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LOW-ALTITUDE MANNED PENETRATORS: A COMPARISON OF DROMEDARY-CARRIED PARASITE AND TANKER-SUPPORTED, LARGE BOMBER SYSTEMS (U)

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UNITED STATES AIR FORCE PROJECT RAND

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PREFACE

This Memorandum, reporting on one phase of RAND's continuing aircraft operation studies, was done in support of the RAND Long Endurance Aircraft Study (RM-3678-PR) and preliminary results were used in that study. The current Memorandum specifically compares small "parasite" aircraft carried by long-endurance Dromedary aircraft with tanker-supported large bombers, but the technological data base (state of the art) for the study is too early to include the current Advanced Manned Strategic Aircraft (AMSA) concept. Therefore the results reported herein cannot be applied directly to the AMSA concept, which may incorporate technology not considered here.

We believe that later work on this comparative study of low-altitude, manned, penetrating aircraft makes it of sufficient interest to warrant publication independently of the larger (LEA) study.

In addition, the methodology of the study should be of interest to strategic planners and operations analysts currently involved in delineating preferred low-altitude manned strategic penetrator systems, since in the Project Definition Phase (DOD Directive 3200.9), comparisons of new weapon systems must be made with a wide variety of alternative systems. It is believed that the methods of comparison employed in this Memorandum are directly applicable and could be of significant utility to such comparisons as are called for by the DOD Directive.

SUMMARY

This Memorandum illustrates a comparative evaluation of alternative low-altitude manned penetrator systems for strategic attack. Two main classes of systems are considered in the example: large, extended-range strike aircraft supported by aerial refueling tankers; and small, short-range combat aircraft carried as parasites in the non-combat environment by large, long-endurance Dromedary aircraft. All systems are selected so as to have essentially the same penetration and target destruction potential. They are compared on the basis of estimated cost and subjective qualitative ranking as to their relative pre-strike vulnerability to enemy attack.

This type of comparative analysis should be of interest to the Air Force and to contractors engaged in strategic planning studies.

CONTENTS

I. INTRODUCTION

A SAC mission requirement of considerable current interest involves deep penetration of potential enemy territory by U.S. ZI-based manned aircraft at high subsonic speed (M ≐ .9) and very low altitude (a few hundred feet above the terrain). The resulting combinations of cruising and combat range required for round-trip missions are extremely difficult to achieve within the current technological art, as demonstrated by contractors' Extended Range Strike Aircraft Studies (ERSAS) conducted in 1963. In fact, neither of two contractors could devise self-sufficient aircraft designs capable of meeting the ERSAS range requirements (which themselves are inadequate for round-trip missions to much of the potential target area) even with the use of advanced powerplant characteristics and such production innovations as variable-sweep wings. RAND studies of low-altitude aircraft[1,2,3] yield similar results--as displayed in Fig. 1. At best, such aircraft would require extensive refueling support in forward areas, either in the air or on the ground, to displace the range exchange capability lines of Fig. 1 sufficiently far to the right to achieve satisfactory round-trip mission capabilities--particularly for symmetrical minimum-penetration missions to the entire Communist bloc (target region C of Fig. 1). Such forward-area refueling introduces undesirable elements of both cost and vulnerability to enemy attack. Even with aerial refueling, many of the tankers would have to be based in forward areas and await approach of the bombers before taking off--otherwise the tanker force requirements become exorbitant.

An alternative means of accomplishing these low-altitude manned penetration missions, with significant reduction in vulnerability to enemy attack, is a composite system utilizing a relatively small manned bomber (capable primarily of the combat range requirement) carried as a parasite by a "Dromedary" long-endurance mother support aircraft (capable of the non-combat range requirement and of maintaining the bomber economically on combat patrol or airborne alert). Such a parasite[4] weighing 70,000 lb could satisfy the M = .9, sea-level penetration range requirements while carrying the same 16,000-lb

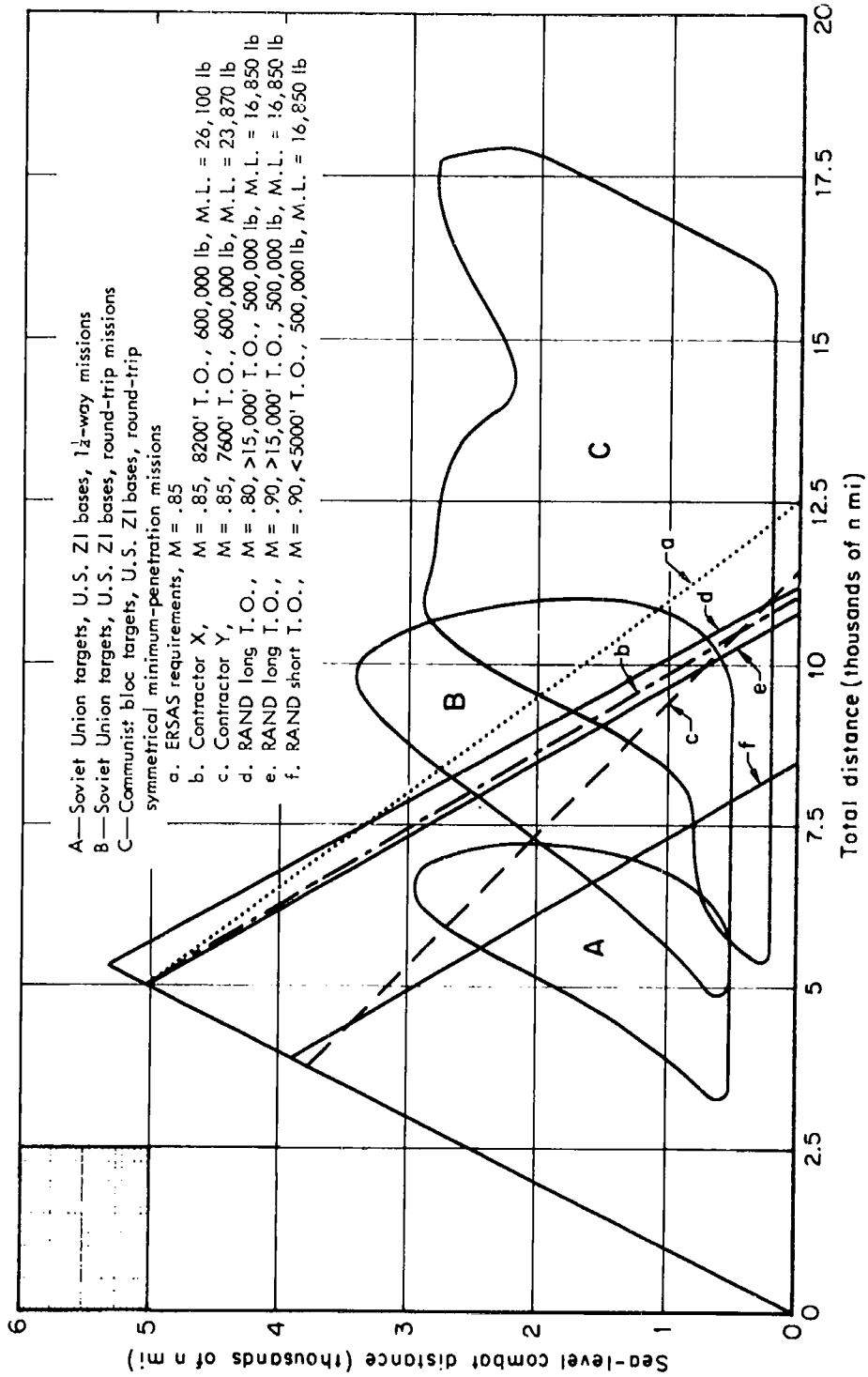

Fig. 1—Range requirements and capabilities of low-altitude bombers

military load as the 500,000-lb RAND long-range, low-altitude bombers of Fig. 1. A 600,000-lb Laminar Flow Control (LFC) Dromedary support aircraft[5] could carry such a parasite for over 100 hours--sufficient to conduct combat patrol missions that completely circumscribe the entire Communist bloc territory with sole reliance on U.S. ZI bases.[6] In the interest of economy, such a system might normally remain on ground alert, like the long-range tanker-supported bomber systems; in periods of tension, however, it could assume the combat patrol posture described in Ref. 6 with greatly reduced vulnerability and weapon delivery time (and with a very significant strike option time). In either posture, both peacetime and post-strike recovery of both components could be made non-stop to U.S. ZI bases. The Dromedary-carried parasite system in a combat patrol posture also offers significant bonus utility in a cold-war or limited-war surveillance/reconnaissance role. The far-ranging patrol routes described in Ref. 6* pass near many of the potential trouble areas of the northern hemisphere, thus affording opportunity for immediate and continuing surveillance and spot reconnaissance upon demand, should Cuba-like situations develop far from our shores.

This investigation seeks to determine and compare the requisite system physical characteristics and costs for achieving essentially the same low-altitude penetration and target destruction potential with alternative Dromedary-carried parasite and tanker-supported bomber systems. Results of the investigation are given first; determination of the requisite physical characteristics and costing of the systems are explained in subsequent Sections.

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*And summarized here in Fig. 8, p. 19.

II. RESULTS*

The investigation of requisite system physical characteristics has led to the selection of four "equally effective" systems of interest for comparisons of pre-strike vulnerability and cost. When supported and operated as outlined below, all combat aircraft of these systems are capable of .9 M sea-level penetration and withdrawal along similar minimum-penetration routes to approximately 90 to 95 per cent** of Communist bloc territory (target region C of Fig. 1) with military loads of 16,000 lb. A representative military load is considered to be divided equally between a four-man crew (with equipment and furnishings) and weapons (such as eight 1000-lb short-range air-to-surface missiles). Thus, exclusive of pre-attack vulnerability differences (and disregarding differences in physical size of the combat aircraft), all systems have essentially the same penetration and target destruction potential.

In view of great uncertainties concerning future enemy attack capabilities--as well as our own force posture, alert state, and performance of our warning and defense systems--evaluation of pre-strike vulnerability of the systems is necessarily a highly conjectural matter. Detailed quantitative estimates corresponding to numerous combinations of different assumptions are possible, but are not considered to be appropriate to a preliminary appraisal such as this. Rather, we have chosen to rank the systems qualitatively as to their relative pre-strike vulnerability to enemy attack on the basis of our subjective judgment. This judgment is intended to reflect the major differences in basing and operating characteristics of the systems, as will become evident from the ensuing descriptions and discussions. These four systems are

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*The systems described in this section were conceived some time ago and do not reflect some later concepts that are now under consideration.

**To reach the remaining few per cent of the target region requires an extravagant increase in design range capabilities of the systems. It would be more prudent to reach these most distant targets by exchanging military load for additional fuel or by flying a very small portion of the penetration or withdrawal at high (more economical cruise) altitude.

described briefly in increasing order of pre-strike vulnerability as follows:

1. 74 per cent airborne alert: 70,000-lb parasite carried by 600,000-lb LFC Dromedary.
   (Operating on 100-hr combat patrol missions per Ref. 6. Peacetime and post-strike recovery of both components non-stop to U.S. ZI bases. Long runways required, hence no dispersal.)
2. Undispersed 50 per cent ground alert: 70,000-lb parasite carried by 600,000-lb LFC Dromedary.
   (Operating round-trip from U.S. ZI bases. Long runways required, hence no dispersal.)
3. Dispersed 50 per cent ground alert: 500,000-lb RAND STO bomber (f of Fig. 1) supported by similar 500,000-lb STO tankers.
   (Bombers operate round-trip from U.S. ZI bases. Average of 1.2 tankers required per bomber. 61 per cent of bombers rely on forward-based tankers which delay their takeoffs until bomber approach. 5000-ft runways are adequate for both bombers and tankers; hence, the aircraft can be widely dispersed to secondary airfields.)
4. Undispersed 50 per cent ground alert: 500,000-lb RAND LTO bomber (e of Fig. 1) supported by inherited 300,000-lb KC-135A tankers.
   (Bombers operate round-trip from U.S. ZI bases. Average of .8 tankers required per bomber. 45 per cent of bombers rely on forward-based tankers which delay their takeoffs until bomber approach. Long runways required for both aircraft, hence no dispersal.)

The 50 per cent ground alert [of Unit Equipment aircraft (UEAC)] * is representative of current SAC practice. Cost comparisons of systems 2, 3, and 4 thus permit relative evaluation of the Dromedary-carried parasite and tanker-supported bomber systems on a common alert posture basis. The 74 per cent (effective) airborne alert (of UE aircraft) of system 1 corresponds to a maximum continuous airborne-alert effort involving 100-hr missions (93 hr effective), such as the combat patrol missions of Ref. 6. Cost comparison of systems 1 and 2 thus permits assessment of the incremental cost of achieving maximum airborne-alert capability of the Dromedary-carried parasite system on a continuous basis. The tanker-supported bomber systems considered here are inappropriate for airborne-alert operation because of the exorbitant increase

* The number of various aircraft authorized for specific Table of Organization units by Headquarters USAF.

in the number of tankers that would result (particularly the forward-based ones, which are here operated on short-duration missions in order to be efficient refuelers and on which much of the required distance capability of the bombers depends).*

Cost comparisons of these four selected systems are shown in Fig. 2, in which total system cost (R&D, investment, and five years of operation) is displayed versus number of combat aircraft on alert. Of the ground-alert systems (2, 3, and 4), the least expensive is also the most vulnerable--probably unacceptably so--to pre-strike attack (system 4, the undispersed LTO bomber + KC-135A). the incremental cost of reducing system pre-strike vulnerability by dispersal of STO bombers and tankers (system 3) is from three to four times as much as by using undispersed Dromedary-carried parasites (system 2, costing only about 15 per cent more than system 4) which rely on U.S. ZI bases only and, hence, are believed to be less vulnerable than the delayed-takeoff, forward-based tankers required in both tanker-supported bomber systems. The STO system 3 is thus a very poor alternative--in fact, for somewhat less than its cost, the Dromedary-carried parasites can be operated on maximum continuous airborne alert (system 1) to achieve by far the most invulnerable of all these systems.

On the basis of alert combat aircraft, the cost of continuous airborne alert for the Dromedary-carried parasite (system 1) is only about 30 per cent greater than that of the 50 per cent ground-alert posture (system 2). This is a startlingly moderate airborne-alert cost compared to experience with the B-52 system. The reason is primarily the very long duration (100 hr) combat patrol missions permitted by the selected Dromedary which in turn permit 74 per cent of the UE combat aircraft to be kept continuously airborne in positions for effective launch; this contrasts with B-52 maximum effective airborne alert of about 30 per cent on 24-hr missions. On the basis of UE aircraft, the cost of maximum continuous airborne alert for the Dromedary-

*An efficient aerial-refueled airborne-alert system would make use of Dromedary long-endurance tankers; however, other investigations[4,7] demonstrate that for the long distances and flight times here involved, parasiting, i.e., system 1, is much to be preferred to aerial refueling.

