems." But these systems do not adequately support the entire acquisition community. Generally, they were developed independently to meet the information needs of specific organizations and in a time when the technology could not cost effectively support more broadly based systems. Thus, the various acquisition data bases remain independent of one another, contain redundant or inconsistent data, and cannot support new acquisition organizations and requirements.

Compounding this problem is the fact that acquisition policy and organization are changing faster than the acquisition information systems can be improved. Individual organizations are defining requirements and designing systems to meet their own changing requirements. However, the task of identifying and satisfying the common requirements for the entire acquisition community is the role the AIM Program is designed to play. While new hardware or software solutions may stem from AIM efforts, its central role is to integrate, coordinate, and streamline the RDA community's acquisition information support systems.

Although much needs to be done, much has already been accomplished. The foundation for AIM is in place. Hardware and software are being developed in organizations at every level to help them execute their responsibilities for the Army. AIM will build on these separate initiatives and provide the integration which is beyond the scope of the individual organizations. Practically speaking, the Army cannot afford to discard the in place investment in automation capabilities, e.g., the costs of requirements definition, hardware acquisition, software development, and training, to develop a totally new acquisition information system.

Incremental Development

The AIM program will not tackle the whole problem at once. Integrating 50 systems into a cohesive, coherent, and comprehensive acquisition information system is a big enough task without also requiring that it all be done at once. Instead, the problem has been divided into executable increments.

Program Planning and Budget

Before the DOD Reorganization Act of 1987, the Army relied heavily on the in-house expertise of DCSRDA to consolidate its RDA budgets. But the reorganization act eliminated DCSRDA, dispersing the expertise on which the Army had relied. Since that time the Army's "method" of consolidating its budgets has been a patchwork of manpower intensive electronic communications, shipped magnetic tapes, and hand carried hard copies. Thus, the AIM Program's first priority is supporting the RDA Program Planning and Budget Execution System (PPBES). This priority has resulted in the urgent requirement for establishing a secure network among HQDA, PEOs, PMs, the Army Training and Doctrine Command, the Army Materiel Command, and the mission area managers in the field.

AIM has inherited the secure AMP MOD (Army Materiel Plan Modernization) network, but it is fragile, difficult to use, and does not extend to all required sites. Enhancements have already been made to the AMP MOD network which provide an initial capability as shown in Figure 2, but a great deal of work is still required to upgrade AMP MOD to the comprehensive network required for the PPBES community.

In addition to constructing a secure network, the AIM Program must provide for the integration and coordination of the data in various PPBES data bases. For example, AMP MOD data bases contain data which must be synchronized with data in the LRRDAP (Long Range RDA Plan). These data bases do not need to be consolidated, but the data must be made consistent, by building a reliable process to ensure that they remain synchronized.

