R-3304/1-AF

Integrating Basing, Support, and Air Vehicle Requirements

An Approach for Increasing the Effectiveness of Future Fighter Weapon Systems

M. B. Berman
With J. M. Halliday, T. F. Kirkwood, W. E. Mooz, E. D. Phillips, R. J. Kaplan, C. L. Batten

August 1985

Rand

PROJECT AIR FORCE

The research reported here was sponsored by the Directorate of Operational Requirements, Deputy Chief of Staff/Research, Development, and Acquisition, Hq USAF, under Contract F49620-86-C-0008.

ISBN: 0-8330-0729-7

Published by The Rand Corporation

R-3304/1-AF

Integrating Basing, Support, and Air Vehicle Requirements

An Approach for Increasing the Effectiveness of Future Fighter Weapon Systems

M. B. Berman
With J. M. Halliday, T. F. Kirkwood, W. E. Mooz, E. D. Phillips, R. J. Kaplan, C. L. Batten

August 1985

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

Rand
1700 MAIN STREET
P.O. BOX 2138
SANTA MONICA, CA 90406-2138

PREFACE

This report describes and demonstrates a new methodology for increasing the effectiveness of future fighters that must face growing enemy threats in Europe and the Third World. The U.S. Air Force's traditional methodology accepts the current basing and support systems as "givens" when assessing the effectiveness of alternative future air vehicle designs. By contrast, this new methodology integrates changes in the design of air vehicles with changes in the basing and support systems they will use.

The methodology calls not only for such conventional measures as the speed, acceleration, altitude, payload, and maneuverability of the air vehicle, but also for such new measures as the flexibility, mobility, sortie generation capability, aircraft ground survivability, and cost of the air vehicle, its basing methods, and its support structure.

Broadly stated, this research aims at providing useful conceptual and methodological guides for those in the Air Force and in the aircraft industry who must grapple with issues of the effectiveness of future fighter aircraft. The concepts underlying the study were defined in

> M. B. Berman with C. L. Batten, Jr., *Increasing Future Fighter Weapons System Performance by Integrating Basing, Support, and Air Vehicle Requirements*, The Rand Corporation, N-1985-1-AF, April 1983.

The present report relies on previously unpublished work by R. J. Kaplan and C. D. Roach on sortie generation and resource requirements for dispersed operations; by T. F. Kirkwood, W. E. Mooz, and M. Kamins on alternative air vehicle designs and their costs; by J. M. Halliday on the survivability under enemy attack of alternative basing modes; by W. E. Mooz on infrastructure costs of dispersed operations; and by E. D. Phillips on the operational feasibility of dispersed operations.

This research is part of the Project AIR FORCE study effort "Alternative Basing, Support, and Design Concepts for Future Tactical Aircraft." It falls under the Resource Management Program agenda concerned with improving the treatment of weapon system support characteristics in force modernization programs. An overview of this research appears in

M. D. Rich, W. L. Stanley, and S. Anderson, *Improving U.S. Air Force Readiness and Sustainability*, R-3113/1-AF, April 1984.

Recent work in this program has focused on methods for improving the formulation of operational and contractual requirements and the planning of test and evaluation programs. Findings are reported in

W. L. Stanley and J. L. Birkler, *Improving Operational Suitability through Better Requirements and Testing*, The Rand Corporation, R-3333-AF, forthcoming.

Lieutenant Colonel J. M. Halliday and Lieutenant Colonel E. D. Phillips are Air Force officers who were on assignment at The Rand Corporation during the course of the study.

SUMMARY

This report argues that **designs for future fighter aircraft and major modifications to current fighter aircraft must consider not only air vehicle performance, as they currently do, but also designs for new basing and support systems used by these aircraft.**

The need for this new approach is especially great because of the changing nature of future air conflicts:

- **In Europe**, main operating bases (MOBs) and support equipment previously thought survivable may become extremely vulnerable. Thus attacks on these bases and their support equipment may disable even aircraft with superior air vehicle performance.
- **In Third World locations**, aircraft may lack large bases and large amounts of support equipment. Thus even aircraft with superior air vehicle performance may be unable to operate in such areas if they require large MOBs and large amounts of support equipment.

This report describes and demonstrates **a new methodology aimed at improving fighter effectiveness in the face of such changing threats and environmental uncertainties.** With this new methodology, the U.S. Air Force can compare the effectiveness of the broader system—consisting of the aircraft, its basing method, and its support structure—with that of other systems. **This new methodology differs from the traditional one**, which largely considers the current basing method and support structure as "givens" when assessing the effectiveness of new air vehicle designs.

To integrate basing, support, and air vehicle requirements, this methodology considers:

- **Alternative Basing Modes.** These basing modes include operations from damaged MOBs, dispersed sites in Central Europe, "austere sites" in the Third World, and rear-based MOBs in places like England.
- **Consequent Changes in Aircraft Design and Support.** Changes in aircraft design and support include short takeoff and landing capability, vertical/short takeoff and landing capability, rough or soft field landing gear, less support equipment, and fewer support personnel.

- **Measurements of the Cost and Performance of Aircraft.** Measurements of cost include the number of aircraft that can be purchased with a fixed amount of money and the gross weight of the aircraft. Measurements of performance include air vehicle performance, flexibility, mobility, sortie generation capability, and aircraft ground survivability.

By so doing, this methodology assists in identifying concepts that produce the greatest overall wartime performance for a given cost.

Since this report primarily aims at describing and demonstrating a new methodological approach by using realistic calculations for representative air vehicles, it does not aim at making specific basing, support, or air vehicle recommendations for future aircraft.

Nevertheless, several implications arose out of our calculations:

1. Operations from dispersed sites in Central Europe seem logistically feasible if certain steps are taken in the design of the air vehicle and its support concepts.
2. Designing ground support equipment into new tactical fighters or current aircraft appears economically and operationally feasible.
3. Landing gear produces the largest weight penalty in designing aircraft for dispersed operations from austere fields.
4. Cross-training support personnel and designing new tactical aircraft with increased reliability can decrease the costs of dispersed operations.
5. If runway repair times can be kept to one-half day or less, an MOB (with additional takeoff surfaces and other enhancements) is a cost-effective way of generating sorties and protecting aircraft in the face of attack.
6. Dispersal seems a cost-effective way of increasing survivability and sortie generation during attack if the dispersed aircraft are kept in shelters or if procedures are developed that allow some aircraft to escape immediately before an enemy attack. In addition, the capabilities needed for dispersal provide aircraft with characteristics favorable for operating in the Third World.

The U.S. Air Force development community could strengthen its ability to evaluate future fighter designs by undertaking follow-up work aimed at expanding the analyses described in this document and at developing mechanisms to provide contractors and source selection personnel with information needed to apply this methodology.

ACKNOWLEDGMENTS

Many colleagues at The Rand Corporation have contributed to this work through their past efforts in trying to unravel the complex relationships among support systems, basing concepts, and weapon system performance.

Of most notable assistance have been the research endeavors of D. E. Emerson, F. Kozaczka, and J. M. Halliday in modeling air base attacks and analyzing their effects on the vulnerability of support structures; R. J. Hillestad, R. A. Pyles, and M. J. Carrillo in assessing combat capabilities of support resources; S. M. Drezner, I. K. Cohen, R. J. Kaplan, R. M. Paulson, C. D. Roach, and T. F. Lippiatt in evaluating alternative logistics structures; H. L. Shulman, J. R. Gebman, M. D. Rich, and G. K. Smith in designing acquisition strategies leading to improved equipment reliability; and N. W. Crawford, J. W. Ellis, C. T. Kelley, and T. F. Kirkwood in exploring weapon system employment, deployment, and performance. T. C. Tompkins aided us in examining site security considerations.

In addition, special thanks go to M. D. Rich for his many suggestions, to J. P. Mullins and C. T. Kelley for their guiding comments on early drafts, and to J. L. Birkler and C. J. Bowie for their very helpful critiques of this report.

CONTENTS

FIGURES

TABLES

GLOSSARY

AGE	Aerospace Ground Equipment
AIS	Avionics Intermediate Shop
ALS	Automatic Loading System
CBR	California Bearing Ratio
CEPS	Central European Pipeline System
COB	Collocated Operating Base
CTOL	Conventional Takeoff and Landing
DOL	Dispersed Operating Location
EDS	European Distribution System
EPU	Emergency Power Unit
FRG	Federal Republic of Germany
GSE	Ground Support Equipment
ILM	Intermediate Level Maintenance
JFS	Jet Fuel Starter
LCN	Landing Classification Number
LOX	Liquid Oxygen
MER	Multiple Ejection Rack
MIPU	Multipurpose Integrated Power Unit
MOB	Main Operating Base
O&S	Operation and Support
OBOGS	On-Board Oxygen Generating System
PAA	Program Authorization, Aircraft
POL	Petroleum, Oil, and Lubricants
R&R	Remove and Replace
RRR	Rapid Runway Repair
STOL	Short Takeoff and Landing
TER	Triple Ejection Rack
TFW	Tactical Fighter Wing
TSAR	Theater Simulation of Airbase Resources
USAFE	United States Air Forces, Europe
UTC	Unit Type Code
V/STOL	Vertical/Short Takeoff and Landing
WRSK	War Reserve Spares Kit

I. INTRODUCTION

Fighter aircraft are but one part of a total system that consists of the aircraft, its base, and its support equipment and personnel. Thus an aircraft design that emphasizes only aircraft performance will suffer serious handicaps

- If an enemy can impede the aircraft's operations by damaging its runways and support system, and
- If the aircraft requires runways and support facilities that are absent in possible conflict locations.

To assess the effectiveness of new fighter aircraft designs, we consequently need to evaluate simultaneously the aircraft's performance, its basing requirements, and its support system. This report describes and demonstrates a methodology to perform this kind of evaluation, and it argues that the Air Force should use this new type of integrated conceptual approach when designing future fighter aircraft and when modifying current ones.

CURRENT BASING, SUPPORT, AND AIRCRAFT

In many important respects, current basing structures and support systems employed by the U.S. Tactical Air Forces have evolved through a series of gradual changes over the past 30 years. For the most part legacies of World War II and the Korean War, operating bases have developed into small cities often containing:

- Complex and bulky diagnostic, support, and repair equipment for airplanes,
- Large supply facilities for spare parts,
- Sophisticated facilities for manufacturing and repairing support materials, and
- Extensive housing, recreational facilities, and shopping areas for personnel.

Their size and complexity are reflected in an average replacement cost of three-quarters of a billion dollars per base.

These large and complex operating bases and support structures now face growing threats from increased enemy capabilities. Dependence on them concentrates large amounts of critical personnel and

equipment, and it limits the deployability of the aircraft they support. The size and combat value of current operating bases make them prime targets for increasingly capable enemy aircraft, surface-to-surface missiles, enemy air mobile forces, and chemical and biological munitions. Indeed, the 1970s saw the Soviets and their allies for the first time develop air power capable of attacking our air bases and their defenses.[1]

Although worst in Europe, these growing threats now exist in all theaters and in several potential Third World contingencies. Since the end of the 1960s, the Soviet Union has established numerous staging locations from which they can potentially operate throughout the world. At least 14 countries in Latin America, Africa, East Asia, the Near East, and Southwest Asia allow the Soviets special military access. Along with the Soviets' demonstrated ability to project forces, these locations indicate the increased geographic breadth of their potential threats.[2]

CURRENT METHODOLOGY

To counter these threats, the current methodology has resulted in the development of increasingly capable air vehicles that can operate from existing—although occasionally enhanced—bases. So far, these enhancements have largely involved:

- Developing ground defenses aimed at protecting main operating bases (MOBs) from enemy air attacks,
- Distributing Tactical Air Force squadrons to allied MOBs (calling them collocated operating bases or COBs),
- Providing some hardening and chemical protection,
- Planning alternative takeoff surfaces, and
- Developing rapid runway repair techniques.

Thus, use of this current methodology has led us to design highly capable air vehicles like the F-15 and F-16 that rely on large amounts of specialized support that only MOBs or COBs can provide.

The F-15's dependence on an avionics intermediate shop (AIS) is symptomatic of this current need for large amounts of specialized support, which in turn greatly reduces mobility. Sortie generation and force flexibility suffer whenever airplanes must deploy or redeploy,

[1]For example, see "Soviet Aerospace Almanac," *The Air Force Magazine*, March 1982; *Soviet Military Power, 1985*, Government Printing Office, Washington, D.C., 1985.

[2]See M. D. Rich, W. L. Stanley, and S. Anderson, *Improving U.S. Air Force Readiness and Sustainability*, The Rand Corporation, R-3113/1-AF, April 1984.

especially to Third World areas. At least three C-141s are required to transport an AIS, and when in operation this AIS requires 4500 square feet of level, air-conditioned floor space. The AIS consists of one station for the F-15's tactical electronic warfare equipment plus four manual and three automatic stations for the remaining avionics. The three automatic test stations alone cost $18 million per set, and a squadron needs at least two such sets to operate efficiently.

The F-15 and F-16 also rely on unusual and hard-to-handle support materials. For example, the F-16 uses hydrazine to fuel its emergency power unit (EPU). Since hydrazine is not readily available throughout the world, a wartime support pipeline would have to be established to supply it. In addition, use of this corrosive material creates the need for specialized ground support equipment (GSE) and personnel.

Deployment of a typical F-15 squadron currently requires 13 to 18 C-141s to carry equipment and spares just to set up operations at a prepared MOB—and much more equipment and spares to set up at an unprepared base.[3]

FUTURE BASING, SUPPORT, AND AIRCRAFT

Although these requirements currently hamper mobility, create added vulnerabilities, and decrease the number of sorties that the F-15 can fly, they will become even more detrimental in the future as the weapons of our potential enemies grow in number, capability, and geographical distribution. Our current logistics structure evolved in the early 1950s, when the requirement was to generate one sortie (or less) per day per airplane operating out of a large U.S. MOB or safe Allied COB.