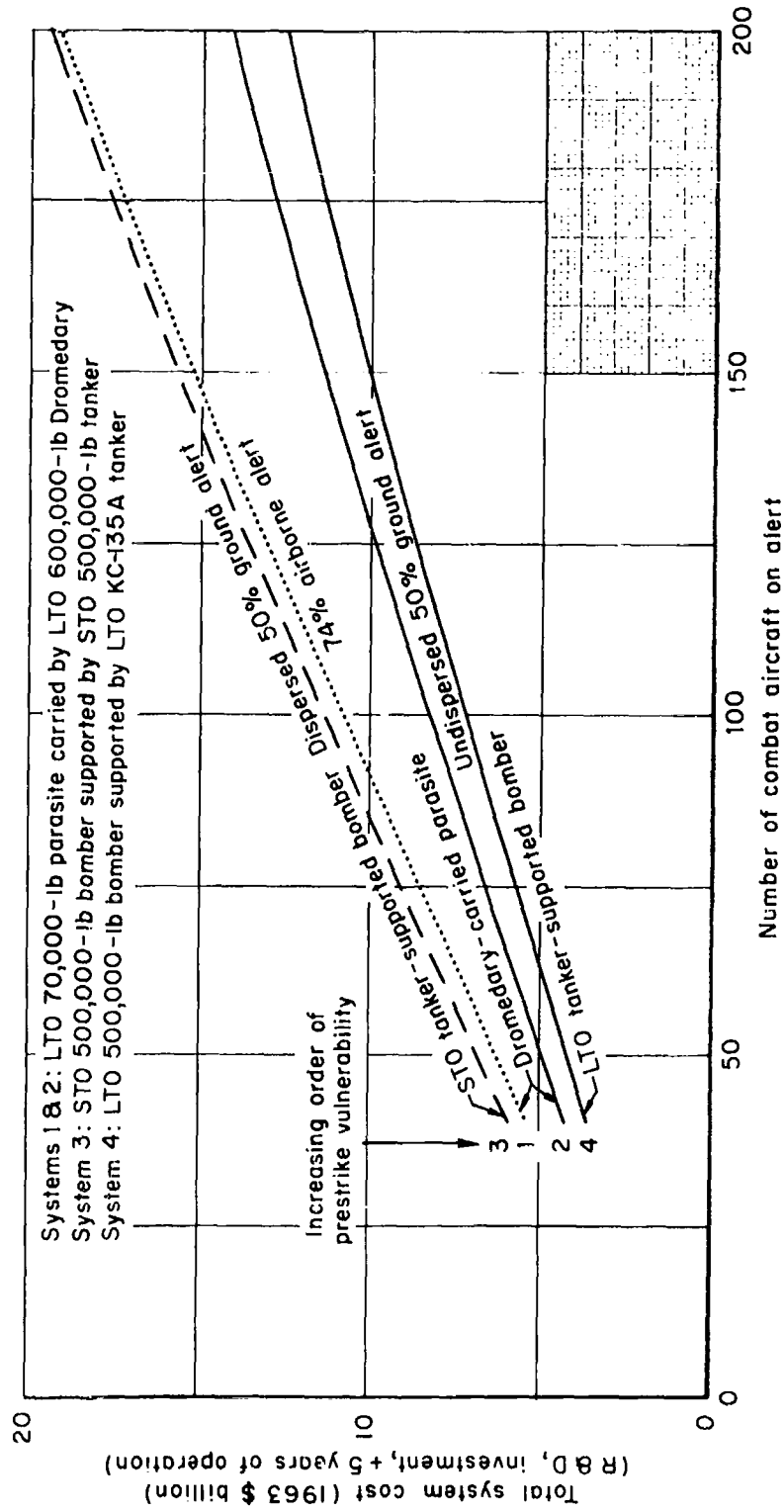

Fig. 2—Cost comparison of four low-altitude manned penetrator systems having equal penetration and target destruction potential

carried parasite is about 80 per cent greater than that of 50 per cent ground alert; this seems a not unreasonable cost increase in view of the superior pre-strike invulnerability and much-reduced response time (or significant strike option time) that it would provide--as well as the bonus utility that it would offer in cold-war or limited-war surveillance/reconnaissance capability. Of course, if the airborne-alert posture were exercised at less than maximum degree or only occasionally in periods of tension, its cost would be intermediate to those of systems 1 and 2, so that partial or part-time invulnerability could be obtained at very low cost indeed with the Dromedary-carried parasite system. This moderate and ready cost-invulnerability exchange is a versatility feature of efficient airborne-alert systems that is lacking in the tanker-supported bomber systems 3 and 4. Thus, the Dromedary-carried parasite system offers a unique potential for economical and effective quick response to changing tensions.

Tanker support accounts for about 32 per cent of the total cost for the STO bomber system 3 and only about 7 per cent for the LTO bomber system 4 (the KC-135A tankers being assumed inherited at no R&D or investment cost in system 4). Thus, even rather drastic reductions in the required tanker/bomber ratios from those determined herein would not cause the tanker-supported bomber systems to overshadow the superior vulnerability and cost position of the Dromedary-carried parasite systems displayed in Fig. 2.

A summary cost breakdown of the systems at force levels corresponding to 100 alert combat aircraft is given in Table 1. Details of system physical characteristics and costs are discussed in subsequent Sections.

While the specific results of this comparative analysis may not be totally valid because of changing circumstances, the methodology exercised therein should be useful to persons responsible for planning future strategic systems. In particular, strategic planners and operations analysts currently engaged in delineating preferred low-altitude manned strategic penetrator systems should find the techniques useful in comparing alternative systems, as is prescribed in the Project Definition Phase (DOD Directive 3200.9).

Table 1

SUMMARY COST ALLOCATION FOR 100 ALERT COMBAT AIRCRAFT
(In millions of 1963 dollars)

System Number	1	2	3	4
Basing	Undispersed	Undispersed	Dispersed	Undispersed
Alert Posture	74% Airborne Alert	50% Ground Alert	50% Ground Alert	50% Ground Alert
Combat Aircraft	70,000 lb Parasite	70,000 lb Parasite	500,000 lb STO Bomber	500,000 lb LTO Bomber
Support Aircraft	600,000 lb Dromedary	600,000 lb Dromedary	500,000 lb STO Tanker	KC-135A Tanker
No. of Unit Equipment Combat Aircraft	135	200	200	200
No. of Unit Equipment Support Aircraft	135	200	240	158
RDT&E Cost				
Bomber/Dromedary-Parasite	$ 753.0	$ 753.0	$ 790.0	$ 610.0
FIAM	65.0	65.0	65.0	65.0
Sub-total	818.0	818.0	855.0	675.0
Tankers	--	--	190.0	--
Total RDT&E Cost	$ 818.0	$ 818.0	$ 1,045.0	$ 675.0
Initial Investment Cost				
Bomber/Dromedary-Parasite	$ 4,100.0	$ 4,600.0	$ 3,925.0	$ 3,390.0
FIAM	210.0	306.0	306.0	306.0
Sub-total	4,310.0	4,906.0	4,231.0	3,696.0
Tankers	--	--	2,318.0	56.0
Total Initial Investment Cost	$ 4,310.0	$ 4,906.0	$ 6,549.0	$ 3,752.0
Annual Operating Cost				
Bomber/Dromedary-Parasite	1,103.0	432.0	435.0	384.0
FIAM	49.0	73.0	73.0	73.0
Sub-total	1,152.0	505.0	508.0	457.0
Tankers	--	--	212.0	93.0
Total Annual Operating Cost	$ 1,152.0	$ 505.0	$ 720.0	$ 550.0
RDT&E, Initial Investment + 5-hr A.O. Cost				
Bomber/Dromedary-Parasite	10,368.0	7,513.0	6,890.0	5,920.0
FIAM	520.0	736.0	736.0	736.0
Sub-total	10,888.0	8,249.0	7,626.0	6,656.0
Tankers	--	--	3,568.0	521.0
Total	$10,883.0	$ 8,249.0	$11,194.0	$ 7,177.0

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III. SYSTEM PHYSICAL CHARACTERISTICS

DROMEDARY-CARRIED PARASITE SYSTEMS 1 AND 2

Parasite Distance Requirements

It is visualized that the Dromedary-carried parasite system might operate either on airborne alert (system 1, on the continuous combat patrol of Ref. 6) or on ground alert (system 2). In either posture, the Dromedary is expected to provide the necessary endurance and cruising range to permit launch and recovery of the parasite combat aircraft anywhere along the entire periphery of Communist bloc territory (target region C of Fig. 1). Low-altitude combat distance for penetration and withdrawal through defenses is thus the only distance requirement for the parasite. This omnidirectional approach permits penetration by the parasite combat aircraft along minimum-distance routes to targets, and withdrawal along these same routes, if desired in order to capitalize on pre-strike defense busting.

Utilizing such symmetrical minimum-penetration and withdrawal routes, the cumulative percentage of area reached versus one-way distance from the Communist bloc border is shown in Fig. 3. This simple curve is believed to be a reasonable crude approximation of the manner in which actual future targets, in a gross sense, might be distributed, i.e., uniformly in density. It seems unlikely that the enemy could achieve or would necessarily desire any overwhelmingly different distribution. Also, our choice of this uniform density assumption throughout this study is believed to be an impartial one from the standpoint of the system comparisons being made. At the very least, it avoids tying prognostications for future weapon systems to the vagrant popularity of various current specific target systems.

Figure 3, then, is used as a representation of target accumulation versus combat radius for the Dromedary-carried parasite; a like treatment involving similar symmetrical minimum-penetration and withdrawal routes and uniform target density will be employed for the tanker-supported bomber systems.

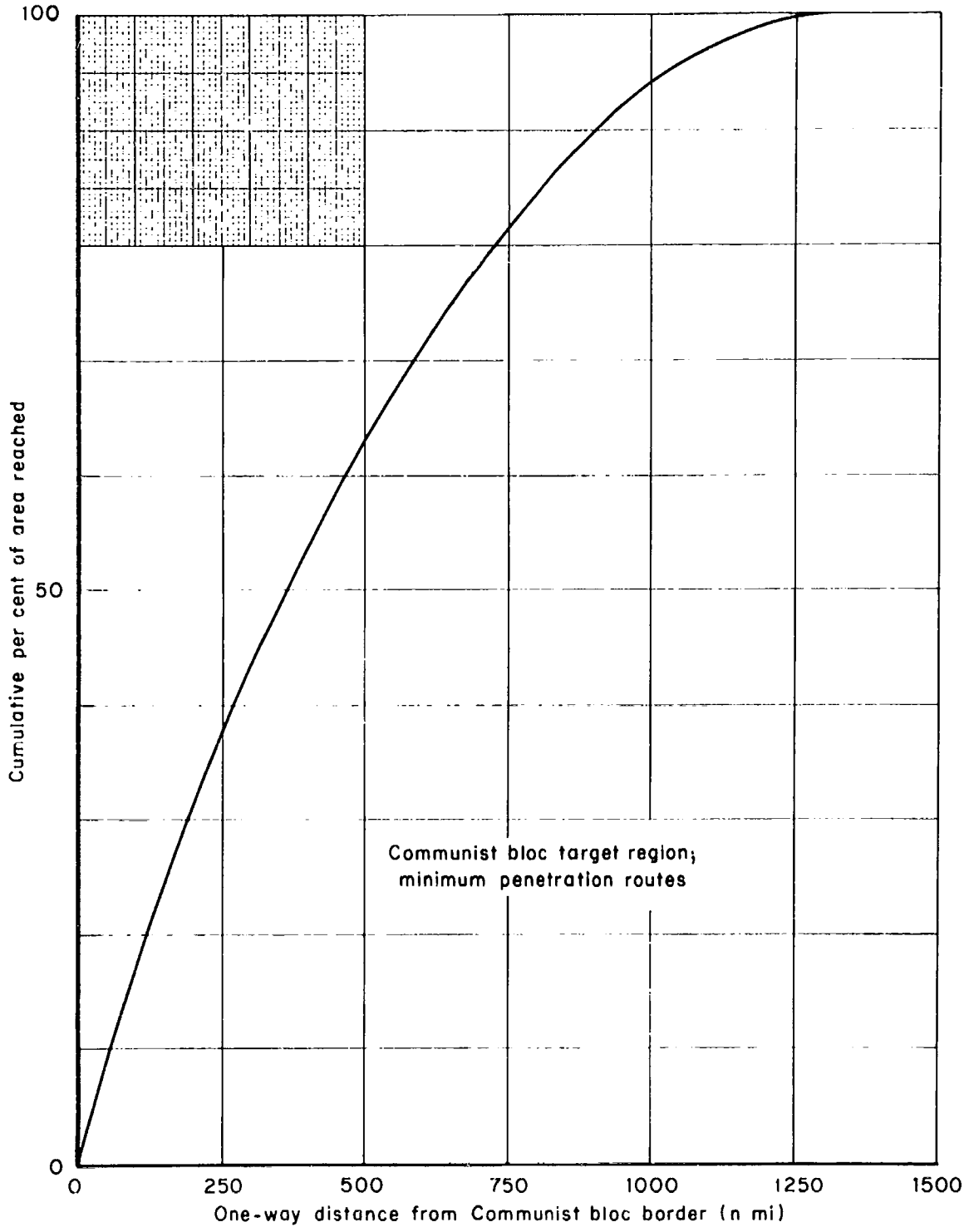

Fig. 3—Target area accumulation versus penetration distance

Parasite Combat Radius Capabilities

Reference 4 is a brief generalized design study of a family of small .9 M low-altitude bombers intended primarily for use as parasite penetrators for the kinds of missions under consideration here. These bombers require quite long runways for takeoff even when only partially loaded with a minimum fuel load. Thus, they could not easily be dispersed to secondary airfields, and would require coupling to the parent Dromedary aircraft soon after takeoff from SAC bases. It is visualized that the parasite crew would then enter the Dromedary to rest or assist its crew until embarking on a training or combat mission in the then fully fueled parasite.

For the purpose of selecting a preferred parasite, the data of Ref. 4 have been extrapolated to lower gross weights and extended to include military load as a variable (under the assumption that fuel and military load are interchangeable without incurring drag or structural weight changes). The resulting .9 M sea-level combat radius capabilities of these LTO parasite bombers are shown in Fig. 4.

It is also desirable to consider similar STO low-altitude bombers--not for reasons of dispersal in this study (since the Dromedary carrier is not very amenable to dispersal), but because such bombers could have significant alternative utility as tactical combat aircraft in limited warfare involving forward basing on small airfields. Data from Ref. 3, 8, and other unpublished RAND studies of such aircraft suitable for 5000-ft runways, have been extended in a manner analogous to that employed above for LTO parasites. The resulting .9 M sea-level combat radius capabilities of these STO parasite bombers are shown in Fig. 5.

Parasite Selection

The selection of a preferred parasite bomber is facilitated by combining the target-distance relationship of Fig. 3 with the combat radius capabilities of Figs. 4 and 5 in a manner such that the relative efficiencies of the various possible parasites are readily observable. For this purpose, half the military load is assumed to

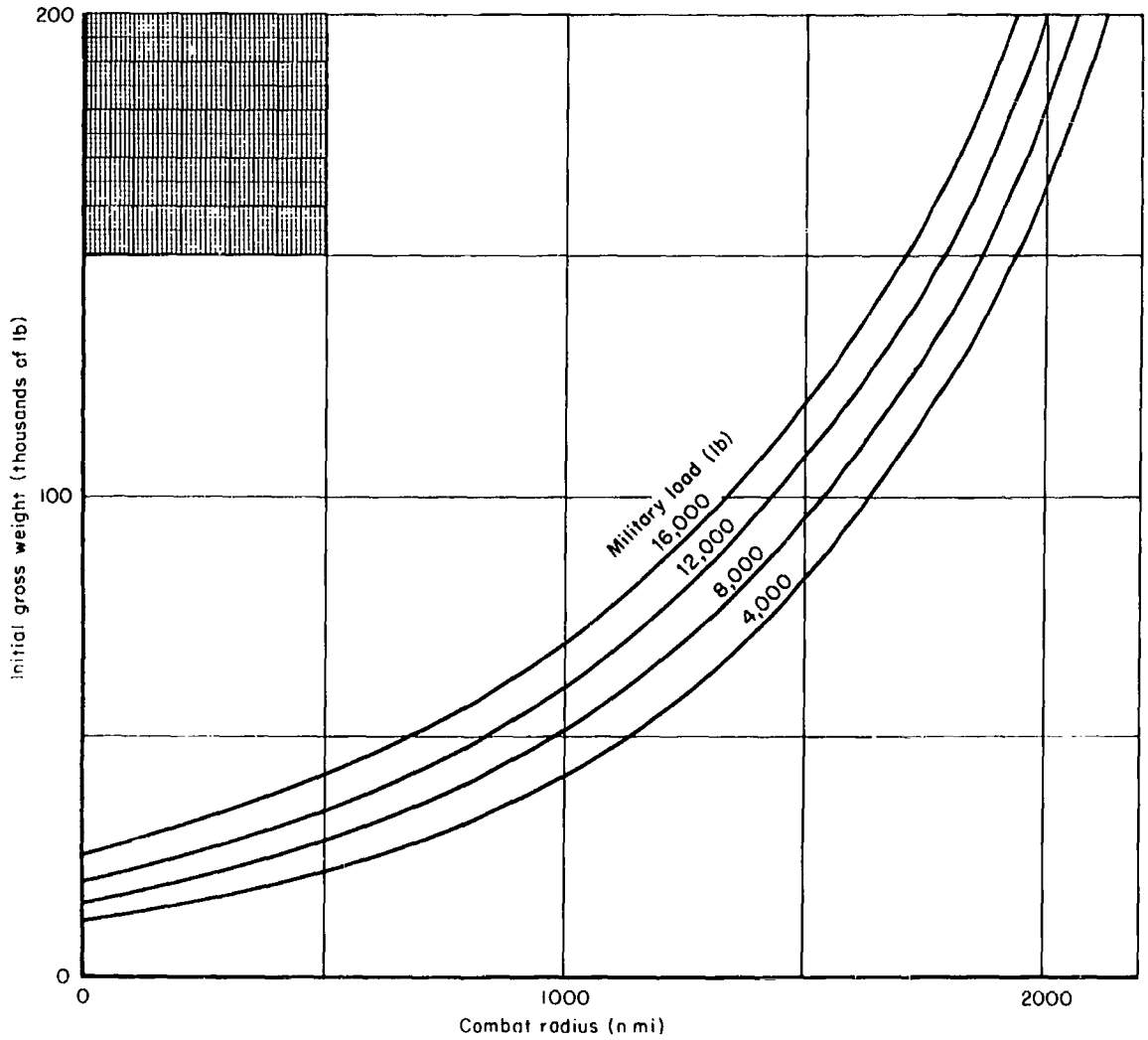

Fig. 4 — LTO parasite combat radius capabilities
(.9M, sea level)

