Combat Benefits of a Responsive Logistics Transportation System for the European Theater (U).

Executive Summary

M. B. Berman
with M. J. Carrillo, Major J. M. Halliday (USAF),
N. Y. Moore, J. E. Peterson

December 1981
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A Project AIR FORCE report
prepared for the
United States Air Force

UNCLASSIFIED
A conflict in Europe between NATO and Warsaw Pact forces would severely stress the United States Air Forces in Europe (USAFE). The stresses are difficult to forecast, but they could be expected to be unequal across the set of USAFE bases and thus would create imbalances in spare-parts inventories among the bases. These imbalances could reduce the number of aircraft available for combat unless mutual support among the bases were to restore the balance. Mutual support may require better transportation arrangements than currently exist.

The study summarized here investigates the value to USAFE of a responsive intratheater spare-parts transportation system during a European conflict. It estimates the gain in combat capability (expressed in sortie-generation-related measures) attributable to such a transportation system, and calculates the costs of several alternatives for moving spare parts.

This summary was designed for executives involved in transportation decisionmaking in the Air Force, the Department of Defense, the Office of Management and Budget, and the Congress who need some first-hand information about the study, but have only limited time for review. The main Rand study is titled Combat Benefits of a Responsive Logistics Transportation System for the European Theater (U), by M. B. Berman with Major J. M. Halliday (USAF), M. J. Carrillo, and N. Y. Moore, R-2860-AF, December 1981 (Secret).

This work was done under the "Assured Intratheater Transportation System for Spare Parts" project of the Project AIR FORCE Resource Management Program.
The basic hypothesis that a responsive logistics transportation system for spare parts might enhance combat performance was advanced by Lt. Gen. Billy M. Minter, Hq USAF, DCS/Logistics and Engineering. We wish to thank General Minter and the many members of his staff who made contributions to this study. We are also grateful to the Logistics staff at Hq USAFE, and personnel at USAFE air bases and aerial ports who made many contributions to this study.

This summary report benefited from the critical comments of Giles K. Smith.
NOTE ON CLASSIFICATION

Although individual paragraphs, sections, figures, tables, diagrams, etc., are unclassified, this report is classified CONFIDENTIAL overall, because the compilation of information identifies a major deficiency in combat readiness of U.S. Air Forces in Europe.
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I. INTRODUCTION

In recent years, logistics decisionmakers have begun to suspect that existing logistics arrangements would not provide sufficient support for U.S. air forces in a European conflict. Present policies aim at making tactical aircraft bases self-sufficient in repair capabilities and spare-parts inventory for the opening weeks of a war. However, the dynamics of combat work against this planning objective. Careful projections and preplacement of resources cannot fully anticipate or overcome the shortages that would occur and occur unevenly across bases in wartime. As fighting intensified, bases would experience different flying rates, aircraft attrition, and attack damages. Inevitably, surviving spare parts and repair facilities would be unevenly distributed, and some bases would not have adequate capacity to repair all their aircraft. Under these conditions, sortie generation rates would depend on timely, effective, mutual support among bases.

This situation raises three related questions for Air Force policymakers:

1. Can the existing transportation system in Europe provide adequate mutual support?
2. Would U.S. Air Forces in Europe (USAFE) combat capability be enhanced by a new intratheater responsive logistics transportation system (RLTS)?
3. Would buying such a system cost more or less than investing in additional spare-parts inventories sufficient to achieve similar effects?

The design and performance characteristics of an RLTS are described below. All costs in this report are adjusted to FY80 dollars.
The study summarized here attempts to answer those questions by establishing the combat benefits and costs of an RLTS. Our purpose is to provide useful information for logistics planners who must assess wartime requirements for NATO (and other major theater conflicts) and future USAF transportation requirements. This executive summary focuses on the most policy-relevant issues and conclusions of the study. Readers interested in detailed technical information and descriptions of our methodology should consult the project report, particularly the appendixes.

We tested the effects that an RLTS would have on sortie generation first in an extremely benign and then in a moderately damaging wartime environment. Our rationale was that although wartime damage cannot be predicted with any certainty, the more damage U.S. bases sustained, the more spare-parts transfers would be needed. Thus, if the RLTS would pay off in benign circumstances, it would be worth even more as damage became more serious. In comparing the RLTS to the current transportation system, we used two forms of the latter: a pessimistic (but likely) case in which the present system moves no spare parts for the first 30 days of a European conflict and a (very) optimistic case in which it can move parts but sporadically. This should bracket the current system's likely performance in wartime.

Our analysis indicates that even in relatively benign and moderate damage environments an RLTS would make available significantly more combat-capable aircraft than the present system could in a NATO-Warsaw Pact conflict. It also indicates that the RLTS would make more combat-capable aircraft available with more certainty and at less cost than investing in additional spare-parts inventories. In Sec. II, we examine the current policy and the present transportation system in light of combat-generated needs for a responsive transportation system. Section III outlines the design and costs of an RLTS and summarizes the combat-related gains for three representative aircraft (the F-15, F-4, and A-10). Section IV summarizes the RLTS costs and payoffs.

