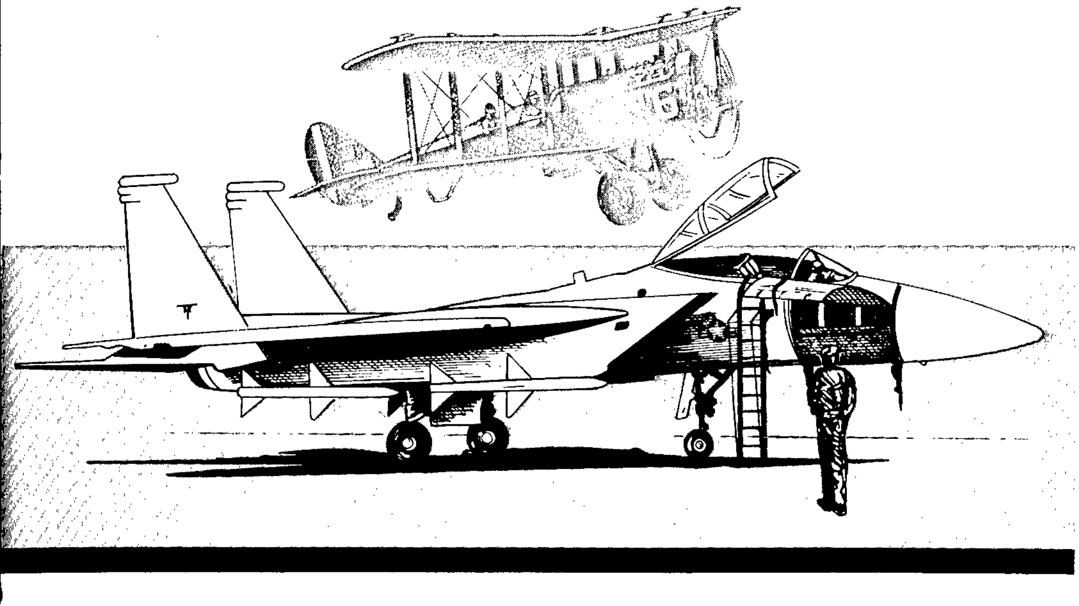

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AIR FORCE JOURNAL of LOGISTICS

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The Short War: Strategy for Defeat

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Several centuries ago a Roman military philosopher suggested: "If you want peace, you must prepare for war." But preparing for war is no simple task. Perhaps the most difficult and crucial aspect of preparation is trying to foresee the type and magnitude of war that should drive our efforts.

Three themes are relevant. First, war is a destructive activity that attrites large quantities of resources. Second, although a short war is possible, it is unlikely. The third, and major, theme follows from these. *Given the conditions of war, industrial surge and sustainment are essential to success in future conflicts.* While we have progressed significantly in building our capacity in this arena, a number of vexing problems still face us.

The Reality of Attrition

We have experienced the effects of attrition even in a relatively limited conflict such as Vietnam. Modern warfare in this low-level action demanded extensive logistics efforts to overcome the effects of attrition on the military operations in Southeast Asia. But it is World War II and the German experience that offers the greatest insights into the relationship between industrial mobilization and the war-fighting capability of modern states. In World War II the ruthless, incontrovertible laws of attrition were indisputable to even the casual observer. I believe these same laws of attrition would repeat themselves today in a NATO-Warsaw Pact confrontation. Moreover, German society—although politically dissimilar from our own American society—held some of the same chauvinistic views prevalent throughout the United States (US) today. For example, the Germans believed in the supremacy of their technological expertise and the qualitative superiority of their military forces, which they were convinced could overcome western and Soviet industrial advantages.

In fact, the Germans believed so strongly in their battlefield invincibility that from 1938 to 1942 no one in the Luftwaffe was in charge of strategic planning, force structure development, *or* industrial production. Even after the fall of France and the acquisition of its significant industrial and materiel resources, German production rates remained virtually unchanged due to ignorance or arrogance. "Total" mobilization in Germany did not come until after July 1944. More remarkable was evidence that British aircraft production exceeded German production as early as 1940. In short, German leaders cared little for the "nonoperational" requirements of production and failed to integrate their scientists, managers, and technicians into their war-fighting machine.

In *A Genius For War*, author Trevor Dupuy substantiates German battlefield excellence:

> In 1943-44 . . . on a man-for-man basis, the German ground soldiers consistently inflicted casualties at about a 50 percent higher rate than they incurred from opposing British and American troops under *all* circumstances. This was true when they were attacking and when they were defending, when they had a local numerical superiority and when, as was usually the case, they were outnumbered, when they had air superiority, and when they did not, when they won and when they lost.

Yet, the immutable laws of attrition began to take their toll. From January to October 1942, the Germans lost 5,793 aircraft and another 1,617 were damaged. From July to August 1943, the Nazis lost over 3,200 aircraft. And this attrition was not confined to combat. In fact, from 1941 to 1944, 40% to 45% of the Luftwaffe losses were due to *noncombat* causes such as training mishaps.

Of course, attrition was not limited to the Germans. In 1943 alone, we Americans experienced 20,389 major aircraft accidents in which 2,200 pilots and 3,300 aircrew members were killed. And all these accidents occurred in the continental US, 4,000 miles from the war! The expression "one a day in Tampa Bay" still haunts MacDill Air Force Base. This expression captures the grim reality of war—the friction and trauma characterized by the dramatic attrition that transpires in modern conflict as a result of the tempo of activity.

The Germans eventually began to understand the laws of attrition. Erhard Milch performed miracles in producing some 36,000 aircraft in 1944 despite the allied bombing campaign, the inefficiencies of dispersed production facilities, and Hitler's own preoccupation with the V1 and V2 rocket production. But for the Germans, it was too little too late. The decisions made in the late 1930s and early 1940s doomed the Germans to lose the industrial battle and ultimately the war.

Although attrition is an undeniable fact in modern war, industrial production can alleviate some of its effects. As the Trenchard Papers concluded:

> The air war during the second world war . . . was attrition war. . . . Victory went to the air forces with the greatest depth, the greatest balance, the greatest flexibility in employment.

The Lure of the Short War

The issue of attrition is difficult enough to address on its own. However, in recent decades, this task has been further obstructed by a concept or idea that I would label the "short war" philosophy. This concept holds that the next war will last only a few weeks or, at worst, months. The short war idea is based on the central belief that the destructiveness of modern weapons—both conventional and nuclear—would consume and/or destroy resources at such a catastrophic rate that a prolonged war would not be militarily or politically feasible.

"No historical evidence exists to indicate a short war is even probable between modern, industrial states."

Although the short war is not currently an assumption for defense planning and programming, its origin in the Air Force can be traced back to 1955 with the concept of a "force in being." And despite its official disfavor at present, the short war has been, and continues to be, a popular notion both within and outside of government.

But whether one believes in a short war or not, we must understand that this idea is based on theory and *not* experience. For no historical evidence exists to indicate a short war is even *probable* between modern, industrial states. In fact, as the author Williamson Murray suggests: "Since the time of the American Civil War, modern war has been a struggle of industrial production as well as conflict on the battlefield."

When one looks at history, the short war appears to be the repeated invention of optimistic politicians, strategists, and planners who otherwise would be confronted with a logistics nightmare—in both magnitude and detail— of planning and advocating a protracted conflict. For example, the Schlieffen Plan of the Germans in World War I called for mobilization, deployment, and execution, all to take place within 42 days. This plan was easy to sell but impossible to implement. Not only did the Germans fail to meet their ambitious goals, but the cost in lives and materiel far exceeded even the most pessimistic estimates.

Today, our military objective is to improve combat capability across the entire spectrum of warfare. First, we must deter an enemy and, if deterrence fails, engage the enemy and seek earliest termination on terms favorable to the US and our allies. To achieve this objective, we must have a modern force structure that is both ready and sustainable. And, it is here that my third theme comes into play. We must have the requisite industrial capability to ensure success in future conflicts. If we are serious about national security, we must confront this need in its many facets.

Industrial Base Issues

First, we must recognize our society is changing from an industrial/manufacturing economy to an information/services economy. This is not a new phenomenon. In 1967, 46% of all jobs fell into the latter category; today, 90% of all new jobs are information and/or service oriented. The obvious result is a dwindling manufacturing base. Furthermore, the US is becoming more dependent on foreign suppliers as the world economy becomes increasingly interdependent. These trends obviously are beginning to impact national security and we need to understand their implications.

According to the Department of Labor, the number of aircraft spare parts produced by foreign sources rose from 13% in 1980 to 25% in 1984. To fully grasp the significance of this, one must understand that 50% to 65% of a weapon system is comprised of subcontractor parts. The F-15 fighter is an amalgam of components produced by over 300 major contractors and thousands of other vendors. In order to produce one additional F-15 aircraft above the current peacetime schedule, it would take 39 months due to the current availability of component parts.

Although the US possesses the final assembly capability to produce a weapon system, it is losing the capacity to build the parts required to complete an entire system. In the past, the US industrial base had the capability and only had to increase the capacity. Today, both the capability and capacity are waning.

We also need to think through the quality versus quantity issue with regard to *producibility*. Simplicity is one of the Air Force's principles of war. Unfortunately, this principle has been confined to the battlefield. In other words, simplicity has meant simple to operate and simple to maintain. The principle has not extended to the industrial base in terms of designs that are simple to produce in quantity.

Again, the Germans in World War II never solved many of the issues of producibility. They had a "Mercedes" mentality when it came to quality. As a result, widespread waste of manpower and materiel occurred throughout their aerospace industry. For instance, inordinate amounts of time were spent upholstering aircrew seats to luxurious standards. Needless man-hours were wasted machining minor fittings to close tolerances which had no effect on aircraft performance, reliability, or maintainability. Moreover, in their zeal to churn out high performance aircraft that would quickly crush the enemy, the Germans did not give adequate consideration to the production of spares to sustain the battle. The relationship of first line production and replenishment spares production to aircraft availability was never fully appreciated by Luftwaffe leaders; they elected to produce one "Mercedes" to ten allied "Chevys."

Another area the Germans wrestled with was the integration of new technology into their force structure. It has been reliably estimated that the industrial effort devoted to the V1 and V2 rockets could have produced another 24,000 sorely needed fighter aircraft in the last year and a half of the war. Whether these additional fighters would have made any difference in the outcome, of course, would be pure conjecture on my part. But, conversely, if the V2 rocket could have been perfected and coupled with an atomic bomb, it takes little imagination to see what Hitler may have been able to achieve despite allied conventional numerical superiority.

These vignettes beg contemporary questions:

- Does the US have mobilization organizations with the visibility and expertise to make the right trade-off decisions between competing technologies?
- Do they understand the effects of introducing new technologies into the production base and the resulting impact on war-fighting capability?
- Are we capable of making balanced decisions with regard to weapon system performance, reliability, maintainability, and manufacturing efficiency?

These choices are further complicated by the issue of affordability and the inevitable trade-offs between peacetime efficiency and wartime effectiveness. Here again, the short war concept has served as the philosophical underpinning for many cost-conscious public servants. Unfortunately, as Roderick Vawter of National Defense University has pointed out: "The short war concept has tended to become the basis for *establishing* requirements, rather than the rationale for allocating fiscally constrained resources against an unconstrained requirement."

> ***"Because industrial planning for a 'long' war involves such a horrendous work load, the establishment has found the 'short war' a convenient excuse for not taking on the tough industrial issues of attrition warfare."***

Efficiency is only important to the extent it contributes to wartime effectiveness. Requirements determination for industrial mobilization must be driven by combat operational needs. Fiscal constraints are a reality that cannot be ignored, but they should not hinder our ability to think about mobilization in terms of the enemy *threat*.

In effect, the short war concept has hampered our planning by providing a rationale for not thinking through a "worst case" mobilization scenario. And because industrial planning for a "long" war involves such a horrendous work load, the establishment has found the "short war" a convenient excuse for not taking on the tough industrial issues of attrition warfare.

We are fortunate today to have an administration that appreciates the principle of balance in war preparation. This appreciation has been promulgated in National Security Decision Directive 47 which gives guidance on the development of programs to provide sufficient manpower and materiel for mobilization. This presidential directive reestablished the planning criterion for a global war of indefinite duration. In other words, it again brings into vogue the D to P (deployment to production) planning we abandoned in the mid-70s. In essence, the directive has once more created a linkage between the capability of the industrial base and war reserve stockpiles. Sustainability has been resurrected (at least, in principle) to a level comparable with readiness.

This year the Air Force produced a document called the *Production Base Analysis*. Although it was not the first, it was the most extensive to date. It demonstrates we are beginning to identify many of the deficiencies we have long neglected, although most solutions appear to be somewhere in the distant future. Essentially, the *Production Base Analysis* concluded that the ability to surge was "more coincidence than the result of purposeful direction." In the aggregate, our industrial ability to surge and sustain *whole* weapon systems remains suspect:

- For large aircraft, we cannot surge the C-5 but can surge others; however, none can be sustained.
- We can surge fighter/attack aircraft but cannot sustain them.
- We can surge helicopters but cannot sustain them.
- The same is true for aircraft engines: surge but not sustain.
- Finally, tactical missiles cannot be surged or sustained without prestocked long leadtime pacing items, rolling inventory, and special test equipment.

This paints a grim picture, indeed, should we have to engage another super power capable of attrition warfare.

Some of the other salient findings of the analysis applicable across the aerospace industry are:

- Weapon systems often outlive the technologies that support them. Yet, the requirement for these technologies will increase dramatically in war, and industry may be unable to replicate "old" technologies due to fundamental structural changes in the manufacturing sector.
- Plants and facilities operate well below capacity, thereby making them vulnerable for consolidation and/or closure.
- Aerospace manufacturing is labor intensive, and the ability of the aerospace industry to increase its productive capacity may well depend on the capability to *train* an expanded labor force.
- A few large companies dominate the industrial base.
- At the prime contractor level, the government is the dominant customer.
- The subcontractor and vendor base has not been emphasized; concentration has been on the primes.
- Component lead times may dictate program schedules, as in the F-15 example.
- Critical skills may become a problem during surge or mobilization. (We still have no good feel for the magnitude of this problem.)

Prescriptions

Not pretending to be an expert on industrial preparedness, I would humbly offer some old, but untried, ideas that could improve our industrial posture:

- First, we must halt the wild fluctuations in industrial requirements and keep mobilization goals at the forefront, especially during the lean years in military procurement.
- Next, we need to accept the profit motive as an integral part of the American economic structure. That means biting the bullet when private investment profitability is inadequate by ensuring government investment takes up the slack in critical mobilization areas.
- We also should simplify regulatory and administrative practices to minimize the hassle of doing business with government.

> *"We should never allow our fiscally constrained programming requirements to interfere with our unconstrained long-, mid-, or short-term planning as that planning applies to mobilization."*

- Finally, we should develop realistic mobilization requirements based on specific mobilization scenarios recognizing the needs of allies as well as US forces. And these scenarios should include a *total* mobilization scenario as well as a *low intensity* scenario geared to weapon systems with a special operations mission. Most importantly, we should never allow our fiscally constrained programming requirements to interfere with our unconstrained long-, mid-, or short-term planning as that planning applies to mobilization.

Conclusion

War is a destructive activity and there is no historical evidence to suggest that attrition will not play a significant role in determining the outcome of the next conflict. Although a short war is possible, it should not be used as a basis for establishing requirements. That means we are obligated to do the best job of industrial planning possible, tough as the job may be. As Captain James Hamilton stated in 1949 at the ninth session of the Industrial Mobilization Planning Indoctrination Course, "We are still looking for the expedient answer, some way to do this job without work, without detail. Well, it can't be done." We must invest during peacetime in industrial improvements or the costs will be unacceptable in war.

Oil and Water

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The Air Force policy is to ensure that spacecraft maintenance options are considered . . . wherein these options might be reasonably implemented. The Air Force should actively examine the utility of spacecraft maintenance options . . . and avoid, wherever practicable, design actions which would appear to preclude on-orbit maintenance later in the spacecraft life cycle.[1]

Air Force Policy on Spacecraft Maintenance (SAFUS Ltr), September 1984

Introduction

The Air Force's current policy on spacecraft maintenance was established despite a predeliction that the concepts of space operations and space-based maintenance, like oil and water, tend not to mix very well. The policy reflects the likelihood that future needs and capabilities will make space maintenance and repair a viable, even necessary, option. This paper presents basic issues that bear on this emerging subject of considerable complexity and explores some of the ultimate ramifications of maintenance policies.

Terminology

The term *space logistics,* coined for use in the Strategic Defense Initiative, includes the end-to-end logistics support for both the ground and space-based infrastructure of the President's "Star Wars" concept.[2] Thus, the term includes such functions as transportation to orbit, orbit transfer, and the focus of this paper—*space maintenance and repair (SMR).* The term does not indicate any sense of roles and missions for either the Air Force or its major commands, but is used as an intellectual shorthand to provide a convenient means of discussing a broad and highly interrelated set of ideas. Also, a spacecraft or satellite consists of a mission or payload complement attached to a mechanical and electronic framework known as a *bus*. The bus provides an interface between the payload and the launching system.

Background

Beginning in the early 1970s, as the concept of the space shuttle evolved, people in the National Aeronautics and Space Administration (NASA) and elsewhere began to think about the possibility that man might someday be able to reach orbiting satellites and that his presence might allow repair, maintenance, and servicing with consumables. This possibility appeared a likely mission for the shuttle until personnel safety precautions prohibited work on *active* payloads in the shuttle's cargo bay. Though this constituted a setback for SMR, it by no means ended investigation of maintenance possibilities for spacecraft in orbit.

NASA began devoting some serious effort to the SMR area and, by the end of the decade, designs existed for the "common bus"—a modular framework which could be used as the basis for a variety of satellites.[3] By forcing the mission payload designers to design their systems to be compatible with common interfaces, considerable money could be saved by avoiding proliferation of buses and interfaces.

The success of the resulting multimission modular spacecraft (MMS), though, was less than resounding. In hindsight it is clear that this initial attempt to enforce standardization was doomed to failure. The reason was simple economics, as revealed by an Air Force study of the common bus.[4] The primary mission package of a satellite is not considered by designers to be an area of compromise. They understandably try to get every nuance of optimization they can into the mission hardware, whether a sensor or a communications package, for every ounce that goes into orbit. The very nature of a common framework means that some compromises would have to be made for virtually every payload which might use it, in turn suboptimizing heat rejection schemes, pointing accuracies, or the amount of reaction control propellant needed. This means that for essentially the same cost, the spacecraft designer would get a less capable spacecraft than otherwise.

> *"While space repair, maintenance, and servicing may intuitively appear to make good economic and engineering sense, long-term operational practicality has not thus far been adequately demonstrated."*

Further, one of the largest costs of a spacecraft, other than the primary mission equipment, is the *integration* of that equipment onto the bus. Since every payload package is unique—or at least thought by its designers to be so—integration costs do not decrease via commonality. In some cases, they actually may rise since some common bus schemes would be more complex than necessary. For these reasons, the idea of the common bus was unworkable in the mid-1970s and did not go very far in the Air Force. In fact, the idea was not well accepted within NASA either. While several MMS-based spacecraft existed, the idea did not catch on in the civil space community.[5] The best known example of the MMS was the *Solar Max* experiment, which was very successfully revisited and repaired during a recent shuttle mission.[6]

Though Solar Max may appear to have been a significant victory for SMR, the jury is still out—and for good reason. While space repair, maintenance, and servicing may intuitively appear to make good economic and engineering sense, *long-term* operational practicality has not thus far been adequately demonstrated. The Solar Max repair; earth recovery of satellites such as Westar VI and Palapa B2; certain in-orbit repairs from Apollo and Skylab; and open-source literature concerning the Salyut space stations—all these demonstrate the feasibility of SMR. But *feasibility* does not necessarily imply *practicality*.[7,8]

Example: A Military Space Station

The major problem is best illustrated by examining the utility of a military space station.[9] Unlike NASA satellites, most of which go to geosynchronous orbit from low Earth orbit—and thus easily pass through a common transportation nodal point—military spacecraft must go to many different inclinations and altitudes.[10] The satellites of the Global Positioning System, for instance, employ multiple planes and inclinations at altitudes of 11,000 miles.[11] Servicing such disparately deployed spacecraft from a single node—a manned military space station orbiting at perhaps 250 miles altitude—would be colossally difficult.

> ***"Imagine trying to gas up a car traveling ninety degrees to your path as you travel 55 mph in one direction and it whizzes past you travelling perpendicularly at the same speed."***

Logistically, one can compare the difficulty to using a moving gas station constrained to travel on only one highway at 55 mph. If an individual is on the same highway (comparable to the same inclination in orbit), then he has a chance to stop for refueling. He has to maneuver very accurately to intersect the gas station, in both time and position. Although this task is difficult, it is certainly possible. But consider the vast majority of other cars riding highways which may not intersect the one on which the gas station travels, except at very high crossing speeds. Imagine trying to gas up a car traveling ninety degrees to your path as you travel 55 mph in one direction and it whizzes past you travelling perpendicularly at the same speed. The time for possible interaction is vanishingly small. Now extend this analogy to consider the crossing speeds of spacecraft employing 17,000 mph velocities and altitude variations from hundreds to more than 22,000 miles.

This limitation means that a manned space station—as it is presently envisioned—is an impractical military logistics node *for the time being*. But the fact that some servicing tasks would be very difficult from a manned platform does not mean that *all* servicing concepts would be unwise. SMR activities might be more practical and economically feasible if a proper mix of man and machine systems were employed.[12] Where a man on the actual site might not be practical or possible, remotely piloted or autonomous expert systems might be more obtainable. Trade studies to determine this proper mix of man *and* machine are being conducted at this time, but the exact nature of the results is as yet unknown.[13]

Furthermore, man's presence is not the panacea envisioned in the early days of the shuttle. The cost to the Nation for capturing and repairing the Solar Max was probably more than the cost of a replacement satellite. But a replacement satellite would have further delayed the Solar Max experiments, so the trade-off in repair was not solely economic, but heavily influenced by the need to restore the capability as soon as possible.

More recently, the attempted restart of the on-board timer of the Leasat—by hitting the power-interrupt switch with a "flyswatter" from the shuttle—did not work. Man's presence does not *ensure* success any more than the shuttle did. In fact, the reason why the Leasat failed was due in part to the shuttle's safety environment restrictions. The power-interrupt switch is required to keep satellites safely dormant to prevent danger to the crew in the shuttle, whereas satellites in expendable launch vehicles are "awake" from liftoff and have no power-interrupt switches.

Visions Become Realities

Is SMR, then, a bad idea? Absolutely not. What we have described is the infancy of a fundamental alteration of the way the Air Force does business in space. It is in fact considerably more hopeful than were the early days of aviation in terms of demonstrated practicality. Recalling the state of the art in airplanes in 1913, it was quite a leap in conjecture to predict they might be used in a pivotal warfare role. With far less experience in aerial warfare and air operations than we presently have with space, Henry "Hap" Arnold, then a lieutenant, wrote a visionary article entitled "Aircraft and War" in a 1913 issue of the *Infantry Journal*.[14] He cited uses of aircraft in peacetime maneuvers, as well as limited combat experience in tactical, brushfire wars. Arnold explained the use of aircraft for reconnaissance had been confirmed, and he further conjectured aircraft could be used for air superiority, messenger service, forward air controlling, air transport, and offensive operations.

