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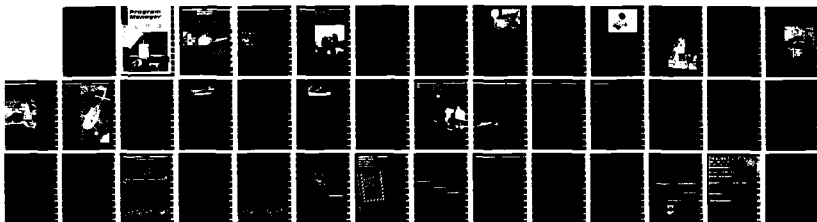
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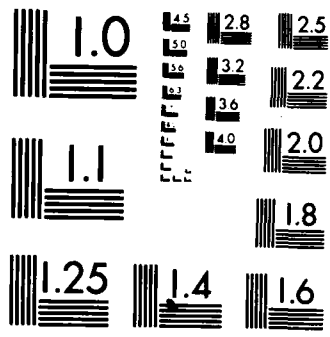
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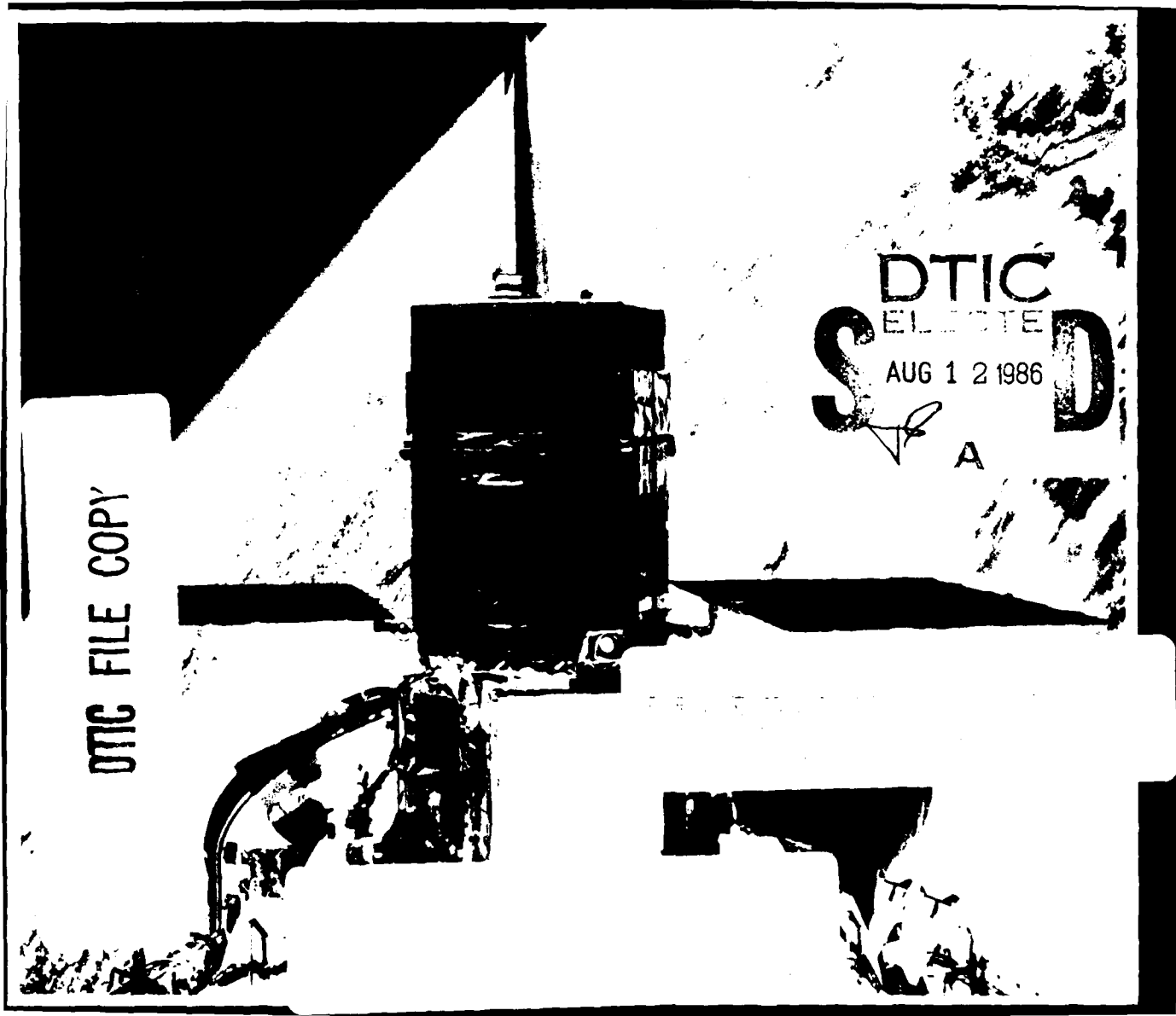




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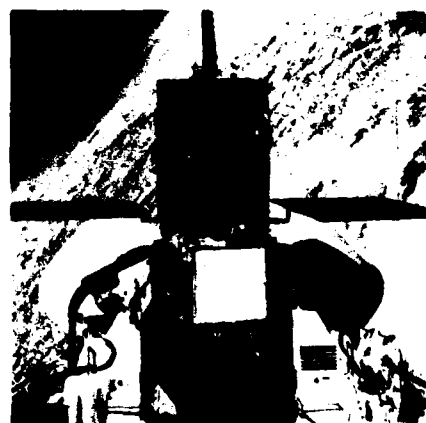


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Cover: NASA's Solar Maximum research satellite awaits repair in the Space Shuttle's cargo bay. The view is aft from the cockpit with the earth in the background. This photograph was taken during Mission 41-C, April 1984.



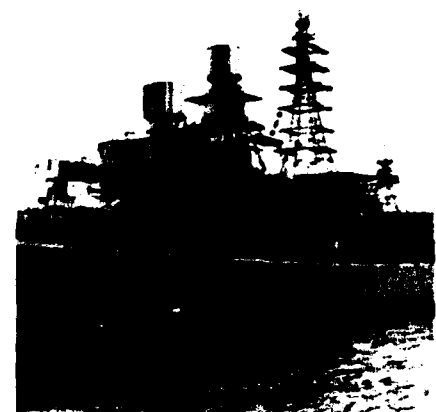
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Lieutenant Colonel Samuel Craig,
USAF

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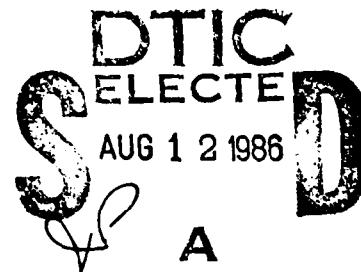
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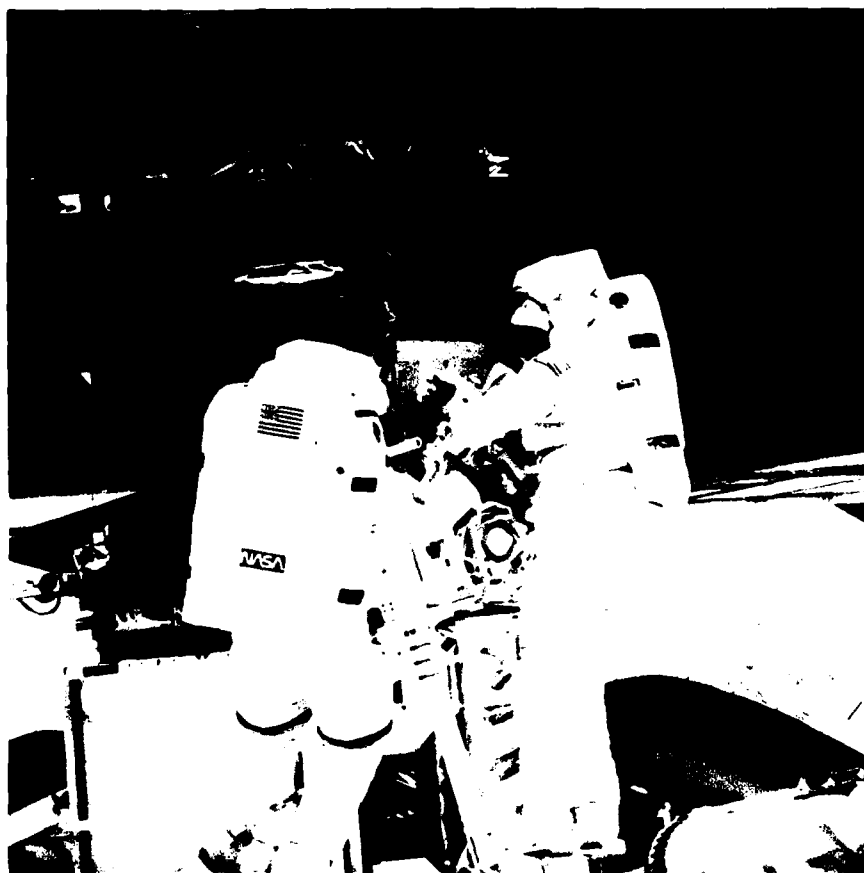
On-Orbit Servicing

The Next Step in Space Development

William T. Motley
Lieutenant Colonel Samuel Craig, USAF

The technical achievements of the United States and the Soviet Union during the past 25 years have proved that man and his equipment can function effectively in space. Current and projected technical capabilities, combined with the potential for high-benefit and high-return uses, will draw increasingly greater amounts of human and capital resources from government and industry into space development. Scientific research, national defense missions, and commercial development will see increased activity. Due to the costs and unique capabilities of future systems, it will become increasingly difficult to use on-orbit spares or rely on ground-based backups. It will not be economically feasible to fund the costs of redundant systems which include the recurring costs of production and launch; nor will it be feasible to discard a platform if it fails. These costs rapidly become prohibitive if we consider that today a typical communications satellite will cost \$85 million, weigh 2,000 pounds, and cost approximately \$5,000 per pound to launch on the Shuttle. This launch cost includes the amortization of the Shuttle's development and production costs. As a result of high initial acquisition and support costs, plus an increasing dependence upon these systems, users of future spacecraft and space platforms can be expected to desire longer mission lifetimes and greater availability in conjunction with the ability to upgrade both the hardware and software of their systems.

Space development in its current state is a high-risk, resource-intensive activity. Regardless of technical capability or the potential for high returns, rapid and effective space development will depend on lowering operating costs and increasing the productivity of man and machine, both on the ground and on-orbit. It is estimated that 50 percent of the cost of each Space Shuttle mission is expended on the labor required for launch and flight operations. The California Institute of Technology Jet Propulsion Lab estimates that each hour of extravehicular activity (EVA) costs approximately \$4,000 per hour, independent of any prior training or planning. Due to NASA's two-man rule for EVAs, this equates to \$8,000 per EVA-hour. This



A Solar Maximum Repair Mission

Users, designers, producers and maintainers must begin now to evaluate system design trade-offs and life-cycle cost implications for future space systems.

is compounded by the time and resources to practice and simulate repair missions, 2 1/2 years in the case of the Solar Maximum Repair Mission and 9 months for the Palapa B2 and Westar 6 repair mission.

Influences on Developers

Scarce resources, budgeting constraints, and public scrutiny will influence government and commercial developers of space. On-orbit servicing and its related effects will have the

potential to amortize fixed costs over longer system lifetimes, decrease payload turnaround time, simplify launch manifesting and allow users to accomplish platform technology upgrades, and make design corrections or change missions. On-orbit servicing will benefit commercial users by decreasing insurance premiums. Premiums currently cost about 20 percent of the insured value of the platform, if insurance can be obtained at all.

On-orbit servicing will be utilized for five purposes: (1) repair of worn-out, misaligned or damaged components; (2) refurbishment of consumables such as propellants, cryogenics, and batteries; (3) payload changeout and retrieval; (4) technology upgrades; and (5) preventive maintenance.

Users, designers, producers and maintainers of space hardware and software must begin now to evaluate system design trade-offs and life-cycle cost implications for future space systems. A systems engineering approach is necessary to accomplish this kind of an evaluation.

In this paper, we will describe a system engineering approach, identify on-orbit servicing as a major design driver, and provide thoughts about on-orbit servicing to consider during the systems engineering process.

Systems Engineering Approach

A systems engineering approach implies that we need a control process helping to manage the design and development of space systems. The systems engineering (SE) process meets this need and is now used by government agencies and civilian contractors to integrate the many functional requirements and constraints of space systems.

The systems engineering process is an iterative and logical sequence of analysis, design, test, and decision activities that transforms an operational need into descriptions required for production and fielding of all operational and support system elements (Figure 1).

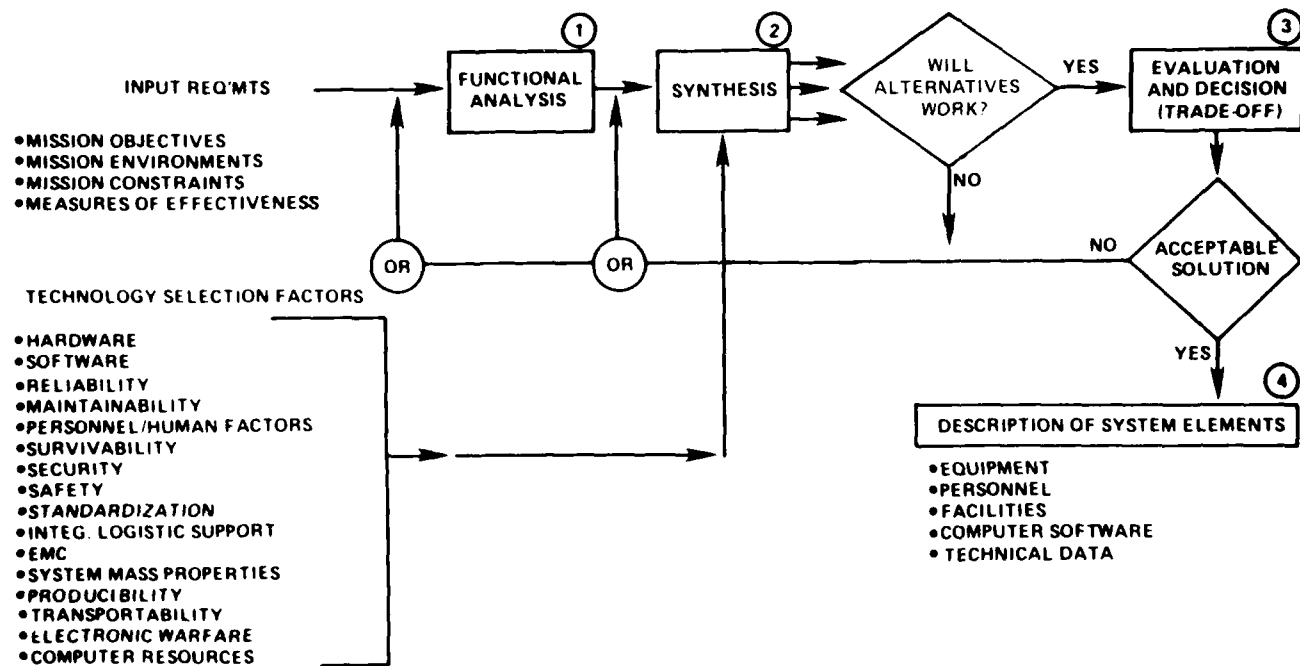
The inputs to the SE process are mission objectives, mission environments, mission constraints, and measures of effectiveness. On-orbit servicing

should be a major consideration within the mission constraints, and measures of effectiveness inputs.

System engineers should increasingly emphasize on-orbit servicing during the development of logical functional flow-block diagrams to help formulate what technical system functions are required to satisfy the input requirements (Figure 2). Also, an equal amount of emphasis should be given while "synthesis" is taking place to determine how functions will be performed and achieve their assigned technical performance requirements. Trade-offs have to occur between the what and how steps within the systems engineering process to arrive at the proper balance among input requirements.

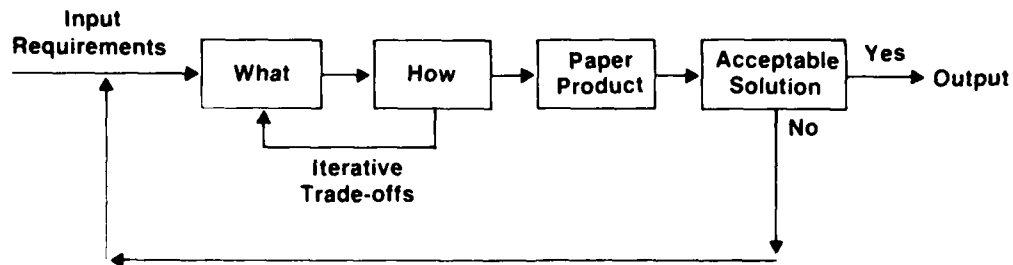
A key tool, the work breakdown structure (WBS), which helps to accomplish the how, is developed during the functional analysis and synthesis iterations of the SE process, and defines the total system configuration. System engineering trade-offs are made within the framework of the WBS. Therefore, to provide the proper emphasis to on-orbit servicing, it should be given a level two position in

Figure 1. System Engineering Process



Courtesy Technical Management Department DSMC

Figure 2. Another Way of Looking at the System Engineering Process



Courtesy Technical Management Department DSMC

the WBS (See Figure 3; not meant to be all inclusive). The integration of on-orbit servicing to the other functions identified in the WBS should be given increased emphasis within the systems engineering process during the development and production of future space systems. This integration should include defining and allocating requirements; defining how engineering specialties like reliability, maintainability, human factors, safety, producibility, etc., relate to on-orbit servicing; identifying organizational responsibilities for prime- and sub-contractors; identifying how verification, configuration management, documentation management, plans and schedules for design and technical reviews will take place.

Now that we have stated there is a need to incorporate on-orbit servicing concerns during the systems engineering process, we need to discuss ideas that system engineers, designers, specialty engineers, and acquisition logisticians should consider during the iterative steps of functional analysis, synthesis and trade-off analysis in the systems engineering process.