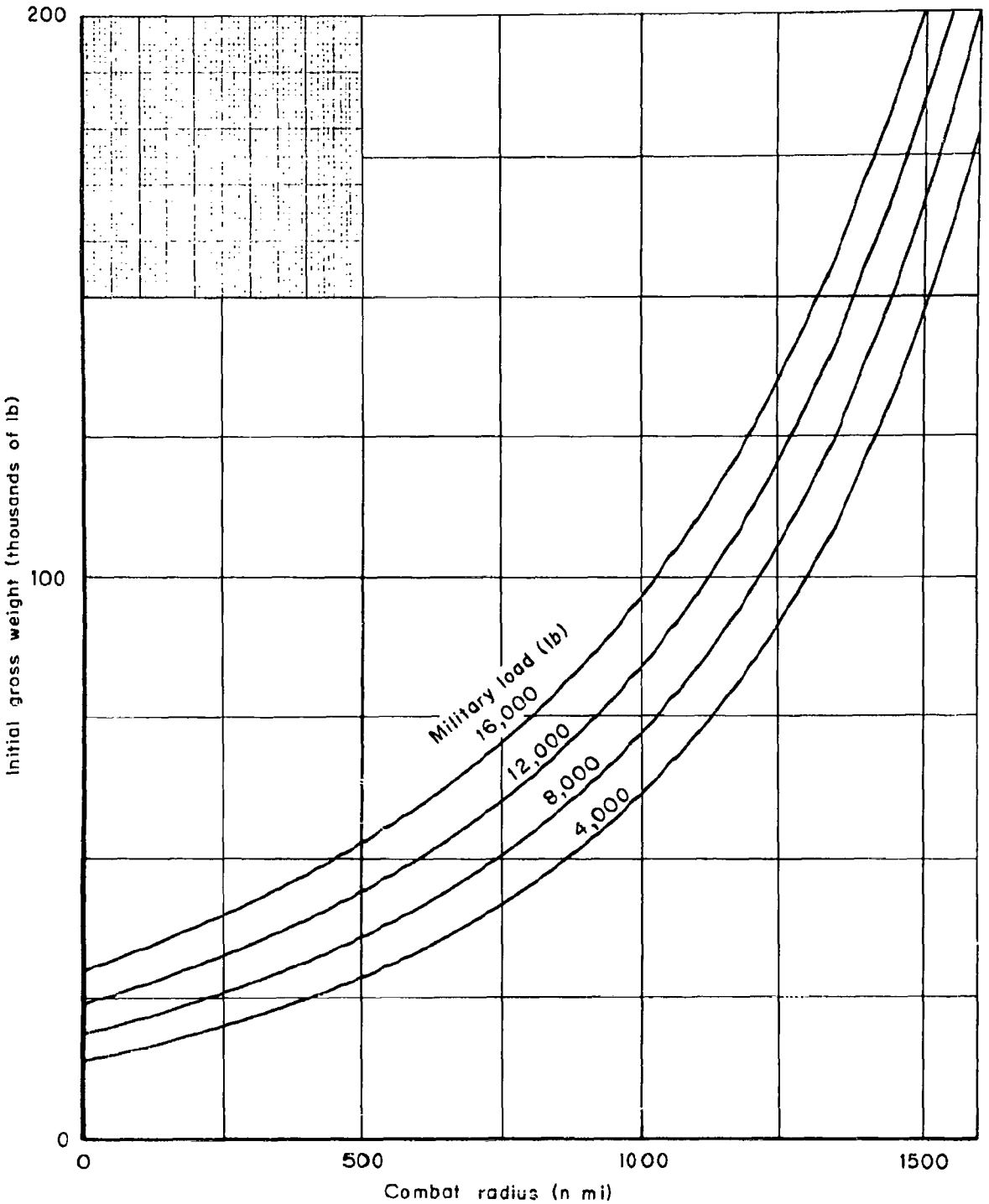

Fig. 5— STO parasite combat radius capabilities
(.9M, sea level)

be devoted to crew with associated furnishings and equipment (2000 lb per man, total) and the other half is assumed to consist of 1000-lb weapons (such as the accurate short-range, forward-launched air-to-surface missiles, FIAM, of Ref. 9). It is also assumed that the parasite will be launched and recovered by the Dromedary parent aircraft 100 n mi outside the Communist bloc border (preferably at low altitude in order to stay below the enemy ground-based radar horizon).

These assumptions permit plotting cumulative percentages of target area reached versus parasite gross weight per 1000-lb weapon for various parasite gross weights and military loads as shown in Fig. 6 (LTO parasite) and Fig. 7 (STO parasite). A crude measure of parasite efficiency is denoted on such plots by the magnitude of the slope of radial lines through the origin (target area accumulation per unit of parasite gross weight required for each weapon delivered). Since Ref. 5 shows that the Dromedary gross weight required for a given endurance capability is very nearly a constant multiple of its payload (the parasite gross weight), such radial lines are indicators of total system efficiency as well. Greatest efficiency is seen to be associated with the largest military load (16,000 lb, 4 men, 8 weapons); the incremental efficiency over the 12,000-lb military load is small, however, so little or no benefit is to be expected from still larger military loads. Maximum efficiency is, of course, obtained at the point where the maximum-slope radial is tangent to the family of military-load and gross weight curves (indicated by a triangle). A considerable and desirable increase in target area accumulation can be achieved with small sacrifice in efficiency by selecting a somewhat greater gross weight and combat radius point along the 16,000-lb military-load curve. Hence, we select a 70,000-lb gross weight LTO parasite (16,000-lb military load, 1000-n mi combat radius, 90 per cent target area accumulation at 8750-lb gross weight per weapon) for purposes of our system comparisons.* Beyond this gross weight and

*Physical characteristics are summarized in Table 2, p. 21. More detailed information concerning the parasite may be obtained from Ref. 4.

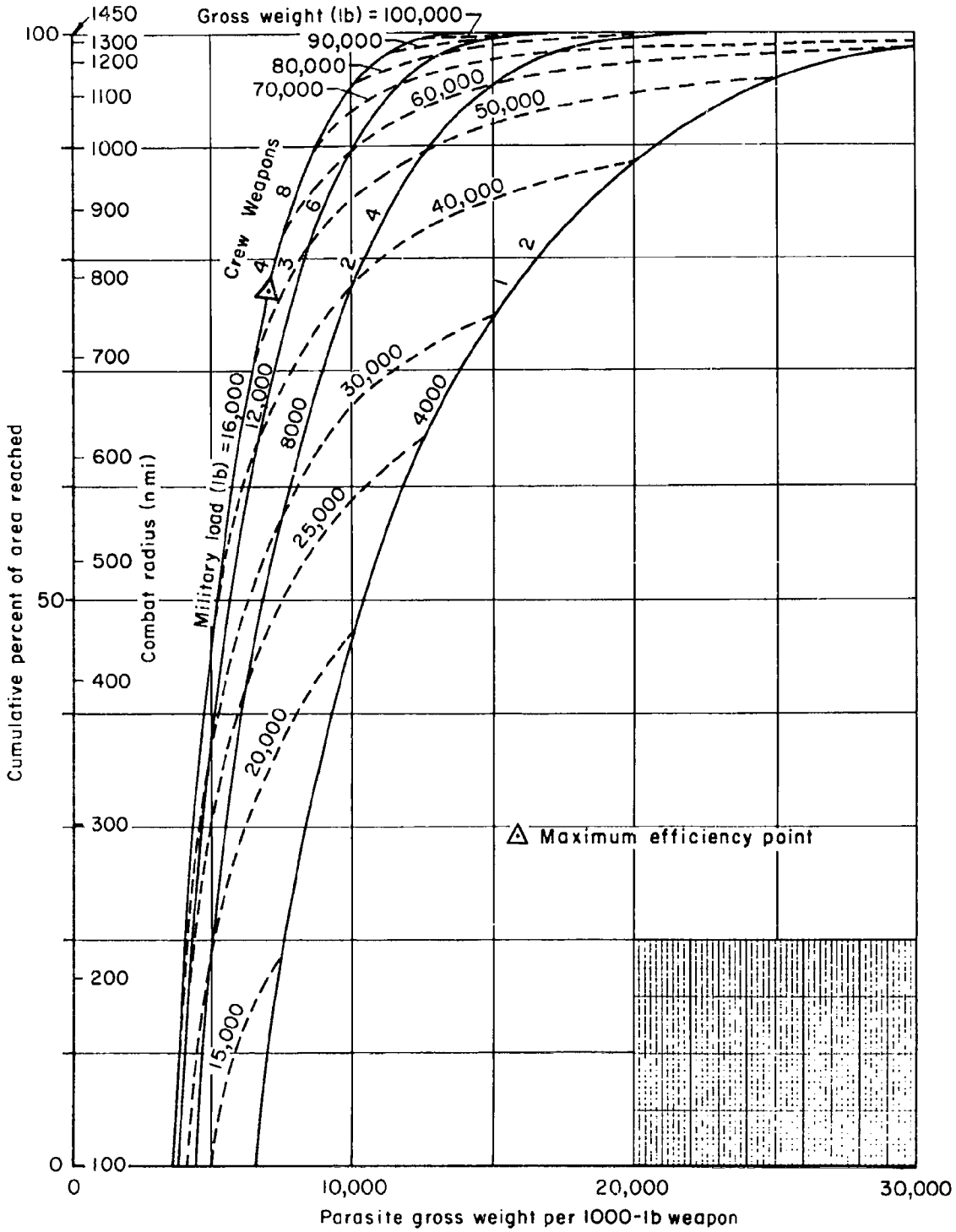

Fig. 6—LTO parasite: target area accumulation versus gross weight per weapon

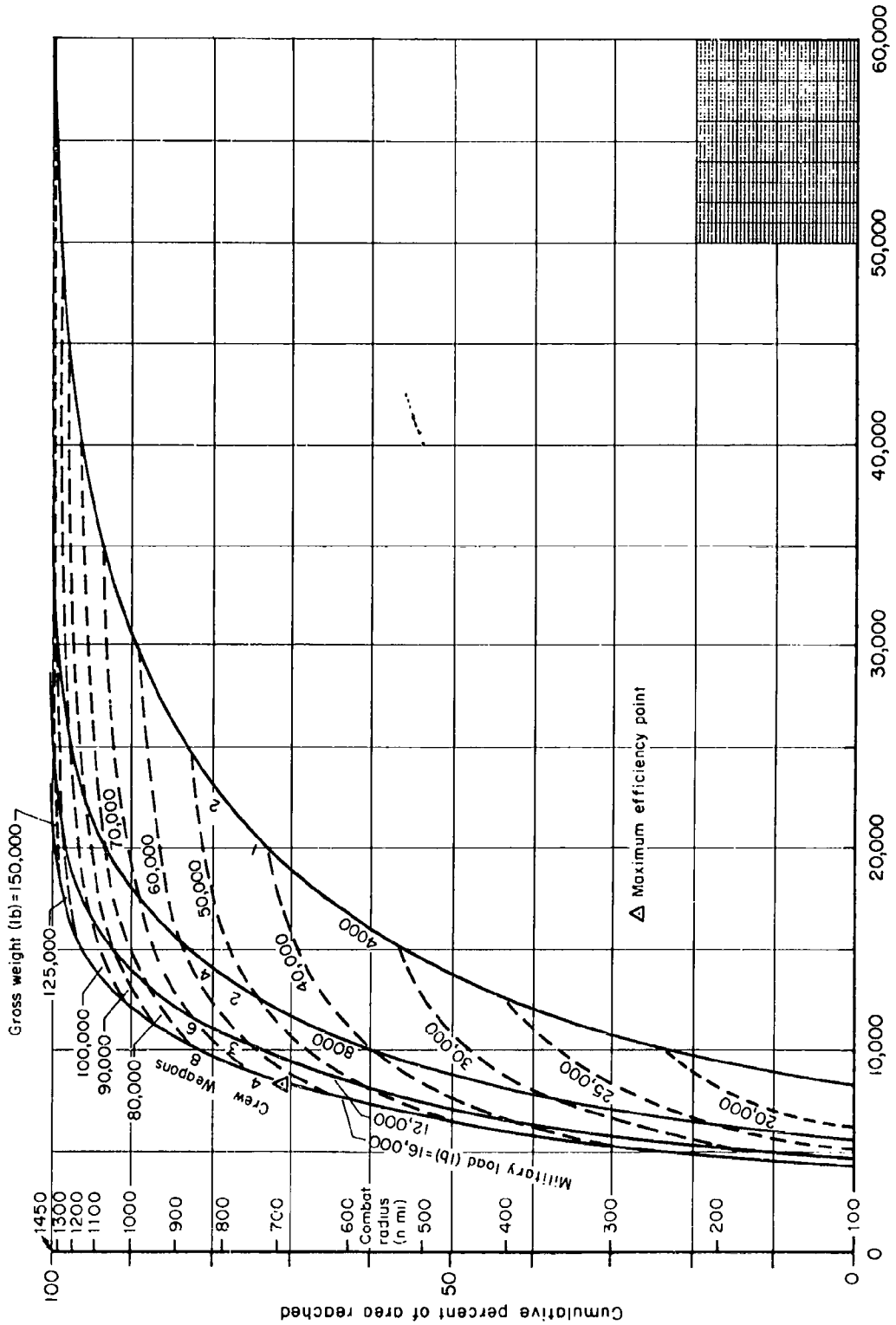

Fig. 7 — STO parasite: target area accumulation versus gross weight per weapon

radius, efficiency deteriorates rapidly. Rather than designing the entire parasite force to reach all of the target area with 16,000-lb military loads, it would be more prudent to reach the most distant 10 per cent of the target area by exchanging military load for additional fuel on a few of the 70,000-lb parasites, or by flying a very small portion of the penetration or withdrawal to such targets at high (more economical cruise) altitude.

The same 90 per cent target area accumulation with the STO parasite would require about 95,000-lb gross weight at 16,000-lb military load, or almost 12,000-lb gross weight per weapon. The resulting 25 per cent decrease in efficiency from that of the LTO parasite is believed to be too severe a penalty to be justified by the alternative-use value of the STO feature; hence, the STO parasite is omitted from further system comparisons here. It is quite possible, of course, that a development program for the 70,000-lb LTO parasite could include--at moderate additional development cost--an alternative STO version for use in tactical theatre warfare, should such an aircraft be desired.

Dromedary Selection

Reference 6 analyzes combat patrol operations of Dromedary aircraft of varying endurance capability. The most desirable of these operations require 100-hr missions with 18-hr peacetime landing fuel reserves. This total endurance capability of 118 hr permits far-flung patrol routes that completely circumscribe the Communist bloc periphery--as shown in Fig. 8--to yield full target area coverage with minimum response time and with both peacetime and post-strike recovery of the aircraft non-stop to U.S. ZI bases. Effective time on these 100-hr missions is 93 hr; i.e., when approaching the U.S. ZI after 93 hr in the air, the Dromedary can still turn around, launch its weapons against some Communist targets, and return to a ZI base. With forward post-strike recovery at overseas bases, similar 100-hr patrol missions can be achieved with 109-hr endurance capability.

The selected 70,000-lb parasite can be carried at 30,000-ft average cruise altitude for a 118-hr endurance capability (U.S. ZI

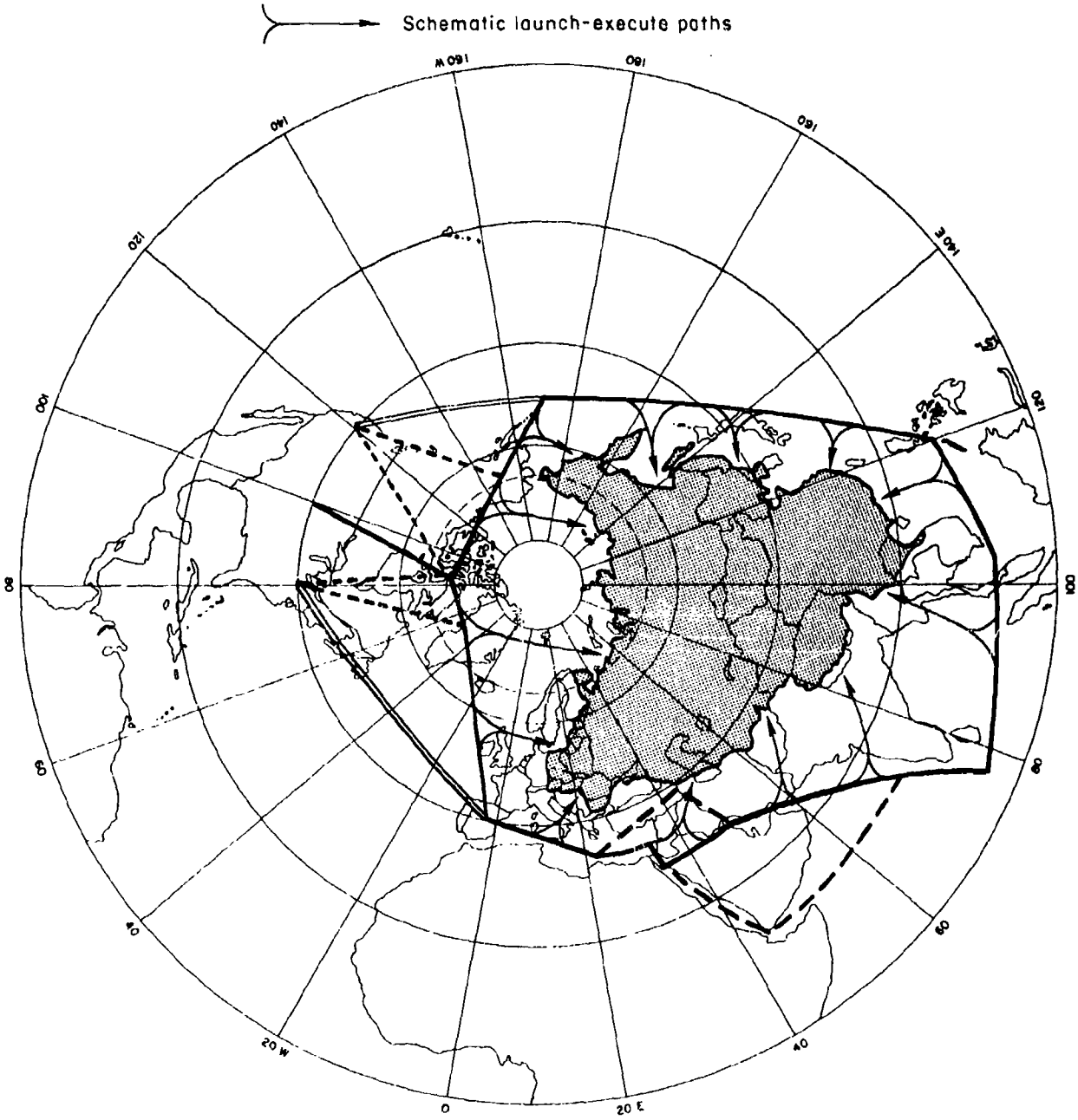

Fig. 8—Combat patrol route for Dromedary-carried parasite systems

post-strike recovery) by a 600,000-lb Laminar Flow Control (LFC) Dromedary, or for a 109-hr endurance capability (forward post-strike recovery) by a 500,000-lb LFC Dromedary--as shown by Fig. 8b of Ref. 5.*

The advantages of ZI post-strike recovery are believed to outweigh the associated 100,000-lb incremental Dromedary gross-weight penalty; hence, the 600,000-lb LFC Dromedary is selected as the parasite carrier for our system comparisons. Physical characteristics of the selected Dromedary are summarized in Table 2.** More detailed information may be obtained from Ref. 5. Since these Dromedary aircraft, like the LTO parasite, require rather long runways, the Dromedary-carried parasite systems cannot be easily dispersed to secondary airfields. They are eminently suited to airborne-alert operations, however, so a maximum airborne-alert posture, as well as a non-dispersed, 50 per cent ground-alert posture, will be considered.

