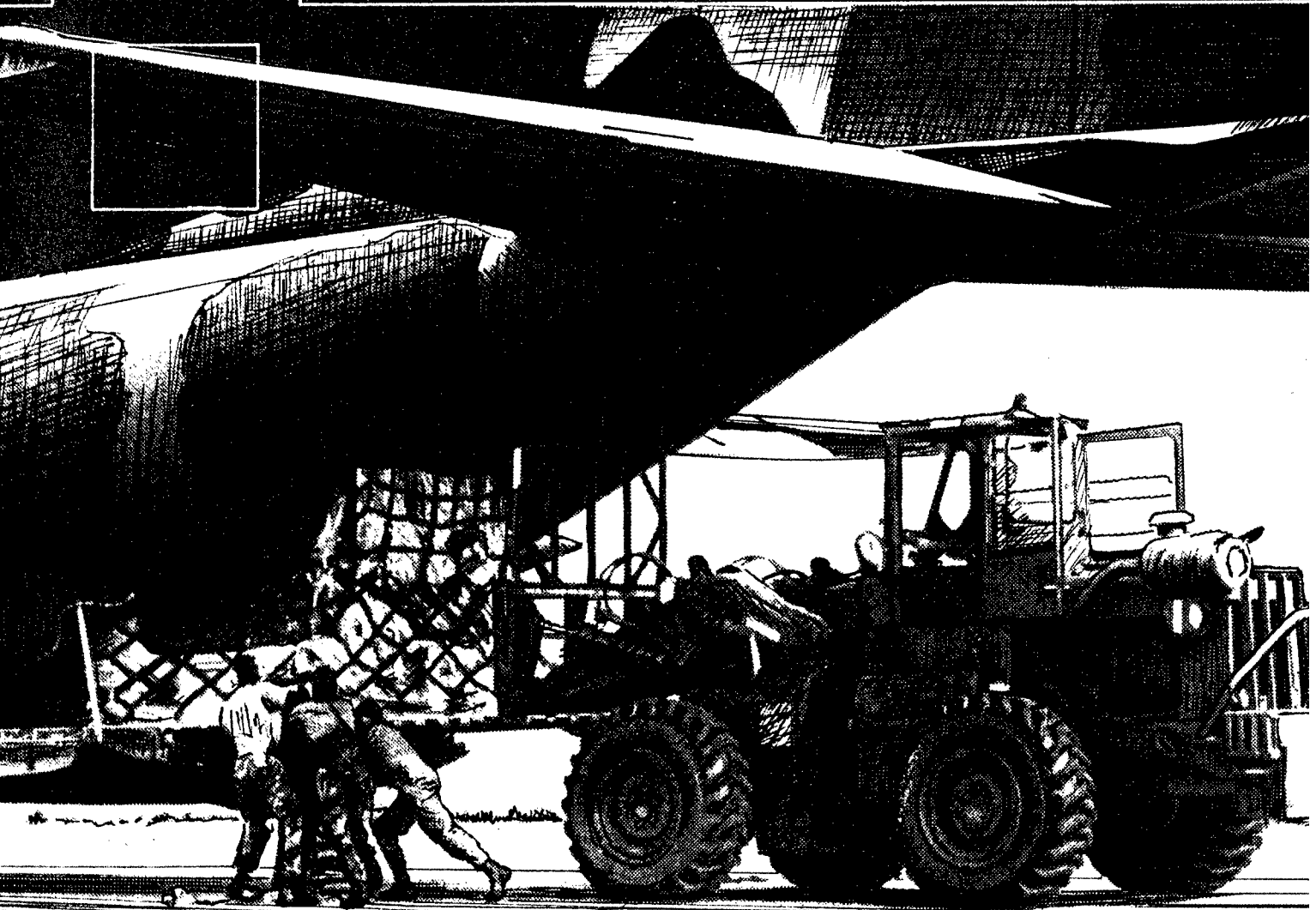


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The Future of Air Force Supply

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Introduction

The 1990s bring to us a challenge of greater complexity and a promise of reduced resources. The idea of supply system integration, which once was a matter of conceptual idealism, has become a matter of practical urgency. Fortunately, technologies exist or are emerging that will make the needed integration possible. Still, fundamental functional planning is required to bring the supply mission into focus and chart a vision of the future of the supply system.

There are many ongoing actions within the Air Force supply community to take on the supply integration task. At the heart of those actions is creation of an environment for change which will provide the framework for moving forward. That change includes formalizing a supply planning process, gaining continued management support and commitment, and establishing a control infrastructure to keep things on track (Figure 1). This article presents an overview of one component of the change environment, the planning process, with specific emphasis on accomplishments to date in building and institutionalizing a supply master plan (SMP).

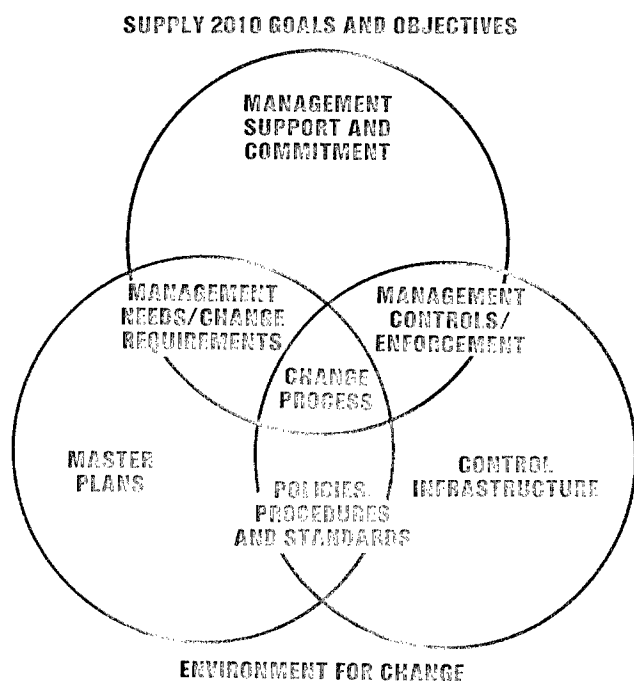


Figure 1: Total Air Force supply system – implementing concept.

Background

The concepts and objectives for the future of Air Force supply were originally documented in the "White Paper on the Future

Direction of the Air Force Supply System," which became the basis for the project Harvest Supply 2000 and is published as Section H of AFM 67-1, *USAF Supply Manual*, Volume I, Part One, Chapter 1. This document provided some basic guidelines for a total Air Force supply system. We found, however, many supply people were unaware of its existence. Further, some inconsistencies were present, and there was no indication that it was a driver in current programs or in the overall supply planning process. Despite these problems, the future direction document still contained most of the current thinking within the supply management community. Thus, we concluded the future direction document would be the logical starting point for developing a new master plan.

In keeping with the broader Department of Defense (DOD) program, "Logistics 2010," which provides logistics planning guidance for DOD, the Harvest Supply 2000 project has been redesignated Supply 2010 and the title shortened to "The Future of Air Force Supply." The intent of the program is to focus supply goals and objectives toward operations in the twenty-first century.

Supply 2010 consists of three components:

(1) A description of the way supply does business today. This description began as part of a logistics command and control study and will be developed into a supply functional description.

(2) A wartime concept of operations which was developed by a working group of major command representatives.

(3) The SMP which is the primary focus of this article and which serves as the "umbrella" for the other components and any other supply initiatives.

The Environment

To survive the current period of austere funding and keep up with technological changes in automation and modernization of other logistics systems, the supply leadership recognizes a need for change. But before instituting changes, they also recognize the need to look at the way we do business today and the way we want to do it in the future.

For example, two of the major objectives originally documented in "The Future Direction of the Air Force Supply System" were to "evolve from a two-tiered supply (wholesale/retail) to an integrated Air Force supply system" and "further integrate the Air Force supply system with other supply, logistics, and related functions." Given those objectives, there is a need for making some up-front decisions regarding specific issues:

(1) What does "integration" mean here in a technical sense?

(2) What specific integration is required/desired and how much is it worth?

(3) How much is the Air Force willing to pay for integration in terms of money and time?

The proposed starting point for answering these questions was development of the SMP. The direction for this

development process was provided by the "Implementation Plan for the Vertical and Horizontal Integration of the Air Force Supply System," a study done by Synergy, Inc., for the Supply Policy Division (HQ USAF/LEYS.)

Linkage to a Planning Hierarchy

The initiative to build the SMP started with the development of a comprehensive set of goals and objectives to support the supply mission. A new supply mission statement and a preliminary list of goals and objectives were developed by a small group of senior supply officers at a supply strategic planning workshop conducted at Andrews Air Force Base in March 1989. That workshop was jointly facilitated by Synergy, Inc., Bernier and Associates, and the Transportation Systems Center (TSC).

Results of the planning workshop were coordinated with the major command directors of supply and discussed at the April 1989 Air Force Supply Executive Board (AFSEB) meeting. Suggestions for improvement were incorporated into the emerging SMP and resulted in the mission statement, goals, and management objectives presented later in this article.

In working supply goals and objectives, there evolved a common thread of ideas bridging the various areas of supply and establishing a central theme that may be described as target characteristics of the future supply system:

- Data will be accessible by those who need it, but protected from those who do not.
- The various subsystems and modules which constitute the supply system will be fully integrated, vertically and horizontally. This includes integration both internal and external to supply.
- Air gaps will be minimal.
- Paper will be generated only when it is smart to use hard copy products.
- To the extent practical, source data will only be entered once.
- The system will be responsive to changes in policies and the environment—changes will be easy, quick, and inexpensive.
- Processes will be automated where it makes sense.

Framework of the SMP

The SMP is being designed to provide comprehensive, integrated supply planning guidance for the Air Force. It will be the basis for supply planning by all Air Force activities performing weapon system-oriented supply functions.

The basic framework of the document is patterned after "Logistics 2010." The "Logistics 2010" concepts and ideas are directly incorporated into the SMP where appropriate. Using that framework reflects the supply community's commitment to supporting an integrated logistics master planning process.

The SMP provides policy direction regarding supply planning by presenting a structured hierarchy of planning components (Figure 2). Those components include statements of the supply mission, goals, and objectives, and their supporting assumptions, constraints, critical success factors, problems, and needs. The relationships of the various planning components are presented in a manner designed to provide context and enhance understanding of how the various pieces fit together.

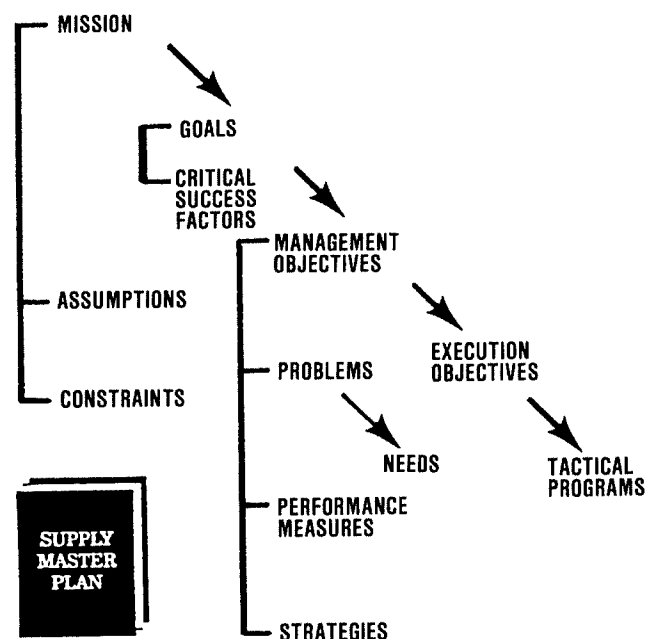


Figure 2: Supply planning components.

Supply Mission, Goals, and Objectives

Using the general structure described, senior Air Force supply managers developed the high level statements of direction that form the core of the SMP. Their first task was to define what is meant by the term "supply" and its purpose.

They defined supply as the inventory management of commodities for the Air Force. It consists of determining user needs, initiating the procurement process, managing the inventory, and assessing weapon systems support. Supply is responsible for ensuring that, within the scope of their managed commodities, the right item, in the right condition, is at the right place at the right time to meet mission needs.

The purpose of the Air Force supply system is to provide required supply support within the Air Force logistics system structure, which in turn is a component of the DOD logistics system. Understanding this hierarchical relationship is essential to building needed capabilities for Air Force supply.

From this foundation, they developed the following mission, goal, and objective statements. The mission of the Air Force supply function is to achieve and sustain survivable materiel support in response to all wartime mission requirements. As an integral part of combat forces, emphasis is to provide simple, responsive, quality supply support. Achieving this mission requires the dedication and commitment of everyone within the supply community plus the support and cooperation of the other logistics and operations functions within the Air Force, the other Services, the defense agencies, and DOD.

Four goals support the Air Force supply mission. These goals focus on the key areas in which supply takes action to achieve and maintain a capability to accomplish the supply mission.

Goal I - Ensure operational supply support to meet readiness and sustainability objectives. This goal is supported by four management objectives:

- (1) Provide a simple, responsive, survivable, mobile system.
- (2) Relate supply resources to combat capability.
- (3) Provide responsive command and control.

(4) Embed wartime supply in peacetime operations.

The Goal I management objectives focus on combat operations or, more specifically, how supply is used in combat. The execution objectives and tactical programs supporting these objectives will relate directly to combat support and the role of supply in supporting wartime operations.

Goal II - Ensure weapon system and combat support system availability through supply support. Three management objectives support this goal:

- (1) Manage and assess by weapon system.
- (2) Achieve or exceed all weapon system support objectives.
- (3) Allocate and distribute by weapon system.

This set of management objectives highlights the vital importance of weapon and combat systems to combat capability. While all supply support areas are important, these systems must be singled out for an extra measure of emphasis.

Goal III - Provide quality supply management and operations. There are four management objectives supporting this goal:

- (1) Provide a quality, efficient work force.
- (2) Achieve vertical and horizontal integration.
- (3) Provide quality physical facilities and automated systems.
- (4) Refine supply processes to meet needs effectively.

The emphasis is the supply function, or how supply works. These management objectives support building a strong and efficient supply system with quality people, facilities, and automated systems. The bulk of the systems-oriented initiatives for the supply functional area fall under these objectives.

Goal IV - Improve external supply interfaces. This goal is supported by two management objectives:

- (1) Make supply simple to the customer.
- (2) Improve the quality of external supply support.

These last management objectives focus on the two sets of interfaces that are the very essence of the supply operation. First is the interface with the customer. That interface is where the rubber meets the road, since customer support is the sole reason for existence of the Air Force supply system. Those customers include both those who receive materiel from supply and those who receive data. The second interface includes the multiple activities that support supply by providing the physical materiel and data that allow supply to function and by providing other types of support services, such as communications, transportation, facilities support, and utilities.

These goals and management objectives, presented in the "Logistics 2010" format in Figure 3, establish specific areas for action. These management objectives are qualitative in nature and are intended to provide a framework for execution planning. Subobjectives supporting each management objective are currently being developed. These subobjectives will be quantitative and time-oriented to support execution of the SMP and will be called execution objectives. Strategies and tactical plans will also be developed for each goal area. These will be further supported by a hierarchy of subordinate plans that cover actions down to the increment level (Figure 4).

Summary data will be developed for all supply plans supporting each execution objective. That data, which will include project descriptions, status, and relationships to supply goals and objectives, will be maintained in the supply planning system.

In addition to presenting basic supply planning doctrine, environmental considerations are also documented in the SMP in the form of the most important assumptions, constraints,

critical success factors, problems, and needs affecting the supply world. These environmental components, in combination with supply planning doctrine, are designed to shape action in the form of tactical plans. The intent is to provide a clear frame of reference regarding the overall supply planning process and the many factors influencing future supply direction.

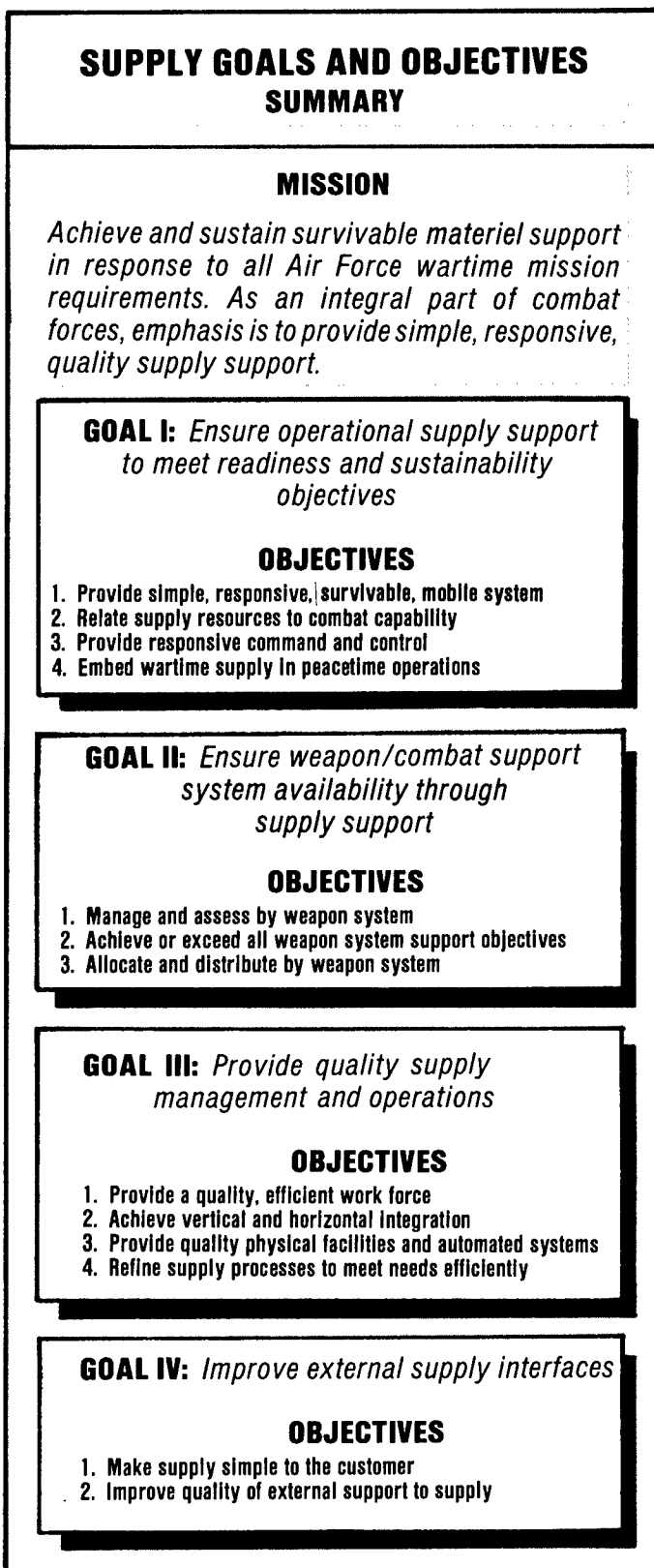


Figure 3: Supply goals and objectives.

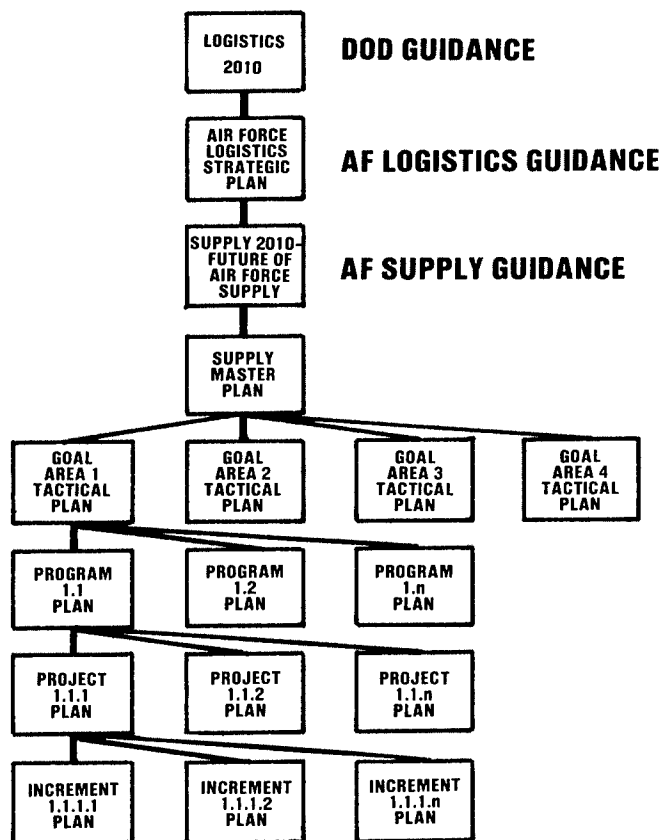


Figure 4: Planning hierarchy.

The Supply Planning Process

The initial work described was facilitated by the use of a personal computer (PC) based software tool specifically designed to support the development and presentation of the SMP. That tool, the Automated Logistics Analysis System (AutoLAS), was developed under a TSC contract by Bernier and Associates and Synergy, Inc., and is currently being used to support further SMP development. The tool is being embedded in the supply planning process as both the official repository of the plan and one of its primary presentation mediums. In addition, the tool will continue to be used to facilitate a very structured change process designed to keep the plan current on a continuous basis.

While the software tool is a valuable aid to the process, the most important feature of this planning approach is that it is being implemented as a living process, embedded into the operation of the AFSEB. That process will be the focal point of all strategic and tactical planning for supply. The Supply Master Planning Panel (SMPP), a subgroup of the AFSEB, will be charged with ensuring the process is kept alive and the SMP is current and complete.

Ensuring Consistency Between the SMP and Tactical Programs

All tactical programs and projects in the supply area will be assessed within the planning framework and must have demonstrable value to the SMP *before* being approved for

implementation. Inconsistencies in supply planning guidance found in any document and suggestions for improving supply planning will be brought to the attention of the SMPP through HQ USAF/LEYS.

It should be noted this approach advocates and encourages parallel development and implementation of multiple projects. The underlying idea is to first establish a control baseline and then break the target system down into manageable pieces and establish controls at the interface level. Concurrent work on multiple modules can therefore proceed as long as the interfaces are maintained. Conformance within those modules to fundamental design rules will ensure systemic consistency as the individual modules evolve and are integrated into the total seamless system.

Prioritization of Competing Requirements

Given wants always seem to exceed execution resources, there will be a need to sequence projects and programs supporting the SMP. The prioritization system built into the plan will provide the mechanism to control the speed with which individual modules or increments are implemented so overall planning objectives can be achieved. Where immediate restructuring is not possible, the plan must lay out sufficient guidelines to at least redirect ongoing projects, putting them on parallel tracks while specific integration plans are formulated and implemented.

At the heart of the plan will be functional requirements which will serve as the basis for all development activities. A common failing in the development of functional requirements is lack of supporting rationale and substantiated benefits. Too often, requirements are defined in general terms that call for on-line, interactive, real-time systems without any reference as to why the system needs to have those characteristics or what benefits will be gained. Strong functional requirements must pass the "so-what" test and must have sufficient benefits to justify the cost of design, development, implementation, and operation. To be effective, SMP execution objectives and tactical programs need to be fleshed out to meet the "so-what" requirement.

Where Do We Go From Here?

The institutionalization of a dynamic supply planning process and the development of an SMP are but the first of several steps necessary for the supply community to take charge of its own destiny. As we move toward the twenty-first century, we need to maintain clear focus on the supply mission, which may well change. We need to establish a flexible automation environment that can keep up with major changes in the way we do business and continue to provide necessary support with less people and materiel resources.

A primary characteristic of the SMP will be flexibility. The plan is being designed to adjust quickly and easily to the changes that will inevitably occur. Changes in both functional requirements and technology will occur before the ink dries on the planning document. Also, changes will be needed due to adjustments in funding, external mandates, and simple management discretion. We know these things happen and must plan for change from the very beginning.

Within this framework, Air Force supply is:

(1) Developing a comprehensive, well-documented master plan, the SMP. That plan is supported by an automated planning tool, and the planning process is being embedded into day-to-day supply operations.

(2) Establishing enforceable (and smart) policies, procedures, and standards governing supply system development efforts. Actions will be in coordination with the data automation community.

(3) Institutionalizing a new control infrastructure that provides visibility of change requirements, a mechanism to integrate and prioritize those requirements, an effective method of resource allocation, and a tracking system that keeps management in a proactive rather than reactive position. This control infrastructure will be fully integrated with the supply planning process and will be worked in partnership with the data automation support activities.

A Formula for Success

The overall strategy for supply is to create an environment for change that will be perceived by all players as a "win-win" situation. The Air Force supply community believes creating such an environment is possible if an effective process control mechanism can be developed. That process must reduce current system development inefficiencies to the point where everyone can get better automation support from the existing base or, for that matter, from the reduced resource base that is likely to exist over the next several years.

A key challenge in this environment for change will be that of gaining the willing involvement and commitment of both the managers and workers within the supply and data automation communities. Air Force supply plans to make that happen.

Staying on Course

Maintaining current and meaningful direction requires making the supply master planning process an integral part of day-to-day supply operations. As noted, the responsibility for maintenance of the SMP is being given to the SMPP. The SMPP, a select group of supply officers from the major commands led

by HQ USAF/LEYS, will operate under the control of the AFSEB.

To ensure consistency with Air Force and DOD planning guidance, a continuous review process is being established as a part of SMPP responsibilities. All planning guidance affecting supply will be reviewed as changes to that guidance are issued. The SMP will be updated as necessary to maintain consistency, or the new guidance will be challenged through official channels. Once the source of controversy is resolved, appropriate changes will be made to the SMP and other documents.

