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| AD NUMBER |
| **ADA950178** |
| CLASSIFICATION CHANGES |
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| AUTHORITY |
| **31 Jul 1961, DoDD 5200.10, gp-3** |

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(LO)381-49
12 July 1949

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UNCONFIDENTIAL

# OPERATIONS EVALUATION GROUP
(14) OEG - STUDY No. 394

(10) John B. Lathrop (11) 12 Jul 49

(12) 40

(6)

# SOME FACTORS AFFECTING THE FEASIBILITY OF VERY LONG RANGE BOMBING FROM NORTH AMERICAN BASES



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OPERATIONS EVALUATION GROUP

STUDY NO. 394

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VERY LONG RANGE BOMBING FROM NORTH AMERICAN BASES

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## SUMMARY AND CONCLUSIONS

1. For the information of naval agencies participating in joint planning, a study has been made of certain factors related to the feasibility of current plans for very long range strategic bombing from North American bases.

2. The relative capabilities for delivery of bombs to USSR target areas circa 1950 have been estimated for typical medium and heavy bombers--the B36, B50, and B47. Account has been taken of the effects of refuelling, and of the use of high altitude and high speed. Within the limits of current knowledge, magnitudes have been suggested for expected losses and aborts. The effects of navigation errors, bombing accuracy, diversionary raids, and hours of darkness are discussed. These measures have been combined to compare the relative suitabilities of aircraft types and flight plans, and to provide rough estimates of force requirements for conventional or atom bombing campaigns.

3. Measures of the economic cost, and the cost in strategically critical aviation fuel, per ton of bombs delivered, have been compared for the various aircraft, flight plans and refuelling plans.

Conclusions, <u>before considering the consequences of enemy action</u>, are as follows:

a. Use of the B36 as a bomber requires the lowest dollar cost or fuel expenditure per ton of bombs of the types considered. Use of the B50 or B47 as a bomber generally doubles the dollar and fuel cost per ton of bombs over that for the B36.

b. Refuelling generally reduces the cost and fuel per ton of bombs over non-refuelling costs, and also provides higher performance over enemy territory.

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c. Use of 40,000 ft. altitude over Europe by the B36 generally reduces bomb loads to about half those for maximum range flight plans. A requirement that maximum speed be used about 1/3 of the miles over Europe, to provide reduction in losses to enemy action, would further reduce bomb loads.

d. From United Kingdom or North Africa bases, bombs should be deliverable, without refuelling, at from 1/2 to 1/5 the cost and fuel per ton as with refuelling from North American bases.

4. Tentative measures of losses and aborts have been estimated, using as a starting point the planning factors recommended for use by the Air Force, with conclusions as follows:

a. With enemy interceptor capabilities as estimated for 1950, losses to enemy fighters should be predominant. Operational losses and losses to AA are much less important.

b. For a given force of enemy interceptors, the absolute number of bombers lost to enemy action from any raid should be about constant for any given bomber type, bomber tactic and enemy efficiency, regardless of the size of the raid.

c. It is estimated that, per 1000 operational interceptors based within range of a bomber track, there would be lost 50-100 B 36's from any raid at low altitude, 10-30 at high altitude, 4-20 at high altitude and high speed. Losses to B50 aircraft should be comparable to those of the B36, but the B47 raid may lose only 1-6 aircraft.

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d. Changes in the general level of estimated loss rates would be the same as changes in the number of defensive enemy units. The enemy may, therefore, offset individual inefficiences by increasing the number of units devoted to defense.

5. The hours of darkness available for cover of bombers over enemy territory is measured as to the effects of season of the year, target area, aircraft speed and base location, with the following conclusions:

a. Although in midwinter all bomber hours over Europe can be in darkness, refuelling may likewise be necessary in darkness. Such refuelling may not be technically or operationally feasible.

b. During a substantial portion of the year, the bombers considered will be unable to operate over polar regions against many USSR targets without considerable exposure over Europe during daylight.

c. Use of the B47, by reason of its greater speed, may avoid or reduce substantially any daylight hours over Europe which might be required for the B36.

6. A measure of effectiveness to combine bomb delivery capabilities and expected losses--tons of bombs delivered per aircraft lost--is discussed, with the following conclusions:

a. Tons of bombs delivered per aircraft lost increases continuously with size of raid.

b. For the levels of losses considered low performance flight plans do not seem advisable, since increased bomb loads are more than offset by increased losses.

c. The B47 may actually deliver more bombs per aircraft lost than the B36 or B50, under certain circumstances.

7. Minimum raid sizes required for given bomber loss rates are computed, with the following conclusions:

a. Raid sizes of upwards of 120 B36 or B50 aircraft--up to perhaps several thousand--may be necessary if bomber loss rates are to be held to 5% in the face of an enemy force of a thousand interceptors based enroute. For instance 120-530 B36 (the spread within the bracket depending on enemy efficiency) may be required for a raid at high altitude and high speed, with 2100-4400 required for a raid at lower altitude and cruising speed. Refuelling requirements, and the technical difficulties associated with successful refuelling of large flights of aircraft, may prevent raids of these sizes.

b. The B47 seems quite attractive, relative to other types, because of the small raids possible at low rates of loss.

c. Even when bomber loss rates as high as 25% may be acceptable, as may be true for delivery of atom bombs, raids considerably larger than the 8-10 contemplated by current Air Force plans may be required--except possibly for the B47 operating against near targets.