Future combat situations will impose very different demands on tactical fighters. If already within the theater of action, they may have to survive a first attack of major proportions. If not, they may have to deploy in less than 24 hours to distant places serviced by austere bases. Because of the simultaneous deployment of ground troops, airlift capabilities for support equipment and personnel will probably be severely limited. In any event, the fighters will need to generate three or more sorties per day almost immediately after the initial attack, and they will need to do so for sustained periods of time—probably while their bases are under heavy fire.

To succeed in such situations, future tactical fighters will need improved ground survivability. Enhanced defenses at MOBs may

[3]See C. J. Bowie, *Concepts of Operations and USAF Planning for Southwest Asia*, The Rand Corporation, R-3125-AF, September 1984.

contribute to this survivability, but greater survivability might derive from options that also include some dispersed or rearward basing. And for such basing (including operations from MOBs and COBs with damaged runways), future tactical fighters will benefit from short takeoff and landing (STOL), rough field landing capabilities, or increased combat range. In addition, they will benefit from improved reliability and the ability to operate with minimal amounts of support equipment and personnel.

Meeting these goals will be difficult. Each new capability may be very costly, involving not only dollars spent in research, development, production, and the like, but also possible decreases in cruise, carriage, or maneuverability capabilities. For example, the Air Force could require future fighters to generate their own compressed nitrogen and oxygen on board. Such a capability should greatly reduce reliance on support equipment and personnel, but it might cost in the neighborhood of $20,000 per aircraft and add about 200 lb. Such a weight addition might decrease the fighters' ordnance load by a comparable amount or decrease its combat radius by perhaps 10 miles. Alternatively, maintaining the original air vehicle capability would require increases in powerplant and structure weight.

In addition, each new capability will need to be *integrated* with other capabilities. It makes little sense to design a fighter with a STOL capability and not simultaneously consider the problem of the extensive support it requires. If the fighter uses its STOL on MOB runways that have been shortened by bombs, the MOB's support facilities will probably also have received severe damage. If the fighter uses its STOL on dispersed austere locations, these fields will not have access to the extensive support equipment fighters currently need. Future fighters require more than just the ability to take off and land on short fields: They also need to be able to operate successfully from them. Any commitment to develop STOL capabilities should thus entail consideration of reducing the amount of ground support needed.

All such design decisions involve extremely difficult tradeoffs. One must, of course, keep cost in mind when determining the necessary degree of increased combat capability. But one must also ensure that the airplane will have the ability to deploy, generate mission-effective sorties, and survive in combat.

The above descriptions reveal some of the emerging shortcomings that have resulted from designing fighters with the current basing and support systems as "givens." In the past, this method has worked and has allowed us to design more capable aircraft by shifting certain functions (such as munitions loading equipment) from the aircraft to the base. In the future, however, this method cannot ensure the combat

effectiveness of aircraft that must rely on extremely vulnerable runways and support systems and that must be able to operate in austere Third World locations.

PROPOSED METHODOLOGY

This report proposes a new methodological approach that evaluates broader aspects of the weapon system and that can assist the Air Force in making difficult tradeoffs. The variations it considers are neither exhaustive nor completely evaluated. It primarily aims at demonstrating a methodology that considers:

- Alternative basing modes, which in turn require changes in aircraft design and support,
- Measurements of the cost and performance of these aircraft in light of potential wartime threats, and
- Integration of basing, support, and air vehicle requirements to ensure greatest overall performance for a given cost.

Alternative Basing Modes

To demonstrate the versatility and robustness of this methodology, we have considered four very diverse kinds of basing modes from which the Air Force may wish to operate future tactical aircraft. Each basing mode involves potential—and at times major—changes in aircraft design and support.

We have formulated and evaluated these basing, support, and air vehicle requirements with an eye to their diversity. They range from conventional aircraft operating with current basing and support facilities to an unusual type of vertical/short takeoff and landing (V/STOL) aircraft operating with innovative basing and support facilities. We stress that our selections do not represent endorsements of particular kinds of basing, support, and air vehicle designs. Rather, our selections serve as examples to illustrate our methodology's potential usefulness.

The four basing modes we investigated were:

1. *Damaged Nominal MOBs*. This is our base case. If the runway of a standard USAFE MOB is damaged by enemy bombs, undamaged sections may not be long enough to allow existing fighters to operate. To solve this problem, the Air Force might consider providing future tactical fighters with some degree of:

- STOL capability,
- V/STOL capability, and
- Rough/soft field landing gear.[4]

The Air Force currently is also considering enhancing MOBs by providing them with alternative landing strips, increased defenses, and the like. We examine this option and refer to it as an *Enhanced MOB*.

2. *Tactical Dispersal to Dispersed Operating Locations (DOLs) in Central Europe*. For short periods of time, the Air Force could operate a portion of its aircraft from dispersed locations within "commuting distance" of its support bases.[5] These DOLs would be numerous enough to complicate enemy targeting, but they would be close enough to MOBs or COBs to rely on them for certain maintenance and support resources. To achieve this basing option, the Air Force might consider providing future tactical fighters with some degree of:

- STOL capability,
- V/STOL capability,
- Rough/soft field landing gear,
- Decreased amounts of support equipment needed by dispersed airplanes,
- Decreased numbers of additional personnel needed to service dispersed airplanes, and
- Hardened shelters or covered revetments at COBs and DOLs.

3. *Austere Sites in the Third World*. Potential conflicts may make it necessary for tactical fighters to operate from austere sites near Third World engagements. To do so, the Air Force might consider providing future tactical fighters with some degree of:

---

[4]For the purposes of this study: (1) the STOL capability uses a no-flare landing approach, a swiveling nozzle that acts as a thrust reverser, and an airplane with a thrust/weight ratio of 0.97; (2) the V/STOL capability uses a higher (1.30) thrust/weight ratio, and it is a 55,000 lb tail-sitter aircraft capable of operating in both a conventional and a V/STOL manner; and (3) the rough/soft field landing gear is "adaptive." This means that it uses a free floating piston at one end of the regular oleo chamber, the other side of the piston being loaded with compressed nitrogen. By valving nitrogen in and out of the strut, the motion of the wheel may be controlled so as to force the wheel to follow the terrain with the least possible aircraft motion. The soft field landing gear enables an airplane to land on areas that have no artificial surfaces (such as asphalt, concrete, or steel mat) and on soil that has not been stabilized by the addition of cement.

[5]Dispersal is not necessary for all aircraft based on an MOB. Those that remain may be the less expensive, older, conventional takeoff and landing (CTOL) type rather than the newer and more expensive STOL type. Given the large investment the United States has in CTOL aircraft such as the F-4G, F-15, and F-16, such mixed basing seems worthy of consideration.

- STOL capability,
- V/STOL capability,
- Rough/soft field landing gear,
- Decreased amounts of support equipment needed by deployed airplanes,
- Decreased numbers of additional personnel needed to service deployed airplanes, and
- Covered revetments at austere sites.

4. *Rear-Based MOBs*. These MOBs would be located far enough to the rear to reduce the risk of air attack or to ease Third World coverage problems. In Europe, for example, a number of MOBs are located in England and other countries where aircraft would be less vulnerable to attacks by Soviet and Warsaw Pact fighters. To operate from these MOBs, future fighters would need to fly unrefueled combat radii as great as 600 to 1000 n mi and still enjoy the same performance characteristics in the combat arena as regular MOB-based fighters. Unless capable of very high speeds, such aircraft would not be as responsive as fighters located closer to the forward edge of the battle. To achieve this basing option, the Air Force would have to provide future tactical fighters with greater range.

Measurements of Cost and Performance

To evaluate these basing alternatives, we first need measures to assess improvements in overall weapon system performance. These measures must certainly include operational *air vehicle performance* (e.g., speed, acceleration, altitude, payload, maneuverability). Such measures are already commonly used by the development and operational community for any new air vehicle.

While the trend in development programs has been toward increased operational measures, we propose to broaden that trend by also examining such combat capability measures as the *flexibility, mobility, sortie generation capability*, and *aircraft ground survivability* of the basing and support systems:

- Flexibility can be measured by the number and type of operating surfaces available to a particular air vehicle design and the amount of support facilities a unit of force requires.[6]

[6] A "unit of force" is the smallest number of airplanes that can operate independently to satisfy mission requirements. Flexibility increases when the number of available operating surfaces increases and when the "hardness" of required operating surfaces and the dependence on support infrastructure decrease.

- Mobility can be measured by the number of C-141s required to move a squadron with enough support resources for both initial and sustained operations.
- Sortie generation capability can be measured by the numbers of sorties that can be flown before, during, and after enemy attacks. It is a function of inherent characteristics of the air vehicle and support equipment, the availability of spare parts and consumables, the support policy, and the performance of support personnel.
- Aircraft ground survivability can be measured by the numbers of aircraft that survive ground attacks.

To evaluate alternatives, we also need measurements to assess costs and overall weapon system performance. These costs can be measured by:

- The number of aircraft that can be purchased with a fixed amount of money allocated for necessary acquisition, operation and support (O&S), spares, transportation, manpower, necessary base modifications (such as adding revetments to DOLs), and the like. More expensive aircraft and more base modifications result in fewer aircraft being purchased—and thus a lower force ratio against the enemy.
- The gross weight of the aircraft. In evaluating alternatives, we hold constant the air vehicle performance (e.g., equal excess thrust-to-weight ratios) of each aircraft. Thus growth in aircraft gross weight to maintain constant performance serves as a measure of possible development difficulties.

To measure cost and performance, we began with a *base case* involving CTOL aircraft, similar to those currently in Europe and Asia, operating from current MOBs with 10,000 ft runways and 8000 ft taxiways. We then conceived of a series of alternative CTOL and STOL aircraft with several types of landing gears, with V/STOL capability, and with long-range subsonic cruise capability. All aircraft carry a one-man crew, guns, and both infrared and radar guided air-to-air missiles. In addition, they carry 8000 lb of ordnance on air-to-ground missions of 400 n mi radius and have a "multirole" design, i.e., they can fly at supersonic speed (Mach 2) while retaining good subsonic performance and maneuverability for both combat and ground attack. All aircraft have the same combat radius except the long-range alternative, which has an 800 n mi radius. All have similar flight performance except the V/STOL alternative, which has excess performance because of the high thrust-to-weight ratio it needs for vertical takeoff.

To compare sortie generation and aircraft ground survival rates, we investigated the various alternatives using the following attack scenario.[7] The enemy divides his efforts between cutting runways and attacking aircraft on the ground. The campaign lasts five days, with attacks occurring on days one, two, and four. The enemy attacks with one, two, or three regiments, each with 36 aircraft. Each enemy aircraft carries the equivalent of eight 500 lb weapons and attacks a 72 PAA USAF wing located on a MOB or a MOB combined with a number of DOLs known to the enemy.[8] Our MOBs have one runway and one taxiway that can be used as a runway during wartime; these runways can be repaired in one-half a flying day. Whenever runways are open, aircraft fly three sorties per day. For each landing surface, four of our aircraft escape before the enemy's attack. This means that eight aircraft escape when attacks are made on MOBs, 12 escape when attacks are made on enhanced MOBs (which have an additional runway), and 24 escape when attacks are made on both MOBs and DOLs.

Integrating Basing, Support, and Air Vehicle Requirements

Starting with CTOL aircraft based on MOBs (the base case), we selected enough variations in basing, support, and aircraft design concepts to show how to assess them in an integrated fashion. In particular, we examined cost and attribute measures involving the base case and the following additional variations:

- Long-range cruise capability,
- STOL capability (the airplane can land on a strip 50 × 2000 ft),
- V/STOL capability (the airplane can land on virtually any properly prepared surface), and
- Operation from enhanced MOBs (MOBs that have been provided with an additional 50 × 5000 ft emergency operating surface).

[7]This scenario does not include attacks using nuclear and chemical weapons. Future evaluations would benefit from the inclusion of these weapons in the attack scenario.

[8]In most cases, 10 DOLs are available to each MOB. (We also investigated the effect of having 15 DOLs available to each MOB; this, however, required employing unsurfaced fields and consequently using soft field landing gear, which raises the cost of the aircraft.) For our attack scenario, 32 of the 72 PAA are dispersed to four of the 10 (or 15) available DOLs, leaving 40 on the MOB. Aircraft on the MOBs are all protected by third-generation shelters. We examined three kinds of protection on DOLs: no shelters, covered revetments, and shelters.

Table 1

SAMPLE FINDINGS

Basing, Support, and Air Vehicle Concept	Cost	Attributes: Flexibility	Mobility	Sortie Generation	A/C Ground Survivability	Rank
CTOL + MOB (base case)	Green	Red	Red	Red	Green	9
Rear-based MOBs	Red	Green	Yellow	Red	Yellow	10
STOL options:						
Nominal MOBs						
STOL + MOB	Green	Red	Red	Yellow	Green	6
STOL + MOB + 1 day RRR + advanced weapons	Green	Red	Red	Red	Yellow	11
Enhanced MOBs						
STOL + MOB	Green	Red	Red	Green	Green	3
STOL + MOB + 1 day RRR	Green	Red	Red	Yellow	Green	5
Nominal MOBs + DOLs						
STOL + DOL	Yellow	Yellow	Green	Yellow	Red	7
STOL + DOL + imperfect information	Yellow	Yellow	Green	Green	Yellow	2
STOL + DOL + extreme rough landing + imperfect information	Yellow	Green	Green	Yellow	Red	4
STOL + DOL + DOL shelters	Yellow	Yellow	Green	Green	Green	1
V/STOL	Red	Green	Yellow	Yellow	Red	8

NOTE: Cost is measured by the number of aircraft that can be purchased for a constant amount of dollars and by the gross weight of the aircraft; flexibility is measured by the number and type of operating surfaces from which the aircraft can operate; mobility is measured by the number of C-141 loads per squadron needed to transport support equipment and materiel; sortie generation is measured by the number of sorties that can be flown during attack; aircraft ground survivability is measured by the number of aircraft remaining after five days (see Tables 7 through 11). A quantitative summary is shown in Table 12.

sets of integrated basing, support, and air vehicle requirements. Finally, Sec. IV draws some conclusions and implications concerning the methodology proposed in this report.