Since planning is a continuous process, there will never be a final plan. The supply plan will be dynamic and contain the flexibility necessary to meet combat support needs in a changing world. The AFSEB will review and make necessary updates to the SMP as part of their semiannual meetings. Recommendations for change will be prepared by the SMPP and presented at each AFSEB. Field recommendations will be submitted to the SMPP through HQ USAF/LEYS.

Conclusion

The concepts and supporting tools being put in place by Air Force supply have set the overall supply planning process into motion. If the baseline approach is implemented, the desired integration and general planning results are attainable. The process, however, must be clearly documented, widely understood, and scrupulously followed.

The future vision of Air Force supply is being shaped now. That future vision is being embedded in a living planning process that facilitates change management and maintains constant focus on where supply is going and how it will get there.

Success of the supply master plan will depend on direct management support and commitment, Blue Two understanding and acceptance, and the assignment of sufficient resources to keep supply plans current and dynamic. It is the stated intent of the supply community to maintain those required levels of support and commitment.



SOLE Logistics Symposium

The 25th Annual International Logistics Symposium sponsored by the Society of Logistics Engineers (SOLE) will be held August 21 - 23, 1990, at The Pointe at South Mountain, Phoenix, Arizona. The theme of this year's symposium is "Logistics Futures—Where We Are . . . Where We're Going." The keynote speaker will be General Charles E. McDonald, Commander, Air Force Logistics Command, and the Air Force's senior-ranking logistician. Nine technical panels will discuss Logistics Management R&D, DOD Logistics Technology R&D, CALS, Logistics Education, Collaborative Logistics, TQM, Software Logistics, Space Logistics, and Soviet Logistics. For more information, call Patricia Sutherland at SOLE Headquarters (205) 837-1092.

Making Sense of Spare Parts Procurement

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Introduction

Another article on spare parts? Yes, but this one is different. This is an objective look at how the Air Force prices spare parts, as opposed to the usual biased "reporting" of horror stories by the media. If you are not sure just how the Air Force buys spares or if you do not know what is behind the horror stories (like the \$7,000 "coffee pot"), this article will be of interest to you.

The issue of Department of Defense (DOD) spare parts procurement has been hotly debated for years. Congress, the media, DOD management, industry, and others have aired their positions in the press, in testimony, and on television. The general feeling of Congress is that DOD has regularly been overcharged for spare parts and that DOD should improve defense contracting procedures to prevent such overcharging permanently.¹

To help DOD managers make the desired improvements, Congress has enacted laws to bring about lasting change. In H.R. 5064, the House Armed Services Committee stated: "The committee was concerned that the legislation effect a fundamental change in the process and not simply address a symptom."²

Many in DOD and industry do not feel that congressional "help" is needed, yet the now-familiar accounts of grossly over-priced hammers, diodes, allen wrenches, coffee pots, and toilet seats have captured and maintained the attention of the public and Congress. Unfortunately, the simple truth is that overpricing continues, for a variety of reasons. Not everyone in the acquisition business is honest, as the recent scandals involving the buying and selling of information during source selection (known as Ill Wind) attest. Furthermore, human error is inevitable. The millions of contractual actions executed each year will undoubtedly produce a few real bonehead horror stories. Congressional help may not be wanted, but it is not hard to understand why it is given.

This paper cuts through the rhetoric and emotion surrounding the spare parts debate and provides an objective look at how spare parts are purchased by DOD.

An Overview of Spare Parts Procurement

The Department of Defense manages about four million spare parts, broken out as shown in Figure 1.³ What are spare parts and what is involved in their acquisition? In its report to Congress on DOD spare parts procurement practices, the Office of Federal Procurement Policy (OFPP) defined spares as:

Spare Parts. Spares and repair parts, repairable and consumable, purchased for use in maintenance, overhaul, and repair of equipment such as ships, tanks, guns, aircraft, missiles, ground communication and electronic systems, ground support and associated test equipment.... It includes items, spares, repair parts, parts, subassemblies, components, and subsystems, but excludes end items such as aircraft, ships, tanks, guns and missiles.⁴

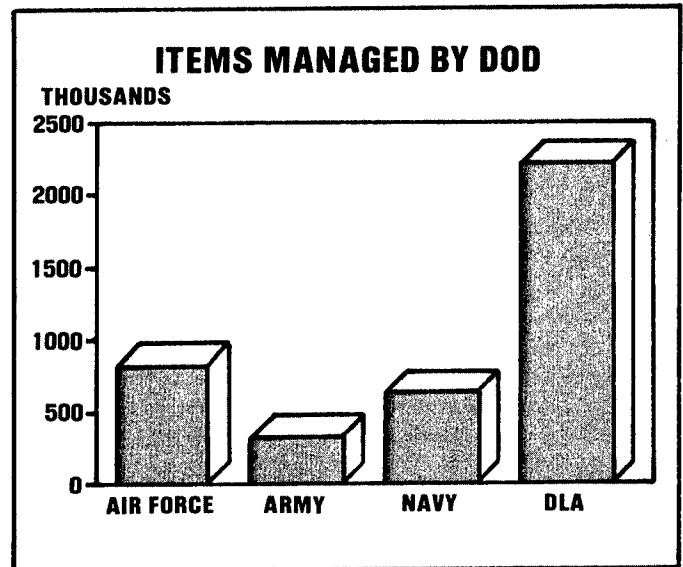


Figure 1.

Spare parts can generally be classified into two categories: **initial and replenishment** spares. Initial spares are those that are necessary to support a weapon system when it is initially deployed for field use. Replenishment spares are necessary to support the system during its lifetime.

Initial spares are usually purchased by the program office buying the system. Ideally, these parts are acquired with production units, taking advantage of the economies of scale associated with large production runs. To determine what spares will be necessary to support the system initially, the system end-user meets with program office personnel and the organization that will eventually provide support for the system once fielded. This meeting, which includes the contractor, is called a provisioning conference at which, as the name implies, the parties produce a proposed list of initial spare parts to be purchased with the system.

Provisioned Item Orders (PIOs) are placed by either the contracting officer in the program office or air logistics center, or by the administrative contracting officer in the contract administration office. To ensure these spares are indeed available when the system is initially deployed, PIOs are usually "unpriced," which means the price is not negotiated at the time the order is issued. The contractor starts work immediately to produce the initial spares while preparing a detailed price proposal for the work. After the proposal is submitted, the parties negotiate a price for the spare parts and execute a contract modification to reflect the agreement.

Replenishment spares are purchased in much the same manner during the initial life of a system. Unpriced PIOs are used because often the "best guess" made at the provisioning

conference is inaccurate. There are many reasons for this, but chief among them is the failure of systems to perform at the levels specified in the contract. This causes a greater demand for spares than anticipated, which forces contracting officers to use "extraordinary measures," such as unpriced contractual actions, to expedite production and delivery of the critically-needed parts.

To reduce the price of replenishment spares, DOD requires buying activities to compete their requirements whenever possible. Spares are not to be purchased from the prime system contractor unless the prime is, in fact, the only source. Even then, component breakout of parts from the system contract is encouraged to foster competition and reduce unit prices. Buying replenishment spares from the prime contractor when a known subcontractor or alternate source exists is not just a violation of administrative regulation—it is against the law (Competition in Contracting Act). It also results in paying unnecessary overhead and profit to the prime, thus driving up the final cost of the item to the government.

Despite this, PIOs are often placed with the original system contractor, primarily because sufficient time does not exist to search for or develop alternative sources of supply.⁵ This situation leads to sole-source price negotiation of thousands of items, often procured in a hectic environment in which contracting personnel are "rewarded" more for the quantity of work produced and the speed with which they obtain delivery of the parts than for the prices negotiated or extent of competition achieved.

As a weapon system matures and demand information on spare parts usage becomes available, fewer unpriced PIOs are issued. However, the magnitude of individual line items per order makes pricing each line item separately infeasible. To the working-level contracting officer, the more esoteric considerations like component breakout, dual sourcing, competition, socioeconomic considerations, etc., are less important than keeping up with the constant stream of purchase requests filling the in-basket.

Scope of the Problem

How big a problem is this spare parts issue? Does it deserve all the attention it has received over the years? It depends on your perspective. The basic goal of the contracting business, according to Robert Costello, is "... to get line managers and commanders the quality products and services they want, when they want them, at a reasonable price."⁶ As OFPP points out:

DOD purchases equipment, from the smallest individual weapon or field communication device to the largest air, ground or ocean-going system, to support national security objectives. Any evaluation or assessment of spare parts must include this critical factor ...⁷

The problems aired in the press are, in many cases, legitimate. Many are not. Colleen Preston summarized the contribution of the press in the spare parts debate in saying "... the atmosphere in which this legislation was passed was created in large part by unfair and often erroneous publicity ..."⁸ Individuals familiar with the DOD procurement program have expressed the belief that, overall, the process is sound. For example, the House Armed Services Committee report on H.R. 5064 states that "H.R. 5064, in many cases, codifies recent Department of Defense initiatives or current Department of Defense regulations."⁹

There is no doubt, however, that the negative publicity surrounding DOD procurement has fostered the impression that DOD procurement officials are inept, that defense contractors

are crooked, and that the two are jointly, either deliberately or through their incompetence, defrauding the American taxpayer. This perception leads to a problem of potentially greater magnitude than isolated horror stories—the undermined confidence of the public and Congress in the leadership of both DOD and the defense industry.

This erosion of trust may be a prime factor in the reduction in funds appropriated for the national defense, which may in turn lead to a degradation of the national defense—a serious long-range consequence.

With this broader perspective of the problem, the fact that only about 2% of the DOD budget is directly at issue in the spares debate is irrelevant.¹⁰ Corrective action is warranted, and the full attention of senior government and industry management is justified.

Pricing Policies and Procedures

How are prices actually determined for the four million items in the DOD spare parts inventory? Three pricing practices and their associated pitfalls are examined:

- (1) Cost allocation
- (2) Small quantity orders
- (3) Formula pricing

A fourth problem, that of over-specification, will also be discussed.

Cost Allocation

The "cost allocation" problem is actually two problems. The first involves indirect and direct cost allocations, which are made to the overall contract from the contractor's accounting system. Cost Accounting Standard (CAS) 418 (Allocation of Direct and Indirect Cost) is the primary guidance on this subject.

In general, cost allocations must be based on a causal-beneficial relationship between the costs being allocated and the contract to which they are allocated. For instance, one recent case of alleged improper allocation involved the indictment of a major defense contractor for fraud charges. The contractor had reached ceiling price on one of its fixed price incentive contracts. The indictment alleged the contractor charged over \$800,000 in labor costs on that contract to other Air Force contracts that had not reached ceiling, allowing recovery of those costs.

This was apparently a deliberate case of improper allocation.¹¹ Investigations of contractors by the DOD Inspector General and the various audit organizations have frequently focused on these improper, fraudulent misallocations.

Probably the least understood, most confusing (to the public at least) aspect of the spare parts pricing problem involves the second allocation problem. It can be categorized as "line item price distributions." This practice is not truly a cost allocation problem in the CAS sense, but that terminology has been used regardless of its technical accuracy. Many of the "overpricing" stories carried in the media have been due to perfectly legal, albeit irrational, price distribution practices.

Line item price distribution refers to the division of spare parts "support" costs among individual contract line items in an arbitrary manner. This practice has produced such well-known fiascos as the \$435 hammer, the \$9,600 allen wrench, and the \$1,500 pair of pliers.

Contracts for spare parts are often negotiated on a "bottom-line" basis. After all the allocations have been made to the overall contract as described, the total contract price is

divided among the individual line items. One frequently-used (and legitimate) method is to divide support costs equally among all the contract line items. When the intrinsic value of the line items differs substantially, this practice results in vastly overstated prices for items on the low end of the scale.

An example illustrates the point (Figure 2). Let us say the fixed price for a hypothetical spare parts contract is negotiated at a bottom-line figure of \$10,000,000, which includes support costs of \$500,000. The contract lists 2,000 line items, including a landing gear assembly with a cost of \$19,000 and a phillips-head screwdriver at a cost of \$4.00 (screwdrivers and other common tools and equipment are normally procured through the General Services Administration or Defense Logistics Agency; however, the "horror stories" often involve such items bought "by mistake" from the spare parts contractor).

Dividing the support cost figure of \$500,000 by the total number of parts, 2,000, yields a prorata share of \$250 of support costs each line item will bear. That, of course, makes the cost of the landing gear assembly \$19,250, which may appear quite reasonable to the public. It also makes the cost of the screwdriver \$254, which appears ridiculously high to the layman, despite the fact that the bottom-line price of the contract may be fair and reasonable.

ANATOMY OF A HORROR STORY			
Total Contract Price:			\$10,000,000
Support Costs:			\$500,000
Total # Line Items:			2,000
Pro-rata support/line item:			\$250
(\$500,000/2,000 items)			
Cost of Landing Gear Assy:			\$19,000
Cost of Screwdriver:			\$4
Final Price:			
Landing Gear:	Cost		\$19,000
	Support		250
	Total		\$19,250
Screwdriver:	Cost		\$4
	Support		250
	Total		\$254

Figure 2.

Two specific problems may result from questionable line-item pricing:

(1) *Artificially Increasing Contractor Cash Flow.* This occurs when a contract is structured so overpriced low cost items are delivered much earlier than underpriced high cost items. The effect of this is to prefinance the higher cost items.

(2) *Creating Exorbitantly High Contractor Profits.* This could occur on a contract with many line items and no guarantee that the Government will order all the items. If only the overpriced low cost items are ordered, the contractor's actual costs can be very low relative to the total payments received from the Government. This could result in exorbitant profits even though actual orders against the contract turn out to be much lower than anticipated.

The Air Force now discourages equal distribution of support costs among line items of disparate value, saying:

... Public opinion will not be swayed by appeals to the reasonableness of overall contract price if the price of individual line items appears unreasonable.¹²

Small Quantity Orders

DOD buys small quantities of spare parts at relatively frequent intervals. OFPP reported that 43% of Boeing Aerospace Company spare parts orders were for a quantity of **one each** (21,469 out of 50,117) over a given period of time.¹³ Simple economies of scale dictate that the smaller the number of units purchased, the larger the share of fixed costs and indirect expenses each must carry, which drives the unit price up.

A well-known example illustrates this point by showing the impact an increase in quantity would have had on the unit price of the infamous \$110 diode.¹⁴ Figure 3 shows the dramatic decrease in the price of the diode, from \$110 each when just 2 are purchased, to \$2.25 each for a quantity of 100, to just \$0.27 each for a quantity of 1,000. Without belaboring the point, it is obvious that small quantity orders should be avoided whenever possible and practicable.

UNIT PRICE CALCULATIONS—SPERRY DIODE			
Element	Quantity		
	2	100	1,000
Spares support cost	\$181.74	\$181.74	\$181.74
Material (.04 each)	.08	4.00	40.00
Subtotal	181.82	185.74	221.74
G/A at 10%	18.18	18.57	22.17
Total Cost	200.00	204.31	243.91
Profit at 10%	20.00	20.43	24.39
Total Price	220.00	224.74	268.30
Unit Price	\$110.00	\$2.25	\$.27

Figure 3.

Formula Pricing

Formula pricing involves the negotiation of indirect cost rates in advance of individual contract negotiations. These rates can then be applied to direct cost figures to arrive at a negotiated line item or total contract price. Commonly called Forward Pricing Rate Agreements (FPRA), the rates are in effect for a specified period of time and can be used by any number of contracting officers at different procurement activities to negotiate contracts with the contractor, depending on the limits set in the FPRA.

The time required to price an order or contract for spares can be drastically reduced using FPRAs, since the price is a result of a mathematical calculation involving direct costs and the rates specified in the FPRA, plus profit. This method is particularly useful when mid-to-high value spare parts are being purchased, but is of limited value when direct costs are not known, as is the case in orders for a large quantity of varied low-value items. Unfortunately, it is this latter group that produces most of the "horror stories." FPRAs are a great help to system program offices, but of less benefit to air logistics centers facing the task of buying millions of spare parts for a variety of weapon systems.

Over-Specification

While not a pricing problem per se, no discussion of this issue would be complete without mention of a chief culprit in the spare parts problem—over-specification. Over-specification is the practice of using a detailed specification for an item that could either be bought off-the-shelf, or could be much simpler. Examples abound. The Army's chocolate chip cookie recipe is longer than this article. The "coffee pot" purchased for about \$7,000 by the Air Force was in reality a highly complex beverage center similar to that used on commercial airliners—purchased for less than the cost obtained by the air carriers. The reader is no doubt aware of the penchant by the press for stories involving simple washers, nuts, and bolts that could supposedly be purchased for pennies commercially. Unfortunately, the stories are often accurate. This part of the system definitely needs work.

Conclusion

In this summary of pricing policies and procedures, the most common approaches to spare parts pricing have been discussed. Unfortunately, regardless of the method used to price spares, pricing errors will probably continue to occur. The Air Force Audit Agency provides this insight:

The procurement and pricing directives are intended only to provide guidance rather than a precise set of criteria to be applied in every case to obtain fair and reasonable spare part prices Because the pricing process is not precise, but includes judgment, all pricing errors cannot be eliminated.¹⁵

Air Force General (Ret) Earl O'Loughlin, former Commander of the Air Force Logistics Command, stated, "Even if we were 'Ivory Soap Pure'—that is, 99 and 44/100 percent pure, that would still leave us with a potential 560 horror stories each year, since we price 100,000 items per year."¹⁶

This fact—that pricing errors will continue despite the best efforts of all concerned—causes us all problems in this era of Total Quality Management. Congress is apparently convinced it can "legislate out" the remaining human error. Harvey Gordon commented on congressional intent:

What Congress wants is a fail-proof system in which every item is perfectly priced, but it fails to realize that the items that can be procured under such a system won't necessarily meet our requirements, or be available in the right quantities at the right time.¹⁷

Despite the misgivings of such knowledgeable individuals, much has been done by Congress, and by DOD, to "fix" the spare parts problem. While an in-depth discussion of procurement reform is beyond the scope of this paper, the practical impact of reform legislation and administrative remedy has been felt.

Preliminary studies show that administrative lead times have increased dramatically while prices have decreased.¹⁸ The tradeoff between price and delivery is a classic procurement decision, which must be addressed on an item-by-item basis. A spare part delivered too late to keep an airplane flying becomes a much, much more expensive item. Whether the decrease in

prices is worth the delay in getting spares to field commanders when they need them remains to be seen.

The intent of this account has simply been to inform readers about spare parts pricing practices in use by DOD. It should be evident that many of the reported "horror stories" are attributable to a misunderstanding of just how spares pricing is done. On the other hand, legitimate cases of human error, as well as fraud, waste, and abuse, are common.

Our goal and responsibility, as professional logisticians, should be to eliminate mistakes and unethical conduct wherever we find them. We must also strive to inform critics and colleagues alike that what we do in DOD procurement is vital to the nation's defense. Any discussion of this issue should be framed in that context.

Notes

¹H.R. 5064, 98th Congress, sec. 1202, states: "The Congress finds that recent disclosures of excessive payments by the Department of Defense for (spare) parts have undermined confidence by the public and Congress in the defense procurement system."

²Ibid.

³U.S., Office of Management and Budget, Office of Federal Procurement Policy, *Review of the Spare Parts Procurement Practices of the Department of Defense* (Washington DC: Government Printing Office, 1984), p. 5.

⁴Ibid.

⁵For example, see General Accounting Office, *Procurement: Spare Parts and Support Equipment for Air Force C-5 Transport Aircraft*, Report No. NSIAD-88-57BR (Washington DC: Government Printing Office, May 1988).

⁶Costello, Robert B. Unpublished text of speech given to 1987 Department of Defense Procurement Conference, 4 March 1987.

⁷U.S., OFPP, *Review of the Spare Parts Procurement Practices of the Department of Defense*, p. 5.

⁸Preston, Colleen A. "Competition and the 98th Congress," *Contract Management*, March 1985, p. 9.

⁹H.R. 5064, p. 17.

¹⁰Estimates vary as to the percentage of the DOD budget expended on spare parts of all types. OFPP, in its report cited in footnote 3, put the figure at \$17.7 billion, or 7.3% of the FY83 defense budget. *Defense News* reported the figure to be \$5.8 billion for FY89, or just 2.0% of the budget ("U.S. Defense Budget," *Defense News*, Vol 4, No 3, 16 January 1989, pp. 31-40).

¹¹"Air Force Suspends (name omitted by author); DOD Asks Refunds from (name omitted) for Spares Contracts," *Federal Contracts Report*, Vol 43 (4 April 1985), p. 541.

¹²"Air Force Policy Guidance on Cost Allocation and Line Item Distributions for Spare Parts and Support Equipment," *Federal Contracts Report*, Vol 42 (16 July 1984), p. 98.

¹³"Findings and recommendations of Pricing Methods and Contracting Techniques," *Report Prepared for OFPP Project Review of DOD Spare Parts Procurement Practices*, 13 April 1984, p. 3.

¹⁴Ibid.

¹⁵U.S., Department of Defense, *Pricing Replenishment Spare Parts*, Air Force Audit Agency Report, Project 5046411, January 1986, p. 2.

¹⁶U.S., Department of Defense, Department of the Air Force, Air Force Logistics Command Pamphlet, *Mission Support—Pricing: Telling the Whole Story*, November 1986, p. 2.

¹⁷"DOD Official Calls Procurement Process Misunderstood, Criticizes IG Role," *Federal Contracts Report*, Vol 42 (20 August 1984), p. 252.

¹⁸"Procurement Fraud Probes Growing: Spare Parts Pricing Improving, IG Says," *Federal Contracts Report*, Vol 47 (9 March 1987), p. 381. Also see James Kitfield, "Cheaper Spares, But at What Price?" *Military Logistics Forum*, Vol 2, June 1986, pp. 16-19.



A Simulation Study of a Jet Engine Overhaul Facility

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Introduction

The Directorate of Maintenance at the Jet Engine Division (SA-ALC/MAE), Kelly AFB, Texas, is currently responsible for the complete repair of three engine types: the T-56, TF-39, and F-100 series. In addition to complete engines, component parts in need of reconditioning are sent directly from the field to Kelly AFB in the form of MISTRs (maintenance items subject to repair).

Over the next ten years, three significant changes will impact the operation of the repair facility at Kelly AFB:

(1) Current engine induction levels are expected to increase. The net result of this growth will be a rise in the use of existing machines, personnel, and floor space.

(2) Four new engine rework processes may be awarded to SA-ALC/MAE. The incorporation of these engine types will require additional resources and change current operating procedures.

(3) New technology is continually becoming available to aid in the rework of both the current and new engine types. Introduction of this technology will create an unknown impact on the current operating environment.

Because of these anticipated changes, the Division needed a comprehensive study to aid in determining the resources necessary to support future engine overhaul operations. A project team from the Graduate Program in Operations Research at the University of Texas at Austin (1) was selected to perform the study. Simulation was chosen as the project analysis tool because it allows the investigation of the complex interactions between personnel, machines, and operational tasks not possible with other techniques. Selected experiments with simulation models can be performed to identify contention for scarce resources and bottlenecks in the system. Further, the effects on overall system performance of varying resource levels and operating conditions can be investigated and quantified. Such an investigation can identify feasible groups of process scenarios that meet expected throughput levels within given budget and other operational constraints.

Project Objectives

The primary objective of the study was to determine the resources required to adequately process various induction levels expected over the next ten years. (2) Resource categories explicitly modeled in the simulation included personnel and machines. The future induction levels for the F-100, TF-39, and T-56 engines were forecast based on historical and current demand. Induction levels for new engine rework contracts were varied to perform a sensitivity analysis on the effect of this possible increase in workload. Process adequacy was evaluated with respect to throughput rates (the average time required to

process a specific engine type or item), work in process inventory queue lengths, and resource utilization levels.

Modeling Approach

From the beginning of this study, it was apparent the complexity and size of the overall repair operations of MAE presented a formidable modeling task. The project team focused on the portions of the rework process performed within the primary buildings occupied by SA-ALC/MAE. A generalized layout of the main work center, Building 360, is shown in Figure 1. Building 324, schematically presented in Figure 2, contains other major overhaul shop areas. All tasks performed outside these buildings or by organizations other than MAE are treated as simple activities whose required time durations were provided by MAE personnel.

To simplify the modeling task, the repair operations were partitioned into subsets of more tractable size. A modular approach was used for the three engine types under study. For

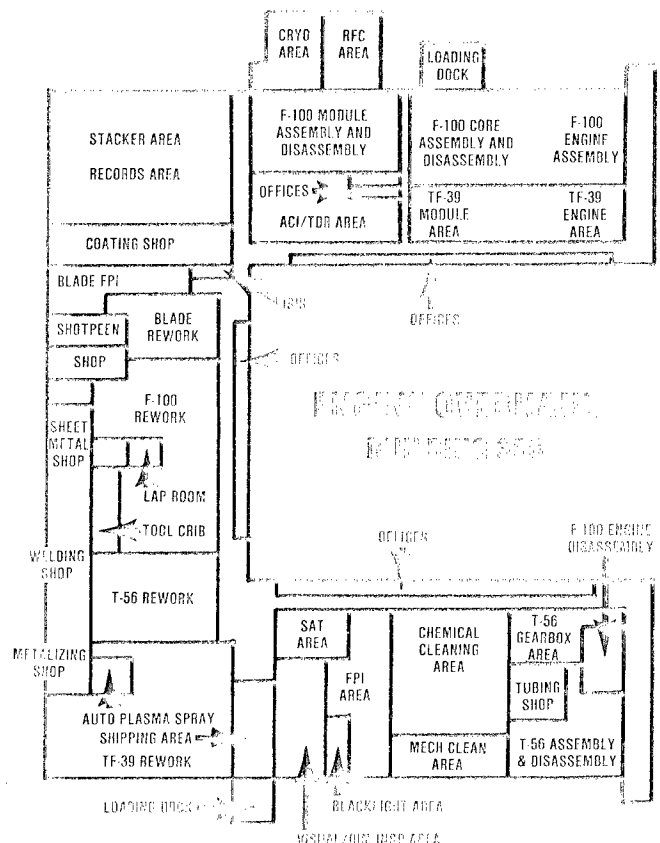


Figure 1: Building 360 facility layout.

