A RAND NOTE

Effective Logistics Support in the Face of
Peacetime Resource Constraints

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Prepared for the
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PREFACE

This Note contains the text of a briefing presented in November 1988 to the Air Force Advisory Group, a body of senior Air Force officers who oversee the research program of RAND's Project AIR FORCE (PAF). The work described here evolved as part of an ongoing logistics research effort, "Enhancing the Integration and Responsiveness of the Logistics Support System to Meet Wartime and Peacetime Uncertainties," also known as the "Uncertainty Project." An important component of PAF's Resource Management Program, the Uncertainty Project seeks to increase the ability of the Air Force logistics support system to respond effectively to major uncertainties in resource demands. Since this Note presents the text of a briefing, the material is largely unsupported by references or thorough explanations of the analysis.

This document should be of interest to senior Air Force logisticians. It develops a central message: The same management initiatives that help mitigate wartime sortie generation constraints can also mitigate peacetime resource constraints.

SUMMARY

RAND has quantified substantial levels of variability in peacetime demands for resources, in particular aircraft recoverable spare parts. The unpredictability of peacetime demands is likely to be compounded in wartime by system disruptions, enemy attacks, and inevitable deviations from peacetime planning as the combat scenario unfolds. Resource shortages and imbalanced allocations are unavoidable given wartime surprises.

The major air commands, under the leadership of Headquarters, USAF/LE, have developed a new logistics concept of operations (CONOPS) intended to enhance the responsiveness of the logistics system in the face of wartime uncertainties. Many of the initiatives in the CONOPS were largely derived from work carried out by RAND.

The initiatives incorporated in the CONOPS, although originally intended to enhance the responsiveness of the logistics system in wartime, also improve its effectiveness in mitigating resource constraints that may develop in peacetime. Moreover, it is important that those initiatives be in place and well practiced in peacetime so that they can be brought to bear immediately and effectively when the need arises in combat. Routine use of the CONOPS initiatives can mitigate the effects of budget reductions, temporary loss of repair capability, tardy deliveries of assets from contractors, and many other events that induce asset shortages in peacetime.

Several CONOPS initiatives are described and evaluated here:

- Mutual base support
    —Proactive lateral supply (asset redistribution)
- Responsive depot support
    —Depot priority repair
    —Reducing depot pipelines
- Air base operability
    —Base-level priority repair and cannibalization

Each of these initiatives enhances the effectiveness of the logistics system in the face of resource shortages in peacetime, thus enhancing the readiness and sustainability of the combat force.

ACKNOWLEDGMENTS

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FIGURES

EFFECTIVE LOGISTICS SUPPORT IN THE FACE OF PEACETIME RESOURCE CONSTRAINTS

The purpose of this discussion is to describe some recent evaluations of management initiatives that should help the logistics system cope with resource constraints in peacetime.

Future peacetime resource constraints could be serious. Budget reductions have already occurred. Most notably, in FY88 the Air Force Logistics Command's component repair budget was reduced. The acquisition of some war reserve spares has been deferred, and further reductions are predicted in the months and years ahead. Naturally the potential effect of reductions on readiness and sustainability arouses great concern.

The problem of budgetary constraints is compounded by the usual peacetime crises: temporarily lost maintenance capability, failure of contractors to deliver serviceable assets to the system either from procurement or repair, etc. Those kinds of events disrupt the system and often induce asset shortages. Moreover, the unpredictability of demand further aggravates the problem, even in peacetime.

RAND's past work in logistics has traditionally focused on combat support in wartime scenarios. Some of the initiatives we have explored in that work are also relevant to the problem of mitigating peacetime resource constraints.

Air Force planning for wartime currently makes some optimistic assumptions about the predictability of both wartime tasking and resource demands in wartime. It also assumes that units will have sufficient resources to carry them through the early days of a conflict. As part of the "Uncertainty Project," we quantified the unpredictability of peacetime demands. That unpredictability is dramatically worsened in the wartime scenario by system disruptions and resource losses due to enemy actions and the inevitable surprises of combat.

Given that unpredictability, it is difficult to determine the right mix of resources to make the goal of unit self-sufficiency a reality in wartime. Thus we conclude that shortages in wartime are inevitable. Units are bound to face resource constraints that affect their ability to meet sortie generation goals.

In response to this thinking, the major commands formed an intercommand work group consisting of the Assistant LGs (Assistant Deputy Chiefs of Staff for Logistics) from the major commands and chaired by a representative from AF/LE. They formulated a new logistics concept of operations (CONOPS), which comprises many of the

initiatives that we evaluated in this work. Although these initiatives were intended to mitigate wartime sortie generation constraints, they are also effective in helping relieve peacetime resource constraints.

Figure 1 shows the nine elements of the Logistics CONOPS. The discussion that follows will explore some management initiatives imbedded in the first three elements.