SMR is currently impractical, but holds similar burgeoning promise. That promise has been studied and is great enough to have warranted some important actions by the Air Force. These actions will improve the practicality of SMR and may be most beneficial in the future.

In late 1982, Dr. Charles Cook, the Deputy Assistant Secretary of the Air Force for Space Plans and Policy, tasked the Air Force to examine the area of spacecraft maintenance and repair, and to determine whether the time was right for a related policy. The Air Force Logistics Command (AFLC) led a study team on which the Air Force Systems Command (AFSC), Space Command, and others participated.[15] NASA had been concentrating on some aspects of SMR and had developed a comprehensive list of special tooling needed, standard refuelling ports for space, and a set of services available through extravehicular activities conducted from the shuttle and the NASA Space Station.

The Air Force study, springboarding from the work by NASA, also examined what private industry had done. Spacecraft design contractors had also been looking seriously at the potential for SMR. Some pointed out that the same access needed to fix a spacecraft on the launchpad could be used to repair spacecraft in orbit. Others stressed that very simple techniques could be added in the early design phase of spacecraft to enhance their modularity, the accessibility of their high-failure rate internal components, and other aspects of spacecraft design necessary to make SMR practical. The team also examined a variety of parametric economic models which suggested the potential for economic payoff was high for *certain subsets* of properly designed spacecraft. The reason SMR did not pay for *all* spacecraft pointed back to another logistics function and its cost: transportation to and from orbit.

Two important criticisms of SMR examined in the study were that modular design could result in reliability penalties and spacecraft nearing the end of their lives would have such out-of-date technology that no one would want to repair them anyway. But the study group found that these reservations may be unfounded. Proper modular design, on which the commercial companies have presented some innovative and well-founded ideas, will *not* necessarily decrease reliability to any significant degree. Further, modularity permits an enthralling solution to the "out-of-date" problem. Why repair a nine-year-old satellite within one year of its predicted ten-year life span? Because, by doing so, we can *update the technology* on board as well as repair whatever is broken. By following the same form, fit, and function ideas prevalent in the aircraft industry for years, the argument against repairing an out-of-date satellite becomes one *for* technological update when the technology is available and a routine maintenance or preventive maintenance visit is scheduled. Thus, we would no longer be obliged to let satellites grow technologically old, but could have the very best technology in space at all times.

The study concluded the time was right for a policy statement to begin moving towards SMR. As transportation costs come down in the future (which they must if space is ever to become a truly operational arena), and as more spacecraft incorporate sensible means of access and design features amenable to SMR, the practical envelope of SMR will gradually encompass all but a very few satellites. As a result, on 13 September 1984, Mr. Edward C. Aldridge, the Under Secretary of the Air Force, signed the Nation's first policy regarding maintenance and repair of spacecraft in orbit and on 19 October 1984 the Air Force Vice Chief of Staff signed a subsequent, more detailed policy.[16,17]

The actual implementation of that policy came in a Space Division Regulation (SDR 540-8, *Space Servicing*, 25 October 1984).[18] Consideration of incorporating maintenance options is now becoming part of program management direction, system operations concepts, and a variety of documents which will start turning the tide of spacecraft design and operation towards the new way of doing business.

The Future

The consequences of the SMR policy are hard to determine as yet. Properly implemented, SMR should benefit a variety of lower flying spacecraft, reachable from the shuttle either directly or with small man-in-the-loop vehicles such as the orbital maneuvering vehicle. Studies underway at present will help target which classes of satellites have the highest payoffs. These parametric analyses will, of course, take into account the cost of transportation. Unfortunately, if transportation costs do not relax, SMR may forever be a great idea but a bad policy.

One possible scenario for the future might be that all spacecraft will ultimately be repairable. Since technological update features are compatible with routine maintenance and repair functions, spacecraft, once launched, might continue to stay aboard their host vehicle bus and have their lifetimes extended indefinitely by proper update of various subsystem components. In other words, once a spacecraft bus design adequately meets the needs of the payload, that bus would stay in orbit and the components might simply be changed out from time to time. The development of a new bus would come along only occasionally, allowing long production runs of common subsystems to drive down component costs. Today, we do not build a new airplane when the radio goes on the blink; in the future—if the various trade studies and analyses continue to work out that way—we may not have to build new satellites when a subsystem goes bad.

> ***"Only if SMR is considered in initial design stages can we expect servicing to ever fulfill its potential as an economical enhancer of space operations."***

There is much work yet to be done. We must answer questions such as where to dispose of old pieces of spacecraft. We must develop optimum repair level analyses for space systems, subsystems, and components. In the meantime, we should not let systems and components be designed without up-front regard for servicing. Only if SMR is considered in *initial* design stages can we expect servicing to ever fulfill its potential as an economical enhancer of space operations.

Our equipment is becoming more capable of SMR, and some believe that all significant roadblocks have been overcome. Clearly, we must drive down transportation costs, but that only makes sense with or without SMR. After 27 years of operating in space, we now have in hand the policies necessary to bring about a more operationally oriented future. Space and logistics are not like oil and water: they can be mixed, but with some caution.

Notes

[1] SAFUS Ltr, Air Force Policy on Spacecraft Maintenance, 13 September 1984.

[2] The term was coined since, in the present way of performing the space transportation functions, transportation is not viewed as a "traditional" logistics function. Also, it is viewed in a somewhat narrower context. By coining a new term, this allowed the SDI Office to include factors which have a synergistic effect on the transportation of great quantities of mass from Earth to space.

[3] *Air Force Systems Command Space Plan*, Vol. 1, pp. 5-12.

[4] Ibid.

[5] Sprott, L. and M. Bay. "Solar Maximum Servicing Lessons Learned," Presentation to Dr. Charles Cook, Deputy Assistant Secretary of the Air Force, Space Plans and Policy, by Fairchild Space Company, May 1985.

[6] *U.S. Air Force Spacecraft Maintenance Policy Review Study Report*, June 1984, pp. 4-5.

[7] Ibid, Vol. II, pp. 6-13.

[8] *Salyut, Soviet Steps Toward Permanent Human Presence in Space* (Washington, D.C.: Office of Technology Assessment, 1983), p. 33.

[9] The studies of a military space station have been too many to enumerate. However, this discussion summarizes the most common findings.

[10] *Air Force Space Plan*, August 1984, p. 4-1.

[11] U.S. Air Force Fact Sheet 83-4, *Global Positioning System*.

[12] *USAF Spacecraft Maintenance Policy Review*, p. 27.

[13] *USAF Spacecraft Maintenance Policy Review*, pp. 31-32.

[14] Holley, Professor I.B. Jr. "Looking Backward to See Ahead in Space." (Speech delivered to Second Annual Military Space Symposium, 12 October 1982.)

[15] The result was the *USAF Spacecraft Maintenance Policy Review*.

[16] SAFUS Ltr, Air Force Policy on Spacecraft Maintenance, 13 September 1984.

[17] AF/CV Ltr, Air Force Policy on Spacecraft Maintenance, 19 October 1984. This letter expands considerably on Secretary Aldridge's original policy and outlines a six-fold approach to implementing the Secretary's policy.

[18] Space Division Regulation 540-8, *Space Servicing*, 25 October 1984.

Best Article Written by a Junior Officer

The Executive Board of the Society of Logistics Engineers (SOLE) Chapter, Montgomery, Alabama, has selected "The Air Freight Terminal Model: Easing the Bottleneck" (Fall 1985 issue), written by First Lieutenant Barbara A. Yost, USAF, as the best *AFJL* article written by a junior officer for FY85.

AFJL SPECIAL SECTION: COMBAT SUPPORT DOCTRINE

By early 1986, the Air Force expects to have superseded AFM 400-2, Air Force Logistics Doctrine, with a 2-series document establishing a new entity called "Combat Support Doctrine." This first attempt to blend the diverse elements of support into a unified, coherent scheme of how forces are created and sustained represents a major and long-awaited milestone in the maturing of aerospace power.

Unsupported by theory, historical evaluation, and doctrinal scrutiny, the logistical support element of airpower has developed in a piecemeal, reactive fashion—ignored by most, preached by some, and comprehensively understood by relatively few. Lack of doctrine is reflected by difficulty in communicating logistical needs, opportunities, and shortfalls to strategists and tacticians, and by problems with defining roles, missions, and responsibilities of combat support elements. Functional parochialism, allowed to flourish for lack of interconnecting doctrine, has tended to isolate logistics functions from one another. And failure to codify a commonly accepted set of terms and frame of reference has detracted from efforts to foster cohesive mutual support.

A vibrant doctrine can go a long way toward healing these ills. This AFJL Special Section provides an overview of the doctrinal process in general and combat support doctrine in particular. In "The Role of Doctrine," Dr. I.B. Holley (Maj Gen, USAFR, Retired), who for the past 30 years has massively influenced the framework and substance of Air Force doctrine, succinctly describes the purpose and nature of doctrine and confirms its applicability to the support environment.

The new doctrine synopsized in "Combat Support Doctrine: An Abbreviated Preview" is a significant advancement because it addresses basic questions: What is "combat support"? What does it do? Do any principles apply? The "answers" represent no more and no less than the "best shot" of a relatively broad-based, well-informed group of officers charged with distilling a sense of deliberateness from a massive conglomeration of history, procedures, functions, and processes born of expediency and developed without benefit of the "pillars of recorded knowledge" that have nurtured basic and operational doctrine.

Though "blessed" at highest command and staff levels through the formal coordination process, this "first cut" doctrine boasts no immunity from criticism and change. In fact, if our doctrine is to be usable and current, it is essential that logisticians study, debate, and challenge it—much as if we all were personally participating in the initial formulation process. To help recreate this critical state of mind for readers, AFJL asked the action officer primarily responsible for advocacy of the new doctrine to describe the formulation process, key issues, and points of contention that permeated the doctrine's creation. Lt Colonel McDaniel's article, "The Doctrinal Challenge: A Rebirth of Logistics Thought," provides much food for thought in his description of the conceptual and semantic battles inherent in this kind of embryonic effort.

Combat support doctrine is, of course, only a starting point. From this "umbrella" document, logisticians and other support people will need to write more specific doctrine to capture, in more substantial detail, the concepts and methods that have proven most effective in accomplishing their missions. In "The Relevance of Doctrine to Air Force Civil Engineering," Colonel Kishiyama illustrates this cascading doctrinal process with respect to one area of support. Clearly, though, his thought processes about the need for functional doctrine and a roadmap for producing it apply conceptually to all logistical activities.

If doctrine is to fulfill its potential as a medium for rigorous analysis of warfare's support dimensions, logisticians across the Air Force must aggressively contribute cogent thought and creative interchange. We at AFJL hope this Special Section helps to kindle an enduring doctrinal flame within the combat support community.

> *"To reach the ultimate goal of war efficiency, we must begin with principles, conceptions and major doctrines, before we can safely determine minor doctrines, methods and rules. We must build from the foundation upwards and not from the roof downwards. . . . The service which neglects so essential a part of the art of war command as the indoctrination of its commissioned personnel, is destined to fail in its ambitions for great achievement."*
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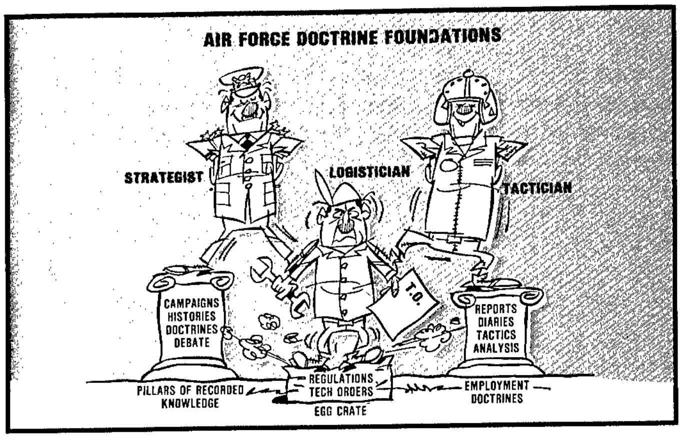
> *Commodore Dudley W. Knox, 1915*



The Role of Doctrine

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The armed forces of a nation are maintained principally to provide the means by which external threats can be countered. These forces function in two ways: they may resist attack by the direct application of force, or they may seek to deter would-be aggressors from attacking by maintaining a military potential sufficiently powerful to dissuade them from initiating such a move. To prevail in a resort to force, or to ensure the credibility of the deterrence, the armed forces of a nation must have a sufficient number of troops at an appropriate level of training armed with weapons and equipment not inferior to those of a potential enemy. But large numbers and superior weapons—and all that the existence of these assets connotes in the way of political support to provide the necessary funds and industrial support, including research, development and logistics, to provide weapons with a suitable margin of superiority—are not enough to ensure success in a resort to arms. Unless the armed forces are guided by appropriate *doctrines,* greater numbers and superior weapons are no guarantee of victory.

What, then, is doctrine? Reduced to its simplest terms, doctrine is what is officially approved to be taught—whether in a service school or an operational unit engaged in training—about what methods to use to carry out a military objective. While doctrine is most commonly thought of as relating to military action, the term is *not limited to tactical applications.* There can, and should, be doctrine guiding personnel actions, the acquisition process, logistical operations, purchasing, and other support tasks.

For the most part, doctrine is derived from past experience; it reflects an official recognition of what has usually worked best from observation of numerous trials. These may be reports of actual combat operations, or they may be limited to tests, exercises, and maneuvers. Only when necessary will doctrine consist of extrapolations beyond actual experience of some sort; for example, in the use of nuclear weapons where the nature of the weapon normally precludes the gathering of experience in any but the most limited sense.

Doctrine, as officially promulgated, has two main purposes. First, it provides guidance to decision makers and those who develop plans and policies, offering suggestions about how to proceed in a given situation on the basis of a body of past experience in similar contexts distilled down to concise and readily accessible doctrinal statements. Secondly, formal doctrinal concepts provide common bases of thought and common ways of handling problems, tactical or otherwise, which may arise. In the absence of communication with superiors, subordinates who are guided by doctrine in shaping a course of action will have a greater probability of conforming to the larger operation than if they were to act without knowledge of the doctrinal guidelines.

The term "guideline" is appropriate, for doctrine lays out a suggested course but is not mandatory. In the words of the official definition in JCS Pub 1, doctrine is "authoritative but requires judgment in application." An earlier version of Pub 1 put it even better, observing that doctrines "indicate and guide but do not bind in practice."

To understand *what doctrine is not* is no less important than knowing what it is. Doctrine is not to be confused with strategy. At its highest level, grand strategy, the term is virtually synonymous with national policy and embraces *all* the means used by a nation to carry out its policies—diplomatic, economic, social, or military.

Military strategy involves the selection of objectives and courses of action, the choice of targets, and the selection of forces to be employed. Military strategy is concerned with the ends sought and the means to attain those ends. Doctrine, by contrast, has nothing to say about the ends sought, as these can be ephemeral, reflecting the ebb and flow of policy.

Doctrine is, however, related to *means.* If strategy is concerned with *what* is to be done, doctrine involves *how* it is to be carried out. Where the defection of an ally or some other sudden turn of events may require an abrupt change in strategy, doctrine responds to a different set of variables. One such is the introduction of a novel and highly effective weapon by the enemy, a turn of events requiring a recasting of doctrine when the experience of the past no longer offers an adequate guide for coping.

Manifestly, then, it becomes a matter of crucial importance to be sure that doctrine, as officially promulgated, is kept complete and abreast of the times. Doctrine must be periodically revised to respond to advances in technology and other variables. This is a formidable task. In organizations as large as the armed forces, literally tens of thousands of individuals may be involved in the process of learning from experience and passing the word up to those in authority. While certain members of the staff at headquarters may be charged with responsibility for developing revised doctrines, the individuals involved cannot effectively carry out their duties without the cooperation of many others in the operating echelons who alone can provide the detailed feedback required to make sound adjustments and modifications to existing doctrine and, where necessary, to *generate new doctrine in hitherto untouched areas.*

Because those charged with the formulation of doctrine depend upon feedback from observers in the operating echelons which is both timely and cast in a form to maximize its usefulness, all potential contributors who upgrade doctrine should understand the role they, as individuals, are asked to play. One reason for publishing combat support doctrine is to remind each and every individual in the Air Force of this obligation. By seeing his or her part in the larger whole, the individual officer or airman will be better equipped and more inclined to exercise that initiative which differentiates the true professional from the mere time-server.

The Air Force's new doctrine of combat support is properly presented at a relatively high level of abstraction. It provides a broad overview from which lower levels of doctrine will be developed in greater specificity. The formidable challenge is extended for logisticians to codify the vast experience and lessons of combat support into a doctrinal framework.

The Doctrinal Challenge: A Rebirth of Logistics Thought

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Every profession has a set of shared beliefs and values. In fact, these values help define the profession itself. They represent those fundamental ideas that both describe and prescribe the activities within a profession. In the military profession, these beliefs and values are normally found in doctrine. Unfortunately, the Air Force has not had a strong doctrinal tradition. Many Air Force beliefs are not documented, which allows competing ideas to proliferate causing organizational ineffectiveness. This situation is especially true in logistics since most Air Force doctrine is almost exclusively employment oriented; i.e., it begins at 30,000 feet at about Mach 1. Recognition of this fact prompted Lieutenant General Leo Marquez, Air Force Deputy Chief of Staff for Logistics and Engineering (DCS/L&E), to create a doctrinal development position in the Logistics Concepts Division of the Logistics Plans and Programs Directorate. I was assigned to this position and charged with resurrecting doctrine to a place of influence within the logistics community. What follows is a history of the doctrinal process—formulation, coordination, publication, and indoctrination—that led to the development and institutionalization of Air Force Combat Support Doctrine.

> ***"The Air Staff had made several abortive attempts to publish a new doctrine beginning in 1980, but all had failed."***

No logistics doctrine had been published since 1968 when Air Force Regulation (AFR) 400-2, *Air Force Logistics Doctrine*, was last distributed. The Air Staff had made several abortive attempts to publish a new doctrine beginning in 1980, but all had failed. These attempts were largely based on the extensive work of Lt Colonel Richard V. Badalamente, a Ph.D instructor at the Air Force Institute of Technology (AFIT) School of Systems and Logistics. He had written several drafts and numerous articles in his effort to publish new logistics doctrine. But a new doctrine never materialized. The problem appeared to stem largely from his location within the Air Force organization rather than the merits of his work. In other words, the *Air Staff*, rather than academia, offered the best, if not the only, opportunity to successfully advocate and publish Air Force doctrine both then and now. Colonel Badalamente's association with AFIT did not offer him the necessary access to Air Force policymakers.

Initial Formulation

The new initiative was officially heralded at the 1984 CROSS TALK Conference when Lieutenant General Alfred G. Hansen (then Director of Logistics Plans and Programs) introduced a briefing outlining plans to publish logistics doctrine as soon as possible. Following this major command (MAJCOM) logistics planners conference, I began my research to formulate a new doctrine.

The first task of the formulation process was to define *logistics*. This was difficult because the Air Force had a very limited view, confining logistics to several narrow functional areas: maintenance, transportation, supply, logistics plans, and, perhaps, procurement. In short, no universally accepted definition existed and no Air Force dictionary was able to arbitrate. (Air Force Manual (AFM) 11-1, *US Air Force Glossary of Standardized Terms,* was last updated in 1976.) A decision was made to use JCS Publication 1 as the authoritative source for all terms, but the definition of logistics in JCS Pub 1 was too broad and imprecise for a unified, coherent doctrine.[1] Yet, as the foundation for doctrinal formulation, the definition selected would need an authoritative source for subsequent advocacy during the coordination process. After much research, a modification of the "principle of logistics," as recorded in AFM 1-1, *Basic Aerospace Doctrine of the United States Air Force,* seemed to fulfill the requirement for both precision and authority. This principle was changed to read: *"Logistics is the art and science of preparing man and machine for combat by obtaining, moving and maintaining war-fighting capability."* Not only did this definition have sufficient specificity to conform to current Air Force precepts, but it elevated *people* to a level commensurate with *equipment* with regard to their relationship to aerospace power.[2]

With a tentative definition in mind, I defined some goals for the new doctrinal manual so it would be both readable and teachable. The manual would be an umbrella document for follow-on logistics doctrine and would intentionally be written at a fairly high level of abstraction. The target audience would be commanders, first, and logisticians, second. Although the reading level would be pitched for commissioned and senior noncommissioned officers and senior civilians, the doctrine was to remain as simple, yet complete, as possible. (As the task evolved, the tension between simplicity and completeness was an ever present problem.) Moreover, no attempt was made to predetermine the level of doctrine or to conform to the format of AFR 1-2, *Assignment of Responsibilities for Development of Aerospace Doctrine*. Under this regulation, three levels of doctrine exist: basic (1-series manuals), operational (2-series manuals), and tactical (3-series manuals). As evidenced by both title and content, the focus of all three levels has been almost exclusively *employment*. Therefore,

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[1] JCS Pub 1 defined logistics as: "In its most comprehensive sense, those aspects of military operations that deal with: a. design and development, acquisition, storage, movement, distribution, maintenance, evacuation, and disposition of materiel; b. movement, evacuation, and hospitalization of personnel; c. acquisition or construction, maintenance, operation, and disposition of facilities; and d. acquisition or furnishing of services."

[2] This was especially important to me because the Air Force has had an inordinately mechanistic, materiel-bias in the preparation and conduct of warfare despite a declaratory policy that people always come first—for compensation, maybe, but not for employment in war.

since the doctrinal manual was breaking new ground, I chose to ignore the existing AFR 1-2 architecture and concentrate simply on how to best present logistics to the entire Air Force community.

The First Cut

The initial draft was based on an architecture comprised of three basic elements: *process, principles, and missions*.

Process. The process was to describe the basic tasks or activities of logistics with regard to man and machine. Unlike AFR 400-2 and previous drafts, the process would not be described linearly but would be circular to represent the life cycles of man and machine. Instead of having the traditional chronologically-based elements of *requirements determination, acquisition, distribution, maintenance* and *disposal,* the logistics process became four subprocesses: *acquisition, distribution, restoration,* and *disposition,* all of which would be driven by requirements or combat needs. The linear model improperly suggested that only *acquisition* was preceded by *requirements determination*. *Restoration* replaced *maintenance* to be compatible with man as well as machine. Finally, *disposition* replaced *disposal* to encompass more than simple divestiture. *Disposition* would become both the beginning and end of the life cycle and would be the subprocess that involved decisions to acquire, retain, and dispose of manpower and machines. Finally, the logistics process would be strictly descriptive, not prescriptive—dealing with *what* logistics is, not *how* it is done.