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2Mort Berman et al., Combat Benefits of a Responsive Logistics Transportation System for the European Theater (U), The Rand Corporation, R-2860-AF, December 1981 (Secret).
II. THE NEED FOR RESPONSIVE LOGISTICS TRANSPORTATION

This section provides: insight on how the need for spare parts transportation arises; an indication of the size of the transportation requirement; and information on the problems of the current transportation system in meeting the requirement.

SPARE-PARTS SHORTAGES

Even with low peacetime flying rates, the U.S. Air Forces in Europe (USAFE) experience spare-parts shortages. Bases usually respond to shortages by withdrawing from their war reserve materiel (WRM), cannibalizing their combat aircraft, and using intratheater transportation to get spares from other bases.

Table 2.1 shows the situation for parts-short F-4 and F-15 aircraft during the first seven months of 1979. Mutual support by lateral shipments is common: During the first seven months of 1979, total lateral shipments in USAFE averaged 1000 per month.¹

In wartime, lateral shipments would have to increase. Bases would not have the peacetime expedient of using WRM because that materiel would be needed to support increased sortie rates. If cannibalization and additional lateral support could not overcome shortages, grounded aircraft would remain grounded, and sortie generation rates would suffer.

USAFE bases might possibly be stocked with enough spare parts to overcome anticipated (predictable) shortages. But wartime conditions would create unanticipated, unevenly distributed shortages that would make transportation necessary. For example, in peace and wartime, the USAF inventory system aims to provide near identical stocks to like units.² Nevertheless, during combat, identical units would probably

¹Hq USAFE MICAP Analysis System Reports (D-165), January through July 1979.
### Table 2.1

**DISTRIBUTION OF METHODS FOR OVERCOMING SPARE-PARTS SHORTAGES**

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Average Daily NFMC Aircraft</th>
<th>WRM Withdrawal (%)</th>
<th>Cannibalization (%)</th>
<th>Lateral Support (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F/RF-4</td>
<td>33.7</td>
<td>31</td>
<td>15</td>
<td>27</td>
</tr>
<tr>
<td>F-15A/B</td>
<td>14.5</td>
<td>18</td>
<td>44</td>
<td>6</td>
</tr>
</tbody>
</table>

**NOTE:** Percentages do not add up to 100 because there are additional categories (depot resupply, for example).

**SOURCE:** Hq USAF, MICAP Analysis System (D-165), January through July 1979.

have different daily inventories because of randomness in parts failures and, more important, because they would have different daily flying experiences, that is, different weather conditions, air-to-air attrition rates, and assignments from theater command authorities.

Several other conditions would create unanticipated, uneven shortages: attack on USAFE bases, theater flying rates higher than originally provisioned for, and differences in total assets among bases. In all three cases, lateral transportation could make a significant difference for sortie generation rates across the theater.

Take the third condition: even when units have their full authorized stocks, they differ in total assets. Main Operating Bases (MOBs) feature in-place units that have full repair capability and sufficient authorized spare stocks to keep nearly 95 percent of their aircraft available through the first 30 days of combat. Units that deploy to Europe from the United States after a conflict begins usually operate from bases collocated with allied forces (COBs), have limited repair equipment, and use a War Readiness Spares Kit (WRSK) as the major source of parts. Under those constraints, COBs could have 30 percent or more not fully mission capable (NFMC) aircraft by the 30th day of
conflict—unless transportation allowed COB units to share stocks and repair capabilities with MOBs.³

Table 2.2 shows the effect of lateral support for two types of aircraft and implies how much mission ready rates across a theater could improve with lateral transportation among COBs and MOBs. When units must fly more than anticipated, transportation among these bases also pays off. For example, in a group containing one MOB (with repair) and three COBs (with WRSK) that must fly at a rate 30 percent

Table 2.2

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Average Daily NFMC Without Transportation</th>
<th>Average Daily NFMC with 36-Hour Transportation</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-15 (F100 engine)</td>
<td>18.4</td>
<td>9.3</td>
</tr>
<tr>
<td>F-4E (All systems)</td>
<td>31.6</td>
<td>21.8</td>
</tr>
</tbody>
</table>

SOURCES: Rand Dyna-METRIC and TSAR model runs.

higher than initially provisioned for, a transportation system that provides delivery in an average of 36 hours increases combat capability by 12 sorties and four additional fully mission-capable aircraft each day.

CURRENT TRANSPORTATION SYSTEM'S CAPABILITY

The present system combines surface transport and airlift to move parts and repair equipment among bases.