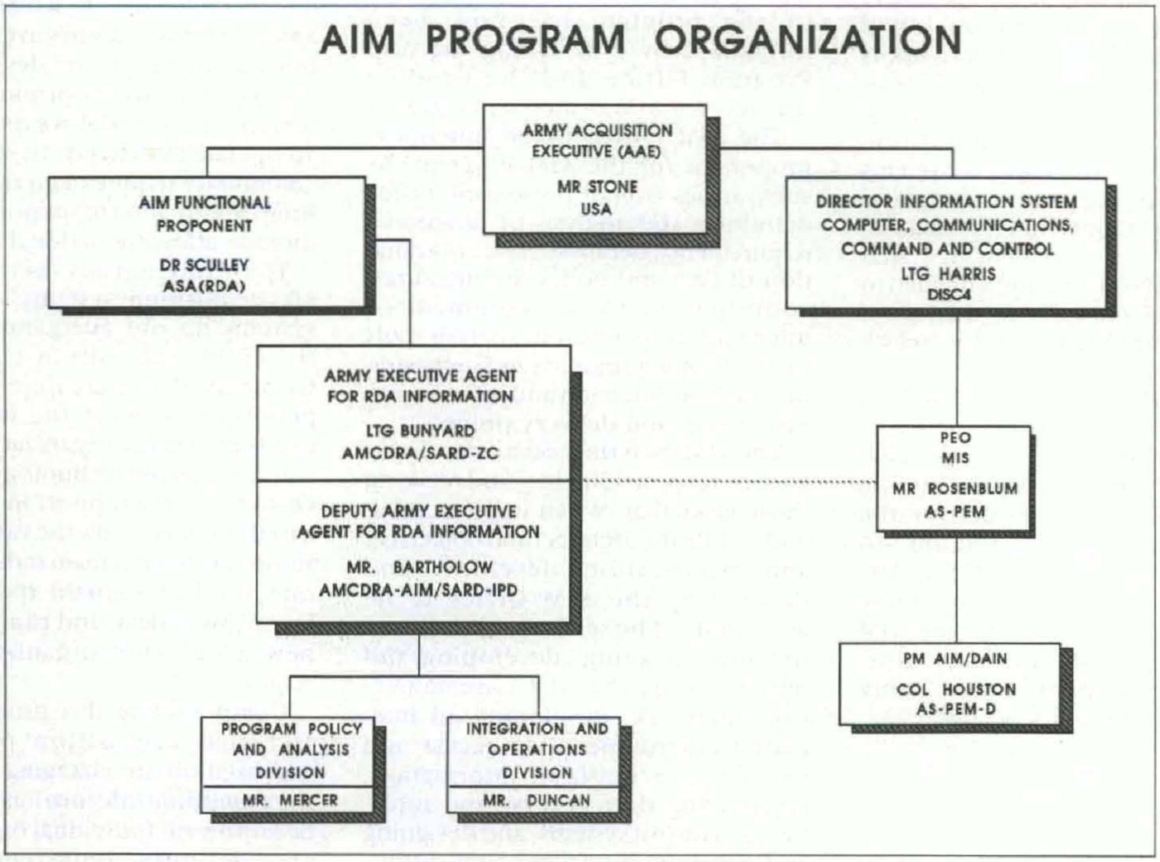

Figure 1.

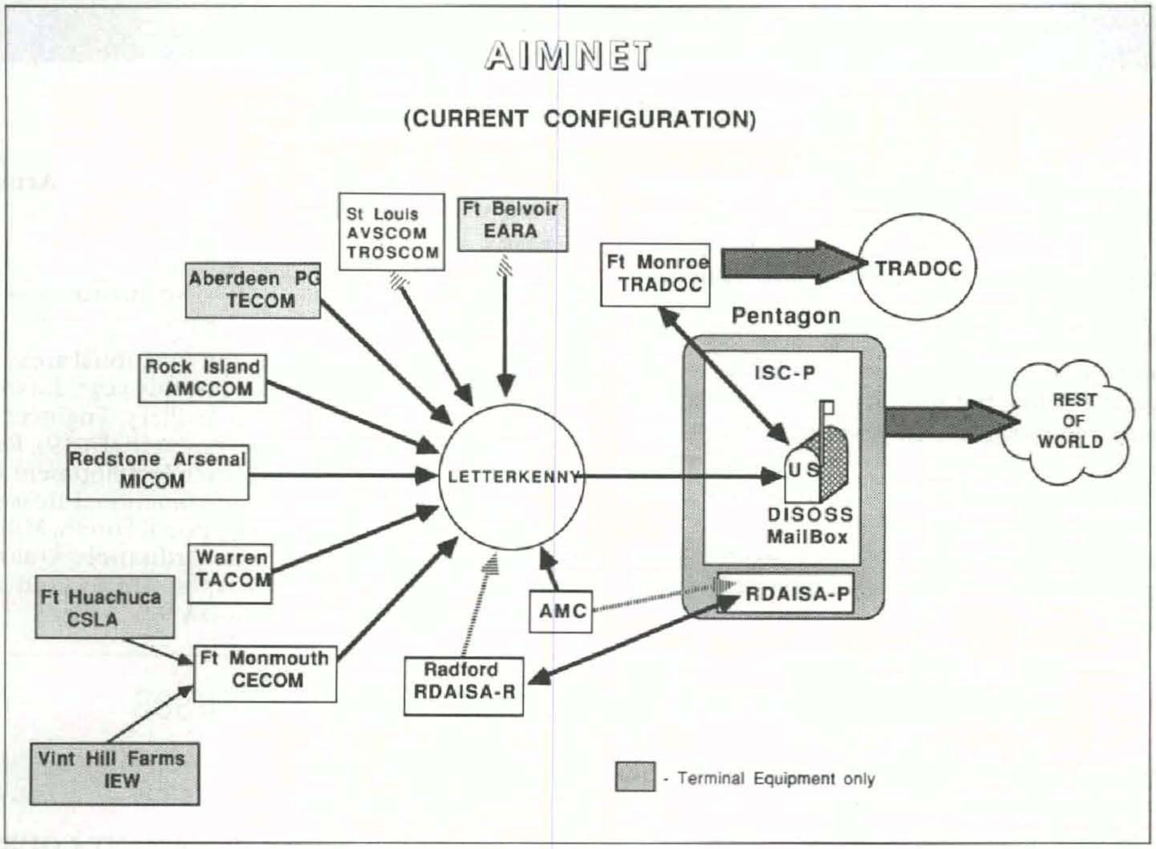

Figure 2.