Principles. Similarly, principles of logistics would be objective principles rather than operating principles, describing *what* to do, not *how* to do it. Operating principles would be developed in subsequent, lower level, doctrine. Moreover, these principles would conform to Dr. I.B. Holley's idea of a doctrinal principle—a self-evident truth that can only be declared and accepted as opposed to being empirically verifiable.[3] The first draft contained seven principles: *goals, balance, leadership, control, effectiveness, flexibility,* and *synergy*. These principles were largely derived from a compilation of principles from the armed forces of the United States and other countries, both friendly and otherwise. A list was made of all the principles having an application to logistics. Then these principles were aggregated into categories using a means-ends methodology. Two questions were asked: "Are some principles subordinate or contributory to other principles?" And, "Can a capstone statement be made that embraces the central theme of a principle or set of principles?" The answers to these questions led to the development of seven capstone statements that captured the main ideas of the principles. Although the titles changed for two of the principles—*goals* became *objective* and *synergy* became *synchronization*—the capstone statements changed little throughout the entire formulation and coordination process; however, additional paragraphs were added that offered examples of the principles' application to combat support.

Missions. Support missions formed the third element of the first draft. They attempted to replicate for logistics what the employment missions did for operations in AFM 1-1. Missions established objectives for the logistics process—those that must be accomplished to obtain, move, and maintain war-fighting capability. They included *Infrastructure Disposition* (development of basing systems), *Weapon System Acquisition, Mobilization, Intertheater Distribution, Coalition Logistics, Weapon System Generation, Intratheater Distribution, Recovery and Reconstitution* and *Demobilization*. These missions were primarily those activities defined as the responsibilities of the DOD in the National Defense Act of 1947. In addition to these nine support missions, other specialized support tasks were defined that did not neatly fall under the missions (and/or required special emphasis). These tasks included *Health Services; Security Support; Logistics Command, Control, and Communications;* and *Combat Support Education and Training*. All these missions and tasks were meant to describe the desired output of the logistics process. Clearly, these missions and tasks covered a very wide scope of activities, many of which some people would consider outside the scope of the traditional logistics support structure.

Besides the three basic elements—process, principles, and missions—each occupying a separate chapter in the first draft, there were also three other chapters plus some appendices. These chapters introduced doctrinal precepts, provided definitions, and described the military, economic, and political environment, giving considerable attention to the future battlefield, the support officer, the weapon system, and the support organization. The appendices described procedures for revising the manual, an architecture for lower level logistics doctrine, a reading list, and selective JCS Pub 1 definitions.

One final significant change to the first draft occurred prior to the first briefing to the DCS/L&E. The word *logistics* was largely removed from the document and replaced with the term *combat operations support*. It was apparent from the many diverse readers of the evolving draft that the term *logistics* had a very narrow connotation in the Air Force. If this document was to bring doctrinal coherency and unification to the Air Force community with an emphasis on man as well as machine, then a more descriptive term than *logistics* had to be found, especially for those involved in personnel, engineering, security, and acquisition activities. In short, Jomini's view of the *Art of War* being comprised of a triad of strategy, tactics, and logistics[4] had never been widely accepted in the Air Force, and any change did not seem remotely possible in the future.

The term *combat operations support* offered the proper orientation for the commander and logistician without offending other functional areas. Moreover, the term was politically and militarily sound for either programmatic or war-fighting purposes. It demonstrated by inference that all support activities (no matter how distant in time and location) contribute to combat operations. And it helped imprint on both operators and logisticians that support and operations have an integral relationship.

Replacing *logistics* with *combat operations support,* though, led to another conflict with a concurrent doctrinal effort being managed at the Air University Center for Aerospace Doctrine, Research, and Education (CADRE). Lieutenant Colonel Ted Moscheau, of the Airpower Research Institute (ARI) at CADRE, had been tasked to write combat support doctrine "without discussing logistics." This flawed concept had evolved due to an AFR 1-2 requirement to produce a logistics manual and a combat support manual with responsibility for publication divided between DCS/L&E and

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[3] For deeper understanding of doctrinal terminology, see Dr I. B. Holley, "Concepts, Doctrines, Principles: Are You Sure You Understand These Terms?" *Air University Review* (July-August 1984), pp. 93-96.

[4] Henri de Jomini introduced this triad in *The Art of War;* it was further expanded upon by RADM Henry E. Eccles in many sources, including *Logistics in the National Defense*.

CADRE. Despite the unreasonableness of the task, Lt Col Moscheau had produced, based on extensive MAJCOM interviews, a draft manual that addressed combat support functions residing outside the traditional logistics career fields. The concept of having two manuals was so obviously inappropriate and unwieldy that we agreed to collaborate on a single manual to embrace all support functions. It was at this juncture that the idea crystallized to divide the aerospace "world" into *support* and *operations*. The long-term goal would be to ultimately merge the two, once support doctrine had been fully institutionalized to a level equivalent to employment (operations) doctrine in the basic, operational, and tactical manuals.

The Worldwide Conference

With CADRE involvement, a second draft was produced without any architectural changes, and the decision was made to jointly host a conference to garner a broad base of support for the new doctrine. The draft manual was sent to every major command vice commander as well as key Air Staff agencies and the JCS. Each organization was asked to review the document and send a working representative (lieutenant colonel or major) to a week-long conference at Air University to finalize the draft. Although the DCS/L&E and his directors had been briefed and been given copies to read, no formal LE staff position had been established nor was one solicited by the time the conference convened.

A Diverse Gathering. The conference opened on 1 April 1985 at Maxwell AFB, Alabama, home of the old Air Corps Tactical School where United States air doctrine was first formulated. With high expectations for a historically significant conference, I introduced Dr. David McIsaac who presented a historian's view of the upcoming undertaking. Those who listened that first day represented every MAJCOM except Space Command. All the LE Directorates, as well as the Surgeon General; Plans and Operations; Manpower and Personnel; Research, Development, and Acquisition; the Air Force Office of Security Police; the Air Force Logistics Management Center; the Engineering and Services Center; the Air Base Survivability Program Office; and the Office of the Joint Chiefs of Staff, sent participants. Most people were from their respective plans (XP) or logistics (LG) directorates.

The stated objective of the conference was to finalize the draft. The approach was to (1) give the doctrine a title; (2) approve the architecture; (3) address specific content, format, and style; and (4) determine into what doctrinal series to place the manual. It became obvious from the start that a wide range of experience, intellect, and motivation comprised the group. But the greatest problem was clearly the lack of experience of the participants with regard to the history and language of warfare as applied to logistics in general and doctrine in particular. It was not until Dr. I.B. Holley spoke on day two that the conferees began to appreciate the purpose and significance of doctrinal terminology.

From the start, the group perceived that a document was going to be published; however, members were not sure to what extent they would be allowed to contribute. And in the beginning, many were unconvinced of the need. Still, nearly all had brought formal, written comments from their organizations.

Fundamental Doctrinal Issues. The first major issue was the title of the doctrine. Somewhat surprisingly, the group easily discarded *logistics* for *combat support*. The term *combat operations support* was thought too cumbersome and the word *operations*, redundant. Moreover, *combat support* had never been defined in JCS Pub 1 and therefore was "available" for use.

Considerable discussion ensued as to which functions should be included under combat support. Then, once it was understood that *all* support activities were to be addressed, substantial debate occurred as to whether combat support should be further subdivided into *direct* versus *indirect* support, *wholesale* versus *retail* support, or some other dichotomy. The idea persisted that some support activities contributed more to combat operations than others. But, once the group wrestled with the issue of placing support functions into different categories, no agreement was possible or desirable. Every function had a role and the role would vary with the operational requirements. And although some activities, such as system acquisition, might occur years prior to and outside the theater of operations, the resources procured would remain indispensable to war-fighting capability.

The next major discussion centered on the definition of *combat support,* "the art and science of preparing man and machine for combat by obtaining, moving, and maintaining war-fighting capability." While the conferees favored the emphasis on man as well as machine, they felt the definition was incomplete (facilities were excluded) and too "logistical" in its verbiage. As the group agonized over this single definition, its corporate consciousness was raised as to the lack of preciseness in many support terms and the inadequacy of AFR 11-1 and JCS Pub 1 to resolve connotative differences. Therefore, rather than get bogged down on the definition of *combat support,* the group agreed it would revisit the definition once it had identified the basic tasks or activities that make up the combat support process.

A brainstorming session followed to identify all the processes that must be completed prior to and during aerospace employment. This session, lasting a full day and half, expanded the four basic processes of the first draft manual—*acquisition, distribution, restoration,* and *disposition*—to eight processes with the addition of *definition, maturation, integration,* and *preservation* (word symmetry, i.e., four syllables and "-tion" endings, was intentionally sought to aid in "teachability"). These eight processes evolved by labeling and categorizing a list of basic tasks identified during brainstorming. At the outset, the group was comfortable both with these terms and the notion of defining *processes* rather than *functions*. They also agreed that doctrine should be cross-functional and confine itself to basic tasks or processes. In this way, future functional alignments would not be constrained by doctrinal precepts; yet, doctrine would provide insight for Air Force organizational adjustments to a changing force structure.

A New Definition. Once eight distinct processes had been generally agreed upon, along with their subordinate activities, the conferees again revisited the basic definition of *combat support*. When Admiral Henry E. Eccles' definition of *logistics* was introduced as a candidate for *combat support,* the group generally agreed it accommodated all eight processes. The Eccles definition described combat support as "the art and science of creating and sustaining combat capability."[5]

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[5] This definition remained unaltered throughout the remaining staffing and formal coordination process, although the word *moving* was suggested by a few agencies as a possible addition to the definition. The rebuttal to this suggestion was that the word *sustaining* embraces the notion of movement or distribution.

With a definition and the processes outlined, the conferees considered the support missions and associated ideas to be superfluous and felt they could be subsumed by the processes. Thus, missions were dropped from the architecture, leaving *processes* and *principles* as the basic elements of the document. Also, the idea was introduced that a building block approach consisting of definitions should be used prior to discussing the combat support process and principles. This introductory chapter would introduce the three traditional resources, *people, materiel,* and *facilities,* plus the added coequal resource of *information*.

At this point, the conference was into its fourth day and the polemics had begun to take their toll on the conference hosts and participants. Therefore, the only remaining substantive issue discussed was the adequacy of the original seven principles. Whether exhaustion and/or apathy had set in, discussion began to diminish although two additional principles were introduced—*sychronization* and *friction*. After these proposals, dialogue centered on the figures and format, neither of which provoked strong feelings. Finally, the conferees agreed the document was most appropriately a 2-series (operational doctrine) manual but, when published, should be the basis for revising AFM 1-1.

"The conference validated the contention that, as a community, the Air Force did not agree on what its fundamental support tasks were or how best to carry them out."

An Enlightening Experience. If for no other reason, this milestone conference was a watershed because it demonstrated the need for a unified, coherent doctrine for support activities. It revealed the narrowness of most participants' perspective of war (which likely was significantly more lucid than the majority of people in their parent organizations). And the conference validated the contention that, as a community, the Air Force did not agree on what its fundamental support tasks were or how best to carry them out. While the conferees departed not knowing precisely what the next formulation stage would be, most stated in writing their strong support for the publication of doctrine at the earliest opportunity.

The Committee of Six

While most MAJCOM participants felt the conference had made significant progress in defining improvements to the draft manual, representatives from the Air Staff LE Directorates were not as convinced. Although they believed in the need for logistics doctrine, they perceived the conference had missed the mark. Recognizing this discontent, I solicited the support of General Hansen for an ad hoc group (composed of these malcontented but highly talented officers) to produce a final draft of the combat support manual. Two weeks were allotted to the task involving six officers from five disciplines (maintenance, supply, transportation, civil engineering, and logistics plans) on a full-time basis.

"The architecture outlined at Maxwell demonstrated its resiliency by remaining solidly intact."

Building on the conference, the ad hoc group began to put "flesh" on the architecture established at the conference. Significantly, the architecture outlined at Maxwell demonstrated its resiliency by remaining solidly intact. Most of the group's time was spent developing a new first chapter which was to serve as a broad overview of combat support. This chapter became the mechanism for establishing the context for the two succeeding chapters—process and principles—by describing the relationship of combat support to combat operations as they both relate to aerospace power. Special emphasis was placed on aerospace systems; i.e., the fact that the system is more than a vehicle but includes all the people, materiel, facilities, and information needed to employ a weapon. The term *aerospace system* was used in lieu of *weapon system* since the latter had the unfortunate connotation of only including lethal systems, thus excluding transportation, communication, and other support systems. Moreover, emphasis was given to the combat support structure as defined by the *bases* and *lines of communications* where resources are aggregated and channeled to sustain aerospace power. These bases encompassed the industrial complex as well as operating and support bases. Other than producing Chapter 1, the major contribution of the group was the formulation of the principle of *trauma/friction*. In adopting this principle, the committee expressed a doctrinal need to debunk the myth that the Air Force functions in peacetime as it does in wartime.

Beyond these additions, the group's remaining effort was mainly editorial, although further examples were added to amplify several of the combat support principles. In spite of much intense debate and skepticism, the group was able to deliver a product to the LEX Director on schedule, and he wholeheartedly endorsed what he believed would become official doctrine of the United States Air Force.

Formal Coordination

Having received and incorporated comments from the MAJCOM conference representatives in a third draft, we were ready to begin formal coordination of what was then a fourth draft of *Combat Support Doctrine*. Formal coordination meant the Air Force Plans and Operations (DCS/XO) community would assume administrative control of the draft as specified in AFR 1-2. Because of the extensive coordination to date, we attempted to shorten formal coordination by advocating that DCS/XO send the fourth draft out for "concurrence/nonconcurrence" rather than "for comment." However, this effort was foiled due to some conservatism on the XO staff and the untimely transfer of the only XO participant at the conference.

As the XO staff adjusted to personnel changes, the DCS/L&E held its FUTURE LOOK Conference with most MAJCOM logistics deputies (LGs) in attendance. General Marquez asked for the personal involvement of the MAJCOM LGs during upcoming XO coordination of the new doctrine. Within a month after FUTURE LOOK, the DCS/XO solicited formal coordination from the MAJCOM Plans (XP) communities and key Air Staff offices. In a few weeks, the majority of comments had been received with the responses being very favorable and most agencies offering only editorial improvements.[6] These were consolidated and adjudicated

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[6] The only organizations expressing major concerns were Space Command and the Air Staff intelligence community, both of which had not participated directly in the formulation process. Essentially, both the space and intelligence communities had been wrestling with where they fit in both combat support *and* combat operations. The Air Force Space Plan signed by the Air Force Chief of Staff suggested Space Command performed a combat support function while the support doctrine clearly placed the Command in the operational arena, especially in its new role as a unified command. Similarly, the intelligence community appeared ambivalent as to its proper categorization as operations or support, but had no formal documentation to assist in this dilemma.

between the XO and LE staffs, and a fifth and final draft was sent out for final coordination/concurrence.

> **"The process of formulating new doctrine will force logisticians to debate those issues they have been unable or unwilling to deal with at the policy or procedural level."**

Publication and Institutionalization

Although the publication of combat support doctrine appears imminent, the doctrinal process has only begun for combat support. Formulation and coordination are complete, but publication will merely represent a milestone, albeit a major one. The real test will come as the new doctrine is inserted into the curricula of the Air Force professional military and technical schools where the indoctrination process must begin. And proper indoctrination will require the development of 3-series manuals, since the 2-series manual is only an umbrella document meant to scope the boundaries of combat support. The follow-on doctrine (3-series manuals) will address the issues of *how* to best perform the support tasks by describing in greater detail the various processes and principles guiding those processes. For example, the 3-series manuals might elucidate the doctrinal underpinnings for "push" or "pull" supply, the appropriateness of cannibalization, the efficacy of two versus three levels of maintenance, the effects of contractual "breakout" on mobilization and weapon system reliability, the relationship of civil and combat engineering, and the personnel replacement philosophy for combat units, to suggest a few. Yet, the 3-series manuals will have to evolve without appearing to establish Air Force policies and/or procedures. And because many of the issues will be subject to internal and external politics, not to mention uncertainty and ignorance, the formulation of follow-on doctrine will present many challenges to the support community. But the process of formulating new doctrine will force logisticians to debate those issues they have been unable or unwilling to deal with at the policy or procedural level. And creating a forum for debate was, after all, the primary goal of our entire effort.

Final Thoughts

The publication and institutionalization[7] of combat support doctrine represents a pioneering effort to fundamentally and irrevocably alter the mind-set of Air Force members. Doctrine was chosen as the means of achieving this metamorphosis. But the influence of Air Force doctrine has been limited. Historically, doctrine has not played a major role in the Air Force since World War II with regard to planning, programming, organizing, equipping, training, or sustaining aerospace forces. Regardless, the study of doctrine remains the best means of mentally preparing the Air Force for war. This is especially true since most Air Force people are not prone to reading military history or biographies. If doctrine can distill the experience of history and be effectively presented to Air Force members, the Air Force may come to better understand itself and begin to focus on understanding its enemies. As Sun Tzu once noted, "Know the enemy and know yourself; in a hundred battles you will never be in peril. When you are ignorant of the enemy but know yourself, your chances of winning or losing are equal. If ignorant both of your enemy and yourself, you are certain in every battle to be in peril." Combat support doctrine will, for the first time, give the Air Force a more complete knowledge of itself—the support dimension of creating and sustaining aerospace power.

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[7] To help institutionalize combat support doctrine, a research fellow position in CADRE is being sponsored by DCS/L&E for one year beginning in the summer of 1986. This position will be filled by a graduating student from Air Command and Staff College. In the long run, this position will become a permanent logistic position in the Airpower Research Institute of CADRE. In the near term, the research fellow will help manage the institutionalization of support doctrine. Some of the projects will include producing a video of the 2-series manual, managing student research for 3-series manuals, incorporating doctrine in ATC/AU curriculum (to include the wargaming center), and advocating combat support doctrine throughout the education and training community.

Combat Support Doctrine: An Abbreviated Preview

Every warrior has a combat perspective. Doctrine gives this perspective by providing a working knowledge of combat support and its relationship to aerospace power. This preview of Air Force Combat Support Doctrine defines the role of combat support and outlines basic tasks necessary to support combat operations. In addition, it presents the principles that guide the performance of the combat support tasks.

Role of Combat Support

The Air Force is comprised of a variety of aerospace systems. The aerospace "vehicle" is the most visible part of a system. These vehicles can be manned or unmanned aircraft, missiles, or other aerospace platforms. But a system is much more than a vehicle; it includes the people, materiel, facilities, and information needed to employ an aerospace vehicle. To accomplish employment missions, aerospace systems are formed into aerospace forces. These forces constitute war-fighting potential in the form of complementary systems organized to meet the operational requirements of specified and unified commanders. An aerospace force performs two basic activities: combat operations and combat support. *Combat operations* is the activity that deters and fights by deploying and employing aerospace forces. *Combat support* is the activity that creates and sustains war-fighting capability by organizing, training, and equipping aerospace systems for employment (Figure 1).

In the broadest sense, *combat support is the art and science of creating and sustaining combat capability*. Both a peacetime and wartime activity, combat support exists at the forward-most employment locations and extends throughout the combat theater back to the national industrial base and its sources of international supply.

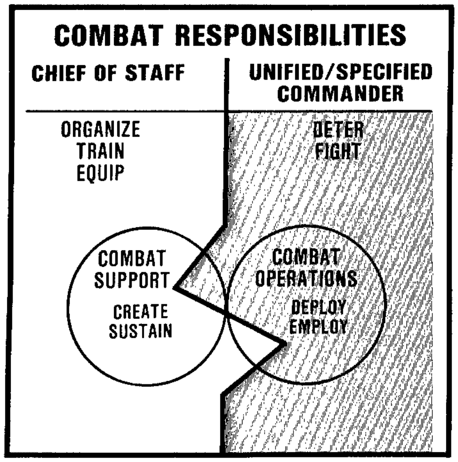

Figure 1.

Common to all aerospace systems are *bases* and *lines of communication (LOCs)*. Bases are

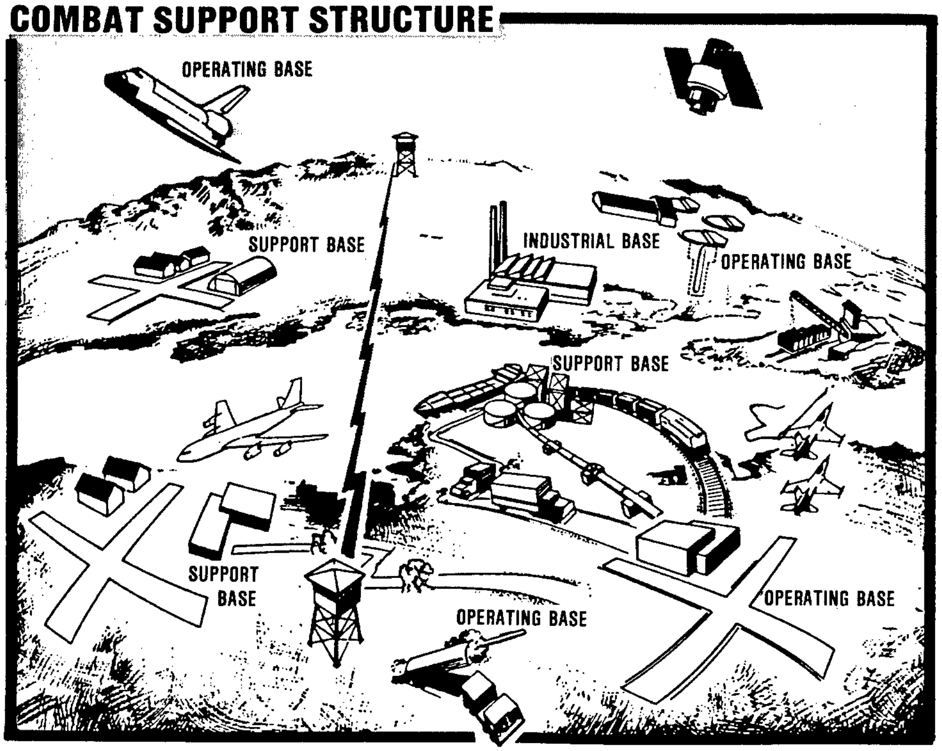

Figure 2.

the sites from which operations are originated and/or supported while the LOCs are the routes for transmitting resources between bases. Bases are the critical junctures at which aerospace power is most dependent. For it is at the bases that resources are concentrated in order to manifest combat power. Therefore, the bases and their LOCs must *survive* to sustain combat operations. Aerospace bases fall into three broad groups: operating, support, and industrial (Figure 2).

Because an operating base for one aerospace vehicle may be a support base for another vehicle, the category of a base is unimportant. What is significant is to know what role each base—operating, support, and industrial—plays in the employment of an aerospace vehicle. More importantly, the warrior must understand the fundamental relationship between the combat support activity and the combat operations activity—the reality that combat operations ultimately depend on the combat support structure, its bases and LOCs, to sustain aerospace forces in battle.

Combat Support Process

Air Force combat support transforms resources into combat capability. It consists of eight basic processes by which Air Force combat operational needs are met: definition, acquisition, maturation, distribution, integration, preservation, restoration, and disposition. In essence, the entire support process encompasses the life cycle of an aerospace system—its people, materiel, facilities, and information (Figure 3).