Figure 2 lists the management initiatives that we evaluated. Each initiative focuses on the achievement of specified aircraft availability goals. Our evaluations assume the existence of responsive transportation; a command and control system that specifies availability goals, force beddown, and operating tempos; and information and management systems to support these initiatives.

These are not unreasonable assumptions; however, none of them is trivial. Transportation times, especially to and from overseas locations, are considerably longer than assumed in these analyses. Logistics command and control functions now reside largely in logistics readiness centers that tend to react to emerging shortages rather than proactively in preventing shortages. The difference between what exists and what is assumed here is largely behavioral, but it also involves using available data differently and developing appropriate mechanisms and algorithms. Current information systems would support the kinds of initiatives discussed here but are largely partitioned, often creating the need to integrate data from several different sources to support resource allocation decisionmaking.

The first of these initiatives is "proactive lateral supply." Its overall goal is to anticipate needs rather than wait for holes in aircraft before shipping parts to bases that require them.

The Log Con Ops comprises the following elements:
- Mutual base support
- Responsive depot support
- Air base operability
- Assured, responsive intertheater transportation
- Assured, responsive intratheater transportation
- Integrated logistics command and control
- Forward support
- Mobility
- Joint/Allied support

Fig. 1—Logistics concept of operations

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│                                                             │
│     Mutual base support                                     │
│          • Proactive lateral supply (asset redistribution)  │
│                                                             │
│     Responsive depot support                                │
│          • Depot priority repair                            │
│          • Reducing depot pipelines                         │
│                                                             │
│     Air base operability                                    │
│          • Base level priority repair and cannibalization   │
│                                                             │
│     All initiatives tied to aircraft availability goals     │
│                                                             │
│     Evaluations assume in-place                             │
│          • Responsive transportation                        │
│          • Command and control system                       │
│          • Information and management systems               │
│                                                             │
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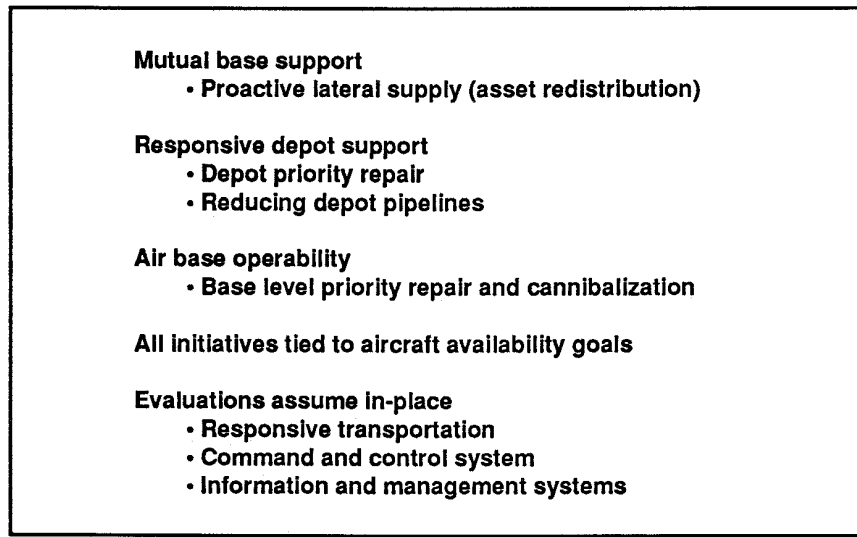
Fig. 2—Management initiatives evaluated

Peacetime asset positions—the distribution of aircraft spare parts across bases—are often characterized by maldistribution. Some bases have far more assets than they need while other bases are short of assets. To some extent, maldistribution is induced by changes in the force beddown. In the illustrations that follow, the data are drawn from the F-16A/B force, whose beddown has been especially dynamic in recent years because many of these aircraft have migrated to the Air National Guard.

The proactive lateral supply initiative simply seeks to keep up with the evolving asset position through routine redistribution. Emphasis is given to achieving availability goals in peacetime and maintaining an asset position well balanced for war. We believe that this initiative will also tend to prevent holes in aircraft before they occur, thus helping the system cope more effectively with resource constraints.

However, assets should be reallocated only when the payoff is sufficient to warrant the cost, which is obviously greater than second destination transportation charges alone. Additional costs are associated with moving assets around the system. For example, they can be damaged in shipment, misrouted, or lost, at least temporarily.