This data management function is yet another major facet of the AIM Program.

Program Management Information System

The Army has no standard project management automation package. A new PM cannot even be assured that his staff will have ready access to word processing or electronic mail. PMs which have automation tools have developed them at their own expense or have been fortunate enough to be assigned to a site which offers them.

The AIM Program's second priority is to define and develop standard functional capabilities for PMs and program executive officers. Since a number of PMs and PEOs have already constructed their own systems to meet this need, the AIM Program will take advantage of that capability in developing a common resource for all. As discussed previously, forfeiting the sunk costs in the existing systems is not cost effective.

A Program Management Information System (PMIS) user group has already consolidated its requirements in a PMIS Functional Description which, besides requiring basic hardware and office automation for all PMs, stresses connectivity with functional ADP systems at their installations. The hope is that PMs can simply view or down-load the information they need rather than requesting it from their matrix support and receive a computer printout in response. Further staffing of the PMIS Functional Description is anticipated shortly.

Other Priorities

Initial research into decision support and executive support systems continues. Broad capabilities have been defined, but considerable narrowing of requirements must be accomplished before this requirement can be handed off to PM, AIM. Procurement contracts, tech base and independent R&D, and other initiatives await further definition.

Conclusion

Approval of AIM's Mission Element Need Statement by the Army MAISRC establishes HQDA agreement that the Army has a problem which an automation effort may solve. The problem in this case is that the Army RDA community has a great many users whose information needs are not being satisfied by the many current single-purpose automated systems. Agreeing that these problems are real and important, the Army MAISRC has authorized the AIM Program Office and the AIM PM to investigate alternative solutions and to submit a recommended approach at MAISRC Milestone I in about a year. Considering the size and complexity of the problem, we will need the support and participation of the entire Army Acquisition Community to be successful.

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CAREER DEVELOPMENT UPDATE

LTC Promotion Board Results

Officers in Research and Development (FA 51) and Materiel Acquisition Management (Skill 6T) faired well on the recent (FY 88) LTC board.

The overall primary zone selection rate was 65 percent. The FA 51 selection rate was 66.3 percent (71 of 107 eligible) and the MAM selection rate was 59.7 percent (89 of 149 eligible). While the primary zone rate in MAM was slightly below average, the below the zone selection rate for MAM was 8.7 percent, well above the Army average of 6.1 percent.

The selection floor for FA 51 was met at 80 officers selected. The MAM floor was set at 57 officers, but was greatly exceeded with 102 officers selected.

This year's LTC selection rates continue a positive trend, generally at or above Army average selection rates for FA 51 and 6T officers:

	FA 51	Skill 6T	Army Average
FY 83	72.2	86.4	71.7
FY 84	70.2	91.3	70.9
FY 85	75.6	94.8	76.4
FY 86	No Board		
FY 87	77.6	81.4	69.5

The following branches and functional areas were above the Army average for selection this year: Infantry, Armor, Field Artillery, Air Defense Artillery, Engineer, Chemical, Signal, Finance, Operations Research (FA 49), Research and Development (FA 51) and Force Development (FA 50).

The following branches and functional areas were below the Army average: Aviation, Special Forces, Military Police, Military Intelligence, AG, Ordnance, Quartermaster, Transportation, Nuclear Weapons (FA 53) and Contracting and Industrial Management (FA 97).

Defense Systems Management College Courses

The following is a partial listing of Defense Systems Management College Courses offered during FY89. An "R" after the course number indicates regional offerings at the stated locations. An "S" after the course number denotes special offerings. Asterisks indicate changes made since publication of the July 29, 1988 academic calendar. For information about courses, call the Registrar's Office on AUTOVON 354-1078 or commercial (703) 664-1078.

CONTRACT FINANCE FOR PROGRAM MANAGERS COURSE

COURSE NO.	BEGINS	ENDS	LOCATION
89-4	6 Mar —	10 Mar 89	
89-5R	5 Jun —	9 Jun 89	Los Angeles
89-6R	24 Jul —	28 Jul 89	Huntsville
89-7	28 Aug —	1 Sep 89	