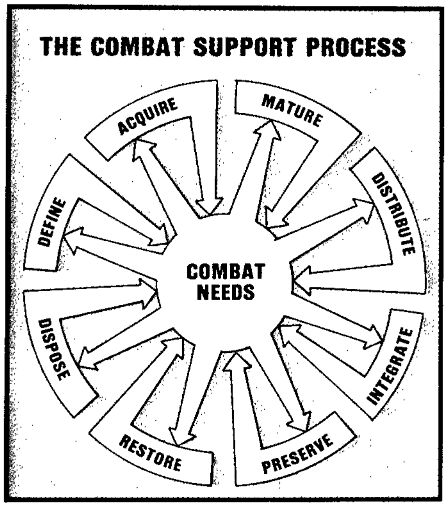

Figure 3.

The support process begins, proceeds, and ends with the determination of combat operational needs. These requirements for combat drive the whole process. Combat needs govern the formulation of Service objectives as the Air Force plans its force scheme during the DEFINITION process. These plans then lead to the procurement of various aerospace systems through the ACQUISITION process. Once acquired, the Air Force places these systems at various locations where they are operated, tested, exercised, and refined for combat as part of the MATURATION and integration processes. With the anticipation or actual outbreak of war, aerospace systems are integrated and moved (if not already positioned as part of an aerospace force) via the DISTRIBUTION process to their wartime operating sites. At these sites, these forces may be joined by other allied or Service forces to complete the INTEGRATION process. Then, these forces are made available—protected and sustained for combat operations—through the ongoing PRESERVATION and RESTORATION processes. Finally, if an aerospace system proves ineffective or outdated in its combat role, it may be removed from the Air Force inventory or assigned a new role as part of the DISPOSITION process. A description of each process within the support life cycle follows.

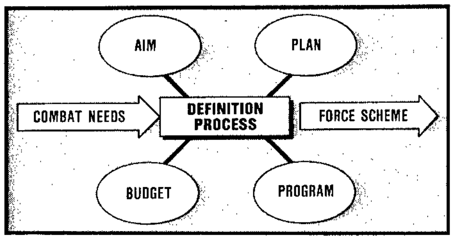

Figure 4.

The combat capability of tomorrow's Air Force reflects the quality of today's planning. The *definition* process begins with the formulation of Air Force aims within the context of national objectives, policies, and strategies (Figure 4). In this process, the Air Force determines the aerospace capabilities it must provide the unified and specified commanders to achieve sufficient combat power. This process is primarily an Air Force planning activity that balances national priorities against combat needs and translates them into a future scheme for aerospace forces. Based on doctrine, these plans determine the organization and composition of aerospace resources—the quantity and quality of people, materiel, facilities, and information. They specifically address force structure—numbers and mixes of aerospace systems—in terms of modernization, readiness, and sustainability. Very general and conceptual long-range plans as well as very specific, near-term plans that detail budgetary programs are also included. The whole process is concerned with defining combat capability: what it is and how to measure and acquire it.

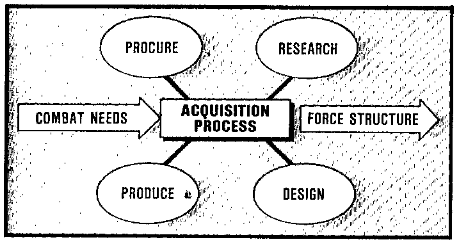

Figure 5.

Acquisition of resources for Air Force use is both a political and economic process. It involves obtaining resources from the national and international economy and converting them into potential war-fighting assets (Figure 5). The Air Force acquires people based on combat needs and budgetary limitations. The goal is to obtain people with the required skills or abilities to acquire those skills. As for equipment and facilities, the Air Force cannot always procure items in the private economy that can meet the rigorous demands of combat. Therefore, the Air Force sometimes must manage the development and production of equipment and facilities so they will be effective in the combat environment.

The acquisition process should begin with an idea or concept to improve combat capability. The concept is then evaluated based on research and analysis to ascertain its feasibility. If judged feasible, the concept enters a design and development phase to be transformed into a product. Once developed, this product is reviewed and tested to demonstrate its combat value. If the tests are successful, a production decision may follow provided the new equipment or facility fits into the evolving force scheme as determined by the definition process. Sometimes, an older system may be modified to improve its combat performance or efficiency. Whether modifying an existing system or creating a new one, the process is essentially the same. Yet, acquisition is not confined to people, equipment, and real property. Obtaining information is equally vital. Information is a resource that must be created from raw data so it can augment the effectiveness of the other combat resources.

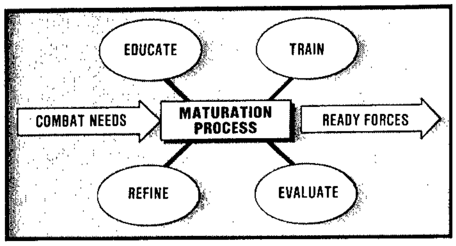

Figure 6.

A well-trained and tested aerospace force is better able to endure in combat. The *maturation* process takes the military resources obtained from the acquisition process and prepares them for combat as part of an aerospace system or force (Figure 6). For people, maturation is an ongoing process that stretches over entire Air Force careers. This process is meant to instill the will—the war-fighting spirit—as well as the skills of a warrior as people are trained, educated, and indoctrinated to lead and manage at the unit, theater, and global levels. For equipment and real property, the process includes operational use and evaluation to discover system deficiencies. This may lead to equipment and facility modifications and reentry into the acquisition process. Or, procedures and techniques may be refined to enhance system design characteristics. Moreover, information must also mature and become both more precise or more abundant in describing the aerospace world. However, only when all the resources are integrated as part of a force do aerospace systems begin to demonstrate the capacity to generate combat power.

The positioning of resources where and when they are needed is vital to combat operations and an essential task of combat support. The *distribution* process encompasses activities to find and transfer resources—people, materiel, facilities, and information—from one location to another for deterrent or war-fighting purposes. The process involves four basic tasks: demand, movement, storage, and issuance (Figure 7).

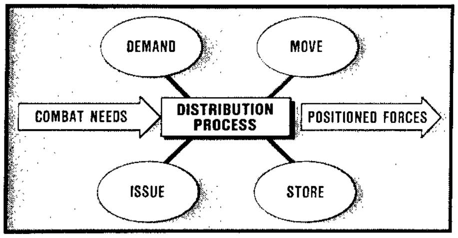

Figure 7.

A specific combat need must be identified by a demand on the part of either a provider or user. The type resource, quantity, destination, and timing must be determined. Once this data is known, the distribution system can match resources with requirements. When a source is located, it is prepared for movement. Prior to movement, while in transit, and upon arrival at destination, resources must be marshaled, organized, and protected until they can be delivered to the user. The storage function performs this role by holding and maintaining assets in a secure environment until called for by the user. The final activity of the distribution process is that of issuance. This task is concerned with giving possession of a resource to a user. This activity involves handling, unpackaging, delivering, and transferring responsibility for an asset.

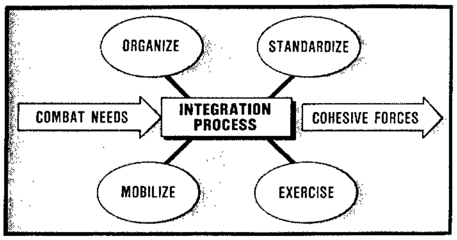

Figure 8.

Cohesion enhances economy of force in combat. For aerospace forces to achieve an economy of force, every combat element must be *integrated* to form a cohesive war-fighting team (Figure 8). This integration includes fundamental organizational realignments to provide the Air Force improved access to national and allied resources—manpower, materiel, facilities, and information.

If the integration process is to be successful, it must begin well in advance of hostilities with the definition process and continue throughout the entire support process. First, within the Air Force the combat operations and combat support activities must be melded together to form a cohesive team. This melding includes both active and reserve components at every echelon of command. Then, the Air Force must be able to support and employ forces in concert with the other Services and allies in joint and combined operations. Also, these combined forces require integration with their own national economies as well as with the civilian economy of the host country where they are deployed. Effective integration demands joint and combined plans and agreements, acquisition programs leading to common aerospace systems, standardized procedures, and extensive training for both military and civilians inside and outside of allied governments.

Forces must survive before they can prevail in combat. The *preservation* process includes all activities required to protect aerospace resources from nuclear, chemical, biological, and conventional threats. It includes active and passive defense, concealment, deception, and all other techniques for securing vital combat resources (Figure 9). Protection begins with the definition process and proceeds throughout the acquisition and maturation processes as weapon systems are planned, designed, and evaluated to endure the combat environment.

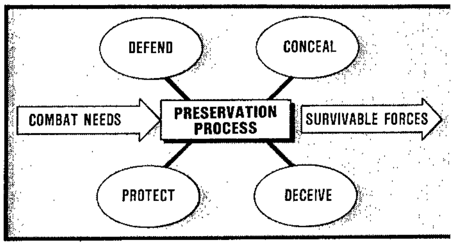

Figure 9.

For people, the preservation process means protecting individuals against disease, injury, stress, and combat threats. Safety discipline, preventive medicine, physical fitness, sanitation practices, and law enforcement combine to contribute to people's well being. People are armed and trained to work with security forces to defend themselves from enemy threat and are provided protective clothes. Their working and living locations are concealed and/or hardened.

Similarly, equipment and real property are dispersed, concealed, hardened, and defended from enemy attacks. Information, too, requires protection; it must be withheld from the enemy, yet made readily available for use by friendly aerospace forces. Also, misinformation should be used to confuse the enemy and protect vital resources.

Ready forces can deteriorate unless periodically *restored*. Many factors, such as age, intensity of use, design limitations, exposure to combat, and the adaptability of an aerospace system, determine restoration requirements.

Equipment and facilities must be continually inspected and problems diagnosed. Once a remedy is chosen, degraded or unusable equipment and facilities are quickly repaired, upgraded, and tested. In addition to repair, the system may be serviced and/or configured for employment. In short, the restoration process ensures vehicles, shelters, spare parts, support equipment, pavements, and utilities are all made available for combat (Figure 10).

People, too, have basic needs which, if not satisfied, can lead to defeat in combat. These needs affect attitude—the motivation to win. Attitude is a fragile thing that can quickly

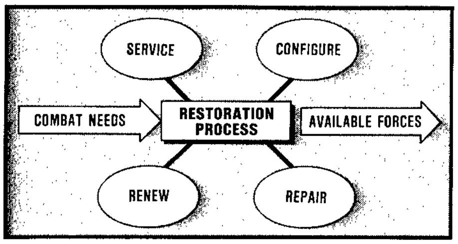

Figure 10.

evaporate if a person is hungry, tired, scared, sick, and/or hurt. Therefore, people cannot be left untreated if ill or injured. Health depends on corrective medicine and dentistry. People also need food, rest, and recreation. They need to be emotionally, physically, and spiritually renewed, especially in combat.

Another perishable resource is information which needs continuous renewal to remain current, especially in a dynamic war-fighting environment. Information must also be digestible, requiring reconfiguration to meet the format needs of multiple users. When information has been contaminated by enemy intrusion or friendly error, it must be repaired and serviced by removing misinformation and replacing it with correct data.

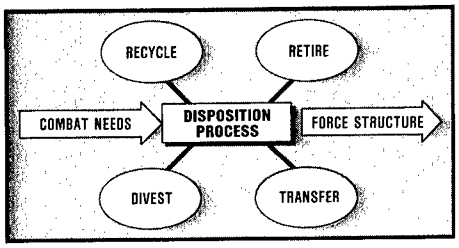

Figure 11.

Effectiveness in war is the single criterion for determining resource *disposition*. This process recycles, transfers, retires, or divests elements of the force structure no longer required to meet combat needs in their current role (Figure 11). Disposition of vehicles, people, materiel, facilities, and information is accomplished by continually reassessing the force structure's ability to meet current combat operational needs. Disposition is more than the disposal of used resources. Each resource is a critical national asset from which maximum use must be obtained. The inability of a resource to satisfy a combat need in its present role does not preclude significant utility in another role. Disposition must, therefore, be carried out in a prudent and rigorous manner, extracting the greatest benefit from each resource prior to its disposal.

Principles of Combat Support

Principles are the distilled experience of warriors. They represent a set of statements describing how combat support works best. The eight principles of combat support are as follows:

OBJECTIVE
LEADERSHIP
EFFECTIVENESS
TRAUMA/FRICTION
BALANCE
CONTROL
FLEXIBILITY
SYNCHRONIZATION

The principles of *objective, leadership,* and *effectiveness* provide direction to the application of combat support. *Trauma/friction* describes the external and internal influences that affect support. *Balance, control, flexibility,* and *synchronization* focus on the means of perfecting the combat support tasks.

Objective

> **Know what you want to do before you do it and keep reminding everyone until it's done.**

A fundamental principle for success when planning or executing any aerospace operation is a clear and concise statement of the objective. For combat support personnel, the objective is to give commanders the greatest freedom possible to deploy and employ aerospace forces. The principle of objective is applicable to every combat support activity at each level of command regardless of task—planning, organizing, directing, coordinating, or controlling. This principle is valid whether supporting an entire theater of operations or merely managing a staff meeting. It may involve a 15-minute technical change order or a five-year facility construction program. The principle of objective has three requisites: (1) stating the objective at the outset; (2) ensuring everyone understands the objective; and (3) never letting the team lose sight of the objective.

Leadership

> **You are the single most important factor in achieving military victory.**

In the most difficult of all human endeavors—preparing for and engaging in war—leadership offers the path to victory. Heroic battlefield leadership has been a hallmark of American fighting forces. But, in an age of nuclear weapons and highly mobile and lethal conventional forces, the leadership exercised in preparing aerospace forces for war may prove to be decisive. Peacetime organizations can only remain dynamic and viable through personal leadership; groups are less capable of managing organizational change because group action demands consensus and avoids risk-taking. Thus, the imagination and creativity of the individual leader can bring vision to an organization and motivate people to accomplish extraordinary deeds.

Effectiveness

> **Do only those things that improve combat capability.**

Because survival is at stake, cost cannot be the primary consideration in national security decisions. Air Force leaders must effectively articulate military needs, but other public officials should determine what the country can afford and the risks the country can assume. This civilian prerogative allows the Air Force community to concentrate on combat capability—what it is and how to develop, measure, and apply it. Although affordability is the purview of the civilian leadership, efficiency and productivity are not confined to the private economic sector. For efficiency is important to the extent it contributes to combat effectiveness. Therefore, Air Force managers must always extract the greatest return possible for every military dollar spent. Cost avoidance not only leads to resource conservation but, more importantly, enhances system availability that directly translates into aerospace power. In short, combat effectiveness is the standard for judging all support actions as they apply to aerospace forces.

Trauma/Friction

> **Understand: War is hell!**

The high intensity and massive destructiveness of modern warfare create a punishing and uncertain environment through trauma (shock and damage to combat elements) and friction (the chaos resulting from the failure of events to follow plans), especially during the critical early stages of a war. Trauma from enemy assaults on the combat support structure is characterized by deaths, organizational disruption, destruction of critical materiel, and loss of communication between combat elements. Recovery from trauma is complicated by the confusion and disorientation caused by the friction of war. Friction results from organizational realignment, inadequate plans, malpositioned resources, poorly trained people, lack of cohesion, ineffective equipment, incorrect doctrine, and indecisive leadership occurring simultaneously as the combat support structure adjusts to the wartime environment. To withstand the combined effects of trauma and friction, the combat support structure must be capable of transitioning rapidly from peacetime to wartime and operating in a self-sustained, independent mode as it adjusts to war-fighting conditions.

Balance

> **Get the right thing in the right amount to the right place at the right time.**

The principle of balance is most obvious in the distribution process, especially as it relates to a major intertheater force deployment. A balanced distribution network is regulated and integrated to allow continuous and controlled flow of forces and supplies into and within a theater of operations. Efficiency is enhanced to the degree that interface requirements between modes of transportation, ports, and storage facilities have been planned for and implemented. Continuous flow is improved by minimizing handling, the number of transfer points, and the number and variety of carriers. Saturation can be avoided and balance achieved by ensuring the distribution system "pushes" or "pulls" people and materiel at a rate that can be accommodated at every point along the network from origin to destination.

A major system acquisition is another area where balance is essential to the attainment of combat goals. Balance is sought between system performance, costs, schedules, and supportability. A major acquisition program often takes 10 to 15 years to complete. In that time, a program office can improperly downplay the importance of supportability as it fights for fiscal survival by striving to stay within budget and on schedule while achieving the vehicular performance specifications demanded by the employment environment. The principle of balance dictates that extraordinary performance—measured by factors such as lethality, speed, range, and maneuverability—cannot compensate for inadequate system reliability and maintainability. A "grounded" aerospace vehicle, no matter how effective in the air or space, cannot contribute to combat capability unless it can be made available to the commander. Moreover, the most effective time to achieve high supportability is during the initial acquisition of a vehicle, not when operating out of an air base during a war. Balance is a vital ingredient to every combat support process, and the Air Force can best prepare aerospace forces for combat by giving emphasis to all the support processes.

Control

> Never lose contact with your resources.

An objective of all commanders is to keep control of their forces and supplies so they can plan and execute their operations at will. Knowing where combat resources are is as important as having them physically present. Information gives the commander this knowledge. Whoever controls information can control the organization; however, data is not to be confused with information. Data can bewilder commanders and render them ineffective, especially in the "heat of battle." Data only becomes information when it is timely, relevant, accurate, concise, simple, and digestible. Moreover, commanders must fully appreciate how information is processed by people and machines, initiating procedures to discover false, inconsistent, and/or erroneous reporting. In the end, the best information system is the one that allows commanders to retain control of the organization without forecasting their intentions to the enemy.

Flexibility

> Create aerospace forces that can operate in any combat environment.

The next war may not resemble past wars. Technological advances can overpower tradition and create new and unanticipated environments for combat operations. Therefore, a flexible combat support structure is elastic, modular, and simple. It is capable of rapidly expanding and contracting to meet the demand for people, materiel, facilities, and information wherever the requirement exists. Moreover, plans, organizations, and equipment are designed to be taken apart and quickly reassembled to form new capabilities in a changing combat environment. Finally, support flexibility demands simplicity at the operating base, in the depot, and at the factory.

For the Air Force to develop into self-sufficient aerospace forces, the evolution must begin by producing aerospace vehicles that are more reliable and maintainable, break less frequently, are less susceptible to combat damage, require fewer support personnel and equipment, and need only minimum servicing or reconfiguring before each mission. In addition, people must be trained to work with more vehicles or more parts of a single vehicle. Equipment should also be developed to replace people, but only when equipment can be more combat-effective. Finally, organizations should be structured with economies of scale to offer the greatest adaptability to a variety of combat situations. In summary, the key to creating flexible aerospace forces is to merge the four basic tasks of the Chief of Staff—organizing, training, equipping, and sustaining—into an integrated activity.

Synchronization

> Remember: combat power equals the combination of combat operations and combat support.

Combat support is the source of aerospace power: the creation and sustainment of combat capability which permit aerospace forces to be employed tactically to accomplish the objective of strategy. Combat power is achieved only when combat operations and combat support come together in unison. Strategy cannot deter or harm the enemy unless it can be executed tactically, and tactics will not succeed without modern, ready, and sustainable aerospace systems. Therefore, the strategy and tactics of combat operations depend on combat support. In essence, combat operations and combat support are inseparable in the application of aerospace power (Figure 12).

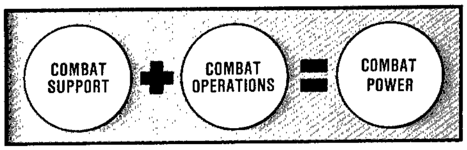

Figure 12.

Synchronization is built through effective training and leadership and by generating a sense of common identity and shared purpose. Training is the peacetime investment made in people to yield wartime capability. Training prepares and sustains the war-fighting spirit of both the combat operations and the combat support warrior. All Air Force training must focus on establishing and maintaining teamwork and the capability of a force to win. The will and the skill of the warrior must be jointly developed and continuously reinforced. A true war-fighting spirit will evolve with training and be sustained with leadership, reinforcing unit cohesion, and pride. Together they can renew an appreciation for basic military values such as discipline, patriotism, and professionalism.

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The Relevance of Doctrine to Air Force Civil Engineering

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Although Air Force civil engineering (AFCE) has a rich history of war-fighting experience, the fundamental principles and lessons learned from those experiences have not been recorded in official doctrine. There are many reasons for this unfortunate state of affairs: difficulty of subject matter, complexity of terms, disagreement on definitions, bureaucratic roadblocks, and organizational inertia. In AFCE's case, engineers have usually been action-oriented, with a proud tradition of "can do, will do." For this reason, AFCE people have not been markedly disposed toward formal, doctrinal-level writings.[1]

This inattention to doctrine is worrisome because the war-fighting experience of engineers is not being applied to the study and formulation of current Air Force doctrine. AFCE has already lost the airmen-engineers who experienced the challenges of World War II and transitioned from the Army Air Corps. Lessons learned from the Korean conflict have essentially vanished and memories of AFCE's mobilization for Vietnam are rapidly fading. In short, AFCE has long been negligent in the development of Air Force doctrine and the historic basis for that activity is quickly slipping away.

The Need for AFCE Doctrine

Aerospace power depends on the employment of total *warfare systems*—the integrated application of airborne *weapon systems* and *basing systems*. With the increasing sophistication of enemy threats, the technology of weapon systems has rapidly advanced. At the same time, the pace of basing systems technology has lagged behind in a resource constrained environment. The resulting vulnerability of primarily fixed-site basing systems may be a limiting factor to the combat effectiveness of current and future aerospace warfare systems.

Such profound change surely affects the aerospace environment. However, Air Force Manual (AFM) 1-1, *Basic Aerospace Doctrine of the United States Air Force,* does not address the operational environment in terms of increased danger or lethality. Instead, current doctrine describes the aerospace environment as a medium in relation to the Earth's surface and defines space as the outer reaches of that medium. Moreover, basic doctrine's description of the aerospace environment curiously excludes the terrestrial environment where most aerospace systems are based.[2]

The destructiveness of current and future operational environments, particularly on land, is fully recognized. *Air Force 2000,* for example, describes that terrestrial environment as:

> a dynamic and fast-moving conflict characterized by the expanding threat of highly accurate and destructive enemy capabilities to the operational support structure and weapon systems it supports. . . . Command, control, and communications will be susceptible to disruption by extensive application of new electronic warfare systems; massed air raids with the possible use of chemical, biological, and nuclear weapons will *reduce the sanctuary of air bases,* whether located in the Continental United States (CONUS) or in theaters of conflict.[3] [Emphasis Added]

Close examination of the current AFM 1-1 shows some acknowledgement of aerospace vulnerability. Under the principle of security, for example, active and passive defense measures are related to deception, dispersal, posturing, defense, and hardening of forces. AFM 1-1 also addresses the issue of technology:

> . . . the development of emerging technologies may well influence the development of doctrine, but the procurement of weapon systems must primarily provide the capability to execute current doctrine. . . . Providing this force involves selecting reliable systems, in adequate numbers, and with the capability to survive and be maintained in all combat environments.[4]

This approach to technology is properly directed at the idea that doctrine should drive technology, rather than the reverse. However, the extent to which the enemy's technological *threat* must directly influence doctrine is only subtly addressed.