II. DEFINING A FEASIBLE SET OF BASING, SUPPORT, AND AIR VEHICLE REQUIREMENTS: THE CASE OF TACTICAL DISPERSAL

This section uses tactical dispersal to DOLs in Central Europe as a case study to demonstrate how to define a feasible set of basing, support, and air vehicle requirements that can in turn be evaluated in an integrated fashion. It focuses on the DOL basing option because it places some of the most serious demands on support and air vehicle requirements and it poses some of the most potentially far-reaching implications for integrating basing, support, and air vehicle requirements. Similar analyses are required for all of the other basing options.

Tactical dispersal involves relocating and operating a portion of a wing's aircraft to DOLs for short periods of time. The DOLs should be within convenient distances (e.g., 50 to 100 n mi) of the MOB or supporting COB, and they should be numerous enough to complicate enemy targeting. Once fighters are launched from a DOL, they can return to it, to the MOB, or to a different DOL depending on tactical and maintenance considerations. Tactical dispersal entails moving minimum amounts of personnel and equipment to DOLs for short periods of time—perhaps a week at most—and then returning them to the MOB. This allows fighters to benefit from the heavy maintenance and support resources of their home MOB (or a central maintenance facility) but at the same time to avoid the direct effects of attacks on the MOB, operate from alternative fields, function aggressively, and make an enemy's job more difficult by being in less obvious locations and in smaller concentrations.

With some promise of benefits in terms of flexibility, mobility, sortie generation, and aircraft ground survivability, tactical dispersal also involves a number of risks that must be weighed by planners. For example, it may expose aircraft to air and ground forces carrying conventional and chemical weapons, it may place heavy demands on command and control systems, and it would require changes in traditional logistics systems.

In any event, tactical dispersal can succeed only if there are

1. *Adequate numbers of DOLs close to centers of support and supply.* This can be assisted by designing future fighters with STOL and rough field landing capabilities.

2. *Decreased amounts of deployed equipment to DOLs.* This can be assisted by leaving nonessential equipment at MOBs and COBs and by designing future fighters with built-in equipment.
3. *Minimum numbers of additional personnel needed to service the deployed airplanes.* This can be assisted by eliminating intermediate level maintenance (ILM) at DOLs, by cross-training maintenance personnel, and by improving the reliability of the aircraft.

Current fighters and the current support structure cannot, however, meet all these requirements needed to make tactical dispersal succeed.

ADEQUATE NUMBERS AND LOCATIONS OF DISPERSAL SITES

Requirements

DOLs should be relatively numerous and relatively close to centers of major support and supply.

They should be relatively numerous so that dispersing action need not always be to the same sites. This would allow airplanes to be elusive when moving from one site to another, to abandon sites that have been located or destroyed by the enemy, and to place decoy aircraft at some sites to confuse the enemy. The greater the number of sites, the more flexibility is available.

In addition, DOLs should be relatively close to centers of major support and supply. This would reduce the numbers and type of personnel dispersed and would do away with certain kinds of spares (such as engines) and the equipment required to perform heavy ILM. Remove-and-replace (R&R) maintenance would be performed at the DOLs with rapid air transport delivering needed components; ILM would be performed at the nearest support center; difficult maintenance would be performed at a support center or by a team from that center if the airplane could not fly. Major support centers would be MOBs, but they could also include COBs and even selected locations not collocated with any base. In addition, closeness to sources of supply would reduce the transportation required for DOLs, particularly for petroleum, oil, and lubricants (POL) and munitions. When flying a wartime sortie rate, each fighter requires roughly 25 tons of POL and munitions per day. If DOLs were close enough to sources of these materials, movement of POL and munitions could be handled by ground transportation.

Potentiality of Dispersed Sites in the FRG

Analysis of airfields and potential highway strips shows that sufficient numbers are available, if tactical aircraft can be built with STOL capability. Of course, if future tactical fighters are designed with V/STOL capabilities, they can potentially employ a virtually unlimited number of DOLs.

Such dispersal basing relies, however, not only on new air vehicle requirements (i.e., some degree of STOL and rough field landing capabilities), but also on a resupply system. After aircraft have been dispersed for short durations, MOBs and COBs would have to provide necessities (like food, personnel rotation, specialized teams for difficult repair problems, and spare parts) to the DOLs. In addition, MOBs, COBs, or ammunition depots would have to provide ammunition carried by over-the-road vehicles. Analysis shows that sufficient ammunition storage space is potentially available. Resupply of ammunition requires only a few daily truckloads per DOB, and the distance to the depots is quite short. Finally, POL is available from a variety of POL depots located throughout the FRG. Again, only a few tanker loads are required per day, and the distance to POL depots is also quite short.

DECREASED AMOUNTS OF DEPLOYED EQUIPMENT TO DISPERSAL SITES

Requirements

Tactical dispersal works best if a minimum amount of equipment needs to accompany fighters when they leave the MOB to operate from a DOL. Initial dispersal is usually accompanied by

- GSE,
- Spare parts and repair materials in the War Reserve Spares Kit (WRSK),
- Miscellaneous items that range from small arms to briefing stands (non-GSE/WRSK equipment and materiel), and
- Housing, rations, and site security protection.

The categories and consumption factors of GSE, WRSK, and non-GSE/WRSK equipment and materiel initially deployed are carefully itemized in the Unit Type Codes (UTCs) for each fighter aircraft type.

Present fighter aircraft and present deployment concepts make tactical dispersal difficult and costly, since they require the initial deployment of such large quantities of equipment and materiel.

Reducing Ground Support Equipment

The F-16 UTC calls for 17.2 tons per fighter, or about 0.8 C-141 loads per aircraft when eight fighters are deployed for seven days. Of this, 140,000 lb, or just over 60 percent, is GSE. We examined two methods of reducing the amount of GSE:

1. Leave behind equipment required only for heavy ILM,[1] equipment for which there is infrequent need, and equipment that is a "convenience" but not a "necessity." This method would be appropriate for current aircraft.
2. Replace some of the GSE with equipment either built into the aircraft or carried along in fly-away pods. This method would be appropriate for future aircraft.

Leaving Equipment Behind for Current Aircraft. Table 2 lists equipment that the UTC of a fighter like the F-16 would contain after "unnecessary" equipment was left behind at an MOB.[2] The total weight is 61,765 lb, or 78,236 lb less than currently required by the UTC. This list of necessary equipment omits the following items in the UTC:

- *MC-32A-60 Generator and C-10 Air Conditioner.* These items provide power and cooling for diagnosing electronic faults while the aircraft is on the ground with the engine not running. Since the F-16 has a built-in diagnostic system, fault diagnosis could take place by running the aircraft engine on the ground for an acceptably short period. The engine could then be shut down, the faulty modules replaced, and verification of the repair could be made with another acceptably short engine run.[3]
- *MC-2A Air Compressor.* The very occasional need for low pressure air could be satisfied by using reduced pressure nitrogen from the nitrogen cart.[4]
- *MB-4 Tractor.* This heavy tractor tows the aircraft. In its place, we suggest a "bobtail"—a shortened pickup truck without a bed.

[1]This equipment could be left behind because DOLs would be close to MOBs or other locations where heavy ILM would be performed.

[2]This list was prepared with the help of maintenance officers and enlisted men at the 388th Tactical Fighter Wing at Hill Air Force Base, Utah.

[3]An alternative to this is to specify that the fighter have a built-in multipurpose integrated power unit (MIPU). This unit would provide electrical power, air conditioning, and hydraulic pressure without running the aircraft engine.

[4]Low pressure air would also be available from an MIPU.

Table 2

GSE REQUIREMENTS FOR TACTICAL DISPERSAL

Item	No.	Weight (lb) Item	Weight (lb) Total	% of Total
Hydraulic servicing cart	1	300	300	0.48
C-1 stand	1	160	160	0.26
Nitrogen trailer	1	1,920	1,920	3.10
LOX cart	1	1,480	1,480	2.40
15 ton axle jack	1	75	75	0.12
AGE tractor (bobtail)	1	4,240	4,240	6.86
H-70 trailer	1	3,400	3,400	5.50
Tank pump unit	1	85	85	0.14
Hand tow bar	1	25	25	0.04
Aircraft ladder	3	25	75	0.12
MJ-4 jammer	1	6,600	6,600	10.69
Tow bar	1	500	500	0.80
MHU-110 trailer	3	5,428	16,285	26.37
Pump handle	1	50	50	0.08
Fire extinguisher	8	150	1,200	1.94
Composite tool kit	1	220	220	0.35
B-1 stand	1	1,080	1,080	1.75
MJ-1 jammer	3	3,840	11,520	18.65
Fork lift	1	2,500	12,500	20.23
Hand gun loader	1	50	50	0.08
Total	—	—	61,765	99.96

- *B-4 Stand.* The B-4 stand permits access to the vertical fin. In its place, we suggest using the C-1 stand that is currently part of the GSE.
- *NF-2 Light Carts.* These carts provide nighttime illumination. In their place, we suggest that maintenance crews can use smaller mobile lights for short periods.
- *Grating Assemblies.* These assemblies are occasionally used to prevent damaging the F-16 with foreign objects. While we suggest they are unnecessary on paved surfaces, they may be required on unpaved ones. If new aircraft were designed with engine air inlets higher off the ground, damage from foreign objects could be greatly reduced and such assemblies could be eliminated.
- *3000 Trailer.* This trailer is not needed, since it carries spare engines not taken to DOLs under tactical dispersal. Most

major engine problems are detected in flight; if this occurs, the fighter will land at a location that can change engines. If the problem is detected on the ground, the engine and other required equipment would be brought to the DOL.

- *MHU-141 Trailer.* These munitions trailers can be replaced by MHU-110 trailers, which can handle heavier loads.
- *ALS and Generator.* These automatically load the 20 mm cannon on the F-16. In their place, we suggest smaller and less complex hand-operated gun loaders that are quicker to use.

Building in Equipment on Future Aircraft. When designing future aircraft, the Air Force might more profitably reduce the amount of deployed GSE by building some of it into the aircraft or by carrying it in pods. Such built-in or pod-carried support equipment should have one or more of the following characteristics:

- It should be critical to the operation of the aircraft. This means that the next sortie cannot be flown until this equipment, or its equivalent, is available.
- The need for it should be immediate. Items whose use can be deferred for several sorties should probably not be built in.
- Its presence on board the aircraft may eliminate the need for fluids that may be in short supply or difficult to handle, particularly under austere or wartime conditions.
- Its installation on board will eliminate items that require a substantial logistics effort to deploy.
- Its installation on board will reduce the manpower required to support the airplane.
- The weight and volume of the equipment should not be so great as to impose a severe penalty on the performance and cost of the airplane.

Five items in particular could be either wholly or partially eliminated by means of built-in equipment: the LOX cart, the H-70 response trailer, the aircraft ladder, the bomb jammers, and the combination of hydraulic power cart, air conditioner, and power generator.

- The *LOX cart* would be unnecessary if the aircraft were designed with an on-board oxygen generating system, commonly known as OBOGS.[5]

[5]This equipment has been developed, tested, and found to be a satisfactory replacement for the LOX system. See, for example, "Navy to Test On-Board Oxygen Generator," *Aviation Week and Space Technology*, February 4, 1980; J. D. Harris, *Technical Evaluation of an On-Board Oxygen Generating System Installed on the AV-8A Aircraft,*

- The *H-70 response trailer* contains hydrazine and all the equipment required to deal with spills of this toxic chemical. The hydrazine is used in the emergency power unit, which could be replaced with a similar unit fueled by jet fuel and oxygen, the latter generated by an OBOGS unit.
- The *aircraft ladder* is built into some fighter aircraft, such as the F-18, but not the F-16. Providing it on the aircraft would eliminate it as a piece of GSE.
- *Bomb jammers* are the most significant item, weighing 18,120 lb or over 28 percent of the total GSE. They are used to load single bombs, multiple ejection racks (MERs), and triple ejection racks (TERs) on the fighter. The jammers are self-propelled, heavy, and rugged and require their own maintenance facilities. There are two basic ways to eliminate them: (1) Provide the aircraft with small built-in pulleys that work with an external cable hoist to raise the bombs to the attachment points. This reduces the GSE weight by 18,120 lb. The Swedish Air Force has used similar equipment and has determined that it does decrease the speed of loading bombs and that its added weight does not affect the aircraft's operation. (2) Use a simpler and lighter unit such as the mini-RAZ or RAZ[6] developed for the Israeli Air Force. The mini-RAZ handles TERs and other loads up to 3300 lb (excluding MERs), and it weighs 1200 lb. It replaces the MJ-1 jammer but weighs less than one-third as much. The RAZ handles MERs, loads up to 6600 lb, and weighs 1900 lb. It replaces the MJ-4 jammer but weighs 30 percent as much. Replacing the MJ-1 and MJ-4 jammers with the mini-RAZ and RAZ reduces the total GSE by 12,620 lb.
- The *combination of hydraulic cart, C-10 air conditioner, and -60A generator* can be replaced. Electric and hydraulic power and cooling air for avionics are needed if any ground checkout is to be performed, and some method of starting the engine will be needed before the first sortie can be flown. Thus, an auxiliary power unit in addition to a jet fuel starter is a prime candidate for on-board installation. These functions, together with the supply of emergency power in case of an in-flight engine failure, can be combined in a single piece of turbo-machinery—an MIPU—or may be accomplished by separate power units. An MIPU can operate as an air-breathing unit, or as a

---

Naval Air Testing Center, SY-136R-81, December 1981; F. Haigh, "A New Concept in Life Support Systems," *Technological News*, Normalair-Garrett Limited, Spring 1982.

[6]RAZ multiconcept trolley, manufactured by Electra Mikun (Industries) Ltd., Petach Tikva, Israel.

blowdown turbine using gas obtained from a fuel and oxidizer combination. When used in its air-breathing mode, it serves as an auxiliary power generator for supplying electric and hydraulic power on the ground, and as a jet fuel starter (JFS) for starting the engine either on the ground or in the air (at altitudes up to about 20,000 ft, above which it is difficult to start a small air-breathing unit). When operating as a blowdown turbine, the MIPU functions as an EPU to supply electric and hydraulic power necessary for flight control on a fly-by-wire airplane in the event of engine failure.