The dark bars in Fig. 3 indicate the expected number of demands for the F-16A/B radar transmitter. (The component is peculiar to this particular aircraft; it does not apply to the C/D or any other F-16 series.) The expected demand is a simple mathematical expectation related to the mission and flying programs of the bases; the bases are shown across the bottom of the figure: Hill, Nellis, Moody, Homestead, etc. The totals are derived by adding the number of expected component demands during a peacetime
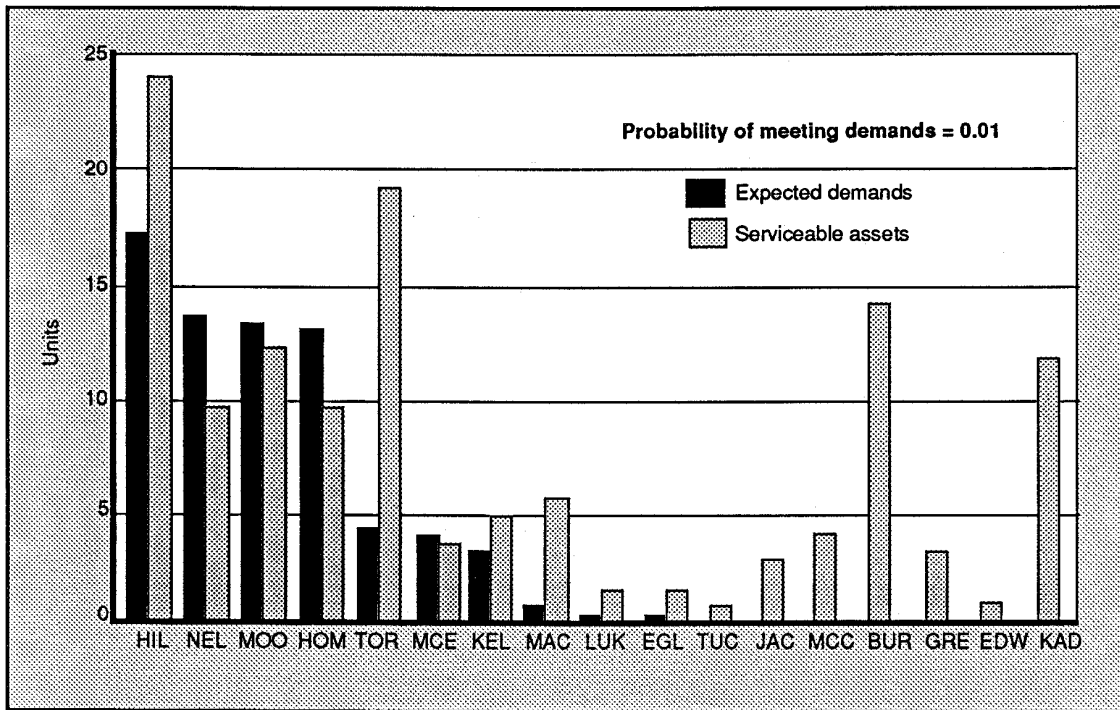
Fig. 3—F-16 A/B radar transmitter asset position on 20 July

planning horizon to the number representing 30 days of war for those units with wartime tasking. This information is very important in decisions involving asset allocation to fill the war reserve spares kits (WRSKs) as well as to maintain peacetime readiness.

The light bars show the number of serviceable assets actually on hand at each of these bases on 20 July 1988. They also include serviceable assets in transit to each base. The dissimilarities between the black and gray bars underscore the maldistribution in the asset position. The probability that this asset position will satisfy all of the demands without redistribution is very small. The lack of balance in this component's worldwide asset position is not atypical. In our work at Ogden, we have often observed this sort of situation.

See the appendix for an explanation of the analyses reported here.

Figure 4 shows the same number of assets once they have been redistributed. The redistribution is not perfect. The idea is to stop when the payoff of the next redistribution action is less than its cost. Underlying the reallocations represented here is a
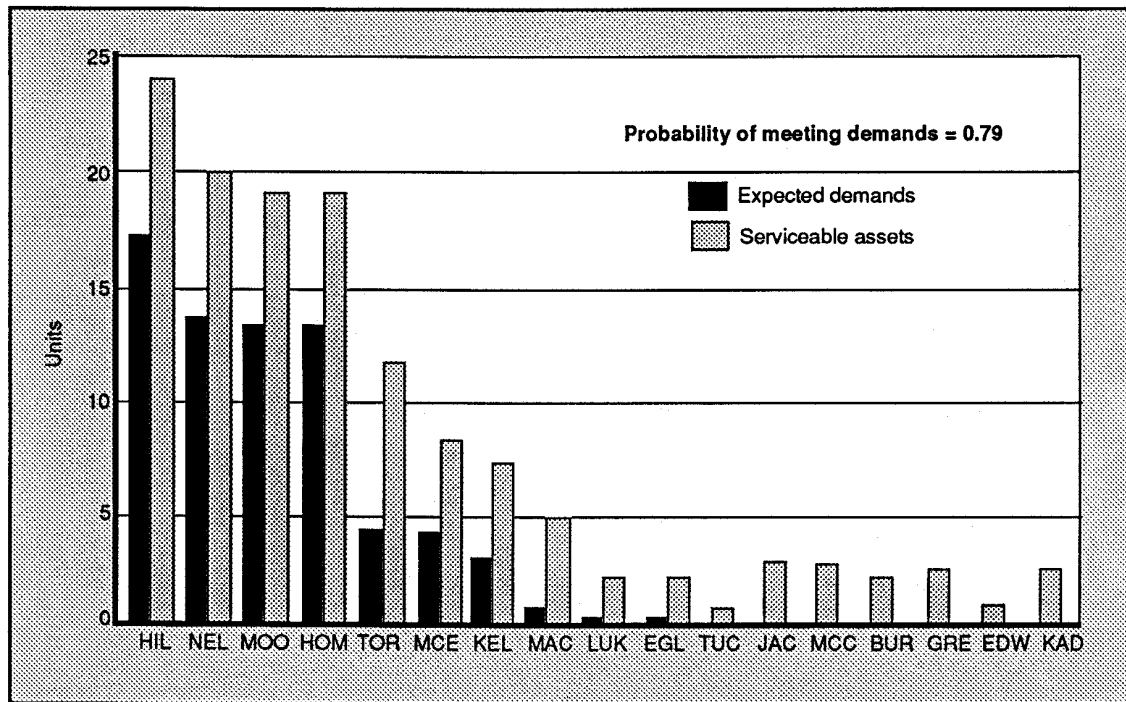
Fig. 4—F-16 A/B radar transmitter asset position revised