> ***"Most of our current doctrine focuses on the employment of weapon systems independent of the ground-based support environment."***

Little more regarding the vulnerability of the air base ground environment is noted and there is very little concern for the consequences. Most of our current doctrine focuses on the employment of weapon systems independent of the ground-based support environment. Thus, in part by heeding current doctrine (and lacking a supplementary AFCE doctrine), Air Force plans and programs consistently focus on the procurement of weapon systems with relatively little regard for their basing systems.

One possible explanation for this bias is a basic principle of doctrine itself—that fundamental doctrine is established from combat *experience*. With a few minor exceptions, the United States Air Force has operated with impunity from the sanctuary of its air base "safe havens." Hence, our Air Force has little experience in building a doctrine recognizing the consequences of vulnerable basing systems.[5] This absence of experience, however, should not preclude doctrinal attention. Both a theater nuclear doctrine (AFM 1-5) and military space doctrine (AFM 1-6) have been developed without war-fighting experience in either arena.

One military analyst argues that the longer the interval between wars, the more difficult it is to predict how technological change invalidates the doctrinal lessons of previous wars.[6] On that basis, entering the second decade since Vietnam, we are approaching a dangerous period of high risk. Another analyst suggests the principal catalyst to doctrinal change has historically been military disaster and that if we are to avoid such disasters, doctrinal innovation is essential in view of rapid technological change.[7]

Because AFCE plays an important role in providing essential elements of basing systems, this situation alone should encourage AFCE doctrinal involvement. But additional reasons exist for AFCE initiative in the doctrinal process. For example, AFCE has frequently reacted to pressures and controversies ranging from debates on roles and missions to major changes in force posture. Forced organizational consolidations, manpower reductions, military-civilian conversions, contracting-out, and difficulties in advocating AFCE force structure requirements may, at least in part, be attributed to the absence of official AFCE doctrine.

There may be several missing elements in current doctrine: the recognition of change, the impact of military technology, and the resultant vulnerability of our relatively soft support infrastructure. These factors support the need for well thought-out AFCE doctrine on which to base programming and strategy formulation. What would be the consequences of ignoring this need?

"Without coherent doctrine clearly expressing the influence of technological change on the vulnerability of our basing systems, we cannot devise equally coherent strategies for our plans and programs."

Consequences of Having No Doctrine

In the absence of a coherent doctrine articulating basing system considerations, how effective can Air Force strategies be for the acquisition and employment of *warfare systems?* Robert W. Komer, Under Secretary of Defense for Policy, provides a straightforward definition of strategy as, "the art of making real-life choices as to missions and capabilities within a context of constrained resources—linking ends to means." In relating policies, plans, and programs to strategy, Mr. Komer explains:

> We rarely face up to setting regional or functional priorities when resources are constrained. . . . Programming tends to dictate strategy, rather than the reverse. As the result, there is little systematic policy- or strategy-making in DOD. . . . Instead, the reality is best characterized as a piecemeal, irregular, highly informal process, driven largely by cumulative program decisions influenced more by budget constraints . . . .[8]

Without coherent doctrine clearly expressing the influence of technological change on the vulnerability of our basing systems, we cannot devise equally coherent strategies for our plans and programs. Instead of relating aerospace power in terms of *warfare systems,* the integrated application of *weapon* systems and *basing* systems, we plan and program as if they were independent entities.

For example, over the last several years, we have spent billions of dollars on the procurement of essentially needed tactical aircraft, while spending only a few million dollars for wartime runway repair capabilities. Without the latter, aircraft may be severely limited as warfare systems.[9] This does not mean, however, that progress is not being made.

As one British writer observes, rapid runway repair technology is being expanded to launch and recover 10 fighter aircraft within one hour after airfield attack. However, "to achieve such results, it will be necessary not only to develop the requisite technology but also to overcome a historical reluctance actually to invest in support facilities rather than aircraft."[10] The Air Force has not wholly neglected to recognize the vulnerability of its basing systems. The *Theater Air Base Vulnerability (TAB VEE) Study*[11] resulted in the US and allies spending substantial sums for passive air base defense, including measures such as aircraft shelters, facilities hardening, alternate runways, and tone-down. These efforts evolved into the Air Force Air Base Survivability (ABS) Program, a multibillion dollar effort to improve passive defenses, active defenses, air base recovery, and command, control, and communication systems, and add aircraft enhancements. But in spite of its importance and huge scope, the ABS Program is funded at less than 1% of the Air Force's total obligational authority.[12]

Our principal adversaries are clearly capable of disrupting or destroying NATO basing systems. Their doctrine features surprise through preemptive strikes, particularly against nuclear-capable NATO airfields. They are organized and trained for a combined arms conflict exploiting battlefield maneuver. The growing threats of Soviet tactical ballistic missiles and chemical warfare capability have placed our fixed-site, immobile basing systems at extraordinary risk.[13]

"The consequences of basing system vulnerability driven by technological advancement must be recognized. We can ill-afford to wait for military disaster to change our doctrine."

Formulating AFCE Doctrine

The doctrinal arena provides an extraordinarily important area of focus, driven not by competition for resources, but by the best way to employ aerospace forces. Doctrine is the fundamental departure point for all Air Force activities, including the allocation of limited resources. As principal players in the sustainment and development of basing systems, the airmen of AFCE must articulate a doctrine based on a history of war-fighting experience and assessment of the future. The consequences of basing system vulnerability driven by technological advancement must be recognized. We can ill-afford to wait for military disaster to change our doctrine. Now is the time for AFCE action. But what form might such a doctrine take?

Organization and Content

Operational doctrine for AFCE might be organized as follows:

(1) An *Introduction* providing the purpose, scope, objective, and applicability of the AFCE mission area, including key terms and definitions.

(2) A *Concept of Operations,* reflecting AFCE characteristics, capabilities, and requirements.

(3) An official description of the AFCE *Organization,* including its force composition.

(4) A description of AFCE *Command and Control* arrangements at the component-level and for joint and combined operations, an area not well understood or applied by civil engineers.

(5) An explanation of *Planning* considerations for intelligence, requirements, and logistics, including AFCE priorities for allocation.

(6) A discussion of AFCE *Employment* concepts for conventional, nuclear, biological, chemical, and special operations, including any unique AFCE support requirements.

(7) An official approach to *Training,* to include AFCE requirements, equipment, and scheduling.[14] More senior or experienced Air Force engineers should readily recognize the need for the publication described and that such a document does not currently exist.

> **"A set of fundamental, enduring principles should reflect axioms and universally-accepted truths concerning the best way to employ engineer forces."**

Regardless of organization, I believe AFCE doctrine should include three crucial elements. First, *fundamental missions and tasks* must be clearly articulated. The doctrinal process would allow these missions to develop full connectivity with other doctrines and missions across the full spectrum of conflict, from low-intensity warfare through strategic nuclear exchange. Second, a set of fundamental, enduring *principles* should reflect axioms and universally-accepted truths concerning the best way to employ engineer forces. Structured in part around existing "principles of war" such as unity of command, cohesion, and economy of force, a set of engineering principles would provide a concise framework of fundamental, proven beliefs against which the merits of any new initiative, plan, or program may be tested. Finally, doctrine would provide an ideal vehicle for promulgating an engineering professional code of ethics patterned after the Army's "profession of arms" in Field Manual 100-1, *The Army.*

An Objective Methodology

To effectively develop doctrine, AFCE must use an objective methodology. Major General I.B. Holley (Ret) recommends a superbly constructive approach. He views doctrine development as consisting of three important phases: the *collection* phase, the *formulation* phase, and the *dissemination* phase.[15]

The *collection* phase involves the gathering of information from the widest range of sources possible; there are many sources for AFCE doctrinal material. Of course, two primary sources must be *basic* doctrine as promulgated by AFM 1-1 and the "Combat Support Doctrine" currently being circulated as a draft 2-series Air Force regulation. AFCE doctrine must also be melded with other current operational doctrines such as TACM 2-1, *Tactical Air Operations,* and Allied Tactical Publication 33(A), *NATO Tactical Air Doctrine.*

Historical accounts of landmark engineering decisions and strategies are recorded in such studies as *A History of the Warfighting Capability of Air Force Civil Engineering,* the *TAB VEE Study,* and the 1979 *Joint Contingency Construction Requirements Study,* which chronicles the bitter Army-Air Force debates over engineering roles and missions. The important *Air Force 2000* study, with its emphasis on mobility, flexibility, and survivability, also provides strong theoretical underpinnings for AFCE doctrine.

Many doctrinal possibilities can be gleaned from full-scale maneuvers, unit exercises, and war games (General Holley cautions that unit exercises are unavoidably flawed as doctrinal sources in the absence of a full context of arms and "friction.") We should also not ignore accounts of other nations' air forces (the Falklands conflict and 1967/1973 Arab-Israeli wars come immediately to mind). Finally, current AFCE directives, war and mobilization plans (WMP), and joint civil engineering support plans (CESP) contain procedures and policies which have withstood the tests of time and employment in carrying out the AFCE mission.

The *formulation* phase is next, in which doctrine is initially defined, drafted, and revised to the maximum point of perfection possible. General Holley places great emphasis on objectivity, cautioning against hierarchical pressures, either real or imagined, which could result in doctrine the way we "want" it, rather than the battle-tested truth of experience we really need. This step involves formulating tentative doctrinal statements, followed by an unofficial review and input process. Within AFCE, informal verification might include major command working groups in a symposium format; the use of informal networks of AFCE people; "trial balloon" articles for the *Engineering and Services Quarterly, Military Engineer,* or *Air Force Journal of Logistics;* and presentations at periodic meetings of the AFCE senior leadership.

The final step in doctrine development is the *dissemination phase.* General Holley cautions that mere publication of an official doctrinal manual does *not* constitute dissemination. Unfortunately, most doctrine is published as pure doctrine; that is, unadorned generalizations gleaned from past experiences. Such pure doctrine declares validity through official sanction and invites belief as an act of faith. If AFCE doctrine is to be *effective,* it must be understood and believed by AFCE people. To be effective, doctrine must be internalized.

Dissemination opportunities avail themselves within ongoing programs at Air Training Command technical training schools, the Air Force Civil Engineering School, and the Air Force Engineering and Services Center. Plans for teaching AFCE doctrine should begin not later than the midpoint of the formulation phase.

Conclusion

Because AFCE plays an important role in development of basing systems, the airmen of AFCE have a professional responsibility to enter the doctrinal arena. Moreover, the doctrinal process provides a new opportunity to articulate AFCE mission areas, focused on how to best employ aerospace forces, rather than on an often fragmented competition for scarce resources.

An AFCE doctrine would fulfill four major objectives: guide AFCE combat support commanders; guide capability

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USAF LOGISTICS POLICY INSIGHT

TAC's LOGFAC System

In the Fall of 1985, the Air Force implemented the Logistics Feasibility Analysis Capability (LOGFAC) System, a new standard Air Force logistics data system, on MAJCOM Honeywell 6000 computers. LOGFAC is designed to provide better visibility of consumable war reserve materiel (WRM) requirements and on-hand assets, weapon system logistics assessment analysis capability (for consumables), and the MAJCOM's war consumable distribution objective (WCDO). Originally developed by HQ TAC, LOGFAC has now been modified and released USAF wide under the administration of the Data Systems Design Office at Gunter AFS AL. Currently, AFLC, TAC, MAC, SAC, USAFE, and PACAF are LOGFAC capable. HQ AFLC is responsible for development of consumable requirements for MAJCOMs that do not currently have LOGFAC capability. LOGFAC will allow for development of more accurate and timely consumable requirements and will substantially enhance WRM asset visibility.

Logistics Information Systems Roadmap

As computer technology has expanded, so has the use of information systems throughout the logistics and engineering community. The first AF/LE "Roadmap" Project Directory is scheduled for release in mid-November. It will contain current data on emerging logistics information systems in a quick reference format. As the project evolves, the directory will feature expanded descriptions and will include existing systems. The directory will allow managers to benefit from the work of others and avoid duplication of effort. All MAJCOM and SOA LG and DE functions will receive copies of the 1985 Directory. If you are planning a project and do not want to reinvent the wheel, work with your MAJCOM and SOA representatives.

Industry Support for R&M 2000

Industry reaction has been positive to the Air Force's reliability and maintainability (R&M) 2000 initiatives. The assessment is based on the large number of corporations that are placing high level management attention to R&M, establishing R&M goals, and increasing R&M technology investment. We have also noted a greater emphasis on R&M in industry advertisements, symposiums, seminars, and visits by corporate special assistants for R&M. Finally, companies have sponsored their experts to participate, through industry associations, in R&M initiatives to improve weapon system reliability.

Study of Repair Processes

Project RIVET REPAIR is an in-depth evaluation of the Air Force repair process aimed at ensuring maximum repair capabilities. Spearheaded by the AF/LEY Rivet Repair Steering Committee, the review effort is being undertaken on two fronts. First, HQ AFLC is making a sweeping review of how repair activity is conducted at the depot level. Significant progress has already been made in terms of better maintenance/supply interfaces and improved requirements forecasting, resulting in more parts on the shelf. Second, a Retail Study Group has been established to review and revitalize base-level repair of Air Force assets. This group is chaired by AF/LEYM and is comprised of representatives from AF/LEYS, AF/LEYE, AFLC/MM, AFLMC, and MAJCOM directorates of maintenance and supply. We expect both review groups to continue to make significant progress during the next year, resulting in improved Air Force repair policies. Recommendations for improving the repair process should be forwarded to Major Sullivan, AF/LEYM, AUTOVON 227-1493.

New NDI Policies

The new AFR 66-38, *Air Force Nondestructive Inspection (NDI) Program,* has been published and should be available through your local publishing distribution offices now. Major changes to the revised regulation include increased emphasis on establishing NDI as a major design criteria early in the weapon system acquisition process and the regulatory formation of an NDI Steering Group. The new regulation also more clearly defines and expands the responsibilities of the Air Force NDI Program Office. Expanded responsibilities include the requirement to establish an Air Force-wide process assurance activity and an Air Force NDI technician proficiency program.

Airlift Policy Memorandum

The Air Force has successfully completed negotiations on DOD International Airlift Policy with the Services. A soon-to-be published DOD Transportation Policy Memorandum calls for the use of MAC owned or contracted airlift when capability is available and meets mission requirements. The memorandum will also include policy implementation guidance concerning forecasting requirements, channel and market-place analysis, and publication and use of DOD routing instructions. The DOD objective is to fully utilize MAC owned and contracted capability to maintain wartime readiness and to effectively meet the peacetime air logistics support mission.

New UMMIPS Standards for NMCS

The Air Force has developed uniform materiel movement and issue priority system (UMMIPS) time standards for not mission capable supply (NMCS) requisition processing and item movement. The new standards were applied against current UMMIPS time segments. Prior to this initiative, NMCS requisitions/shipments were required to meet UMMIPS 01-03 priority designator standards. All MAJCOM/SOAs were invited to participate in the design, which was implemented Air Force wide, November 1985. After a period of data collection and review, the new time standards will be finalized and proposed for DOD application.

Total Order-Ship Time/Days

	CONUS	*AREA 1*	*AREA 2*	*AREA 3*
New NMCS Standard	3.5	7.0	7.5	8.5
Current 01-03 Standard	8.0	12.0	12.0	13.0

SAIP Update

The Air Force has updated its policy for Spares Acquisition Integrated with Production (SAIP). SAIP is a technique where the requirement for spares is combined with the requirement for identical items produced for installation on the end item. Use of the SAIP technique has resulted in more economical production runs for both production items and spares. Air Force Regulation 800-26, *Spares Acquisition Integrated With Production (SAIP),* 21 August 1985, requires the SAIP technique be considered on all acquisition programs, including joint programs, foreign military sales (FMS) programs, and major modifications where the end item is in or will be in production.

Revised Fiscal Guidance for Spares Funding

The Air Force remains committed to improving its wartime readiness and sustainability posture even though an increasingly austere fiscal climate has begun to constrain that commitment. The peacetime operating spares (POS) program, which supports our readiness training, continues to be fully funded. This program also provides the inventory base of spare parts to which our wartime stocks are added. But for the first time since FY84, our initial wartime requirements (WRSK/BLSS) are not fully funded, due primarily to Congressional budget reductions. This shortfall means selected updates for strategic and tactical electronic countermeasure systems must be deferred. Revised fiscal guidance also eliminated any dollars for sustainability stocks (OWRM). Because of strong prior year funding, however, the impact on our FY88-89 levels of sustainability will be minimal. Nevertheless, the handwriting is on the wall: the Defense Department, along with other sectors of the Federal Government, is in for a potentially extended period of fiscal belt-tightening. With Congress taking an increasingly critical look at defense requirements, future logistics support requests will have to be well conceived and stand up to rigorous DOD programming scrutiny.

READER EXCHANGE

Dear Editor

I am writing this to bring up a couple of points about Rivet Workforce (Fall 1985 issue, *AFJL)* not mentioned in any of the articles so far. First, since the overall maintenance workforce is not going to increase and is eventually expected to fall after AFS consolidation, who is going to do the work while the "Super AFSs" are being trained in-depth. Presumably, while we are phasing into Rivet Workforce, experienced maintenance people will continue getting out, retiring, and transferring at the current rates. Meanwhile, local leaders will be eagerly awaiting their usual replacement with three-level tech-school graduates who won't be coming for quite a while. Of course, the ready answer is that this is only a temporary problem to be overcome by patience and careful planning. However, I see it as a trend in personnel procurement analogous to, and tending toward, the debilitatingly long lead times we now suffer in equipment procurement. After all, whatever its drawbacks, specialization is the most efficient means of quickly getting the needed skills from the classroom to the flight line. If the next war is a short "come-as-you-are" affair we won't have time to train replacements anyway, but suppose it's not. How is a small unit going to operate if one or two casualties wipe out the workforce and replacements are still being trained?

This leads to my second point: increasing the value of individual troops also increases their vulnerability and the vulnerability of the unit that relies on them. Putting more skills in fewer people is putting more eggs in fewer baskets and the old admonition against doing that, I think, still applies. These "Super AFSs" will be more valuable to the Air Force not only because they can do more but also because it costs more and takes longer to train them. Consequently, it will hurt more and have greater impact to lose them. In addition, their value to anyone else who wants them is likewise increased, including the civilian job market. I have always felt that Air Force maintenance specialization provided an unadvertised benefit to Air Force retention. For example, no matter how qualified or experienced an individual may be in his Air Force maintenance specialty, he generally cannot qualify for a civilian job requiring an FAA certificate, without additional training. This is because his Air Force training is concentrated in a narrow specialty. Depending on general economic conditions, of course, any AFS restructuring which eliminates this restraint may turn out to be very costly indeed.

In conclusion, I see in Rivet Workforce, a danger that, combined with unwise equipment procurement policies, could result in the Air Force depending on small numbers of very expensive super weapons being maintained by small numbers of very expensive super maintainers, both of which are irreplaceable, useless without the other, and much too valuable to be risked in actual combat.

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1986 Aerospace Power Symposium

The Tenth Air University Aerospace Power Symposium will be held 10-12 March 1986 at the Air War College, Maxwell AFB, Alabama. This year's topic is "Impact of Space on Aerospace Doctrine." The Symposium will examine the role of space doctrine across the conflict spectrum. Policy, strategy, and doctrinal issues will be addressed to determine the potential roles of aerospace power in the space environment. Additionally, the operational aspects in preparing for and fighting in the space environment will also be examined. The Symposium will conduct four interrelated sessions: (1) National Security Policy for Military Action in Space; (2) Military Strategy for Implementing Space Policy; (3) Aerospace Forces for Conflicts Involving Space; and (4) Assessment of Past and Current Doctrine. For information on submission of papers for the Symposium, please contact Lt Colonel Donald W. Bishop (AWC/XP), AUTOVON 875-2831 (Commercial (205) 293-2831).

Expert Systems for Logistics: Harnessing the Technology of the Eighties

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Introduction

Logisticians today have the potential to harness a technology so new and so powerful that one can only guess what its real potential and ultimate impact might be. The technology is artificial intelligence (AI), and the forecasted impact is a complete "knowledge" revolution.

This paper examines the current state of the art in artificial intelligence, particularly the subdiscipline of AI known as *expert systems*. Although there are currently 49 expert systems actually in use in the United States (US) in fields such as bioengineering, education, law, manufacturing, and medicine, very little research has been done in terms of applying expert systems to logistics. This paper reviews the generic tasks performed by existing systems as a prelude to identifying tasks in the various logistics subdisciplines (purchasing, inventory management, transportation, maintenance, etc.) which may be directly amenable to the use of expert systems. In addition, this article reviews three specific criteria for determining the relevancy of expert systems and discusses two potential problems which may be pitfalls to successful logistical applications. Also, the paper identifies relevant works of current research related to developing prototype expert systems for specific logistics functions.

Intelligence and Artificial Intelligence

Intelligence can be viewed in many different ways as indicated by the following definitions from the literature:

> Intelligence is the ability to learn or understand from experience, and the ability to acquire or retain knowledge. To be considered intelligent one must have the ability to respond quickly and adapt fully to a new situation. Also, the facility of reason must be applied to improve one's level of performance based on one's past experience in solving problems. (17:1)

Also, intelligence can be perceived to be the ability of any decision-making entity to achieve a degree of success in seeking a wide variety of goals under a wide variety of environments. (8:119)

The common clue to intelligent behavior, whether of men or machines, is the capability of highly selective search, or drastically pruning the tree of possibilities explored. (5:6) Obviously, then, intelligence is not a dichotomous construct but, rather, a continuum of values of human capacity or ability. However, recent advances in the field of study known as "artificial intelligence" provide a legitimate challenge to the consideration of intelligence as a strictly human or mammal characteristic.

AI is the subfield of computer science that concerns itself with "making machines do things that would require intelligence if done by humans." (17:1) But, can machines and computers really be made to think, to reason, to learn? Obviously, again this is a question of degree. Feigenbaum and Feldman have suggested that computer programs behave intelligently when they "search problem mazes in a highly selective way, exploring paths relatively fertile with solutions and ignoring paths relatively sterile." (5:6)

Others have argued against the potential for imparting true intelligence to a computer. They contend that two of the most important aspects of human intellect—originality and the ability to learn—could never be performed by a computer. (11:6) Today's expert systems are, however, converting even these skeptics.

AI differs from traditional computer science in two major aspects. First, rather than using the traditional programming languages of FORTRAN and BASIC, it employs a language such as LISP which is capable of processing symbols, words, phrases, complicated formulas, and numbers. Second, AI programs do not necessarily solve problems by performing sequential calculations. Rather, they "take logical shortcuts—or 'symbolic inferences'—essentially common sense reasoning." (10:111)

Recent interest in AI has been so spectacular that the study could probably be viewed as a discipline in its own right. Indeed, several subfields of interest in AI have already developed and are being actively pursued. These include problem solving (more popularly known as expert systems or knowledge representation), natural language (the ability to convert English into computer language), sensing (vision and speech understanding for robotics), manipulators (hand and arm movement), and search techniques. (17:2) Although all these subfield areas of study will likely be beneficial contributors to future logistics applications, this paper will concentrate on the first subdiscipline, expert systems.