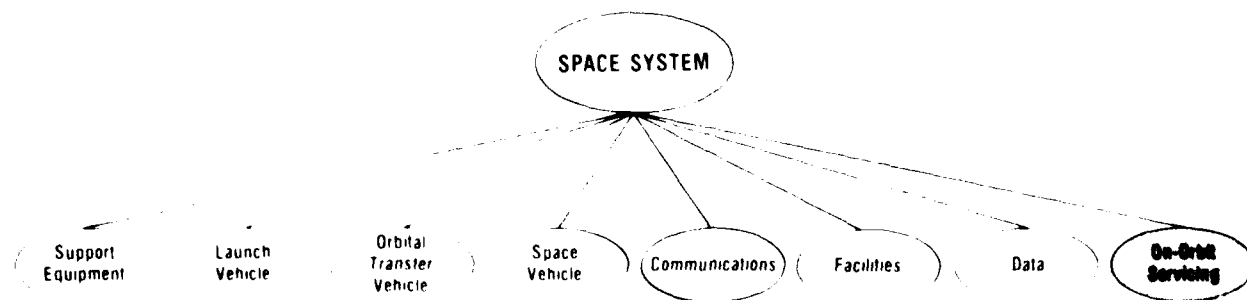
Design Considerations

On-orbit servicing, like all system requirements, will require that design trades be made among constrained resources and bounded physical parameters. There will probably be weight and cost penalties incurred to make servicing possible. There are estimates that current military satellites designed specifically for servicing will incur design/development costs 4 percent higher, and unit production costs 8 percent higher than comparable non-serviceable satellites. There would be a probable weight increase of 600 to 800 pounds for these same vehicles. The effects of accessibility and standardization will be to force some volumetric inefficiencies for payloads and launch vehicles. The benefits of servicing must be weighed against the negatives of increased cost, weight, and volumetric losses while simultaneously evaluating platform lifetimes, payload change-out cycles, and mission criticality. You should realize, however, that the attributes making a design serviceable will increase the ease with which pre-launch payload processing can be accomplished. This is an

important consideration because the severest environment a spacecraft will face, other than launch, is ground transportation and launch processing. The ease with which a platform can be produced is important not only for reduced manufacturing costs but because production problems are potential maintenance problems. If assembly is difficult and time-consuming under controlled conditions, then maintenance may be impossible on-orbit.

We are entering a new era of requirements and economics in the space business. The Space Station and Strategic Defense Initiative (SDI) are being designed to be evolutionary systems requiring availability over longer periods of time than has been required of previous space systems. This evolutionary, long-lived aspect will be one of the fundamental systems requirements affecting all other design considerations. To conduct our primary tasks in a cost-effective manner, we will have to improve the way we manage and design serviceability into our space systems.

Figure 3. Top-Level WBS



Courtesy Technical Management Department DSMC

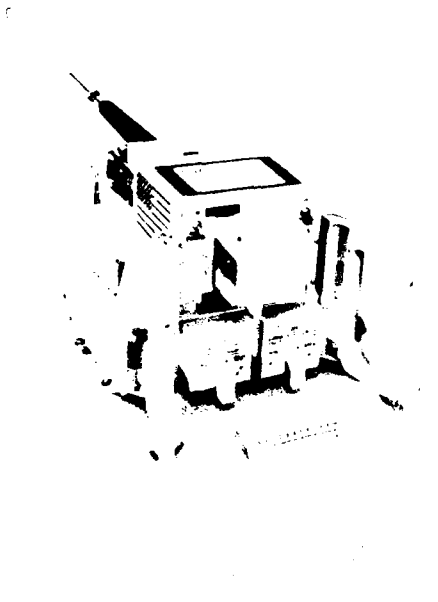


Figure 1. Servicing vehicle. The vehicle is designed to service the platform and to provide access to the platform and then to the component or unit. Platforms must assist in this process by providing external and internal features that reduce skills and resources needed by the servicing unit.

Accessibility

To service a platform, the astronaut or servicing device must be able to gain access to the platform and then to the component or unit. Platforms must assist in this process by providing external and internal features that reduce skills and resources needed by the servicing unit. External features include radar and laser reflectors for target recognition and tracking, strobe lights and beacons for visual acquisition, and grapple hold points for astronauts and teleoperated or automated manipulators. Lighting schemes and geometric shapes of common fasteners may need to be modified to adjust for the absolute shadow of space, and to increase the visual acuity of machine vision systems and astronauts. Internal to the platform, common avionics procedures need to be implemented; these include color-coded cables and terminals, and hazard indicators, using captive hardware and providing numerous external test points.

During the design process, efforts must be made to determine the best means for removing replacement units, radially or axially. Past experience has shown that for best results no more than one unit should have to be removed to gain access to another unit. The detailed vehicle layout for

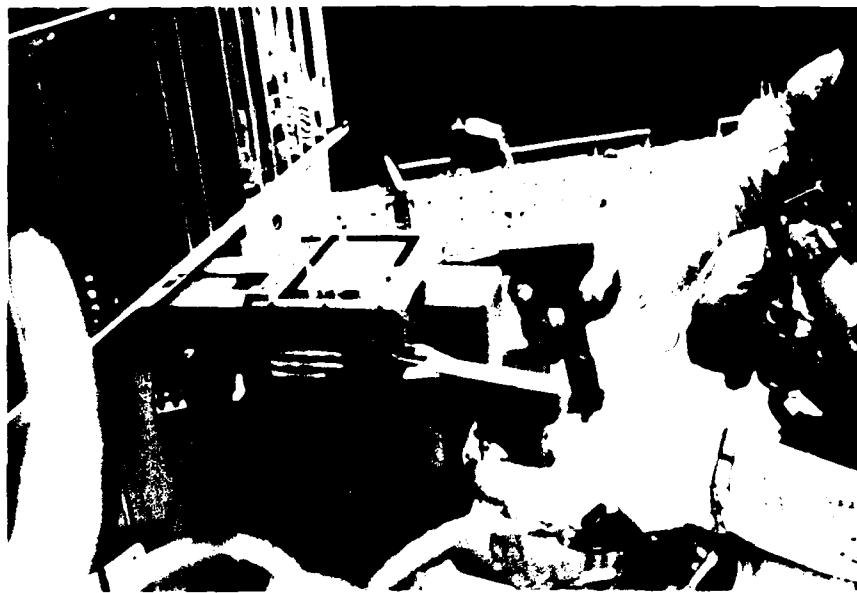


Figure 2. Servicing vehicle. The vehicle is designed to service the platform and to provide access to the platform and then to the component or unit. Platforms must assist in this process by providing external and internal features that reduce skills and resources needed by the servicing unit.

components should relate to the failure modes and effects analyses. Components with the highest failure rates should, where possible, be located near the outside of the structure. Consumable units, especially batteries and reaction control propellant tanks, should be located in this manner. Ease of access should be emphasized for infrared and ultraviolet sensors and optical devices such as star trackers which are very susceptible to damage and misalignment. This must, of course, be done with appropriate regard for the platform's center of mass, thermal control, radiation shielding, and wiring paths.

The design of servicing vehicles must be considered. Access to the platform assumes some type of cost-effective means to rendezvous with the platform. The costs of launch, complex orbit changes (orbit size, shape, inclination), and time in station must be minimized. Current research in the areas of low-earth orbit and high-earth orbit space tugs (the orbital maneuvering vehicle and orbital transfer vehicle) addresses these issues. These vehicles will be used to minimize the time and fuel required to make orbital plane changes. Although these vehicles are beyond the scope of this paper, it is evident that they must be

able to interface with planned platforms. The considerations of serviceability also will apply to their design because these vehicles will be long-lived, reusable systems.

Standardization

Standardization probably provides the fastest and easiest manner to move toward serviceability. Orbital replacement units (ORUs) have been designed for some current systems, the most notable being the Hubble Space Telescope with 25 ORUs. An emphasis on physical and functional partitioning, via modularity, should extend beyond the traditional applications in electronics to mechanical components such as thrusters, antennas, propellant systems, and solar arrays. Partitioning simplifies test, production, and maintenance by minimizing interfaces with other components. There may, however, be some weight and volume penalties. Standardization will decrease procurement costs and speed the process of inserting new technologies by simplifying the qualification of space-rated components. Standardization will assist EVA training by allowing astronauts to train for generic tasks rather than for specific missions.

Standardization will allow the automated manufacture of high labor

content products such as wiring harnesses. It would not be unreasonable for a scientific satellite to require four men one year to fabricate the wiring harness. Such harnesses for spacecraft experience the same high-failure rates that aircraft harnesses do. Automated manufacturing would assist in dramatically lowering the failure rate of harnesses.

Standardization can play a role in high-order programming languages and test languages so that on-board families of computers and standardized automated test equipment can become feasible. The role of on-board computing and the required amounts of hardware and software can be expected to increase greatly in the future. Standardization will facilitate this expansion and make it manageable.

Standardization of platforms is currently receiving the greatest amount of attention. Other areas where many benefits can be gained from standardization are the launch vehicle, launch facilities, servicing facilities, operational ground support, command, control and communications links, servicing procedures, and documentation. As launch rates increase, efficiency and safety will require that more emphasis be given to operations management. More attention must be directed to sizing facilities and procedures for optimum turnaround while minimizing the opportunity to either underutilize or over-extend our resources. Standardization of facilities and procedures for all aspects of the space system will be an important first step.

Today, the space business is, to use an analogy, transitioning from the "job shop," or R&D phase, to high-rate production, at least in terms of launch rate. In terms of the efficiency of operations, the manufacture of space platforms is currently equivalent to the state of the aircraft industry before World War II. Eventually, the space business will have to adapt to high production rates and high launch rates. Correspondingly, our design and management philosophies, which have been based on development and performance parameters, must begin to recognize and implement more operations and cost concerns.

Configuration Management

Configuration management is a proven discipline that is critical for on-

orbit servicing. Configuration management not only assists servicing but aids in preventing failures resulting from incorrect manufacture and incorrect maintenance. Due to the high cost of satellite failures, it is imperative that our best efforts be made to prevent errors in assembly and to ease the servicing function. To do this, we will need to augment our present techniques of configuration management.

The easiest and fastest method is to require the use of close-out photographs to ensure that engineering documentation represents the actual "as-built" configuration. It is invaluable if problems arise during servicing and the ground is called upon for assistance, or if simulation of servicing is ever needed.

More use must be made of common engineering data bases that will allow the use of master equipment lists and computer-aided logistics. Such data bases will allow real-time access to information on component description, function, location, hazards and interfaces. This data base will track and document any configuration changes due to design, manufacturing, or servicing actions. Computer-aided logistics (CAL) will provide modeling of platform layouts to test for accessibility, and physical interference that could hamper serviceability. The use of computer modeling and high-fidelity mock-ups will aid in the original design process for servicing and in simulating contemplated repair missions. The combined use of close-out photographs, computer-aided logistics, and high-fidelity mock-ups should be made mandatory for high-cost, high-criticality systems. These methods will prove invaluable if difficulties are encountered while the system is being serviced.

Technology Enhancements

New technologies present opportunities to make platforms serviceable by either increasing standardization and accessibility, or because they possess inherently greater reliability. The following are technologies that may be applicable to space systems. This list is not meant to be exhaustive, but only to present the idea of using "servicing friendly" technologies.

Fiberoptics: Their use as data paths increases bandwidths and resulting data rates while being immune to elec-

tromagnetic interference (EMI) and electromagnetic pulse (EMP). The use of fiber optic cables results in reduced weight, volume, and fewer cables and connections. Fiber optic/laser gyroscopes will provide greater reliability and higher accuracy.

Composites: Provides increased strength-to-weight and stiffness while providing greater dimensional stability under large temperature extremes and steep temperature gradients.

Advances in Microelectronics: Gallium arsenide based semiconductors and very-high speed integrated circuits (VHSIC) will present the opportunity for faster circuits, fewer cables and connectors while being more tolerant to radiation and temperature. These new technologies will require less weight, power, and cooling than existing semiconductor technologies. Where possible, hardware capability in terms of memory size and cycle speed, should be used to simplify the programming of on-board computer systems. Although "brute force" is not an elegant solution to a computing problem, it does simplify and increase the reliability of the programming effort. Such margins provide the ability to upgrade with minimum disruption.

Solar Dynamic and Radioisotope Sources of Electrical Power: New advances in these areas may provide the ability to increase power for more demanding missions, increase the ability for on-board processing and increased autonomy while decreasing reliance on batteries and solar arrays.

Ada High-Order Programming Language: This is designed specifically for real-time control applications. It is a structured, modular language that facilitates software maintenance and portability among computers and assists in using families of standardized computers. Ada will allow algorithms developed for one spacecraft function to be used on another platform with minimum or no modification to either software or hardware.

Built-In-Test and Fault Isolation: Existing avionics techniques provide the ability to reduce the skills and

■ Mr. Motley is a professor of engineering management and Lieutenant Colonel Craig, USAF, is a professor of system acquisition management both in DSMC's Technical Management Department

resources needed by the servicer. Fault isolation to the ORU level will facilitate rapid repair and reduce redundancy requirements.

Stages to Serviceability

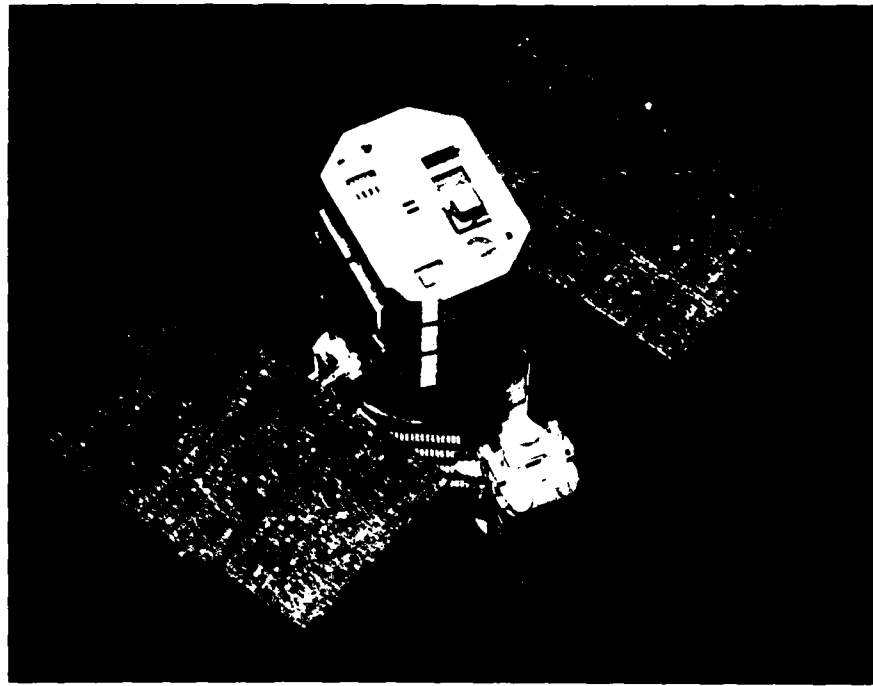
The ability to service will increase with experience and with technological advances. It is difficult to forecast technology. However, we have the advantage of reviewing similar work, with regard to servicing, in the areas of underwater work and exploration. Some features are similar: an environment that is hostile to man; great distances between the user, servicer and platform; and high costs in terms of platform failure. We believe that useful information can be gained from increased study of the progress and problems of underwater technology and how this experience can be applied to space operations. If the work done underwater is any indicator, we will probably see the following pattern develop:

Phase One: Manual Extravehicular Activity, the current method being utilized.

Phase Two: Teleoperation, remotely conducted servicing conducted using manipulators under the supervision and control of a human operator located either on-orbit or on the ground.

Phase Three: Autonomous Operation, servicing is conducted by intelligent robots utilizing dextrous manipulators under the control of expert systems.

Although autonomous robots have the greatest potential for long-term servicing, their full potential is 15-20 years away according to most authorities. In the near future, the majority of our servicing missions must be accomplished either manually or telerobotically. However, the move toward more advanced forms of servicing can be enhanced by already well-developed design approaches which will also aid the current technique of EVA servicing. On-going research concerning automating conventional manufacturing processes indicates there are many relatively simple design techniques which can not only reduce the need for intelligence and dexterity in machines but also make the current manual methods of platform manufacture and EVA servicing faster and more efficient.



Increasing automation in servicing will reduce crew load by freeing astronauts from repetitive, non-skilled tasks.

One of these approaches, design-for-assembly, combines time and motion studies with producibility engineering. Distinct efforts are made to reduce the total parts count, incorporate self-guiding features, relax tolerances, and use geometric parts wherever possible. This approach has proved beneficial in reducing the time and skill requirements of human and machine assemblers. It appears that incorporating design—for assembly into current space—platform design would be beneficial in terms of aiding all types of servicing, manual or automated. A complementary approach is astronaut task loading analyses and work method engineering to simplify and speed EVA tasks. These techniques could have large payoffs in the assembly of the Space Station which will require extensive EVA activities.

Increasing automation in servicing has many benefits. It will reduce crew-load by freeing astronauts from repetitive, non-skilled tasks; it will reduce the exposure of humans to hazards, and allow servicing at much greater distances than is possible today. Intelligent robots have the potential to be faster and more accurate in performing servicing tasks, especially

those that are physically well-defined. Given the proposed large numbers of diverse platforms in numerous inclinations and various altitudes—SDI for example—it will not be possible to service such a system manually. The cost in fuel for the Shuttle would be prohibitive, as would the safety and monitoring procedures required whenever an EVA is in progress.

Fully-automated servicing will require advances in many areas. Dextrous compliant manipulators must be improved. Greater capabilities will be needed in sensing, range-finding, positioning, and touch force control. Machine vision must be enhanced with the ability to perform real-time control, such as being able to evaluate thousands of sensor inputs 30 or more times per second. The majority of these developments will require advanced computational ability that will necessitate distributed nodes of parallel processors. Another important requirement will be the generation of large common engineering data bases containing geometric design and interface data on the servicer and platform. This will allow for the off-line programming necessary to make robotic

positioning more accurate. It will be an absolute necessity, for robotic servicing, that the robot know where it is at all times with regard to the platform. Reference points on the platform must be entered into the coordinate system of the robot. As an interim means of providing geometric reference data, before common engineering data bases become feasible, bar-code plates can be placed on predetermined sections of the platform. Information on the bar codes would be input via optical scanner. The servicer's platform location and special instructions would then be downloaded into the servicing vehicle. This is the same principle being used today in some automated manufacturing facilities. For example, parts are automatically identified by bar code and special instructions and numerical control machine-tool programs are automatically downloaded from engineering data bases into machine-tool controllers.

Near-Term Efforts

There are several techniques that can be used to increase the serviceability of space systems now in the design or development stage. In any event, platform designers should make a concerted effort to be sure their designs do not preclude future servicing efforts, even if servicing is not a major driver in the original design.

Design for assembly has been discussed, as have standardization and modularity. Designing for functional and physical partitioning has proved its value in all fields of manufacture and maintenance. Providing handholds and grip-points is another technique which, although relatively inexpensive, is a decision that could affect whether a future servicing mission is feasible. External surface symbols on the platform provide an inexpensive means of visual acquisition; their shapes could provide a means of telling a man or machine where he or it is on the surface of the platform.