³NFMC means the aircraft has at least one "hole" from a missing line replaceable unit (LRU), which could be still in the base repair cycle. Thus, NFMC may include some Not Mission Capable Maintenance (NMCM) as well as Not Mission Capable Supply (NMCS). (The study included only WRSK items, which are usually mission-critical.)
Current Surface Transportation

Surface transportation is effective only in the central region of Europe and in the United Kingdom. It cannot connect bases in Turkey with those in Greece or the rest of Europe, link the United Kingdom to the continent, or easily move materiel up the coast of Norway, and is inappropriate for moving shock-sensitive buildup serviceable engines. In peacetime, surface transport can reach nearly all the in-place U.S. aircraft. In wartime, it could reach only a little over half of the expanded combat fleet.

Aside from limited ability to employ trucks there are further constraints on the use of surface vehicles. These constraints include shortages of vehicles, difficult access to the controlled road system, enemy action, refugee movements, and possible preemption for priority Army battle needs. In sum, relying on the current surface system for spare-parts support in wartime would be risky. Even though the evidence indicates difficulties with trucks, we include their use in our subsequent analyses so that decisionmakers can weigh their perception of risk against transportation costs.

Current Air Transportation

During wartime the current intra-theater transportation aircraft are devoted for several weeks to cargo that has higher priority than spare parts. Even with some expensive (and optimistic) alterations that increase system capacity, one cannot expect continuous availability of these aircraft for spare-parts movement.4

Transportation Requirements

Normally, transportation problems center on load size, but, in this case, distance and frequency of service create greater problems for logistics planners. Excluding engines, the components whose failure results in NFMC aircraft are small in size and number. For example, a typical F-4 squadron would need fewer than 17 components a

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4 Quantitative measures of this unavailability are contained in R-2860-AF, Sec. II.
day to repair aircraft that are short of parts. This represents 500 pounds and 75 cubic feet—a load that could be handled by a pickup truck or single sortie of a small (5000-pound capacity) transport. Indeed total spare-parts movements would amount to less than one percent of theater air-eligible tonnage. Thus, even though they have low priority, they might possibly fit somewhere aboard aircraft handling higher-priority loads. Unfortunately, that would not solve the logistics problem.

Figure 2.1 shows the bases that would have to be serviced. If the transportation system were going to reduce the number of aircraft grounded by parts shortages, it would have to provide approximately daily service to a very far-flung set of bases. However, the routes the current system plans to follow would not permit routine service even for the peacetime air base set.

CONCLUSION

All these limitations suggest that the present system could not provide efficient, continuous spare-parts support among bases during the first 30 days of a European conflict. Its inadequacies would certainly affect sortie generation rates, and most probably, combat results, unless the Air Force supplied those bases with considerable stocks of additional spare parts or designed and implemented an RLTS.

Examination of other alternatives (e.g., resupply from CONUS, hardening facilities to invulnerability, and caching stocks off base) have shown them to be impractical.
DESIGNING AN RLTS

Alternative RLTS designs are predicated on wartime loads, combinations of vehicles, and possible network structures. A series of performance measures is used to choose among the resulting designs. They include number of vehicles required to service the network, number of hours per 24-hour day the vehicle is actually in transit (utilization rate), and typical and average service times. Costs of the alternative designs are based on the initial investment and operating and support (O&S) costs for each kind of vehicle over a ten-year period.

A transportation planner would not find our design sufficiently detailed for a working system. For example, it is not a minimum-cost design nor does it deal with scheduling, loading and unloading, the mix of air and surface transport for base sets, etc. USAF personnel are more qualified to design a specific system that takes these details into account. Our objective was simply to size a system accurately enough to make its costs and payoffs easily comparable with those of other systems.

Design Criteria

We used the following criteria to design the RLTS:

1. It must provide continuous, responsive, daily service to each base in the theater.
2. It should directly link bases with similar aircraft types, to help minimize part transfer (service) times.
3. It must have sufficient residual capacity to handle emergency requests or redistribute theater spare parts immediately after base-damaging enemy attacks.
4. Its vehicles must be large enough to carry built-up jet engines, since engine shortages will definitely ground aircraft.
5. Its procurement and operating costs must be kept low.
6. It must operate with minimal command and control, since communication resources are scarce and at risk in wartime environments.

Transportation Design

Because we cannot know how a European conflict will develop, it is difficult to estimate the load an RLTS would have to carry. If there were sufficient tactical warning, if the war went as "planned," and if bases were not attacked, lateral movement of spare parts would be needed infrequently. However, if one or more of these conditions were not met, there would be high demand for movement of spare parts. To ensure that sufficient capacity would exist to cover the base-damage situation, we used an estimate that may appear high to knowledgeable USAF supply experts.