What is an Expert System?

An expert system is a computer program that mimics a human expert; using the methods and information acquired and developed by a human expert, an expert system can solve problems, make predictions, suggest possible treatments, and offer advice with a degree of accuracy equal to that of its human counterpart. (9:34)

What makes human counterparts experts? Dr. Davis at the Massachusetts Institute of Technology (MIT) classifies experts as possessing seven attributes: the abilities to solve problems, explain results, learn by experience, restructure their knowledge, break rules when necessary, determine relevance, and employ graceful degradation of performance. Shurkin states that to date, "expert systems exhibit only the first three properties in any depth." (15:75)

Expert systems have also been distinguished as "intelligent assistants" that permit their bosses to work more effectively and creatively. The key difference between them and human experts is computers have special-purpose intelligence, designed to perform a limited task and perform it superbly, whereas humans are general purpose beings able to perform a wide variety of tasks reasonably well and a few tasks brilliantly. (17:2)

Since expert systems, by definition, mimic human experts, we must understand how people solve problems. Research has shown that we do not consider all possibilities and their expected outcomes in making decisions; rather, we "simply apply an enormous store of textbook knowledge and experiential knowledge," switching between these two as necessary. (17:3) Expert systems emulate our reasoning processes by employing search heuristics.

Structure of an Expert System

Perhaps at this point these concepts could be clarified by examining the basic structure of an expert system (Figure 1). The knowledge base of this system contains the basic information gleaned from the human expert. Two types of knowledge are typically included within this knowledge base: basic facts and heuristic knowledge or good judgment. The inference system, frequently termed the inference engine, provides overall control of the system. It establishes the method of reasoning used to match rules to data and determine which rule should be applied next. In addition, it adds the conclusions drawn from this process to the problem data base. (18:78) This inference system may provide advice or explanations to the user, or it may query the user for additional facts and data to add to the existing data base. Ham notes a distinct design objective relative to the ability of the inference system to provide explanations back to the user, which he terms an "explanation facility." This facility enables the expert system to explain how it arrived at its present conclusion or why it is pursuing a certain line of reasoning. (9:37) Such a capability is critical to validating and debugging the expert system, and can serve as an excellent training tool.

The *expert* and the *knowledge engineer* play particularly crucial roles in the development of an expert system. Peltu notes that the real starting point of an expert system is an expert—called a "domain specialist." (12:71) The expertise of this specialist must then be captured in the rules and knowledge base of the program—this function is called "knowledge engineering." This task is particularly difficult. People simply do not know exactly how they make decisions or perform tasks. The knowledge engineer's job is to draw out this information. Special cases, in particular, can present problems. "Human experts are not very good at remembering special cases—until they are confronted with a concrete example." (18:79)

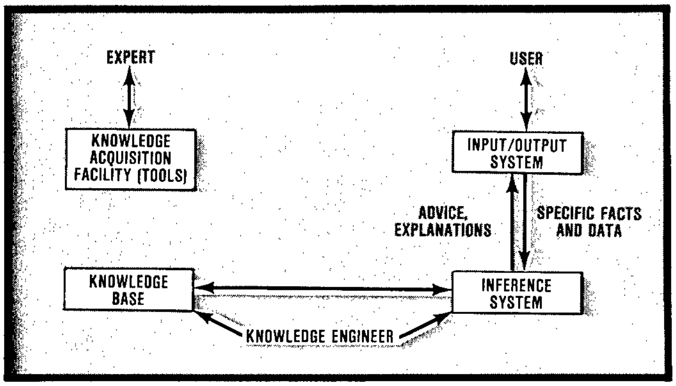

Figure 1: Basic Structure of an Expert System.

Principles of AI

AI is the next step in the evolution of computer technology. AI involves a different approach to computing which is based on symbolic, rather than numeric, processing and is presently underpinned by the idea of putting as much knowledge in the system as possible. Significant differences exist between symbolic and numeric processing. Also, the guiding paradigms in AI research have shifted.

In numeric processing, numeric operators (plus, minus, times, etc.) are used to manipulate data (numbers) in a database. Problems are represented numerically and must be solvable using a specified set of operations. These operations are mechanically applied one-by-one until the solution is found. Frequently, the knowledge required to solve the problem is the actual procedure used to transform input data.

In symbolic processing, on the other hand, logical operators (and, or, not, etc.) are used to manipulate data (lists) in a knowledge-base. When coupled with an appropriate control structure (production system), the knowledge is analyzed and a problem solution is found. Rather than making a cryptic numeric problem representation, a symbolic representation of the rules governing finding a solution is created. Then, the rules are coupled with a search strategy to test hypotheses and find solutions.

In addition, the production system architecture separates facts from the constructs (i.e., rules, search strategy) which use them. This structure leads to more flexibility because new facts and rules can be added without redesigning the system from scratch.

An important qualitative difference is the application of rules in a production system is permissive, rather than imperative, at each step in the solution process. Heuristics are used to choose the rule most likely to lead to a solution.

J. Pearl describes heuristics as "criteria, methods, or principles for deciding which among several alternative courses of action promises to be the most effective in order to achieve some goal." In simple terms, a heuristic is a rule of thumb which can be used to guide the actions taken during the problem solving process. Early AI research focused on the use of heuristic search in problem solving.

Pearl describes AI as non-algorithmic, since it attempts to solve problems for which no known algorithms exist. AI uses algorithms, but goes further by attempting to find good solution methods where algorithms do not exist. It is useful to remember that good solutions can frequently be less than optimal. In many cases, just finding *a* solution is all that is required. (1Lt Jeffrey A. Jones. "An Approach to Artificial Intelligence for Logistics," *SOLE 20th Annual Symposium Proceedings.)*

Steps in Development

The Systems Manufacturing Technology Group at the Digital Equipment Corporation discusses seven steps: (1) *system design* (expert and knowledge engineer talking about knowledge the expert uses); (2) *prototype development* (knowledge engineer creates actual rules to be used in expert system; (3) *making the prototype an expert* (knowledge debugging); (4) *evaluation and acceptance* (modifications of actual computer code); (5) *extended use in a prototype environment* (field testing which usually results in new rules and knowledge being added to system); (6) *development of maintenance plans;* and (7) *system release.* (17:6)

Applicability to Logistics

For purposes of determining the potential applicability of expert systems to the logistics area, the Logistics Management Council definition of business logistics will be employed. Coyle and Bardi present this as the term describing the integration of two or more activities for the purpose of planning, implementing, and controlling the efficient flow of raw materials, in-process inventory, and finished goods from point-of-origin to point-of-consumption. These activities may include, but are not limited to, customer service, demand forecasting, distribution communications, inventory control, materials handling, order processing, parts and service support, plant and warehouse site selection, procurement, packaging, return goods handling, salvage and scrap disposal, traffic and transportation, and warehousing and storage. (3:5)

In addition, the expert systems literature provides several guidelines for the applicability of expert systems. It is noted expert systems are not applicable to all disciplines. Rather, the Systems Manufacturing Technology Group suggests a coaptation of expert systems with conventional systems—each exploiting its own area of advantage. Further, they provide three specific criteria for determining the relevancy of expert systems:

(1) At least one human expert acknowledged to perform the task well must be accessible.

(2) The primary source of the expert's exceptional performance must be specialized knowledge, judgment, and experience.

(3) The task must be a well-bounded domain of application. We want narrow areas of specialization because it is easier to assemble this knowledge than the vast amount of knowledge that humans bring to bear on everyday problems. (17:4)

Feigenbaum and McCorduck note that expert systems lend themselves especially well to two generic types of problems. These are combinatorial problems where the number of possible alternatives is unmanageable; for example, chess. The second group of problems particularly suited for expert systems are those where large amounts of distinguishing or signal data must be interpreted. (6:67-68) Medical diagnosis is one such problem.

Backward and Forward Chaining

A backward chaining expert system does not consider every possible cause of a given symptom or cluster of symptoms. Instead, it makes a tentative hypothesis about an underlying cause. Then the system proceeds to test the hypothesis until it proves itself wrong. Its efficiency lies in narrowing the field of possibilities. Its inefficiency results from the fact it cannot recover easily from error without starting over. Typically, a doctor can handle several hypotheses at once and will be able to judge a mistake long before a diagnosis is finally played out.

Fault isolation follows the backward chaining model. Programs using similar techniques have been written for such systems as diesel engines, helicopter flight control systems, electronic circuits, and fixed electrical systems. The process remains the same—observe what is wrong, analyze it, assess the most likely cause, and iterate the process until the final problem has been discovered. Then fix the cause and see if the symptom goes away.

A second format is forward chaining. Here the present state predicts some desired future condition. Forward chaining systems are very significant in logistics applications. Forward chaining systems include planning, routing, solving chess problems, and configuring systems. In reality, thought processes—and even computer processes—chain in both directions. Analysis and prediction remain closely linked in problem solving. (Philip Borden et al. "Expert on a Disk or Genie in a Bottle? Notes on Software to Improve Maintenance While Reducing Cost," *SOLE 20th Annual Symposium Proceedings.*)

Still another way of determining which logistics functions might be amenable to this technology is to review the generic tasks which expert systems currently perform. These include interpretation (analysis of data to determine their meaning); diagnosis (fault-finding in a system); monitoring (continuously interpreting signals and setting off alarms when intervention is required); prediction (forecasting the course of the future based upon a model of the past); planning (program of actions that can be carried out to achieve goals); and, finally, design (the making of specifications to create objects that satisfy particular requirements. (16:136-140)

Ballou suggests the application of expert systems to the logistics performance monitoring area as an excellent start to introducing expert systems into the logistics domain. (1:10) Two potential problems, however, should be carefully considered. First, expert systems appear to hold their greatest current potential in limited applications. The logistics system is a very complex web of interactions. A small subfunction within logistics might be a more appropriate target for such a system. The second factor is closely related to the first. Given the complex interaction of functions, the right "expert" might be difficult to locate. Indeed, in a more recent article, Ballou addresses what he terms "the weak link in the application of artificial intelligence to physical distribution," noting that because of all the interactions and cost trade-offs (e.g., between inventory and transportation), defining "relationships that convert observations into possible courses of action" will be quite challenging. Ballou goes on to explain:

> These relationships embody our understanding of physical distribution management. It is all of the rules of thumb, principles, and concepts that we practice, teach, and write about. Quantifying or just structuring this knowledge will be the most difficult part of AI application. Research will need to be undertaken to establish these relationships. (2:511)

Several more specific logistics problems/decisions appear applicable to expert systems technology. Inventory planning and control expert systems could be designed to decide what actions to take on items (cancel orders, local purchase, expedite shipments, etc.) and implement the decisions as appropriate.

Warehouse location problems fit the generic expert system classifications of both planning and design where a large amount of signal data must be evaluated. Further, the combinatorial possibilities of locations are almost endless. Such an expert system could recommend plant, distribution, and/or consolidation locations based upon specific requirements provided to the system by the user (e.g., shipping time, capacity). In the transportation area, rate negotiation, shipment routing and scheduling, freight bill auditing, and mode selection decisions are all potential candidates for separate systems.

Logistics information offers still another highly likely area where this technology might be successfully applied. Logistics systems, by nature, tend to be quite data intensive and employ numerous mathematical models for decision-making. An inordinate amount of time, however, in running any model is involved with properly structuring and grouping the input data. Expert judgment is a must for such a task. Expert systems could be developed to serve as preprocessors for the logistical modeling effort.

Actual Applications and Current Research

Research is currently ongoing at Carnegie-Mellon University to develop a knowledge-based simulation model of a corporate distribution system. The project, termed INET, applies an AI approach to the modeling and simulation of discrete systems.

To deal with the complex interactions involved in the logistics system, INET displays its output on a screen which can be split four ways. This permits conflicting performance measures such as customer satisfaction, transportation effectiveness, and corporate inventory to be displayed simultaneously. In this manner, the manager can readily see how the various measures are impacting one another. The most recent research concerns an expert system capable of automatically analyzing this simulation output. (14)

A second research study assessed the feasibility of designing an expert system for automating Air Force aircraft maintenance diagnostic functions. The system would be designed to assist average maintenance technicians in the performance of their duties. A system which would automate the maintenance technical manuals and assist technicians in their understanding was found to be both feasible and desirable. (7)

Still another area of Air Force research involves a feasibility study of developing "expert price analysis computer systems." The study addresses expert pricing analysis at the Air Force Systems Command, Air Force Logistics Command, and base levels in an attempt to determine the feasible expert system design alternatives, what assistance can be provided to price analysts, and finally, what effort would be required by the Air Force to maintain such systems. (4:1)

Dillard et al determined that, in the short run, an "intelligent manual" type of expert system was a realistic alternative for the price analysis task. They developed an actual prototype system which confronts the user with requisite purchasing decision sequences. Each of these in turn has pointers to a tutorial program, which can be called upon for additional instruction and explanation, if required.

The researchers noted that base-level analysts are most in need of such a system, as little expert assistance is currently available here. This base-level system could, in turn, be used as the nucleus for developing more sophisticated expert systems for other purchasing activities.

Ramakrishna et al explained the major implications of such systems for government contracting:

(1) A reduction of the skill level necessary to perform routine procurement tasks.

(2) The need for appropriately structured *knowledge bases* that contain a wide range of needed information.

(3) The need to maintain such systems up-to-date with respect to the latest rules and regulations. (13-14)

Indeed, such implications are appropriate for all the expert systems which might be implemented within the logistics domain.

Conclusion

Expert systems offer a unique opportunity to alleviate some of the critical manpower shortages of trained technicians and to magnify the abilities of our best managers and extend their expertise to others. Although these systems will never replace human expertise and judgment, they can greatly expand our capabilities. As Edward Feigenbaum has so wisely stated: "We should give ourselves credit for having the intelligence to recognize our limitations and for inventing a technology to compensate for them."

AI - The Logistics Context

AI technology will have a large impact on logistics both in logistics support systems using AI and in the acquisition of the resources required to support AI systems. This will be felt as pioneer projects mature and shift into the logistics community. With the existing level of emphasis, the first significant applications of AI will need to be supported in the 1990s. These will consist primarily of mature projects initiated through the Strategic Computing Program. Logistics organizations will need to follow these projects to plan for their support.

The first effects of AI will be felt in organizations responsible for logistics information systems or directly supporting embedded computer resources. Education of the users, logistics managers, and support personnel will go a long way toward ensuring the procurement of AI systems which meet logistics needs. Proper application of new technology is always of great concern due to the investment and commitment of the organizations' stake in the benefits expected by its use. Numerous demonstration projects on specific problems should help validate the usefulness of particular logistics applications.

The need for personnel trained in AI is of particular concern. A shortage of personnel trained in AI presently exists. Both the Air Force Institute of Technology and the Naval Postgraduate School have AI programs to help meet this need. Still, logistics organizations will need to take an active role in training personnel in AI. (1Lt Jeffrey A. Jones. "An Approach to Artificial Intelligence for Logistics," *SOLE 20th Annual Symposium Proceedings.)*

The technology of expert systems has emerged from the laboratory. The potential to now harness this technology to enhance and forever change logistical management is ready and waiting.

The author is currently pursuing a research effort sponsored by HQ USAF/LE which investigates the feasibility of developing an "expert item manager." Four specific hypotheses are under investigation:

(1) Expert inventory managers use key knowledge and heuristics in decision-making.

(2) This knowledge and these heuristics can be captured and programmed as an "expert system."

(3) Expert systems for inventory management can make decisions at least as good as human experts 90% of the time.

(4) Use of expert systems will allow inventory managers to make more efficient and effective decisions.

As part of this effort, an expert system will be developed to consider the purchase decision on replenishment spares: if to buy, when to buy, how many to buy, should cost, and the required delivery date. The ten best experts in the area of replenishment spares management will be elected. With the assistance of these experts, a model of the decision processes and the exact knowledge and rules that apply will be developed. This knowledge will then be programmed as an expert system. Following a validation of the system by the experts and any required modifications, experiments will be conducted to determine the level of expertise (novice, intermediate, or advanced) at which the expert system performs and how efficiently it is able to make decisions compared to its human counterparts.

Captain Allen's paper was presented at the 20th International Logistics Symposium; complete symposium proceedings can be ordered ($28/copy) from Society of Logistics Engineers, Suite 922, 303 Williams Avenue, Huntsville AL 35801-6961.

TO 18 ▶

CAREER AND PERSONNEL INFORMATION

Military Career Management

Logistics Plans and Programs Officer (AFSC 66XX) "Get Well" Plan

We completed FY85 with healthy manning (94%) in the Logistics Plans and Programs career field. The "Get Well" plan worked, as advertised, to improve manning over the past year. During FY85 we acquired 40 new lieutenants, most of whom filled positions in MAC, TAC, SAC, and ATC. Along with these new accessions, we also acquired a significant number of officers from other support AFSCs. We plan a similar program in FY86. Ideally, accessions would be 50% prior service and the other half non-prior service. We will place these officers in all major commands, both CONUS and overseas, paying careful attention to maintain acceptable experience levels in the units where new accessions are assigned.

Rated supplement officers accounted for approximately 18% of the 66XX career field. This is well above the 7% average for other support career fields. Our problems still revolve around losses due to retirements, separations, and rated supplement tour completions. Due to demands in the rated areas, and the short term impact of the rated supplement on the career field, we plan to reduce the rated supplement to about 10%. To fill the void, we will consider the other logistics career fields to broaden the officers' knowledge of the entire logistics spectrum. The key contributors are Maintenance (AFSC 40XX), Transportation (AFSC 60XX), and Supply (AFSC 64XX).

We are increasing the number of logistics and other support career field inputs over previous years, but we cannot realistically expect to tap other support career fields to totally fix the 66XX problem. Feedback from MAJCOMs indicates that using new lieutenants has, for the most part, been successful. Our "Get Well" plan looks at both the long and short term, accommodating present requirements for experience and quality, while also building experienced captains and majors for the future. The appropriate mix of lieutenants, along with retrainees and career broadening officers from other support career fields and rated supplement officers, will sustain the Logistics Plans and Programs career field.

Source: Major Thomas W. Roomsburg, HQ AFMPC/DPMRSL4, AUTOVON 487-5788

▶ *FROM 21*

development programs and force planning; provide a basis for relations with other services and nations; and provide a point of departure and ultimate evaluation for all AFCE activities.

Doctrine is indeed relevant to Air Force civil engineering. *The first and most important step is commitment.* We can ill-afford the risk of military disaster to seek doctrinal change. We must delude ourselves no longer. Air Force civil engineering must heed the words of General H. H. "Hap" Arnold, who in 1945 said:

> . . . any Air Force which does not keep its doctrines ahead of its equipment, and its vision far into the future, can only delude the nation into a false sense of security.[16]

Notes

[1] As documented in Robert Frank Futrell, *Ideas, Concepts, Doctrine: A History of Basic Thinking in the United States Air Force, 1907-1964*, Air University 19 (Maxwell Air Force Base, Alabama: Department of the Air Force, 1974), pp. 7, 198.

[2] As recorded in *Basic Aerospace Doctrine of the United States Air Force*, Air Force Manual 1-1 (Washington, D.C.: Department of the Air Force, 16 March 1984).

[3] *Air Force 2000: Air Power Entering the 21st Century* (Washington, D.C., Department of the Air Force, 1982), p. 168. (Classified)

[4] *Air Force Manual 1-1*, pp. 4-8.

[5] This lack of Air Force air base attack experience has recently been examined. For example, see Colonel Joseph S. Bleymaier, *Air Base Air Defense—An Air Force Commitment?* (Maxwell AFB, Alabama: Air War College, 1984), pp. 12-19. Also, see Lieutenant Colonel John S. Choate, *Implications of Runway Survivability Upon Future TACAIR Doctrine and Force Structure* (Maxwell AFB, Alabama: Air War College, 1984), pp. 11-16; and Lieutenant Colonel Floyd A. Ashdown, *A History of the Warfighting Capability of Air Force Civil Engineering* (Maxwell AFB, Alabama: Air War College, 1984), p. 77.

[6] Dupuy, Colonel T.N. (USA, Retired). "Perceptions of the Next War," *Armed Forces Journal International*, May 1980, p. 49.

[7] Historic examples cited included defeat of the Austrian army at Marengo in 1800; reorganizations of the Russian army after the Crimean and Russo-Japanese conflicts; and French doctrine prior to World War I and World War II. See Gordon H. McCormick, "The Dynamics of Doctrinal Change," *Orbis*, 27, No. 2 (Summer 1983), pp. 266-274.

[8] Komer, Robert , "The Neglect of Strategy," *Air Force Magazine*, March 1984, p. 59.

[9] Choate, Lieutenant Colonel John S. *Implications of Runway Survivability Upon Future TACAIR Doctrine and Force Structure* (Maxwell AFB, Alabama: Air War College, 1984), pp. 5-8.

[10] Brown, Neville. "Immobilisation on Base," *RUSI* (Royal United Services Institute), 3 September 1983, p. 31.

[11] *Theater Air Base Vulnerability (TAB VEE) Study*, (Washington, D.C.: Department of the Air Force, 15 December 1965), Volume I, pp. 17-29. (Classified)

[12] Belmont, Colonel Paul A. *Air Base Survivability Overview* (Maxwell AFB, Alabama: Air War College, 1983), pp. 1-7, and as amplified by the author's own experience after three years at the Air Staff.

[13] The Soviet threat in Europe has been extensively described in unclassified literature. Selected examples include: William F. Scott, "The Themes of Soviet Strategy," *Air Force Magazine*, March 1984, pp. 68-73; Otto P. Chaney, Jr., "The Soviet Threat to Europe: Prospects for the 1980s," *Parameters, Journal of the U.S. Army War College*, September 1983, pp. 2-22; C.N. Donnelly, "The Development of Soviet Military Doctrine," *International Defense Review*, 14, No. 12 (1981), pp. 38-51; John Erickson, "An Evaluation of Soviet Combined Arms Operations," *Armor*, May-June 1980, pp. 16-21; John D. Correll, "Air Defense from the Ground Up," *Air Force Magazine*, July 1983, pp. 27-43; and Major Stephen C. Hall, "Air Base Survivability in Europe: Can USAFE Survive and Fight?" *Air University Review*, September-October 1982, pp. 36-46. See also previously noted Choate, pp. 11-16.

[14] *Assignment of Responsibilities for Development of Aerospace Doctrine*, Air Force Regulation 1-2 (Washington, D.C.: Department of the Air Force, 25 July 1984).

[15] Holley, Major General I.B. "The Doctrinal Process," *Military Review*, April 1979, pp. 2-13.

[16] As quoted in *Basic Aerospace Doctrine of the United States Air Force*, Air Force Manual 1-1 (Washington, D.C.: Department of the Air Force, 16 March 1984), pp. 4-7.

"Late twentieth century warfare consumed materiel in such enormous quantities as to put very long drawn-out operations out of the question."