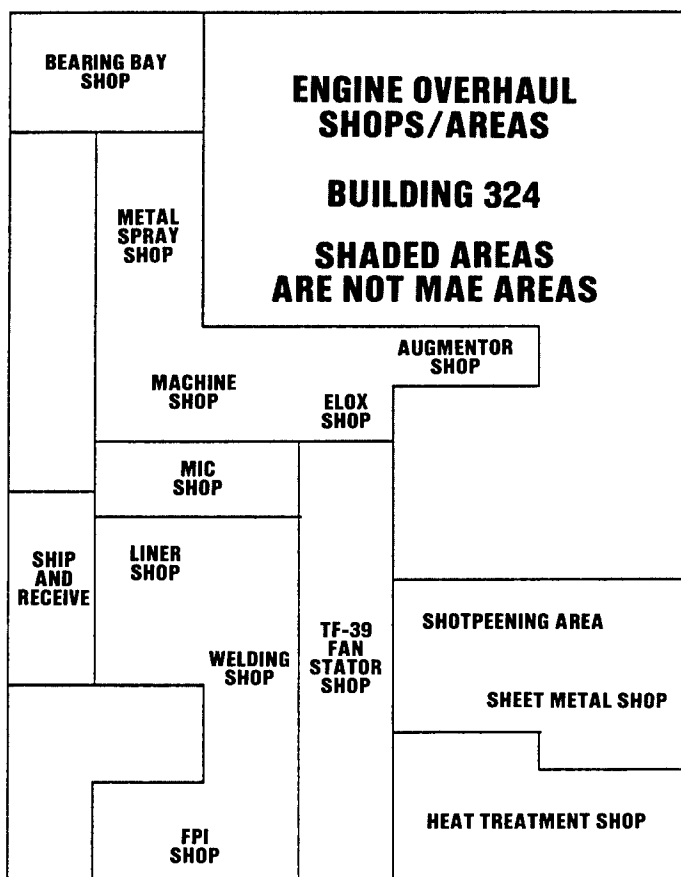


Figure 2: Building 324 facility layout.

the F-100, five standard modules formed a basis for study and five additional modular groups were identified. For the T-56, the engine, reduction gear, and torquemeter were used and three additional modular groups were identified. For the TF-39, thirteen modular parts were identified. (In the following discussion both modular groups and standard modules will be referred to as *modules*.) With the assistance of the production engineering personnel for each engine type, these modules were further divided into part classes. Part classes form the major assemblies for each module.

Following these preliminary actions, the project team began work in two major areas. First, visits were made to the cleaning, inspection, rework, assembly, and disassembly areas in buildings 360 and 324. These visits were followed by interviews with supervisors and workers and by a review of available records. The supervisors for the various areas provided detailed information describing the number and type of machines in place and the number of personnel available on each shift. Second, detailed interviews with production engineering personnel were conducted. Pertinent documents, such as work control documents (WCD) and technical orders (TO), were also obtained and reviewed.

The information gathered was used in the construction of visual process flowcharts for each module and engine. The project team developed flowchart standards and guidelines to aid in preparation and understanding of the flowcharts. (3) As shown in Figure 3, the process flowcharts consist of three levels. The Level 1 engine overview flowchart gives a broad look at engine processing. The Level 2 engine flowcharts track the flow of each engine from disassembly into the modules and then back

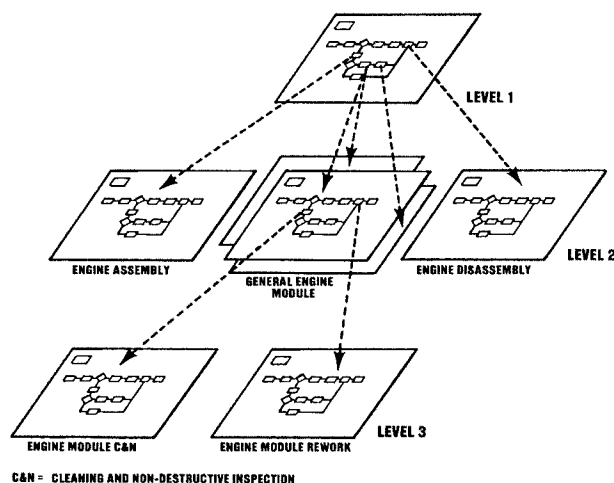


Figure 3: Flowchart hierarchy.

through assembly. The general engine module flowchart shows the module entry from either engine disassembly or from supply as a MISTR, disassembly into part classes, and then assembly into the module for MISTR shipment or engine assembly. The Level 3 module process flowcharts show the part class paths through cleaning and inspection processes and rework processes. Times and resources for each operation in each part class were identified and annotated on the process flowcharts. Figures 4 and 5 are representative examples of the 143 process flowcharts required. Frequent reviews by the production engineering personnel assured the accuracy of the flowcharts.

While the flowcharts were being completed, parallel work began on the coding of the SLAM computer simulation program that would eventually capture all the detail embodied in the flowcharts. As they were developed, each set of module flowcharts was converted into a module of SLAM program code that strictly adhered to a set of coding standards. (4) The SLAM code modules for each engine type were then combined and debugging runs were conducted. Finally, all three engine code groups were merged and final debugging runs were completed.

Verification and Experimentation

Once the development of the present method of operations (PMO) model was complete, its output was verified against historical data. This model became the Baseline PMO model for all subsequent investigations. (5)

The induction data was then augmented to include the 1995 inductions for the projected engines and MISTRs. This created the future method of operations (FMO) model. Differences in statistics were reviewed. Increases in resources necessary to remove bottlenecks in the FMO model were iteratively identified and implemented. When a final FMO model was established, the FMO and PMO resource levels were compared. This comparison directly yielded the necessary resource increases required by the projected 1995 induction levels.

The Simulation Approach

The SLAM Simulation Language

Several process-oriented simulation languages are available. Some examples are SIMSCRIPT (6), GASP (7), and SLAM (8). The project team selected the SLAM II simulation language because it increases the efficiency of the modeler by providing easily managed building blocks of code. Once the model is

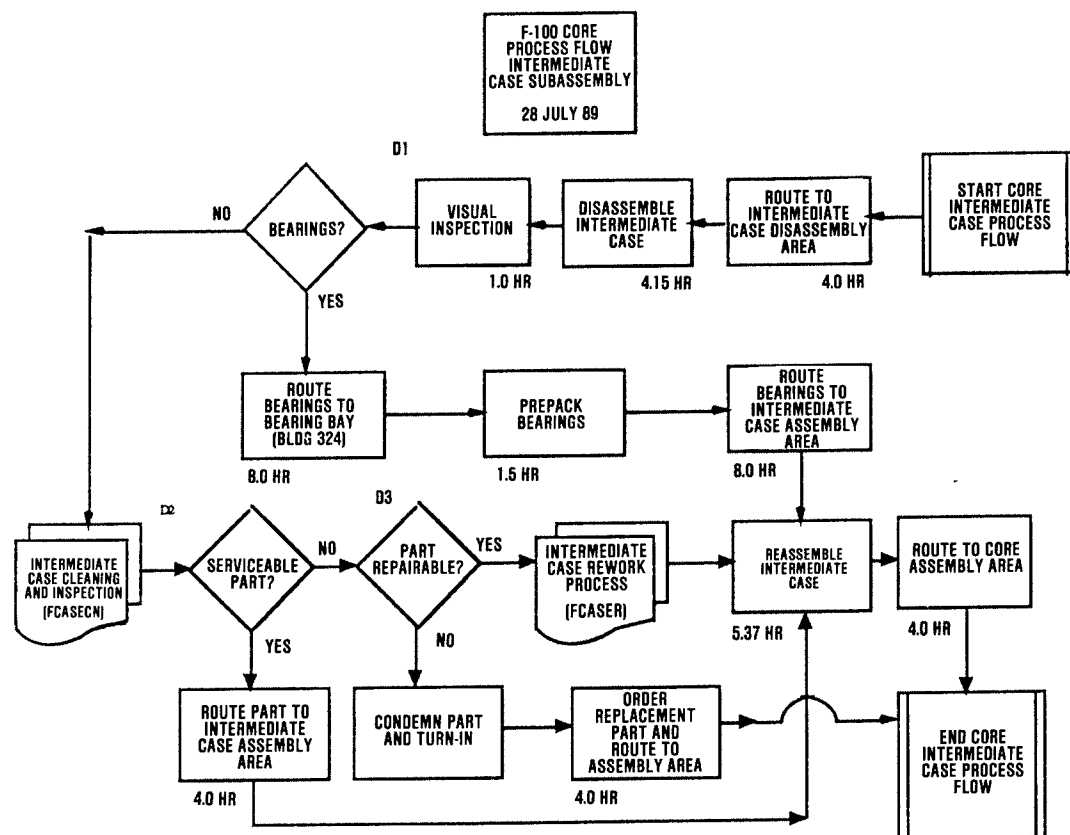


Figure 4: An example level 2 module process flowchart.

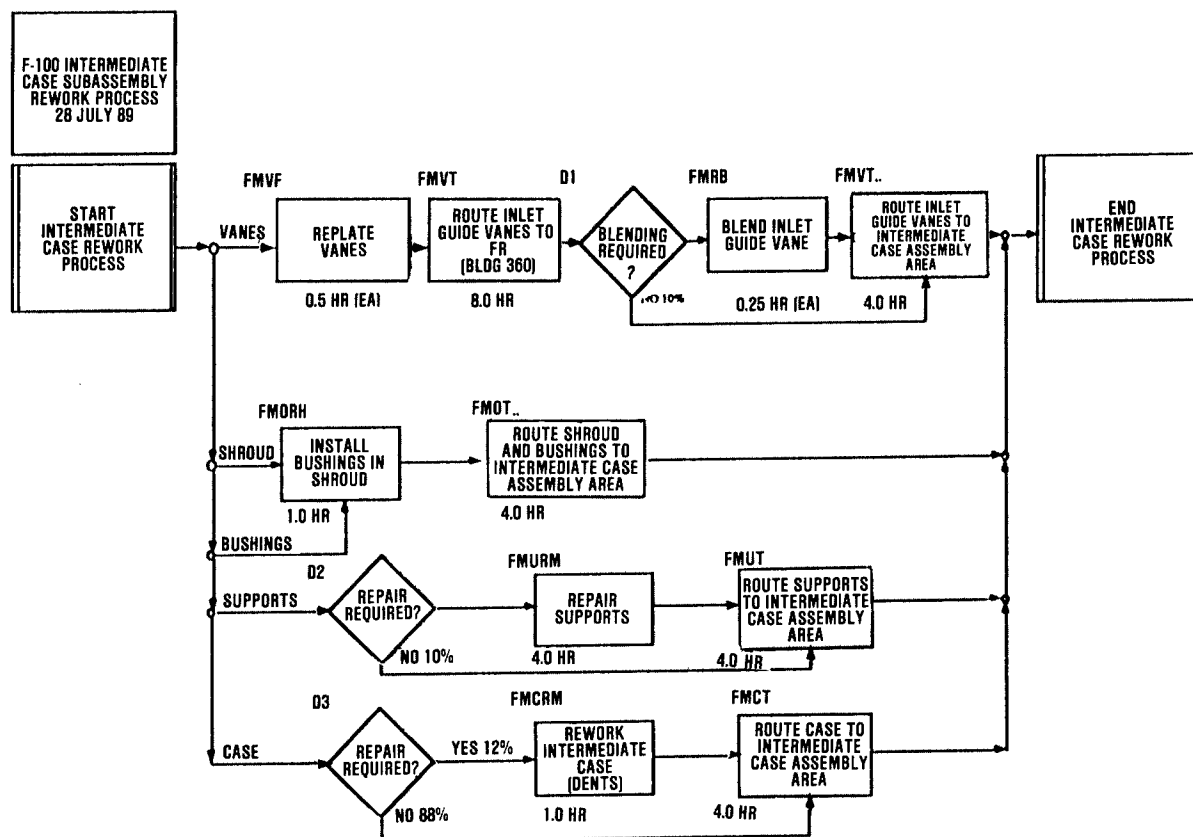


Figure 5: An example level 3 module process flowchart.

coded and run, the simulation language translates these building blocks into an executable program.

These building blocks are easily related to a typical manufacturing process. An explanation of selected SLAM terms and how they relate to the general process shown in Figure 6 is:

ENTITIES—Units or parts that enter the process. These may vary in size from a whole engine, to a set of disks, or to a single part.

TIME BETWEEN CREATIONS—The induction rate for entities in terms of time units between arrivals.

ATTRIBUTE—A “marker” or tag placed on an entity to identify a particular routing or resource requirement.

RESOURCES—Machines and/or personnel. Resources are normally allocated at QUEUES.

QUEUE—An area where entities wait for processing, normally a storage area.

ACTIVITIES—In Figure 6, activities are indicated by the connecting lines. Activities can have conditions, i.e., “drilling required,” and may have time durations or probabilities for dividing flow.

Flowchart Background and Categories

The process flowcharts already discussed define the logic and structure incorporated into the simulation model. There are a number of points concerning the creation of these flowcharts that need to be explicitly stated. (3)

Included in the process are the rework activities of all modules and major non-modular accessories associated with each engine type. The modules and accessories were specifically identified by MAEE personnel. As previously stated, engine modules were further expanded into several part classes. These part classes were identified by MAEE personnel as items requiring significant resources throughout their overhaul. For example, the Inlet Fan was defined as a major module of the F-100 engine. Although thousands of items are contained in the Inlet Fan, only the disks, air seals, cases, shroud, bearings, carbon seals, and blades/vanes were identified as major part classes of this module. Accordingly, only the rework tasks associated with these parts were included in the process definition.

In many cases, similar parts were grouped under a common part class name (all stages of disks might be generically defined as “disks”). In these cases, a common process flow was developed where possible. However, decision nodes were used in order to reroute processing to consider significant differences in the rework requirements for individual part types. For example, if the 5th stage disk required special overhaul

operations, it was separated from the remaining disks at a decision node and routed to those operations.

The process flowcharts were separated into four categories: Common Operation Processes, T-56 Engine Processes, TF-39 Engine Processes, and F-100 Engine Processes. All flowcharts included in the Common Operations category define work center processes that can be shared between engine rework operations and can be considered functionally similar regardless of the engine type being processed. Specifically, Common Operations include the automated and manual cleaning lines, the vibratory and blasting centers, and all common nondestructive inspection centers. By defining these common groups of tasks in a central location, redundancy is minimized and the process may be succinctly referenced in engine specific flowcharts. The flowcharts included in the T-56, TF-39, and F-100 engine categories define the operations associated with the overhaul of each specific engine type.

As shown in Figure 3, engine specific flowcharts at the three levels can be related to one another in order to create a single flowchart describing the entire overhaul of an engine or engine part type. The relationship between flowcharts is controlled by selected flowchart symbols and standards that allow easy cross-referencing.

On a generic level, all engine specific flowcharts are related to one another. This process structure can be used to review the process flow for an entire engine or part class; only the starting point differs. The relationship between flowcharts exists on different levels with a move to a lower level resulting in a one-to-many dependence. At lower levels, the information becomes more detailed.

As a specific example, consider the overhaul operation of the T-56 engine. The engine overall processing begins with the “T-56 Engine Overhaul Process Overview,” the Level 1 flowchart, which provides an overview of the major rework operations performed on a T-56 engine (induction, preliminary inspection, final engine testing, and release to distribution).

This chart references eight additional flowcharts: the “T-56 Engine Disassembly Process,” the “T-56 Engine Assembly Process,” and six charts describing the modular and nonmodular parts defined for this engine. These eight charts are defined as Level 2. If one were to review the disassembly and assembly flowcharts, a more detailed description of the T-56 engine disassembly and assembly process would be found. The remaining six Level 2 module specific flowcharts provide a general process definition of each module’s rework operation (the disassembly and assembly of the specific module).

Each general Level 2 module flowchart references two additional flowcharts at Level 3. The first of these defines the

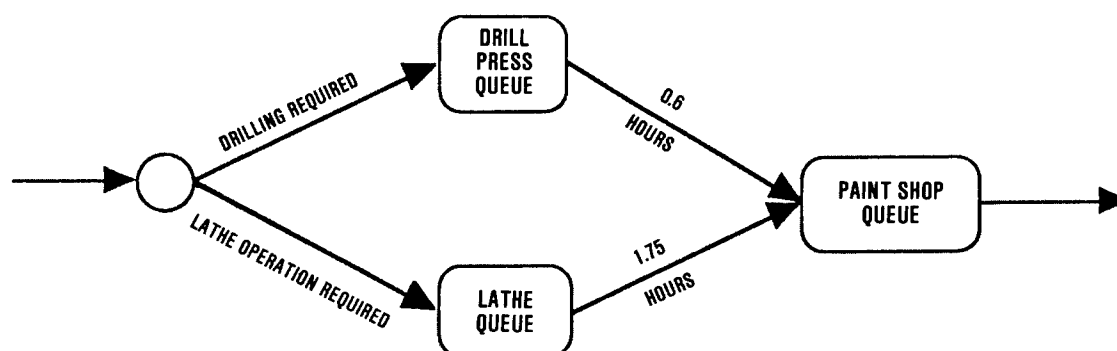


Figure 6: Process flow network.

cleaning and inspection processes performed on each identified part class of the module. For example, in the case of the T-56 Accessory Drive Housing Module, the cleaning and inspection for the drive cover, drive housing, and gears are defined on the flowchart titled "T-56 Accessory Drive Housing Cleaning and Inspection Process Flowchart." Similarly, the second Level 3 flowchart referenced on the Level 2 general module flowchart, titled "T-56 Accessory Drive Housing Rework Process Flowchart," defines the overhaul processes performed on each part class of the module.

In charting the rework operation of a part class, one would begin with the Level 3 flowchart for the specific part of interest. For example, the rework process of the T-56 Compressor/Rotor disks can be reviewed by looking at the "T-56 Compressor/Rotor Rework" flowchart.

Model Parameters

The model parameters consist of durations, number of modeled machines/tools available per shift, number of personnel available per shift, the engine/MISTR induction rates, and resources. The induction rates for the PMO model were determined by a review of MAE records for the past five years. The FMO induction rates were based on forecast data from HQ AFLC and provided by MAEE. The model code did include a section that accomplished the shift change adjustment of personnel and machines over a 24-hour period.

Resources from every major rework shop or area were included in the model. The resource information, provided by MAEP supervisors, consisted of the number and grade of people on each shift (or shifts), the number of major types of machines in the shop or area, and the availability of machines per shift.

Analysis and Results

Warm Up Period and Run Duration

Using a *warm-up period* is a common method for reducing bias in determining steady state statistics. This is achieved by delaying the collection of statistics until a certain period of time has passed. The intent is to remove the influence of initial conditions; i.e., when the model starts, the queues are empty. Parameters collected during this idle and empty period would cause many of the statistics to be different from their steady state values. By eliminating this initial transitory period, the quality of the statistics is improved.

For this project, a warm-up period of 2 working years was chosen. This warm-up period represents 40% of the 5-year-total run time of the model. During the model development, several warm-up periods were tested. It was determined this length would ensure that queue lengths had reached steady state.

The 5-year run time allows collection of 3 working years of statistics after the warm-up period. The figure of 5 working years of simulated time was chosen as a compromise. Clearly, the longer the run time, the better the statistics. However, computer time and computer expenses increase accordingly. For example, increasing the run time to 10 working years would result in a small increase in statistical accuracy while more than doubling the computation time required. The PMO model required approximately 19 hours of VAX 11/750 CPU time. Doubling the 5-year run time would increase the CPU time to about 38 hours. Depending on the scenario analyzed, there could be other computer limitations, such as a maximum running time limit, that could prevent longer runs. The 5-working-year run

time chosen appears to provide an excellent balance between run length and statistical accuracy.

Statistics Collected

The SLAM Output Report provides statistics on the following items:

- (1) The average time, the standard deviation, and the coefficient of variation for the time between entity arrivals at selected points in the model.
- (2) The average and standard deviation of queue lengths of entities waiting for service at specified points in the model.
- (3) The maximum number of entities, the minimum number of entities, and the average waiting time for entities in any queue.
- (4) The average, maximum, minimum, and standard deviation of utilization of resources, and the average, minimum, and maximum number of resources available.

PMO and FMO Results

After the Baseline PMO model was determined, the statistics for the model were analyzed. Those resources with average waiting times over 8 hours were identified. Discussions were conducted with shop and area personnel to verify that these resources were "bottlenecks." When these were confirmed, an average waiting time of 8 hours was used as a guideline in subsequent runs. Typical of the results available from the model, Tables 1 and 2 show the statistics for the resources in the Baseline PMO model with average waiting times of greater than 8 working hours.

A set of representative engine induction rates for the years 1995 and 2000 were investigated, and the resulting changes in resource level requirements were examined. For example, a typical 1995 scenario yielded the resource quantity requirements presented in Table 3. Any changes were translated into the machine resource percentage increases shown in Table 4.

Name	Avg Length	Avg Waiting Time
Automated Blade Personnel	21.9612	9.8525
Manual Blade FPI Line	32.2565	19.4800
PD 680 Tank	9.5043	28.4178
Manual Cleaning Work Station	1.6003	8.5886
Eddy Current Machines	9.6483	12.8685
Laser Machine	0.2112	11.8291
Heat Treat Horizontal Furnace Hydrogen	7.7518	11.9697
Heat Treat Horizontal Furnace Small	13.5328	17.3314
FRO Vertical Turret Lathe	2.4366	17.3745
FRO Manual Lathe	16.7208	15.2516
FRO Drill Press	5.8615	12.7878
T-56 Engine Stand	0.6960	9.7219
T-56 Accessory Drive Stand	0.7198	9.2895
T-56 Compressor Stand	0.7039	9.0901
T-56 Turbine Rotor Balancer	4.4679	20.3796
TF-39 HPT Rotor Stand	0.1168	14.6137
F-100 Core Disassembly Personnel	4.7569	9.1775

Table 1: PMO resource queue lengths and waiting times.

Analysis of Runs

Based on the typical 1995 scenario, the results show the anticipated increase in engine inductions would cause large increases in requirements for FPI equipment, chemical and mechanical cleaning equipment, Eddy Current machines, metalizing equipment, heat treatment furnaces, lathes and drill presses, engine stands, and disassembly workstations. The

Name	Avg Utilization	Avg Available
Automated Blade Personnel	1.2117	0.6635
Manual Blade FPI Line	0.4490	1.4261
PD 680 Tank	4.4759	0.5242
Manual Cleaning Work Station	0.3556	2.7695
Eddy Current Machines	3.7472	0.0028
Laser Machine	0.0045	0.3081
Heat Treat Horizontal Furnace Hydrogen	3.8820	0.1180
Heat Treat Horizontal Furnace Small	4.6552	0.3448
FRO Vertical Turret Lathe	2.0886	1.6614
FRO Manual Lathe	1.8641	5.6359
FRO Drill Press	1.5421	5.9579
T-56 Engine Stand	0.4402	4.2479
T-56 Accessory Drive Stand	0.1550	0.4704
T-56 Compressor Stand	0.3097	2.1906
T-56 Turbine Rotor Balancer	0.4516	2.6737
TF-39 HPT Rotor Stand	0.0799	1.1702
F-100 Core Disassembly Personnel	3.6785	0.0720

Table 2: PMO resource utilization and availability.

Type/Name	Resource PMO	Quantity FMO
Manual FPI Line	10	20
Mag Part Booth in AR	4	4
Manual FPI Line in AR	3	3
Visual Inspection Booth in Vis Insp Area	20	22
Manual FPI Line in Welding	5	10
Manual FPI Line in Bldg 324	2	2
Manual FPI Booth in Bldg 324	3	3
Local FPI in Blade Inspection Area	3	12
Blade Water Flow Tester	1	2
Sermetal Booth	2	2
Paint Booth	5	10
Glass Bead Wet Blaster	4	8
Vibratory Machines	12	16
Steam Cleaner	7	10
PD 680 Tank	8	14
Petroleum Solvent Booth	3	3
Alkaline Rust Remover Tank	4	8
Vapor Degreaser	3	4
High Speed Balancer in Cryo	3	6
Eddy Current Machine	4	8
Thermo (Flame) Metalizing Booth	2	3
Automated Plasma Spray	5	14
Electron Beam Welder	5	8
Lathe in Machine Shop (Bldg 324)	3	6
Riveter in Sheet Metal Shop (Bldg 324)	1	2
Horizontal Heat Treat Furn Large	8	14
Horizontal Heat Treat Furn Hydrogen	4	6
Horizontal Heat Treat Furn Small	5	6
Vertical Heat Treat Furnace	4	4
Vapor Degreaser in Heat Treat Area	2	2
CNC Jig Mill in AR	3	3
CNC Grinder in AR	2	2
Milling Machine in AR	5	5
Radial Drill in AR	3	3
CNC Grinder in JR	1	1
Lathes in JR	1	1
Drills in JR	1	1
Vertical Turret Lathe in FR	4	6
CNC Turning Center in FR	3	3
Manual Milling Machines in FR	6	6
Manual Lathes in FR	8	12
Drill Press in FR	8	16
F-100 Disassembly Vertical Engine Stand	3	12
F-100 Assembly Rollover Engine Stand	4	6
F-100 Assembly Vertical Engine Stand	5	10
Core Disassembly Workstation	5	10
T-56 Turbine Wheel Balancer	10	10
TF-39 HPT Stand	4	4

Table 3: Resource levels for PMO and FMO models.