Table 3.1 represents our estimate of loads from data developed by the Air Force Logistics Management Center. These numbers presume that nearly 100 percent of the repairable spares move from the COBs and are eventually returned. (Usually, only the subset of these items in short supply throughout the theater would be expected to move.) To carry these loads, we considered several combinations of trucks and aircraft. The aircraft differed in size, but all can carry a buildup

<table>
<thead>
<tr>
<th>Parts</th>
<th>Weight (lb)</th>
<th>Volume (cu ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Components</td>
<td>55,992</td>
<td>6,085</td>
</tr>
<tr>
<td>F-15 engines</td>
<td>48,960</td>
<td>3,488</td>
</tr>
</tbody>
</table>

\footnotetext{1}{USAFE-CILC Study: Weapon Applicability for USAFE CILC F-15, F-16, F-111, 15 June 1978.}
engine mounted on a "low profile" skid. Table 3.2 shows their capacities and costs and summarizes their operating characteristics.

### Table 3.2

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Cargo Weight (lb)</th>
<th>Cargo Volume (cu ft)</th>
<th>Cruise Speed (mph)</th>
<th>Number of Pallets (44x54 in.)</th>
<th>Taxi, Load, and Unload Time (hr)</th>
<th>Unit Total Cost ($ millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck</td>
<td>5,000</td>
<td>350</td>
<td>35</td>
<td>6</td>
<td>1.33</td>
<td>0.8</td>
</tr>
<tr>
<td>Small aircraft</td>
<td>5,000</td>
<td>305</td>
<td>150</td>
<td>4</td>
<td>1.0</td>
<td>8.5</td>
</tr>
<tr>
<td>Medium aircraft</td>
<td>18,000</td>
<td>1,089</td>
<td>201</td>
<td>12</td>
<td>1.0</td>
<td>16.2</td>
</tr>
<tr>
<td>Large aircraft</td>
<td>45,000</td>
<td>2,970</td>
<td>335</td>
<td>20</td>
<td>1.0</td>
<td>25.0</td>
</tr>
</tbody>
</table>

*a This is the design cargo weight.  
*b Initial investment plus recurring O&S costs.  
*c 2-1/2-ton class.

The transportation system employing these vehicles is designed as a set of subnetworks, determined by a series of bases whose combined loads completely fill a vehicle. Generally, subnetworks comprise bases that have similar aircraft and can be serviced by the same type of vehicle (truck or airplane). Aircraft must be used if routes are long, if the region has poor roads, if bodies of water or neutral countries create barriers, or if shock-sensitive built-up engines must be moved. Each subnetwork terminates at an exchange point where cargo can be transferred for movement to other subnetworks. Ideally, the design links COBs and MOBs of the same aircraft type and touches an aerial port providing a link to the United States. Figure 3.1 illustrates this transportation network.

Operation of this network requires no complex scheduling and minimizes command and control requirements. A vehicle starts at a fixed time from one end of a network, picking up and dropping off spare parts as it heads for the exchange point. There it discharges cargo for other subnetworks, picks up cargo for its own, and works its way back toward the point of origin. Aircraft make the trip one way in 12 hours, trucks in 18. This limits air operations to day or night
only, reduces the number of crews required per aircraft, and permits some surge capacity for emergencies or immediate movements. If a vehicle takes less than 12 hours to service a subnetwork, it is also assigned to another one. Two vehicles may be assigned to one subnetwork if its load exceeds vehicle capacity or if service frequency is doubled. In the latter case, doubling allows a vehicle to start from each end of the subnetwork at the same time daily.

MEASURING PERFORMANCE AND COSTS OF AN RLTS

Table 3.3 summarizes the performance and costs of the main alternative network and scenario of operation we used to assess the RLTS combat payoffs and comparative costs. In this scenario, the RLTS covers all the bases for the F-4, F-15, and A-10 aircraft, providing one visit daily to each with transport aircraft operating 12-hour days. For all three aircraft types, the system carries components
(LRUs) and Shop Replaceable Units (SRUs); for the F-15 bases, it also carries engines and Automatic Test Equipment (ATE) parts.

Table 3.3.

COST AND PERFORMANCE OF AN RLTS IN USAFE
(Serving: F-4, F-15, A-10, including F-15 engines)