CONTRACT MANAGEMENT FOR PROGRAM MANAGERS COURSE

COURSE NO.	BEGINS	ENDS	LOCATION
89-3R	27 Feb —	3 Mar 89	Los Angeles
89-4	27 Mar —	31 Mar 89	
89-5R	22 May —	26 May 89	Huntsville
89-6R	5 Jun —	9 Jun 89	Boston
89-7	13 Mar —	17 Mar 89	Huntsville
89-8	17 Apr —	21 Apr 89	
89-6R	6 Mar —	10 Mar 89	Huntsville
89-7	13 Mar —	17 Mar 89	
89-8	17 Apr —	21 Apr 89	
89-9R	8 May —	12 May 89	Boston
89-10	5 Jun —	9 Jun 89	
89-11R	12 Jun —	16 Jun 89	Los Angeles
89-12	24 Jul —	28 Jul 89	
89-13R	7 Aug —	11 Aug 89	Huntsville
89-14R	11 Sep —	15 Sep 89	St. Louis
89-15	25 Sep —	29 Sep 89	

DEFENSE MANUFACTURING MANAGEMENT COURSE

COURSE NO.	BEGINS	ENDS	LOCATION
89-2	9 Jan	13 Jan 89	
89-3	5 Jun —	9 Jun 89	
89-4	18 Sep —	22 Sep 89	

EXECUTIVE MANAGEMENT COURSE

COURSE NO.	BEGINS	ENDS	LOCATION
89-1	3 Apr —	21 Apr 89	
89-2	11 Sep —	29 Sep 89	

EXECUTIVE REFRESHER COURSE

COURSE NO.	BEGINS	ENDS	LOCATION
89-2	30 Jan —	10 Feb 89	
89-3	10 Jul —	21 Jul 89	
89-4	14 Aug —	25 Aug 89	

FUNDAMENTALS OF SYSTEMS ACQUISITION MANAGEMENT COURSE

COURSE NO.	BEGINS	ENDS	LOCATION
89-3R	23 Jan —	27 Jan 89	Boston
89-4	13 Mar —	17 Mar 89	
89-5R	13 Mar —	17 Mar 89	Huntsville
89-6R	15 May —	19 May 89	St. Louis
89-7R	26 Jun —	30 Jun 89	Los Angeles
89-8R	10 Jul —	14 Jul 89	St. Louis
89-9R	21 Aug	25 Aug 89	Los Angeles
89-10	25 Sep —	29 Sep 89	
89-11R	25 Sep —	29 Sep 89	Huntsville
89-12S	3 Oct —	7 Oct 88	Ft. Leonard Wood
89-13S	29 Nov —	2 Dec 88	Indianapolis

MANAGEMENT OF ACQUISITION LOGISTICS COURSE

COURSE NO.	BEGINS	ENDS	LOCATION
89-2R	30 Jan —	3 Feb 89	St. Louis
89-3	27 Feb —	3 Mar 89	
89-4	24 Apr —	28 Apr 89	
89-5	19 Jun —	23 Jun 89	
89-6R	31 Jul —	4 Aug 89	Boston

MANAGEMENT OF SOFTWARE ACQUISITION COURSE

COURSE NO.	BEGINS	ENDS	LOCATION
89-2	27 Mar —	31 Mar 89	
89-3	12 Jun —	16 Jun 89	
89-4	11 Sep —	15 Sep 89	

COURSE NO.	BEGINS	ENDS	LOCATION
MULTINATIONAL PROGRAM MANAGEMENT COURSE			
89-2R	9 Jan —	13 Jan 89	Los Angeles
89-3	23 Jan —	27 Jan 89	
89-4R	20 Mar —	24 Mar 89	St. Louis
89-5R	24 Apr —	28 Apr 89	Boston
89-6	15 May —	26 May 89	
89-7R	17 Jul —	21 Jul 89	Bonn, FRG*
89-8R	28 Aug —	1 Sep 89	Huntsville
PROGRAM MANAGEMENT COURSE (Part I)			
89-2R	6 Mar —	14 Apr 89	Los Angeles
89-3R	12 Jun —	21 Jul 89	Huntsville
89-4R	11 Sep —	20 oct 89	Boston
PROGRAM MANAGEMENT COURSE			
89-1 Part I	9 Jan —	17 Feb 89	
Part II	21 Feb —	26 May 89	
89-2 Part I	17 Apr —	26 May 89	
Part II	30 May —	1 Sep 89	
89-3 Part I	24 Jul —	1 Sep 89	
Part II	5 Sep —	8 Dec 89	
PROGRAM MANAGERS BRIEFING COURSE			
89-3R	9 Jan —	13 Jan 89	Huntsville
89-4R	13 Feb —	17 Feb 89	Los Angeles
89-5R	13 Mar —	17 Mar 89	St. Louis
89-6R	17 Apr —	21 Apr 89	Huntsville
89-7R	15 May —	19 May 89	Los Angeles
89-8R	5 Jun —	9 Jun 89	Boston
SELECTED ACQUISITION REPORT COURSE			
89-11	9 Jan —	13 Jan 89	
89-12	23 Jan —	27 Jan 89	