Type/Name	Current Resources	1995 Resources	% Increase
Manual FPI Line	2	4	100
Visual Inspection Booth	20	22	9
Manual FPI Line in Welding	1	2	100
Local FPI in Blade Inspection	1	4	300
Water Flow Blade Tester	1	2	100
Paint Booth	2	4	100
Glass Bead Wet Blaster	2	4	100
Vibratory Machines	4	5	25
Steam Cleaner	4	5	25
PD 680 Tank	1	2	100
Alkaline Rust Remover Tank	3	6	100
Vapor Degreaser	1	2	100
High Speed Balancer in Cryo	3	6	100
Eddy Current Machine	4	8	100
Thermo (Flame) Metalizing Booth	1	2	100
Automated Plasma Spray	2	6	200
Electron Beam Welder	2	3	50
Lathe in Machine Shop (Bldg 324)	3	6	100
Riveter in Bldg 324	1	2	100
Horizontal Heat Treat Furn Large	6	11	83
Horizontal Heat Treat Furn Hydrogen	2	3	50
Horizontal Heat Treat Furn Small	1	2	100
Vertical Turret Lathe in FR	4	6	50
Manual Lathes in FR	2	3	50
Drill Presses in FR	8	16	100
F-100 Disassembly Vertical Engine Stand	2	8	300
F-100 Assembly Rollover Engine Stand	4	6	50
F-100 Assembly Vertical Engine Stand	5	10	100
Core Disassembly Workstation	4	8	100

Table 4: Current and 1995 resource requirements.

actual increase in machine resources could easily be translated into floor space requirements. For example, if each furnace has a 400-square-foot footprint, the increase in furnaces will require 2000 square feet of additional space. Table 5 shows the additional floor space requirement if all the additional machine resources were satisfied by ordering additional machines.

A review of the output statistics showed that most FMO resources had queue lengths that were increased approximately 50%. This implies that even if all resources were increased as indicated in Table 5, approximately 50% more storage space will be required to store the parts while they are awaiting work.

A full analysis of the PMO and FMO runs is contained in the Final Simulation report. (9)

Summary

The results contained in references 2, 3, 4, 5, 9, and 10 satisfy the primary objective of the study which was to enable SA-ALC/MAE to project the resources required for its operations over the next ten years for a given induction scenario. In addition, the 25,000-line simulation computer code created as a result of this study has been provided to SA-ALC/MAE in a form compatible with their on-site computer. This simulation model provides sufficient detail of the total overhaul process to

enable MAE to look at the results of various changes in personnel, machines, and induction levels. It can be used as a short-range or long-range planning tool with relatively short turnaround times.

Equally important is the fact that the general analysis approach and the experience gained by performing the analysis

Type/Name	Number of Additional Resources	Sq Ft Per Resource	Additional Floor Space Requirement
Manual FPI Line	2	2400.0	4800.0
Visual Inspection Booth	2	54.0	108.0
Manual FPI Line in Welding	1	225.0	225.0
Local FPI in Blade Inspection	3	225.0	675.0
Water Flow Blade Tester	1	75.0	75.0
Paint Booth	2	480.0	960.0
Glass Bead Wet Blaster	2	90.0	180.0
Vibratory Machines	1	180.0	180.0
Steam Cleaner	1	360.0	360.0
Vapor Degreaser	1	105.0	105.0
High Speed Balance in Cryo	3	48.0	144.0
Eddy Current Machine	4	288.0	1152.0
Thermo Metalizing Booth	1	300.0	300.0
Automated Plasma Spray	4	7500.0	30000.0
Electron Beam Welder	1	270.0	270.0
Vertical Turret Lathe in FR	2	756.0	1512.0
Manual Lathes in FR	1	108.0	108.0
Drill Presses in FR	8	27.0	216.0
F-100 Disassembly Vertical Engine Stand	6	192.0	1152.0
F-100 Assembly Rollover Engine Stand	2	255.0	510.0
F-100 Assembly Vertical Engine Stand	5	192.0	960.0
F-100 Core Disassembly Workstation	4	300.0	1200.0
Total Additional Floor Space Requirement—45192.0			

Table 5: Additional floor space required.

described should form a sound base and planning tool for similar studies at other repair and manufacturing facilities.

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The authors would like to acknowledge the extraordinary assistance of all the personnel at Kelly AFB who were involved in the project. In particular, we would like to acknowledge the support of Colonel C. D. Portz, Lieutenant Colonel B. Blackwell, Mr R. Baty, Mr H. Rippa, Mr S. Buchanan, Ms M. Hoch, and Ms S. Killam.

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Now if part of the proper mission of the military is to preserve the peace, then *peace* should receive at least as much emphasis as war. So we can point to one of the virtues military officers should cultivate—a virtue that may at first seem odd. That virtue is peacefulness. My purpose in starting with this virtue rather than with some of the traditional virtues of loyalty or courage or honor is to point out that peacefulness is at least as central to the military's mission as the others, and peacefulness has implications for the military that we usually overlook. For this reason it should be made part of our code. . . .

Preferring peace to war has implications for the way officers train, plan, and act. It need not impede their ability to act immediately if appropriate. But it does affect their view of their mission and the proper way to fulfill it. To emphasize this, the first item of an Ethical Code for Officers might read: *(1) I shall prefer peace to war, and realize that the military serves most effectively when it deters and so prevents war rather than when it engages in war.*

Military Ethics,
National Defense
University Press

A New Indicator for Avionics Maintainability¹

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Introduction

The traditional view of reliability and maintainability (R&M) relies on a simple precept of equipment operating problems: either the equipment is broken or it is fixed and it is easy to identify when it is broken. Such a view leads to relatively simple measures for characterizing R&M. At the subsystem level, the most frequently used traditional measures are mean time between failure (MTBF) and mean time to repair (MTTR). At the weapon system level, the traditional measure is the fully mission capable (FMC) rate. Within the simple view, this set of measures is complete in that it accounts for all possible conditions of the equipment. Unfortunately, the world of modern integrated avionics is not so simple, both because of advances in reliability and because of continuing growth in the amount, versatility, and complexity of avionics.

The Need for a New Indicator

Nowadays, reliability and versatility of avionics equipment has grown to the point where equipment very rarely experiences total failure. Rather, it typically falls victim to faults that erode its performance superiority over potential enemy weapons. When equipment fails to deliver its full measure of designed performance, the performance degradation is often subtle and difficult to observe. In addition, faults may develop symptoms that occur only in specific operational modes. A subsystem with multiple modes, like a fire control radar, can have a fault that affects performance in only certain modes. Other faults may develop in specific environments, such as in an aircraft when it is in a high vibrational condition or when it is executing a violent maneuver.

Because the traditional measures of R&M fail to adequately account for these realities, they can provide only a partial picture of the R&M situation. They fail to reflect, for example, situations where:

- The pilot sees a symptom of a fault but does not report it to maintenance.
- The pilot reports a symptom as a discrepancy deserving the attention of maintenance technicians, but the flight-line technicians do not remove a line replaceable unit (LRU) from the airplane because they could not duplicate (CND) the symptom.
- The airplane's built-in-test (BIT) detects a fault during a flight, but flight-line technicians do not remove an LRU from the aircraft because they reran the BIT test and it failed to detect the fault; the technicians could not duplicate the symptom.
- Flight-line technicians remove an LRU from an airplane and send it to the avionics shop, but the shop technicians find that the LRU bench checks serviceable (BCS) when they test it because their tests failed to detect the fault.

- Shop technicians remove a shop replaceable unit (SRU) from an LRU and send it to the depot repair center, but the depot technicians find the SRU retests OK (RETOK) when they test it because their tests failed to detect the fault.

By not reflecting such situations, the traditional set of measures for equipment R&M portrays only a partial picture of the overall R&M situation. The resulting lack of situational awareness greatly weakens capabilities to fully support the designed capabilities of mission essential avionics equipment.

An effort to improve R&M situation awareness must cope with two challenges. First, R&M is a quality that has many dimensions. Second, precise characterization of this quality becomes increasingly more difficult as the complexity of the equipment and its support process grows. Each of these realities is especially applicable to modern military avionics.

For such equipment the two main dimensions of interest are the mean time between initiation of new faults and the efficiency of the maintenance process in removing faults. Because the usual practice is to estimate MTBF by calculating the mean time between shop confirmed failures, such an estimate for MTBF usually provides a plausible estimate for the mean time between initiation of new faults.² To complement the MTBF parameter, the Air Force needs a parameter that reflects the efficiency of maintenance personnel in fully restoring the designed performance of a system once a fault has developed. Such a parameter should serve to attract needed management attention to the more serious maintainability problems. To do this, the parameter must be sensitive to the factors that determine the maintainability of a subsystem. These factors include the airborne equipment as well as the ground support equipment (including tests) at all levels of the maintenance process.

With such a parameter serving as a maintainability indicator, and with the MTBF parameter serving as a reliability indicator, the Air Force would have a reasonably complete capability to estimate the overall R&M situation for complex military avionics.

Fault Removal Efficiency: A New Maintainability Indicator

We propose the following requirements for a new maintainability indicator:

- Complement the existing reliability indicator (MTBF) and together with it provide a comprehensive overview of the R&M situation at the subsystem level.
- Reflect the full range of problems encountered in identifying faults and isolating their causes.
- Account for all flights with indications of faulty subsystem operation.

To achieve such thorough accounting, pilots and technicians need to report all indications of situations where either they or the BIT perceive a subsystem's performance departing from

designed capabilities. Such full reporting of symptoms is absolutely essential. Such thorough accounting for all perceived indications of faulty operations is a complete change from the comfortable traditional view that a problem not found on the ground did not exist in the air.³

The following maintainability indicator is consistent with the noted requirements:

$$\text{Fault Removal Efficiency} = \frac{\text{MTBI}}{\text{MTBF}} \times 100\%$$

where

MTBI = mean time between flights with indication(s) of faulty operation of the avionics subsystem.

mean time between flights that resulted in shop

MTBF = confirmation of a failure of the avionics subsystem.

To arrive at a meaningful MTBI, pilots not only need to report all indications of suspected faults, but maintenance personnel need to maintain a historical record of such pilot reports for the critical subsystems on each aircraft. Such serial number tracking of aircraft is also essential to improving the capability of maintenance technicians to identify units of equipment (both LRUs and SRUs) that have faults which are evading detection by the standard tests used by shop and depot technicians.⁴

To achieve its full potential productively, thorough reporting of symptoms for suspected faults will require a new mindset for pilots, technicians, maintenance supervisors, and maintenance managers. Pilots and technicians need an environment where they can feel comfortable in documenting and discussing symptoms. For example, rather than penalize units for the quantity of symptoms reported, incentives need to be created to encourage dialogue between pilots and maintenance. Further, it may be appropriate to protect the free flow of such information by establishing policies to restrict the application of such information in ways that could be counterproductive to the intended use.

One potentially counterproductive application would be the comparison of units based upon their fault removal efficiency for specific subsystems. A practice of making such comparisons could make it awkward for units to document symptoms. On the other hand, it is important for those involved in acquiring and supporting avionics to understand which subsystems pose the greatest burdens in terms of fault removal efficiency. The challenge would be to provide such information on an appropriately aggregated basis that would preclude the identification of specific units.

Example Application

An example can show the utility of this indicator. Suppose a subsystem averages 82 flight hours between flights with a failure confirmed by the shop (MTBF = 82 hours) and averages 6 flight hours between flights with an indication of one or more faults (MTBI = 6 hours). While the MTBF indicates very good reliability for a technologically sophisticated subsystem in a modern combat aircraft, the comparatively lower MTBI raises a flag about the subsystem's maintainability, as does the following estimate for the fault removal efficiency:

$$\text{Fault Removal Efficiency} = \frac{6 \text{ hours}}{82 \text{ hours}} \times 100\% = 7\%$$

This result means that maintenance personnel could find a shop confirmed fault in this subsystem for only 7% of the flights

where symptoms were indicated for one or more faults. Note that this maintainability indicator ensures a relatively high reliability indicator does not obscure a subsystem's relatively poor maintainability.

Such a low fault isolation efficiency should draw management attention to the possibility of problems in one or more of such areas as the timeliness of requests for maintenance, the avionics subsystem itself, the BIT, the shop equipment and tests, the depot equipment and tests, the technical orders, and training of maintenance personnel. To identify the specific problems that are the dominant causes of such low performance usually requires the subsystem's developers to field a special engineering data collection and analysis effort.

Such special efforts were launched during 1984 as part of a special Air Force project entitled "F-15/F-16 Radar Reliability and Maintainability Improvement Program." This program included special six-month data collection efforts led by the developers of these radars, Hughes Aircraft Company for the F-15's radar and the Westinghouse Defense and Electronic Systems Center for the F-16's radar. Data were collected during a six-month period (June to December 1984) by engineers and technicians from these companies. These data collectors interviewed pilots after maintenance debrief, documented all symptoms of in-flight faults observed by the pilots, including BIT indications of faults, and also documented maintenance on the flight line, in the shop, and at the depot. The companies also conducted special tests to resolve the root causes of difficult problems.

Figure 1 draws on this database to illustrate an estimate for the overall **fault isolation efficiency** for the F-16 A/B radar and its associated ground test equipment. It shows the fault isolation efficiency not only on the flight line, but also at the shop and depot levels of maintenance. Fault isolation efficiency on the flight line was about 50% for the radar. That is to say that, when flight-line maintenance technicians were asked to correct a fault in the F-16 A/B radar subsystem, only about half of the time were they able to replace a suspect LRU. Moreover, in the air base's Avionics Intermediate Shop (AIS) fault isolation efficiency was also imperfect, though somewhat better than on the flight line. When an LRU from the radar was sent to the shop, 68% of the time the shop was able to find a suspected faulty SRU to replace. When the shop pulled an SRU and sent it to the depot, the depot was able to find some fault to fix about 80% of the time.

FAULT ISOLATION EFFICIENCY

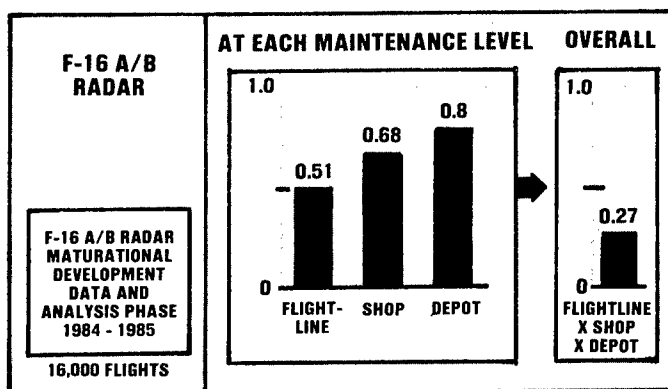


Figure 1: Overall fault isolation efficiency for the F-16 A/B radar—special data collection, 1984-1985.

At first glance, this track of improving efficiency might look good, and in discrete aspects it is good. But the overall fault isolation efficiency for the maintenance process on the radar, which in approximate terms is the product of the rate at each maintenance level, is not very good. The flight-line rate multiplied by the shop rate multiplied by the depot rate yields an overall fault isolation efficiency of 27%. In other words, for every four requests for maintenance at the flight line, the overall support process ultimately makes about one repair action. One quarter of the time, when pilots report a discrepancy against the radar (Code 2 or Code 3), a fault gets fixed.

But fault isolation efficiency is only one of two factors that determine fault removal efficiency. The second factor deals with pilot requests for maintenance. Specifically, of the flights where there is a symptom of a fault with the radar, how often do pilots request maintenance? Figure 2 shows that fault removal efficiency is a function of both maintenance requests per flight with a fault symptom and fault isolation efficiency. While the fault isolation efficiency is still one in four, the special data collection effort also found that the pilots were asking for maintenance at the rate of once for every five flights in which they saw a fault symptom. So the fault removal efficiency for the entire subsystem is the product of the rate of these maintenance requests and the overall fault isolation efficiency. For the F-16 A/B radar subsystem, this estimate for the efficiency is 5%. Note that this is close to the 7% estimate obtained previously in the hypothetical example. The data used in that example are for this radar. So, either way that one estimates the

INEFFICIENT FAULT REMOVAL

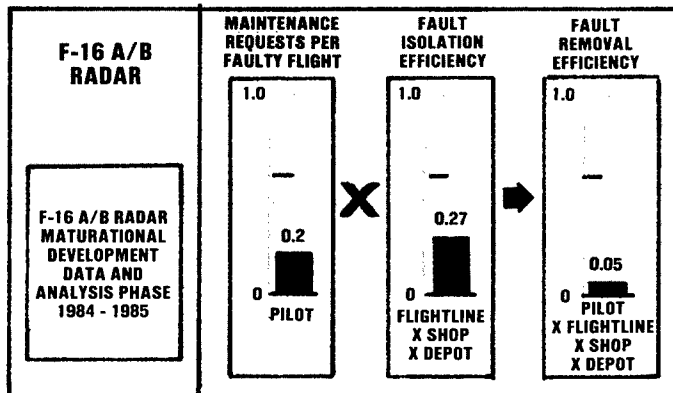


Figure 2: Fault removal efficiency for the F-16 A/B radar—special data collection, 1984-1985.

fault isolation efficiency for this subsystem, the result is in the range of 5% to 7%.

This low fault removal efficiency is not a problem peculiar to the F-16 A/B radar. The parallel special data collection effort on the radar for the F-15 C/D also found serious limitations on the maintenance technician's ability to fix radar LRUs. Thirty-two units were sent to one air base's shop five or more times; seven of these units were sent eight or more times. (On average, a unit would go to the shop only once in such a period.) Moreover, radar engineers found shop repairs to be irrelevant for 20% of all units sent to the shop. In 32% of all units sent to the shop, the shop found no fault. Thus, less than half of the LRUs sent to the shop received relevant repairs.

To illustrate the similarity in fault isolation difficulties and their effect on the condition of radars, Figure 3 illustrates the

consequences of inefficient fault removal for the radars of the F-15 C/D and F-16 A/B. The graph represents the number of flights with a fault symptom in the radar per 100 flights. In the case of the F-15 C/D radar, faults were indicated in 33 out of every 100 flights during the special data collection effort. Eighty-five percent of these 33 flights were the victim of old faults which had initiated during a prior flight. In the case of the F-16 A/B radar, the situation looks better: Only 22 flights out

CONSEQUENCE OF INEFFICIENT FAULT REMOVAL

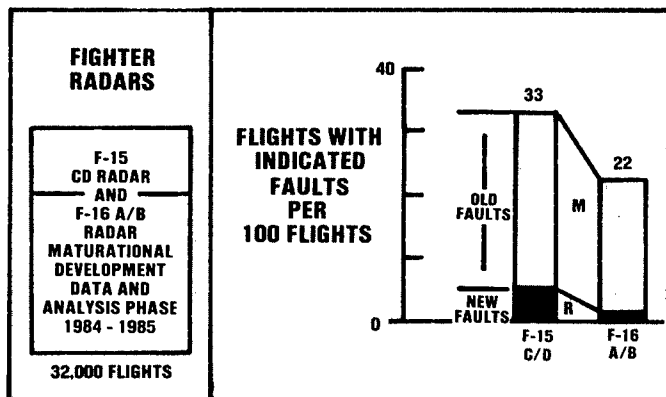


Figure 3: Consequences of inefficient fault removal in the F-15 C/D and F-16 A/B radar—special data collection, 1984-1985.

of 100 had some indications of difficulty, but 95% of those with fault indications are old faults rather than new faults.

A lesson from these data analyses is that the R&M problem lies not so much with reliability as it does with the maintainability of the full capabilities designed into these radars.

Figure 4 shows how using MTBF and fault removal efficiency in concert can provide a composite view of the R&M of a system. As the figure shows, the F-16 A/B is far better than the F-15 C/D radar in MTBF, but its fault removal efficiency is actually worse. Nevertheless, in both cases the fault removal efficiency is still very low. Such low fault removal efficiency can actually confuse the difference between reliability and

A NEW VIEW OF R AND M

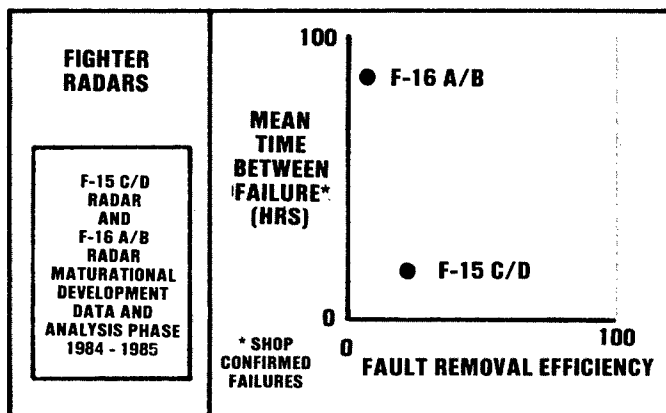


Figure 4: A new view of R&M for fighter radar—F-15 C/D and F-16 A/B radar—special data collection, 1984-1985.

Continued on page 23 →

Tracking R&M Performance of Air Force Ground Vehicles

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Background

Reliability and maintainability (R&M) are essential considerations in the acquisition and support of any weapon system. Within the Air Force, all phases of the weapon system from design and development to fielded operations are charged with improving performance over time to increase combat capability—the ultimate goal of the Air Force's R&M 2000 program. The correlation between improved availability (better reliability with shorter maintenance times) and increased combat capability is obvious with the more glamorous of the Air Force's weapon systems, the aircraft and missiles. But combat capability hinges just as much on the ground vehicles charged with keeping the sorties going. These loaders, refuelers, fire trucks, and other vehicles need the attention for improved R&M directed by R&M 2000 just as much as aircraft and aircraft systems. The vital support vehicles must not become the weak link in sortie generation.

Much attention has already been given to aircraft systems and electronics regarding R&M. Meanwhile, the more mundane ground vehicles are plowing ahead with initiatives and management involvement designed to procure better equipment. A new aircraft loader is being developed with R&M being equal to cost and schedule performance. Fire trucks are being bought from contractors who promise best availability and not just cheapest price. Tow tractor acquisitions include design reviews historically reserved for fighters and bombers. In short, R&M 2000 is thriving in the world of ground vehicles. But all the management attention in the world will not assure the proper identification of areas in the vehicle fleet which will benefit most from R&M improvement efforts. For this, an accurate vehicle data system is essential.

A means to collect R&M information on fielded systems and systems under development is essential to any R&M program. Data collection systems for these parameters, however, are not simple to generate. One must identify the correct data fields in order to ensure the right information is being captured. One must also consider the environment in which the data collection will occur. For instance, will the data be entered manually or will data entry occur automatically as a built-in part of the system? In order to minimize errors, care must be taken when designing user interfaces. Furthermore, once the data is collected, it must be managed in such a way as to provide the right information to the right people at the right time. If all these characteristics were not enough, the physical size of the database required for vehicles must be considered. With 200 or so data elements required for each of approximately 146,000 vehicles, the size of the data files can quickly get out of control.

As recently as January 1989, ground vehicles lacked such a system to track R&M performance. The only options available were to either use an existing maintenance data collection system

or develop an entirely new one for R&M. Since lack of funding and the immediate need for a system precluded developing a new system, the existing maintenance data collection system for ground vehicles was the only hope. This system is the On-Line Vehicle Interactive Management System or OLIVIMS. To quote AFM 77-320, the OLIVIMS end users manual:

The purpose of OLIVIMS is to provide an on-line, interactive system of records and files which can be created, accessed, updated, deleted, exercised, and summarized in a real-time manner The user has total control and responsibility for the accuracy of the database OLIVIMS is designed as a base-level management information system, that allows upward reporting.

In order for OLIVIMS to be useful, its data must be accessible to vehicle engineers and program managers. A derivative of OLIVIMS, called the Command and Air Force Vehicle Integrated Management System (CAFVIMS), is currently available to those responsible for vehicle management. This OLIVIMS derivative forms the basis for the RELiability Parameter RETrieval for Vehicle Engineers (REPREVE) system, which is designed to provide vehicle R&M parameters. The rest of this article is devoted to the types of R&M parameters currently being extracted using REPREVE and the future of REPREVE as an R&M tool.

R&M Parameters from REPREVE

The CAFVIMS database was recently dissected to reveal a wealth of information essential to a thriving R&M program. Locked within its numerous fields and records are the vital statistics of vehicles, statistics needed by engineers and program managers to determine the current state of reliability and to define future improvements. This data does, however, require some manipulation and translation to be useful. Using REPREVE, R&M parameters are, for the first time ever, available and being used.

The three most important R&M related parameters extracted using REPREVE are mean time between maintenance action (MTBMA), failure rate, and down time per operational hour (DT/OH). While not a standard part of the CAFVIMS data, each parameter can be derived from existing data fields. Careful interpretation and application of these parameters will result in vehicles being designed and procured to provide double "R" (reliability) and half "M" (maintainability), the mainstay of R&M 2000.

MTBMA

MTBMA is analogous to everybody's favorite reliability parameter, the mean time between failure (MTBF). Simply put, MTBMA is the average operational time a vehicle accumulates before some component on the vehicle is in want of maintenance. CAFVIMS data contains a tally of all maintenance actions

broken into the types of restorative actions taken. These actions include repair, replace, service, and adjust. CAFVIMS also contains the operational time accumulated on a vehicle for a reporting period. So, while a good point estimate for the MTBF is:

$$MTBF = \frac{\text{total operating time}}{\text{number of failures}}$$

The calculations for MTBMA become:

$$MTBMA = \frac{\text{total operating time}}{\text{number of maintenance actions}}$$

If maintenance actions are considered as “failures,” then the two equations are exactly alike. Furthermore, since maintenance actions include repair, replace, adjust, and service, another useful parameter can be obtained called the mean time between repair and replacement (MTBRR). The MTBRR is:

$$MTBRR = \frac{\text{total operating time}}{\text{number of repair and replacement actions}}$$

Repair and replacement is a more accurate picture of a physical failure of a piece of mechanical equipment, the type typically found on vehicles. Consequently, MTBRR gives a more accurate measure of how fast items are breaking on a vehicle and how available a vehicle will be to assist in sortie generation.