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Planes</th>
<th>Trucks</th>
<th>Planes Only</th>
<th>UTE Rate (hr)</th>
<th>Service Time (hr)</th>
<th>Costs ($ millions, FY89)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Typical</td>
<td>Average</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Initial</td>
<td>Total Ten-Year</td>
</tr>
<tr>
<td>Small</td>
<td>7</td>
<td>6</td>
<td>..</td>
<td>7.9</td>
<td>30.6</td>
<td>52.8</td>
</tr>
<tr>
<td></td>
<td>..</td>
<td>..</td>
<td>11</td>
<td>6.4</td>
<td>29.2</td>
<td>42.8</td>
</tr>
<tr>
<td>Medium</td>
<td>5</td>
<td>6</td>
<td>..</td>
<td>5.2</td>
<td>30.6</td>
<td>52.3</td>
</tr>
<tr>
<td></td>
<td>..</td>
<td>..</td>
<td>7</td>
<td>3.8</td>
<td>28.2</td>
<td>42.9</td>
</tr>
<tr>
<td>Large</td>
<td>3</td>
<td>4</td>
<td>..</td>
<td>4.9</td>
<td>29.6</td>
<td>42.7</td>
</tr>
<tr>
<td></td>
<td>..</td>
<td>..</td>
<td>4</td>
<td>2.7</td>
<td>28.1</td>
<td>42.6</td>
</tr>
</tbody>
</table>

In selecting this network and mode of operation, we used the following performance measures to evaluate alternatives:

1. The number of vehicles required to service the network.
2. The utilization rate (UTE), defined as the number of hours (per 24-hour day) that the vehicle actually moves rather than waiting, loading, unloading, taxiing, or fueling.
3. The "typical parts transfer time," which measures the average time required to move a spare part between locations within a subnetwork ("typical" because the majority of demands and "fills" for a serviceable part will probably occur among the bases closest in a subnetwork).
4. The "average parts transfer time" among all base pairs, which includes delays in moving from one subnetwork to another across cargo exchange points (considered because of the low probability that a part might move across the theater to satisfy a demand).

Before selecting the alternative RLTS network represented in Table 3.3, we tested networks for each aircraft type individually and
collectively, investigated moving only components, assessed the number of aircraft needed just to service each base without carrying significant loads, tested the effect of replacing aircraft with trucks to reduce costs, and considered the effects of increasing and decreasing service frequency.

In setting costs for our alternative designs, we estimated the costs of three aircraft types and a 2-1/2-ton truck, including the initial investment and the ten-year O&S costs for each. The aircraft costs shown in Table 3.3 are calculated for a 16 aircraft squadron containing an additional three aircraft for attrition fillers. In these calculations, we assumed that the aircraft would operate as a separate squadron, even though attaching them to already existing units would lower costs (primarily O&S personnel costs) by ten percent. This assumption is consistent with our generally conservative approach.

The performance and cost measurements led us to these five major conclusions:

First, RLTS alternatives using trucks cost 25 to 35 percent less than those that use only aircraft, but they have longer service times and, recall, they have uncertain availability. Moreover, to service the entire theater, substantial numbers of aircraft are still needed to carry engines and cross geographical barriers.

Second, because costs are so similar, other factors should, perhaps, determine the choice of RLTS aircraft type. For example, if attacks result in cratered runways, short-take-off-and-landing capability like the Buffalo's might be desirable. Or simultaneous demands to move small quantities of critical parts rapidly might make a larger number of the smallest aircraft valuable.

Third, aircraft UTE rates are three to eight hours a day. These moderate rates allow sufficient ground time for maintenance activities.

Fourth, the RLTS supply-to-supply time is roughly 1.5 days. This figure represents the typical service time between adjacent bases with similar aircraft types (28 to 31 hours) plus time for transfer from delivery dock to supply accounts at the destination. (Average time across all base pairs is 42 to 53 hours.) However, the RLTS has
sufficient residual capacity to respond to time-urgent requests and to redistribute surviving stockpiles across the theater immediately after attacks.

Fifth, 24-hour service makes three to seven percent more combat aircraft available during the first 30 days than 36-hour service does. However, this increase requires 1.5 to 2.0 times more vehicles and raises the investment and ten-year costs of air transportation by $60 to $100 million. We believe the improvement does not justify the cost.

Selecting a particular RLTS design would be premature; if payoff is sufficient, criteria other than the small cost difference might prevail. As Table 3.3 shows, the total cost of an RLTS should range between $64 and $113 million.

**COMBAT BENEFITS OF AN RLTS**

What combat benefits would USAF get for this investment? To answer that question, we assessed the gains an RLTS would achieve in wartime environments that place increasing demands on transportation. Combat aircraft operating in more demanding environments would benefit most from efficient spare-parts transportation; however, those environments are difficult to forecast. Thus, if the RLTS outperforms the current system in the less demanding, easier-to-forecast, environment, it will certainly have greater payoffs under more demanding conditions.

We examined the transportation cases in three combat environments, as described in Table 3.4.² To bracket the current transportation system's possible performance, we compared the RLTS to two base cases.