Whereas the original GSE requirements listed in the UTCs were 140,001 lb, using the reduced listing in Table 2 would change the GSE to 61,765 lb and by designing a fighter to further reduce this, the total weight could then be 44,100 lb, or 2.8 tons per aircraft.

Reducing the War Reserve Spares Kits

For a dispersal of eight aircraft for seven days, the UTCs specify 17,336 lb of WRSK. We suggest no changes in weight, although the composition of the kit would change to accommodate the remote maintenance support.

Reducing Non-GSE/WRSK Equipment and Materiel

Non-GSE/WRSK equipment and materiel are quite diverse and include spare engines and the associated tools and equipment to install them, MERs, TERs, and munitions build-up items, munitions racks, office supplies, small arms and ammunition, communications equipment, and the like. Non-GSE/WRSK equipment and materiel listed in the F-16's UTC weigh 123,906 lb for eight aircraft deployed for seven days.

Ways to reduce the amount of this materiel follow directly from the previous actions regarding GSE and from the fact that no heavy ILM will be performed at the DOLs. We removed all aircraft engines together with the equipment required to install them. Next, we deleted all MERs and TERs because aircraft will be configured before dispersal. The munitions racks listed in the UTC are used on the trailers, and their number relates to the number of trailers. Fewer trailers would be taken and fewer racks accordingly. Office supplies and miscellaneous items are a small part of the total but are arbitrarily halved in keeping with the austere nature of the dispersal. All small arms, ammunitions, and communications equipment would be taken. The

result is that only 50,725 lb are required—about 40 percent of the original amount.

Once again, this reduction in materiel taken on tactical dispersal would require the delivery of assembled munitions from build-up teams at MOBs, COBs, or ammo depots, the performance of flightline maintenance only at the DOL, and the concept of lean operations for short periods of time.

To put the above into context, Table 3 compares the items required by the UTC to deploy eight F-16s for seven days with the minimums we estimate would be required for an eight fighter tactical dispersal for the same length of time.

This comparison is based on a dispersal of seven days. However, the length of time that the fighters can be dispersed is almost unlimited, given the close ties with the MOBs, COBs, and ILMs, and the fact that personnel can be rotated to and from the DOL. Therefore, while the above comparison is striking, it becomes even more striking when it is made with the amounts of material required by the UTC for a dispersal of 30 days (see Table 4).

Reducing Housing, Rations, and Site Security Protection

Housing. The Air Force has two existing systems for housing deployed units:

Table 3

COMPARISON OF F-16 UTC REQUIREMENTS WITH A SPECIALLY DESIGNED FIGHTER
(EIGHT FIGHTERS, SEVEN-DAY DISPERSAL)

	Weight (lb)		
Item	F-16	Specially Designed Fighter	% Reduction
GSE	140,001	44,100	68.5
WRSK	17,336	17,336	0
Non-GSE/WRSK	123,906	50,725	59.0
Total	281,243	112,161	60.1
Total, tons per fighter	17.6	7.0	60.1
Total, C-141 per fighter	0.80	0.32	60.1

Table 4

COMPARISON OF F-16 UTC REQUIREMENTS WITH A SPECIALLY DESIGNED FIGHTER
(EIGHT FIGHTERS, 30-DAY DISPERSAL)

	Weight (lb)		
Item	F-16	Specially Designed Fighter	% Reduction
GSE	161,341	44,100	72.7
WRSK	17,336	17,336	0
Non-GSE/WRSK	130,757	50,725	61.2
Total	309,434	112,161	63.8
Total, tons per aircraft	19.3	7.0	63.8
Total, C-141 per fighter	0.87	0.32	63.8

- *Harvest Bare* equipment consists of collapsible hard wall shelters and buildings that can be deployed by air and erected to produce a full-sized base.
- *Harvest Eagle* equipment consists of large tents that can be deployed and erected to produce a camp capable of sustaining the deployed force.

Tactical dispersal would be difficult with either of these systems, which are designed for slow, massive build-ups. Accordingly, they are large, heavy, time-consuming to erect and take down, and very visible to an enemy. The tactical dispersal would involve moving a relatively short distance with a relatively small group of personnel for a limited number of days. Many amenities might be dispensed with, so as to not jeopardize the prime objective—survival of the weapon system and its effective operation.

Accordingly, shelter could be provided by high-grade, weather-resistant, off-the-shelf, two-person tents. A large variety of such units are available that are efficient, roomy, light weight (about 10 lb), and inexpensive. Sleeping bags and air mattresses that together also weigh about 10 lb per person could be used.

Rations. By the same token, field rations would be issued to each person. Thus there would be no need for mess facility, kitchen, or food

preparation. U.S. Army documents[7] suggest 7 lb of rations per person per day; 110 people[8] would therefore require 5390 lb of rations for seven days.[9]

Site Security Protection. Although the primary purpose of tactical dispersal to numerous small sites is to dilute attack by enemy aircraft, some protection against attack will be dispersed as well. Each site would have two to five Stinger hand-held missile launchers, with an initial 30 missile load. The 30 packaged missiles weigh roughly 1500 lb. Protection is also required from a diversity of ground threats. Thus, we include 1500 lb of antipersonnel devices (hand grenades, Claymore mines, grenade launchers, and Squad Automatic weapons) in addition to the M-16 rifles already provided.

MINIMUM NUMBERS OF PERSONNEL DEPLOYED TO DISPERSAL SITES

Requirements

Dispersing a wing of fighters to more than a single location requires additional maintenance personnel, since some skills are required at every location where fighters are based. If one person with a critical skill can service an entire wing of 72 fighters at an MOB, then 18 people with that skill will be required if the wing disperses to 18 separate DOLs of four aircraft each.

Figure 1 shows personnel requirements. The maintenance staffing illustrated in Fig. 1 does not, however, result in normal operations. Because some tactics require at least two fighters to operate as a flight, dispersal to numerous sites greatly impairs the ability to generate sorties. For instance, if one fighter is down for maintenance on a base with 72 fighters (and if two fighters must operate as a flight), then only 3 percent of the fighters are unavailable for sorties. By contrast, if one fighter is down for maintenance at a DOL with four fighters (and if

[7]FM 101-10-2 Field Manual. Staff Officers' Field Manual, *Organizational, Technical and Logistic Data Extracts of Nondivisional Tables of Organization and Equipment*, Headquarters, Department of the Army, July 1975.

[8]See Table 6.

[9]Recent movement away from the use of canned foods toward freeze-dried foods may substantially reduce this weight.

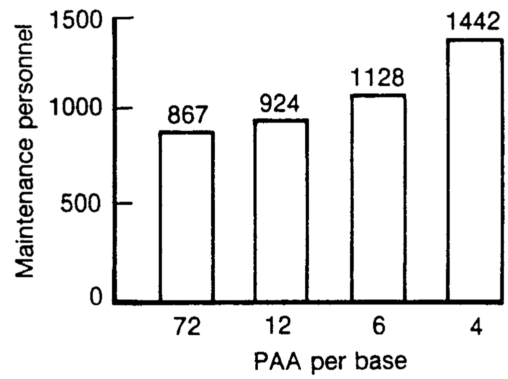


Fig. 1—Maintenance personnel needed for varying degrees of dispersal of 72 fighters

two fighters must operate as a flight), then 50 percent of the fighters are unavailable for sorties.[10]

Figure 2 illustrates the sortie rates that result from dispersed operations with the "full" manning illustrated in Fig. 1. This situation can be corrected by servicing and repairing planes faster, which in turn requires more maintenance personnel.

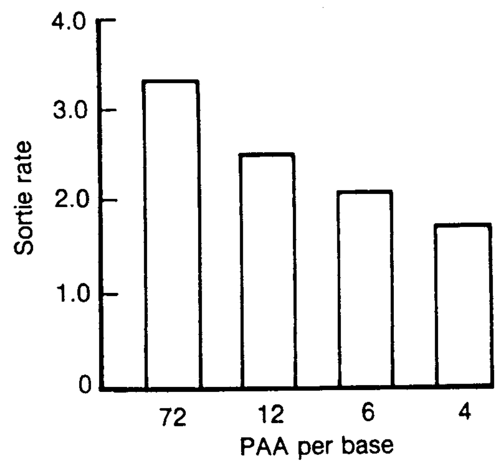
Using the Theater Simulation of Airbase Resources (TSAR) model,[11] the numbers of additional personnel were estimated so that the sortie rate would not degrade relative to the 72 PAA wing (see Fig. 3). According to these computations, to maintain the wartime sortie rate with as few as four fighters per DOL, the manpower must be approximately doubled.

There are, however, several ways to reduce the total number of dispersed maintenance personnel:

- Eliminating ILM at DOLs by performing it at MOBs or other centralized locations,
- Cross-training maintenance personnel so their skills are broadened, and

[10]One could conceive of operations where odd aircraft from adjoining sites could fill out flights. This practice might increase the utility of DOLs with small numbers of aircraft.

[11]See D. E. Emerson, *An Introduction to the TSAR Simulation Program*, The Rand Corporation, R-2584-AF, February 1982.



NOTE: Manning for each dispersal option shown in Fig. 1.

Fig. 2—Degradation of sortie rate with varying degrees of dispersal of 72 fighters

- Improving the reliability of aircraft so that fewer maintenance actions are required.

Because of the many uncertainties involved in cross-training and in improving reliability, we have not used these improvements when estimating the costs of various integrated air vehicle, basing, and support options in Sec. III. However, the following discussion shows the large gains potentially achieved by cross-training and improving reliability.

Eliminating ILM at Dispersed Locations

The F-16 UTC calls for the personnel listed in Table 5. Eliminating the need to deploy the ILM personnel reduces not only the 25 ILM personnel but also 10 of the "other" personnel.[12] This decreases the total of number of dispersed personnel to 165.

[12]Decreases in the "other" category result because dispersed personnel will use field rations, and some maintenance personnel will double as security guards. Site security supervision is provided by eight full-time security specialists who will draw on others to provide shifts of 15- to 20-man perimeter defense teams. All personnel require small arms and appropriate air base ground defense training. Augmentation by rear area U.S. or FRG security personnel is also possible.

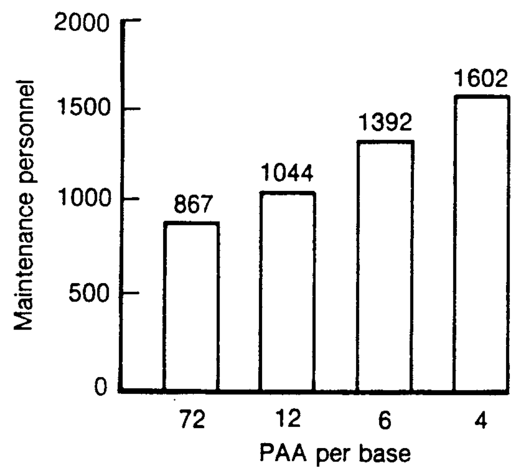


Fig. 3—Maintenance personnel needed to sustain constant sortie rate with 72 fighters

Cross-Training Maintenance Personnel

The 110 personnel performing flightline maintenance at each DOL containing eight aircraft are needed because certain skills are required at each DOL, and even though one or two people with these skills would be adequate for a wing of 72 aircraft, this number would still be required at each site to ensure the presence of skilled personnel.

Table 5

F-16 UTC PERSONNEL REQUIREMENTS FOR DEPLOYMENT OF EIGHT FIGHTERS

Function	No.
Flightline maintenance	110
ILM	25
Munitions	11
Other	51
Total	197

One way of coping with this problem is to cross-train maintenance personnel so that each has several critical skills. This may be difficult to achieve, since it would involve a new view of maintenance training. Costs without cross-training may be tolerable down to eight aircraft, at which time they start to increase unacceptably.

With cross-training, simulation runs with the TSAR model show that the aircraft sortie rate of three per day can be maintained while reducing the flightline maintenance manpower by 20 percent.

Improving Reliability of Aircraft

Further reductions in flightline maintenance personnel were tested in the simulation by increasing fourfold the reliability of avionics, engine, and fuel systems. When these changes were combined with cross-training, reductions of 40 percent in flightline maintenance personnel were possible without impairing the sortie rate.

Using this factor, the 110 flightline maintenance personnel listed in Table 5 could be reduced to 66 (see Table 6). No reduction in munitions handling personnel is made, and the "other" category is reduced to 38. This category consists of 18 officers (including the pilots), two supply/clerical personnel, eight security specialists, one medical corpsman, and nine quality control and maintenance control personnel. Table 6 lists the full complement of personnel dispersed.

In sum, from a maintenance and supply perspective, tactical dispersal to DOLs in Central Europe is a feasible basing alternative *if* fighters are provided with STOL and rough field landing capabilities and if the amount of equipment deployed to DOLs is reduced by leaving nonessential equipment at MOBs and COBs and by designing future fighters with built-in equipment. (Some modifications to

Table 6

REDUCED NUMBER OF DISPERSED PERSONNEL

Function	No.
Flightline maintenance	66
Munitions	11
Other	38
Total	115

current aircraft are also possible.) Tactical dispersal would be further enhanced if the number of additional personnel needed to service the deployed airplanes is decreased by eliminating ILM at DOLs, by cross-training maintenance personnel, and by improving the reliability of the aircraft.

III. METHODOLOGY FOR MEASURING COSTS AND PERFORMANCE IN AN INTEGRATED FASHION

This section demonstrates the methodology needed to measure the costs and performance of various sets of integrated basing, support, and air vehicle requirements. In so doing, it employs the following measurements defined in Sec. I:

- Cost,
- Flexibility,
- Mobility,
- Sortie generation, and
- Aircraft ground survivability.[1]

These measures enable us to assess the effects of changes in aircraft design (long-range, STOL, V/STOL, and extreme rough landing capabilities) and changes in basing and support (operations from enhanced MOBs, combinations of MOBs and DOLs, and DOLs with shelters).

COST

Our proposed methodology estimates cost using

- The number of aircraft that can be purchased with a fixed amount of money, and
- The gross weight of the aircraft.