In terms of platform design margins, there are two areas where providing more than initial requirements can be beneficial technologies: these are electrical power and computational and data handling capabilities. Power is a real problem in current systems where primary missions must sometimes be interrupted for platform health and welfare functions. Future platforms,

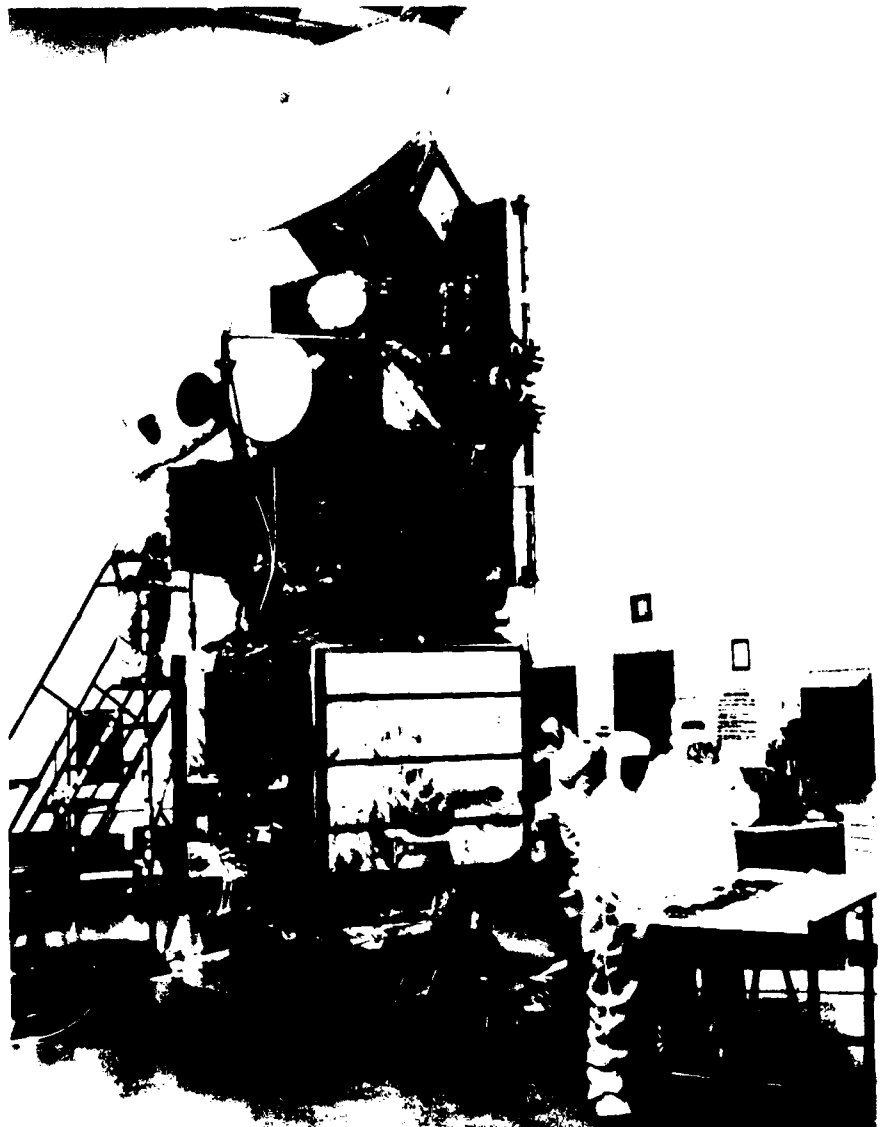
due to their long lives, will probably see the addition of more missions; also, they may become more autonomous regarding mission operations to reduce recurring costs and dependence on ground stations. Power sources like radioisotopes and solar dynamic should be considered in the initial design even if the system does not have a foreseeable requirement for the power these systems can generate. Similar requirement creep occurs in the computer area. Providing excess memory and excess computing power in terms of cycle time can ease the future need to

upgrade capabilities or change missions. Similarly, if it can be tolerated, excess volume should be considered in order to adapt to future unanticipated demands.

Future Concepts

In the future, the development of space will reach the point where the distances involved and the cost of any servicing that originates from earth, will force some degree of autonomy. These systems must be able to design and reproduce components as necessary, and cannot be dependent on

The development of space will reach the point where the distances involved and the cost of services originating from earth, will force some degree of autonomy.



spares or resupply from earth. The complexity of future missions and their long-durations (longer than 1 year) greatly increase the probability of some type of catastrophic equipment failure. However, the ability to design in redundancy or to carry spares for all possible contingencies is clearly not possible. The solution will come from research now being conducted in the areas of flexible manufacturing and computer integrated manufacturing. These systems will provide the ability to manufacture electrical or mechanical parts on demand, either from information previously stored in on-board data bases or directly from computer-aided engineering systems. Research into these technologies is ongoing, most notably at the Automated Manufacturing Research Facility (AMRF) of the National Bureau of Standards. Although the research at the AMRF concerns conventional manufacturing processes, information gained on hierarchical computer control systems, CAD/CAM, and common engineering data bases will be the basis for future independent manufac-

turing facilities in space. Current techniques assisting in developing these autonomous manufacturing facilities are standardization and the utilization of multiple function components. These techniques are being used to manufacture parts automatically, where parts are grouped into "families" based on similar work envelopes, weights, functions and required manufacturing processes. Such grouping simplifies the manufacturing process and reduces the amount of common raw materials required to manufacture any given set of functionally different yet physically similar components. This concept of flexible, or on-demand, manufacturing can be employed for both mechanical and electrical assemblies.

The continued success of space development will depend to a large extent on the emphasis on-orbit servicing receives in the systems engineering process during the iterative steps of functional analysis, synthesis, and trade-off analyses. ■

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DOD Health Program Affects All

Gerry Wiechmann

The Department of Defense Directive 1010.10, "Health Promotion" was signed March 11, 1986 by William H. Taft IV, deputy secretary of defense. This directive, which will affect most everyone in the Department of Defense, "establishes a health promotion policy within DOD to improve and maintain military readiness and the quality of life of DOD personnel and other beneficiaries."

The health promotion plan references:

- Education and training in alcohol and drug abuse prevention
- Physical fitness and weight control program
- Employee fitness
- Alcohol and drug abuse by DOD personnel
- Rehabilitation and referral services for alcohol and drug abusers.

The directive concerns all military personnel and retirees, their families and, where specified, to civilian employees.

This comprehensive directive requires top-down coordination for health promotion to "include those activities intended to support and influence individuals in managing their own health through lifestyle decisions and self-care."

Procedurally, "each service component shall prepare a plan for the implementation of a comprehensive health promotion program that includes specific objectives...and measurable action steps for all of the program elements."

As of June 1, 1986, implementation documents are being prepared at all DOD levels. The documents are due within 90 days according to the directive signed by Mr. Taft, and "shall consider workload, systems support, and training needs of individuals charged with responsibility at all organizational levels."

In upcoming *Program Manager* articles, an understanding of the whole human being (WHB) as may affect program management offices will be

addressed. The WHB concept can provide a framework on which program managers and others, can "hang their hats" to expedite Directive 1010.10. ■

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**Give me your tired, your poor,
Your huddled masses yearning to
breathe free,
The wretched refuse of your
teeming shore,
Send these, the homeless, tem-
pest-tossed to me:
I lift my lamp beside the golden
door.**

*The New Colossus, Inscription
for the Statue of Liberty, New
York Harbor, Emma Lazarus,
1849-1889*

Weapons and Money

A General's Perspective

General Robert W. Bazley, USAF

This is drawn entirely from a letter written by General Bazley, Pacific Air Force commander in chief. The letter was published in a major metropolitan newspaper and addresses defense-related expenditures, cost and complexity of modern air force as compared to earlier systems like World War II ones and such.

I recently read an article that, like many articles critical of defense-related expenditures and programs, was unbalanced and poorly researched. It offers but one side of the story, uses manipulated partial truths, plus apples vs. oranges comparisons to draw conclusions which do not logically follow.

Many, if not most, of the "numbers" used are inaccurate, but we won't quibble. I'd rather address, as a senior military commander who believes firmly in democracy, a strong defense, and freedom of the press, the larger implications of the article.

The Good Old Days

One could conclude from the aforementioned article that the root of most problems lies in bureaucracy, sophistication and cost, and that the "good old days" and the good old cheap weapons were more effective and cost efficient. The questions to ask here are: What is the threat we must deter, counter, and what capability do we get for the increased cost?

The truth is that the simple, cheap and beautiful combat aircraft of World War II, as compared to today's, were not efficient in doing their jobs. Example: On the second raid of the Schweinfurt, Germany, ball-bearing factory we massed an air armada of 291 B-17s, jeopardized almost 3,000 airmen, lost 60 aircraft and almost 300



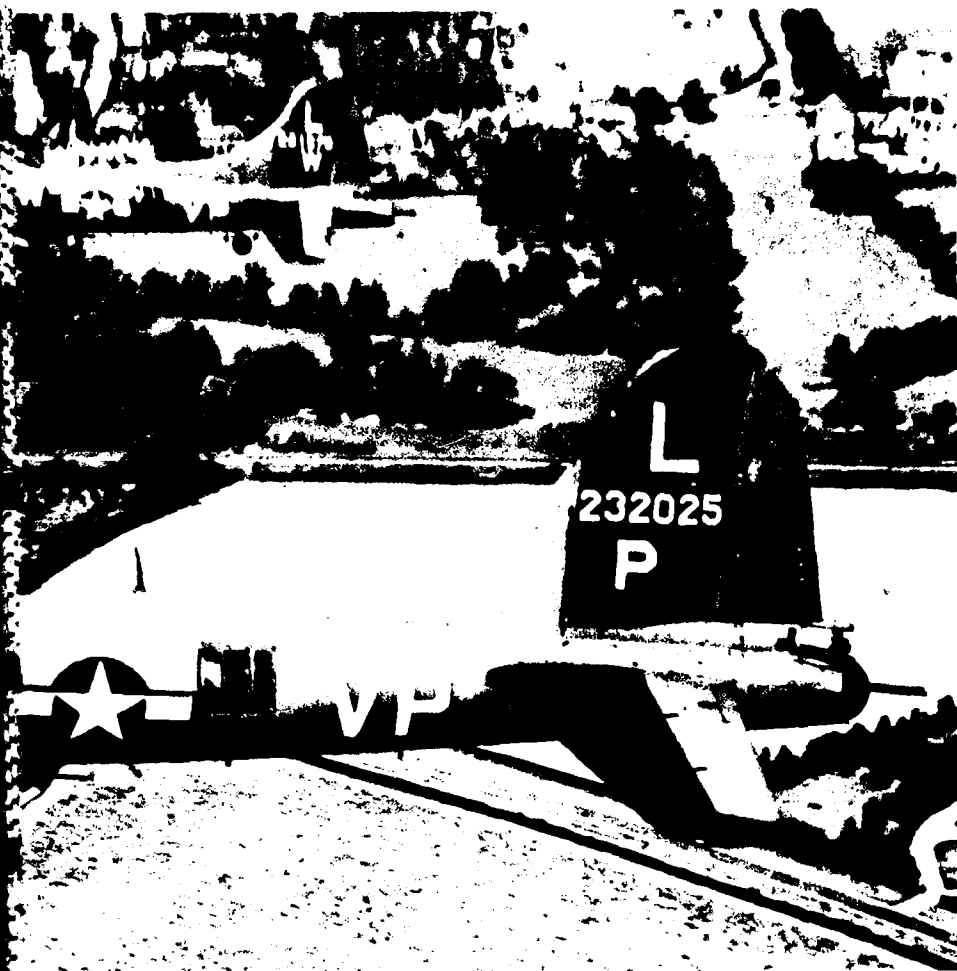
B-17 Bomber

young Americans, and did some damage to the target. The first raid was somewhat similar, and the Germans continued to produce those war-important ball bearings.

The B-17 was inexpensive by today's standards, but labor intensive, not very reliable (fewer sorties flown per week than modern aircraft fly per day), and had only a fraction of the capability. For an "apples and apples"

comparison, with a handful of F-16s, we could take out the same target with non-nuclear ordnance (dumb bombs), smart pilots and airplanes. Most, if not all, of the airplanes and airmen would return to fight again. We could do it at night or in weather with even fewer

The truth is that the simple, cheap and beautiful combat aircraft of World War II, as compared to today's, were not efficient in doing their jobs.



completed the first accident-free year in the history of any major operational command.

This compares with the World War II timeframe when we lost 5,603 airmen while crashing 20,389 U.S. Army Air Forces aircraft—about three times more aircraft than the Air Force owns today—in 1 year (1943) in non-combat-related accidents.

We also read in this aforementioned article of spare parts pricing problems that are said to be more than a "public relations problem." Certainly I'd agree with that, but the side of the story that doesn't get told with the same emphasis concerns that number of problems the services have uncovered and corrected themselves and the number of rumored purchases that never took place. The military did buy a diode for \$110. It also bought 122,000 of them for 4 cents each and got a refund for the overpriced one. We never bought the infamous \$9,600 Allen wrench and we paid less than \$10 for common toilet seats.

Dedicated People

Although some in our defense industries are being cited for improper practices, they are a small minority of the dedicated people in that industry that support us.

Unfortunately, there are those who will shave quality or otherwise produce inferior and overpriced products in every area of endeavor. We are ferreting out those few and taking action against them as quickly as we can. We've put crooks behind bars and recouped millions of dollars in fines and penalties.

On the other hand, there are tens of thousands of honest people in defense industries who are delivering weapons as contracted. The B-1B is being delivered ahead of schedule and under cost. The C-141 was "stretched" under project cost. The C-5 modifications are ahead of schedule and under cost. Our fighter engine competition produced prices and qualities that are at the upper limits of our best expectations. The reliability, maintainability and capability of the A-10, F-15 and F-16 are proved daily, are readily quantifiable, and are highly visible in utilization rates, operationally ready rates, sortie generation rates, bombing accuracy and safety.

(See Weapons, page 19)

F-111s or F-15Es and we wouldn't "waste" the B-1B on such an easy target.

Oranges and Oranges

We could do it because of a combination of technology, realistic training, professionalism and discipline. We believe these same aircraft will be just as effective over battlefields of the 1980s and 1990s and will not suffer

"unspeakable losses in the first 2 weeks of a European conflict."

In the category of "unspeakable losses," let's look at some "oranges and oranges."

Not only are today's weapons better, they are dramatically safer by any measurement. The Air Force completed in 1985 its safest-ever year. In the Pacific Air Forces Command, we

Impacts on German National Economy

*From
U.S. Defense
Research
Development
Acquisition*

Hermann O. Pfrengle

In the Multinational Program Management Course at the Defense System Management College, students receive extensive exposure to the ways in which other NATO allies do business. As a German guest lecturer in that course, I am asked frequently about the impacts of U.S. Department of Defense research, development and acquisition on the economy of the Federal Republic of Germany. Other student interests focus on the German defense industry and policies concerning technological innovation, including intra-European collaboration. In this article, I address such aspects and economical implications from a German perspective.

National Defense Industry Imperative

Like any industrialized nation of the Western World, the Federal Republic of Germany considers a national defense industry vital to its security, and important as a conveyor of high-tech and technological innovation.

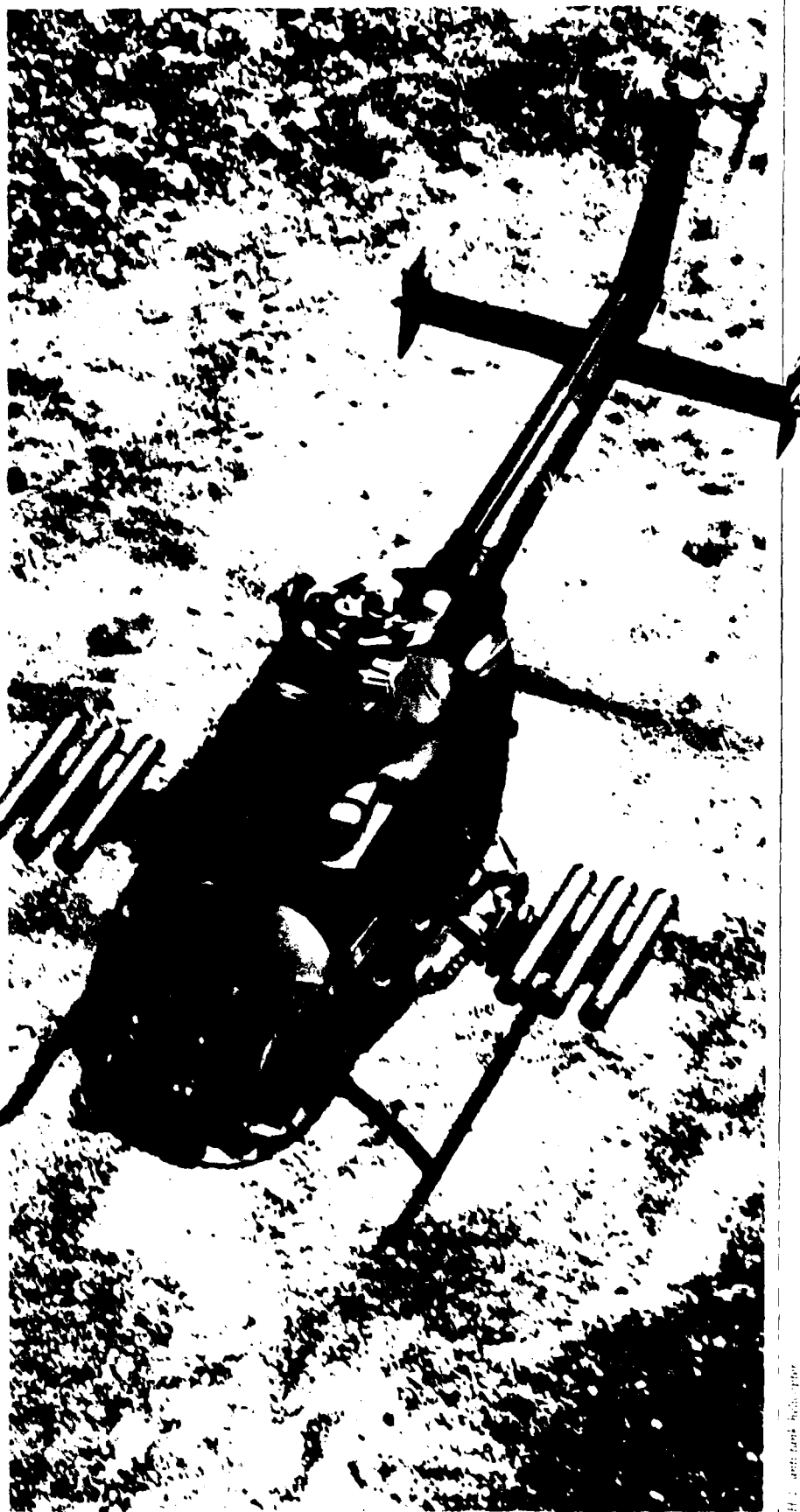


PHOTO: ARMY/DAVID H. HARRIS

Providing the German Armed Forces with complex weapons systems, and the operation and maintenance of such systems, requires a technologically advanced industrial base with appropriate capabilities. In terms of NATO alliance policy, having one's own defense industry strengthens that nation's ability to cooperate as a partner in the alliance, provides political clout, and lessens unacceptable dependencies on other countries. In addition, defense research, development and production at the advanced technological level required for military equipment, generates important stimuli and spin-offs for industries in the civilian sector.

Overview of Defense Industrial Impacts

The German defense industrial development and production capabilities and capacities evolved simultaneously with the buildup of the German Armed Forces commencing in the mid-1950s. Their high standard of performance in many technological areas has since become internationally recognized. Examples are nationally developed and produced systems like the "Leopard 2" main battle tank, the "Gepard" air defense system, the "PAH 1" anti-tank helicopter, or the "F 122" frigate. But, I should note that these nationally developed and produced systems incorporate also foreign componentry; e.g., electronics and target acquisition, which is an indication of the need to cooperate in the interest of NATO rationalization, standardization and interoperability. Such use of foreign componentry also stimulates cooperative ventures, technology exchanges and know-how gains among the industries involved.