²Two Rand models enabled us to assess the combat value of various transportation systems. The Rand Dyna-METRIC model uses queuing theory results and provides measures that include the expected value and variance of NMC (or NFMC) aircraft. The Theater Simulation of Air Base Resources (TSAR) model is a large scale simulation that models sortie generation activities on a series of air bases, permitting them to operate in concert or independently. Its theater capabilities allow the user to examine the gains in available aircraft and sorties generated from lateral supply or repair, alternative distribution disciplines, and transportation availability. For further description of Dyna-METRIC and TSAR models, see Appendixes I and J, respectively, in R-2860-AF.
Table 3.4
THE COMBAT ENVIRONMENTS

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Available Transportation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benign—no base attack, no initial shortages, and planned flying</td>
<td>None</td>
</tr>
<tr>
<td>Benign—no base attack. Stresses include: Flying more than planned</td>
<td>Optimistic view of current system</td>
</tr>
<tr>
<td>Differential flying among bases</td>
<td>RLTS</td>
</tr>
<tr>
<td>Higher than expected part removal rates</td>
<td></td>
</tr>
<tr>
<td>Stock shortages</td>
<td></td>
</tr>
<tr>
<td>Damage—attacks against air bases</td>
<td></td>
</tr>
<tr>
<td>No stresses</td>
<td></td>
</tr>
<tr>
<td>Stresses</td>
<td></td>
</tr>
</tbody>
</table>

cases. The first is a case in which no spare parts can be moved during the first 30 days of conflict. The second is an optimistic case in which the current system can move spare parts after the first week (with some occasional interruptions) in 2.5 days point-to-point, regardless of delivery mode. In the RLTS case, the system operates without interruption from D-day on, provides 1.5-day service, and has the capacity to respond to urgent requests and damage conditions.

Performance Measures

Performance is gauged by the number of NMC aircraft (i.e., aircraft that cannot fly because of a missing engine) or NFMC aircraft

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This 2.5-day delivery time is optimistic considering the current system's record. In peacetime, Military Airlift Command gives special handling to items that cause mission-aircraft groundings, yet it achieved only 2.7 days, point-to-point, for the first half of 1979. Although surface transportation is supposed to deliver in 12 hours, for a sample of 483 shipments from aerial ports, 45 percent were one to seven days late.
(i.e., aircraft missing some mission-essential part but that may possibly still fly for a limited mission or evacuation purposes). Obviously, combat capability increases as the number of parts-short aircraft decreases, and additional aircraft make it possible to maintain or increase the number of sorties that can be flown.

We used five performance measures to assess the combat payoffs and relative costs of the RLTS:

1. The expected daily value of NMC or NFMC aircraft for the first 30 days of a European contingency.\textsuperscript{4}
2. The average of daily expected NMC or NFMC aircraft over the 30 days.
3. The number of NMC or NFMC aircraft on the day that the optimistic case for the current system provides the worst support relative to the RLTS.
4. A cost estimate of making the current transportation system (in both base cases) equal the average performance of the RLTS by augmenting authorized spare parts.
5. The simple procurement costs of a number of combat aircraft equivalent to the average daily NMC (or NFMC) aircraft. (This is an underestimate of the worth of additional combat aircraft.)

We have serious reservations about additional supply as an alternative means of decreasing NMC or NFMC aircraft in combat. First, in damage cases, estimates for additional stock really represent a lower bound on true cost: We cannot know with certainty what quantities of what parts would be damaged or where. As an example, taking the risk of damage to additional A-10 parts and variation in their damage into account, we estimate that twice the quantities implied by the lower bound dollar estimate would be necessary to equal the RLTS performance. Second, even with additional stocks, favorable outcomes might

\textsuperscript{4} We examine only those days because after that resupply of spare parts and maintenance is expected from the United States.
depend on some transportation during the times when the optimistic
system is not available. Third, quick-reaction efforts that depend,
for example, on providing a specific part to support a time-sensitive
mission are difficult to accomplish with only extra supplies. In
short, as an alternative to an RLTS, increasing stockpiles lacks com-
parable flexibility.\(^5\)

Summary of Individual Analyses

Although there are other systems, the F-15, F-4, and A-10 air-
craft selected for analysis represent an important part of the tac-
ctical forces in Europe. Because they cover a range of complexity,
they can serve as analogues for other kinds of aircraft. Thus,
although our results may not be directly applicable, they should pro-
vide insight into the RLTS payoffs for other combat aircraft. Table
3.5 summarizes our analyses.

Here, we discuss only the most general conclusions for each air-
craft type. Readers interested in more detailed, more technical dis-
cussion of the analyses should consult Sec. V of R-2860-AF.