Number of Aircraft Purchased for Fixed Amount of Money

We have estimated costs using the number of aircraft that can be purchased with a fixed amount of money allocated for acquisition, O&S, spares, transportation, manpower, DOL costs such as revetments

[1]We suggest that one should also consider such difficult-to-quantify measures as responsiveness, agility, and command and control. For example, long-range aircraft cannot respond to requests either for battlefield support or for intercepting enemy aircraft as quickly as aircraft based closer to the front. This delay greatly reduces the utility of long-range aircraft, especially in a NATO environment. As for agility, aircraft with STOL or V/STOL capabilities can more quickly than CTOL aircraft abandon damaged operating locations and more rapidly resume operations at other sites. And in terms of command and control, aircraft operating out of MOBs and COBs are more easily controlled than those operating out of DOLs.

or shelters, and the like. These costs in turn influence the overall force ratio between U.S. aircraft and those of the enemy.

In estimating costs (expressed in 1984 dollars), we have considered airplane acquisition costs, 20-year O&S costs, costs of on-board equipment, and reduced costs of GSE. We have used current maintenance specialty classification manpower costs. Where we have made occasional excursions involving cross-training and improvements in reliability, we have included the savings that accrue but have not estimated the costs involved.

To estimate acquisition costs, we have used the following historically based relationship: airframe equals $1100 per pound, landing gear equals $366 per pound, and engine equals $396,160 plus 52 times the maximum thrust.[2]

To estimate 20-year O&S costs, we have used the following relationship: For each million dollar increment in acquisition cost above the base case, average O&S costs increase by $120.17 per flying hour and $6823.60 per year. Using a 20-year life cycle and 300 flying hours per aircraft per year, a one million dollar increase in the acquisition cost results in a 20-year O&S increase of $857,492 and a total system increase of $1,857,492.

To estimate the costs of on-board equipment, we used Air Force data for some equipment and manufacturers' estimates for the remainder. Annual O&S costs for this equipment were estimated to be 10 percent of acquisition costs, or twice acquisition costs for 20 years.

To estimate the savings of eliminating GSE, we calculated the amount of equipment required for a full squadron deploying for 30 days and then divided by 24 to obtain the average reduction per PAA.

Figure 4 displays the estimated costs of several aircraft under different basing concepts, showing the effects of support equipment on these costs (basing costs such as DOL revetment and shelter costs are excluded here).

Table 7 shows the cost effects of various basing, support, and air vehicle concepts expressed as the number of aircraft that could be purchased for a fixed amount (basing costs are included here). These costs range from those for the CTOL option to those for the V/STOL option. The CTOL option costs the least; as the base case, it allows purchase of 360 aircraft. The V/STOL option costs the most because it is heavy and has a large engine; it allows purchase of only 278 aircraft, 77 percent of the less expensive CTOL option.

---

[2]Costs are based on cost estimating relations derived in part from data in *USAF Cost and Planning Factors*, AFR 173-13, February 1983.

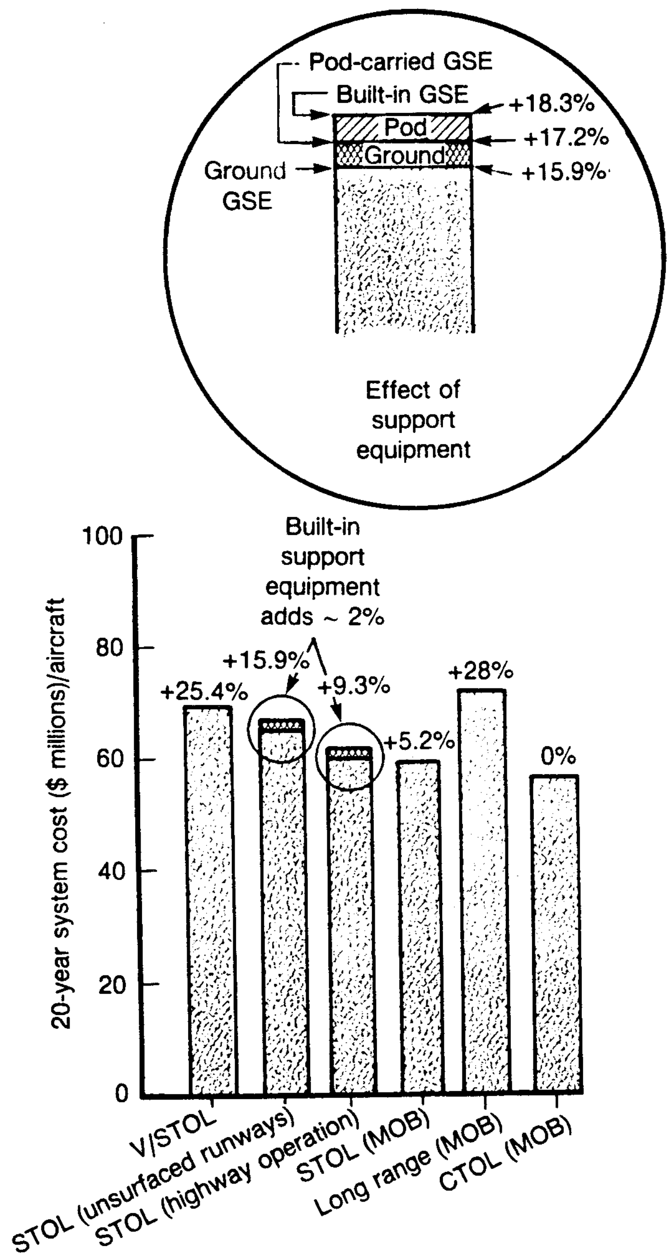


Fig. 4—Life cycle costs of aircraft designs under different basing concepts

Gross Weight of Aircraft

To estimate aircraft costs, we determined the gross weight of a series of aircraft all having the same payload, range, and in-flight characteristics.[3]

Figure 5 displays the gross weight of several aircraft under different basing and support concepts, showing the effects of support equipment on these weights.

Table 8 shows the effects of various basing, support, and air vehicle concepts expressed as increased weight when compared with CTOL aircraft operating out of MOBs. Gross weight—and thus cost—are primarily affected by the following:

Table 7

COSTS OF INTEGRATED BASING, SUPPORT, AND AIR VEHICLE CONCEPTS IN TERMS OF FLEET SIZE

	Fleet Size	
Basing, Support, and Air Vehicle Concept	No.	% of Best Performing Concept
CTOL + MOB (base case)	360	100
Rear-based MOBs	282	78
STOL options		
Nominal MOBs		
STOL + MOB	342	95
Enhanced MOBs		
STOL + MOB	342	95
Nominal MOBs + DOLs		
STOL + DOL	312	87
STOL + DOL + extreme rough landing	305	85
STOL + DOL + shelters	310	86
V/STOL	278	77

NOTE: Landing gear for damaged MOBs or highway operations is designed to California Bearing Ratio (CBR) 8; that for extreme rough landing is designed to CBR 4. The CBR is a measure of relative hardness of the takeoff surface.

[3]The only exception is the V/STOL alternative, which has excess performance because of the high thrust-to-weight ratio it needs.

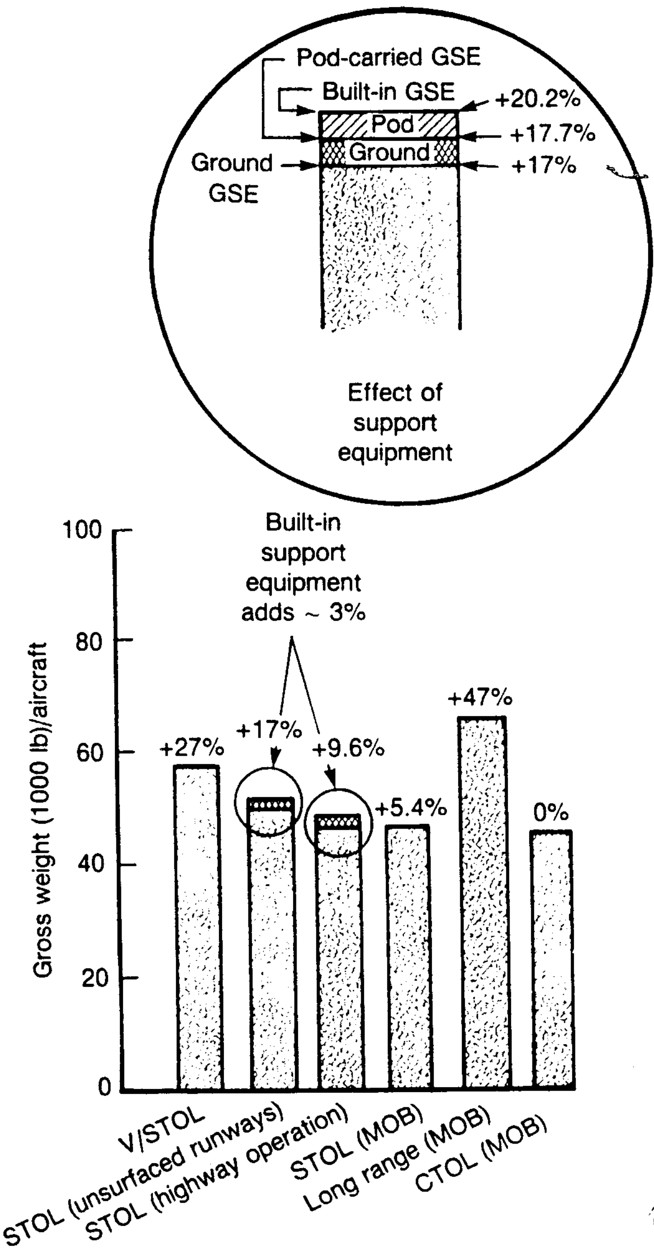


Fig. 5—Costs of basing, support, and air vehicle concepts in terms of gross weight

Table 8

COSTS OF BASING, SUPPORT, AND AIR VEHICLE CONCEPTS IN TERMS OF GROSS WEIGHT

Basing, Support, and Air Vehicle Concept	Aircraft Gross Weight: Pounds	Aircraft Gross Weight: % of Best Performing Concept
CTOL + MOB (base case)	43,750	100
Rear-based MOBs	64,280	68
STOL options		
Nominal MOBs		
STOL + MOB	46,120	95
Enhanced MOBs		
STOL + MOB	46,120	95
Nominal MOBs + DOLs		
STOL + DOL	49,200	89
STOL + DOL + extreme rough landing	52,590	83
V/STOL	55,610	79

- Rear-based aircraft require larger engine and structure to deal with increased fuel load.
- STOL aircraft operating from MOBs require a thrust-deflecting nozzle and more complex landing gear.
- STOL aircraft operating from highways or lightly paved fields require more complex (and heavy) landing gear and tires. In addition, highway operations require built-in support equipment.
- STOL aircraft operating from unsurfaced runways require very complex (and heavy) landing gear and tires. In addition, such operations require built-in support equipment.
- V/STOL aircraft require larger engine and structure.

FLEXIBILITY

Flexibility means the ability to deploy easily not only to dispersed operating locations in Europe but also to austere locations throughout

the world. The concept of flexibility is easier to visualize than to measure. We advance the following method of quantification: Develop a series of operating scenarios for a number of Third World contingencies and then express the "flexibility" of a particular point design as the relative number of locations from which aircraft can effectively operate. This number depends on the combat radius and the runway requirements of the airplane.

We examined a series of 11 operating scenarios during this study, covering African, Asian, and South American countries. Figure 6 shows one such scenario. It requires operating from country A with tactical aircraft that can cover targets in the southern portion of country B. (The arrows indicate nautical miles to the target area.) With current aircraft (such as F-15s and F-16s) normally using 8000 ft runways, only two operating locations are available, both more than 1000 n mi from the target. However, if STOL aircraft requiring 2000 ft runways are available, then four become available. Thus operating distance has been cut in half, and twice as many operating locations have become available.

Table 9 sums up the gains in flexibility achieved by various basing, support, and air vehicle concepts when applied to the series of scenarios we examined similar to the one described in Fig. 6. STOL aircraft designed to operate only from MOBs are penalized more than those designed to operate from DOLs because of their lower landing gear capability. Because of their longer range, rear-based aircraft can choose among a large number of operating locations. Rough landing gear greatly extends the flexibility of STOL, especially in Third World countries with their large number of rough fields. In practice, V/STOL aircraft cannot operate from all conceivable locations, but they certainly can operate from more locations than can CTOL or STOL aircraft.[4]

MOBILITY

To measure mobility, we estimated the number of C-141 loads required to move a squadron for both initial and sustained operations. To do so, we used calculations shown in Sec. II for built-in (or pod-carried) support for aircraft operating from DOLs, and we used similar calculations for supporting V/STOL and long-range aircraft.

[4]V/STOL pads require site preparation before deployment; in addition, our design requires that they be supported from DOLs or MOBs. These requirements thus restrict the number of locations from which V/STOL aircraft can operate.