General Sir John Hackett
<u>The Third World War</u>, August 1985

Lower Cost Wideband ATE Switching Systems— Simpler to Manufacture and Repair

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Automatic test equipment (ATE) stations for testing electronic warfare systems have an impressive array of signal sources to stimulate devices under test and measure the resulting device responses. The routing of these signals requires a switching system which can handle signals from direct current to frequencies of many gigahertz (GHz). Another ATE design constraint is high reliability to reduce support costs.

Specifications for electronic warfare ATE stations demand microwave switching systems with wider bandwidths and simpler field maintenance. The cost competitive supplier of these ATE systems is then faced with a mutually exclusive design requirement. Conventional wideband microwave signal switching systems are expensive. These microwave switching systems are neither simple to manufacture nor inherently easy to repair and maintain in the field.

New Technologies

Two new technologies will allow designers to simplify both field repair and production problems when producing microwave signal switching systems:

- Multilayer stripline circuit boards to interconnect the signal relays.
- Push-on connectors to attach the relays to the multilayer stripline circuit board.

Problems With Conventional Wideband Switching Systems

Fabrication

Wideband microwave signal switching systems made with conventional technology are difficult to manufacture and repair. The signal switching relays are connected with coaxial cables. To provide sufficient channel isolation at microwave frequencies, these connections must be made using semi-rigid coaxial cable.

Semi-rigid cable assemblies are not simple to make. Skilled personnel are required to cut the cables to the correct length and bend them to the correct radius without kinking the cable jacket. Once these cables are bent and formed to the correct shape, the coaxial cable connectors must be attached.

Placing the connectors on the cables also requires precision assembly work. A poor cable connector installation on either end renders the cable worthless. Serious reflections of signal power will occur from the poor cable voltage standing-wave ratio (VSWR).

Reliability

The cable assembly procedure presents switching system assembly risk in terms of cable yield and cable uniformity. These factors directly impact switching system assembly time and cost. In addition, the cable assemblies and their connectors largely determine the baseline VSWR for the switching system.

Since station space is limited, conventional switching systems must also be built using compact layouts. The semi-rigid cables and relays are densely packaged in these systems to conserve space. Figure 1 illustrates this point showing a typical radio frequency (RF) interface drawer from an ATE station. Note how the semi-rigid cable routing complicates the RF interface drawer assembly layout.

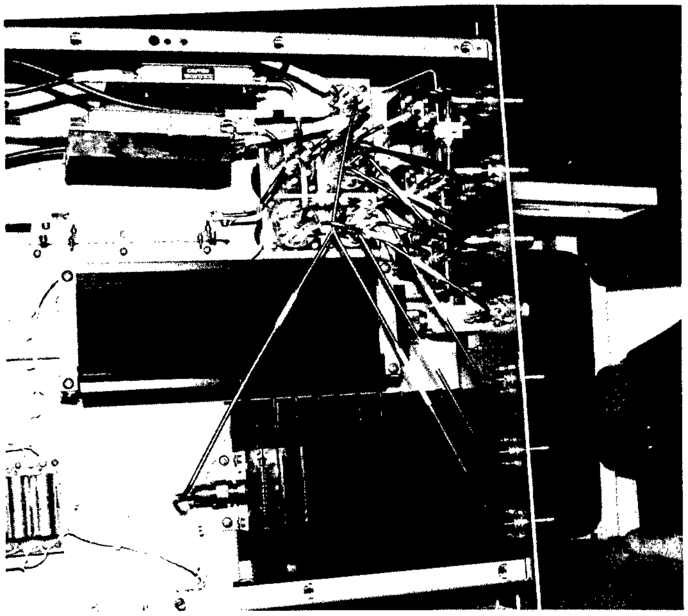

Figure 1. Note Semi-Rigid Cable Routing

Field Repair

The same factors of complexity that make these switching systems so costly to manufacture also create repair problems in the field.

Field repair is expensive because skilled technicians are required. If care is not used, systems can be damaged further by the repair effort itself.

The most probable failure in switching systems is a relay. Replacing a relay in one of these switching systems is often a difficult task. The relay must first be disconnected from the rest of the switching system. The semi-rigid cables must be removed from the relay and moved out of the way. This can damage the semi-rigid cable causing cable VSWR problems from damaged connections, kinked coaxial cable, or hairline cracks in the semi-rigid cable jacket.

The repair effort to replace a bad relay causing switching system problems can create totally new VSWR problems. Although a new relay with acceptable VSWR can be installed, the overall switching system VSWR can be seriously degraded to the point of failure due to cable damage from the repair effort.

Wideband Switching Systems Using New Technology

Using multilayer stripline circuitboards to connect the relays in wideband switching systems provides a compact, low cost connection scheme that is easier to build and more reliable to use than coaxial cables. The multilayer stripline circuitboards also make a compact modular switching system possible.

Push-on connectors make it simple to connect the relays to the stripline circuitboard and to connect the circuitboard to the rest of the ATE station. Relay replacement and board removal is very easy for field repair personnel. Using the push-on connectors, less skilled personnel can be used to replace failed relays or circuitboards.

Two switching systems using these new technologies were built at a significantly reduced cost than if coaxial cables had been used to connect the relays.

Digital Switching Matrix

A 100-MHz bandwidth, 5 x 16 cross-point switching matrix using mercury-wetted reed relays was built to switch digital signals. The relays were connected with 50-ohm striplines in the multilayer stripline circuitboard. The relays connect to the stripline board using female contact pins. Relay removal is simple. The relay just unplugs from the circuitboard.

Figure 2 shows this system. The 85 relays cover one end of the circuitboard. The relay drivers mounted in IC DIP sockets are at the other end of the circuitboard.

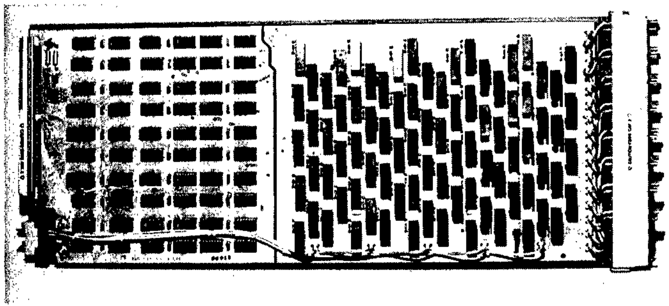

Figure 2. Multilayer Stripline Circuitboard

Microwave Switching Matrix

A prototype 18-GHz bandwidth microwave switching system using a multilayer stripline board with coaxial relays having push-on connectors was also built to demonstrate the use of these two technologies. It was then evaluated over a frequency range covering 10 MHz to 18 GHz. Figure 3 shows this system with one relay removed.

Relays were swapped during the test phase for each system by unplugging several relays and plugging each of them back into different board locations. No obvious effects upon the switching system performance and data were noted for either switching system after the relay swap.

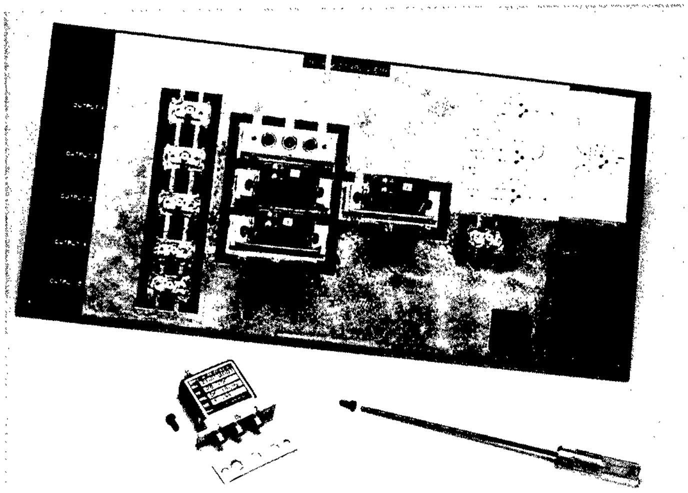

Figure 3. Note One Plug-in Relay Removed

Applications

From this promising development effort, further work on switching systems is underway. This work will provide lower cost ATE systems which can operate longer without failure and yet be simple for a technician to repair.

Reliability and Maintainability: A Short Tutorial

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The time has come to procure a new communications system, and we must specify reliability and maintainability (R&M) figures. Suppose we want the system available 95% of the time. That sounds pretty good. And let us say *mean down time* (MDT) must be 30 minutes. That ought to be a pretty good system.

Given *operational availability* (A_o) is 95%, then it will be down 5%, or 5% × 365 × 24 = 438 hours per year. Now if MDT is half an hour, then we are allowing 438/.5 = 876 failures per year. That is every ten hours or 2.4 failures per day! Is that really what we want?

Maybe we set A_o a little low. Moving it up to 99% and repeating the math yields 175.2 failures per year or every 50 hours. That looks better, but would a person buy a car that breaks every two days? Let us take a closer look at MDT.

Requiring an MDT of 30 minutes puts an incredible load on a wing logistics organization. MDT includes not only troubleshooting and repair time, but also all the associated delays for travel, getting replacement parts or a new set through supply, and any administrative delays. Time must also be included for any downtime required for preventive maintenance. That also requires 24-hour maintenance support and at least one of every part immediately available through supply. If there is only one of each system on each base, the logistics tail becomes astronomical. If there are 20 systems on base, that much supply may be necessary; but even with a failure every 50 hours, one of 20 is going to break every 2.5 hours.

Jumping to the other extreme, the wing's work load can be minimized by specifying an MDT of 10 days, enough for a CONUS MICAP (mission capability) action for every breakdown. Using the original A_0 of 95%, we now get 1.825 failures per year or every 200 days. That is well within the capability of current technology and we no longer have a maintenance-intensive system. Of course, no wing commander is likely to stand still for an MDT of ten days just to ease the burden of the "LG." But we can allow for an occasional MICAP action while getting expeditious restoration most of the time by requesting an MDT of a few hours. This figure must necessarily vary widely from system to system depending on quantity per base, system complexity, and reasonable sparing levels.

> ***". . . specifying A_0 is not a very good way to ensure getting a dependable system."***

This example shows that specifying A_0 is not a very good way to ensure getting a dependable system. We should be more interested in how often it breaks. The specification for that is *mean time between critical failure* (MTBCF) which, over a specified period of time, is equal to the total hours operational divided by the number of failures; i.e., it excludes downtime. Of course, since MTBCF is a statistical "mean" figure, it will be met or exceeded only 37% of the time. If we want a higher confidence—for example, to go X hours without a failure 90% of the time—we must specify an MTBCF of 10X. To make it 95% of the time, the factor is 20. This calls for a practical example.

Let us illustrate in terms of a most important factor—the mission. Assume a tactical communications system has a rapid deployment mission. Suppose we want this system to run 30 days without a failure 90% of the time. Remember, it is statistical so we cannot get it 100% of the time. The mathematics of the statistical curve indicate that to assure performance for 720 hours (30 days), 90% of the time, we must specify an MTBCF (the 37% figure) of ten times 720 hours, or 7,200 hours. If we insist on 95% probability of not failing for 720 hours, the magic factor is 20, for an MTBCF of 14,400 hours.

> ***"If we do not occasionally fail to get bidders, then we are not setting our sights high enough."***

Being able to relate system reliability to the *mission* is far more relevant than an availability figure that "sounds good." But if an availability number is still needed, we can derive it from MTBCF and MDT. Since availability is uptime divided by total time, then

$$A_0 = \frac{\text{MTBCF (Uptime)}}{\text{MTBCF + MDT (Total time)}}$$

Example: If the logistics organization and support concept can handle an MDT of 1 hour and we need an MTBCF of 7,200 hours. Then

$$A_0 = \frac{7200}{7201} = 99.986\%$$

While that figure may sound high, it is *not* unattainable, particularly for small systems. RIVET SWITCH radios are currently running MTBCFs from 8,000 to 16,000 hours. While many people express requirements in terms of availability, it is not the best way to specify system performance. A change of 0.1% in A_0 can result in large changes in MTBCF, given a fixed MDT. The Air Force cannot afford to buy any more systems with 50-hour MTBCFs. MTBCFs in excess of 1,000 hours are well within the capabilities of the industry. Let us start specifying for reliable, maintainable equipment and hold industry's feet to the fire until they deliver it. *If we do not occasionally fail to get bidders, then we are not setting our sights high enough.*

CHALLENGE: SPACE LOGISTICS

USAF logisticians stand at the threshold of a new era of logistics policy. The challenges of space offer untold opportunities for innovative logistics solutions to the complexities of spacecraft and satellites in a theater of operations that extends from the "soles of your feet to the stars." Military space operations are not new. Since the launch of Sputnik in 1957, the United States has exploited the versatility of space in support of USAF military missions. However, the launch, mission control, user, and space segments of space operations have been the exclusive purview of contractor support. From single shot, unique satellites, we are expanding to multiple satellite constellations requiring large numbers of repetitive launches. The advent of the expansion of DOD space operations, the establishment of Space Command, and the upcoming designation of a Unified Space Command (USC) necessitates broad changes in USAF logistics policy over the next several years to accommodate the resolution of space logistics problems. The overall objective of these efforts will be to support a maximum space mission capability at optimum cost.

Lt Col Eric E. Nelson
Acquisition Logistics/Communications Group
Directorate of Maintenance and Supply
HQ USAF

- The Spring 1986 *AFJL* will feature a special section on the logistics challenges of developing an effective and affordable space capability.

The Air Force Logistics Needs Program: Requirements - Not Just Dreams

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The Air Force Logistics Needs Program identifies logistics problems which can be resolved by laboratory research and development. The purpose of the program is to use advanced technology to reduce or eliminate supportability problems for next generation weapon systems and subsystems. Newly developed technology also feeds retrofit programs when life cycle costs are favorable. The Logistics Needs Program is a formal requirements process administered by the Air Force Coordinating Office for Logistics Research (AFCOLR), an office working directly for HQ USAF.

The Air Force recognized in the mid-1970s that, for supportability to be a viable design criteria, the logistician must play a significant role in a weapon system's acquisition cycle. Introduction of the Deputy Program Manager for Logistics (DPML) into acquisition program offices constituted a major step in institutionalizing this role. But, even as the DPML concept flourished, the Air Force began to realize these advocates were influencing only minor perturbations in the design. By further evaluating the acquisition cycle, the Air Force discovered the majority of design decisions were occurring, not during the full-scale development phase but, rather, during the *conceptual* phase. Further, the technologies considered for use during the conceptual phase were those already being worked in Air Force laboratories and in industry's independent research and development (IR&D) programs.

Therefore, if Air Force logisticians were to be successful in influencing design, they would have to work with designers long before full scale engineering development (FSED). This meant developing a requirements program through which logistics supportability problems could be identified early. Further, these requirements would have to drive the technology base to develop technologies which would eliminate the identified supportability problems.

The Program

To bridge the gap between the logistician's dream of solving supportability problems and the reality of war-fighting capability, the Air Force initially established the Logistics Needs Program at the Air Force Logistics Command (AFLC) in 1978. It grew from 17 logistics needs (LNs) to almost 200 active LNs in 1985. Since its inception, over 800 LNs have been submitted. By establishing the AFCOLR in 1980, the Air Force elevated the program to represent the *entire* Air Force. This Air Staff agency works closely with the Air Force Acquisition Logistics Center (AFALC), the operational MAJCOMs, and the Air Force laboratories. One of AFCOLR's primary roles is to be the "honest broker" for all MAJCOMs and their supportability problems.

The annual LN process begins with a January Call to the Field. This call initiates the MAJCOM's LN submissions based on their supportability problems. The LNs—the logistician's dreams of future reality—become a command's policy when formally submitted to AFCOLR in March. The AFCOLR engineers validate the LN submissions by working with LN submitters and potential technology base action agencies. They attempt to determine if supportability problems actually require new or improved technology. The engineers also try to find answers to several questions:

(1) Does a technology exist on the shelf?
(2) What engineering development is necessary?
(3) Is the LN asking for generic or specific improvements?
(4) Is the LN policy or funding oriented?
(5) Can the Air Force eliminate this type problem on next generation weapon systems with the required improved technology?

Once LNs have been validated, AFCOLR conducts a "rack and stack" procedure with the MAJCOMs. This effort results in a priority listing of all LNs. At this point, the LNs become formal research requirements. The LNs are forwarded in June to Air Force Systems Command (AFSC) for assignment to an AFSC action agency. The action agency prepares a support response and sends it to AFCOLR for evaluation relative to the LN submission requirements. This yearly cycle is completed in November when AFCOLR informs the LN submitters of the action agency response.

This, however, is not the complete life of an LN! The cycle is completed only when an LN progresses through the various stages of research and development and the technology is finally applied to resolve a MAJCOM's problem. The LN life is incomplete until the technology can actually transition. Only then has the logistician's dream become reality.

LN strategy has grown to be one of not only formalizing the logistician's dream into a research requirement but also providing a management tool. It allows technology base people to focus limited resources on requirements most important to the MAJCOMs. LN categorizing and rank ordering have provided additional emphasis which allows the technologists to be more responsive to Air Force needs. The timing of a June submission to AFSC allows for a smoother inclusion of LN research and development requirements into the Planning, Programming and Budgeting System (PPBS). The support response sent to the LN submitter in November provides the necessary feedback before the next yearly Call to the Field.

All LN submissions are maintained in a computerized data base in AFCOLR. As the data base system matures, it will be made available to DOD users on a "read only" basis. As the AFSC data bases mature, we expect to be able to electronically transfer project status information into our data base to provide action agency support responses. We also anticipate having

MAJCOMs electronically transmit LN submissions directly into our data base. Further, AFSC action agencies will be able to receive LN formal submissions electronically from AFCOLR's LN data base.

Air Force Laboratories

The overall mission of Air Force laboratories is to conduct Air Force research, exploratory development, and assigned non-systems advanced development programs. To accomplish their missions more effectively, the laboratories have been organized under various product divisions:

a. **Air Force Wright Aeronautical Laboratories (AFWAL), Aeronautical Systems Division, Wright-Patterson AFB, Ohio.** Four laboratories within the AFWAL community are:

(1) *Avionics (AFWAL/AA)*

Mission: conduct research and development (R&D) on aerospace vehicle avionics and associated support electronics.

Major Interests: electronic, electro-optical devices; reconnaissance, navigation, and weapon delivery; electronic warfare; and avionic system technology.

(2) *Aeropropulsion (AFWAL/PO)*

Mission: conduct R&D in air breathing propulsion, flight vehicle power, fuels and lubricants, and fire protection.

Major Interests: turbine engines; ramjet engines; power-electrical, mechanical, and hydraulics for aircraft and space vehicles; fuels and lubricants; and fire detection, suppression, and prevention.

(3) *Flight Dynamics (AFWAL/FI)*

Mission: develop flight vehicle technology for current and future aeronautical and space systems.

Major Interests: structures and dynamics for design and testing; vehicle equipment for landing gear and environmental control; flight control for control systems, simulators, and displays; and aeromechanics for performance and technology integration.

(4) *Materials (AFWAL/XL)*

Mission: conduct R&D in materials and manage the Air Force manufacturing technology (MANTECH) program.

Major Interests: manufacturing technology; thermal protection materials; aerospace structural materials; aerospace propulsion materials; fluids, lubricants, and fluid containment materials; protective coatings; and electromagnetic window and electronic materials.

b. **Air Force Space Technology Center, Space Division, Kirtland AFB, New Mexico.** Three laboratories under this Center are:

(1) *Air Force Weapons Laboratory (AFWL), Kirtland AFB, New Mexico*

Mission: conduct R&D on nuclear weapons/effects and advanced directed energy weapons.

Major Interests: high energy lasers; nuclear weapons effects and analysis and simulation; nuclear survivability and vulnerability testing; nuclear weapons design safety compatibility; and advanced weapons concepts.

(2) *Air Force Geophysics Laboratory (AFGL), Hanscom AFB, Massachusetts*

Mission: conduct R&D on terrestrial, atmospheric, and space environments.

Major Interests: upper atmospheric density; ionospheric propagation; environmental assessment; geodesy and gravity; spacecraft charging technology; and reentry erosion.

(3) *Air Force Rocket Propulsion Laboratory (AFRPL), Edwards AFB, California*

Mission: conduct R&D in rocket propulsion.

Major Interests: booster and payload propulsion for advanced ballistic missiles; longer life and improved propulsion for satellites and spacecraft; high performance advanced propulsion concepts; and high performance smokeless propulsion for air launched missiles.

c. **Rome Air Development Center (RADC), Electronic Systems Division, Griffiss AFB, New York.**

Mission: conduct R&D on command, control, and communication integration technology.

Major Interests: surveillance and communications electronic counter-countermeasures (ECCM) technology; advanced communication architecture; automated communications and communications and intelligence processing; standoff target location systems; advanced computer technology; radiation hardened devices and components; large scale integration (LSI) and microprocessor reliability; and cruise missile detection technology.

d. **Air Force Armament Laboratory (AFAL), Armament Division, Eglin AFB, Florida.**

Mission: conduct R&D on advanced conventional weapons.

Major Interests: air-to-air guidance; air-to-surface guidance; bombs, warheads, dispensers, and fuses; target activated munitions; aircraft guns; weapon effectiveness and vulnerability analysis; and weapon handling and separation.

e. **Air Force Human Resources Laboratory, Aeromedical Division, Brooks AFB, Texas (with an operating Logistics and Human Factors Division at Wright-Patterson AFB, Ohio) and the Air Force Aerospace Medical Research Laboratory, Wright-Patterson AFB.**

(1) *Air Force Human Resources Laboratory (AFHRL)*

Mission: conduct R&D in simulation, education, training, and personnel utilization technologies.

Major Interests: flight simulation; maintenance simulation training; computer based instructional systems; human resources in system design; and personnel selection, evaluation and utilization.

(2) *Air Force Aerospace Medical Research Laboratory (AFAMRL)*

Mission: conduct R&D to define the limits of a person's performance, adaptability, and survivability, and improve effectiveness in the operational environment.

Major Interests: human engineering and mechanical forces; toxic hazards; clinical evaluations; and radiation hazards.

f. **Air Force Engineering and Services Center (AFESC), Research and Development Division, Tyndall AFB, Florida.**

Mission: conduct R&D in civil and environmental engineering.

Major Interests: environmental quality engineering and coordinating tasks across all AFSC labs; facilities energy applications; aerospace structure; aircraft operational surfaces; and rapid runway repair.

g. **Air Force Office of Scientific Research (AFOSR), Bolling AFB, D.C.**

Mission: be the single manager for basic research and provide new scientific knowledge to advance operational capabilities.

Major Interests: life sciences; geophysics; aerospace vehicles; propulsion and power; electronics; weaponry; and materials.

A subelement of AFOSR is the *Frank J. Seiler Research Laboratory* at the Air Force Academy.

Mission: conduct research in the chemical and aerospace mechanical sciences, and support research by the academy faculty and students.

Major Interests: chemistry; aerospace mechanics; and applied mathematics.