TANKER-SUPPORTED BOMBER SYSTEMS 3 AND 4

Distance Requirements

The same target attack considerations used for the Dromedary-carried parasite systems are retained for determining distance requirements of the tanker-supported bomber systems (Communist bloc target region, uniform density of targets, U.S. ZI round-trip minimum penetration routes, and initiation/termination of combat performance 100 n mi outside the border). For the tanker-supported bomber systems, symmetrical target-bound and return routes are used. As illustrated in Fig. 9, western U.S.-based bombers would generally attack eastern and southern targets from Pacific Ocean approaches; central U.S.-based

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*At zero-lift attitude (and assuming no interference drag), the drag of a completely exposed, 70,000-lb parasite at Dromedary cruising conditions is only about 3 per cent of that of the Dromedary; hence, it may be disregarded, and the parasite treated as though it were the variable internal payload considered in Ref. 5.

**Parentheses in right-hand column of figures refer to words in parentheses in Characteristics column.

Table 2

PHYSICAL CHARACTERISTICS SUMMARY FOR DROMEDARY-CARRIED PARASITE

Characteristics	LFC Dromedary	Parasite
Maximum gross weight, lb	600,000	70,000
Maximum wing loading, lb/ft^2	37.5	200
Performance		
Average (initial) long-endurance (range) cruise altitude, ft	30,000	(22,000)
Long-endurance (range) cruise speed, kn (M)	207	(.9)
Maximum endurance, hr	118[a]	--
Max. long-endurance (range) cruise distance, n mi	24,500[a]	(4,660)[b]
Sea-level combat speed, M	--	.9
Max. sea-level combat distance, n mi	--	2,020[b]
Takeoff ground roll, ft	5,850	~15,000[c]
Dimensions		
Span, ft	438	49.5
Wing area, ft^2	16,000	350
Fuselage length, ft	201	80
Fuselage max. diameter, ft	10.8	7.3
Wing aspect ratio	12	7
Wing taper ratio	.6	.2
Wing average thickness ratio	.2	.1
Wing sweep angle, deg	0[d]	45[e]
Powerplant		
Main engines	4 turboprop	2 turbofan
Main engine S.L. static military horsepower (takeoff thrust, lb)	11,900	(16,300)
Auxiliary retractable engines for takeoff and climb	4 turbojet	--
Aux. engine takeoff thrust, lb	23,040	--
Weights, lb		
Military load {payload (weapons)	70,000	(8,000)
Military load {crew, furnishings + equipment	7,250[f]	8,000[g]
Maximum fuel	318,000	32,600
Oil	--	100
Fuel system	11,150	1,050
Installed main powerplant	10,400	4,990
Installed auxiliary powerplant	4,800	--
Wing	101,560	3,630
Empennage	11,340	880
Fuselage	27,000	5,020
Landing gear	27,000	3,150
Surface controls, hydraulics, and electrics	11,500	2,580

[a]Two-hour fuel reserve. [b]10% fuel reserve. [c]Less if lightly loaded. [d]40% chord line. [e]25% chord line. [f]Number of crew = 7. [g]Number of crew = 4.

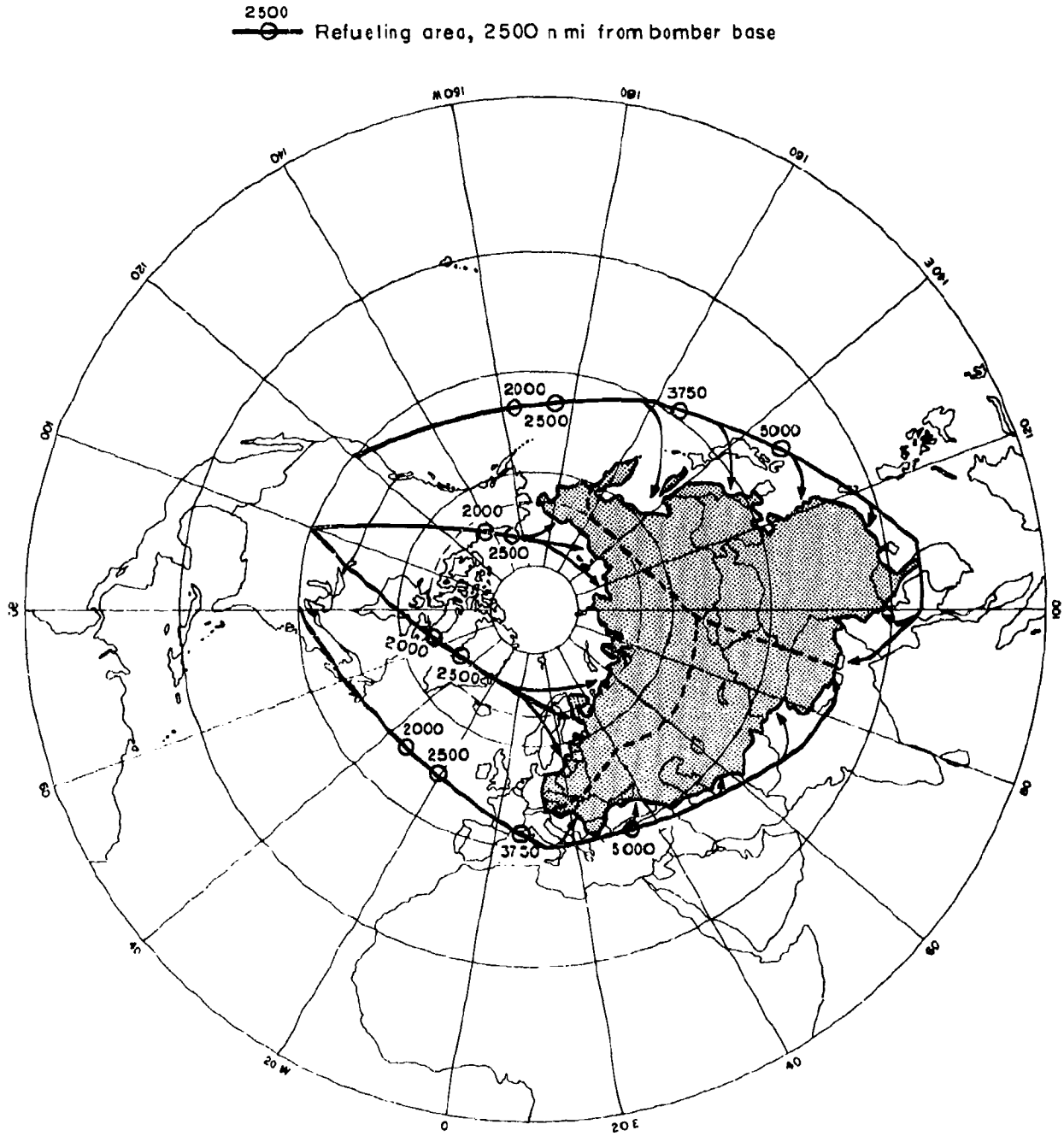

Fig. 9 — Attack routes for tanker-supported bomber systems

bombers would attack northern and central targets via polar routes; eastern U.S.-based bombers would generally attack western and southern targets from Atlantic and Mediterranean approaches.

The resulting distance requirements are shown in Fig. 10 (an enlargement of part of Fig. 1, p. 2), which includes the locational relationships among the target sub-regions. Figure 10 also includes symbols which graduate the target region into the percentages of area accumulated (reachable) by aircraft whose range exchange lines cut the target region at progressively increasing distances, and at total distance/combat distance slopes between the limits of 1.5:1 and 3:1. These are representative slope limits for low-altitude bombers as typified by the RAND- and contractor-study bombers of Fig. 1; they are indicated in Fig. 10 by the two, short, straight-line segments associated with each area-accumulation graduation. Any aircraft whose range exchange line cuts completely across the target region and passes through, for example, the 50 per cent area accumulation graduation with a slope between these limits, is capable of reaching 50 per cent of the target area on symmetrical U.S. ZI round-trip minimum-penetration-distance missions, with its penetration and withdrawal performed under combat performance conditions.

Figure 10, then, is a ready display of distance requirements for the tanker-supported bomber systems under operational assumptions analogous to those utilized for the Dromedary-carried parasite systems. When overlaid with various bomber-tanker combination range exchange lines, it permits determination of the number and location of refuelings, tanker/bomber ratio, and tanker basing locations required to achieve any desired percentage of target area accumulation.

Refueled Bomber Distance Capabilities

Two tanker-supported, large, long-range, low-altitude bomber systems are considered for our systems comparisons. As representative of both the RAND and contractor study results of extended range low-altitude strike aircraft, system 4 utilizes the RAND 500,000-lb,

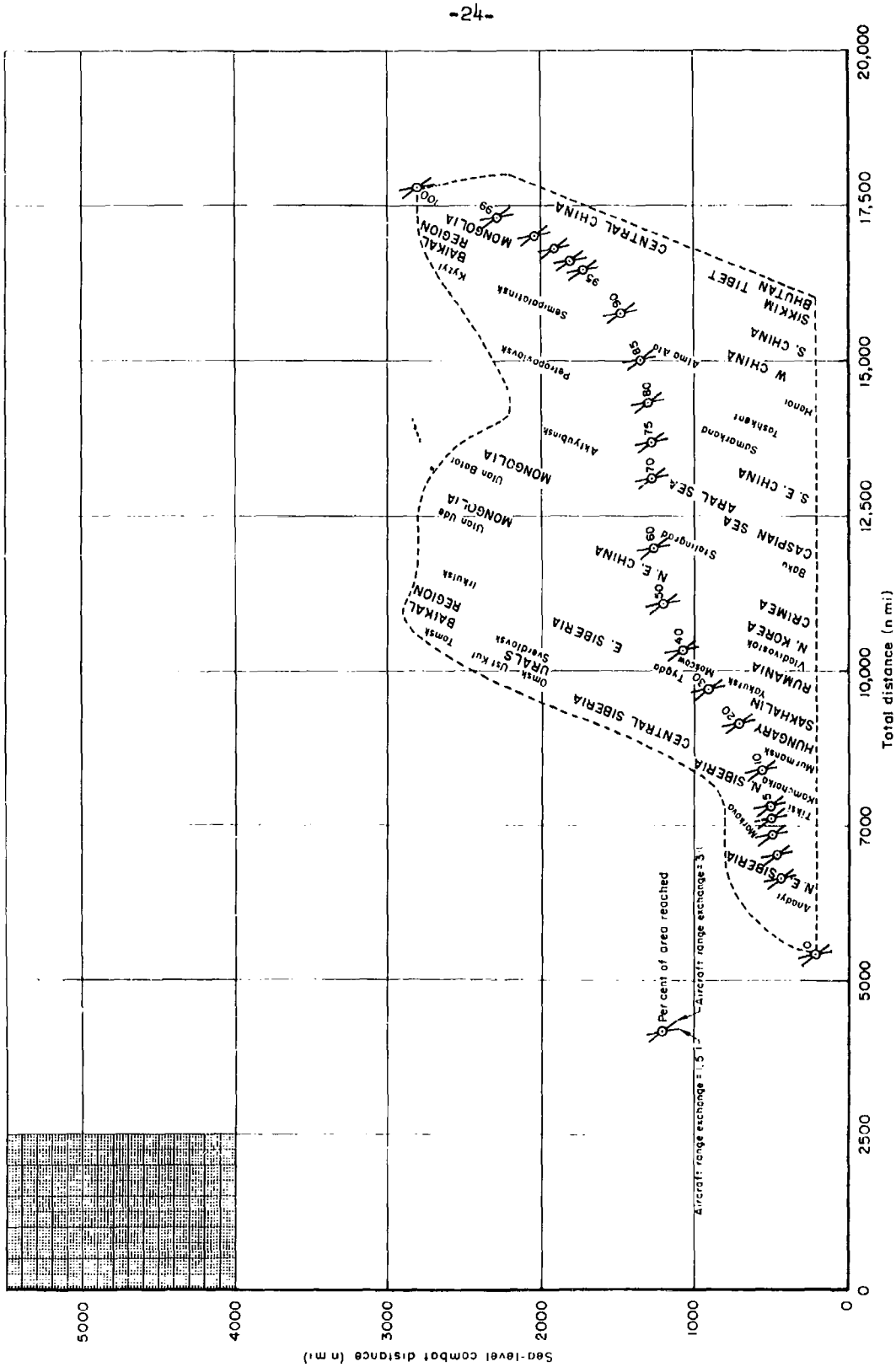

Fig. 10 — Round-trip distance requirements: communist bloc target region minimum penetration routes (symmetrical missions — U. S. ZI bases)

.9 M, LTO bomber* (e of Fig. 1, p. 2) supported by 297,000-lb KC-135A tankers. This LTO tanker choice is made because the KC-135A can be considered as inherited (free of procurement cost) and also because the long takeoff characteristics of the bomber preclude dispersal of the system to secondary airfields; hence, there is no particular point in selecting a new, expensive STO tanker for the LTO bomber. This system is highly vulnerable to enemy attack on the ground because of this inability to disperse; particularly so, because many of the tankers must be based in forward areas and, to be efficient refuelers, must await bomber approach before taking off--otherwise the tanker force requirements become exorbitant.

In order to alleviate this pre-strike vulnerability through dispersal of both bombers and tankers to secondary airfields, system 3 utilizes the RAND 500,000-lb, .9 M, STO bomber** (f of Fig. 1) supported by a tanker version of this same aircraft. These aircraft are capable of operation from 5000-ft runways, hence can be widely dispersed. Again, however, to achieve reasonable tanker force requirements, many of the tankers must be based in forward areas and their takeoffs must be delayed until bomber approach. The forward-based tanker support force thus still creates a significant pre-strike vulnerability problem for this system.

The weights of transfer fuel available and required for the aircraft of these systems are shown in Fig. 11 as functions of distance and tanker loiter time. Buddy refueling operations,*** in which one tanker refills one bomber, can occur out to distances from a mutual base of about 2000 n mi for the LTO system and about 2500 n mi for the STO system. Refilling the bombers at greater distances requires either more than one tanker per bomber or forward basing of the tankers.

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*Physical characteristics of this bomber are summarized in Table 3, p. 26. More detailed information appears in Refs. 1 and 2.

**Physical characteristics of this bomber are given in Table 3, p. 26. More detailed information appears in Ref. 3.

***In the interest of simplicity, the slight cruising speed incompatibility of the LTO bomber and KC-135A tanker is disregarded.