With the MTBMA parameter, MAJCOMs now have insight into the actual performance of critical vehicles regarding the average times between shop visits for various maintenance actions. In planning for a new vehicle, this information can be taken into account to determine if proposed requirements are feasible. Also, the overall weapon system performance becomes a little clearer as the support vehicle parameters are fed into system models. Vehicle engineers will use the MTBMA and MTBRR as guides in establishing reliability requirements and goals for vehicles not predetermined by MAJCOM requirements documents. Thus, the means now exist to justify and verify operational parameters specified in acquisition documents.

Failure rate

Another parameter available from the information stored within CAFVIMS data is the failure rate. Using REPVE, failure rates can be calculated for the entire vehicle or for individual vehicle systems. Currently, 40 systems are available to maintenance personnel when reporting on a maintenance action and are denoted by the numerical codes, called system codes, listed in Figure 1. Currently CAFVIMS data has only two-digit system codes. Soon each two-digit code will be extended to include subsystem and component codes for each system. Thus, failure rates for engines will be further divided into failure rates of the combustion subsystem down to pistons, rings, connecting rods, etc. Failure rates are typically found as the number of failures per one million hours. Using REPVE, failure rates become:

$$\text{Failure Rate} = \frac{\text{number of repair and replace actions}}{\text{operating time}} * 1,000,000 \text{ hrs}$$

Failure rates are normally used to model a system displaying exponentially distributed reliability characteristics. Although using the exponential distribution for vehicles is still under debate, failure rates can be useful to vehicle engineers. These rates, reported along with the MTBRR and MTBMA (Figure 2) or graphically by themselves (Figure 3), can show an engineer which systems are most prone to failure. Emphasis can then be

placed on these systems for reliability improvements on fielded equipment. Moreover, the engineer will know what systems to scrutinize during specification preparation and design reviews on new buys. Furthermore, systems displaying higher failure rates become prime candidates for technology insertion programs geared to improve reliability. REPVE provided failure rates now allow engineers to base decisions on facts rather than “gut-feel.”

CAFVIMS CODE DESCRIPTIONS SYSTEM CODES TABLE			
01	Engine	21	Air System and Brakes
02	Ignition	22	Speedometer or Hourmeter
03	Carburetor	23	Control Cables
04	Cooling	24	Turrets
05	Fuel	25	Hose Reel and Rewind
06	Charging	26	Valves (other than engine)
07	Exhaust	27	Meters and Counters
08	Electrical and Lights	28	Nozzles
09	Starting System	29	Swing Joint
10	Clutch	30	Piping Water and Fuel (plumbing)
11	Heating and Air-Conditioner	31	Foam C-B
12	Transmission	32	Pumping System and Hoses
13	Brakes	33	Tuneup
14	Wheel Alignment	34	Safety Inspection
15	Steering	35	Scheduled Services
16	Suspension	36	Special Inspection 1
17	Universal Joint	37	Special Inspection 2
18	Windshield Wiper	38	Special Inspection 3
19	Differential	39	Other
20	Hydraulic System	40	Other

ACTION CODES			
G	Repair	R	Replace
L	Adjust	S	Service

Figure 1.

Failure rates can also be used when doing a comparative analysis of the same vehicles bought from different contractors (Figure 4). The same type of refueler, for instance, will have a different manufacturer depending on when it was bought. Vehicle program managers and engineers no longer have to wait for complaints from the field to judge whether a new buy exceeded current performance. The “bad actors” of the vehicle world, equipment and contractors, can be monitored more closely in future buys.

Finally, failure rates and MTBMA information displayed by system (Figure 2) will allow for the evaluation of warranty provisions on entire vehicles or systems. As the data input becomes more reliable, contractors should sign up to REPVE as the warranty action recording system. Performance agreements based on the entire vehicle or on vehicle systems can be tracked and measured by REPVE for any length of field verification. Reliability improvement warranties (RIWs) now have a means for establishing baselines as well as determining improvements. Since the data comes from available sources (maintenance shops), few new personnel are required to administer the warranties. REPVE will allow for creativity in product performance agreements never before available.

DT/OH

The final R&M parameter coming from REPVE, DT/OH, is very important to operational commanders. The DT/OH simply shows the amount of time a vehicle spends in the shop per unit of operation. This parameter is a universal measure of merit for senior leadership to measure and track R&M trends and

R & M SUMMARY

FOR INS = 1234011231234AB ; IN-USE NSN = 1234003214321AB
 NOMENCLATURE = VEHICLE X
 NUMBER OF VEHICLES = 94
 HOURS = 25507

SYS NAME	ACTIONS REPORTED	FAILURE RATE (PER MILLION)	MTBRR	MTBTMA
01 ENGINE	166	4,313.	231.9	153.7
02 IGNITION	11	392.	2,550.7	2,318.8
03 CARBURETOR	47	1,215.	822.8	542.7
04 COOLING	227	2,039.	490.5	129.5
05 FUEL	89	2,980.	335.6	286.6
06 CHARGING	179	3,528.	283.4	142.5
07 EXHAUST	8	39.	25,507.0	3,188.4
08 ELECTRICAL AND LIGHTS	361	11,801.	84.7	71.9
09 STARTING SYSTEM	102	2,588.	386.5	250.1
10 CLUTCH	1	39.	25,507.0	25,507.0
11 HEATING AND AIR-CONDITIONER	105	3,450.	289.9	242.9
12 TRANSMISSION	88	1,607.	622.1	289.9
13 BRAKES	28	902.	1,109.0	911.0
14 WHEEL ALIGNMENT	28	235.	4,251.2	1,594.2
15 STEERING	232	7,096.	140.9	109.9
16 SUSPENSION	6	235.	4,251.2	4,251.2
17 UNIVERSAL JOINT	3	0.	25,507.0	8,502.3
18 WINDSHIELD WIPER	11	431.	2,318.8	2,318.8
19 DIFFERENTIAL	60	1,921.	520.6	490.5
20 HYDRAULIC SYSTEM	483	13,212.	75.7	63.0
21 AIR SYSTEM AND BRAKES	151	4,783.	209.1	168.9
22 SPEEDOMETER OR HOURMETER	52	1,882.	531.4	490.5
23 CONTROL CABLES	16	353.	2,834.1	1,594.2
26 VALVES (OTHER THAN ENGINE)	1	39.	25,507.0	25,507.0
29 SWING JOINT	3	118.	8,502.3	8,502.3
30 PIPING WATER AND FUEL (PLUMBING)	1	39.	25,507.0	25,507.0
32 PUMPING SYSTEM AND HOSES	2	78.	12,753.5	12,753.5
39 OTHER (SPECIAL OPERATING EQUIP)	392	7,959.	125.7	67.8
*TOTAL NSN 1234003214321AB	2,853	73,274.	13.6	9.4

MTBRR = Mean Time Between Repair or Replace
 MTBTMA = Mean Time Between Total Maintenance Actions

Figure 2.

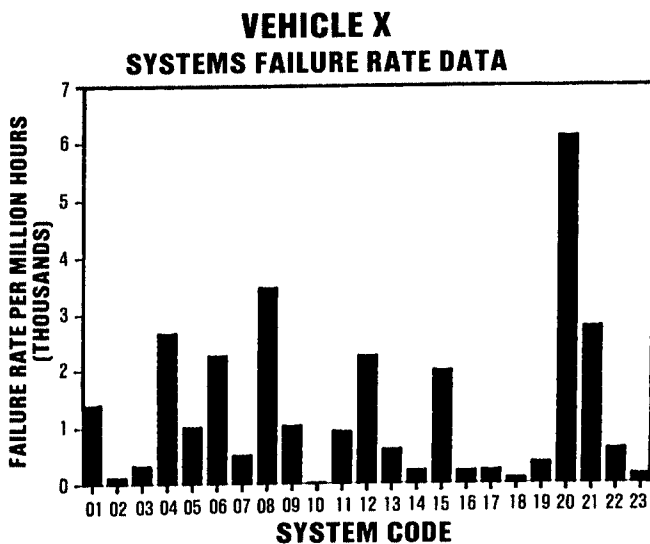


Figure 3.

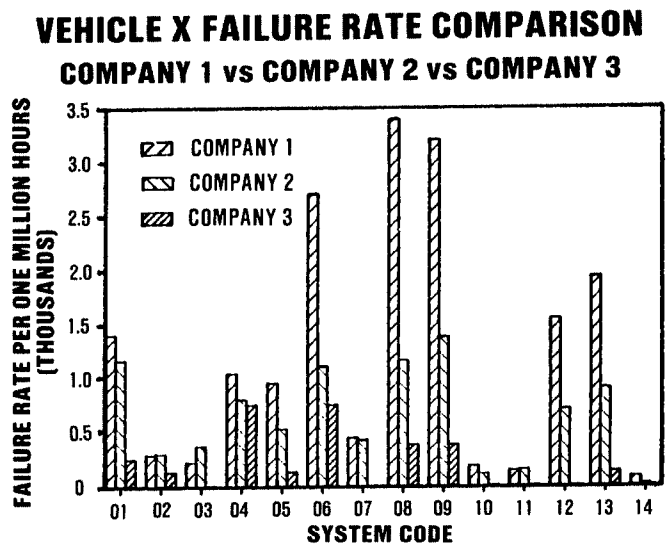


Figure 4.

is used on all Air Force equipment. Using REPVE, DT/OH is:

$$\text{DT/OH} = \frac{\text{down time for maintenance} + \text{down time for parts}}{\text{operating time}}$$

This number represents a level of customer satisfaction with a vehicle and is useful in comparisons of the same vehicle built by different contractors (Figure 5). By making such comparisons, it is possible to verify that vehicles on new acquisitions are in fact satisfying the customer (the field).

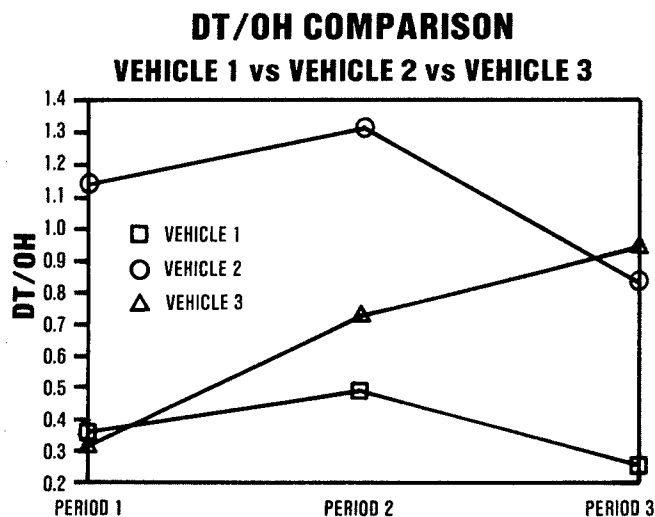


Figure 5.

The DT/OH parameter is also used to plot trends of a given vehicle type from one year to the next. As data is collected, a trend for each vehicle type should show steady R&M improvement. This trend parameter has been chosen by the Air Force to be the single measure of R&M improvements for all equipment, including aircraft, missiles, ground radars, and ground vehicles.

Conclusions

The steps taken so far, consolidating data on a 146,000 unit fleet and constructing a data analysis program which can produce R&M parameters to measure vehicle performance, are just the beginning. REPVE reports are being used to support program managers who are eager to improve their fleets. Failure rate data allows emphasis to be placed on the most troublesome aspects of a particular vehicle when submitting it for overhaul or inspecting it as part of a new buy. Vehicle operating cost information can be used to make mid-term adjustments to vehicle life expectancy. As more experience is gained and historical data accumulated, some of the parameters being tracked will become useful in verifying product performance agreements and determining the amount of incentives or penalties a contractor should be awarded. By making use of incentive-penalty type contracts and reliability improvement warranties, the risk associated with letting a bad vehicle slip into the inventory is greatly reduced. By keeping the manufacturer involved with their product during part of its useful life, a better working relationship should result, with benefits accruing to both sides. Thus, the experience gained in these early efforts with REPVE will eventually allow the integration of R&M into both the acquisition and fielding of a vehicle. And most importantly, the result will be a more reliable, better quality vehicle.



Continued from page 19

maintainability, especially when irrelevant repairs occur in the shop. (Recall that MTBF is based upon shop confirmed failures.) This is one reason why a composite view composed of a reliability indicator and a maintainability indicator (Figure 4) is needed to provide a complete view of R&M. Such a perspective on R&M would also focus attention on the linkage between the ability of weapon systems to deliver their designed capabilities and the increasingly critical roles of BIT, fault reporting and recording, shop test equipment, and depot test equipment.

Notes

¹This paper is based upon some results from RAND research performed under Project AIR FORCE and reported in *A Strategy for Reforming Avionics Acquisition and Support*, by J. R. Gebman and H. L. Shulman, with C. L. Batten,

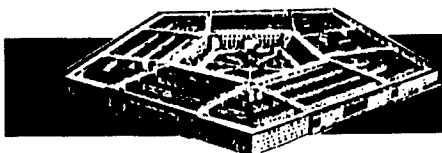
The RAND Corporation, R-2908/2-AF, July 1988; and summarized in *Executive Summary*, R-2908/1-AF, July 1988. A proposal to implement serial number tracking is one of six proposals constituting a comprehensive strategy for strengthening the Air Force's processes for acquiring and supporting avionics.

²This assumes that the equipment and its support process have achieved a state of equilibrium where the rate at which the shop is confirming (and removing) faults exactly matches the rate at which new faults are being generated.

³Such a philosophy becomes increasingly inappropriate as the nature of avionics faults shifts more towards ones where symptoms are situation dependent. Some symptoms appear only under flight stresses, while others depend upon the mode of equipment use.

⁴For a further discussion see *A Strategy for Reforming Avionics Acquisition and Support*, J. R. Gebman and H. L. Shulman, The RAND Corporation, R-2908/2-AF, July 1988.





USAF LOGISTICS POLICY INSIGHT

New Centralized Integrated Diagnostics Office

The dynamics of how the Air Force buys maintenance capabilities for weapon systems must change from the current practice of specifying isolated capabilities to a total integrated support approach. This new focus is essential because of the changing fiscal and support environment projected for the 1990s and beyond. This environment will, for example, dictate less intermediate level equipment with corresponding reductions in support assets. Additionally, weapon systems in this decade will employ more embedded diagnostics technology and associated automated support systems. Consequently, the Air Force's focus must move towards an integrated diagnostics concept. The greatest challenge in this effort is to integrate testability, automatic and manual testing, training, improved maintenance capabilities, and technical information to achieve vertical testability, reductions in manpower, increases in mobility, and cost-effective maintenance capabilities.

The new Centralized Integrated Diagnostics Office is chartered to address the above issues. The initial work force for this office will come from the merger of the Modular Automatic Test Equipment (MATE) and the Generic Integrated Maintenance Diagnostics (GIMADS) System Program Offices. The target date to have this office in place is 1 October 1990. (Lt Col Adams, AF/LEYY, AUTOVON 227-5642)

Senior Officer Course on Combat Munitions Build-Up

The Air Force Combat Ammunition Center (AFCOMAC), located at the Sierra Army Depot, Herlong, California, is developing a two-day senior officer course on combat munitions build-up. This course will be held in conjunction with the practical exercise portion of the AFCOMAC course on conventional munitions production for wartime actions. The course is designed to provide senior officers a perspective on ammunition build-up activities in support of both strategic and tactical war plans. (Contact AFCOMAC at AUTOVON 855-4484 for further details and class dates.)

A-2 Leather Flight Jacket

A recent policy change to AFM 67-1, *USAF Supply Manual*, allows aircrew members to retain the A-2 leather flight jacket, without charge, when individuals separate under honorable conditions. Although the flight jacket will be considered a nonreturnable, personal retention item, accountability will still be maintained through the local Base Supply Individual Equipment Unit. Individuals separating from the Air Force under other than honorable conditions may choose to purchase the jacket. Retirees will continue to be allowed to retain the jacket. (Maj Hamilton, AF/LEYS, AUTOVON 227-5938)

JP-8 Jet Fuel

Recently the Air Force reached a decision to selectively introduce JP-8 jet fuel to locations in the Continental United States (CONUS). The decision was based on the advantages JP-8 provides over JP-4 in the areas of safety, survivability, and environmental compliance. JP-8 is a kerosene-based product very similar to commercial jet fuel but with a military additive

package. The selective CONUS program is envisioned to focus on those locations designated for B-2 support, having environmental problems, or involved in major aircraft maintenance functions or unusual operational refuelings. (A full scale conversion program for NATO land-based aircraft was completed in Europe in 1988.) The Defense Fuel Supply Center is assisting in selecting a conversion method which is supportable and has minimum commercial repercussions. (Maj Sims, AF/LEYS, AUTOVON 227-6613)

New Name for Technical Order Management System

The Air Force Technical Order Management System (AFTOMS) program has been developing an automated, more modern tech order management system for the past few years. The program was well received by the OSD Major Automated Information System Review Council (MAISRC) during the May 1989 Milestone 0 review. At that time, the OSD MAISRC members identified AFTOMS as a program that had multi-Service applicability. Since that time, the Army, Navy, and Defense Logistics Agency (DLA) have been working closely with the AFTOMS program office to identify any unique requirements. Recent Defense Management Review Decisions and other OSD cost-reduction initiatives have formally made AFTOMS a Joint Service Program. To better reflect the joint nature of the program, AFTOMS has changed its name to "Joint Uniform Service Technical Information System" (JUSTIS). With the Air Force acting as Executive Service, JUSTIS will now develop a standard technical manual management system that will be used by all the Services. (Mr Albergo, AF/LEYM, AUTOVON 227-8247)

Construction Technical Letter

A new Construction Technical Letter (CTL), titled the "Management of the MILCON Planning and Execution Process," has been distributed to the MAJCOMs and Bases. The CTL describes revisions to the planning and execution process that have been developed with the goal of improving Military Construction (MILCON) execution. The new process emphasizes planning and brings design closer to construction start. Under this process, the Project Definition package and the Parametric Cost Estimate are sufficient documentation for congressional submittal. The new process is effective immediately for projects in the FY92 and subsequent MILCON Programs. (Mr R. J. Furlong, PE, AF/LEEDP, AUTOVON 227-9886)

Pipe Spec for POL Hydrant Fueling Systems

Recent problems with leaks in welded stainless steel piping in the petroleum, oil and lubricants (POL) hydrant fueling systems at several bases have resulted in a change in the pipe spec. Analysis of the failed systems showed the leaks were caused by fatigue cracking along the longitudinal weld seam. In each case, the crack began as a weld flaw resulting from a faulty manufacturing process. The pipe specified was ASTM A-312, which is fusion welded along the longitudinal seam using no filler metal. It is not possible to reliably verify the quality of this

type of weld with any available inspection techniques. Therefore, we have instituted a change in the welded stainless steel pipe specification to ASTM A-358 with 100% radiography of the weld seam. The welding process for this pipe requires the use of filler metal at the longitudinal seam, and standard x-ray inspection can be performed IAW ASME Boiler and Pressure Visual Code, Section VII. This spec change was issued by message in September 1989 and will provide increased reliability of our POL hydrant systems. (Mr Sid McCard, AF/LEEDE, AUTOVON 297-4083)

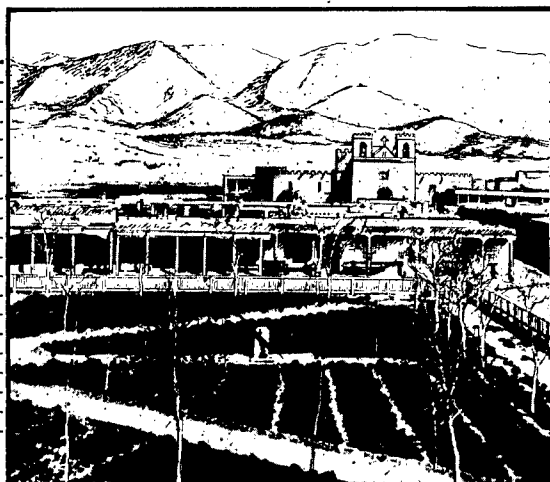
Draft AFM 3-K

Draft AFM 3-K, *Civil Engineering Combat Support Doctrine*, has been forwarded by AF/XOX to all MAJCOMs and SOAs for comment. This doctrine contains the basic truths of engineer combat support and is designed to influence decisions and be the basis for all engineer combat support activities. AF/XOX intends to use this manual as the standard as other combat support functional areas develop their functional

doctrine. For copies of this draft manual or additional information, contact Lt Col Barrett Hicks, AF/LEEX, AUTOVON 225-7774.

HQ USAF PAD 90-1

A recent Program Action Directive (HQ USAF PAD 90-1) requires that hazardous materials (HAZMAT) be selected, used, and managed over their life cycle so the Air Force incurs the lowest cost to protect human health and the environment. The Hazardous Materials Integrated Management Program (HAZMAT IMP) consolidates the ongoing efforts to manage and reduce our reliance on HAZMAT with new strategies to accelerate our progress. This will be accomplished by considering all life cycle costs of hazardous materials to include operations, maintenance, environmental, safety, occupational health, storage, handling, and disposal. Every dollar we save on the use and generation of hazardous materials in our daily operations will be one more dollar we can use to accomplish our mission. (Mr Jeff Short, AF/LEEVO, AUTOVON 297-0276)



Logistics Legacies

Self-Sufficiency in the Old West

The Army Quartermaster and Commissary Generals were tasked to supply the many forts on the frontier. During the immediate post-war period, 1866-1891, this support ranged from nonexistent to inadequate most of the time. The forts were therefore encouraged to "self-help"; in fact, to such an extent that they became centers of production for food, fuel, forage, and construction material.

Later on, as settlers became more numerous, the Army purchased goods, especially fresh vegetables, from them. Even with these barter or purchase agreements, the forts continued their own gardens as supplements since at least 1 pound of fresh vegetables per day per man was needed to keep scurvy at bay. Also, too many civilians overcharged army mess personnel for needed vegetables. At one point, frontier prices for beans were 50 cents/quart and apples were \$25/barrel. Obviously at those prices, fort personnel were further motivated. At one point, gardens at Fort Ellis produced 785 bushels of turnips and 3,865 bushels of potatoes, in addition to sizable loads of carrots, onions, beets, and cabbages. Thus, it is safe for us to say that these "soldier-farmers" were forerunners of the waves of small farmers who came later. In fact, Army reports were often used by real-estate speculators and developers to encourage particular settlements. Some forts even carried on extensive agricultural experiments which received wide reporting in regional newspapers—irrigation tests and related projects received a great deal of public attention. The *Minneapolis Tribune*, for example, carried many stories on garden and irrigation successes in the Dakota territory.

Besides providing sustenance, troopers were their own construction engineers. War Department regulations gave the responsibility for fort construction directly to the troops. In turn, soldiers became very good at lumbering, brick-making, and quarrying. The Missouri River forts were all built from the plentiful cottonwood trees which grew along most of the shoreline—in some instances, the wood had to be dragged or floated 20-25 miles. Major projects usually brought in some civilian workers—as at Fort Assiniborne in Montana which used 2.5 million bricks and 300 civilian laborers besides the usual troopers. Pioneers to Montana looked on Fort Assiniborne with its neat brick buildings, mansard roofs, and bay windows as an oasis in a desert. Fort Sisseton in Dakota used fieldstone for its structures and, once whitewashed against the winds, the buildings were cooler than most in the long, hot summers.

For winter heating, wood was primarily used, although in some instances, nearby open coal deposits were dug up and burned for heat. Fort Stevenson used nothing but coal.

Initially, then, our western armies provided much of their logistical support and had little time for traditional military duties. When settlers came in great numbers, the forts became consumers of many of the goods produced in the settlements they were to protect. At that point, the troops had more time to perfect shooting, riding, and camouflage skills.

North Dakota History (quarterly)
by Gary S. Freedom
(from collection of vignettes
edited by Ted Kluz)



CAREER AND PERSONNEL INFORMATION

Civilian Career Management

New Policy on Career Program Overseas Employment and Return Placement Program

Effective 15 December 1989, the Civilian Career Program implemented a new policy on the Career Program Overseas Employment and Return Placement Program. Stateside activities will no longer have to obligate a specific position for the return of an employee who accepts a career program position overseas. The servicing Civilian Personnel Office will determine the appropriate assignment entitlement and counsel the employee prior to acceptance of the overseas position. The employee will sign an Overseas Employment Agreement (Career Program Assignment) which specifies the installation or geographic area for return placement.

Employees will be encouraged to elect follow-on assignments designed to use the knowledges, skills, and abilities acquired in the overseas assignment. Each career program PALACE Team will work with the employee to effect a return placement that is in the best interest of both the employee and Air Force.

Should an employee reach the end of the overseas tour without a follow-on assignment through the career program, the employee will be returned either to the installation or geographic area agreed to in the Overseas Employment Agreement (Career Program Assignment).

This new approach to career management is expected to improve utilization and placement of key civilian employees, while enhancing management's flexibility in managing positions vacated by employees accepting overseas career program employment.

Geographic Availability

Now is a great time for employees to look at their current geographic availability. Many changes have occurred in the Air Force over the last year which may have an effect on interest in certain areas. The most significant of these changes is the announcement of base closures. We recently reviewed our records and found that 3,609 people are registered for the five bases scheduled to close. We are not recommending that employees change their registration for these bases if they want to go there; however, if they change their minds because of the closures, they should change their geographic availability registration. Sometime in the future, we will no doubt be filling positions at these bases and the pool of eligible candidates will come from those registered for those locations. Being properly registered could save a penalty which could save a possible promotion.