The F-15 Performance: F100 Engine and Automatic Test Equipment
(ATE). Responsive transportation for the F-15's F100 engine would be
decidedly beneficial and affordable. In a benign environment, the
RLTS would provide two to 21 more combat-ready aircraft than the cur-
rent system—unless bases had $29 to $183 million more in additional
stocks. In a damage environment, the payoff is even higher. The RLTS
provides three to 21 additional combat-ready F-15s (worth $47 to $325

\(^5\)Other damage-minimizing alternatives are even more problemati-
cal. Dispersal and aircraft shelter space already protect stocks to
some degree, and additional conventional hardening could reduce (but
not eliminate) damage. However, the costs would be very high (at
least $500 million) to harden stocks and repair facilities to invul-
nerability and would be impractical as long as air forces must be able
to operate from any of the NATO air bases. Caching stocks off base
not only fails to guarantee protection but would slow transfers of
parts to the flight line and make stocks vulnerable to sabotage.
### Table 3.5
BENEFITS AND COSTS OF AN RLTS

<table>
<thead>
<tr>
<th>Weapon System</th>
<th>Aircraft</th>
<th>Performance</th>
<th>Transportation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Increase in</td>
<td>Additional Stock for</td>
<td>Mission Capable Equivalent</td>
</tr>
<tr>
<td>A-10</td>
<td>10-33</td>
<td>13-43</td>
<td>18-32</td>
</tr>
<tr>
<td>F-4</td>
<td>39-67</td>
<td>43-84</td>
<td>26-45</td>
</tr>
<tr>
<td>F-15 (F100)</td>
<td>9-21</td>
<td>101-183</td>
<td>20-36</td>
</tr>
<tr>
<td>F-15 (ATE)</td>
<td>(a)</td>
<td>9-27</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>58-121</strong></td>
<td><strong>166-337</strong></td>
<td><strong>64-113</strong></td>
</tr>
</tbody>
</table>

**BENIGN ENVIRONMENTS**

**With No Transportation from Current System**

<table>
<thead>
<tr>
<th>Weapon System</th>
<th>Aircraft</th>
<th>Performance</th>
<th>Transportation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-10</td>
<td>3-4</td>
<td>7-22</td>
<td>18-32</td>
</tr>
<tr>
<td>F-4</td>
<td>12-25</td>
<td>43-54</td>
<td>26-45</td>
</tr>
<tr>
<td>F-15 (F100)</td>
<td>2-8</td>
<td>29-73</td>
<td>20-36</td>
</tr>
<tr>
<td>F-15 (ATE)</td>
<td>(a)</td>
<td>2-5</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>17-37</strong></td>
<td><strong>81-154</strong></td>
<td><strong>64-113</strong></td>
</tr>
</tbody>
</table>

**BASE ATTACK ENVIRONMENTS**

**With No Transportation from Current System**

<table>
<thead>
<tr>
<th>Weapon System</th>
<th>Aircraft</th>
<th>Performance</th>
<th>Transportation</th>
</tr>
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<tr>
<td>A-10</td>
<td>32-69</td>
<td>12-42</td>
<td>18-32</td>
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<td>F-4</td>
<td>210-214</td>
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<td>F-15 (F100)</td>
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<td>20-36</td>
</tr>
<tr>
<td>F-15 (ATE)</td>
<td>(a)</td>
<td>9-27</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>252-304</strong></td>
<td><strong>450-583</strong></td>
<td><strong>64-113</strong></td>
</tr>
</tbody>
</table>

**With Optimistic Performance from Current System**

<table>
<thead>
<tr>
<th>Weapon System</th>
<th>Aircraft</th>
<th>Performance</th>
<th>Transportation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-10</td>
<td>11-24</td>
<td>7-21</td>
<td>18-32</td>
</tr>
<tr>
<td>F-4</td>
<td>28-59</td>
<td>142</td>
<td>26-45</td>
</tr>
<tr>
<td>F-15 (F100)</td>
<td>3-8</td>
<td>53-106</td>
<td>20-36</td>
</tr>
<tr>
<td>F-15 (ATE)</td>
<td>(a)</td>
<td>2-5</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>42-91</strong></td>
<td><strong>204-274</strong></td>
<td><strong>64-113</strong></td>
</tr>
</tbody>
</table>

*The gains in mission capable aircraft from the ATE are considered to be included in with the F100 engine gains.*

**UNCLASSIFIED**
million); to get the same performance from the current system would take $53 to $213 million in additional stock.

Using an RLTS for ATE spares has similar payoffs. The RLTS provides three to 12 more combat-ready aircraft in a benign and five to 18 more in a stressful environment. Increasing LRU spares to achieve comparable outcomes would cost $2 to $27 million. In sum, additional F100 engines and ATE spares would cost $55 to $240 million. The RLTS is more affordable: The share of its ten-year total cost for the F-15 is $21 to $36 million.

The F-4 Performance: All Aircraft Systems. The RLTS results in 12 to 67 additional fully mission-capable aircraft in a benign environment. To equal that performance with the current transportation system, the Air Force would have to invest $43 to $84 million in additional stocks. In a damage environment, the gain is 28 to 214 additional combat-ready aircraft (worth $160 to $1,260 million), and the alternative investment rises as high as $142 to $301 million. The F-4 share of the ten-year cost of a theater RLTS is $26 to $45 million.