Table 3

PHYSICAL CHARACTERISTICS SUMMARY FOR TANKER-SUPPORTED BOMBERS

Characteristics	STO Bomber[a]	LTO Bomber[b]
Maximum gross weight, lb	500,000	500,000
Maximum wing loading, lb/ft^2	200	200
Performance		
Initial long-range cruise altitude, ft	23,800	20,700
Long-range cruise speed, M	.9	.9
Maximum range (10% reserve fuel), n mi	8,480	10,800
Sea-level combat speed, M	.9	.9
Max. sea-level combat distance (10% reserve fuel)	3,900	5,020
Takeoff ground roll, ft	4,100	~ 15,000[c]
Dimensions		
Span, ft	132	132
Wing area, ft^2	2,500	2,500
Fuselage length, ft	136	136
Fuselage max. diameter, ft	12	12
Wing aspect ratio	7	7
Wing taper ratio	.2	.2
Wing average thickness ratio	.1	.1
Wing sweep angle (25% chord line), deg	45	45
Powerplant		
Main engines	4 turbofan	4 turbofan
Main engine S.L. takeoff thrust, lb	76,950	67,650
Lift engines	14 turbojet	--
Lift engine S.L. takeoff thrust, lb	280,000	--
Weights, lb		
Military load { weapons	8,000	8,000
Military load { 4 crew, furnishings, and equipment	8,850	8,850
Maximum fuel	302,700	328,600
Oil	750	710
Fuel system	8,500	10,090
Installed main powerplant	20,900	18,600
Installed lift powerplant	23,900	--
Wing	51,900	50,900
Empennage	6,300	6,300
Fuselage	34,100	34,900
Landing gear	22,500	22,500
Surface controls, hydraulics, and electrics	11,600	10,550

[a] Support aircraft is tanker conversion of this same bomber.

[b] Support aircraft is KC-135A tanker.

[c] Less if lightly loaded.

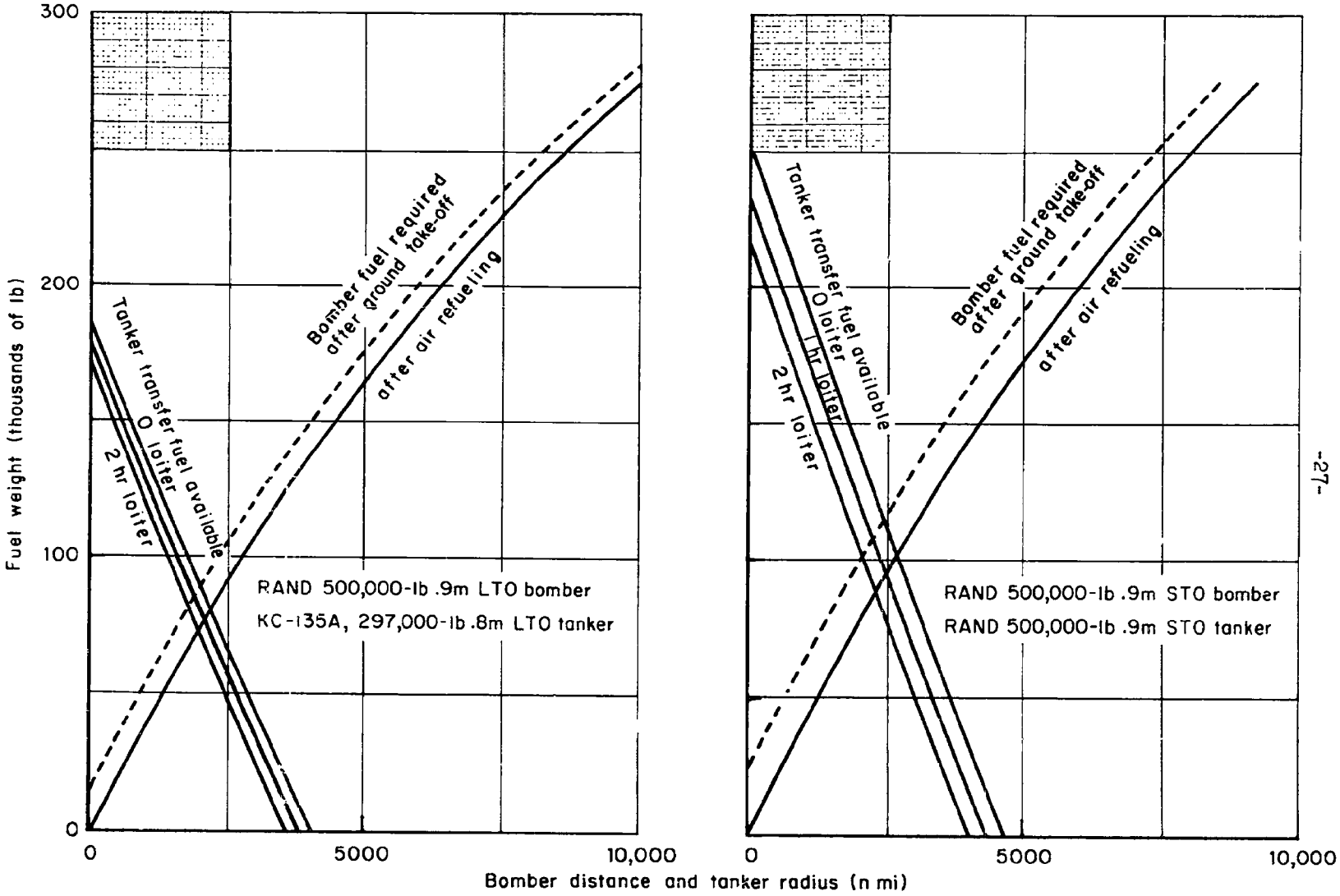

Fig. 11 — Transfer fuel characteristics of tanker-supported bomber systems

It is also evident from Fig. 11 that loitering of the tankers for extended periods would reduce their fuel transfer capabilities markedly. Thus, if forward-based tankers are used, they would be very inefficient refuelers if they took off simultaneously with the ZI-based bombers and loitered 5 to 10 hr awaiting bomber arrival.

To keep tanker force requirements within reasonable bounds, we utilize forward-based, delayed takeoff tankers when necessary to extend the distance capabilities of the bombers farther than is possible with buddy refueling. To provide operational flexibility, the available fuel transfer capability of these forward-based tankers is taken as 140,000 lb for the LTO KC-135A and 200,000 lb for the STO tanker, thus permitting about a 1000-n mi radius with no loiter. On pre-strike refuelings, the bomber is filled with fuel; on post-strike refuelings, it is given only enough fuel to return to its U.S. ZI base with a 10 per cent reserve.

The resulting bomber distance capabilities and required tanker/bomber ratios (T/B) associated with single pre-strike and/or post-strike refuelings occurring at various distances from the bomber base are shown in Fig. 12 (LTO system) and Fig. 13 (STO system) overlaid on the previously discussed distance requirements chart.

Selection of Tanker Operations and Basing

Specific modes of refueling from among the alternatives shown in Figs. 12 and 13 have been selected in order to establish representative tanker/bomber ratios and tanker basing locations so that system costs may be estimated. In doing so, we have assumed that the bomber force is subdivided into fractions equal in size to the incremental fractions of target area that may be accumulated as a result of each progressive increase in refueling distance. Each of these fractions of the bomber force thus requires a unique tanker/bomber ratio determined from Figs. 12 and 13. Likewise, its tankers must be based so that they can reach the refueling points with their 1000-n mi radius of action; hence, it was necessary to further subdivide these fractions of the bomber force into the portions flying

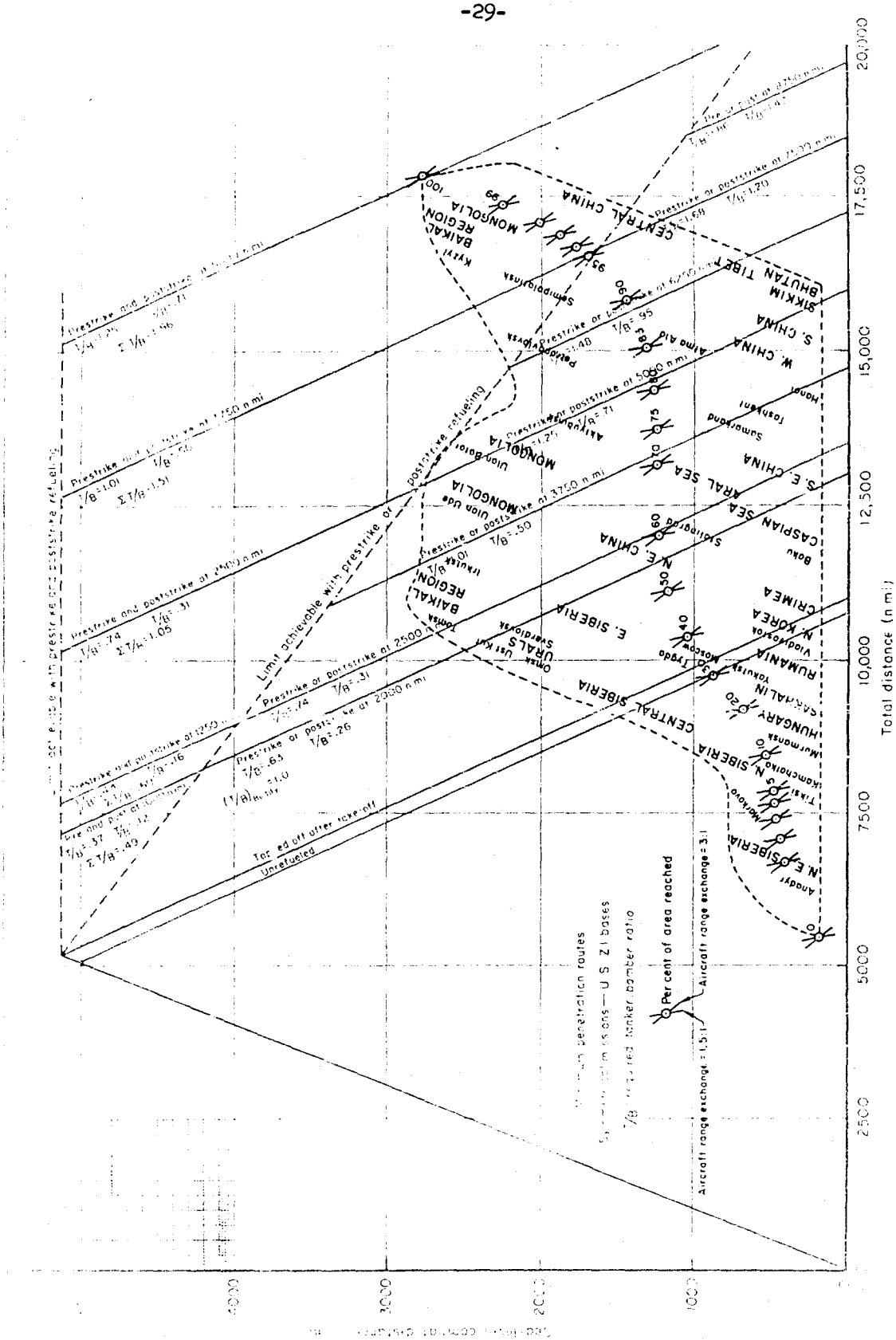

Fig. 12 — Refueled distance capabilities. RAND 500,000-lb .9M LTO bomber; KC-135A 297,000-lb .8M LTO tanker (single prestrike and/or postrike refueling)

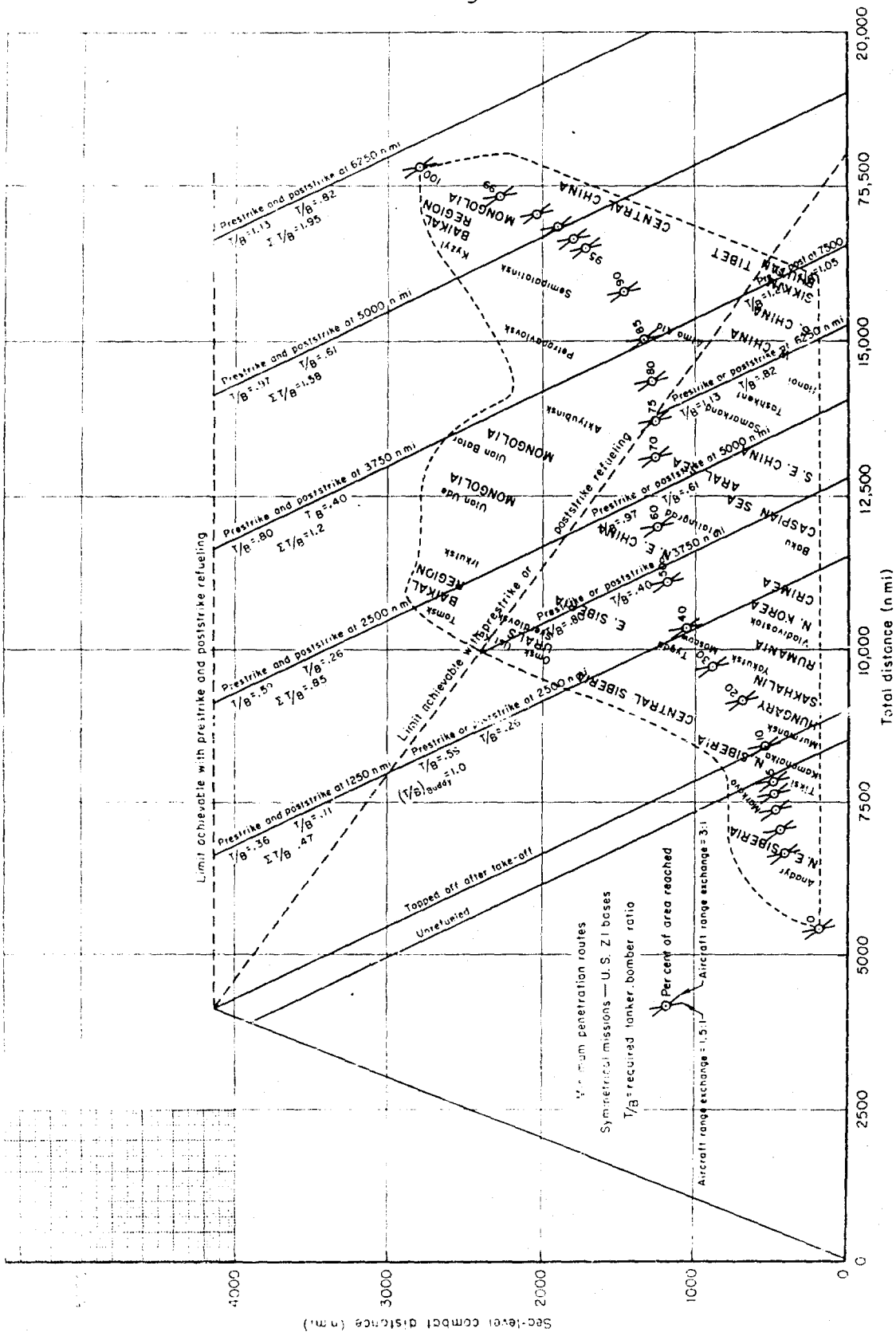

Fig. 13 — Refueled distance capabilities: RAND 500,000-lb, .9M STO bomber; RAND 500,000-lb, .9M STO tanker (single prestrike and/or postrike refueling)

the Pacific, Polar, and Atlantic routes of Fig. 9 (p. 22), and to choose appropriate tanker base locations for each. The use of particularly expensive operating locations is generally minimized. Post-strike refuelings are assumed to require different tankers than those used for pre-strike refuelings; the summations of tanker/bomber ratios required for pre-strike and post-strike refuelings are generally rounded upward to even multiples of .5. As in the Dromedary-carried parasite systems (and for similar reasons), we do not provide design distance capability to reach the most-distant few percentages of the target area.

The resulting selection of tanker operations and basing is shown in Table 4. The selected refueling areas are noted in Fig. 9.

Table 4

TANKER OPERATIONS AND BASING FOR TANKER-SUPPORTED BOMBER SYSTEMS

	System 3--STO Bomber + STO Tanker				System 4--LTO Bomber + KC-135A			
Refueling Mode	Per Cent of Bomber Force	T/B	Tanker Base Locations	Allocation Per Cent	Per Cent of Bomber Force	T/B	Tanker Base Locations	Allocation Per Cent
Unrefueled	6	0	--	--	30	0	--	--
Pre-strike Buddy at 2500 n mi (STO) 2000 n mi (LTO)	33	1.0	U.S. ZI	100	25	1.0	U.S. ZI	100
Pre-strike and Post-strike at 2500 n mi	26	1.0	Alaska, Aleutians	49	27	1.0	Alaska, Aleutians	50
			Canada, Greenland	28			Canada, Greenland	4
			England, Spain	23			England, Spain	46
Pre-strike and Post-strike at 3750 n mi	20	1.5	Japan	45	18	1.5	Japan	35
			England, Spain, Italy, Libya	55			England, Spain, Italy, Libya	65
Pre-strike and Post-strike at 5000 n mi	15	2.0	Okinawa, Philippines	34	--	--	--	--
			Greece, Turkey, Iraq	66				
Target Area Accumulation Under Design Conditions	97%				95%			
Average T/B	1.19				.79			
% of Bomber Force Dependent on Forward-Based Delayed-Takeoff Tankers	61				45			

SECRET

IV. SYSTEM COSTS

INTRODUCTION

The cost analysis presented in this Section is directed at the problem of comparing, on a consistent basis, the resource requirements for the four strategic weapon systems under study. It should be emphasized that even though the cost estimates are preliminary and useful only for gross comparisons, they were prepared to reflect the important system design and operational characteristics. However, uncertainties exist, both in terms of hardware design specifications and system operating concepts, to which resource requirements can be sensitive. For example, the Dromedary long-endurance aircraft with Laminar Flow Control (LFC) has an estimated maximum endurance of 118 hr. Verification of this estimate must await tests now under way to determine the effect of LFC on aircraft endurance at various speeds and altitudes. The resource requirements for system 1 (Dromedary on continuous airborne patrol) are extremely sensitive to the actual endurance capability. Uncertainty also exists for this system in the area of base and depot maintenance requirements. Data do not exist from which a high-confidence estimate can be made for aircraft flying 100-hr missions. Additional sensitivity analysis is required to demonstrate the effect on system requirements of changes in vehicle specifications and system operating assumptions.