redistribution algorithm with a cost function that says, "Stop when the next redistribution action isn't worth the expense." Nevertheless, there is a dramatic increase in the probability of meeting all the demands.

Figure 5 shows the effect of the same algorithm applied to the asset position when the total number of assets in the system has been reduced by 20 percent. Again, sensible distribution against expected demands can substantially improve the system's performance even in the face of asset shortages.

Figure 6 compares the probabilities of meeting expected demands that were illustrated in the three previous figures.

The second management initiative to be discussed is priority repair at the depot. It represents a different view of the sequencing of repairs of components going back to the depot. Emphasis is still on the achievement of availability goals. However, the visibility of the asset position at the bases is continually used to help decide what asset to repair next—that is, which one will do the combat force the most good in terms of aircraft availability goals. Repair actions are sequenced accordingly.
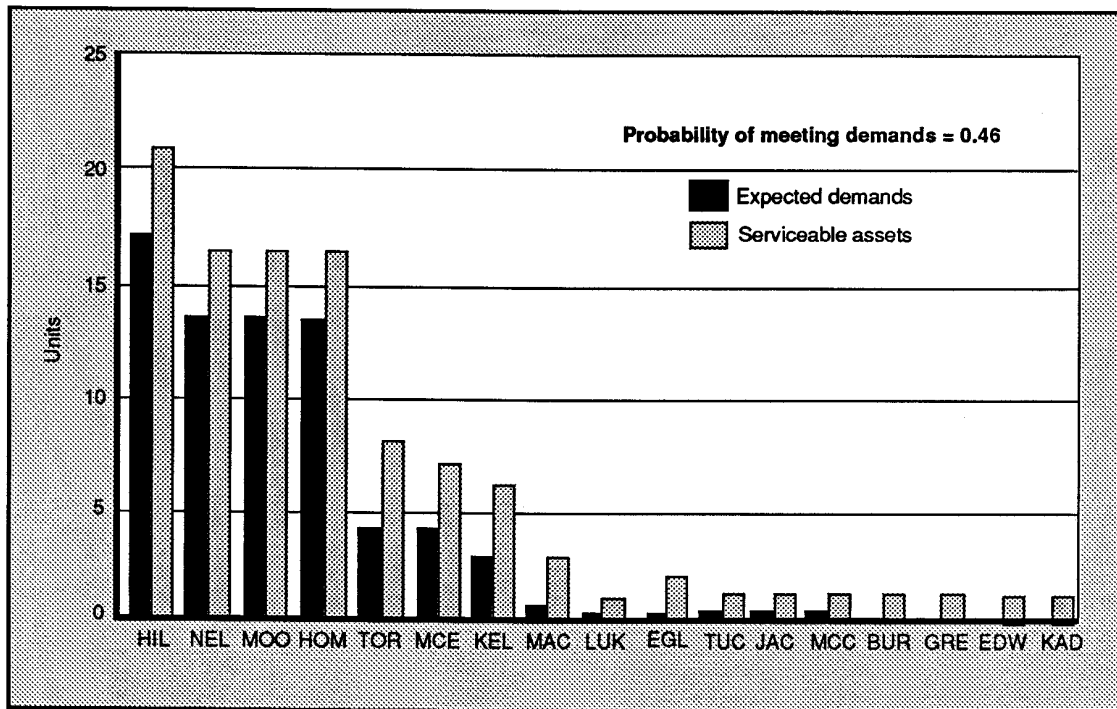
Fig. 5—Radar transmitter asset position reduced by 20 percent, with redistribution
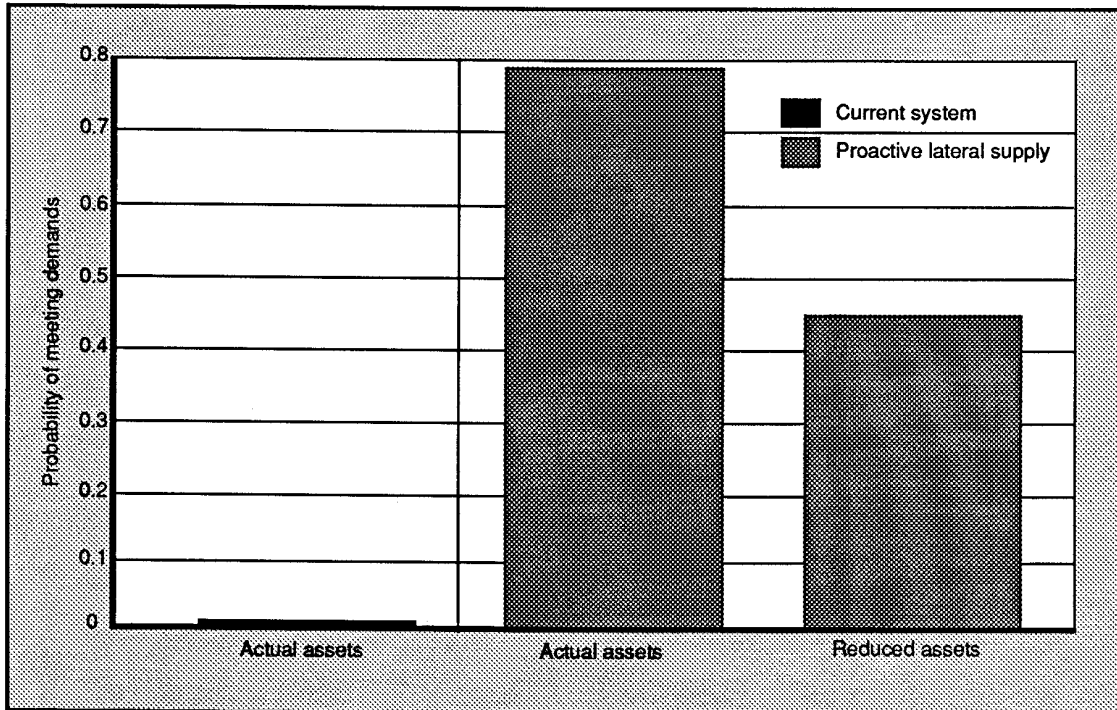