The A-10 Performance: All Aircraft Systems. In a benign environment, the RLTS provides 3 to 33 additional fully mission-capable aircraft and, in a damage environment, 11 to 69 (worth $55 to $350 million). The alternative of additional stocks would require a $7 to $43 million investment. The A-10's share of the ten-year RLTS costs is $18 to $32 million. The lower value in each case refers to an excursion where current high failure rates of one critical subsystem were totally reduced.

The results indicate that an RLTS is more affordable for the A-10 if the current high subsystem failure rates are included. If that subsystem's failure rates can be sharply reduced, and near optimistic

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6 The additionally available combat aircraft have combat value for maintaining or increasing sortie rate and in certain tactics such as massed attacks. Determining this value for cost comparisons is a difficult problem. We instead use the simple procurement cost of the aircraft as a crude measure of their value.

7 This result represents support of only 45 out of the F-15's 110 avionics LRUs. The payoff would have increased if all 110 LRUs and test equipment had been included.
transportation performance can be achieved, then the RLTS is not affordable. However, that subsystem's failure rate would have to fall by more than 90 percent and to date there has been little reason to have confidence in the plausibility of the optimistic transportation case. Nevertheless, this very optimistic case is the only instance that we found in which increasing stock may prove more cost effective than developing an RLTS.
IV. SUMMARY OF RLTS COSTS AND BENEFITS

The wartime value of an RLTS will depend on how available and effective the current transportation system would be during the first 30 days of combat and on how much stress combat flying units experienced. There might be some question about RLTS payoff if USAFE could count on "ideal" combat conditions: high availability of the current transportation system, flying at planned rates, identical flying rates and attrition by like units, "mature" rather than current failure rates, and no air base attack. However, as we indicated in Sec. II, wartime reality will probably depart considerably from that ideal. Thus, if the RLTS yields respectable improvements over optimistic estimates of the current system's performance in benign or slightly stressful environments, it should pay off quite impressively in damage environments. Table 4.1 provides an overall summary of the RLTS comparative benefits and costs.

Payoff ranges in Table 4.1 reflect possible differences in stress and aircraft performance: for the A-10, the difference between low and current failure rates for one critical subsystem and differential flying hours among bases; for the F-4, the difference between surge and super-surge flying rates and differential flying rates; for the F-15, the difference between flying with mature engine failure rates and super-surge flying with current failure rates.

If the current transportation system could not provide service during the first 30 days of a European conflict, the RLTS would provide 58 to 121 additional combat-ready aircraft every day (worth $420 to $900 million), at a ten-year cost of $64 to $113 million. To achieve similar gains by augmenting currently authorized stocks would cost at least $166 to $337 million. The RLTS obviously seems like an effective choice when the current system cannot provide service, even in a benign environment. But how comparatively effective would it be if the current system could provide the service posited by our optimistic case?
Table 4.1

COMPARATIVE BENEFITS AND COSTS OF AN RLTS

<table>
<thead>
<tr>
<th>Combat Environment</th>
<th>Current Transportation</th>
<th>Increase in Average Daily Mission-Capable Aircraft with RLTS</th>
<th>Stock for Equivalent Performance</th>
<th>RLTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benign</td>
<td>Optimistic case</td>
<td>17-37</td>
<td>81-154</td>
<td></td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>58-121</td>
<td>166-337</td>
<td></td>
</tr>
<tr>
<td>Damage</td>
<td>Optimistic case</td>
<td>42-91</td>
<td>204-274</td>
<td>64 to 113</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>252-304</td>
<td>450-583</td>
<td></td>
</tr>
</tbody>
</table>

As Table 4.1 indicates, when the current system performs well, we expect lower payoffs from an RLTS. Nevertheless, an RLTS still provides some gains. It makes 17 to 37 more mission-capable aircraft (worth $115 to $300 million) available each day. To get that kind of performance with optimistic operation of the current system would require $81 to $154 million in additional spare parts. However, getting that optimistic performance would be both expensive and unlikely, and the real gains for an RLTS in a benign environment obviously lie somewhere between the upper and lower bounds. Thus, its payoffs are likely to outweigh its comparative costs even in a benign environment. We can reasonably assume that an RLTS would pay off more as the bases needed more support, that is, when enemy attacks had damaged their stocks or repair capability.

Although we cannot precisely predict the extent and pattern of damage, our calculations indicate that an RLTS would provide up to 300 more combat-available aircraft (worth more than $1.5 billion) in a damage environment than the present system could. For the present system to equal that performance it would cost between $204 and $583 million in additional stocks. In comparison, the RLTS $64 to $113 million price tag offers an attractive alternative. Even assuming that the actual payoffs and additional stock costs lie somewhere between these extremes, we conclude that an RLTS provides the most cost-effective means of supporting USAFE combat aircraft.