TOTAL SYSTEM COSTS

Total system cost includes research and development, initial investment, and five years of annual operation.

Research and development (R&D) includes all of the costs necessary to bring a weapon system into readiness for introduction into the active inventory. Investment includes all of the costs required to phase the system into the operational force. Annual operating costs are those which recur each year that the force remains in the operational inventory. An explanation of the cost elements found in each of the above categories is presented at the end of this Section and in greater detail in Ref. 10.

Figures 14 through 17 present the systems cost curves by major cost category for different force sizes.

WEAPON SYSTEM COST MODELS

The calculation of the resource requirements for each system was done using computerized models developed by the RAND Cost Analysis Department. One model deals specifically with continuous airborne patrol, and the other with ground alert. Both models have the capability of estimating the additional costs associated with procuring and operating air-to-air or air-to-surface augmentation missiles. The cost models differ in the following ways:

The continuous airborne patrol model is structured around aircraft cycle time, or the time from the start of one sortie for a given aircraft to the start of the next sortie for the same aircraft. Cycle time consists of three basic phases--flying time, waiting time, and maintenance time. The utilization rate, for the purposes of this study, is the ratio of effective flying time per cycle to the total cycle time. The utilization rate for system 1--Dromedary on continuous airborne patrol--was computed to be 74 per cent.

Time in maintenance is considered in two parts: the first as a function of the number of sorties, and the second as a function of the number of flying hours per sortie or mission. For each sortie (100-hr length) it was estimated that each aircraft would require 8 hr of maintenance--for refueling, pre-flight inspections, and on-and-off loading. For each flying hour a requirement of .2 hr in maintenance was estimated, including post-flight maintenance, periodic maintenance, and unscheduled maintenance.

The absolute values of these point estimates are much less important than the sensitivity to resource requirements implied by their use. In order to determine how sensitive the utilization rate is to the maintenance factors, a number of tests were made. Sortie lengths of from 25 to 150 hr were examined.

The conclusion reached was that utilization rate or percentage airborne is not highly sensitive to maintenance factors for missions greater than 75 hr. For a 100-hr sortie, as an example, if the

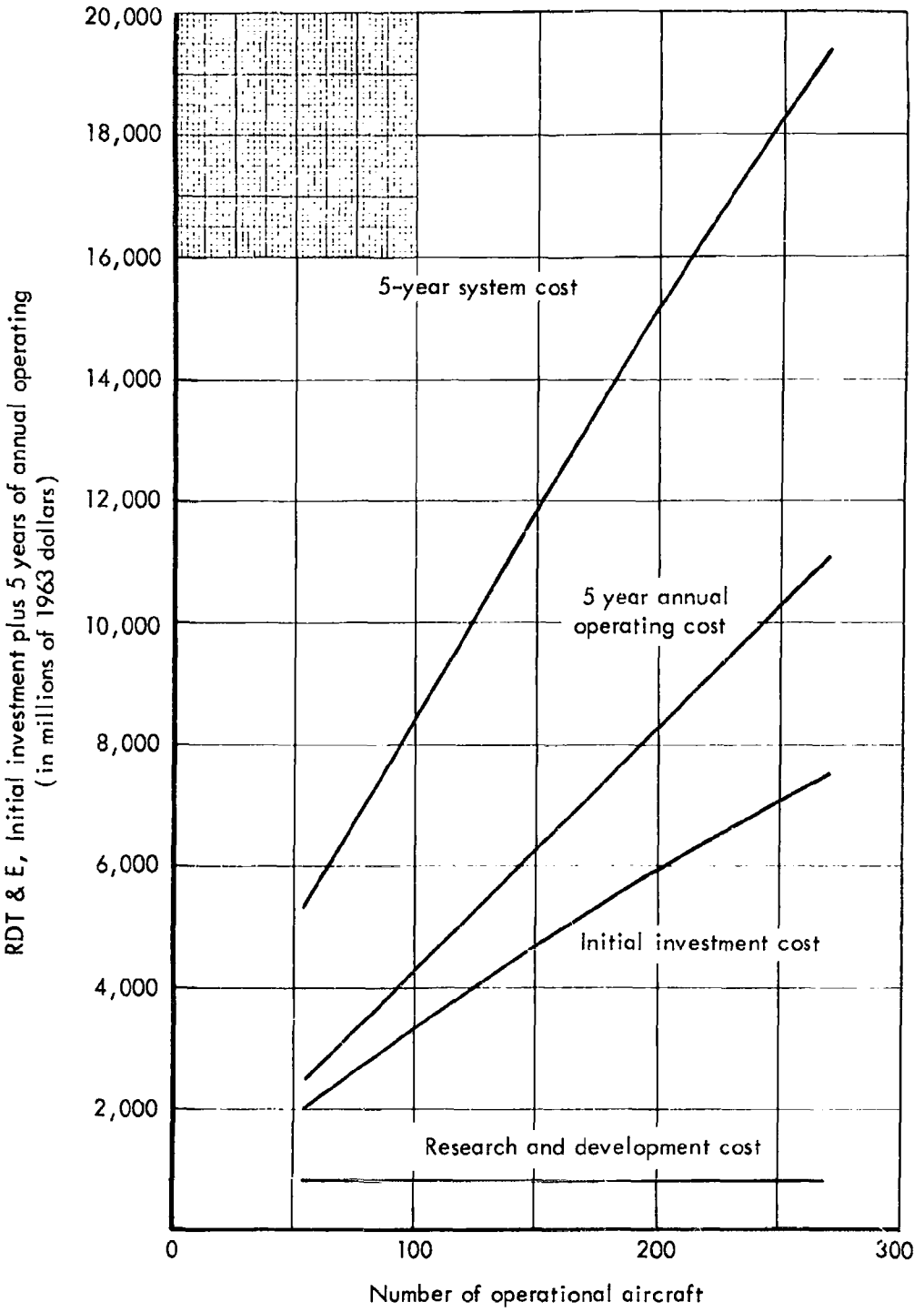

Fig. 14 — Total system cost versus force size: System No. 1 - Dromedary/parasite on continuous patrol

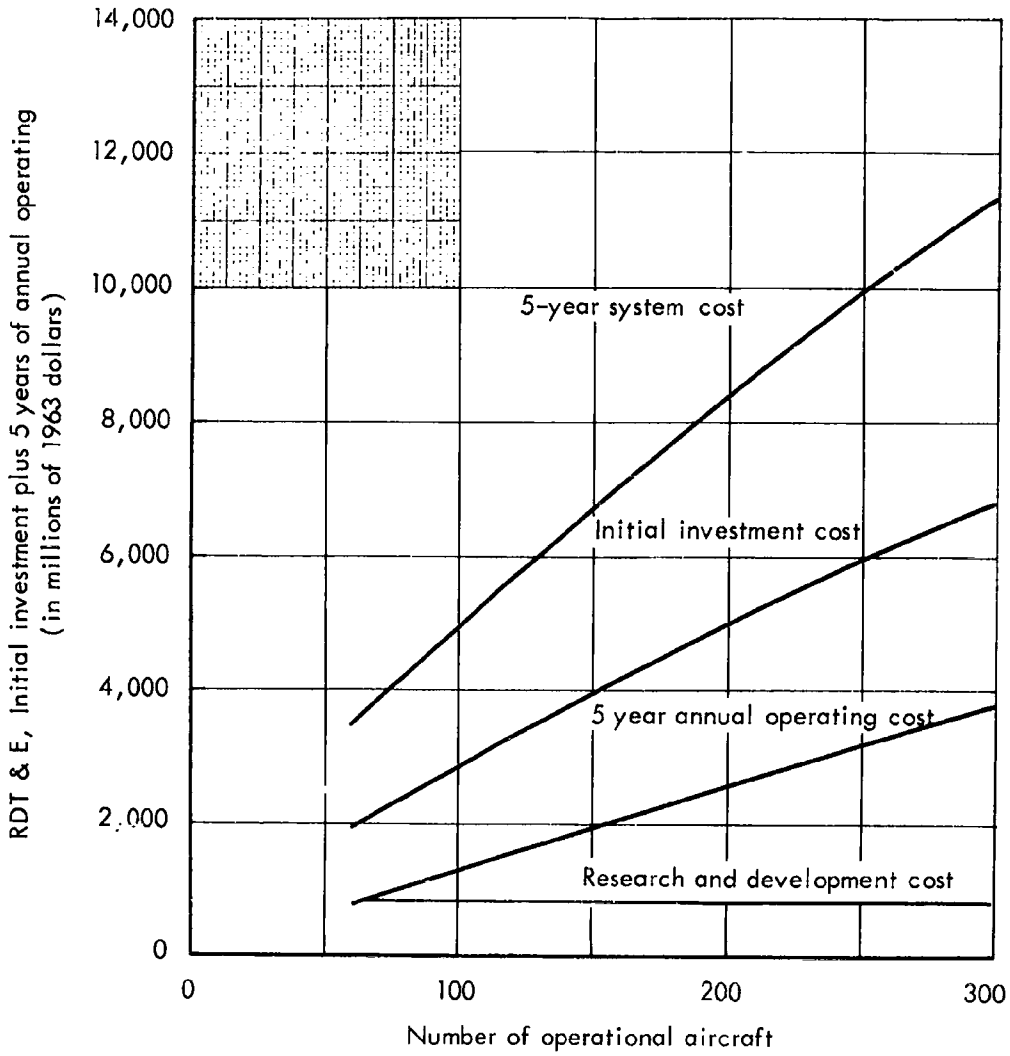

Fig. 15 -- Total system cost versus force size: System No. 2 - Dromedary/parasite on 50 per cent ground alert

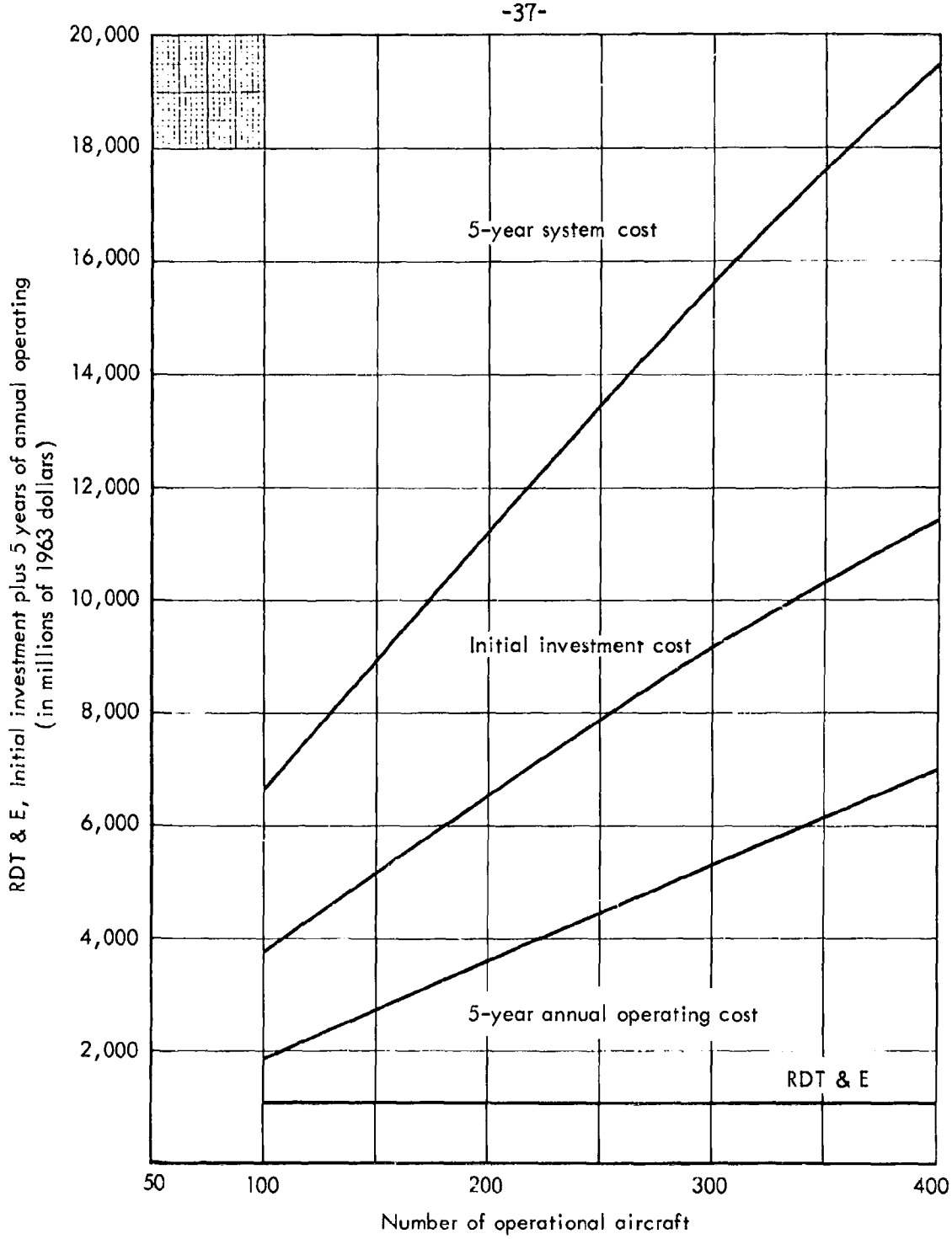

Fig. 16 — Total system cost versus force size: System No. 3 - STO bomber/STO tanker on 50 per cent ground alert

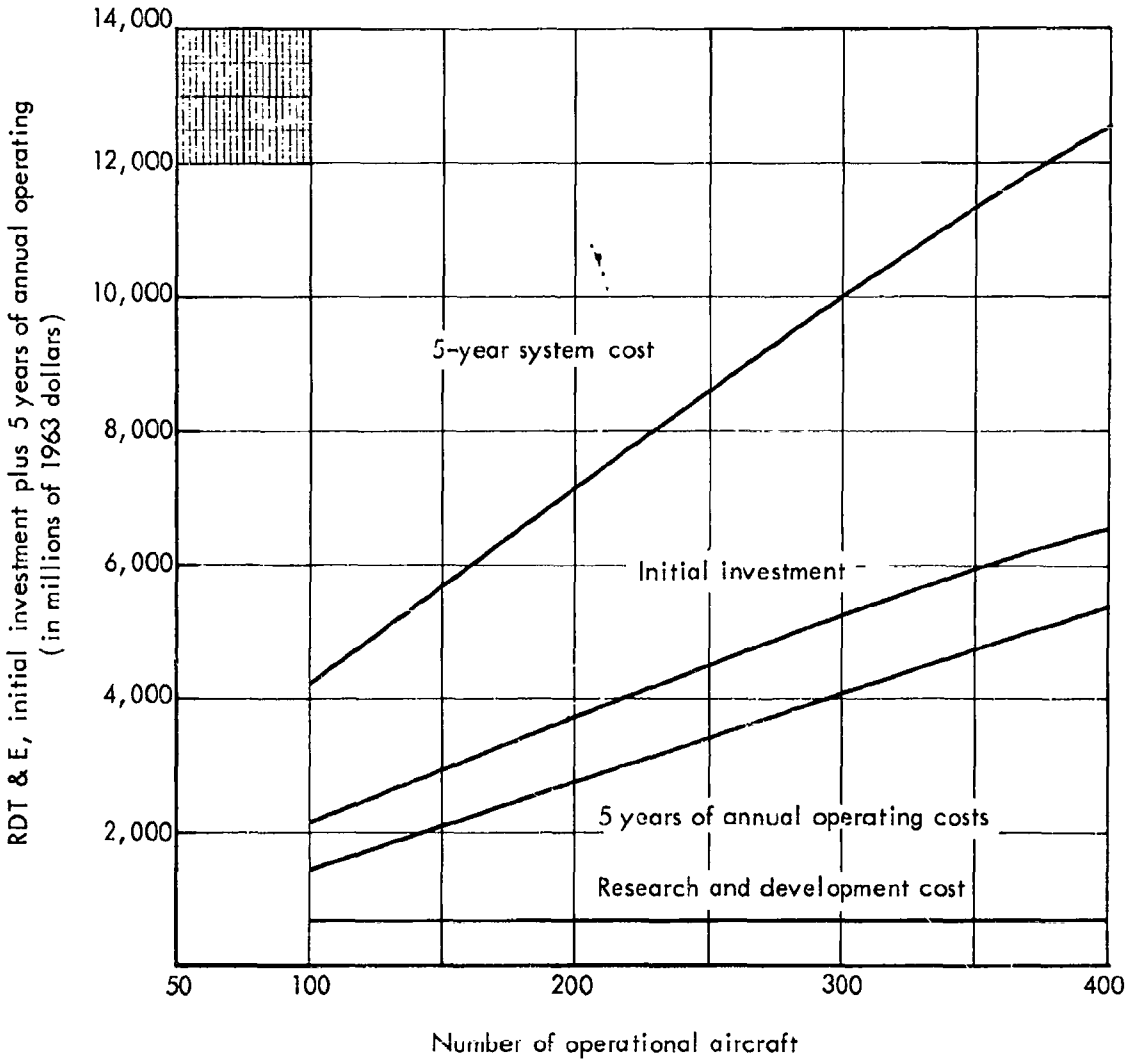

Fig. 17 — Total system cost versus force size: System No. 4 - LTO bomber/KC135 tanker on 50 per cent ground alert

maintenance hours per flying hour are doubled, the utilization rate is reduced 12 per cent. Or, if the maintenance hours per sortie are tripled, there is a reduction of only 6 per cent in the utilization rate. In combination, if the maintenance hours per flying hour are doubled and the number of maintenance hours per sortie are tripled, the cumulative effect on the utilization rate is less than 20 per cent. In addition to endurance hours and maintenance hours, the utilization rate is also affected by the distance from base to station and the number of maintenance shifts assumed.