Fig. 6—Summary of payoffs of proactive lateral supply

A prototype of such a priority algorithm is already in operation at the Ogden Air Logistics Center where it is being used to prioritize the repair of a set of avionics components (about 230 LRUs and SRUs on the F-16 aircraft, mostly the A/B but some items common to the C/D as well).

This represents an important departure from the focus of the current workloading system in the Air Force Logistics Command. It requires some fundamental changes in the views of senior management toward new goals, objective functions, and performance measures that are oriented toward effective support of the combat force rather than toward traditional measures of efficiency that tend to be internal to the depot itself. AFLC plans to enhance this prototype and extend it to other workloads both at Ogden and at Warner-Robbins.

Figure 7 illustrates the effect of applying the depot repair prioritization algorithm in the face of a reduction in funding for component repair—what AFLC calls the depot purchased equipment maintenance (DPEM) budget. The fully mission-capable (FMC) rate for the F-16 force is shown as a function of that funding (100 percent, 90 percent, etc.). As suggested here, the F-16 force enjoys a high peacetime mission capable rate. These data represent a wing-sized operation at the end of one year during which a funding reduction has been in effect. The larger the funding reduction, the higher the payoff of the priority repair system. In these calculations, we have assumed that authorized peacetime operating stock (POS) is on hand. As in the other evaluations, we have limited this analysis to components in the WRSKs. We have made the other simplifying assumptions shown here as well.

The next initiative involves selectively reducing depot pipelines. We define the depot pipeline as the number of reparable assets in retrograde from the base to the depot and the number that are either awaiting maintenance or are in repair at the depot. Obviously, any asset in the depot pipeline is not a serviceable asset on the shelf at the base.