COURSE NO.	BEGINS	ENDS	LOCATION
SYSTEMS ACQUISITION FUNDS MANAGEMENT COURSE			
89-3R	9 Jan —	13 Jan 89	St. Louis
89-4R	20 Mar —	23 Mar 89	
89-5	17 Apr —	21 Apr 89	
89-6R	26 Jun —	30 Jun 89	Boston
89-7	24 Jul —	28 Jul 89	
89-8R	28 Aug —	1 Sep 89	Los Angeles
89-8R	28 Aug —	1 Sep 89	Huntsville
SYSTEMS ACQUISITION MANAGEMENT FOR GENERAL/FLAG OFFICERS			
89-1	31 Oct —	4 Nov 88	
89-2	6 Mar —	10 Mar 89	
89-3	5 Jun —	9 Jun 89	
SYSTEMS ENGINEERING MANAGEMENT COURSE			
89-2R	23 Jan —	27 Jan 89	Los Angeles
89-3R	27 Mar —	31 Mar 89	Boston
89-4 Part II	24 Jul —	28 Jul 89	
89-5R	18 Sep —	22 Sep 89	St. Louis
TECHNICAL MANAGERS ADVANCED WORKSHOP			
89-2	26 Jun —	30 Jun 89	
TEST & EVALUATION MANAGEMENT COURSE			
89-3	9 Jan —	13 Jan 89	
89-4R	30 Jan —	3 Feb 89	Los Angeles
89-5	6 Mar —	10 Mar 89	
89-6R	17 Apr —	21 Apr 89	Boston
89-7	22 May —	26 May 89	
89-8R	21 Aug —	25 Aug 89	St. Louis
TOTAL QUALITY MANAGEMENT COURSE			
PILOT	10 Apr —	14 Apr 89	
89-1	7 Aug —	11 Aug 89	

MAM Certification Board Results

The FY89 Materiel Acquisition Management (MAM) Certification Board was held Sept. 19-23, 1988. The Board reviewed 605 MAM Program (6T) files of LTCs and COLs for certification as materiel acquisition managers. For the first time, certification was tied to Public Law 99-145 and DODD 5000.23 which establish new requirements (education and experience) for program and deputy program managers. A brief article outlining the new MAM certification policies appeared in the September-October 1988 issue of the Army RD&A Bulletin. Officers who had been reviewed twice previously for certification and who were considered not certifiable were removed from the 6T program. Officers serving in acquisition positions and within one year of meeting the experience requirements mandated by Public Law were granted a one year waiver of the "3 looks and out" policy. A standing list of officers, who lacked only the Program Managers Course (PMC) at the Defense Systems Management College (DSMC) to be certified, was also established. This will allow those officers to be automatically certified upon completion of PMC.

Results Of The Certification Board

	LTC	COL	TOTAL
Certified	120	13	133
Not Certified (retained)	171	66	237
Not Certified (6T removed)	68	11	79
Certified Standing List (need PMC)	127	29	156
Total Reviewed	486	119	605

Each officer reviewed for certification will receive a personal letter explaining their certification status. The board made some observations that will be helpful to officers seeking certification in the future. Some officer files did not contain their most recent OERs which made it difficult to establish qualifying experience for certification. A number of job descriptions were poorly written, and in some cases too general, which made it difficult to determine 6T applicability. On the ORB, some duty titles were misleading and not consistent with corresponding duty titles on the OER. Officers are reminded that this is a DA board and, as such, should be given as much consideration as other boards. The board encouraged officers to write a letter to future boards to clarify confusing duty titles or job descriptions.

Museum Used for Research

Every year about 250,000 people visit the U.S. Army Ordnance Museum at Aberdeen Proving Ground. Many are civilian or military personnel from the proving ground bringing their visiting family and friends to see the artifacts at the museum. Others are veterans bringing their children and grandchildren to see the equipment used while they were in the service. Some have never been associated with the military and they come out of curiosity or to gain knowledge about the military.

However there are visitors who come for more than reminiscing or out of curiosity — they come to do research. Whether they're doing a project for middle school, a thesis for a college degree, a military study, or collecting information for a contracting firm, the Ordnance Museum has a lot to offer.

Because of the interest and dedication of so many people who put their time, money and efforts into creating an ordnance museum, more than 300 large weapons — tanks, cannons, rockets and missiles — stand in the Tank Park outside the museum and spill over into the median of Tank Row. Inside, nearly 600 small arms, rifles and other weapons from all over the world are on display and the Ordnance Technical Library is in operation.