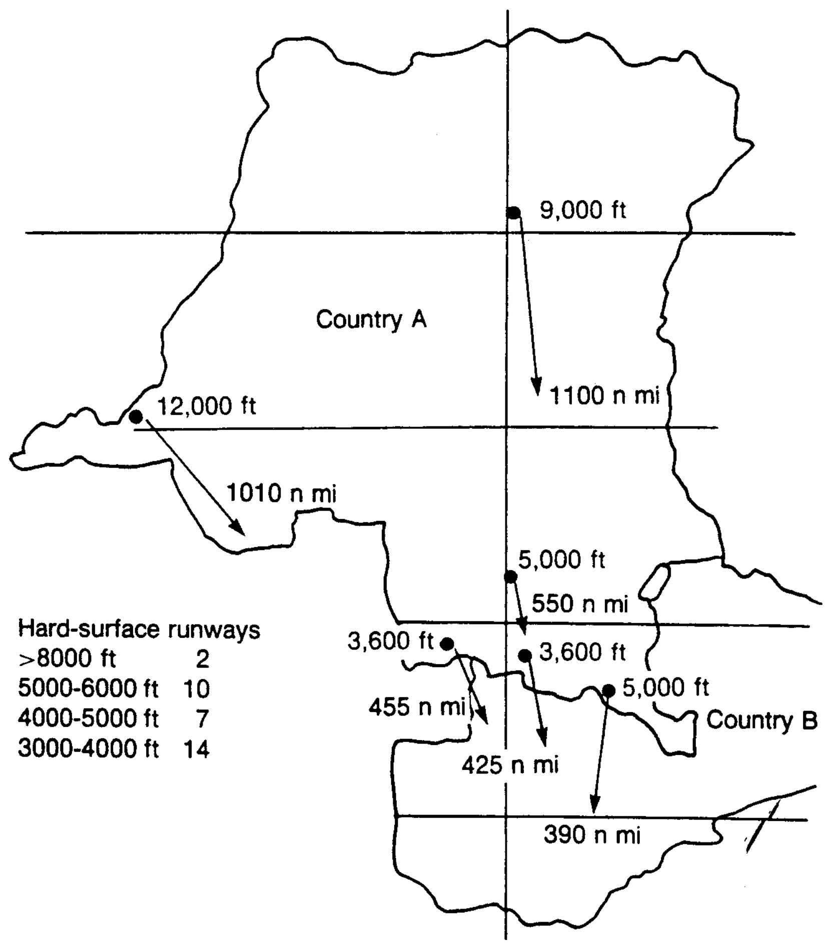


Fig. 6—Landing strips in two Third World countries

Table 10 sums up the gains in mobility achieved by various basing, support, and air vehicle concepts. The greatest gains result from the use of built-in equipment. Reliance on DOLs requires the fewest number of C-141 loads per squadron; reliance on MOBs (except for rear-based MOBs) requires the greatest number of C-141 loads per squadron.

Table 9

FLEXIBILITY OF INTEGRATED BASING, SUPPORT, AND AIR VEHICLE CONCEPTS

Basing, Support, and Air Vehicle Concept	Expected Operating Locations within Combat Radius of Aircraft: No.	Expected Operating Locations within Combat Radius of Aircraft: % of Best Performing Concept
CTOL + MOB (base case)	2	10
Rear-based MOBs	13	65
STOL options		
Nominal MOBs		
STOL + MOB	3	15
Enhanced MOBs		
STOL + MOB	3	15
Nominal MOBs + DOLs		
STOL + DOL	9	45
STOL + DOL + extreme rough landing	16	80
V/STOL	(a)	100

[a]For a conservative comparison, the performance for V/STOL is set at 25 percent greater than STOL with rough field landing gear. The number of operating locations will not be infinite; they will, however, vary depending on site preparation requirements and support arrangements.

SORTIE GENERATION AND AIRCRAFT GROUND SURVIVABILITY

To assess the resiliency of different basing, support, and air vehicle concepts in the face of attack, we estimated the sorties that could be generated and the aircraft that would survive by using a series of equal cost systems (aircraft and basing) during the first week of a Central European conflict.[5] In considering three levels of enemy attack—each using conventional weapons on three days during a five-day period—we employed a simplified survivability model with rough values to determine its parameters. Although approximate, this method is sufficient to compare alternatives and demonstrate the methodological approach we suggest.

Since our methodology is intended to compare the sortie generation and aircraft ground survivability of various systems when under attack,

Table 10

MOBILITY OF INTEGRATED BASING, SUPPORT, AND AIR VEHICLE CONCEPTS

Basing, Support, and Air Vehicle Concept	Required C-141 Loads per Squadron: No.	Required C-141 Loads per Squadron: % of Best Performing Concept
CTOL + MOB (base case)	20	40
Rear-based MOBs	13	62
STOL options		
Nominal MOBs		
STOL + MOB	20	40
Enhanced MOBs		
STOL + MOB	20	40
Nominal MOBs + DOLs		
STOL + DOL	8	100
STOL + DOL + extreme rough landing	8	100
V/STOL	8+	90

[5]This means that the relatively expensive systems, like the rear-based fighter, will be penalized in sortie generation because of its fewer initial aircraft even if it is relatively safe from attack.

we have not considered active defense of the air base. The purpose of active defense is to deter the enemy from attacking the air base by raising the losses he will encounter in doing so. Unless extremely effective, active defense will not prevent an enemy who chooses to attack from delivering most of his weapons. For example, even if the active defense can kill one-half the attacking aircraft, and half of those are killed before reaching the target, the enemy would still deliver three-quarters of his weapons. This argument does not negate the value of active defenses, which may indeed deter an enemy or limit subsequent attacks, but it does suggest that active defense must be combined with passive defenses, such as shelters, if we are to have high confidence in our ability to survive and generate sorties.

Since we are concerned with the ability of the air base to survive a number of weapon hits, we give little consideration to the manner in which these weapons are delivered. For convenience, we have assumed that they are delivered by aircraft, but delivery by tactical ballistic missiles or standoff missiles would not affect our results—provided that the delivery accuracy and warhead types are the same.

Finally, our methodology considers attacks against the runways and aircraft on the base but not against support facilities. We expect that a portion of the attacks will be directed at support facilities and that attacks directed at aircraft will cause collateral damage to support facilities. In earlier simulations, our colleague D. Emerson[6] examined the effect of such damage—and it can be severe. However, these effects are generally not felt heavily until after the first week. In one attack that damaged aircraft shelters, runways, and logistics facilities, sorties peaked on day five but then fell off sharply over the next three weeks. The conclusions from Emerson's work are clear: Key support facilities must be protected by hardening them, by removing them from the attack area, or by providing for their replacement. Given these results, our investigations concentrate on the first week.

A series of assumptions were used to derive a model of both sortie generation and aircraft ground survivability. The outcome is strongly influenced by the way the enemy distributes his attack between aircraft and runways. We have normally selected enemy tactics that minimize the number of sorties generated. (In some cases, however, the enemy had an option of destroying more aircraft by allowing more sorties to be generated—and in such cases, we selected the option that we judged was most advantageous to the enemy.) Our model steps through one

---

[6]D. Emerson, *USAFE Air Base Operations in a Wartime Environment*, The Rand Corporation, P-6810, October 1982.

raid after another, calculating the aircraft remaining, whether the runway is cut or not, and the number of sorties flown in each interval.

Based on the survivability and sortie generation models, Fig. 7 shows the effects of basing, support, and air vehicle concepts on the number of sorties that can be flown and the number of aircraft that survive under various attack conditions for an equal cost fleet. (Similar calculations have been done for fixed fleet size.) Table 11 sums up the gains in sortie generation and survivability achieved by the various basing, support, and air vehicle concepts, including several excursions we performed involving the effects of

- Enhanced MOBs,
- Shelters on DOLs,
- Improved reliability and cross-training,
- Imperfect enemy information concerning the location of our aircraft on the ground,
- Improved enemy airfield attack weapons, and
- Procedures for allowing some aircraft to escape immediately before an enemy attack.[7]

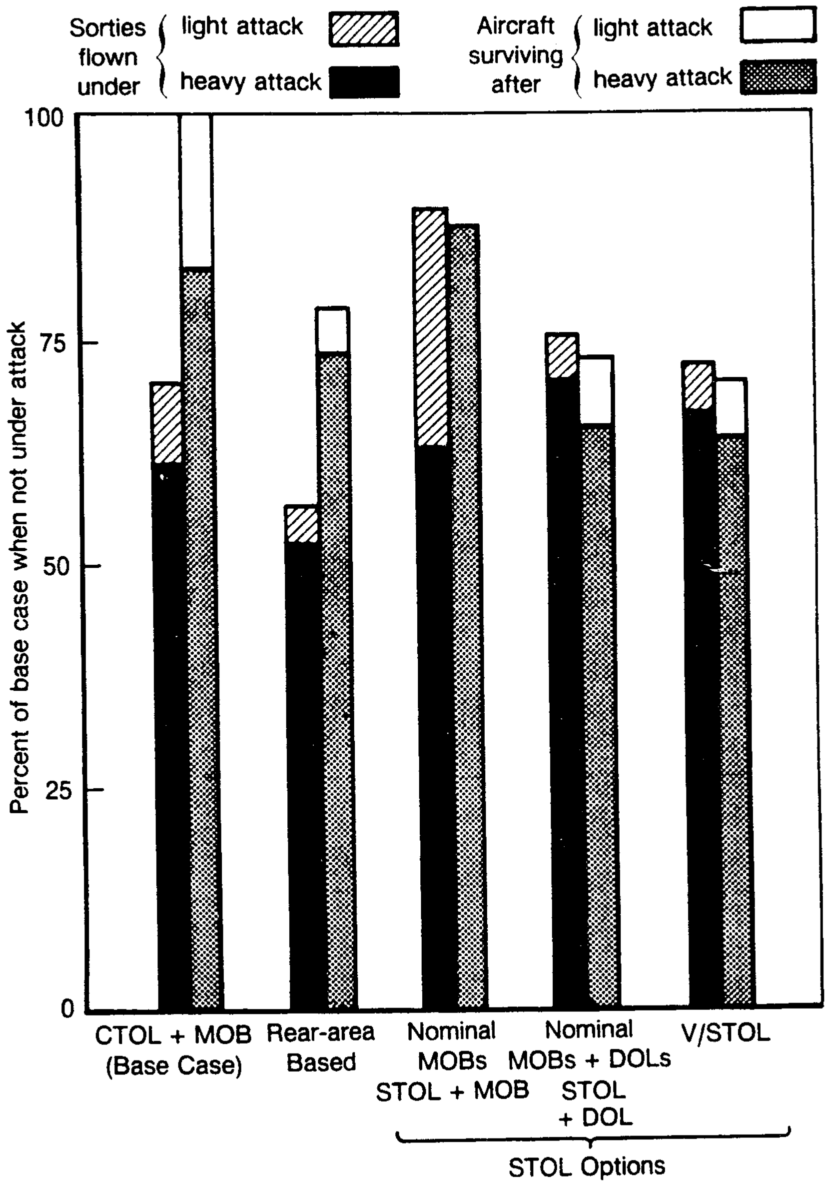
Table 11 shows that highly survivable options like rear-based MOBs and V/STOL do not do well because their great cost reduces the number of aircraft that can be purchased. This in turn reduces the number of sorties that can be flown. Enhanced MOBs with STOL do very well because of their moderate cost, short runway requirements, and full sheltering for aircraft. Depending on attack size and aircraft protection, DOLs can be good performers despite their higher cost.

Effects of Enhanced MOBs

One often discussed option for enhancing current MOBs involves providing each with a 50 × 5000 ft emergency operating surface located so as to be a separate aim point. Figure 8 shows the effect of having this new facility for CTOL and STOL aircraft. As might be expected, the addition of this short runway offers little advantage for CTOL aircraft, since it is easily cut. Enhancement increases sortie generation if STOL aircraft are used under heavy attacks but at an expense of more killed aircraft, since the inability of the enemy strike force to close the runway induces the enemy to attack shelters instead.

---

[7]Excursions involving additional combinations should be calculated when actually evaluating specific design alternatives.



NOTE: Light attack = 36 attacking aircraft; heavy attack = 108 attacking aircraft.

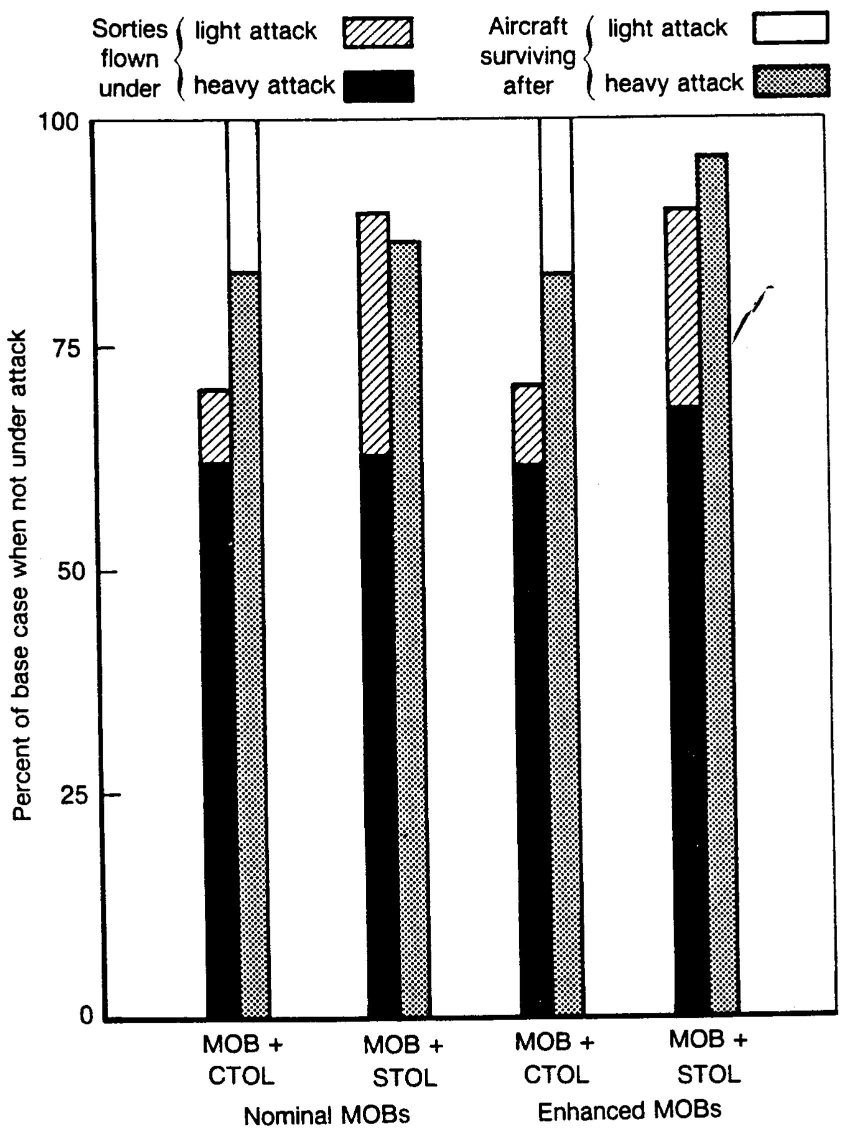
Fig. 7—Effects of integrated basing, support, and air vehicle concepts on sortie generation (equal cost fleet)

Table 11

SORTIE GENERATION AND AIRCRAFT GROUND SURVIVABILITY OF INTEGRATED BASING, SUPPORT, AND AIR VEHICLE CONCEPTS

Basing, Support, and Air Vehicle Concept	Sortie Generation: Average Sorties Flown over All Attacks	Sortie Generation: % of Best Performing Concept	Aircraft Ground Survivability: Average Aircraft Remaining over All Attacks	Aircraft Ground Survivability: % of Best Performing Concept
CTOL + MOB (base case)	3523	82	328	100
Rear-based MOBs	2056	48	272	83
STOL options				
Nominal MOBs				
STOL + MOB	3904	91	320	98
STOL + MOB + 1 day RRR + advanced weapons	2758	64	304	93
Enhanced MOBs				
STOL + MOB	4281	100	312	95
STOL + MOB + 1 day RRR	3982	93	314	96
Nominal MOBs + DOLs				
STOL + DOL	3916	91	248	76
STOL + DOL + imperfect information	4155	97	267	81
STOL + DOL + extreme rough landing + imperfect information	4022	94	260	79
STOL + DOL + DOL shelters	4093	96	306	93
V/STOL	3735	87	241	73

NOTE: This table displays sorties flown and aircraft surviving over the first five days of a presumed conflict during which the enemy attacks with conventional weapons on three of the five days. These data are the averages based on three levels of attack: light (36 attacking aircraft), medium (72 attacking aircraft), and heavy (108 attacking aircraft).