The actual pipeline quantities that we have observed in this work are inconsistent with the assumptions that underlie the requirements computations the Air Force makes in spares procurement. In fact, the quantities tend to be about two-and-one-half to three times as large as the quantities assumed in those requirements computations.
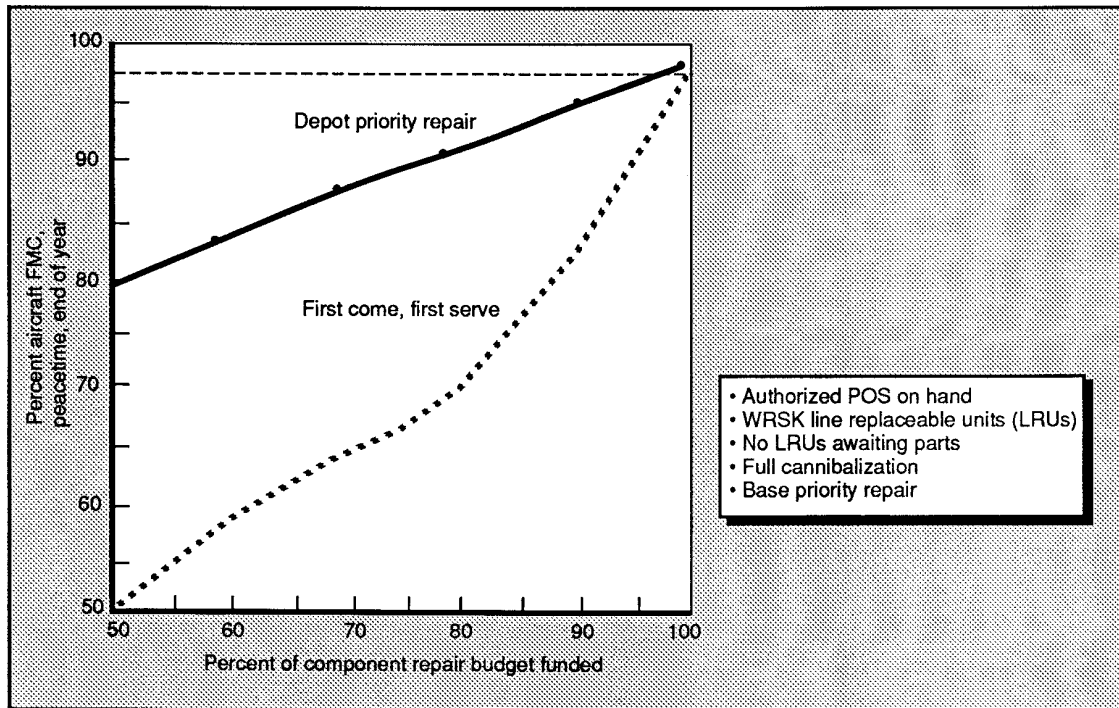
Fig. 7—Depot priority repair, 72 aircraft F-16 C/D wing

Whatever the reason, if system performance is being constrained by asset shortages, selective reductions in depot pipelines can have dramatic payoffs.

In Fig. 8, the dashed line represents essentially full-up POS. The lower curve illustrates the steady-state aircraft FMC rate in peacetime as a function of the percent of total POS on hand in the system. As that stock is reduced, so is the readiness. The upper curve shows the effect of what we believe is a fairly modest and achievable reduction in depot pipeline size. If the pipeline size were reduced by one-third, even with a 20 percent cut in POS the readiness level could still be maintained.

The next initiatives are associated with the CONOPS element called airbase operability. To some extent, the Air Force routinely although somewhat imperfectly carries out these practices in peacetime. Their payoffs are dramatic in both wartime and peacetime, especially in the face of asset shortages. The payoff of priority repair at a base derives from the fact that the shop chief is always in touch with aircraft status at his base. If he isn't repairing the right asset, the flight chief or the line chief is knocking on the shop door to help keep him in touch with what is going on out on the flight line. Moreover, he is also in touch with the asset position because he receives a daily report from base supply that tells him what the asset position is.
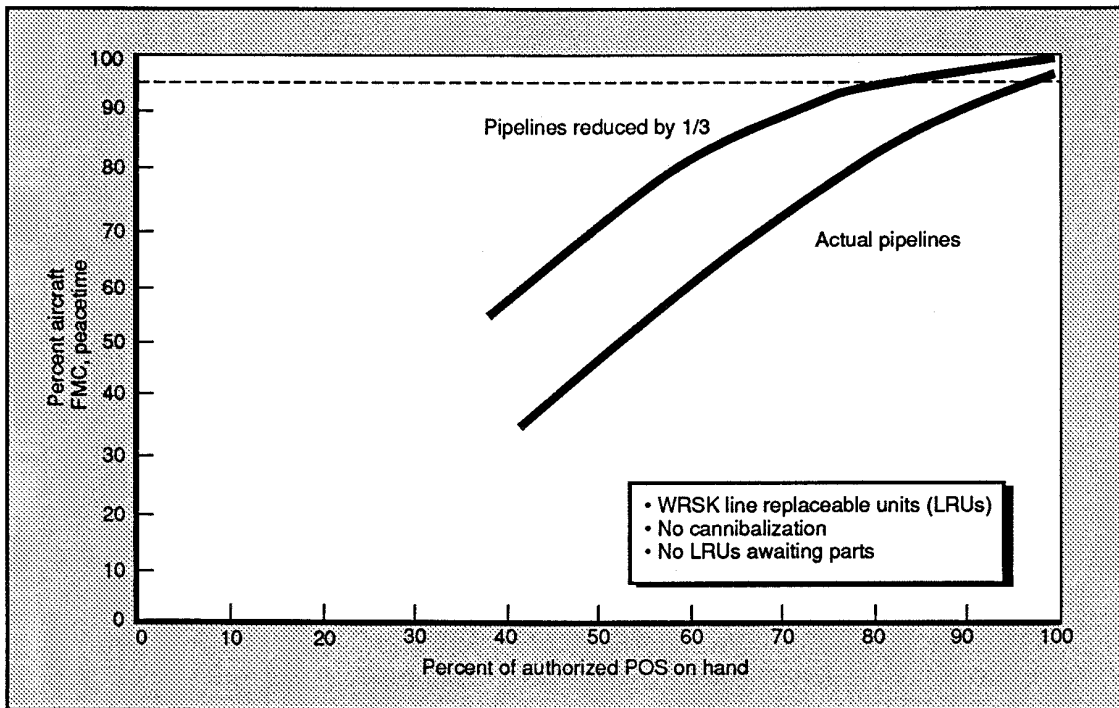
Fig. 8—Reducing depot pipelines, 72 aircraft F-16 C/D wing