Requirements of the German Armed Forces continue to remain the determining factor for the size and structure of the German defense industry. Chances or possibilities for arms exports do not play a determining role. Rather, Germany emphasizes the role of military aid.¹ Of course, Germany exports some defense material, particularly if such export benefits standardization and commonality; to wit, Leopard 2 exports to the Netherlands and Switzerland. From 1981-84, the share of armaments exports was about 0.6 percent of total German exports, representing 0.14 percent of the German gross national product. In their majority, these armaments exports

consisted of naval vessels. While in 1985 Germany's armaments exports have risen to about 0.9 percent of total exports, this is a fraction of the corresponding percentages for the United States, the Soviet Union, France, the United Kingdom, and, as of late, Brazil. Germany's economy does not need to use defense spending as a means to reduce a negative balance of trade.

The defense industrial capacities and capabilities are integrated into the German national market economy system. Germany has no government-owned plants, and only a few companies work predominately, or exclusively, on defense contracts. Many medium-sized and large companies, in addition to their civilian product lines, maintain defense technology, development and production capabilities and capacities. This favors a continuous

The high standard of performance in many technological areas can be seen in systems like the PAH I anti-tank helicopter and the F 122 frigate.

and reciprocal exchange between the civilian and defense technology sectors. Economically, and in terms of jobs, this combination of civilian and defense development and production offers the essential benefit for companies to be able to adjust better to the constantly changing German Armed Forces' requirements during the years.

Defense Shares of German Industry

Of the German defense expenditures for research and development, procurement and maintenance, 85 percent

go to German industry. In the 1986 German Defense Budget these expenditures amount to about DM 20 billion.² The entire defense production of German industry accounts presently, on the average, for not more than 3.4 percent of the total value produced by all German processing industries. For most of the companies involved, the value of defense contracts, as a proportion of total company production, is, at 1 percent, even markedly lower. In some industrial branches it is higher: 1 percent - 2 percent in automotive, well over 10 percent in shipbuilding, and over 50 percent in aerospace, weapons and ammunition industries.

About 260,000 German industry employees work on defense contracts. This is roughly 1 percent of the active work force employed in Germany.

While this percentage is low from an overall economic perspective and many firms utilize their capacities only in part for defense work, there are specialized companies whose economic well-being depends wholly, or predominantly, on defense contracts.

Small and Medium-sized Business

The German government places particular importance on utilizing the capabilities and capacities of small and medium-sized businesses for defense work. Based on a German workmanship tradition and company structure, coupled with relatively low overhead, the high degree of adaptability and innovative flexibility of these businesses lends itself to specialized technological problem-solving. The German government feels that these businesses can develop a potential that helps to counteract bigger companies' monopolistic tendencies.³ In no other major OECD country are the productivity differentials among small, medium-sized and large companies as low as in Germany. In most single industrial non-defense product groups in general, a German firm—often a small or medium-sized specialist—is among the world's leading suppliers. Germany is proof that "big" is not necessarily synonymous with "efficient".⁴ About 15 percent by value of German defense contracts presently go directly to these small or medium-sized businesses. Their share in defense work is considerably higher when including their roles as subcontractors and suppliers to prime contractors.



German Defense and Production Contracts

In the 1984-85 timeframe, the number of German defense development contracts handled by the Federal Office for Military Technology and Procurement (BWB) increased to about 1,500 with a total funding volume of more than DM 7 billion. The following are major examples of ongoing national and multinational development programs that include combat-effectiveness improvements and follow-on developments and which consume the lion's share of development appropriations:

- "Fighter of the 90s"
- "PAH 2" anti-tank helicopter
- "ASRAAM" air-air missile
- "SEA KING" navy helicopter
- "KZO" target location drone
- "DM A3" and "DM A4" submarine torpedo
- "Marder A3" armored infantry fighting vehicle."

It is apparent that the near-to mid-term systems development emphasis is shifting to the aircraft segment of defense industry.

For production procurement contracts, the 1985 defense budget was slightly under the 1984 appropriations, but the multiyear procurement figure as programmed is about DM 20 billion. The following are major examples of ongoing national and multinational production procurement programs handled by the BWB, with near term benefits for the German defense industry:

- "Tornado" multirole combat aircraft
- "AWACS" early warning system
- "Roland" air defense system, wheeled

Near-term emphasis is shifting toward the aerospace/missile and shipbuilding branches of the German defense industry.

- "MLRS" multiple-launch rocket system
- "F 122" frigate
- "206 A" submarine
- Destroyer 103."

As for the systems under development discussed above, the near-term emphasis for systems under production/procurement is shifting toward the aerospace, missile and shipbuilding branches of German defense industry.

While the German government endeavors to place contracts also with a view toward maintaining defense industry capabilities indispensable for German Armed Forces equipment, it cannot and does not assume entrepreneurial responsibility, or employment guarantees. Government expects industry to live with a certain amount of risks resulting; e.g., from necessary changes in the patterns and sizes of production capacities due to shifts of emphasis in armed forces plans. Such a shift toward air and missile systems on the one hand, and essential systems elements (C³ and armaments) on the other, is presently taking place in Germany.

There are, of course, situations where the government has to give in to political-economical pressures. A case in point is the procurement of the German "F 122" frigate. The German BWB had planned initially to have the first six frigates built by one shipyard. This would have been the most cost-effective solution from a defense budget point of view. But regional political-economical pressures emanating from the economically bad shape of German shipyards forced the government to select more than one shipyard, thus preserving about 4,000 jobs. Political costs were reduced at the expense of considerably higher budgetary costs.

Shipbuilding is clearly the German industry branch affected in the worst way. With about 40,000 jobs, German shipyards have been traditionally labor-intensive and relatively slow in opening up to new technology infusion. In the mid- to long-term the German share of worldwide shipbuilding is estimated to drop by 30 percent, from 3 percent to 2 percent. It is clearly in this branch that German defense contracts show the relatively greatest economical impact, and only German navy contractors are better off than the rest of the shipyards. However, a novel approach to the modernization of some German shipyards is presently undertaken in a government-industry and industry-industry arrangement that combines such traditionally strange bedfellows as aerospace and shipbuilding. I will discuss this and others in the next section.

Mid-Term Uncertainties for German Defense Industry

As the preceding discussion shows, defense business for German industry looks quite satisfactory for the near term. But mid-term prospects are not so bright. This applies particularly to

the armored vehicles industry with companies like Krauss-Maffei, Krupp Mak, Thyssen Henschel, and the major components manufacturers Rheinmetall (main armament), Wegmann and KUKA (turrets), MTU (engines), Renk (transmissions), and Blohm & Voss and Jung Jungenthal (hulls). Most of these companies face substantial drops in their capacity utilization beginning with the final deliveries of the Leopard 2 battle tank in 1987. One stop-gap could be a production decision in the late 1980s for perhaps 300-400 "Wiesel" airborne armored minivehicles, with Krauss-Maffei, Krupp Mak and Thyssen Henschel as competitors. Also, Leopard follow-on orders by NATO-countries presently using this battle tank (Denmark, Canada, Greece and Turkey) could contribute toward maintaining the German industrial base in this branch, but prospects for such orders are uncertain.

Companies suffering least from such mid-term decrease of government order would be Rheinmetall and Wegmann, whose capacities could still be utilized to an economically acceptable extent through the Leopard 1 combat effectiveness improvement program. But the overall picture of the German armored vehicles industry would materialize in the early-to mid 1990s. According to initial planning, this family would consist of the following vehicles: tank destroyer/antihelicopter; antitank; and armored infantry fighting. If and when these plans materialize, the bulk of these vehicles' production would fall into the second half of the 1990s. In view of the shifts of development and procurement emphasis to aerospace and shipbuilding industries, of governmental cost-cutting trends, and other long-range uncertainties, it remains to be seen whether the companies affected in the armored vehicles branch can economically retain their development teams and expertise.

The mid-term future of the German aircraft industry, with 12,000 new jobs created in the last 10 years, while not as clouded as that of the armored vehicles branch, does not look exactly rosy, once the "Tornado" deliveries will have been completed. One stop-gap could be a future increase in missile work. Of greater mid- and long-term economical impact than such stop-gaps, particularly concern-

ing high-tech infusion and modernization, may be arrangements among German companies of different industrial branches and high-tech contents; i.e., the recent selection of Germany's largest aerospace company, MBB (competing against the electronics firm AEG), as prime contractor for the "Class 343" Mine/Counter-Mine Vessels. This arrangement, novel in German acquisition history, could become a model for diversifying aerospace know-how and for infusing high-tech into branches traditionally low in high-tech. The technological usefulness of marrying these two different branches becomes, of course, more plausible in view of the vessel's high electronic content. The spin-off potential, and its general economic impact, is significant. There are a few other German industry branches that have not caught up with the surge in high-tech, particularly microelectronics. In contrast, there has been a traditional German lead in precision optics. Beginning in 1984, the European precision optics industry has felt U.S. government restrictions of precision optics acquisition from abroad. Negative impacts of this restriction were felt in Germany and other NATO countries. I will discuss national and multinational, economic impacts later in this article.

New Innovation-centered German Government Policies

To improve and streamline the conditions for high-tech innovation in certain branches of German industry and institutes, the Federal Ministry for Research and Technology has initiated major programs since 1984. Some tie in with similar efforts by other European countries, and have been elevated to a transnational level; e.g., the European Strategic Program of Research and Development in Information Technology (ESPRIT). On the German national level, several ministries are involved in intra-government programs, like the Federal Government Concept for the Promotion of Microelectronics, Information and Communications Technologies. Other initiatives aim at greater university participation; German universities have, in the past, been characterized by an "ivory tower" mentality. An example is the Development of Integrated Circuits program in which 10 universities, the Society for

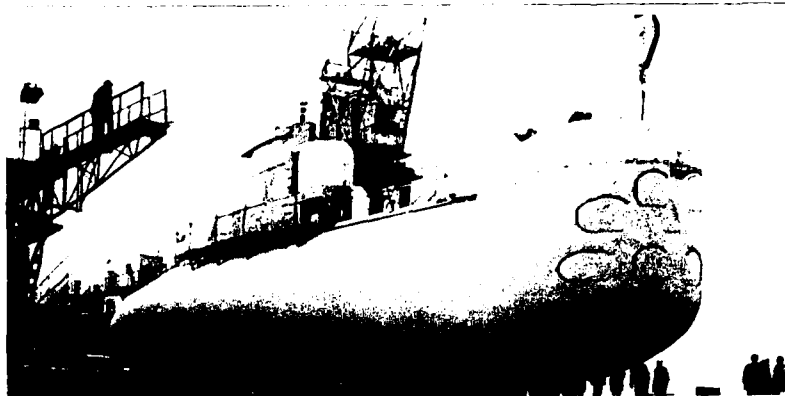
Mathematics and Data Processing, and the Siemens Corporation participate. These new policies and programs, currently funded with about DM 4 billion annually, are accompanied by streamlining governmental acquisition policies, making them more innovation-friendly, encouraging industry to make innovative risks, sponsoring improved research and development coordination among industry, science and government, and orienting research and technology efforts toward mid- and long-term economical goals. For example, the German government may consider the acquisition of initially expensive products if warranted by detailed follow-on cost assessments and future beneficial impacts on the national economy.

Of particular importance among new German government policies in this context is the ministry of defense Research and Technology Concept that I will discuss next.

Research and Technology Concept

A comparison of German research efforts with those of the United States shows that the funds available do not permit Germany to conduct research across the entire spectrum of technologies. Overall United States government research and technology funding is currently about 15 times that of the German government. In the United States the major portion of the research budget is defense-oriented; in Germany it is a minor portion. In the United States there are 36 government-funded research centers, not counting numerous military research and development commands. Germany has several non-profit institutes that carry out some government contracts.⁵ Much of German research and technology effort is contracted out to private industry and research institutions including universities, nationally and multinationally. The United States can make technological self-sufficiency a maxim of its research and technology policy; Germany, by contrast, is compelled to do without

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The eighteen 206 class submarines of the German Navy are scheduled to be improved in the mid 1980s.

technological self-sufficiency which, by the way, wouldn't make economic sense for a middle nation of an alliance. Rather, Germany is establishing near-, mid- and long-term focal points of effort in research and technology.

For defense, these focal points are part of the Research and Technology Concept initiated in 1985. It takes into account armed forces equipment projections and the technological and economical possibilities of realizing them. The concept is designed to create, at the same time, conditions for harmonizing and coordinating research and technology efforts nationally and multinationally with NATO allies. Of great defense-economic importance is that the concept is an instrument for promoting industrial self-initiative in defense research and technology. The concept is based on certain political precepts, such as strengthening conventional defense; beneficial impacts on the national economy; military applicability of high-tech; enhancing cooperation within NATO and increasing the efficiency of resources utilization; streamlining and intensifying cooperation among science, industry and government.

A primary objective of the concept, whose fiscal year 85 budget was about DM 700 million, is to gain a grip on basic research results more systematically and to provide the technological and economic groundwork for translating these results into decision-inputs along the lines of requirements, time, and cost savings for development and production of defense equipment. This continuous updating process defines conditions for goal-achievement; i.e., review of certain militarily required characteristics of future defense equipment, develop-

ment risk reduction, or early assurance of sufficient systems and equipment growth potentials.

The concept's focal points include technological areas of peculiarly German armed forces requirements, such as shallow-water sonar. The concept includes areas in which NATO cooperation is limited, like electronic warfare; also areas of focal points where a certain technological self-sufficiency is deemed necessary, like information processing, computer structures, and associated microelectronics. These focal points are selected also in areas where prospects for international competitiveness are promising, like als millimeter-wave technology for sensors and telecommunications. Furthermore, focal points have been established in areas of research and technology where a high military requirement coincides with a high German technological standard, like air-independent non-nuclear propulsion systems, high-energy electronics, liquid-propellant guns, navigation, advanced armor, and dispensers. The concept thrust is geared also to the armed forces future requirements, and beneficial impacts on the German national economy.

These defense research and technology efforts follow initially from the military threat. But together with their associated development and acquisition effects (though at present still quantitatively and statistically insignificant to the German national economy) will, by the nature of the technologies concerned, impact the future of German national economy to a more significant degree. While spin-offs from the defense to the civilian industrial sector may not always be easy to determine, the spin-off potential is becoming greater than is recognized at first glance.

Some German spin-off examples are:

—Studies of erosion by rain on the F-104 G radar cover led to research results on shockwave effects used as the physical basis for designing medical equipment used for non-surgical shattering of kidney and gallstones

—The defense-funded research and development of non-articulated helicopter rotors and elastic, glass fibre reinforced plastic blades generated a spill-over boost in the civilian helicopter market

—Studies of airfoil behavior on military aircraft were the bases for airfoil design that improved the fuel efficiency and range of the "Airbus" civilian aircraft

—Research on carbon fibre reinforced materials for combat aircraft opened up new approaches in civilian aircraft design and engineering.

It is clear that mid-to-long-term multiplier effects of defense-sponsored high-tech will have, qualitatively, and probably also quantitatively, a more significant impact on the German national economy.

Multinational Considerations

From a purely quantitative-statistical perspective, there is some legitimacy to the question: Does multinational cooperation in defense research, development, and acquisition warrant the emphasis which, particularly European NATO allies, place on it? For example, in 1981 Germany bought about DM 12 billion worth of defense equipment, predominantly from German industry. Of these DM 12 billion, 43 percent flowed back into the German treasury, directly or indirectly, in the form of fiscal and social taxes. Had these DM 12 billion been spent abroad, this would not only have made the German national economy poorer by DM 5.1 billion, but would have increased the German trade deficit.⁶ Therefore, to assess mutual benefits to participants in multinational cooperation, the above perspective must be widened to include other factors.

Most of the factors for the case of multinational armaments cooperation should have become common knowledge by now: NATO rationalization, standardization, interoperability of equipment and materiel; governmental cost-sharing; transnational teaming of industries to the long-term economical benefit of the participating countries; transfer of know-how and technologies, leading to market expansion; larger production runs with resulting economies of scale; common logistics and training during the operational phase of a system (the most costly phase on a system's life cycle); and creating international competition in technological areas where the national conditions for competition do not exist, etc. We are witnessing an intensification of armaments cooperation in European industries that can become viable and internationally competitive only by international teaming. If the United States technology transfer climate were better, United States companies would have a good chance of long-term teaming with German and European companies. The boat may have been missed here in the near-term, but the United States Department of Defense initiatives in armaments cooperation since 1985 give rise to the modest hope of a revitalization in future trans-Atlantic armaments cooperation.

In the meantime, national armaments directors of the Independent European Programmes Group (IEPG) have put together a team for research and technology which coordinates national research and technology efforts; to wit, the German Research and Technology Concept. The resulting Cooperative Technology Projects (CTP) are to generate synergistically more know-how than each of the participating nations could have gained alone. The cumulation of available funds from all participants is then to provide for approaches to finance major investments in selected new high-tech. In the long-term view, the participating nations' economies could benefit from such initially defense-sponsored research and technology efforts to a greater extent than is the case today. Considering the above discussion, it should not be a surprise that of Germany's roughly 45 major bi- or multinational armaments projects,⁷ about 20 percent involve the United States as a cooperative partner nation.

On the other hand, I must mention a new form of arms cooperation initiated by the German-United States cooperative program involving the United States Patriot and the German Roland air defense missile systems. In this program, the United States makes available to Germany the Patriot systems for the air defense belt in Germany. In exchange, Germany procures for the United States forces Roland systems for the defense of United States airfields in Germany, and mans and operates these systems, as well as additional tactical United States Patriot systems until United States and German expenditures are balanced. The economically new feature in this bilateral program is the exchange of goods plus services. It shows that cooperation need not be exclusively confined to defense materiel purchases but may, additionally, include the provision of services and, on the whole, can foster interoperability and standardization of armaments and force planning among allies. In addition to this arrangement's bilateral economical benefits, there are military and political ones to NATO.

Summary

The impact of defense research, development and acquisition on the German national economy is, quantitatively, insignificant. In the near- to

mid-term, certain defense industrial branches (armored vehicles) are faced with uncertainties that would not substantially brighten until the mid-1990s. Defense orders clearly have their relatively greatest economical impact in the ailing German shipbuilding industry on the one hand, and in the healthier German aerospace industry on the other. Through concerted governmental research and technology policies, Germany is catching up in some previously neglected technology areas, (microelectronics). Within the scope of this effort, the German Defense Research and Technology Concept is determining focal points and priorities for future applications nationally, and for intra-European and trans-Atlantic governmental and industrial cooperation. One prime goal is greater competitiveness through industrial teaming

This process is characterized by increasing interdependence of governments and industries, causing greater impacts of defense business on national economies in the mid- to long-term. This trend will intensify particularly in view of defense high-tech multiplier effects on civilian applications. ■

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2. An increase of roughly DM 0.7 billion over the 1985 Defense Budget.
3. Article by Staatssekretär Prof. Dr. Timmermann (German undersecretary of defense for armaments), "Soldat and Technik," November 1985.
4. See, e.g., Peter F Drucker, ("What We Can Learn From the Germans," *Wall Street Journal*, March 6 1986.
5. The German Aerospace and Test Institute, DFVLR, whose 1984 budget of DM 429 million included 13.1 percent from defense and 50.0 percent from non-defense government contracts.
6. This near- and one-sided perspective is an element in national protectionism.
7. Representing 33 percent of all ongoing German major RD&A projects.