Unlike the airborne model, which estimates the number of operational aircraft required to perform a given mission, the ground-alert model accepts as an input the number of operational aircraft in the system. Like the airborne-alert model, it requires inputs describing the basing, deployment, operations, and maintenance concept. In all, there are over 100 inputs that may be varied.

The missile cost model, an adjunct to the aircraft models, generates the additional costs associated with the development, procurement, and operation of air-to-air or air-to-surface missiles.

RESEARCH AND DEVELOPMENT

The techniques employed in estimating research and development costs for the aircraft and missiles are generally the same as those described in Ref. 11. The costs of designing and developing each of the major components are estimated separately. To these costs are added the cost of the procurement of test vehicles and the costs of the flight test program.

Design and development costs include those for research and design studies, for scientific and engineering manpower required to design each of the various components, and for special tooling and test equipment needed for the fabrication of experimental prototypes and mockups. Also included are the costs of components for test and industrial facilities funded by the Air Force.

Flight test costs cover flight test vehicle fabrication, vehicle spares, and test ground-support equipment and test facilities. These costs also include data reduction and analysis, technical data, and

other related activities. The cost of the flight test vehicles dominates this category. For this study, a test inventory of ten bombers and parasites was assumed. An additional requirement for three STO tankers (tanker versions of the STO bomber) was assumed for test and evaluation. It was also assumed that the components (airframe and engines) for these aircraft would be procured after the procurement of the operational bombers.

Table 5 identifies that portion of each R&D estimate associated with design and development, and with system flight test.

Table 5

R&D SYSTEM COST ESTIMATE BY VEHICLE
(In millions of 1963 dollars)

Vehicle Description and Number of () Test Articles	System 1 Dromedary/ Parasite on Continuous A/B Alert	System 2 Dromedary/ Parasite on 50% Ground Alert	System 3 STO Bomber & STO Tanker on 50% Ground Alert	System 4 LTO Bomber & KC-135 on 50% Ground Alert
Bomber (10)				
Design & Development				
Airframe	143	143	200	170
Engine	-	-	100	-
Electronics	20	20	150	150
Flight Test	250	250	340	290
Parasite (10)				
Design & Development				
Airframe	62	62		
Engine	10	10		
Electronics	150	150		
Flight Test	118	118		
Tanker (3)				
Design & Development			90	
Flight Test			100	
FLAM (100)				
Design & Development	45	45	45	45
Flight Test	20	20	20	20
Total System R&D Estimate	818	818	1045	675

SUBSYSTEM PROCUREMENT COST

Vehicle costs make up the major portion of the initial investment in each system. Figures 18 through 21 present cumulative average cost curves for the aircraft procured (except the STO tanker) by major component--airframe, engine, and airborne electronic equipment--for each weapon system, including flight-test aircraft.

The KC-135 was assumed to be inherited, and hence no procurement was required. The STO tanker was assumed to require the same engines as the STO bomber, and the airframe was assumed to require minor structural modifications. The STO tanker was therefore procured using the same airframe and engine cost-quantity curves beginning at the point on the curves after the procurement of airframe and engine for use in the bombers.

The procedures used in estimating the production costs of the Dromedary, parasite, LTO bomber, and STO bomber are the same as above and are relatively straightforward.(12)

There are certain items peculiar to each of these systems which need special consideration. For this study, Dromedary was assumed to be configured with Laminar Flow Control (LFC). LFC aircraft require proportionally larger wings than non-LFC aircraft, and a correspondingly increased structural weight for the same gross takeoff weight. Based on Northrop Corporation's experience and projection of costs, there is an additional overall cost increase of 28 per cent and 10 per cent, respectively, for labor and material. The Dromedary as a launch platform would not have offensive or defensive components--only the normal communications and navigation equipment. The offensive and defensive components would be an integral part of the other combat aircraft and would include an inertial bomb-nav system (with astro tracker) and a doppler radar. Countermeasures and comprehensive communications would also be required. The cost of the electronics for these aircraft reflect these requirements. The engines used for these aircraft have been developed and are available. However, in the case of the STO bomber there is an added requirement for vertical-lift engines. Cost estimates are based on Rolls-Royce information on the RB-162 engine.

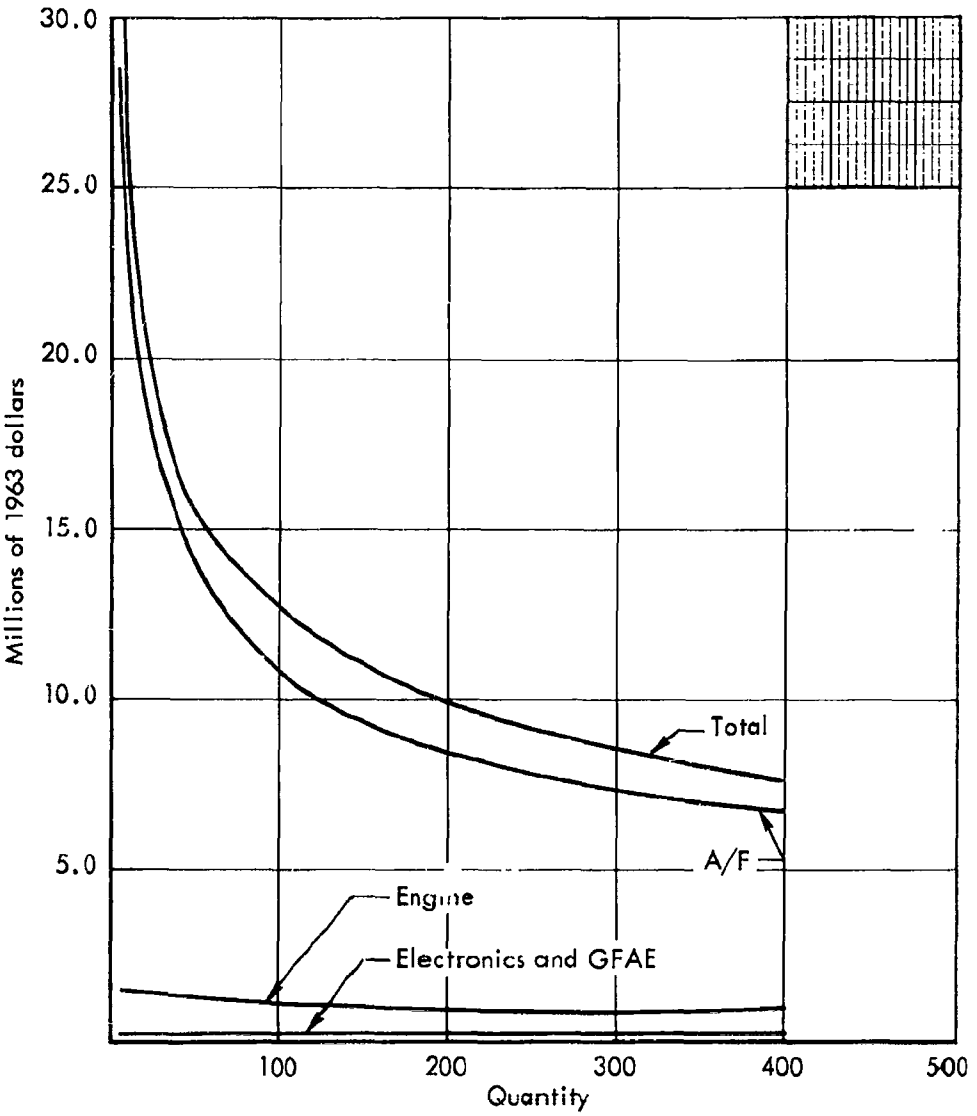

Fig. 18 — Cumulative average cost-quantity curve (600,000-lb Dromedary aircraft with laminar flow control)

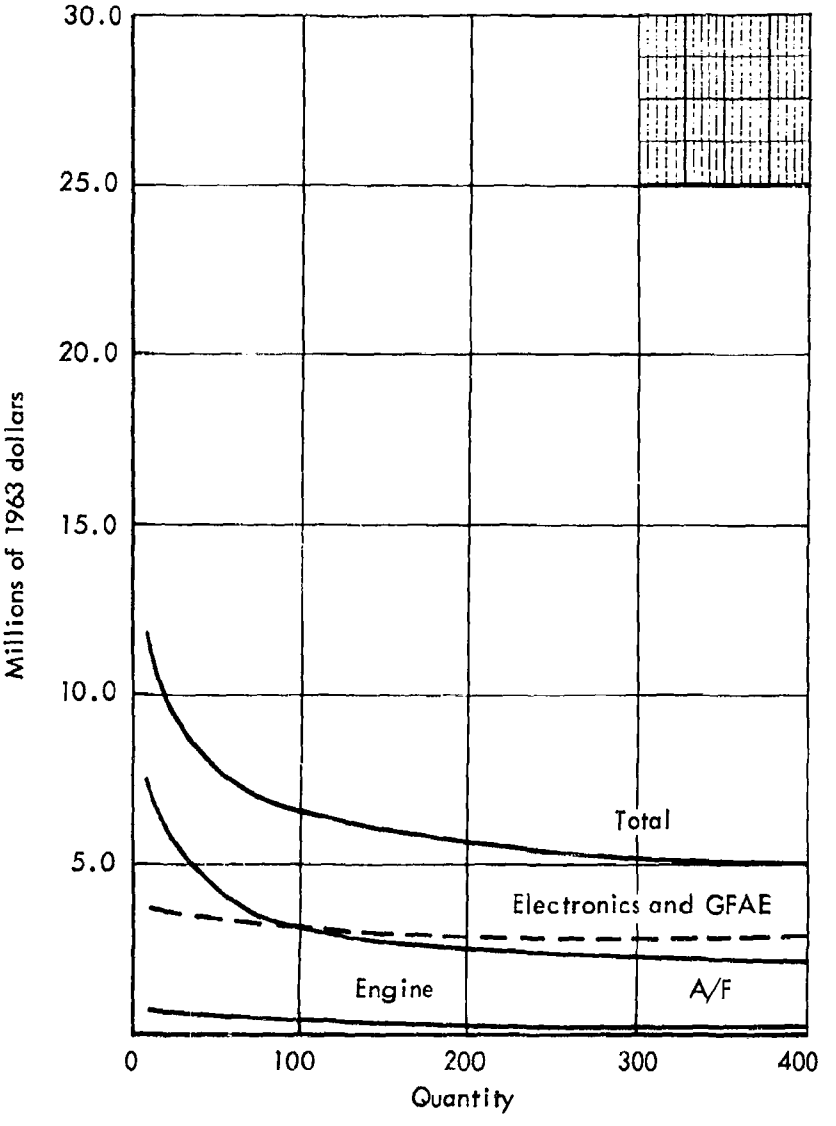

Fig. 19 — Cumulative average cost-quantity curve (70,000-lb parasite aircraft)

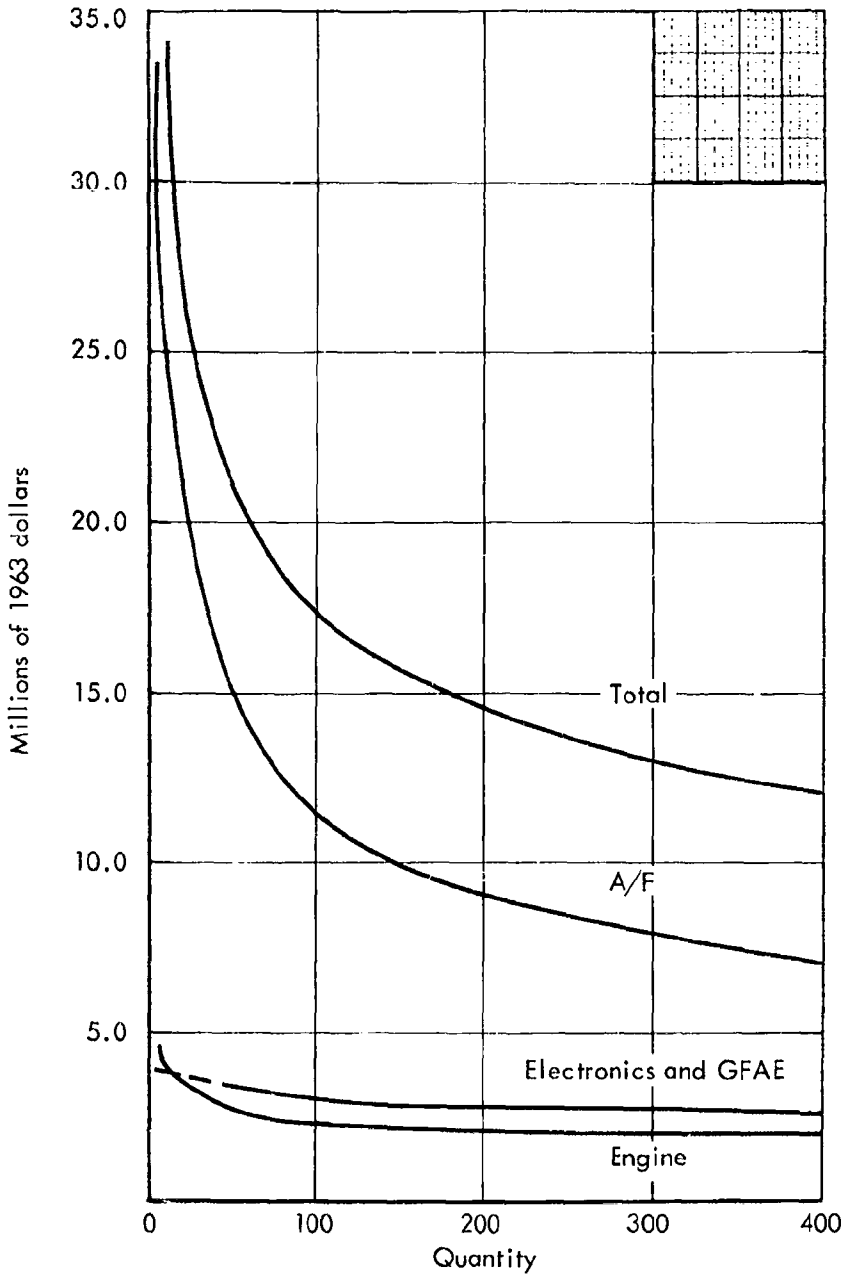

Fig. 20 — Cumulative average cost-quantity curve (500,000-lb STO bomber)

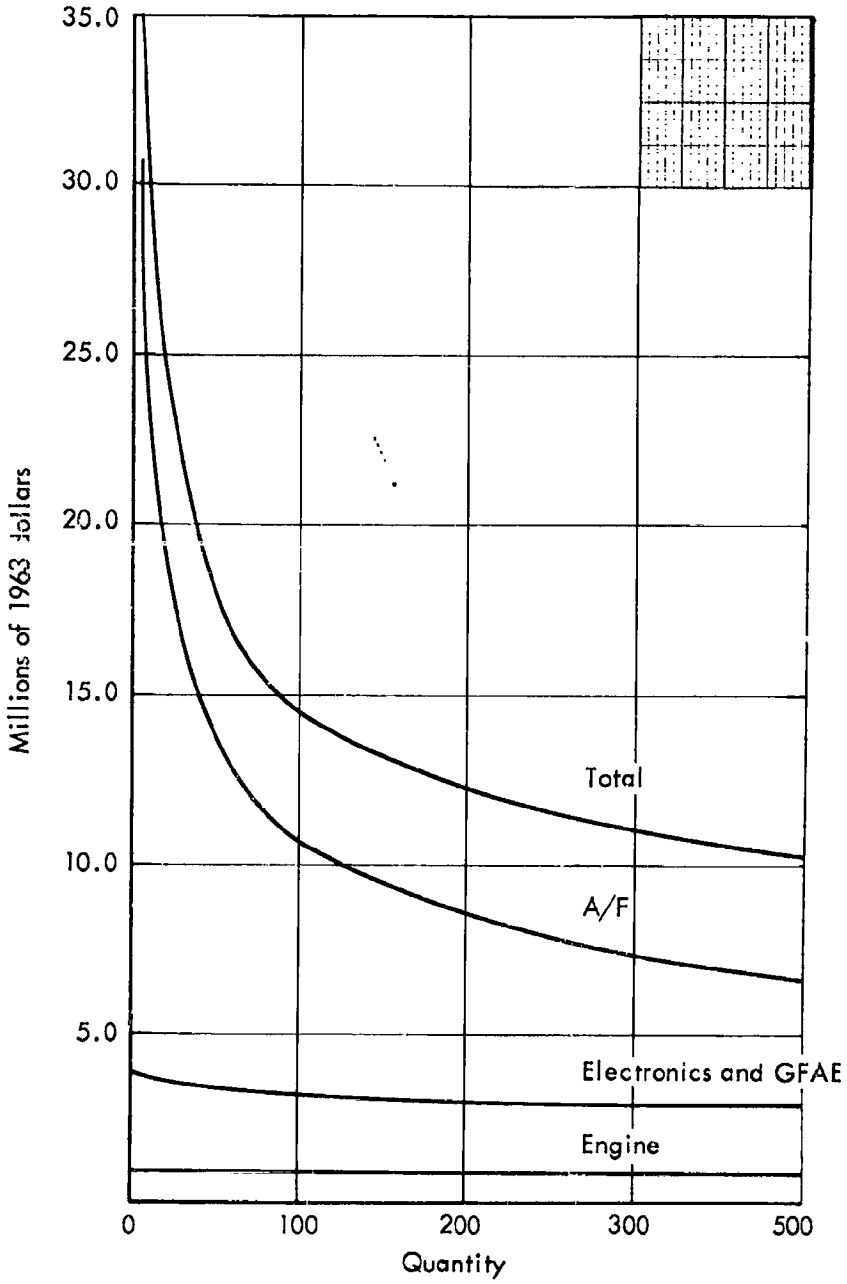

Fig. 21 — Cumulative average cost-quantity curve (500,000-lb LTO bomber)

The FLAM missile design specifications and costs were obtained directly from information presented in Ref. 9.