The evolution of several weapon systems is on display and, as a consequence, the museum is a training resource for the many students and permanent party military personnel at the proving ground. Researchers benefit because they can study the progression of several types of weaponry in one collection rather than having to travel many miles between variations.

Many of the pieces on display at the Ordnance Museum were built for and tested at Aberdeen Proving Ground. Others were action pieces that served in combat or training and may have traveled over a large portion of the globe before coming to rest at the museum, such as the German Leopold railway cannon that fired 550-pound shells at American troops on Anzio Beach during World War II. Some are prototypes of items that were never bought by the U.S. government and were never produced in massive numbers. Because the Ordnance Museum's collection is so diversified, there isn't another collection like it anywhere.

By studying the museum pieces, researchers are often able to avoid pitfalls that have already been encountered by older projects or they may be able to take the best of a past idea and adapt it for future services.

"Every year we get many requests from around the world for information on particular items," says Armando Framarini, acting museum curator. "The Franklin Mint recently contacted us for specifications on the 'Anzio Annie' gun and authors doing technical work often ask our assistance. Even military medical people have come to the museum to do research on better protective eyewear."

Because of staff shortages, Framarini suggests a written request for information for those wanting to do extensive research and telephone requests for students wishing to visit. The address and phone numbers are: U.S. Army Ordnance Museum, Aberdeen Proving Ground, MD 21005-5201, AV 298-2396, commercial (301) 278-2396.

Genetic Engineering Enhances Silk Strength

Researchers at the U.S. Army Natick Research, Development and Engineering Center, Natick, MA, are studying the use of genetic and protein engineering techniques to modify silk proteins for enhanced high tensile strength fibers. Silk was extensively studied at Natick during the 1960s because of its exceptional structural properties, including anti-ballistic performance.

Protein structures, based on silk, can now be produced by using protein engineering. The goal is higher strength, higher extensibility fibers for ballistic and other high performance fiber applications.

Silk is a natural crystalline protein polymer with a predominance of alanine and glycine amino acids. The excellent strength properties of this fiber come in part from the primary structure and from the conformation of the polypeptide chains, particularly the stacked B-pleated sheets.

The excellent extensibility properties are derived from the amino acid sequences in the amorphous regions. Modifications of the natural sequence of amino acids in the silk protein may offer a unique approach toward the development of high performance fibers.

In addition to genetic and protein engineering, researchers will study chemical synthesis of model proteins based on silk and computer modeling of optimized silk-like proteins. Techniques involving the modification of natural proteins through genetic engineering, the denovo synthesis of new proteins through peptide chemistry, or the construction of synthetic genes for protein production will be investigated for their potential in modifying natural silk protein for improved properties.

TACOM Laser Lab Aids in Testing

With the recent addition of a state-of-the-art laser laboratory, the U.S. Army Tank-Automotive Command's RDE Center has increased the Army's capability to reduce the vulnerability of combat vehicle optical systems to lasers.

Lasers are currently used as a part of a fire control system to determine the range to a target or to designate targets for laser-guided munitions. There are no fielded laser devices that now operate as intended weapons, nevertheless they can cause severe damage to the human eye from accidental exposure.

TACOM is now able to use its new laser laboratory for testing and development of filters for optical systems to increase vehicle crew laser protection.

Specifically, the laboratory will be used to focus on improving the unity vision equipment on all combat vehicles in the present and future Army inventory. Unity vision devices are those which provide the viewer a one-to-one magnification of a scene. In other words, what the viewer sees when he looks out of his unity vision device — a periscope or vision block in a tank — is as it exists, with no magnification.

According to Douglas Templeton, manager of the laboratory, "A variety of optical sources. . . make this facility the only Army laboratory currently able to perform all of the required optical performance tests on any type of optical improvement filter used in unity or magnifying sights. This adds immeasurably to TACOM's. . . reputation in the laser protection development community, and has led to recognition of TACOM as an important leader in this critical area."

Armywide efforts toward improving optical system protection are concentrated in four areas: magnifying optics (such as gun sights), Picatinny Arsenal at the U.S. Army Armament, R&D Center, Dover, NJ; unity vision devices, TACOM; night vision equipment, the Center for Night Vision and Electro-Optics, Fort Belvoir, VA: and individual eye protection (eye goggles), Natick RDE Center, Natick, MA.

It has been suggested that unity vision protection would not be needed if laser protection was added to standard tanker's goggles (which are used outside the vehicle), Templeton said. But, he added, the use of these goggles inside the tank is not always practical for several reasons.

First of all, soldiers may not comply with a requirement to wear goggles within a tank, because the goggles may be uncomfortable to wear for long periods inside a vehicle. Secondly, a gunner cannot use goggles on his gunner's sight — his eye cavity must be able to fit snugly against the sight. Lastly, the goggles obscure some indicator light colors which appear within a tank.