Streamlining Navy Acquisition

Vice Admiral Thomas J. Hughes, USN

Recent legislative actions, including Gramm-Rudman, have made initiatives like streamlining imperative. I want to reaffirm its importance in Navy acquisition, and to summarize the basic thrust of where the Navy is, and should be going, with acquisition streamlining.

I do not know of any corporation in American industry that manages the acquisition of as diverse or complex a group of products as does the Department of the Navy. When you consider the magnitude and variety involved in procurement and maintenance of Navy Hi-Tech Weapons Systems, you can be overwhelmed by its size and complexity. There are problems to resolve and room for improvement. If we are to field, or put to sea, the systems needed for the modern defense of this Nation, we must reduce acquisition costs; acquisition streamlining is the principal initiative for accomplishing this objective.

After seeing the title of acquisition streamlining and reviewing the program's objectives, you may assume—or try to make the public assume—that the way we are doing business is totally out of control. That is patently wrong! Even so, the Navy always must be critically introspective of its business methods. We must be sure to use the best techniques and to make adjustments suitable to economic conditions. This will ensure a competitive industrial base from which to obtain our systems; it will incorporate in our contract offerings operational characteristics that will give us the required performance at the most efficient life-cycle cost.

I do not want to sound too one-sided about this effort; the Navy cannot wave a magic wand and find the acquisition business streamlined and ready for the rest of this century. It cannot be done without the full cooperation of the industries that manufacture our weapons systems; their input into our review of Navy requirements is vital to the success of ac-

This is adapted from remarks made by VADM Hughes, deputy chief of naval operations (logistics), at the National Conference on Acquisition Streamlining.



quisition streamlining efforts. The cooperation and participation of members of the aerospace industries association and others have provided a great beginning, but continued and expanded use of this team approach is mandatory.

In connection with the technical base, we are going to streamline Navy specifications and standards. We must modernize specifications if we are to acquire modern systems. This will not be an easy task because the Navy is the preparing activity for approximately 15,000 standardization documents. These documents must be reviewed and maintained in an up-to-date status, which is a time- and man-hour consuming process.

In major systems commands, specification "tiger teams" will attack their respective standards specifications base to assure that operational and performance requirements are not overstated; that they will provide the fleet with modern, reliable, and maintainable weapons systems. This effort will be prioritized and the streamlining of our standardization documents will be performed as soon as possible.

The best reducing pill for acquisition costs is available over-the-counter, no waiting in line.

To be successful, acquisition streamlining of individual program requirements must start early in the acquisition process. Mr. Lehman in his November 1985 acquisition policy stated, and I quote from SECNAV Instruction 4210:

The specification control advocate general must certify that the development specifications, including the contract data requirements list, have been reviewed and tailored to the operational requirements.

This means in-depth reviews of programs by the SPECAG organization which includes SPECAG representatives from the SYSCOMS. There will be special, directed reviews of pro-

grams designated by SECNAV ASN/CNO. The SPECAG has completed 13 such reviews.

We in the Navy will continue to look at the acquisition process and improve where necessary. This means a critical analysis and elimination of unnecessary pre-briefs and serialized reviews. Any in-depth review of the

process must significantly foreshorten the contract lead-time. We continue to explore ways to compensate offerors for pre-contract award efforts in streamlining. I encourage addition of a scoring factor in solicitations to reward industry streamlining ideas. We are exploring other areas to achieve streamlining goals, including the following:

—The maximum practical use of new and available technology like computer-aided design, manufacturing, and logistic support for streamlining and enhancing productivity

—Emphasize acquisition streamlining training in the Navy to be a viable management tool and routine way of doing business

—Establish formal recognition programs to acknowledge personnel contributions in eliminating or reducing non-cost-effective contract requirements.

We will continue emphasizing and enhancing the use of other supporting disciplines like standardization, value engineering, productivity, reliability, maintainability, and logistics support. The message I stress is that only streamlined programs will succeed in the Navy budget process. We will not, and cannot, jeopardize our entire budget for the sake of an unstreamlined program. ■

Weapons

(Continued from page 11)

Products Are Superb

From this warrior/user's vantage point and that of my men and women who maintain and operate them, these products of our oft-maligned military-industrial complex are superb.

The crux of the aforementioned article indicates that we are not sure if our weapons will work if they are called upon. We in Pacific Air Forces know ours will work because we test them daily, and we practice with them in the way they will be required to perform in battle. We do it with a host of exercises, evaluations and inspections that are as realistic as we can make them.

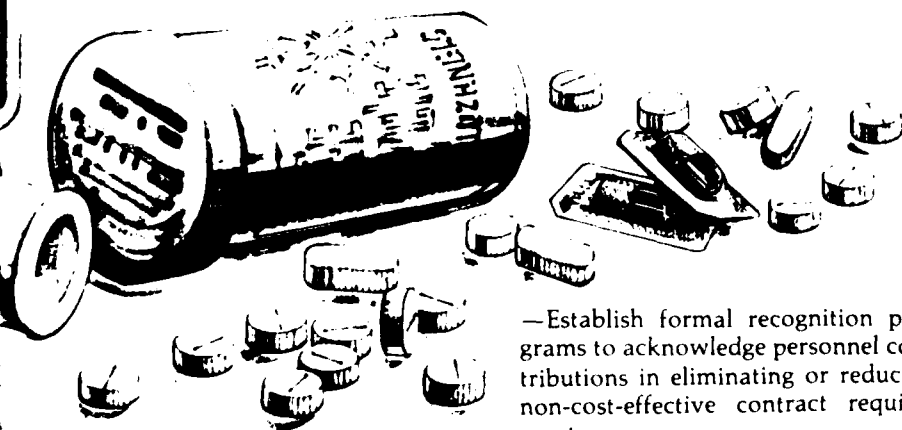
Returning to the aforementioned article again and its headline that dealt with high cost and complexity, the Soviets, no doubt, are dealing with the same conditions in their defense preparations. They continue to work increasingly sophisticated and capable weapons. They also pump them out of their factories at a rate that compared to the United States is staggering (get those "facts" and tell your readers).

Capability Doesn't Come Cheaply

Unfortunately, we are forced to follow suit and do it in the most efficient manner possible. Someday we may need to pay \$50 million for a fighter aircraft. After all, we now pay more than \$12,000 for any of the "low-priced three" automobiles that used to cost \$2,000. Nobody would dispute that cars are better and more capable than they were 25 years ago. The same is true of weapons. Capability doesn't come cheaply.

Although the aforementioned article lacked balance and included some inaccurate "facts" and illogical conclusions, it did contain many truths and legitimate challenges that we have a responsibility to work hard on—and we are. Finally, the American people, the Soviets, and any would-be aggressors need to clearly understand that the authors knew what they were talking about when they stated:

"...Neither American warriors nor their weaponry should be underestimated." ■



Gearing Up for the Fast Lane

New Tools for Management in a High-Tech World

By Deborah Bright, Foreword by Rod Canion
Random House Business Division

There appears to be no end to the number of "how to manage" books coming to the market. While most offer useful ideas, few are sufficiently applications-oriented to be a desk-top companion to the harried manager in a fast-paced, high-tech environment. Fewer still have a message suited to the unique world of the Department of Defense (DOD) weapon systems acquisition management. In the book, Dr. Bright claims to provide "new tools for management in a high-tech world"—and she delivers. Additionally, DOD managers should find her recommendations of value because maintaining a creditable defense is a fast-paced, high-tech business.

The book is not written specifically for the systems acquisition community. But, who can deny DOD relies on a defense industry that must be responsive to ever-changing defense needs, that must be innovative in developing new technologies and industrial processes, and that can deliver effective systems in a timely manner? People managing these firms to keep ahead of the competition may share some of the capabilities Dr. Bright identifies in her book, which affords other managers, in and out of government, insight to motivate their staffs to greater productivity.

In organizing the book, Dr. Bright carefully defines terms, describes high-tech environment, and shares the research methodology of her National High-Tech Management Survey. Chapters distinguish the "High-Techs" from the "Traditionals," explain the concept of "Managerial Leverage Through Exceptional Performance," and provide step-by-step direction, and examples regarding "Achieving Exceptional Managerial Performance." A

format is provided to implement her recommendations.

Dr. Bright's aggressive theme is matched by her aggressive writing style. Early in chapter one she states that "In most high-technology industries a company cannot survive and prosper by producing routine, reasonable performance. Outstanding management achievements are needed just to stay in the game. It's life in the fast lane." She tells us that "...the entire business world is coming to resemble the threatening environment of high-tech industry," and that "...all managers must soon begin to develop some fast driving skills or find themselves in flames on the median strip." This is invigorating advice. Could it apply to DOD and defense industry managers? Surely it does!

Upper- and mid-level managers concerned with developing leadership skills will appreciate chapter four regarding Increasing Managerial Leverage. Dr. Bright concludes from her National High-Tech Management Survey that "...exceptional performers can identify the behaviors they use to keep their own work and the work of their people at a consistently high level." She identifies four major, manager-performance areas supported by 16 essential manager behaviors:

- Building confidence, pride, and commitment
 - Provide experiences to learn from
 - Practice letting go
 - Use symbols and slogans
 - Create the excitement to achieve
- Managing expectations
 - Identify the expectations operating within the organization
 - Make expectations explicit
 - Build the expectations package
- Creating and managing events
 - Communicate a broad vision

- Focus sharply on what is important
- Act decisively to empower others
- Communicate a sense of urgency
- Create activity and momentum (make it happen)
- Managing operating processes
 - Sense the situation
 - Share the glory
 - Target performance
 - Maintain *sang-froid*.

Dr. Bright explains that a manager having achieved the above capabilities is able to "leverage himself" to attain greater total performance by motivating and facilitating others, rather than by doing the technical and professional work himself.

Now then, what can be said in summary on the contribution of this book to management; in particular, weapon systems acquisition management? Management theorists will recognize some of the traditional management themes on leadership, communication, and motivation; systems acquisition managers have already experienced the fast-paced, high-tech work climate in DOD.

The value of the book lies in the tight integration among its research, recommendations, and action plan. Dr. Bright has condensed numerous management skills into specific manager activities that immediately can improve organizational performance. The content and style of *Gearing Up for the Fast Lane* helps the reader experience environmental pressures and challenges in the high-tech world while creating an excitement to achieve and a momentum toward better performance that is difficult to suppress. Keep it handy. ■

Rudy Garrity
DSMC

Air Force Systems Command
**Acquisition Manager
 Career Development
 Initiatives**

Major Dan Lohmeyer, USAF

Recent events within the Department of Defense and the Congress have caused the United States Air Force Systems Command (AFSC) to re-evaluate its career development strategy for military acquisition managers. My purpose here is to discuss the background of those events and the actions being taken by AFSC as a result of its evaluation. I hope to provide a general understanding of how AFSC intends to solve this problem, and to provide exposure of AFSC efforts to the acquisition manager population within that command.

Anyone familiar with current events or associated with developing and producing military hardware is aware of the maelstrom that has developed about the recent discoveries of spare-parts overpricing, equipment not functioning as originally intended, and procurement of excessively over-designed equipment. Public scrutiny has been focused sharply on the defense acquisition community and hard questions are being asked why such practices were allowed to develop. Two examples serve to illustrate.

—Recent congressional language has not only required the imposition of warranties and re-emphasized the importance of competition in weapon system acquisition, but has mandated what experience and education senior acquisition managers will have before becoming managers of large programs.

—The recently published report to the president by his Blue Ribbon Commission on Defense Management (Packard Commission) made sweeping recommendations, including establishment of an undersecretary of defense (acquisition), and "flexible personnel manage-

ment policies necessary to improve defense acquisition." The commission, referring to this, cited "recent steps to improve the professionalism of military acquisition personnel made within the Department of Defense and reinforced by legislation."

During 1985, the Air Force Systems Command recognized the need to evaluate its strategy for the development of acquisition managers; General Lawrence Skantze, AFSC commander, appointed the Acquisition Manager Career Development Task Force (CDTF) headed by Major General Ronald W. Yates, USAF, F-16 program director. The task force comprised 20 senior acquisition managers, lieutenant colonels and above, representing AFSC organizations and functional specialties. It is important to note that the task force was formed not only in response to the external pressures mentioned, but because internal command reviews revealed the lack of a cogent policy plan for training and keeping good acquisition managers in the Air Force Systems Command. In mid-December, the task force presented findings and recommendations to General Skantze for his approval of the plan. Some of the details of the plan are still being worked and I will not discuss them completely. What follows is a general discussion of task force findings and the "plan."

Task Force Findings

Briefly, the task force acknowledged external pressures to develop a better career development path for acquisition managers, and agreed that improvements in their career development were needed. The task force cited the media exposure I mentioned and

agreed that the Air Force Systems Command did not have a visible program to develop acquisition managers. The task force agreed that the problem did not stem from a lack of motivation but, rather, from lack of a cohesive plan/program to train acquisition managers.

Acknowledging the problem, the task force established three objectives:

—Develop a structured acquisition manager career-development model to set forth a definitive and viable career management plan producing broad-based acquisition managers capable of assuming leadership roles.

—Develop an acquisition manager certification process to provide a visible, formalized career path to senior acquisition manager duties.

—Develop a time-phased plan for Command implementation of the acquisition manager career development model and certification initiatives.

Career Development Model

The task force, feeling the career development model should encompass several factors, embraced a philosophy to ensure these seven factors were the model's basis.

First, leadership ability was defined as the key requirement for the acquisition manager, whose leadership abilities should be developed and monitored.

Second, program office experience was mandatory for success as a senior acquisition manager.

Third, operational experience, while not mandatory, was recommended strongly to give the acquisition manager a complete understanding of

user command problems that he/she would be trying to solve.

Fourth, the model must produce an acquisition manager with a broad experience base and allow for transition into the AM career field by individuals from related acquisition career fields; e.g., 26XX, 28XX, 29XX, 49XX, 65XX, 673X, 674X and individuals from the rated force.

Fifth, it must provide a challenging yet achievable career track and should provide for a phased certification process by which the Air Force Systems Command could review the officer's progress.

Next, the task force perceived the need for a screening process to ensure that the best officers are selected for major acquisition manager jobs.

Finally, the model must be definitive and visible to both the officers (so that what is expected is well understood), and to the public (to demonstrate the Air Force System Command's intent to take positive steps).

The career development model, the heart of recommended initiatives, is structured broadly and not meant to address each situation. It provides a guide for the acquisition manager to plan his/her career development based upon what the Command sees as important ingredients in the maturation of an experienced acquisition manager. The model contains four "experience levels," spaced about equally during 16 years. Each level corresponds to a set of education and experience factors essential to proper career development of an acquisition manager. For instance, the first level would be attained early in an officer's career (within the first year or two) and would include a bachelor's degree, 6 months experi-

I wish to acknowledge the assistance provided by Major General Ronald W. Yates, USAF, career development task force commission chairman, and Major Mike Duffee, USAF, HQ AFSC MP. Their source information and helpful comments provided invaluable information to highlight the important personnel initiatives.

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ence in a system project office (SPO), and completion of the System Acquisition School's Introduction to Systems Command Acquisition Management course at Brooks Air Force Base. For completeness, I will describe briefly other recommended levels. Keep in mind that fine details are still being worked on at AFSC headquarters.

—**Second Level:** Occurs at about the 6-year point and would include Squadron Officers' School, 2 years experience in a SPO, completion of the Air Force Institute of Technology (AFIT) Systems 200 course (or equivalent), and a year of operational ex-



Special career models are being worked on for rated acquisition officers, test pilots, and test navigators.

perience (through a CROSSFLOW or BEST type of program, or 2 years experience in other non-acquisition areas within AFSC or the Air Force Logistics Command).

—**Third Level:** Occurs at about the 12-year point and would include completion of Intermediate Service School, a masters degree, other job experience (e.g., headquarters assignments, joint assignments, work in other SPOs, other AFSC/AFIC jobs), at least 3 years experience in a SPO, and completion of the AFIT Systems 400 course (or equivalent).

—**Fourth Level:** Occurs at about the 16-year point and includes completion of Senior Service School, 8 years of acquisition experience, the Defense

Systems Management College PMC or equivalent, and 2 years experience as a project manager within a SPO. Additionally, AFSC CC approval of the acquisition manager would be required to attain this level.

Clearly, the final level is the most challenging and requires the greatest review because the Air Force Systems Command is, in fact, saying these individuals are fully qualified to manage programs of larger responsibility. Moreover, requirements specified for the fourth level match the education and experience requirements mandated by the Congress for SAR program managers.

Again, I need to emphasize this recommendation is a generic model and does not cover many cases. Special career models are being worked on for rated acquisition officers, test pilots and test navigators. Those situations, and others, are being considered and folded into the complete plan being developed at AFSC headquarters. Time and space do not permit me to explain each case completely.

Professional Certification Process

The task force recommended that the Command establish a professional certification process for acquisition managers open to all eligible Air Force officers. Basically, any officer completing requirements for the levels described above would submit an application for certification at the applied-for level. For instance, as soon as an officer had completed level-one requirements, he/she could complete an application and submit it through his/her chain of command to AFSC headquarters for approval. As mentioned, AFSC CC additionally would approve level-four certifications.

There are two points I need to stress. First, this process is open to any officer completing requirements for various levels whether or not he/she is assigned to the Air Force Systems Command at the time of application. Second, the certification process is started only by the officer's application; therefore, anyone may complete the requirements without applying for the certification (for instance, if presently uncertain about pursuing careers as acquisition managers). But, certification at the next level is not automatic and requires an additional application by the officer.

Quality Screening

In addition to articulating specific experience requirements and a certification process, the task force recommended that the Command institute an acquisition manager selection process to identify a pool of officers for selective career management and appointment to senior acquisition manager positions. This philosophy is similar to the squadron commanders lists utilized by some major commands to designate individuals demonstrating potential for the additional responsibility required by a particular assignment. Basically, the task force recommended two levels of quality screening: acquisition manager list (AML) and senior acquisition manager list (SAML). For the AML, a board would convene each year at AFSC headquarters to review records of individuals completing requirements for the third level of certification. The board would use a "best qualified" process to identify those demonstrating potential for additional responsibility and place them on the acquisition manager list. Results of the board would be available to senior commanders and the individual, but would not be published formally; i.e., the way promotion board results are published.

In addition to the AML board, the Command would convene a board to consider senior acquisition managers for inclusion on the senior acquisition manager list. The AMs being considered would be lieutenant colonel selectees and above, and would not have been deferred for promotion to colonel. The SAML board would consist of senior (0002 2006) acquisition managers and the recommendations would be reviewed by product division commanders and the AFSC commander. Those selected for the SAML would be awarded the 2001 specialty code (job identifier) and would be the prime individuals eligible for assignment as SAR- or AFSARC-level program directors. There would be no other path to obtain the 2001 specialty code.