Logistics R&D Objectives

The Office of the Secretary of Defense (OSD) has developed five major demonstration objectives for logistics R&D:

(1) Eliminate or reduce intermediate level maintenance.
(2) Provide survivable logistics command and control.
(3) Improve battlefield materials handling.
(4) Automate low-volume spare parts production.
(5) Accelerate transition from paper to digital information systems.

The Air Force laboratories have over 200 on-going projects which support some or all of these objectives. Also, many other projects indirectly support technologies in these areas. Several important projects and their sponsors are:

(1) **Aerospace Biotechnology for Chemical Warfare Defense (AFAMRL).**

Objective: carry out effectively air base operations and support under chemical warfare conditions. This laboratory will assess and develop decontamination procedures; will design detection and warning systems for field deployment; and, in order to evaluate crew performance, will develop safe simulants for training and model air base operations.

Payoffs: increased sortie generation and support for tactical operations in chemical defense environments.

(2) **Turbine Engine Development (AFWAL/PO).**

Objective: lower cost of ownership in high performance turbine engines. This laboratory will accomplish this through improved diagnostics, controls, and materials which will lead to a lower parts count, lighter weight with greater durability, and damage tolerance.

Payoffs: 3-5 times increase in the mean time between failure (MTBF), 30% lower engine operating and support costs, and a projected life savings cost of $13.3 billion.

(3) **Very High Speed Integrated Circuits (AFWAL/AA).**

Objective: develop the next two generations of advanced integrated circuit (IC) technology through higher density and higher speed circuits. This laboratory will conduct work in submicrometer technology which will allow for new architectural circuitry and built-in test. In fact, a substantial portion of the chip circuitry is dedicated to this built-in test capability.

Payoffs: tenfold improvement in size, weight, and power; enhanced reliability with a lower system LCC. Associated standardization with the increased capability will allow other programs like PAVE PILLAR to generate previously unheard of subsystem and system architectural schemes which will revolutionize support strategies.

(4) **Manufacturing Technology (MANTECH) (AFWAL/ML).**

Objective: automate welding and grinding at the depot repair shop. When added to the integrated blade inspection system capability, the depot will reduce labor requirements and increase production with a decreased recycle rate and improved inventory control and work scheduling.

Payoff: automated turbine engine blade repair facility at Oklahoma City Air Logistics Center.

(5) **Aircraft Battle Damage Repair (ABDR) Handbook for Weapon System Designers (AFWAL/FI).**

Objective: provide the designer with tools allowing him/her to design a system or subsystem which can be readily repaired in the field without special tools or materials. This laboratory will consider the lack of local on-base engineering in a wartime scenario as well as the restrictions of time and biochemical warfare suits.

Payoff: increased sortie generation and decreased spare requirements.

(6) **Increased Air Base Survivability, Recovery, and Sustained Operations (AFESC).**

Objective: improve the survivability of structures, improve capability to evaluate repair and maintain pavements, and reduce facility energy consumption. Another closely related program is the rapid runway repair project.

Payoffs: reduction in pavement maintenance costs, improved post-attack recovery time, and increased sortie generation.

(7) **Program to Develop Computer Based Maintenance Aide (AFHRL).**

Objective: provide a computer system using a digital data base to present multiple levels of information depending upon the skill level of the operator. This allows for paperless technical orders that are responsive to the technical capability of the technician.

Payoff: improved maintenance productivity through rapid access to up-to-date technical order information in a skill-adjusted format.

Also, AFHRL is developing an automated decision aid for the battlefield technician. This will allow the non-engineer technician to evaluate a battle damaged aircraft with respect to the extensiveness of damage, time and skills required to repair, and minimum repairs needed to attain some safe level of operational capability.

AFCOLR "Brown Book"

All these actions take place *within* the Air Force excluding other DOD agencies and industry. In order to preclude fractured, duplicative technology programs, AFCOLR distributes *The Air Force Logistics Research and Studies Program,* a "yellow pages" of what is needed (the LN portion), what is being done (the Logistics R&D portion), and how it fits into the future Air Force (the Logistics Long Range Planning Objectives portion). Known as the "Brown Book," it is available through Information for Industry offices and should also be in most defense contractor technical libraries. DOD personnel should check their local technical libraries for a copy.

Conclusions

The LN program has grown and matured over the past few years. AFCOLR has recently included more USAF MAJCOMs in the program and undertaken a program to educate LN submitters on how a highly successful LN should be formulated. A management strategy of prioritizing the LN submissions has been initiated to allow AFSC to become more responsive to MAJCOM operational support requirements. The immediate future includes expansion of information interfaces to include laboratory information systems.

The LN program has allowed the logistician to rise from an "influencer" to a "requirer." The change is significant: old-fashioned logisticians only dreamt of the future . . . forward thinking logisticians demand it!

CURRENT RESEARCH

Air Force Business Research Management Center (AFBRMC)

The AFBRMC, Wright-Patterson AFB, serves as the Air Force focal point for business research relating to central, systems, or research and development acquisition. The Center also conducts research, analysis, and evaluation to identify and eliminate barriers to competition. The research is performed by professional military education (PME) students, Air Force Reservists, and contractors. Once a study is complete, the AFBRMC distributes the results and makes recommendations for implementation.

On-going Research Managed by the AFBRMC

Estimating Multiyear Savings
Objective: Develop a reliable methodology to estimate the projected savings for a program using multiyear buys versus single year buys.

Competition Strategy Decision Support Model
Objective: Develop and demonstrate a competition strategy decision support model to assist decision-makers in assessing the costs and benefits of establishing/sustaining multiple sources of supply/service throughout the system acquisition life cycle.

Decision Rules for Enhanced Breakout
Objective: Gather and analyze data which reflects the results of increasing competition with the Air Force Logistics Command to develop decision rules to assist breakout managers in allocating resources to breakout for both direct purchase and competition.
(Project Officer, Lt Col Skipp)

Impact of Very High Speed Integrated Circuits (VHSIC) on Air Force Logistics
Objective: Develop a Logistics Support Plan and cite several examples of how insertion of VHSIC technology will affect AFLC operations.

Data Collection System for Estimating Software Development Cost
Objective: Develop a data collection system to help the AF Plant Representative Offices (AFPROs) evaluate contractor software development costs and schedule estimates.

Improvement of Computer Software Quality Thru Software Automated Tools
Objective: Develop a set of Air Force standards for validating software automated tools.

Quantitative Pricing Methods for Warranties in Air Force Contracts
Objectives: Develop and validate a methodology to determine the cost effectiveness of warranties, guarantees, product performance agreements, and similar requirements. Also, develop guidelines for selecting the level of warranty that should be pursued in various acquisition situations and for determining the extent of cost benefit analysis that should be performed prior to contracting for a warranty.

Cost Effectiveness Trade-offs in Software Support Environment Standardization
Objective: Develop an econometric model to determine the benefit to the Air Force of implementing a strategy to control an integrated automated support environment.

Government Software Quality Assurance
Objective: Develop a set of measures to help government in-plant representatives evaluate the quality of computer software.

(Project Officer, Capt Mitchell)

Acquisition Cost Reduction Through Improved Production/Inventory Control
Objectives: Establish performance measures for contractor production/inventory management systems. Develop review procedures for DOD Contract Administrative Services (CAS) organizations to use in evaluating contractor production/ inventory control systems.

Ranking Class IV and Missile Modifications
Objective: Develop an algorithm for use at the system program manager/ operating command level to achieve cost marginal tradeoff between modification and mission support.

Pilot Testing of Linear Digital Filters Against F-16 TECH MOD Program
Objective: Test the utility of linear digital filters to analyze F-16 TECH MOD performance data.

In-Plant Technical Support of Software Contract Administration
Objectives: Analyze the differences between hardware production and software development management systems and the technical functions presently being performed by buying activity and contract administration personnel. Identify the technical functions that "should be" performed by these personnel to obtain maximum efficiency in mission critical computer resource acquisition and determine the personnel skills and policy changes required to perform the recommended functions.
(Project Officer, Capt Smith)

Air Force Logistics Command (AFLC)

Logistics Management Sciences Study Program

The AFLC Directorate of Management Sciences (AFLC/XRS) is responsible for developing, managing, and executing the Command's management sciences study program. The principal goal of the directorate is to support command initiatives through application of operations research methods in both organic and contract studies. XRS has helped AFLC make great progress in relating investments in spare parts to the number of aircraft available in both peace and war. The Directorate is also working on learning more about the effect of maintenance demands and resources on repair times; distribution demands and resources on the time it takes to get assets from one location to another; and procurement systems demands and resources on mean-time-between failures, cost, and procurement lead times.

The senior staff consists of:

Mr. Victor J. Presutti, Jr., Director (XRS), AUTOVON: 787-3201
Lt Col Michael Lacey, Deputy Director (XRS), AUTOVON: 787-3201
Mr. Curtis E. Neumann, Assessment Application Division (XRSA), AUTOVON: 787-6531
Mr. John M. Hill, Concept Development Division, (XRSC), AUTOVON: 787-6920
Mr. John L. Madden, Consultant Services Division (XRSM), AUTOVON: 787-7408
Miss Mary E. Oaks, Study Program Administrator (XRS), AUTOVON: 787-4535

The following studies are representative of recent/current work being done in XRS:

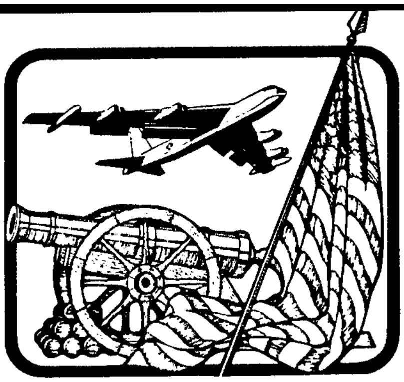
a. *Maximizing Aircraft Availability.* We are investigating techniques for allocating stock levels. The major emphasis is to make the allocations compatible with the aircraft availability criterion which is gaining much importance in the Air Force today. With this in mind, we are now involved in modifying the D028 algorithm to test the effect of changing the criterion from minimizing expected backorders (EBO) to maximizing aircraft availability.

b. *Jet Engine Intermediate Maintenance (JEIM) Flowtimes.* The purpose of this study was to assess the newly developed wartime surge and sustain jet engine intermediate maintenance flowtimes for the TF39 engine in the C-5 aircraft. We used the jet engine management simulator (JEMS) to relate the impact of the war flowtimes to aircraft availability rates and considered the JEIM maintenance crew man-hour availability, shift patterns and productivity, projected basing structure, and other possible management alternatives. We found the aircraft availability was constrained by maintenance crew availability. Also, we tested several alternative work shift patterns for alleviating this constraint.

c. *Capability Assessment Enhancements.* Several efforts are underway to increase the type and scope of logistics resources considered in weapon system capability assessments. These include assessing the impact of munition availability on wartime effectiveness, including test/support equipment as constraining resources, and developing methods to use the Dyna-METRIC model for assessing strategic airlift operations.

Most Significant Article Award

The Editorial Advisory Board has selected "The Aircraft Maintenance Workforce Now and in the Twenty-First Century" by Edward Boyle, Lt Colonel Stanley J. Goralski, USAF, and Major Michael D. Meyer, USAF, as the most significant article in the Fall issue of the *Air Force Journal of Logistics*.



LOGISTICS WARRIORS

PROBLEMS OF TACTICAL RESUPPLY

"For reliable, large-scale supply operations it was necessary to have airfields for landing as near as possible to where the supplies were needed. The lack of these fields was a principal factor in limiting the whole effort. When a forward field could be developed quickly for supply operations, as the one at Orléans for supporting the Third Army, air combat units soon moved in and pre-empted it for the use of bombers and fighters. The other principal hindrance to maximum air delivery was the competing demand of the First Allied Airborne Army. In the summer of 1944 the ground armies were moving more swiftly than the airborne army could plan; a whole series of operations had to be canceled as the ground forces raced past the planned objectives before the airborne operation could be mounted. But the preparation for these operations meant that supplies had to be built up for their support, and transport planes of the Troop Carrier Command had to be diverted to be ready to carry both men and supplies."

James A. Huston, *The Sinews of War*

TEAMSTER TRIBUTE: WWII

"The original plan to capture the ports of all of Brittany was discarded, for the determination of the Germans to fight a major battle west of the Seine, coupled with the advantageous position the Allied Army had attained, caused a shift in Allied plans. The German forces that had withdrawn behind the defenses of the Brittany ports were therefore left largely to their own devices, while the Battle of Normandy was fought and won.

'This meant,' says General Eisenhower, 'that we had to rely for our maintenance at a most vital period of the campaign upon the original supply lines through Cherbourg, the Arromanches Mulberry, and the Normandy beaches. Some cargoes were unloaded through the minor harbors and over the beaches of northern Brittany, but they represented only a small fraction of our total needs. The bulk of the supplies for the Third Army had to be transported by the long, roundabout route down through the Cotentin and then eastward around the German pocket resisting at Falaise and Argentan. The Third Army, when it got into its stride in the dash across France, was advancing at a speed of up to 40 miles a day, and our transport services were taxed to the limit. The incentive offered by the chance of a smashing victory, however, drove the men in whose hands the maintenance of supply rested to feats of superhuman accomplishment. The spectacular nature of the advance was due in as great a measure to the men who drove the supply trucks as to those who drove the tanks.'"

Hawthorne Daniel, *For Want of a Nail*

VAN CREVELD ON VIETNAM LOGISTICS

"Another field in which centralization reigned supreme, helping create a huge demand for information that could not subsequently be satisfied, was the logistic system servicing the American forces in Vietnam. This was originally due to a deliberate decision; in his haste to get as many American combat units into the country within the shortest possible time, Westmoreland in 1965 took the risk of stripping away their organic logistic support. The relatively static nature of the war, and cost-benefit considerations that favored the centralization and pooling of resources, subsequently prevented that support from being restored. Supplies and maintenance were provided instead by specialized Logistic Command Centers that gradually spread throughout South Vietnam and operated on a territorial basis. The system was dependent on constant, detailed communications between the Logistic Command Centers and the outfits in the field and, furthermore, on the former's ability to develop and maintain a statistical model of the latter's requirements, clearly an impossible task in view of the endless movements of units of many different types from one tactical area to another. The inability to forecast demand in turn increased the requirement for supplies still further, often making it necessary to requisition specific items from sources located on the far side of the Pacific. As it turned out, the necessary amount of information simply could not be handled by the requisitioning system, computerized and unprecedentedly sophisticated though it might be. Instead of using information to fine-tune the relationship between supply and demand, units were forced to send back men (the stationary Logistic Command Centers, with no permanent ties to any single outfits, insisted that the field come to the rear instead of vice versa) to walk over acres of stores and depots as far away as Okinawa and pick up whatever was needed. When the necessary items were located, they often turned out to consist of equipment which the headquarters in charge insisted it did not have. In the future, wrote General Heiser of the 1st Logistic Command, it would be necessary to resort to a less centralized system and restore service units to their parent outfits, thus doing away with much of the requirement for information though at the expense of creating some slack resources."

Martin Van Creveld, *Command in War*

PENINSULA WAR TRANSPORT

"Strategically the equal or the superior of the greatest of the marshals of France, Wellington was even more their superior as a master of logistics. He frequently suffered from weaknesses in his system of transport—hired transport, for the most part, manned by Portuguese and Spaniards. His wagon trains grew ever less dependable as his lines of supply stretched farther and farther toward the Pyrenees from Portugal. But the army that was supplied from England was able to defeat the greater forces that lived on the land, and as soon as he had won his final and most decisive battle in Spain, Wellington was able to discard the long and tortuous lines that led from Lisbon. Santander and the shorter roads of northern Spain enormously strengthened the hand of the ablest general of the Peninsular War at the very moment when he was preparing to invade France for the final phases of the struggle."

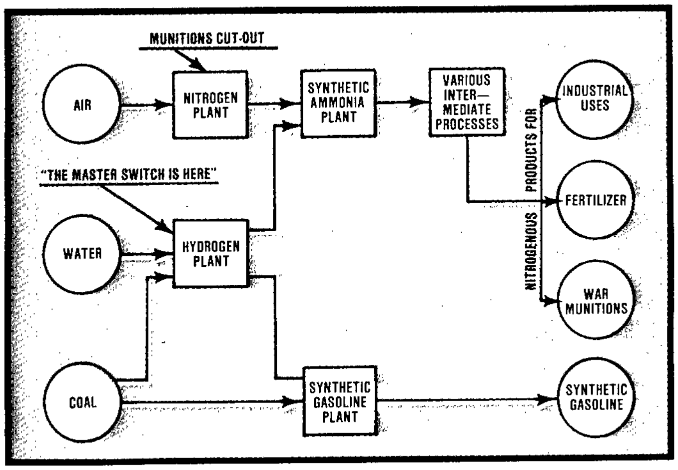
Hawthorne Daniel, *For Want of a Nail*

FINDING THE "MASTER SWITCHES"

"Nitrogen and hydrogen are paramount in war. Nitrogen is a basic ingredient of most explosives; hydrogen is an essential element in the fixing of nitrogen for explosive purposes and in the manufacture of synthetic gasoline. A simplified flow sheet illustrating the interrelation of these two elements is shown on page 135. This relationship holds during peace- and war-time. Only the emphasis changes. During peacetime, munitions are limited to commercial explosives for mining and construction purposes and a minimum amount for military explosives required in target practice. During war-time, war munitions and fuel for internal combustion engines come first. Without nitrogen and hydrogen, belligerents would perforce revert to hand-to-hand in-fighting, as was the practice throughout history right up to the invention of gunpowder. A continuously assured supply of these elements is the prime essential in war.

Germany has no natural sources of nitrogen and, at the beginning of this century, her local production was confined to inadequate quantities derived from by-product ammonia recovered from coke-ovens and gas-works. It was realized in Berlin that the importation of all nitrogenous products would be automatically cut off by the blockade at the outbreak of hostilities. In these circumstances, up to 1913, Germany could threaten but she could not strike.

So the Hohenzollerns had to put off zero hour for World War I until adequate synthetic nitrogen capacity had been put into operation and the country had become independent of Chilean nitrates. The invention by a Jewish chemist with the name of Haber of the process for the fixation of nitrogen from the atmosphere opened up new vistas, and I.G. Farben, that old offender who has always been so closely involved in Germany's war plans, rushed, at the behest of the German war-lords, the study of the commercial application of the Haber process and the completion of the first nitrogen plant at Leuna. By 1914, production was in full swing and this relieved the German General Staff for the first time of the fear of a possible shortage of nitrogen for their armaments; reassured on this point, they had no further hesitation in bringing to fruition their plans for plunging the world into war.



The two largest plants in Germany were built prior to 1914; they have continued in operation and are still to-day undoubtedly the foundation of Germany's munition supply. One, the Leuna plant, whose annual productive capacity of 750,000 tons of nitrogen is the world's largest, is just south of Merseburg on the Saale River; the other, the Oppau plant, is a few miles east of Mannheim. Most of the other German chemical nitrogen plants are in the Rhine Valley. Germany has also harnessed all the nitrogen plants in occupied territory to her war machine; one of the largest of these was the Norsk Hydro plant at Rjukan, Norway; other important ones were located at Sluiskil, Holland; Toulouse, France; and at Ougreé-les-Liége, Belgium. The destruction of any of these plants, many of which have been bombed, is a serious blow to German war economy.

The world productive capacity of chemical nitrogen has been determined by both peace-time requirements and by the prospects of war. War requirements are appreciably in excess of peace-time demand. So we find that, in the decade before this war, consumption was running at about 40 per cent of capacity; but as war drew nearer, consumption rose very sharply to 60 per cent, for the aggressors were building up reserves. With the return of peace, it may again fall to the normal 40 per cent. It can be said in very truth that consumption of nitrogen is a barometer of war and peace."

Murray Harris, *The Logic of War,* 1944

THE YOM KIPPUR WAR: LOSSES AND RESUPPLY

"The exact number of aircraft lost by each side (in two and a half weeks) can not be accurately determined. Israel claimed that Arab forces lost 451 aircraft. According to Israeli sources, more than 370 Egyptian, Syrian, and Iraqi fighters, one Tu-16 bomber, and some 40 Arab helicopters fell to the guns and missiles of Israeli fighters in dogfights, for the loss of only four Israeli fighters.

Maj Gen Benjamin Peled, commander of the Israel Defense Force/Air Force during the war, stated that altogether Israel lost 115 aircraft: four fighters in air combat, another one shot down accidentally by an Israeli fighter, 10 by accidents or unknown causes, 48 by surface-to-air missiles, and 52 by antiaircraft fire. Peled added that overall, Israel lost one aircraft per 100 sorties—a figure that compared quite favorably with the loss rate in the Six-Day War of four per 100 sortie. . . .

Altogether, Arab forces claimed to have shot down several hundred Israeli aircraft, most falling to ground-based air defenses. At a news conference on October 21, Egyptian Maj Gen Issad Din Mulhtar reported that, on the Sinai front, Israel lost 303 fighters and 25 helicopters. . . .

U.S. intelligence sources estimated that Arab missiles and antiaircraft artillery claimed 80 percent of the Israeli aircraft shot down, air combat 10 percent. According to the same sources, 242 Egyptian aircraft, 179 Syrian aircraft, and 21 Iraqi aircraft were destroyed by all causes.

While both sides suffered heavy losses, the Soviet Union and later the United States ferried in massive amounts of equipment. Soviet An-12 and An-22 transports flew 934 round trips to Egypt and Syria carrying missiles, ammunition, crated aircraft, and other materiel. In addition, an extensive sealift operation supplied an unknown quantity.

U.S. Air Force C-5 and C-141 cargo transports flew 566 round trips to Israel, totaling 22,395 tons. Israeli El Al cargo aircraft carried a further 5,500 tons, and an American sealift operation delivered an additional unknown amount. Israel received more than 80 A-4 Skyhawks, 48 F-4E Phantoms, a dozen C-130 transports, and a number of CH-53 transport helicopters.

In addition, the United States supplied such sophisticated weapons as Sidewinder infrared-guided air-to-air missiles, Shrike anti-radiation missiles, Walleye glide bombs, Maverick television-sensor-guided air-to-ground antitank rockets, and TOW (Tube-launched Optically-guided Weapon) short-range anti-tank missiles."

Lon O. Nordeen, Jr., *Air Warfare in the Missile Age*

"The purpose of all logistic effort is the creation and continued support of combat forces which may effectively carry out our national strategy. The nature of modern war is such that its effective conduct requires the greatest economy in the provision and support of these combat forces.

Economy of force in any one operation results in the ability to increase the scope and tempo of other operations and thus to increase the over-all pressure that is exerted upon enemy forces.

But if the wartime effectiveness of our combat forces is jeopardized by false economy, disaster may ensue. Therefore, all measures affecting the control and coordination of logistics must be judged by their effect on sustained combat effectiveness under war conditions rather than by the sole criteria of peacetime economy. An economy of a million dollars a year may be swept away in the first hour of a war and may cost a billion dollars in the opening of the war, not to mention its possible disastrous effects on the ultimate outcome of the war.

This evaluation is one that requires the finest kind of mature and fully informed professional judgment. It is not an area where amateurs and the use of superficial statistics can contribute to our national security."

RADM Henry E. Eccles
Personal Papers, 1954

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