The focus of this base-level priority repair initiative is once again on achieving availability goals and on combining asset and status information in a sensible way to decide what to repair next.

The cannibalization initiative will be illustrated in Fig. 9 by two extreme examples. In the first case, there is almost no cannibalization—that is, parts shortages are randomly distributed over tail numbers. In the second, cannibalization is essentially perfect, which means that the shortages are consolidated into the smallest possible number of aircraft.

Figure 9 shows the peacetime FMC rate as a function of the proportion of POS assets on hand. As noted before, the F-16 force currently enjoys a high mission capable rate. The lower curve represents almost no cannibalization; the middle curve, perfect cannibalization; the top curve, priority repair added to cannibalization. (The lower curve is the same as that shown in Fig. 8.) By implementing this initiative, the system can maintain respectable readiness rates in the face of substantial reductions in the number of serviceable assets.

As mentioned above, the Air Force currently practices both of these initiatives in peacetime, although not as perfectly as in the model underlying these curves. In the
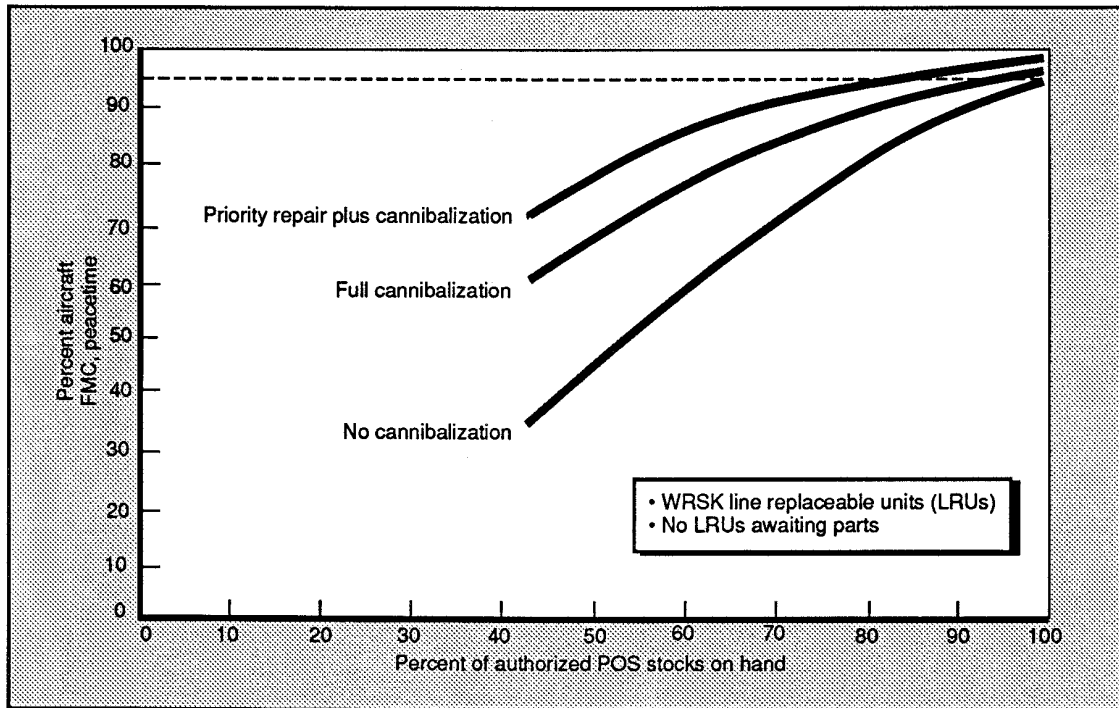
Fig. 9—Base priority repair and cannibalization, 72 aircraft F-16 C/D wing

model, the prioritization and cannibalization are perfect. In real life, they typically are not. Thus the actual performance of the Air Force is somewhere between the upper and lower curves shown here.

RAND's past work in the "Uncertainty Project" has had a marked influence on the Air Force's logistics concept of operations. Although all of the initiatives incorporated in the CONOPS currently concentrate on wartime sortie generation constraints, these same initiatives can also be very helpful in coping with peacetime resource constraints.