PERSONNEL REQUIREMENTS

The personnel estimates shown in Table 6 are based on the assumption that these weapon systems would replace a portion of the present B-52 fleet. As a result, each weapon system was considered to be a host and, as such, requiring personnel to perform all of the necessary functions on a base. In order to determine the number of personnel for each system, it was necessary to use various estimating relationships. The relationships are based on the assumption that these personnel can be categorized into four functional areas: operations, maintenance, administration, and support.

Table 6

PERSONNEL ESTIMATES

Subsystem	UE	System 1 Dromedary/ Parasite on Continuous Airborne Alert	System 2 Dromedary/ Parasite on 50% Ground Alert	System 3 STO Bomber & STO Tanker on 50% Ground Alert	System 4 LTO Bomber & KC-135 on 50% Ground Alert
Bomber/Parasite	15	6129	2898	2653	2474
FLAM Missile	120	215	215	215	215
STO Tanker	18			794	
LTO Tanker	12				504
Total Personnel		6344	3113	3662	3193
Officers		1631	459	488	417
Airmen		4106	2416	2925	2546
Civilians		607	238	249	230

Operational personnel are the aircraft combat crews and other personnel found in the strategic bomber and air refuel squadrons. The crew personnel requirements for the Dromedary system on airborne alert were computed on the basis of the number of aircraft and the allowable flying hours per crew. For this study each crew was assumed to fly 120 hr each month. Operational personnel for the ground-alert cases

were based on the number of aircraft and the crew ratio. B-52 squadrons now operate with a 1.8 crew ratio. In the present study this was arbitrarily adjusted to 2.0.

Maintenance personnel are those personnel at base level engaged in servicing and maintaining the aircraft, missiles, and aerospace ground equipment. In strategic bomber organizations they are assigned to the Organizational Maintenance Squadron, Armament & Electronics Maintenance Squadron, Field Maintenance Squadron, and the Ammunition Maintenance Squadron. For this study, with regard to the strategic bombers on ground alert, a relationship was established between the number of base maintenance personnel and the following aircraft characteristics: maximum thrust, takeoff weight, and the number of aircraft per base.

The maintenance personnel for the airborne-alert Dromedary were computed by the cost model based on required maintenance hours, and on a three-shift, around-the-clock, maintenance policy.

Administrative personnel at base level are those assigned to wing headquarters. Estimates were based on a relationship between the sum of operations and maintenance personnel and wing personnel on Strategic Air Command bases.

Support personnel perform the housekeeping activities on the base. Estimates for both the ground-alert and airborne-alert operations reflect a relationship between the sum of the operations, maintenance and administration personnel, and base support personnel on Strategic Air Command bases.

For the STO bomber system, where bombers and tankers were assumed to be dispersed, approximately 50 additional personnel per base were added to operate and guard the dispersal bases.

BASING AND DEPLOYMENT

Each system in this study was assumed to be assigned to the Strategic Air Command, replacing B-52/KC-135 squadrons in the late 1960 or early 1970 time period.

A review of the Bases Units and Priorities PD 65-2 reveals that sufficient heavy-bomber bases would exist to accommodate the forces being considered in this study without major modification. Each bomber system was therefore assumed to be stationed on single-squadron (15 operational aircraft) bases. The STO bomber system had, in addition, a requirement for two dispersal fields per squadron.

The tanker aircraft associated with the STO bomber (tanker to bomber ratio of 1.2 to 1) were assumed to be based both in the ZI and overseas in a dispersed mode similar to the STO bomber. The KC-135 tankers (tanker to bomber ratio of 0.8 to 1) were not dispersed. In either case it was assumed that events leading up to this time period would not preclude the use of overseas bases in those countries shown in Table 4, p. 32. As in the case of the bomber bases, existing facilities would not require major modification.

OPERATIONS

The major operational concept relates to the flying hour program assumed for each system in the study.

For each of the three ground-alert systems, the assumption was that each aircraft, i.e., bombers, tankers, and parasites, would fly an average of 450 hr per year, or about 20 training flights per month of less than 2 hr each. The current Air Force Program P-65-2 projects a comparable flying hour program for the KC-135 and B-47 and a somewhat higher flying hour program for the B-52.

For the Dromedary, the flying hour program was computed using the utilization rate of 74 per cent, which generated an average of 6482 flying hours per aircraft per year. Since utilization was defined to include only effective time on station, the assumption of ineffective flying hours near the end of a combat patrol mission (7 hr per sortie) generated an additional flying hour requirement per aircraft per year of 494 flying hours. This brought the total to approximately 7000 flying hours per aircraft per year.

The STO system was assumed to operate from a dispersed deployment. The bombers were located in the ZI on three dispersed bases per squadron--five aircraft per base. The STO tankers were also

similarly dispersed. Of the 119 tankers required for a force of 100 bombers, 33 were located in the ZI and 86 overseas.

The LTO system was assumed to operate from a nondispersed deployment. The bombers were located on squadron bases in the ZI. Of the 79 KC-135 tankers required for a force of 100 bombers, 25 were located in the ZI and 54 overseas.

The absolute resource impact of dispersal could not be estimated with any degree of certainty for this study because pre-stockage requirements or operational concepts were not considered in detail. Estimates do, however, reflect the incremental costs associated with the additional personnel required to man dispersal bases.

COST CATEGORIES AND COST ELEMENTS

As mentioned in the beginning of this Section, the three major cost categories--research and development, initial investment, and annual operating--each contain cost elements that are based on the hardware, design specifications, and system operations. There is no standard set of cost elements used for every study. There are as many as 100 elements of costs, which may be examined individually or in aggregation in estimating the resource requirements for a given system. The major cost elements and assumptions relating to initial investment and annual operating costs are discussed in the remaining pages of this Section. (Research and development costs were discussed previously on pp. 39 and 40.)

Initial Investment

Initial investment costs, or one-time outlays required to introduce a new capability into the operational force, include the following major cost elements--facilities, primary mission equipment, unit support aircraft, aerospace ground equipment, personnel training, initial travel and transportation, stocks and spares, and other equipment.

Facilities include costs of land, buildings, roads, utilities, and similar items. For this study it was assumed that only minor

modification of existing bases would be required. The factors that were developed and subsequently used in the study reflect an estimate of the incremental facilities required on existing bases. The estimated costs ranged from $2.0 million per base for the LTO bomber to $6.0 million per base for the system employing Dromedary on airborne patrol. The estimated tanker facilities costs averaged approximately $1.0 million per base. Aircraft facilities estimates included the incremental facilities associated with the ASM.

Primary mission equipment costs include both the aircraft procurement costs (which were obtained from the cost-quantity curves) and the estimated costs for the FLAM missile. The number of aircraft procured for each system include the operational aircraft, an additional 10 per cent of the operational aircraft for command support or pipeline aircraft, and the requirement for replacement aircraft during the five operating years. However, the cost associated with equipment replacement is considered to be an annual operating cost and, therefore, is discussed subsequently under that heading. This cost is based upon the estimated attrition rate and the flying hour program for each system.

The number of FLAM missiles procured for each system includes eight operational missiles per aircraft, 20 per cent of the operational missiles for pipeline, and an additional 25 per cent of the operational missiles for replacement during the five operating years. Missile replacement requirements were aggregated and include those that would have to be replaced because of bomber attrition, proficiency training, and reliability testing.

Unit support aircraft costs include those for the trainer aircraft necessary to maintain pilot proficiency, and cargo aircraft for logistical support. For this study these aircraft were assumed to be inherited from phased-out B-52 squadrons.

Aerospace ground equipment for the bomber and tanker aircraft includes the cost of vehicles and equipment used to refuel, service, and tow the aircraft. For the FLAM it includes checkout, auxiliary, handling, service, and training equipment. Aerospace ground equipment for the aircraft was estimated at 10 per cent of the aircraft procurement

cost. The missile aerospace ground equipment was estimated to be 25 per cent of the missile procurement cost.

Personnel training includes the costs of formal training necessary to raise the level of skill of each man to that required by his occupation in the systems under study. The assumption under which the estimate for this category was made was that transitional training would be required only for crew personnel and missile maintenance personnel. The estimate for the cost of this training varied only slightly between systems and averaged $10,000 per crew member and $5,000 per missile maintenance personnel.

Initial travel and transportation includes the costs of transporting personnel and their dependents to the operating base. It also includes the cost of transporting equipment (except aircraft), stocks (except petroleum, oil, lubricants), and spare parts. Estimates of travel costs were computed based on a per man factor. Transportation costs were estimated by applying transportation factors and overseas factors (when applicable) to procurement costs.

Other equipment usually includes the costs of general purpose equipment not included in previous categories. Items such as construction equipment, materials handling equipment, general purpose vehicles, and communication equipment are included. The estimate for this category was computed on the basis of $1500 per military man.

Stocks and spares covers the costs of personnel supplies, facility supplies, organizational equipment supplies, and POL. The size of the initial stockage is related to the annual consumption as specified in Air Force planning documents.

Initial spares include the initial stockage of spares and spare parts associated with the primary mission equipment. The cost was estimated as a percentage of the procurement cost for each vehicle procured as follows:

Spares Vehicle	Per Cent of Investment System 1 On Continuous Airborne Alert	 System 2, 3, & 4 on 50% Ground Alert
Bomber Aircraft	20	15
Tanker Aircraft		10
FIAM Missiles	25	25
Aerospace Ground Equipment		
Aircraft	15	15
FIAM Missiles	25	25

Annual Operating Costs

Annual operating costs are those recurring outlays needed to operate and maintain a weapon system after it has been introduced into the active inventory. It includes estimates of cost relating to the operations and replacement of the facilities and equipments and to weapon system base personnel. The cost elements considered in this study are discussed below.

Facilities replacement and maintenance costs cover the cost of replacing worn-out base facilities and of providing the material and contractual services required for maintenance of the unit's base facilities. This cost was computed on the basis of a per military man factor and the basing concept of the weapon system, i.e., host or tenant--located in the ZI or overseas.

Primary mission equipment replacement cost for aircraft (due to attrition) was estimated by multiplying an attrition rate per flying hour by the number of flying hours and the average cost of the aircraft procured.

The attrition rates used are presented in Table 7. They are based on current aircraft attrition rates related to cumulative flying hours, complexity of equipment, and aircraft speed. Since the KC-135 aircraft is no longer in production, there is no replacement cost associated with these aircraft; it was assumed that there would be sufficient quantities to meet replacement requirements.

Table 7

AIRCRAFT ATTRITION RATES
(No. of aircraft per 100,000 flying hours)

Combined Dromedary/parasite on continuous airborne alert (based upon Dromedary flying hours)	1.6
Dromedary/parasite on 50% ground alert (based upon 450 flying hours per year)	3.2
STO bomber--450 flying hours per year	2.0
LTO bomber--450 flying hours per year	2.0
STO tanker--450 flying hours per year	1.5

Missile replacement requirements costs were computed as a percentage of the value of the inventory of missiles. For this study a 5 per cent factor was used, which included the missiles required for proficiency training, for reliability checkout, and for missile attrition.

Primary mission equipment maintenance includes the annual cost of material used at base level and in the Air Force depots. It also includes the cost of labor at depots (but not at base level).

Prior to this study, relationships had been developed within the RAND Cost Analysis Department to estimate aircraft maintenance cost per flying hour based upon gross takeoff weight and maximum speed.(13) These relationships were used in this study to estimate maintenance cost for the ground-alert aircraft. Maintenance cost for the Dromedary aircraft was computed in the model, based on cycle time, as discussed previously.

Maintenance cost for the FIAM missile was estimated to be 15 per cent of the missile inventory value.

Primary mission equipment POL includes the cost of fuel and oil for the operation of the aircraft in each weapon system. The costs for this category were based on POL consumption rates, assuming a typical training mission profile for the ground-alert aircraft (450 flying hours per year per aircraft).

Aerospace ground equipment replacement and maintenance includes the costs of replacement and maintenance of this type of equipment. These costs were estimated as a percentage of the equipment value,

viz., 10 and 20 per cent, respectively, for the aircraft and the FIAM missile.

Personnel pay and allowances include basic pay, subsistence and quarters, hazard pay, and all of the other payroll costs associated with military and civilian personnel. These costs are based on geographical location and on such considerations as whether the officers are rated or nonrated and whether the airmen are crew airmen or noncrew airmen. For this study the pay and allowances were as follows: officers--$8,353 to $11,964; airmen--$3,567 to $3,829; and civilians--$6,000 to $7,000.

Personnel replacement training cost covers the cost of training replacements for personnel leaving the Air Force because of discharge, resignation, or death. This cost is a function of the inventory of personnel, the turnover rates, and training cost per man. For this study it was assumed that only crew and missile personnel required replacement training, and that the training cost averaged $10,000 per aircraft crew and $5,000 per missile officer or airman. The annual turnover rate was assumed to be 15 per cent of the total military personnel.

Annual travel and transportation includes travel costs of military personnel incident to normal peacetime turnover, and the cost of bringing onto the base replacement equipment and supplies consumed during the year. The annual travel cost was based on rates of $280 and $750 per man for the ZI and overseas, respectively; similarly, the annual transportation cost was based on rates of $125 and $250 per man.

Annual services and other includes operating and maintenance costs not included in the other categories. Here, an attempt is made to include such items of cost as flight services, base supplies, food, medical services, and maintenance of organizational equipment. For this study these costs were aggregated by geographic location and estimated on the basis of the total number of military personnel.

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DEPARTMENT OF THE AIR FORCE
WASHINGTON, DC

8 November 2005

HAF/ICIOD (MDR)
1000 Air Force Pentagon
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Michael Ravnitzky
1905 August Drive
Silver Spring, MD 20902

Dear Mr.Ravnitzky

This is in reference to our letter dated April 19, 2005 (attachment 1) requesting a Mandatory Declassification Review (MDR) for DTIC Report AD 356668. The review has been completed and the document has been downgraded to UNCLASSIFIED and a copy attached for your information (attachment 2).

Address any questions concerning this review to the undersigned at (703) 696-7265 and refer our case number 05-MDR-056.

Sincerely

JOANNE MCLEAN
Mandatory Declassification Review Manager

2 Attachments
1. Requesting Letter, 19 Apr 05
2. AD Report 356668

cc: DTIC

DEPARTMENT OF THE AIR FORCE
OFFICE OF THE CHIEF OF STAFF
WASHINGTON, DC

13 SEP 2005

MEMORANDUM FOR HQ USAF/XOR

FROM: HQ USAF/XORC

SUBJECT: Mandatory Declassification Review (MDR), Case 05-MDR-056

AF/XORC has reviewed the document pursuant to the subject MDR request. It is our opinion that the document can be declassified in its entirety and provided to the requestor. If you have any further questions or concerns, you can call my action officer, Mr. John Hutto, at (703) 697-0766 or e-mail him with any further questions or concerns.

J. E Allgood

James Allgood, GS-15, USAF
Deputy, GS-GPA Division