Selections for AF-Wide Competitive Mid-Level Management Development Programs

We are pleased to announce the following selections for the Air Force-Wide Competitive Mid-Level Management Development Programs, Academic Year 1990-91:

<i>Program</i>	<i>Selectee</i>
Air War College	Mr Bennie G. Fullen (prim), Andrews AFB Mr Michael L. Green (prim), WPAFB Ms Debra L. Haley (alter), WPAFB
Education for Public Mgt Harvard	Mr John D. Hopper (alter), Hill AFB
Princeton's Educational Program	Mr Donald D. Gregory (prim), Andrews AFB Mr Clayton O. Klein (alter), WPAFB
Legis Fellows Program	Mr Frank L. Jones (prim), Pentagon
Congressional Fellowship Program	Ms Cynthia Beck (prim), Hanscom
Air Command and Staff College	Ms Michelle L. Corcoran (prim), WPAFB Mr William D. Dodge (prim), Hill AFB Ms Linda L. Pangborn (prim), WPAFB Mr Frank L. Garcia (alter), McClellan AFB Mr Frank R. Ruff (alter), Hanscom AFB

We congratulate each selectee and hope this career development opportunity will further enhance their careers. The next nomination cycle will begin in June 1990. If you are interested in these programs, please contact Robert Macias, AFPCMC/DPCMLR, AUTOVON 487-5352.

Logistics Professional Development

MUNSS Site! What's That?

How many 4054As out there are facing either a long or short overseas munitions assignment, but cannot decide what they want to do? What can a munitions type do in USAFE besides run a bomb dump or work in weapons safety? Well, let me tell you about a well-kept secret that does not get much publicity in the munitions world. Getting assigned to a Munitions Support Squadron (MUNSS) in USAFE can be the most interesting tour one will have in the Air Force.

There are 10 MUNSS sites throughout Europe with positions for 4054As. The mission of the MUNSS is to support the NATO strike commitment by providing custody, maintenance, and loading technical support of special weapons to allies in whose countries we serve. Since these units are tactical delivery units flying F-16s, F-104s, and Tornados, individuals still have the opportunity to work with TAF aircraft. The special weapons experience is a real challenge for officers who have never been exposed to that arena of maintenance.

Each MUNSS has a Maintenance Supervisor position (major), an OIC of Maintenance and Inspection (captain), and a Load Monitor OIC (lieutenant or captain). There are eight

officers total at each site, covering a wide range of AFSCs. Individuals have the opportunity to work closely with people they would not normally deal with in a typical maintenance organization. A MUNSS is actually a condensed version of an operational base, usually consisting of maintenance, security and custody, morale, welfare, and recreation (MWR), medical, supply, vehicle maintenance, training, and postal sections, to name a few. Officers gain in-depth knowledge of what these people do and how they affect a unit. They also have the chance to experience their host nation's culture much more intimately than at a large base.

At a MUNSS, personnel work closely with the host nation foreign nationals on a daily basis. Much of their equipment and facility maintenance is performed by the host. They help organize joint exercises, provide inputs for wartime contingency plans, and direct operations that are key to the success of the European Strike Plan. Each officer (except the commander) also becomes certified as an Emergency Actions Officer, otherwise known as a command post controller. In the Squadron Command Post, they encrypt and decrypt USCINCEUR strike messages, use satellite communications equipment, and participate in command-wide exercises. One of the exciting aspects of a MUNSS is that maintenance officers have an immense amount of responsibility, yet also have the leeway to run with the ball and test their managerial skills. They are on the frontlines at a MUNSS, maintaining a vital link between US custodians and the allied host nation.

Their capabilities are challenged twice a year through headquarters inspections. The combined IG inspection incorporates both the Nuclear Surety Inspection and the Unit Effectiveness Inspection. The NATO Tactical Evaluation is a test of wartime capabilities, tasking Command Post operations, chemical warfare defense, full-scale generation, and MUNSS/host interoperability. The two inspections really gauge how well individuals do and, if they excel, their efforts are recognized at the headquarters level. However, the converse also applies.

In a nutshell, a tour to a MUNSS is a chance to career broaden without leaving the maintenance career field. Officers have a chance to really flex their muscles and test themselves. The experience they gain by working closely with a foreign nation's Air Force is invaluable, and they can get base level expertise with small unit camaraderie. This can all be done either accompanied (long or short) or remote. (I obviously cannot cover all aspects of a MUNSS in this article, so if you have any questions feel free to contact me (Turkey/remote/12 mos) or Capt Tim Shockley (Italy/long/18 mos) at AUTOVON 872-3667, USAF Tactical Air Warfare Center, Eglin AFB FL 32542. HQ AFMPC can also provide locations of the different MUNSS detachments (AUTOVON 487-3556/4553).

(The author, Capt Casey Hughson, is currently assigned to the USAF Tactical Air Warfare Center (TAWC); he spent a year (Jul 88 - Jul 89) at Balikesir, Turkey, and describes many of the positive aspects of a MUNSS assignment.)

The Most Significant Article Award

The Editorial Advisory Board has selected "Total Quality Management" by D. Travis Engen as the most significant article in the Winter 1990 issue of the *Air Force Journal of Logistics*.

Most Significant Article Award of 1989

The Editorial Advisory Board has selected "Military Logistics After Gorbachev: Tomorrow's Challenges" by Major H. Robert Keller, IV, USAF as the most significant article published in the *Air Force Journal of Logistics* during 1989.

The Origins of the Warner Robins Army Air Depot and the Air Depot Expansion Program, 1940-1943

Dr William Head
*Office of History
Warner Robins Air Logistics Center
Robins AFB, Georgia 31098-5990*

Introduction

This work recalls the origins of the modern U.S. Army Air Corps facilities developed in the early 1940s. It analyzes the development of one such installation and describes how it came into being. The story of Robins Field, Georgia, and its principal resident, the Warner Robins Army Air Depot (WRAAD/today WR Air Logistics Center), is a microcosm of the history of this developmental era. Robins Field, despite its local differences, was typical of the Air Corps installations growing out of the military expansion of the late 1930s and early 1940s. Examining a specific case like WRAAD provides a means of measuring the significance the prewar buildup had on preparing the US military for war once it finally started in December 1941.

In the late 1930s the sleepy little Middle Georgia village of Wellston (today Warner Robins), population of 47, did not realize that businessmen and civic leaders were taking the first steps to acquire a major military installation in the Middle Georgia region.¹

Bringing the Army Air Corps to Middle Georgia

In 1936 the Macon Chamber of Commerce adopted a program to extricate the city from the economic lethargy of the Great Depression. Initially, the plan sought to expand retail trade, promote livestock production, and provide an agricultural balance in the area to counter industrial and commercial setbacks. While Macon civic leaders sought conventional solutions to their economic problems, events in the world opened a door for them.

Following the upheaval of the Munich Conference in the fall of 1938 and the subsequent Nazi takeover of Czechoslovakia the next spring, President Franklin D. Roosevelt moved to build up America's military, in particular its air arm.² The facilities then in existence at Army Air Depot installations were insufficient even for the small air force existing in 1939. Much of the shop equipment was obsolete and even though some problems began to be solved by the President's 5500 airplane program approved by Congress on April 3, 1939, the new planes demonstrated even more clearly just how outdated these depots were.

In addition, this growth of air power confronted the Army Air Corps with increased responsibilities in the areas of supply and maintenance.³ One result was the need for more air depots to service the additional aircraft. Pertinent to our story is the fact that one new depot was planned for the southeastern United States.

On August 8, 1935, Congress had passed the Wilcox-Wilson Bill or Public Law 263. While a more isolationist nation was slow to act on the tenets of the bill from 1935 to 1939, the President's new emphasis on military preparedness in late 1939 made it the basis for the construction of seven additional and modern Air Corps Depots.⁴

The expansion meant that America's air forces had to develop an organization for logistical support. To do this on the grand scale and within the time limits fixed by the strategic schedules envisioned by the President's buildup program, it became necessary to develop a vast procurement, storage, and distribution system. It had to be established with an almost endless supply of both stock and special items; the ability to provide the means for distributing these supplies to vast and scattered combat areas; and the capability to organize, equip, and train a variety of service units for assignment overseas. Luckily, the special characteristics of the military aircraft had always required special arrangements to adapt to the armed services. In fact, the Air Corps was the only component of the U.S. Army which combined both combat and logistics functions. It made the entire buildup program much easier.⁵

By the fall of 1940, the collapse of France to Nazi Germany forced the US to begin earnest preparations to defend herself.⁶ The construction of new military installations could no longer be delayed. At the same time the Air Corps site selection began, the Macon Chamber, backed with popular support, began to look for ways to involve the city and region in this lucrative new military expansion. They reasoned correctly that acquisition of one of these new war installations was Macon's big chance for economic resurrection. To demonstrate that the city and surrounding area were worthy to receive such a facility, a series of proposals were prepared for presentation to members of Congress. Groups of local businessmen went to Washington to lobby for a military post in Middle Georgia.⁷ The lobbying effort focused on the Air Corps since the Wilcox bill had vested in the Air Corps sole authority for site selection and construction contracting of the new depots.⁸

Under the leadership of the Chamber manager, Lee Trimble, city and county officials worked out a plan to finance the purchase of land at sites south and east of the city and then offer the land to the government for a minimal price.⁹ In Washington, 6th District Congressman Carl Vinson (Democrat-Milledgeville), Chairman of the House Naval Affairs Committee (1931 to 1947), and later the House Armed Services Committee (1949 to 1953 and 1955 to 1965), was enlisted to support the Chamber's initiative.¹⁰

By the spring of 1941, the campaign had brought considerable results. Bibb County had obtained Camp Wheeler, the Naval Ordnance Plant, Cochran Field, and authorization for improvements at Herbert Smart Airport. These installations brought in new construction in excess of \$100 million and boosted the local payroll from \$1 million to \$5 million per month.¹¹ As it turned out, this was just the appetizer. The main course, Robins Field, was still a few months from realization.

Since 1926, when presidentially directed hearings had resulted in the original reorganization of the Army Air arm, the Materiel Division of the Office of the Air Corps (OCAC) played the main role in the Air Corps' logistics systems. With headquarters at Wright Field and a small liaison office in

Washington DC, the Division, through the Field Service Section (FSS), administered the Air Corps' procurement and development programs as well as its four major air depots (1926-1941) located at San Antonio, Texas; Fairfield, Ohio; Middletown, Pennsylvania; and Sacramento, California (located in Coronado before 1937).¹²

After the 1935 creation of GHQ Air Force resulting from the War Department's "Baker Board" investigations, it maintained its own logistics. However, in November 1940, the jurisdiction of the Materiel Division was enlarged to include control of supply and maintenance for GHQ Air Force.¹³ On April 29, 1941, the War Department in order to deal with the ever growing Air Corps size and responsibilities, closed the Materiel Division and activated a new Air Corps Maintenance Command (AMC).¹⁴ With headquarters at Wright Field, the AMC expanded the FSS to six depots, with the two new depots in Mobile, Alabama, and Ogden, Utah. Others such as the Southeastern Depot were placed in the planning stage. In July, four maintenance wings were organized to decentralize and augment the six existing depots.¹⁵

Macon leaders had first heard of these reorganization plans in January 1941. They were told of the plans by Representative Vinson while a delegation was visiting Washington. At their request, Vinson asked the Army Air Corps to send a survey team to Macon to inspect the region for potential construction of an air depot.¹⁶

Other cities were also interested in the new Air Corps facility. Among these were Nashville, Tennessee and Atlanta, Dublin, Albany, Milledgeville, Cordele, and Vienna, Georgia. The contest narrowed down, however, to one location 12 miles southeast of Atlanta and one south of Macon. Both of these cities had the backing of powerful congressional leaders. On February 21, an Atlanta delegation, called on the Assistant Secretary of War for Air, Colonel Robert A. Lovett, to urge that the depot be located at Ellenwood near Atlanta.¹⁷

At first it seemed that Atlanta had the inside track. On March 7, 1941, the *Macon Telegraph* announced that while Macon was being considered for the \$14,000,000 air depot, Atlanta promoters were confident that their city had the best chance.¹⁸ Subsequently, Congressman Vinson arranged that Macon be included on the itinerary of an Army survey board travelling to Georgia in the spring. The board, consisting of representatives from the Air Corps, Ordnance Division, Corps of Engineers, and the Quartermaster Corps, arrived on March 13 and were led on a tour of possible sites by leading citizens of the city.¹⁹ They were shown several tracts of land and boldly promised by Macon officials that the depot could be constructed six months sooner and one-half million dollars cheaper near Macon than at the suggested Atlanta location.

At first the Macon delegation believed the Herbert Smart Airport was the most suitable location for the depot and recommended it to the board. Although the survey board felt the tract was large enough, they balked at the fact that the field was not near enough to a railroad. Another objection was that there was not enough property available adjacent to the field for future expansion.²⁰

A second site visited was located on US Highway 41, but it too had insufficient acreage for expansion and also lacked railroad facilities. A third site, also rejected, was the Bateman Fruit Farm, opposite the Air Corps Basic Flying Training School at Cochran Field. Board members felt such a location was too close to the Training School and would contradict the mission of the new installation.²¹

As it turned out, what at first seemed to be the least important site was the one chosen and is where the base presently exists.

The land was located approximately 16 miles south of Macon. Rail facilities were near, the site being across the highway from the Wellston train station. Another favorable aspect was the existence of adequate artesian water under the tract. The engineers were impressed by this factor since it was not available at the Atlanta site. They also liked the fact that the Wellston location, being in a flat valley, would not require as much grading as the hilly Atlanta location.²²

On March 18, Bibb County, City of Macon, and Macon Chamber officials sent the government briefs enumerating the advantages of building the depot in Middle Georgia. They noted this central location was particularly relevant to War Department desires for its southern Army installations. It also emphasized the advantage of warm weather and nearby transportation facilities. To put the icing on the cake, they offered the Government, as a gift, any tract of land in the vicinity for the site of the air depot.²³

In March and April, as news reports continued to speculate on the location of the new depot, Atlanta businessmen began taking options on the Ellenwood property and their Macon counterparts secured options on the Wellston property. In Wellston, local postmaster, Boss Watson and his brothers bought up most of the options on the property in the proposed depot site. On May 23, General Henry H. "Hap" Arnold, Air Corps Commander, was notified that 1800 acres were available with 700 adjoining acres available for Army condemnation proceedings. Local authorities would absorb all condemnation and pretransfer costs.²⁴

Macon received hopeful news a few days later when the survey board asked for more information on the Wellston location. On May 14, board members, including Maintenance Command's senior engineer, Major Francis Zeigler, arrived for another look and were met by local officials. Later, engineering staffs were sent to Macon and to Atlanta to make topographical surveys and to secure final data pursuant to the ultimate awarding of the site location.²⁵

As the eleventh hour drew near, the Air Corps and the Army Corps of Engineers disagreed on the final location. The Air Corps favored locating the installation near a large city, while the Engineers, considering construction problems, favored rural south Macon. In a last-minute effort to tip the balance in their favor, Macon officials contacted Brosnan for assurances that if they could guarantee the Southern Railroad increased shipping, brought on by the needs of the new depot, the Railroad would in turn reduce freight rates. This was a matter of prime consideration since Atlanta previously enjoyed lower rates than Macon. Brosnan's promise to match Atlanta's rates proved to be a strong trump card from the War Department's point of view.²⁶

Inadequate housing facilities proved to be another last-minute problem for the Macon cause. On June 8, Congressman Vinson told Macon officials the Wellston site would be selected if the War Department received assurances that funds were available for the construction of 2,000 houses.²⁷ Macon was given one week to meet the requirements. In a subsequent interview with the *Macon Telegraph*, Vinson noted:

It is now up to the 'sleeping giant' to awake. . . . If it cannot meet this requirement then the depot will be located at Allenwood [Ellenwood] near Atlanta. . . . I have done my part. Now it is up to Macon.²⁸

Bibb County exceeded the requirement by 50%. Promises were secured from contractors to build 3,000 houses, 1,000 over the quota, and commitments were obtained from insurance companies to buy the mortgages. The Federal Housing Authority (FHA) agreed to ensure all mortgages and the Rural Finance

Corporation (RFC) Mortgage Company promised to purchase mortgages on all houses involved.²⁹

The issue of the location of the depot was finally taken to the Assistant Secretary Lovett by a delegation from Macon on June 13, 1941. The delegation included Mayor Bowden and Congressman Vinson. They were accompanied by Raymond T. Cahill of the FHA who explained the housing and mortgage agreements made by Middle Georgia contractors. The group told the secretary that the lower freight rates, the housing and mortgage commitments, the potential for expansion, and the natural advantages of the Wellston site, made it the logical choice for the Army Air Corps Depot.³⁰

The official decision in favor of Wellston was made the next day. The story was carried in the local newspapers on June 15 and on June 16 was confirmed by a telegram from Vinson to the Macon city fathers.³¹ Macon had won! Mayor Bowden expressed the feelings of all Macon citizens: "Our relief was immense and our joy complete."³²

According to Colonel Lovett, the Army chose Wellston because of the Engineers' reports which declared the new facility could be built six months faster and \$1.5 million cheaper than at any other location. Other less immediate and tangible issues, such as whether the neighboring communities could service the post and supply the necessary labor, were obfuscated by the urgency to provide logistics for the ever increasing numbers of aircraft. The media in Atlanta expressed considerable pique over the Army's apparent failure to consider such points. Such criticism only increased as Wellston ran into early delays and subsequent difficulties in completing the facility.³³

The birth of the Army Air Forces (AAF) on June 20, 1941, and the exemption of all Air Corps installations from corps area control on July 1, facilitated the development of the AMC and the disposition of the new depot in Georgia.³⁴ The Air Corps Commander, Major General Henry H. "Hap" Arnold, became the Chief of the AAF. He had jurisdiction over both the Air Corps and the Air Force Combat Command (AFCC/formerly GHQ Air Force) and thus provided the authority to resolve the existing logistics duplication within the Army Air Arm. Plans soon unfolded for a redesignation of the Maintenance Command as the Air Service Command (ASC), with an expanded role at all AAF bases.³⁵

Within a week after the decision in favor of Wellston, members of the Savannah District of the U.S. Army Corps of Engineers, headed by Major Charles W. Griscom, arrived in Middle Georgia. Bibb County officials were informed that an entrance to the property would be required by August 15, 1941, in order for the Army to begin construction in September. Only one tract of land had to be condemned because of a title defect, and as a result, survey and construction could begin immediately.³⁶

On August 20, 1941, 2,300 acres of the site were opened for construction. The tract, ultimately totaling 3,108.5 acres (Macon's land donation was completed March 19, 1942, with an additional 800 acres) and valued at \$97,011.67, was unofficially turned over to Army control three days later. Technically, Macon donated the land to the government for "one dollar and other good and valuable considerations."³⁷ The "donation" was made in two separate deeds and the original owners were compensated by local and federal governments.

Later, the government bought an additional 2,700 acres for the Cantonment Area, the civilian barracks, and pistol and rifle ranges, at a cost of \$93,870.28. Macon, therefore, actually contributed a little more than half the acreage and a little more than half the cost of the land for what is today Robins Air Force

Base. With the addition of the cost of several trips to Washington, the cost to Macon and Bibb County for obtaining the depot ran just over \$100,000. This money was raised by increasing license taxes on businesses in the city and by raising the ad valorem taxes in the county.³⁸

In fact, so congenial was the relationship between federal and local officials that the federal government did not officially obtain the actual deeds until May 28, 1943. This was, at least in part, due to the fact that prior arrangements had made each step clear to both parties. In short, they trusted each other and knew what to expect. Potential legal obstacles of gifts for the federal government had been previously cleared as early as the fall of 1940 when the local merchants voted unanimously in favor of financial assistance and support of defense projects. They had also been instrumental in proposing an amendment to the state constitution permitting issuance of bonds to be given to the federal government. This amendment was adopted by a vote of the people in June 1941.³⁹

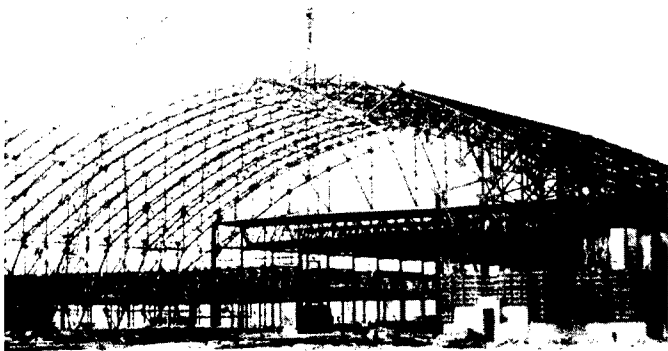
A general law was also passed permitting all counties and cities to contribute to the United States war effort. Macon contributed the air depot, Camp Wheeler, and the Naval Ordnance Plant, all of which totaled more than \$500,000 by the end of 1943. As previously noted, under the terms of the agreement, the land for the depot at Wellston was given to the government for "one dollar and other good and valuable considerations," but also on condition that the title should revert to the city of Macon if the War Department should declare the land surplus to military needs. Obviously, federal, state, and local officials recognized the great value of the land south of Macon. The ultimate irony was that it was only after World War II that anyone really bothered to notice that "Macon's gift" was located in Houston, not in Bibb County. Moreover, the land was not in Representative Carl Vinson's Congressional District. In fact, from a legal standpoint Bibb County would have been hard-pressed to get the land back even though they had such an agreement with the federal government.⁴⁰



Wellston site, 20 Sep 1941.

Base Construction

The depot was built according to standard plans of the Air Service Command with some modifications to fit local conditions. From the beginning, it was planned as one of the nation's air control depots and so designed. Time was important because of growing fear that the US would be forced into the war. As a result, work on the installation was begun quickly and



Aircraft repair hangar, 20 Mar 42.



1st Post Headquarters, 10 Apr 42.

progressed steadily. But, the Japanese attack on Pearl Harbor had the greatest influence on the speed of construction and outward appearance of the depot. Contracted on August 8 and begun on September 1, plans made in 1941 called for the installation to be a tremendous airplane parking lot. By early 1942 these plans had been altered and a hundred hardstands (individual aircraft maintenance stalls), joined by an elaborate network of taxiways, had been constructed instead. The entire Cantonment Area became a dispersal airdrome, similar to those in a zone of operations where the enemy enjoyed parity or air superiority. Significantly US entry into World War II increased the Army's effort to get the new air depot operating in time to be of service to the war effort.⁴¹

On August 8, 1941, the War Department awarded \$14,006,150 in construction contracts to Griffin, Mion, and Shepherd of Macon to build the supply and repair depot and to Aqua Systems, Inc., of New York, New York, for an aircraft refueling system. On September 1, 1941, the U.S. Army Corps of Engineers, Savannah District, began construction; but there was little activity except the taking of soundings to determine the depth of bedrock for anchorage of larger buildings. With the arrival of dirt-moving equipment in October, work was begun on clearing the fields, grading the land, and providing an underground network of drainage lines. Only the landing area required grading, since everything else was relatively flat, but drainage proved a more serious problem since water was found where it had not been expected and proved hard to drain due to the proximity of groundwater from the Ocmulgee Swamp.⁴²

Most of the construction labor came from nearby communities such as Macon, Fort Valley, Wellston, Eastman, Cochran, Perry, and Byron. The number of workers steadily increased from 380 in September 1941 to 1,084, working in two shifts by October 26, 1941. This number increased to 2,200 by Christmas and 6,600 at the peak of construction on May 1, 1942.⁴³

While there were wages-and-working-hours differences between labor unions and contractors, in order to facilitate the job an agreement was reached before groundbreaking in September. As a result, contractors and the Building Trade Council announced that day laborers would be paid 40 cents per hour for a 40-hour work week, very generous for its day. Formal unionization of unskilled workers was delayed until after initial construction efforts were completed. Once the war began, patriotic feelings tempered potential worker discontent.

According to Major Griscom, "there wasn't a single day of labor troubles during the entire job."⁴⁴

But what labor issues could not undo, materiel shortages nearly did. A shortage of steel in October threatened a six-week delay in constructing permanent buildings. This shortage was caused by the demands of other projects in the area. Officials feared that some men would have to be laid off, but the situation was eased by Army initiatives to step up steel priorities to Wellston Air Depot (WAD). The war made this urgency even more apparent and in the end no substantial work stoppages occurred.⁴⁵

Colonel Charles E. Thomas served as commander from September 1, 1941 until May 25, 1944. He was the most significant base leader during the 1940s since, as the first commander, he set so many precedents for future officials.⁴⁶

By August 31, 1942, the essential parts of both the Industrial and Cantonment Areas were completed. This performance was undoubtedly stimulated by the Pearl Harbor attack, for according to the original plans this was expected to take two and one-half years. Instead, it had required only one year. By far the largest aspect of this initial phase of the project was the building of the flight line or landing field and basic parts of the industrial complex such as the hangars, repair areas, and warehouses. It was completed on schedule at a cost of approximately \$20,000,000, exceeding the original estimate of \$13,500,000 set in June 1941.⁴⁷

While the Cantonment Area was not started until May, it was finished in August, two weeks ahead of schedule. The cost of the Cantonment Area was \$3,000,000. These two projects, together with the engineers' headquarters and temporary barracks for the workers completed the main outline of the depot, although a great deal of building was still left to be done.