NOTE: Light attack = 36 attacking aircraft; heavy attack = 108 attacking aircraft.

Fig. 8—Effects of enhanced MOBs on sortie generation and aircraft ground survivability (equal cost fleet)

Effects of Shelters on DOLs

Figure 9 shows the effects of increasing aircraft protection on DOLs including the costs of the protection. DOL shelters (four per DOL) increase the numbers of aircraft surviving at the end of five days and the numbers of sorties generated and thus justify their cost.

Effects of Improved Reliability and Cross-Training

Figure 10 shows the effects improved reliability and cross-training on survivability and sortie generation.[8] The reduced cost of operations increases the number of aircraft purchased. These effects are modest for the three options we investigated: CTOL aircraft operating from MOBs, STOL aircraft operating from MOBs, and STOL aircraft operating from MOBs and DOLs.

Effects of Imperfect Enemy Information

In most of our work, we have assumed that the enemy has perfect knowledge as to which sites are occupied at any given time. Thus the enemy attacks the four occupied DOLs and possibly the MOB on every raid he chooses to, based on a reasonable force allocation. Depending on his strength, he may not attack all of the occupied sites, but he at least knows where they are.

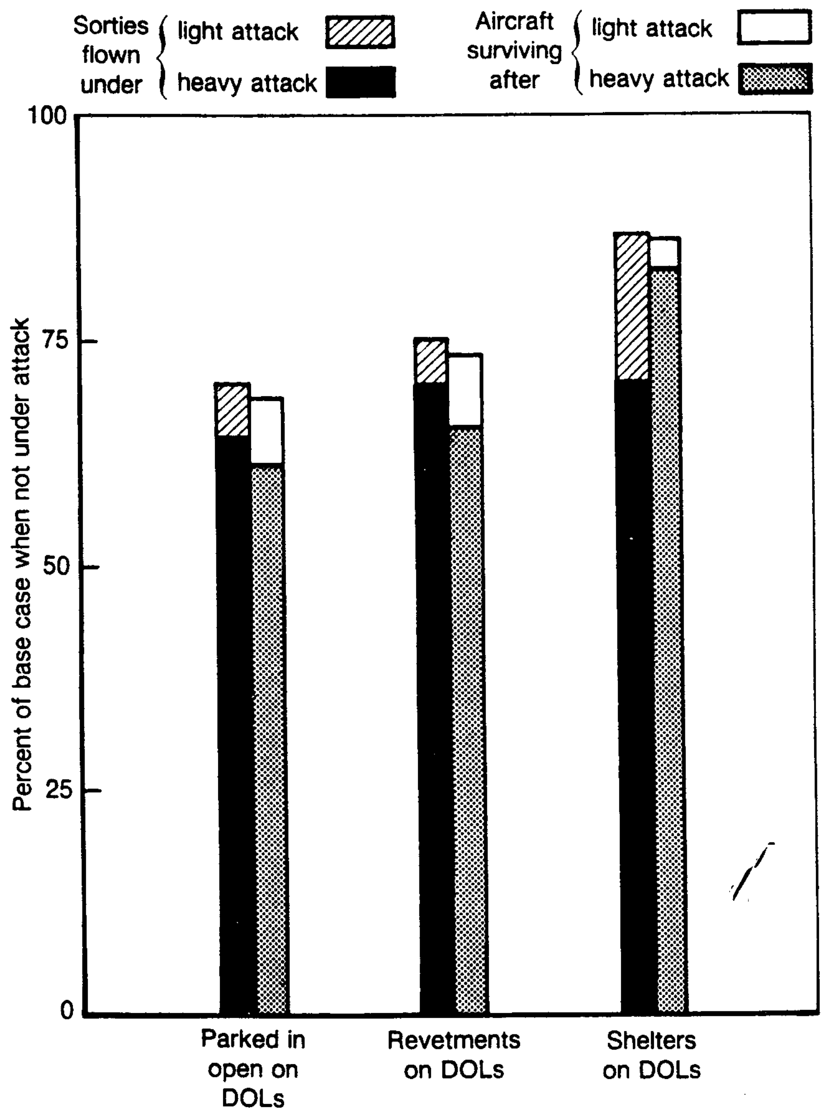
It seems reasonable to assume on several grounds, however, that the enemy may be unable to deliver attacks with such assurance:

- The agility of dispersed aircraft may be such that they have abandoned a previously identified site before attack.
- The enemy may have insufficient forces to attack all dispersed sites (four of which have eight aircraft each) and the MOB (which has the 40 remaining aircraft).
- A programmed attack may fail to complete its assigned task due to interception, effectiveness of our offensive counter air campaign, terminal defenses, navigational error, or an effective NATO deception program.[9]

---

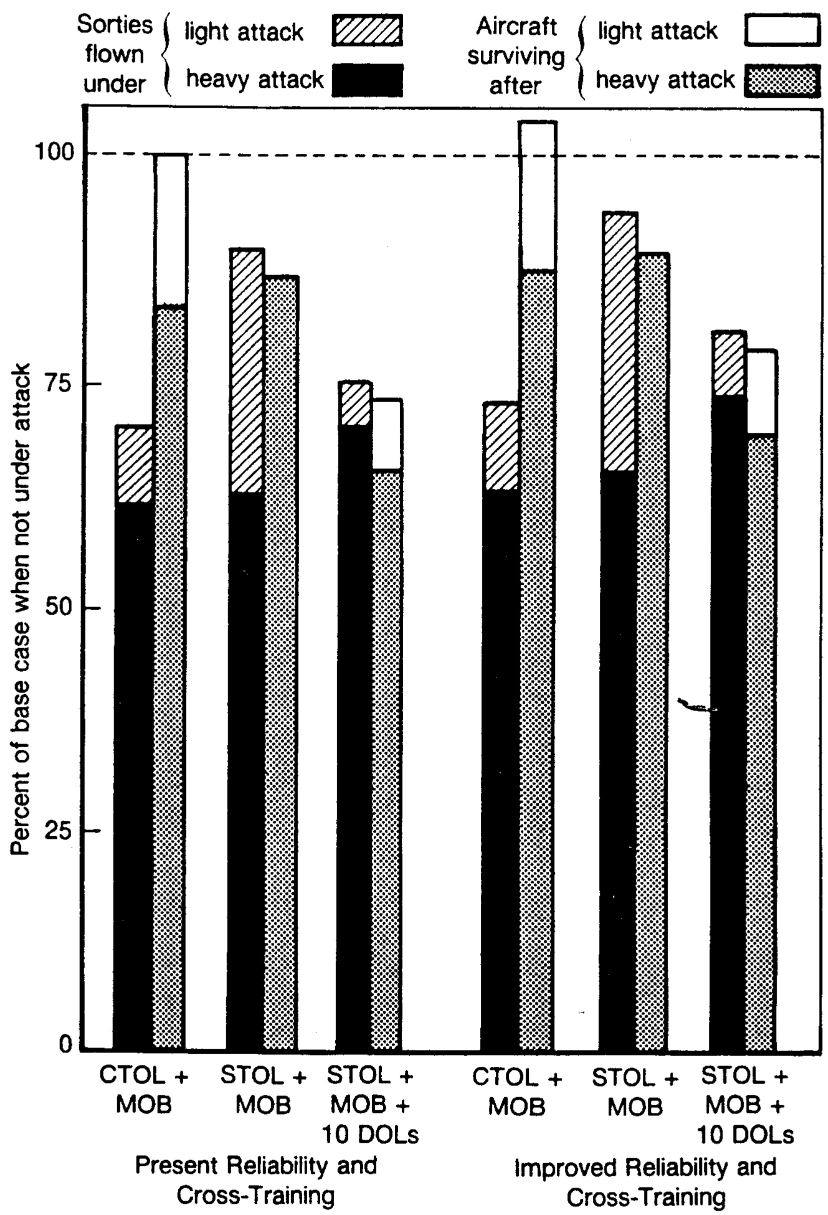
[8]Calculations do not include the cost of cross-training or of improving reliability.

[9]The number of occupied sites successfully attacked in the face of uncertain information was derived as follows. If only four of 10 possible sites are occupied, then the enemy is credited with an 0.4 probability of success for each attack. If he divides his force of 36 into three strike elements of 12 aircraft each, then the average number of occupied sites hit is $3 \times 0.4 = 1.2$. Similarly, if he has 72 aircraft available and sends 48 in four groups of 12 each, the average number of sites hit is $4 \times 0.4 = 1.6$. If 15 sites are available, then the average numbers of occupied sites attacked are 0.8 and 1.1 for 36 and 48 attackers, respectively. In every case, we assume that all residual aircraft attack the MOB either



NOTE: Light attack = 36 attacking aircraft; heavy attack = 108 attacking aircraft.

Fig. 9—Effects of aircraft shelter protection on sortie generation and aircraft ground survivability (equal cost fleet)



NOTE: Light attack = 36 attacking aircraft; heavy attack = 108 attacking aircraft.

Fig. 10—Effects of improved reliability and cross-training on sortie generation and aircraft ground survivability (equal cost fleet)

- The complete set of available dispersed sites may be unknown to the enemy.

Figure 11 shows the effects of imperfect enemy information on survivability and sortie generation. But even these results tend to understate the benefits of having numerous alternative sites because they ignore the following factors:

- More sites mean that enemy intelligence must increase sensor coverage and process more information regarding site occupancy
- More sites coupled with an agile force capable of rapid relocation could make DOLs relatively unattractive targets even if the enemy's intelligence and aircraft allocation system can target a DOL within a reasonable length of time
- More sites provide greater recovery opportunities in the event MOBs are put out of action either temporarily or permanently.

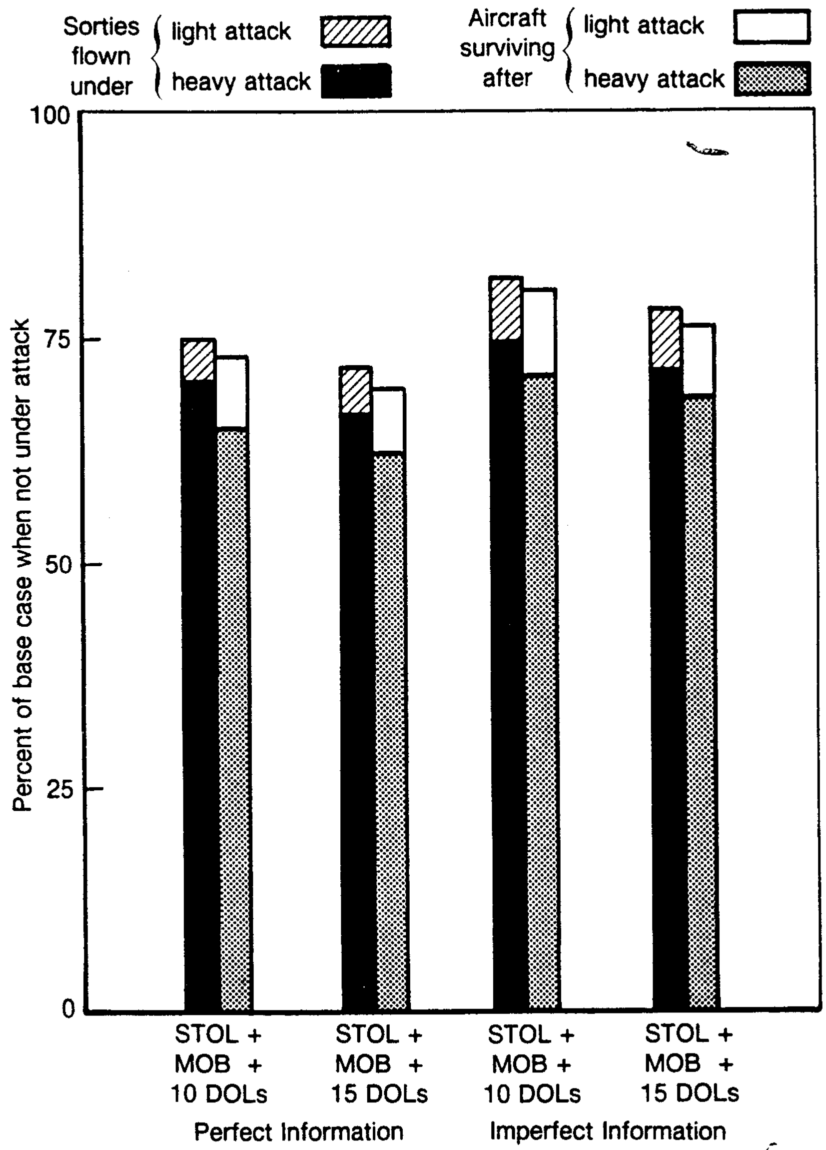
Effects of Improved Enemy Airfield Attack Weapons

Rapid progress is currently being made in weapons intended for attack on shelters and runways, and development of these new weapons may require less time than the development and production of a significant number of new tactical fighters. We cannot at present estimate the effectiveness of weapons that may be used against aircraft and basing systems we consider. However, we can make some preliminary estimates of the effect that improved weapons may have on any conclusions we draw.