Implementation Plan

The task force's final objective was structuring an implementation plan for carrying out the program once it was articulated. As I write this, many actions of that plan have been carried out; for instance, one was for

ASFC MP to assess impacts of the proposed career development model, and that has been completed.

Basically, implementation tasks fell into two broad categories. First, take action to finalize the details and set the system up so that it can be carried out. Four specific tasks included setting up training requirements to include AFIT review of its courses for currency and



One very important aspect of the entire plan is the role the Defense Systems Management College plays in the equation...the PMC is one of the mandatory prerequisites established by the Congress for SAR program managers.

relevancy, establishing the certification process, briefing product division commanders, and preparing a briefing to be carried forward soliciting Air Staff support. Many actions are complete or nearly complete and details will be forthcoming.

The second category of actions deals with "post-production" things like reconvening the task force to review

the system once details have been worked out: advertising the system to the field; putting together a briefing for presentation to field activities explaining the system; and, beginning the certification process.

One very important aspect of the entire plan is the role the Defense Systems Management College plays in the equation. Completion of the Program Management Course (PMC) is one of the mandatory prerequisites established by the Congress for SAR program managers. The task force highlighted the College as a top concern and recommended correspondence courses and shortening the PMC to increase the throughput. You who have attended the PMC recognize the value of the interpersonal aspects, the Distinguished Guest Lecturer program, field trips, and other important learning experiences that cannot be realized except through attendance in residence. The DSMC is working with the Air Force Systems Command to arrive at an acceptable solution ensuring that acquisition managers obtain the training they require, thus providing sufficient numbers to fill the need. The task force recommended increasing the stature of DSMC course completion in the officer's promotion brief; strengthening AFSC control of the DSMC selection process, and emphasizing field-grade selections for DSMC attendance during the transition period until the CDTF recommendations are approved and in place.

Conclusion

As you see, the Air Force Systems Command is addressing the serious need to train and identify qualified acquisition managers. The proposed system has two strong advantages: First, it is simply constructed and is uncomplicated with clearly defined steps in the process; second, it is visible to the officers it affects and to the public, demonstrating the Command's intent. One other note, HQ USAF RD, the functional manager for research development and acquisition career fields, has endorsed the program.

Again, many details I refer to are being finalized and will be communicated to the field units when ready. These initiatives follow on the heels of a comprehensive plan developed by the Army to train and monitor the careers of its acquisition managers. ■

Emergence of **Decision Support Technology** in Military Information Management Systems

A. N. Hafner

The general application of computer-based information systems has progressed from sophisticated mathematical computation, through business transaction processing (TP), to management information systems (MIS) providing summary information to mid-management.

The information management function is migrating to systems that primarily serve upper-management's task of setting goals and planning strategies. Emerging technology, decision support system (DSS), focuses on assisting in the unstructured decision-making processes characteristic at the executive level.

Decision Support System

Information management functions of command and control systems no longer can support decision-making complexities of modern electronic combat. One Navy systems development document said, "Current ship-board systems available for processing digital information do not include adequate software for tactical planning and tactical decision support."¹ Emerging military technology that will provide this support is the tactical decision support system. Within the Navy, one such system is being engineered to fit the Flag Command Center that implements the Navy Combined Warfare Command (CWC) concept. In this paper, I review strategies being pursued to develop emerging decision support systems with a view toward techniques to accommodate this technology into the next generation of information management systems.

Defining Decision Support Technology

A decision support system is a man-machine couple that facilitates incorporation of experience and instinct in

decision-making. Using electronic data recall, manipulation, and graphic display to augment managerial judgment, decision-makers can review and edit their choices selectively before implementing an irrevocable decision. Decision support systems are unique among computer-based information systems in their ability to provide *ad hoc* simulation as a medium for hypotheation and goal seeking to solve problems.

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The primary aspect of decision support systems is their autonomy; that is, distinctly separate existence as information processors apart from the main function of data processing. The decision support system provides an intellectual workbench on which the information-age executive can build, examine, and disassemble management mechanisms. This toolkit of simulation and analysis programs can be assembled from specially developed packages or from more generalized applications programs loaded into the support system application base.

Elements of Decision Support

Decision support systems are characterized by being localized, autonomous, having free access to information, and equipped with modules (that can be assembled) of analytical simulators. The program managers support system (PMSS) project at the Defense Systems Management College predicts that "Within the PMSS...there will be a...model base containing various models for forecasting, simulation, prediction, and other types of operational analysis."² Similarly, emerging military decision support technology combines the best of database management, C² reporting, and simulation technologies. As applied in Navy electronic warfare (EW), it is a composite providing the commander and staff the ability to create instant scenarios and EW action plan analysis packages tailored to the question and circumstances of the moment. It is a means whereby plans and EW plan annexes can be modified and verified based on exigencies of combat EW information of the moment.

By combining the universal availability of data from the C² system with the report-generating capabilities of a flexible program, the decision support system application generator can invoke analysis modules for *a priori* evaluation of alternatives, and of the effects of prospective decisions. In a timely study of applications generators, Horowitz describes them as "...typically consist(ing) of...database management system, report generator, database query language, graphics package, and special-purpose software."³

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Existing Navy tactical decision support system prototypes are libraries of operations and applications programs that can be linked by human users in evaluating controlled data inputs. The following programs from the Battle Group library can be used with the HP9845 desk-top computer in an *ad hoc* simulation of a tactical DSS: NUCDAM II (nuclear damage assessment), SAVUS (satellite vulnerability program), COPS (communications planning), CAST (computer-aided stationing tool), TSS (tactical surface surveillance), SEATAC (screen evaluation aid for tactical commanders), and FASTAD (fleet ASWC tactical decision aid).⁴ In the civilian community, architecturally integrated decision support systems are available for use in arithmetically based analyses, as in the case of the integrated financial planning system.⁵ Initial integration occurring in a civilian implementation is not surprising when you consider the evolutionary chain of data processing (Figure 1); this originated with the creation of the arithmetically based transaction processing of civilian financial data, and developed into the summarized reporting of management information systems.

In spite of work on procurement systems (PMSS) at the Defense Systems Management College, the military appears to be leapfrogging the arithmetically based (financial analysis) step of decision support system evolution. In evolving tactical DSS for senior managers, progression of computer-based information management systems in the military mirrors the civilian community. Like industry, the Navy appears to be approaching DSS technology in two ways: *ad hoc* assembly of modules, and ground-up design. The Navy is creating an integrated tactical decision aids system *ad hoc* from existing tactical analysis programs like those listed above. Alternatively, in a classical evolutionary development program, the Navy is developing a flag command level tactical defense support system, the electronic warfare coordinators module (EWCM) as a tool for allocating and managing battle group electromagnetic resources. In the latter example, the battle group commander is given a decision support tool allowing him to model and re-evaluate the composite meaning of the electromagnetic data his forces collect. It

provides an accessible computerized tool allowing the commander to apply interpretive algorithms and stochastic predictors to raw electronic warfare intelligence data; thus, the commander can evaluate effects of existing atmospheric and environmental conditions on the propagation characteristics of his and adversarial electronic warfare devices—before committing to a plan of action.

Decision Support System Functions

Functions of the decision support system are: communication, data manipulation, report generation, graphical formatting, hypotheication, and goal seeking. The last two are the singular advance the decision support system makes upon management information systems command and control technology. These tools represent its major contributions to information management technology.

Recurrent analysis of a management problem combining real data and hypothesized variable parameters allows the manager to play "what if?" with prospective decisions. Successively changing variables he controls, the analyst/manager observes the impact each tentative choice has on a problem's outcome. Alternatively, having first constructed his support simulator by assembling appropriate analysis and simulation models from the system library, the analyst/manager can set the desired goal as the outcome and allow the decision support system to seek the optimal decision path to arrive at the specified outcome.

Emerging Decision Support Systems

A primary path of current decision support system development appears to be the *ad hoc* assembly of interim support systems from any module or component available. In this instance, the person or group responsible for DSS construction seem to come from the organization's entrepreneurial element. These DSS pioneers have gained access to personal computers and a library of job specific stand-alone applications software; when they become familiar with their library of applications modules, they exercise personal creativity; typically, this group creates techniques extending applicability of their software library to solutions of problems that are tangential elements of the work for which the software was

developed. Thus, as is customary with user-developed "workarounds," these users are creating decision support systems applicable to individual requirements. Three decision support systems being created *ad hoc* are the tactical flag command center decision integrator, manager's operations analysis evaluator,⁶ and tactical development and evaluation program.⁷

In two original cases, decision support systems are being assembled by design, as in the case of the civilian system, integrated financial planning system (IFPS); and the military system, electronic warfare coordinators module. Both are designed to allow the operator to make iterative judgments and incremental evaluations of the effects of decisions, and to create and publish a plan of action for operators' organizations.

Aside from their development path, these systems have the four main components of defense support system technology built into their architectural designs: simplified end-user interface; data storage and retrieval; dissemination support, and operations analysis capability. Implementation of this architecture is unique within each of the emerging systems.

Data Storage and Retrieval. The integrated financial planning system uses relational database management technology in the construction of its DIMENSION data handler. Similarly, the electronic warfare coordinators module system will depend upon relational database technology to maintain files like equipment availability, device capability, rules of engagement, mission objectives, and atmospheric parameters. The Navy Tactical Flag Command Center development system depends on manual transfer of analysis data from its HP 9000 series processors to and from the data display and correlation facilities of its flag data display system.

Simplified End-User Interface. The integrated financial planning system uses a query-based language allowing the user to frame questions into non-structured (any sequence) English-like statements. As I write, the electronic warfare coordinators system will use menu selections for module construction and output because no suitable query-based language is available. In

the case of all *ad hoc* systems, simplicity of the user interface is inherent in the mastery which the user-developer has gained of his software.

Dissemination Support. Both pre-planned systems depend upon written media for the dissemination of decisions; therefore, word processing and graphic illustrators are built into each. The electronic warfare coordinators system has another graphics capability permitting geographical presentation of data and the overlay of geometrical illustrations of decision results. Builders of the integrated financial planning system have provided for electronic networking; the Navy will incorporate the electronic warfare coordinators system into existing shipboard dataflow network. It is reasonable for us to expect that electronic data transfer will be an early modification to both. The dissemination mechanism of the evolving TFCC *ad hoc* decision support system is coupled with the distribution system of the flag data display system, a processing system developed specifically as a data display system.

Operations Analysis. The integrated financial planning system provides analytical models for evaluating the economics of such high-level management decisions as capital allocation, insurance coverage, exploratory development, budgeting and lease-purchase. The EWCM will support communications planning, electromagnetic emission risk analysis, equipment scheduling, and contingency planning with propagation models, equipment status files, environmental simulators, and procedural and rules models. The TFCC tactical decision integrator uses independently developed tactical decision aids such as satellite tracker, AAW station planner, ASW missile engagement planner, and ASW buoy planning model. The operations analysis evaluator offers the standard OA models: linear programming, transportation modeling, markovian analysis, inventory management, decision modeling, assignment modeling, and queuing theory.

Summary

Precedence in the application of computer technology is a moot question. However, there is clearly a pattern of technology transfer between the military and the civilian domain and

vice versa. Just as digital weapons controllers evolved into transaction processors, and management information systems led to command and control systems, so also are decision support systems the harbinger of tactical decision aids for the senior combat commander.

I do not suggest the senior commander will actually manipulate the analysis tool supporting him; no more than he now operates the command and control displays from which he directs his forces. Probably a staff member (electronic warfare coordinator) will perform actual "what-if?" analysis and display the results for review; in this respect, the commander's staff will probably function similarly to emerging civilian information systems specialists.

Precedence in the application of computer technology is a moot question.... Just as digital weapons controllers evolved into transaction processors... so also are decision support systems the harbinger of tactical decision aids for the senior combat commander.

Military development of tactical aids parallels development of the civilian decision support system. By reviewing the composition of the existing objective (quantitative) civilian decision support systems, it is possible to predict components and structure of the more subjective (qualitative) tactical decision support systems. There are elements within the existing civilian DSS systems, the application generators and the interactive language, which

should be anticipated in the preliminary design of military systems. We should accelerate the behavioral science transfer from the civilian community by investigating the structure of "information" and by observing the introduction and reception of these systems by the serviced management communities. From these observations, military defense support system developers can anticipate trends and develop mature and cost-effective tactical decision support systems within the P³I program. ■

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Counter-Obstacle Vehicle

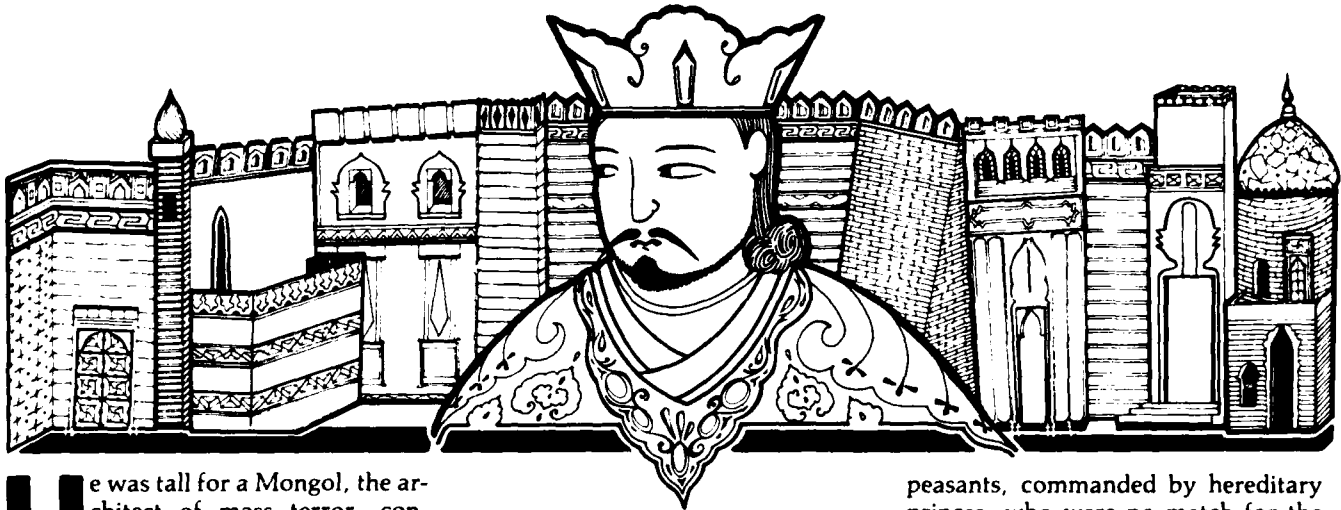
A counterobstacle vehicle (COV) developed by the Troop Support Command's Belvoir RD&E Center to clear safe paths through enemy barriers will be used by "opposing" force elements in upcoming exercises at the National Training Center, Fort Irwin, Calif. The COV will be used to highlight U.S. deficiencies in counterobstacle capabilities. It employs a combination mine plow/bulldozer blade and telescopic arms to clear and create major obstacles and emplacements.

A prototype vehicle, which has undergone gruelling tests at Fort Belvoir, Va., and Fort Knox, Ky., was shown at the 1986 Armor Conference. ■

Genghis Khan

A Logistical Genius

Joseph G. Meaney



He was tall for a Mongol, the architect of mass terror, conqueror of all men. He led and transformed a primitive people into a disciplined professional army and developed the world's first integrated logistical support system. The world knows him as Genghis Khan.

He grew up in a small nomad band among the Yablonovy mountains, east of Lake Baikal, where life was brutish and often short. Mongols survived severe Siberian winters and defended themselves from bandits and rival clans. With a culture as barren as their land, they had no written language or agriculture, built nothing more sophisticated than ox-carts and made no metal tools or weapons. They drank heavily, robbed, violated and murdered their neighbors.

This was the heritage of Genghis Khan, whose genius would mold the Mongols into the greatest logistically supported army the world had known up to that time.

Genghis and his Mongols had conquered much of Asia by 1220, including Northern China. His primitive nomads succeeded in crushing the world's most technologically advanced civilizations; this could be likened to the Sioux Indians under Chief Sitting Bull conquering the United States and Canada after defeating General Custer at the Little Bighorn.

No Raw Manpower

The Mongols did not make conquests with overwhelming raw manpower; manpower never existed and, in fact, they were usually outnumbered. For example, the Khan in 1211 fought to the gates of Peking with a small force of 200,000 men. But, these men had the abilities of a modern army and were well disciplined with a unified fighting force led by professional officers. They triumphed because they were opposed by armed

peasants, commanded by hereditary princes, who were no match for the Mongols.

Genghis organized his army by metric progression; combat units consisted of 10, 1,000 and 10,000. The 10,000-man unit, called a touman, was the basis for army groups commanded by an orlok or field marshal. Because no more than five officers stood between a soldier and Genghis' orders, the army moved with a precision that amazed his enemies. The Mongol soldier was the product of a universal military training system, and able-bodied men more than 20 years old served. On ready reserve in peacetime, they were on active duty for the duration of a war. Genghis created and maintained a full-time officer corps; later, he founded a permanent military academy to study and practice advanced tactics.

Intelligence Network

Genghis learned early in his career that most commanders relied on



guesses about the morale, strength and strategy of enemies. He did not use crude methods; his intelligence network ranged from the Caspian Sea to Korea and the penalty for failure by one of his "moles" was death. Intelligence reached Genghis with incredible speed. His arrow-riders ate and slept in their saddles, and were able to travel more than 300 miles of open country in a day by changing mounts every 35 miles. A fat, middle-aged orlock once rode 1,200 miles from Persia to Mongolia in less than 8 days. It would be 600 years later, with the advent of the steam locomotive, before anyone could travel overland as fast as a Mongol courier. Genghis' battlefield communications were equally impressive, and signal pennants kept him in constant touch with commanders, enabling a quick change of tactics if required. Well-trained Mongol soldiers responded immediately to new orders.

In the same timeframe, Genghis would spread misinformation to confuse his enemy. Methods included false retreats, smoke screens and dummy troop concentrations. Mongol slight-of-hand expertise often enticed or panicked opposing forces into abandoning a strong position and few survived the error.

Logistical Support

Mongols had no problems providing logistical support for their combat arms. One reason was the Mongolian pony, a beast as hardy and disciplined as the riders. While the rest of the world used cavalry to support the foot soldier, the Mongol cavalry *was* the army. To succeed in war, Genghis Khan depended on speed, mobility and surprise; infantry was unable to perform any of these three functions. The light horse performed traditional cavalry roles by disrupting the enemy and exploiting breakthroughs; archers carried javelins, swords or broadaxes, and lariats. Their armor consisted of helmets and small, round shields. The heavy cavalry gave Mongols the shock power of foot soldiers; lancers wore full body armor of metal-reinforced leather, and their effectiveness was based on the stirrup, a Mongolian innovation that allowed lancers to deliver fatal thrusts without being thrown from the saddles.