At this time, a new filter specification and revised equipment drawings for unity vision devices are in the works for release to vehicle program managers. The specification and drawings will ensure the incorporation of the new unity vision ocular hazard protection filter in all combat vehicles. According to Templeton, without the new laser laboratory, development and testing of the filter at TACOM would have been impossible. A number of unique and specialized test procedures, developed by Robert Goedert, an engineer in the Countermeasures Branch, were also necessary.

"One laboratory test studied how well the human eye can see through the filter under daylight conditions," Templeton said. "Based on a huge amount of testing with the user, we found that the effect of the filter on the unity vision device is minimal; there is not significant operational degradation."

In the future, laboratory research will be directed toward the next generation of laser threats — broad bank or frequency-agile lasers. A typical military laser operates at only one wavelength. But, the wavelengths of broad bank or frequency-agile lasers can be changed by the turn of a dial, making protection against them much more complicated. Although these lasers are not part of today's battlefield, technology in place now may make them a threat in future wars.

The preceding article was written by Julie McCutcheon, an editorial assistant at the U.S. Army Tank-Automotive Command. She has a B.A. degree in communications from Michigan State University.

Army Improves Insect Repellent

The U.S. Army has developed a new version of its standard issue insect repellent. The new formulation is effective for up to 12 hours per application, three times as long as the old version.

Nicknamed "Deet," the repellent was adopted as the standard military insect repellent in 1957. Surveys conducted in 1983 showed that 45 percent of soldiers in the field did not like Deet and did not use it. Researchers faced the challenge of improving soldier acceptance of the repellent as well as its effectiveness and duration.

The new extended duration topical repellent is a lotion containing an acryloate polymer formulation of the active ingredient N-,N-Diethyl-3-methylbenzamide, or Deet which sustains release of the chemical from the skin. The new formulation is highly effective, doesn't wash off as easily as the old one, doesn't have the same strong odor, doesn't damage materials such as plastics, and doesn't feel oily on the skin.

It is effective against mosquitoes, several kinds of flies, fleas, chiggers and terrestrial leeches. User acceptance in product testing was greater than 75 percent.

The U.S. Army Medical Research and Development Command began development of the new repellent in 1984. Research included a market survey which determined that no off-the-shelf repellent was available which met Army needs. A competitive evaluation of candidate repellents developed under Army contracts resulted in selection of a product from the 3M Company of St. Paul, MN.

The Environmental Protection Agency has approved the new repellent, and the Army expects to issue it to soldiers by next summer.

Flywheel Power For Medical X-Ray Imaging

The generation of X-rays has changed little since Roentgen discovered them in 1896. Improvements have resulted in better control (heated filaments and hard vacuum), more reliability (different metals and rotating anodes) and safer systems. X-rays are still produced by accelerating electrons, and then stopping them with a metal target. Medical X-ray systems allow the X-rays to escape through an aperture in the systems lead shielding and pass through the patient to a detector which records the location and quantity of X-ray photons striking it.

Originally, film was used as the detector. However, because of the insensitivity of the film, intensifier screens were later added. Today, solid state detectors, which are even more sensitive, are beginning to be used. The increased sensitivity of the detector systems has permitted reduction of the electron beam current used to produce the X-rays, and/or the time of the exposure.

The normal mode of operation of Medical X-ray Imaging uses short exposures of high power (less than 0.1 second and occasionally in excess of 50 kw). X-ray exposures may occur several times per minute in some special types of radiographic studies. However, more conventional use calls for X-ray exposures several minutes apart with potentially long periods of no exposures at all between patients.

Current field X-ray systems require input power (peaks of 30kW are not uncommon) from mobile electric power sources such as gasoline and diesel engine driven generators. These mobile power generators are not sufficiently stable in output voltage or frequency to produce repeatable X-ray output from exposure to exposure nor can they provide sufficient line regulation to respond to large power demands for very short periods of time.

Because of the inherent limitations in present day mobile electric power generators, alternative power sources were proposed to take advantage of the low duty cycle (on time divided by off time) of the Army field X-ray systems. Some of the alternatives investigated were battery power supplies, capacitors, and flywheel storage systems.

Batteries require considerable maintenance and are also heavy and require protection from temperature extremes. Capacitors produce exponentially decaying output voltages, require conditioning before and during use, and are subject to damage by temperature extremes. All of these factors make these methods of energy storage less than desirable for field applications.

In a response to the Broad Agency Announcement, an annual publication of research topics of interest to the U.S. Army Medical Research and Development Command, Professor Melvin P. Siedband of the University of Wisconsin, proposed the use of a flywheel to store the required energy.