Specific construction in the Industrial Area included Post Headquarters, the Operations building, Maintenance hangars, Depot Supply buildings, and the landing field. Other buildings were the Engine Test, Engine Storage, Engine Repair, Equipment Repair, Armament, and Signal Corps Storage facilities. A salvage warehouse and a paint, oil, and dope storehouse were also included. The gasoline storage system was installed at this time to provide fueling areas for all aircraft. Officers' quarters and quarters for noncommissioned officers were also built in the initial phase. There were elaborate utilities installed to maintain the entire post, including an electrical plant and a sewage treatment plant. The electrical system for the

Industrial Area was installed underground and required careful planning and execution.⁴⁸

The landing field had three runways, each 5,000 feet long. At the time the field was laid out, these were considered adequate for all types of aircraft. However, they were placed with an eye to the future. Each of them could be lengthened up to a maximum of 7,500 feet. Obviously, present requirements have exceeded even these farsighted provisions. Still, recent modifications have provided more than adequate landing space (12,000 feet today) even for the huge C-5 "Galaxy."⁴⁹

The Cantonment Area proved to be much simpler to build. Although it was spread over a space almost as large as the industrial complex and the landing field combined, most all of its buildings were temporary structures. The area was completed at a cost of \$3 million and provided facilities for three entire mobile depot groups.⁵⁰

The third installment of construction, the civilian dormitories, 100 hardstands and taxiways for parking aircraft, as well as the Charles E. Thomas III Rifle and Pistol Range, was begun as the first phase ended in August 1942 and was completed on schedule on April 10, 1943. The Range was named for the Commander's son who was killed during flight training early in the war. Those in the surrounding area were moved by the courage of Colonel and Mrs. Thomas during this difficult hour. As a result, they also named the local school after their fallen son.⁵¹

During the remainder of 1943, additional facilities were built in the industrial complex. These included the Engineering Maintenance building, Motor Maintenance shop, Engine Preparation building, Chemical Warfare warehouse, and the Finance building. In the Cantonment Area, several Signal Corps training buildings were erected while new facilities were also added to the hospital. This phase cost an additional \$3 million, while construction of a collection of ancillary buildings, important to the operation of the depot and scattered throughout the installation, cost \$1 million.⁵²

A number of smaller projects were completed under the direction of the Post Utilities Officer, who for most of the war years was Major Griscom. Not the least of these projects was the grassing, seeding, and landscaping of the entire base which began in the late summer of 1942 and lasted nearly six months. This was followed in November by a plan for planting trees throughout the entire Industrial Area, many of which still survive today. These undertakings not only made the post beautiful, but kept the amount of free dust in the air to a minimum. Such dust can be very destructive to machinery and aircraft.⁵³

In the summer of 1942, along with the landscaping program, a project began to camouflage all buildings on the post. However, camouflaging was never carried to completion. For instance, no effort was made to conceal the dispersed hardstands or to hide the dirt piled up on each side of them. As a result, these supposedly hidden parking locations and the taxiways leading to them were more visible from the air than the landing runways, which had been painted green. This incomplete condition can be explained by the fact that all camouflaging in the area was stopped in August 1943 for two very good reasons. First, camouflaging often made it difficult for pilots to locate the green flight line during the spring and summer, since it looked so similar to the surrounding grass. Since the threat of enemy air attack was clearly a very unlikely event by 1943, the danger of missing the runway outweighed the original purpose of hiding the installation from enemy eyes. Secondly, the engineers decided that camouflaging activities did not justify the tremendous expense required to procure the paint and personnel to do the job.⁵⁴

By 1943, housing remained the greatest problem facing the officials at Robins Field. Construction of the depot itself was comparatively simple since the site had been selected for its adaptability. As work progressed it became increasingly apparent that the operation of the depot depended on the availability of housing for civilian personnel. Even though original plans called for 3,000 housing units, the glut of workers needed to quickly complete and subsequently man the installation after Pearl Harbor created a potential crisis. The engineers even went so far as to contemplate a planned city in Wellston.

As early as June 15, 1941, the district engineer stated that extensive housing facilities in Wellston would be necessary. A government community was planned with federal control considered over an area roughly the main outline of what became the future City of Warner Robins. The plan was temporarily shelved as construction of the post began, since Macon had already agreed to furnish 3,000 housing units in order to obtain the depot. This arrangement caused the plan of the US engineers to be set aside for the time being as Macon's limited dwellings were committed to a housing program within the city limits. Macon leaders impressed Colonel Thomas with the fact that adequate housing would be provided in Macon, and the need for the housing in Wellston was not urgent.⁵⁵

But Macon suffered a setback in its housing program when in December 1941, the Georgia State Board of Health ruled that since city sewage lines did not serve the new houses, construction must be halted. This ruling, which was completely unexpected, automatically canceled the FHA loans and jeopardized contractors' investments. In August, officers complained that the \$20,000,000 depot was complete and ready for operation except for the lack of housing within a reasonable distance of the post. The Macon leaders could not be justly blamed for the lack of housing since part of the difficulty lay in the fact that, when the war broke out, more workers were needed at the depot than had been originally anticipated. Eventually most of the problem was alleviated by new sewer lines in Macon, new housing starts in what by now was the City of Warner Robins (Robins Manor), and permanent (North Zeigler Place) and temporary housing. Nonetheless, housing remained a major thorn in the side of post officials throughout the war. Afterward, concerted efforts, such as the Zeigler Housing Project of the 1940s, Ignico Apartments, and Wherry Housing of the 1950s, as



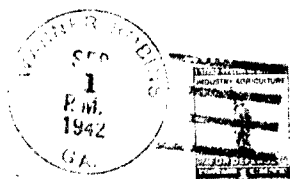
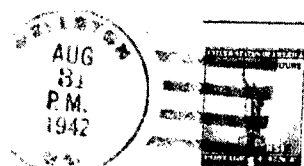
Dedication Ceremony at Robins Field, 26 Apr 1943.

well as expansion and renovation in Chevron Village in the 1960s, ended housing shortages. In addition, as the City of Warner Robins grew, the need for federal housing was reduced since local contractors initiated hundreds of new housing starts every year.⁵⁶

What's in a Name?

The Army Air Force on March 9, 1942, was elevated to the status of one of the three major elements of the Army, while the ASC became one of the major AAF Commands, supervising eleven depots by April 1942.⁵⁷ Each depot became the center of a depot control area, which directed the activities of subdepots within their geographical limits. One problem with the new setup was that some of these boundaries overlapped and, since depots were real focal points of supply and maintenance work, the air service areas never attained the status of fully functioning ASC subcommands.⁵⁸

The name of the newly begun Georgia depot changed in 1942. Colonel Thomas, in an effort to honor his friend and mentor, Brigadier General Augustine Warner Robins, who had died on June 16, 1940, of a heart attack, moved to rename the depot the Warner Robins Army Air Depot. However, since all depots were named for the nearest town or city, the only way to change the name was for the town of Wellston to change its name. On July 3, 1942, city fathers willingly announced the name change which became official on September 1, 1942. The depot name was changed on October 14, 1942, while the City of Warner Robins was incorporated on March 5, 1943, with Boss Watson becoming the first mayor on March 15, 1943.⁵⁹



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Name change of Wellston to Warner Robins, 1 Sep 1942.

On February 1, 1943, the air service areas had been succeeded by air depot control area commands, which were simply the eleven former areas under a new name. The commander was Major General Walter H. Frank. In May AAF headquarters redesignated the air depot control area commands air service commands with appropriate geographical designations. Right up to the end of the war the ASC conducted its operations in the continental US through these commands.⁶⁰ They directed the operations of many different installations and units. Their subdepots proved to be very important to the combat and training units. Just before the war the engineering and supply departments were redesignated subdepots. Groups of key personnel (cadres) in turn were trained to staff the numerous new depots being built, like WRAAD. Such subdepots had the job of

maintenance for Air Corps equipment as well as procurement, storage, and distribution of all kinds of supply items. They came directly under the authority of the depots, but their administrative and housekeeping functions for units assigned to them remained with the base commander.⁶¹ In late December 1941 only 47 subdepots were in operation, with 130 in September 1942, and 238 in early 1944.⁶²

Confusion sometimes results from the many names attached to the depot. Actually these changes made little difference in the functions of the depot and merely indicated changes in the organizational structure of the AAF. When Thomas first opened the facilities on November 9, 1941, the depot, then unofficially called the Georgia Air Depot (by the Army Corps of Engineers)/Southeastern Air Depot (by the Air Corps), operated under the ASC which had been activated one month before Colonel Thomas arrived in Macon to set up his headquarters. The United States was divided into four area service commands. Robins Field was under the third of these commands with headquarters in Atlanta.⁶³

Under General Order (GO) #24 from the Air Service Command, the Wellston Air Depot was officially activated on March 14, 1942, but had its name changed to Wellston Army Air Depot on September 5, 1942, by War Department (WD) GO #45, and to the Warner Robins Army Air Depot on October 14, 1942, WD GO #53. In February 1943, these four area commands were replaced by eleven, each of which had headquarters at one of the large depots such as Warner Robins; Mobile, Alabama; San Antonio, Texas; San Bernardino, California; and Middletown, Pennsylvania. As a result, ASC issued GO #15 changing the name of the installation to the Warner Robins Air Service Command (WRASC) on May 22, 1943. The territory placed under control of WRASC included South Carolina, Georgia, and most of Florida. The part of Florida west of the Appalachian River was placed in the Mobile ASC purview. These changes in title and organization had little effect on the functions at Warner Robins which had, since the beginning, been to repair and maintain AAF weapon systems.

In the early days, Warner Robins ASC shared repair functions with other commands, and its rate of airplanes grounded for lack of parts was high. However, after becoming an independent area headquarters in 1943, it took only a short time to make the necessary adjustments to care for all types of aircraft. As the war industry in the US geared up for the mass production needed to supply weapons for the Allied forces, WRASC focused its priorities on acquiring and maintaining combat aircraft.⁶⁴

Training was also a key function at WRASC, which exercised control over a total of 47 subdepots, although not all at one time. These subdepots were located at Army air bases engaged in flight training. Warner Robins also administered air depot detachments. These were small groups that provided supervision over maintenance and inspection work performed by private contractors.⁶⁵

After considerable experimentation during 1941 and early 1942, the service group and the air depot group had become the two basic field logistics units. Service groups, with their heritage in the air base group setup, had been performing supply and maintenance jobs at combat bases. By mid-1942, it had become better organized and made more mobile. Its assignment was to provide third echelon supply and maintenance for field combat units. In fact, it generally shared the same installation with the group or units it served. In turn, the air depot groups were reorganized to provide only fourth echelon functions in overseas theatres. They were much less mobile than the service units

because they carried heavy maintenance machinery and large supply stocks with them, the basis of their operation.⁶⁶

Even with this success on the field level, early in the war the overall organization of the ASC and its assumption of its unique role remained unclear. Besides issues affecting organization and training, ASC also had difficulty in delineating the division of responsibilities with its parent body, the Materiel Division, renamed the Materiel Command by the general reorganization of March 1942.

On the surface the line dividing the two commands seemed clear. The Materiel Command was principally a procurement agency with responsibility for research and development. The ASC, in turn, had primary control of the distribution of equipment and supplies as well as the provision of maintenance services. However, in reality the new ASC required time to gain a degree of self-sufficiency that was necessary for it to exercise independence from its old relationship with the Materiel Division.⁶⁷ A certain amount of duplication was all but inescapable. No matter how precise the new line of demarcation, it was difficult to make the line absolute while the Materiel Command continued to be the AAF's primary procurement agency. As 1942 unfolded, the ASC gained a limited authority for procurement with some predictable confusion and disagreement.

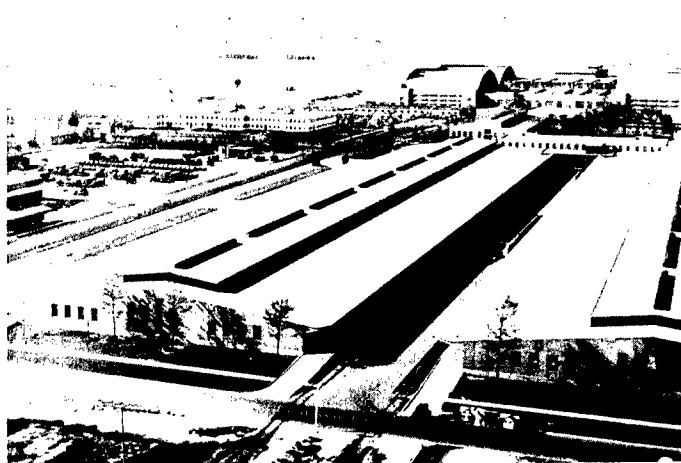
At first the operation of the Defense Aid Organization, which procured, stored, issued, and transported supplies and equipment for beneficiary foreign governments, remained under the Materiel Command, creating much confusion. However, its transfer to ASC in May 1942 facilitated the handling of all distribution through one supply system.⁶⁸ Nonetheless, the dichotomy of authority for requirements continued to demand a closer coordination and cooperation between the two commands than was usually possible. The Materiel Command had the initial responsibility for purchase of airplanes and the equipment originally installed in them. At the same time ASC had to purchase standard organizational equipment. The possibility of overlapping functions in the field was especially great. This resulted in manifold disagreements throughout this early period. There were occasions when the Materiel Command would develop items which ASC would refuse to purchase because they were not convinced that it was superior to existing models. On the other hand, Materiel Command's authority for fixing production schedules often impeded the flow of spares to ASC much to ASC's displeasure.⁶⁹

In an effort to remedy this situation AAF officials suggested, in the summer of 1942, unification of the two commands. Many

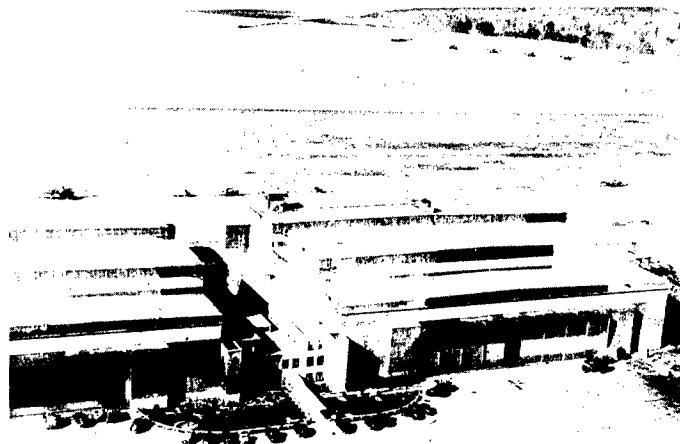
leaders argued that the newly established Air Transport Command (ATC) should be included in such a merger for the sake of a truly integrated logistical organization. Even General Arnold took an interest in this vital issue. In March 1943, he asked for a study to determine the desirability of placing the three commands in one command. However, the idea never took hold and such action was soon dropped. However, in June 1944, AAF Headquarters revived a variation of the plan by combining the ASC and Materiel Command. The new organization was to be designated the Air Technical Service Command (ATSC) and was to be activated on September 1, 1944, under the command of Lieutenant General William S. Knudsen. In truth, the amalgamation of the two groups moved very slowly in an effort to avoid severe dislocations which might hurt the war effort. At HQ AAF the Assistant Chief of Air Staff for Materiel and Services, Major General Oliver P. Echols, retained control over creation of AAF materiel and supply policies. He also oversaw supervision for the execution of these same policies.⁷⁰

Ironically, in a period of only three years, the AAF's logistics organization had come full cycle: beginning as a unified Division, moving to a decentralized depot command, and returning again to the ATSC. In the end, the big difference was that the ATC retained transport authority and the staff and command principle was more clearly established in the ATSC than it had been in the earlier Materiel Division.⁷¹

In fact the maturations of AAF logistics in this period should prove to be no surprise. President Roosevelt's entire style of administration and leadership from the beginning of the New Deal to the end of his life and administration was trial and error. His attitude was that something, anything, must be done to remedy economic ills, social problems, and even military shortfalls. He established organizations to solve tough problems as quickly as possible. If they had loop holes or shortcomings, he would scrap them and set up a new agency or combine two or three old agencies into one. Eventually, the problems were worked out and more streamlined and functional organization performed the herculean tasks of remedying what had seemed to be insurmountable problems. In the early days, the New Deal set up the Civilian Works Administration (CWA) and Civilian Conservation Corps (CCC) to deal with rampant unemployment. After numerous changes and revamping of these organizations a hybrid agency, the Works Projects Administration (WPA), evolved in late 1935 to take over the jobs previously performed by eight organizations. Such was the situation within the military as a whole and more specifically within the function of Air Force logistics.⁷²



Supply buildings, Warner Robins, May 1945.



Operations building, 1945.

Beginning in 1944, the activities of WRASC changed considerably when jurisdiction over its subdepots and some of its air depot detachments was transferred from the Air Service Command to other commands. Warner Robins ASC lost 34 subdepots and 13 air depot detachments, but was still responsible for the supply and maintenance of the airplanes at these fields. By spring, responsibility for North Carolina was added to the Warner Robins control area. The economic and demographic effects of the new installation had already been felt one year after the dedication ceremony. The population of Warner Robins had reached 11,000 despite the scarcity of housing. Robins Field employed 12,184 civilian workers from 29 counties who resided in a 90-mile radius.

As noted in September 1944, the Air Service Command and the Air Materiel Command (AMC) were merged into the Air Technical Service Command (ATSC), with WRASC becoming Warner Robins Air Technical Service Command (WRATSC) on November 16, 1944. This merger of two branches of the Air Corps, one dealing with engineering and procurement and the other with maintenance and shipment of supplies, did not, at the time, alter Warner Robins' activities. In early 1945, however, with victory in Europe in sight, the work of procurement decreased and the Southeastern Procurement District was integrated with WRATSC; and its headquarters moved from Atlanta to Warner Robins. The arrangement lasted only a few months. The six original procurement districts were consolidated into three districts while the ten states comprising the Southeastern District were divided between the Central and Eastern Districts. The procurement activities at WRATSC ended when the war ended on September 2, 1945, the same day the Japanese officially surrendered in Tokyo Bay.⁷³

On July 1, 1946, the Air Technical Service Command changed its name to Air Materiel Command to reflect its postwar duties. In keeping with this change, the Warner Robins Air Materiel Area, or WRAMA, became the new name of the depot and area under its command on July 11, 1946, under GO #61 from HQ AMC. When it acquired worldwide responsibilities in 1974, the functional change also led to another name change. On April 1, 1974, WRAMA became, and remains to this day, the Warner Robins Air Logistics Center (WR-ALC).⁷⁴

Activities at Robins in the Early Days

The Air Service Command's motto, "We Keep Them Flying," was the basis of the function of Warner Robins ASC during World War II. This function included maintenance, supply, and training. The latter activity was divided into the training of civilians to fill former military positions and military training for troops going overseas.

On November 9, 1941, a canvas tent at Herbert Smart Airport near Macon served as the nucleus of the Air Depot being constructed 20 miles to the south. From that tent, Colonel Thomas directed the above-mentioned depot functions. At the same time, administrative and supply activities were set up in office buildings and warehouses in Macon on December 10, 1941.⁷⁵

Supply activities were also started in Macon after November 9, 1941, under the direction of Lieutenant (later Major) George Kegin. The Supply Division was first located at the Atlantic Ice and Fuel Company Warehouse on Waterville Road. In December, the Supply Division moved to a portable hangar at the Herbert Smart Airport, but conditions at the field were far from satisfactory. No heating system was available at the hangar

which had a floor made of a six-inch layer of mud. An elevated platform was constructed for the office forces.⁷⁶

In February, the Supply Division moved back to its original location on Waterville Road where conditions, although still far from adequate, were considerably better than those at Herbert Smart Field. At this warehouse, in addition to the hardware and flying field equipment for planes at Herbert Smart Airport, all other equipment for trainer airplanes began moving in. There were nearly 100 employees at that time, most of whom often had to walk over, around, or under aircraft parts stored in what doubled as their office space. They worked day and night, Sundays and holidays, throughout the winter of 1941-1942, without overtime pay to make sure the depot fulfilled its mission to keep American flyers overseas supplied and in the air.⁷⁷

The Waterville Road warehouse was considered so valuable from the standpoint of storage and office space that it was retained even after the supply buildings at Wellston Depot were occupied in the spring of 1942. In fact, these warehouses were maintained even after the war and it was not until the summer of 1948 that the Air Force relinquished control over these structures. Additional storage and office space was rented by the Quartermaster Division at 306 Bay Street, also in Macon, during the war. The building was the former location of the Gantt Manufacturing Company and had previously housed farm equipment and produce. It was also used by three other air depot groups as well as the units at Herbert Smart Airport for administrative and supply purposes. In short, these large buildings were home away from home for the early employees of Wellston Depot.⁷⁸

By April 14, 1942, Supply Warehouse Number 1, one of the largest warehouses at the Wellston site, was sufficiently advanced in construction to be available for service. Other buildings were also near completion, and various sections of the Supply Division began to occupy these structures. As the Supply Division moved into its new offices, new difficulties arose. Tarpaulins had to be stretched across steel girders to form the office roof. As a result, dust and rain continually plagued the workers. Supplies began to pour in, but there were no lifts or tugs for swift or efficient unloading and storage. It was not uncommon to see officers in their shirtsleeves, unloading boxcars. With a war underway, necessity and speed took precedence and improvements came rapidly. The second floor of Supply Number 1 was readied for occupancy and proper handling equipment was secured. When Supply Warehouse Number 2 was completed, employees who had been training in Pennsylvania and Ohio returned and began the job of supplying the Air Corps with essential materiel.⁷⁹

The maintenance function, unlike the training and supply functions, could not be initiated until the completion of their highly specialized repair installations. While awaiting building completion, many persons were hired by the Maintenance Division and sent to training depots in Pennsylvania and Ohio. In the meantime, as construction progressed, several officers were assigned to secure equipment, laying out the plant work areas and making plans for operation. In July, personnel began to return from their training.⁸⁰

The first department to commence operations was the Parachute Department. It overhauled and repacked approximately 200 parachutes during the first week of September. Minor repair had been made on an A-20 airplane in August; but the first plane (B-24 "Liberator") to arrive for disassembly, inspection, and repair landed October 16, 1942. Full operation of the depot began during September and October

of 1942. The officially acknowledged operations date for the entire Maintenance Division was October 1, 1942.⁸¹

The essential parts of both the Industrial and Cantonment Areas had been completed in August, with 5 subdepots being assigned to WAD on September 1 and 18 more being added by the end of the month. With several of the major site facilities and buildings functional, the installation's name was, as previously noted, officially changed from Wellston Air Depot to Warner Robins Army Air Depot on October 14, 1942.⁸²

Training

Training was an important part of the mission of the WRASC. In order to help repair and maintain aircraft overseas, officers and men had to be trained to perform the functions of supply and maintenance in Europe and the Pacific. The organizations that performed these functions were known as air depot groups. In addition to training personnel in the techniques of maintenance and supply, military police, medical support personnel, signal corps units, and numerous other support training took place at Robins Field. Several air depot groups completed their training at Herbert Smart Airport and went overseas before the Cantonment Area at WRASC was even completed. Within a few months of the completion of this area, there were 7,000 troops on base. Many other thousands of troops received their training at subdepots. By September 1943, there were 35,000 troops in training at various bases within the WRASC area.⁸³

From November 9, 1941, to May 20, 1944, 11 air depot groups, 20 service groups, 50 military police companies, 50 quartermaster companies, 41 ordnance companies, 50 chemical companies, 17 signal companies, and 4,000 replacements, or a total of approximately 50,000 troops, were trained at Robins and sent overseas. In the latter half of World War II (late 1944 to 1945), eight air service groups, averaging 700 men each, and numerous smaller units such as medical platoons and airborne radar and radio teams were also trained at Robins for overseas duty. The air depot groups were sent to both the Pacific and European theatres. Among the troops which invaded North Africa in November 1942 (America's first major World War II land campaign) was a depot group trained at Herbert Smart Airport.⁸⁴

A notable contribution made by personnel from Robins in the training phase of its activities was the creation and development of the Air Service Command School (ASCS). The establishment of this school primarily was the work of Colonel Russell Scott, who had charge of troop training from April 1942 to September 1943. The school was set up in November 1942 to train air depot groups, but its enrollment and reputation for success grew until it gained national recognition. Since the school was the only one of its kind in the country, officers from other areas came to Robins to take the course of studies. Before 1944 this remained an unofficial institution; but, as 1944 dawned, the ASCS became the official training center for all areas of the country. The school specialized in training staff and command officers in all phases of air service. Noncommissioned officers and enlisted men also attended similar courses applicable to their rank and duties. There were four main courses: aircraft maintenance, supply, salvage, and Air Force administration.

The school continued to function until the end of the war and only ceased operations after the final official surrender on September 2, 1945. In the years it existed, 2,699 officers and 2,129 enlisted men attended the ASCS. In the end it proved essential to the successful prosecution of World War II from a maintenance point of view.⁸⁵

Conclusion

Between 1939-1941, with a world war raging in Europe and Asia, US foreign and defense policymakers were forced to recognize the harsh reality that America probably would be dragged into this great conflict. Earlier desperate efforts at neutrality and nonparticipation in World War I and, subsequently World War II, had left the vast majority of Americans to realize that peace without purpose had no point. Nor did it last very long. This meant that, in the early 1940s, America had to prepare for her inevitable participation in a war she hoped would institute a more peaceful world order.

To this end, the Wellston Air Depot was built. When the war did start on December 7, 1941, the Depot performed an essential role in winning that war and restoring peace. Not only did depot personnel repair aircraft weapon systems, such as the B-17, B-25, and B-29, but they also maintained spares, trained Air Corps troops and overseas repair personnel, flight tested aircraft, and trained pilots. These parts and workers went to both the Pacific and European theatres, and participated in all the vital campaigns of the war.

In some ways this all seems rather obvious and yet the great industrial plant named Robins AFB, with all of its political, social, and economic influence, did not always exist. It is from its origins in the 1940s that modern Middle Georgia has grown. It is similar in this regard to all other influential military installations in the US. The case study of one such installation reminds one of that fact.