Horses, used for more than transportation, were the driving force that supplied intricate Mongolian bat-

tle tactics. Years of training enabled horses to maneuver with the precision of polo ponies. This is not surprising because Genghis Khan's cavalry were the world's first polo players

From an organic and logistical support approach, the Mongolian pony was the primary source of provisions for the army. Mares supplied milk and curd paste, staple of the Mongolian diet. Even liquor soldiers drank, a fermented whey called koumiss, came from their mounts. In times of deprivation, soldiers would temporarily open a pony's veins and drink the blood; a field army could subsist for 10 days on blood alone, and could ride routinely for 30 days with no supplies except cooking utensils and small, felt tents. I find it difficult to imagine a more totally integrated, logistical support system.

Siege Warfare

On the other hand, to live by the horse could be to perish with the horse. Although the Mongolian pony was not a picky eater needing barley or grain, it did need grass. If soldiers could not find forage, their mounts would starve; therefore, the Mongolian army could not survive without grass. Barren land was not a serious problem if the toumans kept moving; each soldier, with an average of 18 ponies, would switch mounts every few hours to keep the animals from tiring.

Though unstoppable in open terrain, Genghis Khan had serious strategic problems with siege warfare. A Mongolian field army consisting of 20 toumans required forage for more than 3.5 million horses, meaning that grasslands around a fortified city would disappear before pangs of starvation affected defenders. Genghis experienced this in his first siege of Peking which he lifted because the horses turned surrounding plains into a dust bowl.

To overcome this, the army took a crash course on siege-craft. Mongols learned to use catapults and battering rams and scaling towers—weapons of then-contemporary warfare. But when these new implements were used, first assaults succeeded only in splattering Mongolian blood against unyielding stone.

Unlocking the Gates

Genghis Khan realized he could not sustain wars of attrition, especially the

losses his army absorbed trying to smash through walls. He had to find other ways to unlock the gates. He reasoned that fortifications did not protect a city. "Walls," Genghis said, "are only as strong as the defenders' courage." Keys to the gates were only as strong as the garrison's will to resist; to overcome this resistance, Genghis developed a carrot and stick strategy. If a city surrendered peacefully, the people were treated as friends; homes were protected, shops were not looted, and women were not violated. As Mongolian subjects, citizens were protected against all enemies—under the Yasak Code of enlightened laws developed by Genghis. There was one strict requirement: The city must surrender immediately. If it resisted, even for a day, the people would suffer Genghis Khan's fury, which meant total annihilation.

Genghis, keeping his promises, never broke a treaty, betrayed a friend or deserted an ally. He would not tolerate treachery from his soldiers. One orlock, his son-in-law, was reduced to the ranks when his touman looted a city that had surrendered. Though Genghis was kind to those accepting his offer of surrender, he was brutal to opponents, willing to massacre hundreds of thousands of defenseless people for the acts of a few defiant warriors—he did that more than once.

Total War

With the threat of annihilation, Genghis solved a logistical problem that would have stopped his army dead in their tracks. The Mongolian pony's consumption of grass led Genghis to the concept of total war; now, he was challenged to test his bloody logic on the walled cities of Southwest Asia. By 1219, Mongolian armies approached the Turkish empire of Khwarism-Shah Muhammad. Genghis was tired after fighting 13 years and decided not to turn his toumans loose. He realized that with only 150,000 men at his back, it would be foolish to oppose such a powerful rival. The Shah's rule, extending from Turkey, included much of modern Asia, Afghanistan, Pakistan, and parts of the Soviet Union, and his armies, after crushing the Christian crusaders, threatened to overwhelm Western Europe. The Shah's Southwest Asian garrisons outmatched anything

Genghis could put in the field. There were 100,000 Turks stationed in the city of Samarkand alone. With these odds, the Shah responded with contempt to the diplomatic overtures of Genghis. The Shah's provincial governor attacked the Mongolian peace caravan and executed Genghis' ambassador. When Genghis sent a second mission demanding that the Shah punish his governor, the Shah responded by seizing the emissaries and having their body hair shaved as a sign of humiliation before sending them back. This second insult was too much. Genghis sent his final message to the Shah: "You have chosen war." Genghis assembled his 15 toumans and rode south toward the Jaxartes River.

The Shah in late summer of 1219, planning extermination of the enemy, deployed Turkish forces along the river bank opposite the available crossings. There were no other routes into the Khwarismlan lands.

Splits the Army

Genghis thought otherwise. After feinting along the lower Jaxartes, he split his army, a strategically dangerous plan, with four separate thrusts—three of them with small striking forces embarking across some of the most hostile terrain on the face of the earth. Three toumans under the Orlok Jebel headed toward the Pamir mountains to search for a pass leading to Bokhara and Samarkand. Once Jebel arrived at the enemy's rear, Jochi would strike north toward Khojend. Ogadei and Chagatai were to attack simultaneously the provincial capital of Otrar. Genghis saved the most difficult march for himself; he would lead the main body of the Mongolian army through the Kyzyl-Kum desert, a sand furnace believed to be impassible.

The four Mongolian army groups would be separated by hundreds of miles with temperatures as high as 120 degrees Fahrenheit and elevations of 13,000 feet. Their only links would be

Mongolian arrow-riders and their common ability to endure suffering. After pressing his men through belly-deep snowfields, Jebel found the pass he was looking for. Unshod horses found their way into the Forghan Valley at the junction of the Pamirs and Tien-Shans; weakened but intact, his three Mongolian toumans began their drives on Samarkand.

13th Century Maginot Line

The first gamble paid off for Genghis. The Shah's forces along the Jaxartes were left holding a 13th Century Maginot Line. There was still danger of the separated Mongolian army groups being destroyed piecemeal. A Turkish army led by the Shah's son brought Jebel's exhausted troops to a grinding halt; other elements of the Mongolian blitzkrieg were stalled at the gates of Khojend and Otrar. A startling order was delivered to Jebel's camp by an arrow-rider from Genghis. Jebel was to wheel away from Samarkand and advance deeper into enemy territory, northwest into the Pamirs, and into the Amu Darya Valley. Control of this choke-point by the Mongolians would sever the Shah's communication with his western lands. Then came the blow that broke the Shah's empire into pieces. Genghis stormed out of "impassable" Kyzyl-Kum, his toumans raging like bulls toward Bokhara. Now, the Khwarismlans looked isolated and vulnerable. Bokhara fell easily to Genghis, but his orloks had a difficult time. The garrison, under siege at Khojend, escaped and left Jochi the city's hollow shell.

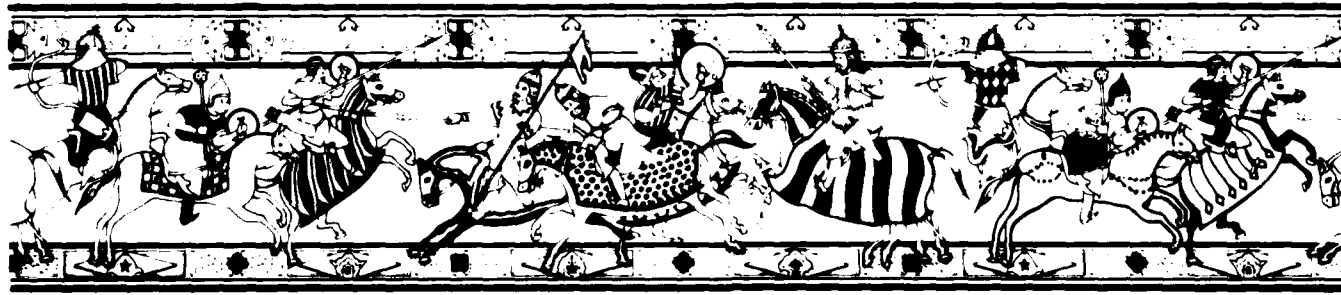
The Turks hung on at Otrar. Inalchik's men fighting with the tenacity of demons. After the Mongolians breached the walls, the Turks fell back to an inner fortress and fought for every room, stairwell and floor. The battle ended with Inalchik on the fort's highest parapet, reduced to hurling roof tiles at the Mongolians before

being captured. The Shah's governor, who would have been better off jumping from the parapet, was executed for murdering the Mongolian ambassador; this was performed by pouring molten silver into the governor's eyes and ear canals, the sentence being passed by Genghis.

Mongolian Firepower

With Otrar's fall, Mongolian armies linked-up at the outskirts of Samarkand. Three toumans were detached to hunt down the Shah; the remaining 12 stood ready to attack Southwest Asia's greatest city whose massive walls sheltered a half-million people who, by all estimates, could withstand siege for at least a year. The estimates were proved wrong because no one had counted on the firepower of the combined Mongolian siege train. Genghis Khan attacked Samarkand with more than one thousand siege engines, which hurled everything from 100-pound stones to huge pots of burning naphtha and fire missiles. According to sources, Mongolians used ultrasophisticated Chinese weapons, including explosives that were the 13th century version of the flame-thrower. The Mongolian psychological firepower inflicted more damage. Thirty thousand Turkish warriors, one third of the garrison, defected to Genghis Khan. The 50,000 Moslems in Samarkand also defected—remembering how their Shah had a Mongolian leader assassinated, they mobbed the Shah's soldiers. Samarkand fell in 3 days.

Genghis decided the people's fate, absolving Moslems of any guilt in the city's resistance. They were granted full rights of loyal Mongolian subjects including total freedom of worship. Turkish defectors were not that fortunate. Genghis Khan did not interpret defection the same as surrender; to him the Turkish defection was treason and, loathing traitors, ordered all 30,000 put to death. The remaining popula-



tion was killed except those with valuable skills such as artists, scribes and craftsmen. Thus, fields surrounding Samarkand became rivers of blood as hundreds of thousands were slaughtered—the price of resistance.

Atmosphere of Fear

News of Samarkand's fall spread throughout Khwarismian lands and created an atmosphere of fear. The Shah's empire disappeared as three Mongolian toumans chased him to Balkh, then Rai and, finally, to near modern Teheran, his last stand. The battle was pathetic. Though equal in numbers, the Shah's 30,000 Persian troops collapsed under Mongolian assault. Gates were smashed and the population slaughtered. The Shah escaped, his empire reduced to a tiny island in the Caspian Sea; this man who once terrified Europe now ruled a few barren acres that could not support basic needs. The Shah died in January 1221, less than 18 months after his proud armies took the field against the Mongolian barbarians. At the end, the Persians could not even provide a burial shroud for the Shah's body.

Genghis survived his rival by 6 years. He was more than 60 years old when, leading 18 toumans against the Hsi-Hsia of China, his horse fell on him. The last order of Genghis forbade his people to mourn his death, or to tell the enemy of his demise. But, after victory and annihilation of the enemy, Genghis' people gave him a proper Mongolian funeral. Every living thing in the cortege path was killed; the soldiers made no distinction as they struck down people, horses, oxen, cattle, rodents, birds and others. Even in death, Genghis Khan destroyed all who dared stand in his way.

Weapons Are Trusted Comrades

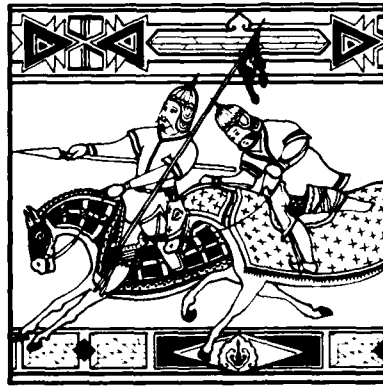
Weapons of the 13th century did not become obsolete. A Mongolian horse archer saw his life written in his bow's burnished wood, telling of enemies and game animals slain, and of hardships endured. Weapons were cared for like trusted comrades.

Today, mature weapon systems still represent an important part of defense preparedness. Our Department of

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Defense inventories include many with 15-20 years field experience and, with current funding constraints, many more will probably join the inventory. It is unfortunate that weapon systems today are not expected to grow old gracefully.

A major problem is that manufacturing sources dry up when production ends because contractors can't anticipate orders for spares and repair parts, causing unpredictable lead times. When system availability drops, operating and support expenses rise sharply. In fact, at this point, Post Production Support (PPS) will cost more



A Mongolian horse archer saw his life written in his bow's burnished wood; weapon systems today are not expected to grow old gracefully.

than systems development and production combined. This high cost of old-age systems can be controlled only through a planned approach to post-production support—the solution is continuity, a smooth and orderly transition from production close-out to follow-on support. This concept is used in some industries, successfully supporting weapon systems of the United States and foreign countries for

configurations with several thousand items involved. Post-production support doesn't end with spare parts, and should include all logistic support elements; factory- and depot-level test equipment, quick react depot-level test equipment, technical data and training manuals, provisioning documents, and engineering needed for design and maintenance improvements.

Compare with Today

Benefits derived from a PPS program could reduce post-production support costs by 30 percent. The lead-time for spares production could be cut in half, thereby sparing defense systems from old-age crippling.

It is important that post-production support receive the same degree of attention as system development, production and deployment. Military strength does not depend on advanced weapons alone. If it did, Genghis Khan would never have set foot outside the Yablonovy mountains of Siberia. ■

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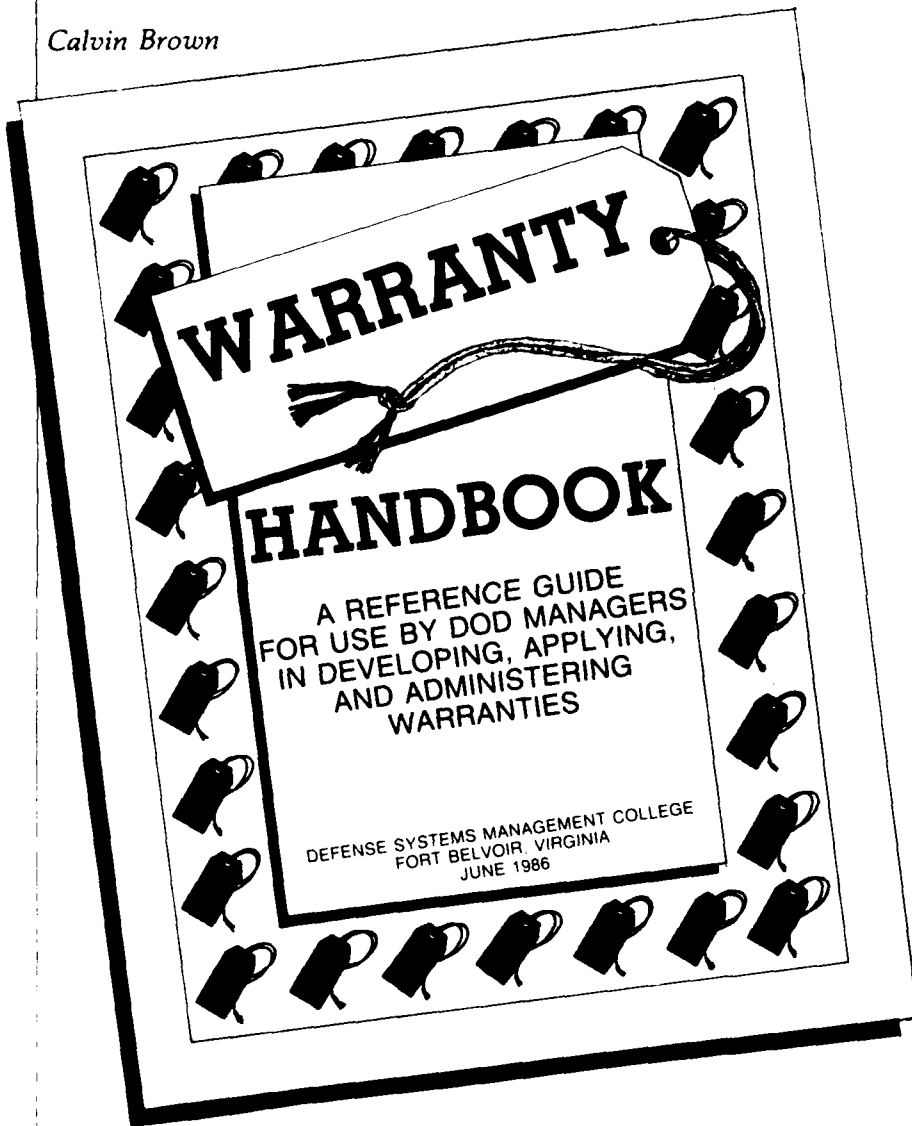
New Mine Killer In The Wings

A vehicle magnetic signature duplicator at the Troop Support Command Belvoir RD&E Center is ready to enter full-scale development as a unique countermeasure system to protect fighting vehicles.

Called VEMASID, the system will enable the Army to counter magnetically fuzed mines. It works by projecting an electro magnetic signal ahead of a vehicle to explode mines in its path. In operation, VEMASID will be used as a complementary system with other countermeasure equipment like the blades and rollers used with the Army M1 and M60 tanks. It will be adapted later for use with other vehicles. ■

DSMC Helps Develop Warranty Handbook

Calvin Brown



Title 10, Section 2403, of the United States Code requires that a warranty be included in procurement contracts for weapon systems. This has generated a great deal of concern from both military and industry. Questions such as the following have been asked:

—How can complex military equipment be warranted?

- How much should a warranty cost?
- What are the potential benefits?
- Can reasonable terms and conditions be developed?
- Can a military warranty be administered effectively?
- Will industry respond?
- Will the military user adapt?
- What tools are needed? What tools are available?

The Department of Defense and the military services have addressed these types of questions through policy directives, guidance documents, research contracts, workshops, and warranty focal points. However, the nearly all-inclusive nature of the warranty law, imposed without much time for phase-in, has presented a severe challenge to the military contracting office, program office, and logistics community to secure and implement effective warranties at a reasonable price.

The Defense Systems Management College sponsored the development of a *Warranty Handbook* to aid program managers of all the military services in meeting the requirements of the warranty law. Representatives of Office of the Secretary of Defense and the three military departments assisted in reviewing the final draft of this handbook.

Summary of Contents

Chapters are summarized as follows:

Chapter One. Introduction.

Chapter Two. Warranty Law and Department of Defense Policy: Provides background information on acquisition controls and a short history of warranty in military procurement; provides details on the current warranty law applicable to weapon system procurements; reviews Department of Defense guidance for implementing the law; presents a summary of military service focal points; and describes the Product Performance Agreement Center.

Chapter Three. Warranty Concepts and Issues: Presents basic definitions associated with warranties; identifies two basic warranty classifications—assurance and incentive; discusses incentive forms of product performance agreements; and addresses warranty issues including conformance determination, remedies, acquisition, costs, and risks.

Chapter Four. Warranty Selection and Structure: Describes acquisition, system, and operational factors that influence warranty decisions; discusses major warranty alternatives; describes the elements normally included in a warranty; and summarizes warranty forms applicable to various system classes.

Chapter Five. Warranty Development: Addresses warranty impacts on the acquisition strategy and procurement plan, system specification, and program office organization; and presents specific recommendations for warranty development for each phase of the acquisition cycle including studies, requirements, request for proposal development, proposal evaluation, and final negotiations.

Chapter Six. Warranty Administration: Addresses preparing for, administering, and evaluating the warranty; making decisions on concluding or extending the warranty; and assessing the benefits of the warranty.