One of the unique features of the proposal was the use of an automotive type alternator to drive the flywheel up to a speed sufficient to store the necessary energy and also to provide the output power to the X-ray source. This approach appeared to the Army as a very viable alternative to conventional mobile field power sources, and the research was funded.

Several different automotive alternators were chosen in order to evaluate their power generating characteristics. It was found that although these alternators are small and inexpensive, they are limited in output power by low flux densities and high series reactance. Aircraft alternators were evaluated next. They include a much more sophisticated design than their automotive counterparts and are capable of much higher flux densities and lower series reactance.

Once a candidate aircraft alternator was chosen, a flywheel was designed and coupled to it. Flywheel energy storage is directly proportional to the mass of the flywheel and the angular velocity. In order to keep the weight of the flywheel power supply as low as possible, high angular velocity was desired. A five kilogram flywheel, 30 cm in diameter, was constructed. Circuitry was designed to provide the necessary input power switching that permitted the alternator to operate in a mode similar to an electric motor and drive the flywheel up to a speed of 10,000 rpm. This combination of flywheel mass and angular velocity produced approximately 30 kJoules of stored energy. Once the operating speed was attained, depressing the X-ray exposure switch would change the alternator from the motor mode to a conventional alternator and make available to the X-ray generator the electrical energy stored in the flywheel in the form of mechanical energy.

The final developed X-ray generating system was capable of producing X-ray exposures at 300 mA, 100 kVp for 50 ms. This slowed the rotational speed by about 2.5 percent. The time required for the flywheel to reach operating speed is inversely proportional to input power supplied. For 500 watts input, about three to four minutes were required to reach 10,000 rpm while 1.000 watts input power allowed the flywheel to accumulate the same amount of energy in less than two minutes.

Although this project was aimed at providing a stable input power source for medical X-ray generation, the same flywheel power generation technique applies to any situation where the electrical requirements demand high power for short durations.

The preceding article was written by Lloyd Salisbury, a bioengineer with the Army Medical Materiel Development Activity, U.S. Army Medical R&D Command.

CONFERENCES

Frequency Control Symposium Call for Papers

A call for papers proposed for presentation at the 43rd Annual Frequency Control Symposium, May 31-June 2, 1989 in Denver, CO, has been issued.

The Frequency Control Symposium serves as the leading technical conference addressing all aspects of frequency control and precision timekeeping. Authors are invited to submit papers dealing with topics such as fundamental properties of piezoelectric crystals, resonator processing techniques, filters, surface acoustic wave devices, sensors and transducers, and measurements and specifications.

Send two copies of summaries (500 or more words) for proposed paper evaluation to: Dr. Thrygve T. Meeker, 2956 Lindberg Ave., Allentown, PA 18103. Please include the names of all authors, their addresses, and their phone numbers. The deadline for submission of summaries is Jan. 20, 1989. Authors will be notified of acceptance of papers by March 20, 1989.

Corrections

• On page 37 of the November-December 1988 issue of *Army RD&A Bulletin*, an incorrect POC and phone number were listed for advanced placement information on the Program Management Course at the Defense Systems Management College. The correct POC is Tom Tabor, AUTOVON 221-3125.

• The photos on pages 6 and 7 of the November-December issue are not associated with the article beginning on page 5, but with a different article by the same author that will be published in a future issue.

NEW BULLETIN OFFICE SYMBOL

As a result of a recent realignment, Army RD&A Bulletin is now part of the Army Materiel Command's Project Management Office. As such, our new office symbol is AMCDRA-PM. Our complete mailing address and phone numbers are:

HQ, U.S. Army Materiel Command
ATTN: AMCDRA-PM
5001 Eisenhower Avenue
Alexandria, VA 22333-0001

AUTOVON Phone: 284-8977
Commercial Phone: (202) 274-8978

ADDRESS CHANGES

A reminder to active duty officers in functional areas 51, 52 and 97 or with a 6T skill: Since the *Army RD&A Bulletin* uses your address as listed in your Officer Record Brief (ORB), it is important that you keep your ORB updated. A number of requests for change of address have been mailed directly to us, but the bulletin office does not have the ability to make those changes. Your address is submitted to us on a computer printout from PERSINSCOM, which is taken directly from your ORB. If you have moved or changed your address recently, please change your ORB so the bulletin can reach you at the proper address in a timely manner.

Address changes should be submitted to Commander, PERSINSCOM, ATTN: ASNM-SMI-R, 200 Stovall Street, Alexandria, VA 22332-0400. **Social Security Numbers must be included with all requests for address changes.**


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