The Air Force has already taken several steps to implement its CONOPS and, with it, the initiatives discussed here. An initiative is underway to extend the prototype depot repair prioritization algorithm, called Distribution and Repair In Variable Environments (DRIVE). Contractors have been asked to help with the enhancement of the prototype and its extension to other workloads. The Air Force also plans the concurrent development of a production version of the system.

The major commands are working toward implementation of their own concepts of operations. In a meeting at Langley Air Force Base, the details of the management initiatives that make up the CONOPS were discussed. Meanwhile, with some of the major commands RAND has been actively pursuing the implementation of mutual base

support initiatives, such as proactive lateral supply, lateral repair, and priority repair at base level.

USAF/LE is also planning further actions. In the near future, that office intends to reconvene the intercommand work group mentioned earlier to pursue further work in the area of mutual base support. The initiatives described here and the other CONOPS initiatives will thus be integrated into the routine logistics support of the force.

Appendix
SUPPORTING EXPLANATIONS

Since this Note presents the text of a briefing, the material is largely unsupported by references or thorough explanations of the analyses. The purpose of this appendix is to provide those explanations along with references for the interested reader.

PROACTIVE LATERAL SUPPLY

The data reflecting the worldwide asset position of the F-16A/B radar antenna was taken from AFLC's D143 data system. The asset data were coupled with estimated demand rates extracted from the Air Force's DRIVE data base for the same date.

The redistribution shown in Fig. 4 was computed with a marginal analytic algorithm that assumes an aircraft availability goal is specified for each base. It then computes, for the starting asset position, the probability that the aircraft availability goals will be met at all bases at the end of a planning horizon (in this case 20 to 60 days long depending on the base-specific order-and-ship time and on whether the base has a wartime deployment tasking). For purposes of this analysis, all base aircraft availability goals were specified to be 100 percent.

At each step of the marginal analysis, for each base the algorithm computes the probability that the base would meet its availability goal if one additional asset were allocated to it; it also computes the probability the base would meet its goal with one less asset. It then computes for each base the new probability associated with an additional asset divided by the current probability and takes the logarithm of the ratio. It makes a similar computation for the loss of an asset.

Having made these computations for each base, it subtracts the smallest loss from the largest gain and compares the algebraic difference with a user-specified cost function. If the payoff exceeds the cost function, it reallocates an asset from the base with the smallest loss to the base with the largest gain and proceeds to the next step of the marginal analysis; if the payoff does not exceed the cost, it stops.

The algorithm used to make these computations has not been published; however, a similar but more sophisticated algorithm is being incorporated in DRIVE and will be discussed in forthcoming RAND research.

THE DATA SET AND GENERAL APPROACH FOR THE OTHER ANALYSES

The Logistics Management Institute (LMI) provided the initial data set from which the data set was built for the remaining analyses presented in this briefing. The LMI data set was based largely on the AFLC D041 data base in March 1988. It contained all recoverable line and shop replaceable units applicable to the F-16C/D aircraft. We extracted from this data set all LRUs authorized in the F-16C/D WRSK for a 24-PAA squadron and further reduced the data set to exclude wheels, tires, and LRUs in the penetration aids and electronic countermeasures system; at the time of this analysis, the item demand rates for this system were largely a matter of uncertainty. The data set that emerged contained 176 LRUs. The analyses ignored all other components of the aircraft.

Two different versions of RAND's capability assessment model, Dyna-METRIC, were used in these analyses. Version 4, a purely analytic model, was used to compute peacetime operating stocks that would deliver an expected 95 percent aircraft availability without cannibalization. The cost of this stock was $40.9 million for 72 aircraft. Version 5 was used to assess system performance under the several alternative assumptions that are discussed in this Note. See the reference list.

DEPOT PRIORITY REPAIR

Dyna-METRIC Version 5 was used for this analysis. It has a feature that enables the user to specify whether components arriving at the depot for repair are repaired in a first-come-first-serve sequence or in a prioritized sequence intended to maximize the probability of meeting specified aircraft availability goals. This enabled us to evaluate the payoff of depot priority repair directly.

REDUCING DEPOT PIPELINES

In this analysis, Dyna-METRIC Version 4 was used. Its user-specified input parameter defining the number of days in the depot repair pipeline was specified to be the values of the current system and then those values were reduced by one-third to represent more expeditious transportation and handling as well as shortened repair times at the depot.

BASE-LEVEL PRIORITY REPAIR AND CANNIBALIZATION

In this analysis, both Version 4 and Version 5 were used. The base case here—i.e., no cannibalization—is the same as the base case in the depot pipeline analysis in which actual pipeline values were specified. The base case was modified by changing the

assumption of no cannibalization to one of perfect consolidation of parts shortages among aircraft, which is referred to here as "full" cannibalization. Version 4 was used to estimate system performance for both cases.

Version 5 enables the user to specify the priority repair option directly, The upper curve in Fig. 9 was computed in this way.

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