Notes

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⁶For more information on World War II and the fall of France see Thomas A. Bailey, *A Diplomatic History of the American People*, Tenth Edition (Englewood Cliffs, New Jersey: Prentice-Hall, 1980), pp. 717-718; Robert A. Dallek, *FDR and American Foreign Policy, 1932-1945* (New York: Oxford University Press, 1979), pp. 233-240 (hereinafter cited as *FDR and American Foreign Policy*); Richard E. Maltais, USAF unpublished outline, *A Short History of WRAMA, 1941-1964* (Robins AFB, Georgia: WRAMA Office of Information, 1965), n.p. (hereinafter cited as *Short History*).

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⁸Baker, *AMC Field Organization*, p. 16.

⁹*WRASC 41-43 History*, pp. 8-11; *Pictorial History*, p. 4; Archival File (WR-ALC/HO), "Lee S. Trimble file," Robins AFB, Georgia (hereinafter cited as Archival File); Richard E. Maltais, WRAMA Office of Information, *Warner Robins Air Materiel Area (WRAMA) Annual History* (1 Jul 63-30 Jun 64), Part III: "Mission Activities; Robins AFB Almanac and Book of Facts, 1941-1964," Historical Study No. 5, p. 1 (hereinafter cited as *RAFB Almanac*); Idem., *WRAMA Annual History* (1 Jul 65-30 Jun 66), Part I: "Special Events; Silver

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¹¹Ibid., pp. 13-15; Ibid., pp. 6-7; *WRASC End of Year History, 1944*, Vol II, Part IV, pp. 13-14, 26-27 (hereinafter cited as *WRASC 44 History*).

¹²Craven and Cate, ed. *AAF in WWII*, Vol VI, p. 363; *ASC History*, pp. 12-25.

¹³Ibid., pp. 364-365; Ibid., pp. 26-28.

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¹⁵Ibid.; *ASC History*, pp. 35-36.

¹⁶*WRASC 44 History*, p. 13; *WRASC 41-43 History*, pp. 7-8, 59. For information on Carl Vinson, see Kenneth Coleman and Charles Stephen Gurr, eds., *Dictionary of Georgia Biography*, Vol II, K-Z (Vinson), (Athens, Georgia: The University of Georgia Press, 1983); Archival File, "Lee S. Trimble file;" *RAFB Almanac*, p. 1; *Silver Anniversary*, p. 12.

¹⁷Ibid.; Ibid., pp. 7-9.

¹⁸*Macon Telegraph*, 7 Mar 41, p. 1.

¹⁹*RAFB Almanac*, p. 1; *Silver Anniversary*, p. 12; Archival File, "Lee S. Trimble," "Mayor Charles L. Bowden."

²⁰Ibid., p. 2; Ibid.

²¹Ibid.; Ibid.

²²Ibid.

²³Ibid.

²⁴*WRASC 41-43 History*, pp. 11-13; Archival File, "C.B. "Boss" Watson."

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²⁷Ibid., pp. 64-65; Ibid., pp. 6, 25; *Silver Anniversary*, pp. 12, 38.

²⁸"Wellston Air Depot Appears Certain," *Macon Telegraph*, 8 Jun 41, p. 1. For a complete copy of the local newspaper articles covering the early years of Robins Field, see Keith E. Banks ed., comp., *Wellston Air Depot: A Media View, 1941-1943*, USAF Special Study, Robins AFB, Georgia: Warner Robins Air Logistics Center, Office of History, 1986.

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³¹*WRASC 41-43 History*, p. 18; *WRASC 44 History*, p. 13; *RAFB Almanac*, p. 3; *Silver Anniversary*, p. 12; *Macon Telegraph and News* (Sunday), 15 June 41, p. 20; *Media View*, p. 23.

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³³Ibid., p. 19.

³⁴*ASC History*, pp. 36-38, 40-41; Minutes, 15 July 1941 meeting Air Council, dated 16 July 1941; Ltr, The Adjutant General (TAG) to Chief of Air Corps (C/AC).

³⁵Army Regulation, 95-5, 12 June 1941; Army Air Forces Regulation 20-4, 17 October 1941; Craven and Cate, *AAF in WWII*, Vol VI, pp. 365-366.

³⁶*WRASC 41-43 History*, pp. 27-28; *WRASC 41-43 History*, Vol III (Supporting Document Volume), "Completion Report of Initial Construction Phases of Robins Field, Warner Robins Army Air Depot," Job A-42, Wellston, Georgia, 20 Sept 43, by Major Edgar B. Boyton, Savannah District, Army Corps of Engineers (hereinafter cited as Completion Report); *WRASC 44 History*, p. 13.

³⁷*Pictorial History*, p. 7.

³⁸Ibid.; *WRASC 41-43 History*, p. 19; Completion Report; Archival File, "C.B. Watson."

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⁴⁵Ibid., pp. 33-35; Completion Report.

⁴⁶Ibid., pp. 39, 45; Archival File, "Maj Gen Charles E. Thomas;" *The Atlanta Constitution*, 10 Dec 42, p. 12A.

⁴⁷*Pictorial History*, pp. 7, 9; *WRASC 44 History*, p. 16.

⁴⁸Ibid., p. 7; *WRASC 41-43 History*, pp. 55-60; Archival File, "Map File, 1942."

⁴⁹*WRASC 44 History*, p. 16; Archival File "Map File, 1942;" *RAFB Almanac*, pp. 162-164.

⁵⁰Ibid., p. 16; *WRASC 41-43 History*, pp. 45-55.

⁵¹*WRASC 41-43 History*, pp. 74, 76-77; "Gen Thomas Gets A New Assignment," *Macon Telegraph*, 22 May 44, pp. 1, 11; *RAFB Almanac*, n.p.; *WRASC 44 History*, pp. 14, 18; *Macon Telegraph*, 9 May 42, p. 1.

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⁵⁵*WRASC 41-43 History*, pp. 64, 69-73; *Pictorial History*, pp. 25-26; *First Quarter History of WRASC 1944*, 1 January-31 March 1944 (WRASC/OI, 1944), pp. 44-47 (hereinafter cited as *1st Quarter History WRASC 44*).

⁵⁶Ibid., pp. 64-68, 76-77, 80-84, 95-101; *1st Quarter History WRASC 44*, pp. 47, 50-53; *Pictorial History*, pp. 7, 9, 27.

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⁵⁹Archival File, "Brig Gen Augustine Warner Robins," "Warner Robins/Wellston, Georgia City File," "C.B. Watson," "Maj Gen Charles E. Thomas;" *Macon Telegraph*, 4 Aug 42, p. 7; *Macon Telegraph and News* (Sunday), 16 Aug 42, p. 23; *Pictorial History*, p. 26; *RAFB Almanac*, pp. 100, 193-197; "Interview with Mrs. Augustine Warner Robins," by Dr. Douglas Southall Freeman, *Richmond News Leader*, 23 Apr 43, p. 16A; *Silver Anniversary*, p. 129; *WRASC 44 History*, p. 16.

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⁶²Ibid., p. 368.

⁶³Ibid.; *WRASC 44 History*, pp. 13-14, 26-33.

⁶⁴*WRASC 44 History*, pp. 14, 16, 17, 21; *Silver Anniversary*, pp. 129-130; *RAFB Almanac*, p. 100.

⁶⁵Ibid., pp. 119-128.

⁶⁶Craven and Cate, *AAF in WWII*, Vol VI, pp. 369-370.

⁶⁷Ibid., p. 372.

⁶⁸*ASC History*, pp. 64-66.

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⁷⁰Ibid., pp. 89-105.

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⁷⁷Ibid., pp. 14, 82-88; Ibid., pp. 8-12, 16-17.

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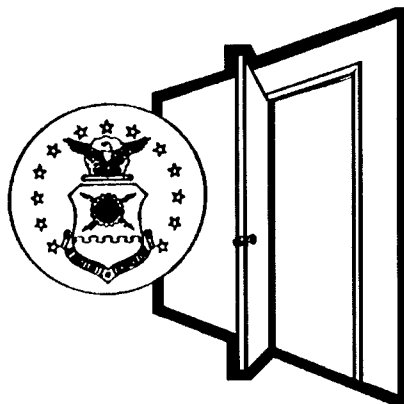
⁸²*Pictorial History*, pp. 20, 26; *Silver Anniversary*, p. 129; *RAFB Almanac*, p. 100.

⁸³Ibid., pp. 21-23; Ibid., pp. 12-13, 50-55; *WRASC 44 History*, pp. 26-33, 119-128, 142-162; *Cochran Field*, pp. 7-14.

⁸⁴*WRASC 44 History*, pp. 26-33.

⁸⁵Ibid., pp. 130-141; *Silver Anniversary*, pp. 14-17; "ASC School at Robins Field," Robins Field News-Beacon, 10 Nov 44, p. 1; GO #95, HQ ATSC to Col Clarence B. Lober, "Assumption of Command, 4117th AAF Base Unit, Robins Field Georgia," 15 Aug 45.

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CORRESPONDENCE PROGRAM: Correspondence courses are available for study by active, reserve, and national guard officers, noncommissioned officers, and civilian employees. The courses are developed by the School's faculty, and most of the courses parallel the resident curricula in subject matter and content. These courses are administered by the Extension Course Institute (ECI).

MORE INFO: Course descriptions, student prerequisites, school information, and detailed application procedures are contained in DOD Catalog 5010.16-C and AFR 50-5, *USAF Formal Schools (Policy, Responsibilities, General Procedures, and Course Announcements)*.

FY90 PCE QUOTA ALLOCATIONS 35,985 TOTAL REQUIREMENTS

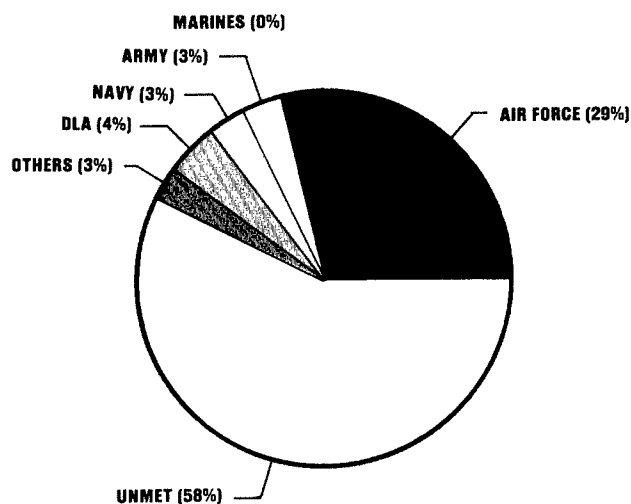


Figure 1.

FY90 PCE REQUIREMENTS & ALLOCATIONS 35,985 REQUIRED AND 15,149 ALLOCATED

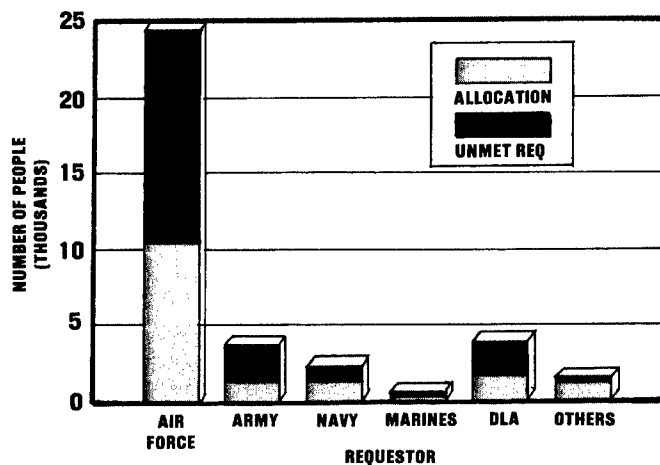


Figure 2.



CURRENT RESEARCH

Air Force Logistics Command (AFLC) Logistics Management Sciences Study Program

The AFLC Directorate of Management Sciences (AFLC/XPS) is responsible for developing, managing, and executing the Air Force Logistics Command's management sciences program. The Directorate is composed of three Divisions: the Assessment Applications Division (XPSA), the Concept Development Division (XPSC), and the Consultant Services Division (XPSM). We conduct and sponsor studies and research of significant logistics issues. We also use, modify, and develop new or improved methods, models, and tools to manage logistics resources. Our goal is to quantify the relationships between logistics resource alternatives and aircraft availability. We work toward this goal by performing studies for customers in the headquarters and by pursuing a few internally developed projects which have significant potential for providing valuable insights into these relationships. We work closely with our customers as we design and perform studies to ensure we have a healthy balance between the rigorous application of operations research techniques and practical, "implementable" solutions.

The following projects are representative of the work we will be involved in during FY90:

Effects of Changes in Order and Ship Times (O&STs) and Depot Repair Cycle Times (DRCTs) on Aircraft Availability and Procurement Costs: A recently completed study showed that more responsive resupply times can mean large savings in procurement costs for aircraft spares. This O&ST/DRCT study further investigates how changes in resupply times affect procurement costs and resultant worldwide aircraft availabilities. It will include all major weapon systems. This study will quantify the cost associated with using the current resupply times, and resupply times of 20, 40, and 60 days. It will also measure the impact on procurement costs of changing the transportation times included in the O&STs and DRCTs by one day.

Alternative Strategies for Funding Maintenance Dollar Shortfalls: The objective of this study is to relate maintenance dollars expended to aircraft availability by weapon system. This will provide Hq AFLC the ability to allocate available repair dollars by weapon system based on selected aircraft availability goals. The study will be limited to D041 aircraft recoverable spares repaired at the depot.

Distribution and Repair in Variable Environments (DRIVE): During the past year, we have supported the DRIVE Production System by developing the production version of the model, providing analysis support to the development effort, and leading the Design Team. We also conducted a joint study effort with the Tactical Air Forces (TAF) to apply the DRIVE logic to redistribution and gain a better understanding of policy, procedural, and systemic issues impacting both DRIVE and its extensions, such as redistribution. Our future efforts will concentrate on ensuring that the DRIVE logic operates as desired and that it is applied properly in developing depot maintenance and distribution priorities. We will also provide support to the policy analysis efforts needed to ensure that DRIVE and Air

Force policies are consistent and that the benefits of DRIVE are incorporated into policy and procedures.

Impact of Considering Cannibalization Upon the Peacetime and the Total Aircraft Spares Requirements: The current Air Force system to compute peacetime spares requirements assumes that no cannibalization of parts occurs among aircraft. There would, no doubt, be significant cost savings if the peacetime spares were computed assuming that cannibalization would occur. However, having fewer spares in peacetime might drive up the wartime spares requirements costs considerably. We plan to use C-17, F-15, and F-16 data to estimate these various spares costs to help the Air Force determine if it would make sense to change our peacetime requirements computation system's cannibalization assumptions.

C-17-Automatic Test Equipment (ATE) Basing Study: The basic objective of this study was to determine the most cost-effective scenario for the ATE needed to repair C-17 avionics parts in both peace and war. An earlier study had concluded that basing ATE at a depot, three CONUS Regional Maintenance Centers (RMCs), and two in-theater RMCs would be most cost-effective. Because of the work in AFLC of investigating Alternatives to Intermediate Maintenance (AIM), we were asked to redo the earlier study using the latest data to confirm that the RMC basing strategy chosen was more cost-effective than a depot only (two-level) strategy. We recomputed the ATE, manning, and spares costs for several basing strategies using various depot resupply times. Our study showed the limited conditions under which the two-level option could be more cost-effective than the RMC option; those conditions include very fast depot resupply times and a need for fewer ATE sets than the C-17 contractor currently estimates.

Weapon System Management Information System (WSMIS): Our primary roles in support of WSMIS are validation of contractor-developed products, trouble-shooting, and system design. Our efforts last year focused mainly on refining strategic airlift wartime capability assessments. This year we are extending the capability assessment horizon to 90 days of war, which involves modeling offshore maintenance and follow-on spares support. We are also heavily involved in developing a recoverable spares requirements computation for strategic airlift aircraft. In the past, HQ MAC has computed its own requirements based on fill rates. HQ AFLC is taking over that responsibility and calculating spares quantities based on an aircraft availability goal.

The senior staff consists of:

Mr Victor J. Presutti, Jr., Director (XPS), AUTOVON 787-3201

Mr Curtis E. Neumann, Assessment Applications Division (XPSA), AUTOVON 787-6920

Mr John M. Hill, Concept Development Division (XPSC), AUTOVON 787-6920

Mr John L. Madden, Consultant Services Division (XPSM), AUTOVON 787-7408

Miss Mary E. Oaks, Study Program Manager (XPS), AUTOVON 787-4406

Air Force Human Resources Laboratory FY89-90 Logistics R&D Program

Following are some additional logistics R&D projects managed by the Logistics and Human Factors Division, which will be active during FY89 and FY90. (Contact: Colonel James C. Clark, AUTOVON 785-3713, (513) 255-6797)

INTEGRATED MAINTENANCE INFORMATION SYSTEM (IMIS)

OBJECTIVE: To develop a means to integrate and deliver automated flight-line maintenance information from various sources. This research centers on a highly portable computer to display graphic technical instructions, interrogate on-board systems, analyze in-flight parameter/failure data, provide intelligent diagnostic advice, and interact with ground-based technical, historical, management, supply, and training computer systems. The intent is to ensure that maintenance sorties can be produced in a tactical combat environment, despite the combined effects of advanced, complex technology, a reduced pool of available manpower resources, a move away from traditional system specialists, and the expected demands of a deployed combat location.

APPROACH: Contract and in-house technology development and test activities consisting of a number of integrated elements (some of which are described below). (Mr David Gunning, AFHRL/LRC, AUTOVON 785-2606, 513-255-2606)

(1) IMIS FUNCTIONAL REQUIREMENTS DEFINITION

OBJECTIVE: To develop a formal requirements definition of functions and information requirements for the current (AS-IS) and projected future (TO-BE) tactical aircraft maintenance environment.

APPROACH: Information modeling combined with job-site interviews, document reviews, and function modeling. (Mr David Gunning, AFHRL/LRC, AUTOVON 785-2606, 513-255-2606)

(2) CONTENT DATA MODEL (CDM)

OBJECTIVE: To develop an interchange specification for exchanging integrated databases for technical data for maintenance. The CDM will provide the basis for interchanging maintenance technical data that is free of redundancies and contains no format information. Data maintained in the CDM can be presented on a variety of computer systems or printed in a variety of formats without any change to the database itself. This feature will make it possible to take advantage of advances in information presentation systems without having to redo the data to make it compatible with the new systems.

APPROACH: Development, field demonstrations, and tests of draft specifications for authoring of "Type C" digital aircraft maintenance technical information in an open architecture, format free, neutral database style. (Mr David Gunning, AFHRL/LRC, AUTOVON 785-2606, 513-255-2606)

(3) IMIS DIAGNOSTIC DEMONSTRATIONS (IMISDD)

OBJECTIVE: To develop an integrated diagnostic system for IMIS using the F-16, F-18, and X-29 aircraft as test systems.

This research will result in a first-generation system that has a control structure to call test procedures, a mechanism to flag and enhance the database where it is insufficient to isolate a failure, and a test logic explanation mechanism for the user.

APPROACH: Development and field test of demonstration software using AF and Navy maintenance personnel and systems (F-16, F/A-18). (Capt Mike Seus, AFHRL/LRC, AUTOVON 785-2606, 513-255-2606)

INTEGRATED MODEL DEVELOPMENT ENVIRONMENT (IMDE) PROJECT

OBJECTIVE: To develop improved, user oriented logistics capability models to assess base-level or theater-wide combat logistics procedures, resources, and requirements.

APPROACH: Development of a new modeling concept using an object-oriented knowledge base linked to high level modeling tools. Model development will occur with graphics-based screen aids to ensure the model is easier to use and customized to the simulation requirements at hand. (Capt Doug Popken, AFHRL/LRL, AUTOVON 785-3871, 513-255-3871)

INTEGRATED DESIGN SUPPORT SYSTEM (IDS) (Information System Research & Development Program)

OBJECTIVE: To improve the capture, management, use, and dissemination of weapon system technical data.

APPROACH: The IDS program is developing an information architecture and a prototype software data dictionary system, two critical components of an integrated information system which would allow the automated storage, retrieval, and configuration management of engineering data for weapon system support. (Mr Jeff Ashcom, WRDC/MTI, AUTOVON 785-2232, 513-255-2232; Capt Steve McClendon, AFHRL/LRL, AUTOVON 785-3871, 513-255-3871)

INFORMATION ENGINEERING

OBJECTIVE: To analyze existing information system specifications and design methods in order to identify technology required to allow the integration of information necessary to support concurrent engineering activities.

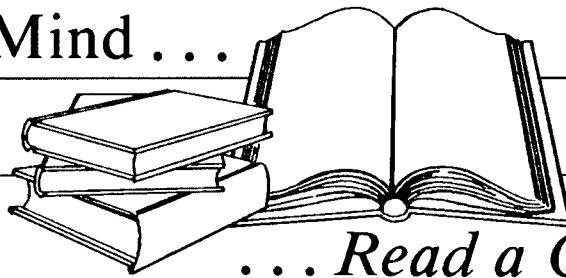
APPROACH: Development of an operating system and database management system that will share data, making it possible to manage and control critical information throughout the product life cycle. (Capt Mike Painter, AFHRL/LRL, AUTOVON 785-3611, 513-255-3871)

DECISION SUPPORT SYSTEMS (DSS)

OBJECTIVE: To develop decision support system technologies.

APPROACH: Key enabling technologies in the area of formal design methods, database structures, database management systems, capturing of design rationale and trade-off analyses, and expert system design tools will be targeted for prototyping and testbed implementation for proof of concept demonstration. (Capt Ray Hill, AFHRL/LRL, AUTOVON 785-3871, 513-255-3871)

Enrich Your Mind . . .



. . . *Read a Good Book*

Oil and War by Robert Goralski and Russell W. Freeburg. Morrow, 384 pages, 1988, \$19.95.

That the Germans, Italians, and Japanese were seriously hindered by a lack of steady oil supplies in World War II is common knowledge. That General Patton outran his gas trucks is also known. And that the Russian Army ran on US oil is also accepted. However, not until the publication of *Oil and War* has the world understood the pervasive dependency of the modern war machine on that elusive hydrocarbon, oil.

In 1942, the Third Reich sent "U" boats to interdict the US oil routes. Up and down the Atlantic coast, oil tankers were attacked and sunk. One quarter of the US tanker fleet was sunk; the beach off Collins Avenue in Miami was black with oil; autos were parked along the North Carolina shore to let occupants watch burning hulks at sea; and, by December, rationing was in full swing. However, Americans answered the Nazi threat to survival with "Big Inch," a 1400-mile pipeline from Longview, Texas, to Linden, New Jersey. It took almost two weeks for a barrel of oil to travel the distance of pipe which itself had been laid in 350 days. To the authors, such monumental deeds were the seeds of victory for the Allies. The Axis had been unable to avoid oil isolation and had been slowly cut off from its oil sources.

The Japanese stockpiled many thousands of barrels before the war, the Italians set supply lines across the Mediterranean, and the Germans began to build a synthetic oil industry. Once the Japanese stockpiles were gone, US submarines made it impossible to get more. (Strangely enough the battleship/carrier orientation of the Japanese navy doctrine kept them from using subs against US tankers.) Eventually, the Allies lost Crete, but kept Malta, and effectively cut the Italian lines; and Allied strategic bombing decimated the synthetic oil industry in the heartland of the Reich.

The authors begin the story early in the war; the Japanese had resolved to replace oil stockpiles with Indonesian crude. They determined to establish an industry there and began to send personnel. The first shipload of oil experts, the cream of Japanese refinery know-how, 780 engineers in all, was torpedoed by the US submarine *Grenadier* on May 14, 1942. It was a loss of skills from which the Japanese would never recover.

By August 1942, the Wermacht was astride the great Russian pipelines. So far, the German army had buried at least 180,000 horses in Russia and they could not be replaced; therefore, the

Reich must have oil-Russian oil. One more push would have gotten the Germans the great oil cities on the Caspian; instead, the megalomaniac Hitler directed that the troops take and later hold Stalingrad, to destroy that city's symbolic value to the Soviets. Thus, the Soviets kept the Caucasian oil fields and kept most of the oil flowing. It was a strategic blunder for Hitler of immense proportion.

In the Pacific, US submarines continued to fire at and destroy Japanese tankers, even though US torpedoes were of dubious quality (*USS Timosa* fired nine torpedoes at a tanker and not one exploded on impact). However, some did work and by 1944 the Japanese felt immense oil shortages. Everything stopped; the air force could not fly, the navy had to stay close to port, and the army was limited to foot slogging.

In the Mediterranean, the British had held Malta, making the Italians very insecure which ultimately gave Rommel, the Desert Fox, a severe case of oil-shortage indigestion. The Fox needed 9,000 barrels a day; he never got more than 6,400. What hurt Rommel, hurt the Luftwaffe, and eventually destroyed the Nazi war machine.

Even in the Central Theater, oil was a player. The river Danube coursed for 1,725 miles through the heart of Axis power. It carried 10,000 tons of shipping per day, including much oil on huge 200 foot-long barges. In April of 1944, the RAF began to mine the river dropping 1,400 mines, and soon this vital waterway too would be closed.

One last event occurred. The final German offensive, Christmas 1944, called endearingly "The Battle of the Bulge," carried the Germans to within 1,000 meters of 2,500,000 gallons of US petrol. The Americans in retreat started a fire which burned 135,000 gallons, but drove the Germans in an alternate direction. The Nazis never got the oil.

Thus is the essence of this book, one instance after another of exhilarating oil history from the annals of World War II. In no other volume is such a comprehensive analysis available. The authors have brought modern warfare and its dependency on petroleum to the surface. The pun is intended. This book is a valuable contribution to the literature of war and will be devoured by the combat support and logistics experts of the world.

Ted Kluz
Faculty
Air War College
Maxwell AFB, Alabama