An unguided shaped-charge weapon capable of penetrating a shelter may weigh 70 kg. Allowing some weight for the containing pod, we assume that one of the enemy aircraft might carry 25 of these weapons. This is roughly three times more than the 250 kg general purpose bombs we have assumed in our scenario. For the purpose of the estimates made here, we have assumed that the probability of a shelter kill is doubled.

In addition, improved runway attack weapons that disperse mines and crater runways may increase runway repair time. Consequently, we have assumed that the use of advanced weapons will require a day

by direct assignment or as a secondary mission after discovering that their assigned DOL is unoccupied. In Central Europe, 15 DOLs per MOB can be obtained only by using some unsurfaced fields. Thus this case requires using aircraft with special soft field landing gears, which increase their cost. This increased cost results in the purchase of fewer aircraft and thus in a reduced total sortie generation capability.



NOTE: Light attack = 36 attacking aircraft; heavy attack = 108 attacking aircraft.

Fig. 11—Effects of enemy information on sortie generation and aircraft ground survivability (equal cost fleet)

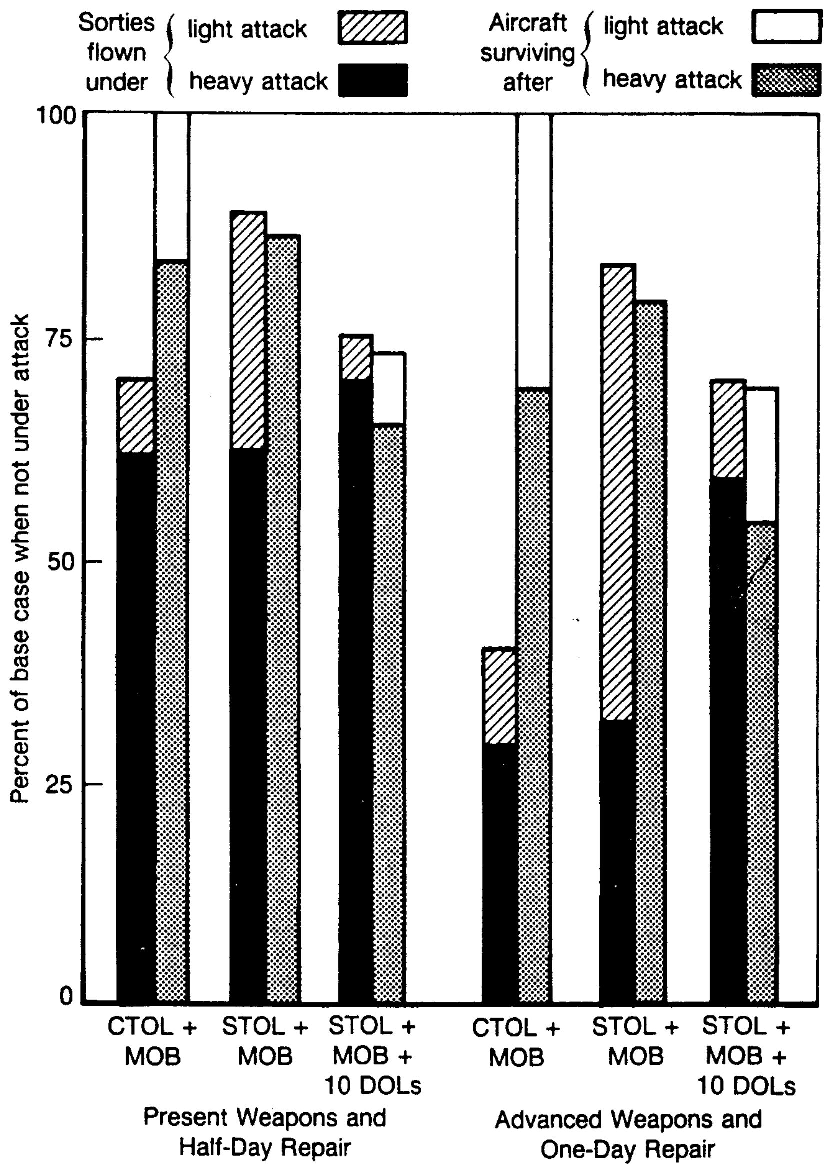
to repair instead of the half day we have assumed for normal weapons. Figure 12 shows the results of these assumptions.

The advanced weapons significantly reduce sorties generated when compared with those generated when present weapons are used. Their use appears to favor the sortie generation ability of dispersed facilities relative to MOBs. It should also be remembered that uncertainty is very important here. If the MOB runway repair time were to be two days instead of one, no MOB sorties could be generated during the first five days of a war.

Escape Immediately Before Enemy Attack

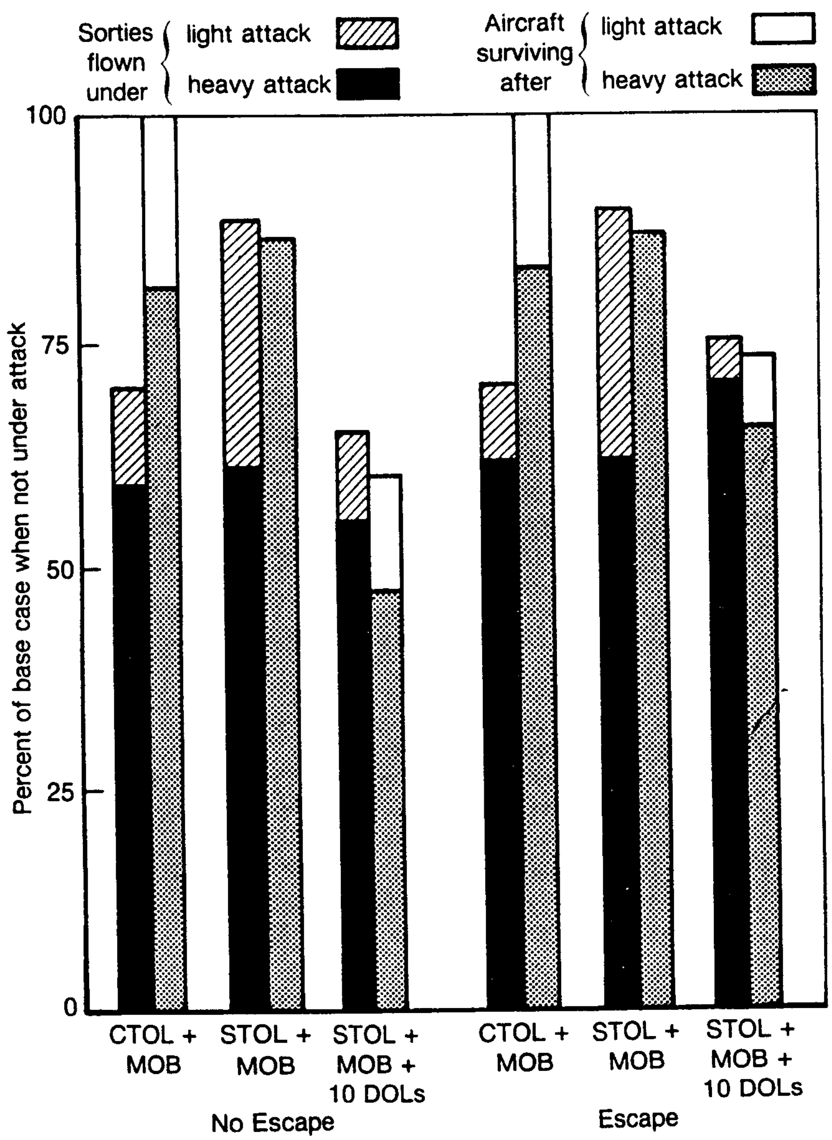
Our calculations have assumed that there is sufficient warning time for eight aircraft per MOB or four aircraft per DOL to escape before enemy attack. Figure 13 shows the effects if such escape is impossible. As Fig.13 indicates, sortie generation and aircraft ground survivability for aircraft dispersed to DOLs are most sensitive to this escape assumption.

One's choice of an integrated package of basing, support, and air vehicle requirements ultimately depends upon the relative importance one places on such measures as cost, flexibility, mobility, sortie generation, and aircraft ground survivability. Section IV shows how the measures can be displayed and ranked.



NOTE: Light attack = 36 attacking aircraft; heavy attack = 108 attacking aircraft.

Fig. 12—Effects of advanced weapons and one-day repair on sortie generation and aircraft ground survivability (equal cost fleet)



NOTE: Light attack = 36 attacking aircraft; heavy attack = 108 attacking aircraft.

Fig. 13—Effects of no escape on sortie generation and aircraft ground survivability (equal cost fleet)

IV. CONCLUSIONS AND IMPLICATIONS

CONCLUSIONS

This report has described and demonstrated a new methodological approach for evaluating the total weapon system performance for future fighter aircraft and major modifications to current fighter aircraft. This methodology calls for integrating the basing, support, and air vehicle design requirements to improve the effectiveness of fighters in the increasingly demanding combat environments.

In so doing, this report has *not* evaluated specific proposals for specific future fighters. Rather, it has shown how integrated evaluations can be performed by balancing costs against such performance measures as flexibility, mobility, ground survivability and, sortie generation capability. Whenever a new point air vehicle design is proposed, it should be evaluated in this fashion using the kinds of tradeoffs considered in Table 12.

The Air Force development community could strengthen its ability to evaluate future fighter designs by undertaking follow-up work aimed at

- Developing a preferred weighting scheme for the performance measures suggested in this report,
- Conducting actual or sample analyses for scenarios beyond the illustrative Central European case to evaluate the power and utility of this methodology, and
- Developing mechanisms to provide the proper information to contractors and source selection personnel to facilitate the application of this methodology.

IMPLICATIONS

Our work aimed at developing a methodology for comparing various air vehicle, basing, and support systems. As such, it used preliminary data and it focused on a single scenario and theater (a short, high intensity war in the FRG). Nevertheless, we feel we should report some of the implications that arise from our study. These implications demonstrate the types of conclusions a more in-depth study might produce and raise some questions that should be given special attention in such a study:

Table 12

SUMMARY FINDINGS

	Percent of Best Performing Concept						
	Cost		Attributes				
Basing, Support, and Air Vehicle Concept	# a/c	Weight	Flexi-bility	Mo-bility	Sortie Gener-ation	Aircraft Ground Surviva-bility	Rank
CTOL + MOB (base case)	100	100	10	40	82	100	9
Rear-based MOBs	78	68	65	62	48	83	10
STOL options							
Nominal MOBs							
STOL + MOB	95	95	15	40	91	98	6
STOL + MOB + 1 day RRR + advanced weapons	95	95	15	40	64	93	11
Enhanced MOBs							
STOL + MOB	95	95	15	40	100	95	3
STOL + MOB + 1 day RRR	95	95	15	40	93	96	5
Nominal MOBs + DOLs							
STOL + DOL	87	89	45	100	91	76	7
STOL + DOL + imperfect information	87	89	45	100	97	81	2
STOL + DOL + extreme rough landing + imperfect information	85	83	80	100	94	79	4
STOL + DOL + DOL shelters	86	83	45	100	96	93	1
V/STOL	77	79	100	90	87	73	8

NOTE: Cost is measured by the number of aircraft that can be purchased for a constant amount of dollars and by the gross weight of the aircraft; flexibility is measured by the number and type of operating surfaces from which the aircraft can operate; mobility is measured by the number of C-141 loads per squadron needed to transport support equipment and materiel; sortie generation is measured by the number of sorties that can be flown during attack; and aircraft ground survivability is measured by the number of aircraft remaining after five days.

1. *Dispersal in the FRG seems logistically feasible.* Supply distances are short, and fuel and armament depots are numerous enough to dilute the effects of enemy attack. We cannot assess the possibility of heavy traffic (either troop movements or refugees) jamming the roads, but short supply distances and numerous available routes reduce the seriousness of this problem.

2. *Designing ground support equipment into new tactical fighters or current aircraft appears feasible with only a minor increase in cost when in-flight performance and load carrying capabilities are held constant.* Proper design of the aircraft can avoid the need for unusual and hard-to-handle fluids such as hydrazine, liquid oxygen, and liquid nitrogen.

3. *Landing gear produces the largest weight penalty in designing aircraft for dispersed operations from austere fields.* Our study of Central Europe suggests that design for highway compatibility (LCN = 15) represents a good compromise between cost and available number of dispersal sites. Designing to operate from unsurfaced areas was less cost-effective than designing for highway compatibility. (This conclusion might be different for operations in other theaters.)

4. *Cross-training support personnel and designing new tactical aircraft with increased reliability can decrease the costs of dispersed operations.* Beside the resulting savings in cost during peacetime, there can be significant reductions in the number of skilled personnel required to maintain sortie generation during a short war.

5. *If runway repair times can be kept to one-half day or less, an enhanced MOB seems a cost-effective way of generating sorties and protecting aircraft in the face of attack.* It is uncertain, however, whether such rapid runway repair can be achieved, especially against future runway busting weapons. Equally uncertain is the ability to repair holes to the smoothness required by current landing gear.

6. *Dispersal seems a cost-effective way of increasing survivability and sortie generation during attack if the dispersed aircraft are kept in shelters or if procedures are developed to allow some aircraft to escape immediately before an enemy attack.* Dispersal capability can also provide air vehicle characteristics favorable for operating in the Third World and is also a hedge against the enemy's developing weapons that can close MOBs for extended periods.

RAND/R-3304/1-AF