Chapter Seven. Warranty Cost-Benefit Analysis: Discusses requirements for, and approaches to, conducting warranty cost-benefit analyses; presents a generalized warranty cost-benefit decision algorithm;

discusses warranty cost elements and warranty benefits; and summarizes available models to aid in performing cost-benefit analyses.

Chapter Eight Case Examples: Presents a brief summary of several previous and current warranty programs including contract background, warranty coverage, remedies, and the essential performance guarantee.

The handbook addresses a wide range of topics, from warranty acquisition strategy, to development of terms and conditions, through planning for the operational phases. In the past, there were few contractual controls available to the government to ensure that an accepted product maintained its specified characteristics in the user environment. It is a challenging task to develop and implement a warranty providing assurance that deployed equipment meets requirements, does

not add appreciably to acquisition cost, and does not impose unacceptable risks on the supplier. This handbook should provide material to help meet that challenge.

A limited number of copies of the handbook are available from the Defense System Management College. To obtain a copy, write to *Warranty Handbook*, Defense Systems Management College, ATTN: DRI-P, Fort Belvoir, Va. 22060-5426. In the near future, copies will be available through the Defense Technical Information Center, Defense Logistics Agency, Cameron Station, Alexandria, VA 22314, or by calling (202)274-6847 or Autovon 284-6847. As of this writing, however, no accession number has been assigned. ■

■ *Mr. Brown is a professor of engineering management, Research Directorate, at DSMC.*

MAM Certifies 228

The 1986 Materiel Acquisition Management (MAM) Certification Board has certified 228 officers, qualifying them to exercise central management over the planning, direction and control of acquisition functions such as research, development, testing, procurement, production and support for Army weapon systems and equipment.

Of 727 officers considered, the board selected 22 colonels, 109 lieutenant colonels and 97 promotable majors.

The MAM program is designed to develop officers with expertise related to the total acquisition process, enabling them to lead an integrated team from government and industry in accomplishing program objectives within designated time, cost and performance constraints.

As outlined in DA PAM 600-3, the program is open to captains with at least 5 1/2 years of active commissioned service.

Proponent for the MAM program Army-wide is the U.S. Army Materiel Command. Information on the program may be obtained from the referenced DA PAM or from HQAMC, ATTN: AMCP/EM, 5001 Eisenhower Avenue, Alexandria, VA 22333-0001. ■

Program Manager

Whenever in this publication "man," "men," or their related pronouns appear, either as words or parts of words (other than with obvious reference to named male individuals), they have been used for literary purposes and are meant in their generic sense. ■

Prototype Generator

The Troop Support Command's Belvoir RD&E Center is testing new prototype generator sets designed to withstand the harsh environments of nuclear, biological and chemical warfare, while emitting less heat and noise than models in the Army's inventory.

The signature suppressed diesel engine driven (SSDED) generator set program, sponsored by the project manager for mobile electric power, will update mobile power units used by U.S. Armed Forces. Current generator sets emit infrared and noise "signatures" that make command, control, communications and intelligence (C³I) systems easily distinguished from less critical targets; the new generator sets will produce external temperatures no more than plus or minus four degrees Celsius from the average ambient background. Noise signature requirements include non-detectability at distances of 300-400 meters.

The new generator sets must withstand a variety of climatic conditions

and be operable by soldiers in arctic clothing. Nuclear, biological and chemical survivability posing new requirements for these systems will necessitate radical changes in structural design and housing. ■

"...The battle, sir, is not to the strong alone; it is to the vigilant, the active, the brave.

—Patrick Henry, 1775

Flywheel Engine Forklift Truck

The Troop Support Command's Belvoir Research, Development and Engineering Center has begun a program to develop a prototype flywheel-engine-powered truck based on a commercial 4,000 pound warehouse forklift.

The flywheel-engine-powered design would use a flywheel spinning at high speed to store energy. This would enable the operator to shut down the engine and operate the forklift on its own stored power for brief periods of time. The engine-off periods allow the vehicle to run without emissions. Because of this, the forklift could be used to go in and out of enclosed storage areas that have limited ventilation. A flywheel has the potential of reducing fuel consumption up to 40 percent. ■

Cost of Competition

And Its Consideration in the Acquisition Strategy

Joseph F. Grosson
Dr. Joseph H. Augusta

In developing an acquisition strategy for a weapon system, a major question is: To what extent and when should competition be employed? Much has been written on this subject. The Carlucci initiatives made increased competition their last point. Commentators on defense acquisition have stressed competition's role in reducing program costs. The Congress has required more competition; i.e., HR5167 which amends Sec. 195(a), Chapter 137 of Title 10, U.S. Code, by adding Section 2306a, Office of the Competition General.

However, program managers frequently resist using competition. While some of this reluctance is caused by the substantial time and effort competition requires, a more fundamental problem is that not all participants in the process believe that competition accomplishes what is claimed for it. One perception is that competition causes the low-cost bidder to win¹ as opposed to selecting a proven performer, a choice more likely to result in the lowest total program costs. Not everybody believes in using the low-cost bidder; the perception is that low cost means inferior workmanship. In medicine, where human lives are at stake, no one, not ever the Congress, talks about using the low-cost bidder. A more serious concern is that competition is not axiomatic with reduced program costs. Another problem is that it often appears as though the decision regarding competition is all or nothing; actually, it is possible to make a separate decision on competition for each of the major phases of the acquisition cycle.

Our position is that competition does have a role, but the timing and form of competition must be considered carefully. This paper deals with the process of deciding when and where competition is cost effective (See Figure 1). Cost is not the only relevant criterion; however, because the cost-saving aspect of competition is stressed, it is the criterion we apply. Our discussion below highlights the factors influencing the interplay of aspects affecting the decision on competition. To put these cost elements in perspective, we begin first with a discussion about the economics of acquisition competition.

Simple Economics of Acquisition Competition

To have competition, there must be a second source; i.e., at least one alternative producer of a weapon system. Because of the unique nature of most weapon systems procured, a second source frequently does not exist. Thus, if a second source is to be utilized after one contractor has essentially completed development, establishing a second source requires substantial non-recurring start-up costs, such as duplicated capital equipment costs (special tooling) and test-equipment costs. These non-recurring costs can be offset only by lower recurring costs. Learning curves, the accepted way of measuring recurring costs, relate the unit cost of producing an item to the quantity produced. Because the relationship is inverse, splitting a fixed quantity to be procured among two or more producers, so that each has a smaller buy, means that the unit cost

Figure 1. Competition

- What are the real total costs?
- Will cost savings always occur?
- Is maintaining the industrial base of value?
- Winner take all or multiple suppliers?
- Can it be tailored to the situation?
- Does it compromise quality?
- Does it inhibit high technology?

for each is higher than if there were only one producer. Advocates of competition argue, however, that the slope, and maybe the position, of the learning curve is driven down sufficiently so that, even though a reduced quantity is produced by each manufacturer, substantially lower costs result. Advocates state that these are low enough so that the total costs of the procurement are reduced, even when added non-recurring costs are included. The counter-argument is that costs of developing the second source offset eventual unit-price adjustments, so total costs are actually and upon occasion, substantially increased.

■ Mr. Grosson is associated with the VSE Corporation.

Dr. Augusta is president of the Administrative Sciences Corporation.

In addition, decisions must be made about the philosophy of the competition (form, fit and function), and the nature of the production competition (winner-take-all or dual source). This paper provides elements that impact cost and that should be considered during each phase to identify the cost effectiveness of alternative competition plans (see Figure 2).

Much effort has been spent on computing the actual cost savings resulting from competition and the methodology to calculate the cost aspects of various acquisition strategies. Reviews of seven empirical studies of the savings from competition showed substantial savings from competition.² However, careful reviews of these have questioned their conclusion(s). All early studies considered the procurement of comparatively large quantities of relatively simple and inexpensive items; their relevance to large weapon systems is not clear. After reviewing more applicable efforts, findings³ indicated that evidence for cost savings from competition in the procurement of large weapon systems was not clear-cut once adjustment was made to ensure consistency of technique and data. In particular, there was no evidence that competition consistently produced cost savings. Another review⁴ concluded that competition caused program costs to be reduced in some instances but increased in others; the report asserted that competition, like all acquisition strategies, should be chosen on a case-by-case basis, and only when there are "reasonable expectations of cost savings." Our discussion below is designed to highlight when these reasonable expectations can occur.

Selection of Competition

A weapon system acquisition begins with the conceptual design phase and moves to demonstration and validation (D&V), full-scale development (FSD) and, finally, production. Our belief is that selection of an acquisition strategy should begin with the production phase, and then move to earlier phases in the acquisition cycle; the reason is that during the production phase, you deal with parameters like delivery rates, production quantities (including foreign users), logistics support, mobilization base issues, etc., which directly affect the need for more than one producer. Once answered for

Figure 2. The Other Costs of Competition

- Production Related
- Administrative
- Logistics and Life-Cycle Support

the production phase, the question of competition for the preceding phases can be answered more logically. Our discussion below, therefore, begins with the production phase and then examines earlier phases.

Production Phase

In choosing an acquisition strategy, the first decision should be on the nature of the production competition. Competition is usually divided into either (1) winner-take-all, or (2) multiple-source competitions when there is either one competition at the start of the production cycle or several throughout the cycle. Not all weapon systems are procured via competition. In a few cases, a single producer is engaged on a sole-source basis. One common situation is the winner-take-all competition held only once when initial benefits of competition are lost over time as the single producer becomes the sole source. Our remarks here are directed toward the multiple-source case, either with one procurement or a series of procurements. The term "multiple source" includes two or more producers, not just one alternative producer. In deciding upon competition, several fundamental questions must be answered:

- How many alternate sources should be utilized?
- When should they be introduced?
- How will alternative sources be qualified—leader/follower or individual qualification arrangements?
- What strategies should be used regarding second and lower-tier vendors (will specific vendors be mandated)?

Cost Elements That Increase Program Costs

Competition increases costs in three major ways: production, administration, and logistics. The principal factors to be considered in each of these areas are discussed below.

-Production Related Considerations

-Facilitates investment-additional production/test equipment, tools and quality assurance for more than one supplier

-Higher learning curve (learning occurring at slower rate) due to lower production rates caused by splitting production quantities or the introduction of a new producer

-Non-optimized economies of scale since, *inter alia*, fixed indirect costs must be amortized over a small production quantity

-Additional government inspection/surveillance requirements.

-Administration Cost Increases

-Government personnel for administering a much more complex, multiple-source selection process

-Program management for second source including travel expenses, R&D center support, contracts personnel, resident inspectors

-Additional warranty/guarantee costs since contractor risk must be spread across smaller production item base

-Costs incident to product certification—techeval, opeval, production readiness reviews, preproduction reliability design reviews, procedure validation and approval

-Producibility analysis of procurement data to assure the government is protected from claim of defective data

-Additional multisupplier industrial preparedness planning

-Configuration control and change management

-Duplication of administrative contract performance data—cost performance reports, periodic reports and other contract data requirements list items, and site program reviews

-Multiple end-of-program termination activities

-Expenditure of additional bid and proposal costs which eventually are reimbursed from a defense program

-Increases to overhead which is spread over a smaller production base number

-Additional G&A profit layering due to increased number of lower-tier vendors.

—Logistics and Life-Cycle Support Related

—Expansion of configuration control board function for multiple suppliers

—Additional logistics support for new parts resulting from second or multiple sources including training material, data maintenance (technical documentation), and application and maintenance computer software

—Rights in data and patent rights that have to be obtained to ensure the ability to procure essential components from alternative sources

—Preservation, packaging, and shipping costs associated with other than primary supplier

—Potential exposure due to non-standard equipment—alterations, planning, and specialized level of effort.

If the leader follower approach is used, the leader must be paid for all services associated with providing documentation, educating, training, and certifying that the follower is qualified to produce the end-item. If a new source is introduced, it usually will be necessary to pay for the services of the previous supplier to ensure that the new source is ready and prepared to commence production.

—**Cost Elements That Decrease Program Costs.** If dual-source procurement is used, competitive pressures eventually should cause unit costs to decrease. These reductions can result from reduced profit, contractor QA, better management, production efficiencies, or a "buy-in" philosophy by the alternate producer. It is important when future unit price reductions occur to differentiate the cause: Is cost reduction due to competitive pressure or simply to the application of learning (which will occur exclusive of competition)?

Full-Scale Development Phase

In full-scale development (FSD), an item being produced will be tested and certified as suitable for production, in a configuration satisfactorily passing operational evaluation. Other reviews relative to this baseline are performed at this time including logistics, readiness, preproduction reliability, and production readiness. When ap-

proval is granted to proceed into FSD, it normally includes authority to produce a limited number of items to ensure a smooth and efficient transition of the production line from a low-developmental rate to a quantity-production rate. The point in the program for greatest leverage of total life cycle cost, while incurring only a small fraction of the cost, is during FSD. There never will be a point in the program where clever engineering will have a greater opportunity to impact the product; thus, it is preferable to have more than one concurrent developer, and to have a well-defined set of criteria for selecting a single developer's product.

One may ask: How many developers do we want during this phase and how are they selected? Choosing more than one FSD developer is based largely on what the program manager can afford. In most cases, cost computations based on the considerations presented below will show that multiple producers will cost more in terms of money and personnel.

Assuming Multiple Developers—Cost Elements That Increase Program Costs

—Preproduction Related

—Specialized high technology development facilities, test equipment, etc., from more than one source

—Additional government surveillance, monitoring, and R&D center support

—Significant review costs incident to more than one supplier for preproduction reliability design reviews, production readiness reviews, etc.

—Provision of multiple sets of government-furnished equipment (computers, displays, special components, etc.)

—Multiple production and producibility analyses.

—Administration Related

—Government personnel for administering source selection, management, contract administration, configuration control, and test/evaluation participation

—Duplication of administration—contract performance data, site program reviews

—Additional G&A profit layering.

—Logistics

—Multiple logistics data packages to permit review by logistics review groups

—Procurement of multiple-developer dependent sets of installation and checkout spares incident to technical/operational.

—Development

—Multiple opportunity for cost growth to handle high-risk areas that are developer dependent—thus, program-manager risk contingency funding must be multiplied by the number of developers.

Assuming Multiple Developers—Cost Elements That May Decrease Program Costs

—Technical competition will increase probability of higher performance or lower life-cycle cost due to technology innovation

—Producibility competition will increase probability of minimizing production unit costs

—Psychic competition among developers can result in more clever approaches contributing to overall product excellence.

Demonstration and Validation Phase (D&V)

In the demonstration and validation phase, alternative approaches should be pursued to satisfy the operational requirements. Equipment should be developed, built, tested and evaluated, leading to selection of the concept(s) which should proceed into full-scale development. The more difficult the requirements, the more demanding the technology application and, therefore, the higher the risk. Limiting this phase to a single developer is generally not prudent. However, the cost of having more than one developer can be ameliorated with a short, initial, multideveloper "proof of principle" phase; or, by selecting an approach in which there is one prime contractor for the system with multiple second-tier developers for high-risk subsystems or major components. Such sub-phases add time to the acquisition cycle but are usually well worth it in terms of reducing technical uncertainty, thus saving overall acquisition cycle time.

—**Competition Considerations.** Of any acquisition phase, demonstration and valuation requires the least percentage

of total acquisition life-cycle cost; therefore, it makes sense to compete and select multiple developers. The government research and development centers can be considered competitors; however, their participation removes a valuable resource for independent review of competing concepts. This overall issue leads to several questions:

—How many developers?

—When should developers with a low probability of success be terminated?

—What should the criteria be for selecting successful developers?

—To what extent should foreign developers be encouraged to participate and what are the implications of sharing domestic technology?

—Are there joint-service implications that should be exploited?

—**Very-High Technology, Security-Sensitive Program.** In this situation, it may make sense to limit D&V participants to sole-source selected, tradi-

tional organizations with proven records of experience and capability. The expense and security risk of educating new sources may not be affordable or wise.

—**Conventional Technology, Typical Defense End-Item.** In this case, it will be most advantageous to cause the maximum amount of developer participation among the most competent adversaries. The higher the interest and keener the competition, the greater the potential for obtaining more than one dollar of effort for each dollar spent by creating strategies that encourage developer interest to augment government research and development money.

Summary

There are many approaches providing a rational strategy for selecting the number of program participants and the process to be used for winnowing-out competing concepts. The major points are that the cost of obtain-

ing and maintaining competition can be high, especially when making decisions during the production phase (particularly for low-production rate, complex products); also, that the unit cost as a function of time may not always be reduced through competition. ■

References

1. Beltramo, Michael and David Jordan, *Issues to be Considered in Establishing Dual Source Competition*, prepared for HQs, Naval Material Command, 24 September 1982.
2. Sherbrooke and Associates, *Quantitative Acquisition Strategy Models*, prepared for HQs, Naval Material Command, 15 March 1983.
3. Ibid.
4. Grosson, Joseph and Joseph Augusta, *Navy Acquisition Cost Study*, HQs, Naval Material Command, 10 March 1981.

INSIDE DSMC

On the Move

Additions

Sarah Beudet, Elizabeth Cates, George Creel, Donald Dyeas, Rica Gonzales, Patrick Lowry, Timothy McGrath, and Amy Pruett, summer hires.

Changes

Lieutenant Colonel Mason S. Botts, USAF, is the director of research, Department of Research and Information. He had been a professor of systems acquisition management, Policy and Organization Management Department.

Losses

Colonel Stanley J. Souvenir, USA, deputy commandant, to the U.S. Army Strategic Defense Command, as deputy.

Lieutenant Colonel (Colonel Select) Francis W. A'Hearn, USAF, director of research, Department of Research and Information, to the National Defense University, Fort McNair, Washington, D.C., for 1 year as a Senior Research Fellow. While there, he also will attend the Industrial College of the Armed Forces

PNCM Raymond V. Stuchell, USN, master chief personnelman, Office of the Commandant, retires Aug. 1, 1986.

Joanne Barreca, Policy and Organization Management Department, to the Defense Logistics Agency.

Lieutenant Colonel Melvin Gambrell, USAF, Policy and Organization Management Department, to Brooks Air Force Base, San Antonio, Texas.

Colonel William V. Murry, USA, dean, Department of College Operations and Services, to the Army Materiel Command.

Legion of Merit to LTC Peoples



Lieutenant Colonel Thomas Peoples, USA, the new assistant for contracts at DSMC, has received a

high honor, the Legion of Merit, for service as the executive officer, Combat Support Systems Directorate, Office of the Deputy Chief of Staff (Research, Development and Acquisition). The presentation was in June at the Pentagon. ■

The OSD Ace Program II

Members of the OSD Acquisition Enhancement (ACE) Program II are working at the Defense Systems Management College through November 1986. They are: Chuck Caloia, Army; Lieutenant Colonel Jack Dwyer, USAF; Walter Featheringham, DLC; Thomas Hatheway, OASD (FM&P); Colonel Joseph Nickens, USA; Martha Niewehous, Navy; Commander Arnold Shapack, USN; Phil Stand, DLA; Colonel Robert Tindell, USA, Defense Training Data Analysis Center; and Lieutenant Colonel Charles West, USAF, Defense Training Data Analysis Center.

Edward Hirsch, DSMC Research Directorate, is director of the study. ■

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