8. Force requirements of aircraft on hand and monthly replacements are computed for a conventional bombing campaign from North American bases of 50,000 tons per month with the following conclusions:

a. Force requirements in aircraft and bases on hand for such a campaign do not depend greatly on assumptions as to loss rates or enemy defensive strength. Monthly replacements, on the other hand, are nearly proportional to loss rates and decrease as raid sizes increase.

b. Such a campaign would appear to require an operational force of 3000-6000 B36 aircraft or their equivalent, and bases for them.

9. Force requirements for an atom bombing campaign from North American bases of 25 atom bombs per month have been estimated, the only conditions being that on the average one atom bomb per raid be delivered and that no more than 25% of bombs be lost to enemy action prior to drop. Conclusions are as follows:

a. Raid sizes of 12-170 B36 aircraft, 40-200 B50, or 6-18 B47 (to some targets only) may suffice, choices within these ranges of sizes depending upon enemy opposition.

b. Bomber loss rates of 35-40% should be expected for these raid sizes.

c. If such loss rates are unacceptable larger raids would be required and the usefulness of A-bombs would tend to disappear as the capacity of the raid in conventional bombs becomes equivalent to one or more A-bombs.

d. It should be possible to carry out the sample A-bomb campaign with a far smaller inventory of aircraft and bases on hand than for a presumably equivalent conventional bombing campaign. Monthly replacements of aircraft, however, may be comparable to--or even exceed--those required for the conventional campaign.

10. It is considered that this study may provide useful insight into the factors affecting the feasibility of very long range bombing from North American bases. Assumptions as to aircraft performance, enemy capabilities and forces available, and conclusions as to the effects of aircraft type or flight plan, and force requirements are tentative only. Some relevant factors have not been discussed. As more precise knowledge--or assumptions accepted for any particular operational situation--become available, however, they can be fitted into the framework of measures developed here.

## A. INTRODUCTION

1. Various agencies of the U.S. Navy, by reason of participation in the activities of such joint bodies as the Joint Chiefs of Staff, the Research and Development Board and its Committees, the Air Intelligence Division, and the Atomic Energy Commission, are required to form opinions and join in decisions regarding the feasibility of current Air Force plans for strategic bombing.

2. In accordance with requests from several of these naval agencies, a study of certain factors affecting the feasibility of such bombing has been made. The effects of each such factor on the feasibility of contemplated operations has been estimated, within the limits of current knowledge. All information concerning aircraft performance, vulnerability, etc., is taken from sources normally available within the Department of the Navy. Wherever possible, planning factors promulgated by the Air Force have been used as an initial basis for measurement.

3. This study examines the proposal that particular medium and heavy bombers, operating from bases in Alaska or the United States, may be used to deliver an effective attack on strategic targets in the USSR, utilizing the following tactics:

   a. Bombers may be refuelled in flight.

   b. Attack missions are unescorted beyond the combat radius of fighters from homeland bases, and normally use cover of darkness over enemy territory.

   c. For atom bomb attacks, each attack flight normally will consist of one or two bomb carriers plus 8-10 similar planes for defense and RCM activities.

   d. For each "live" atom bomb strike two or more diversionary strikes of similar size, carrying conventional bombs, may be employed.

4. For the purposes of this study, all targets were assumed to lie in the area bounded by Moscow, Odessa, Chelyabinsk and Baku. The range of distances of these targets from possible base areas is approximately as follows:

| | | |
|---|---|---|
| a. | From Alaska or N.E. United States | 3600-4500 n.m. |
| b. | From United Kingdom | 1400-2200 n.m. |
| c. | From Cairo-Suez | 1500-2000 n.m. |

5. For the purposes of this study, the following aircraft were considered:

   a. As bombers:

      1. B36D with jet pods (hereafter B36)
      2. B50B (hereafter B50)
      3. B47B (hereafter B47)

   b. As refuelling tankers*
      1. B36B (hereafter B36T)

*In preliminary investigations, the use of a stripped B29 as a tanker was considered, but since analysis indicated it to be less efficient in that role than the B36T, only the latter is used in this study.

6. The suitability or military worth of the use of weapons of mass destruction against enemy cities was not considered in this study, and was not assumed. In view of current divergent opinions, (references (p), (q), (r)), this question should be given separate study.

7. No comparison was made in this study between the costs, rates of losses and force requirements for the bombing proposal examined, and similar factors for attack by means other than medium and heavy bombers. Such comparisons have been made tentatively in references (s) and (t).

B. AIRCRAFT PERFORMANCE

1. References (a) and (b) provide data concerning performance of medium and heavy bombers for sample missions. Typical data available from such sources are those appearing in Table I.

2. Performance data similar to that of Table I are not by themselves suitable for estimating the capabilities of bombardment aircraft to perform the type of mission contemplated, for the following reasons:

   a. Bomb loads at combat radii other than those of Table I must be estimated.

   b. Neither the average nor the combat speeds of Table I are typical of aircraft speed over enemy territory during that portion of the flight when enemy measures will be encountered. In fact, speed normally changes continuously with aircraft weight or altitude.

TABLE I

AIRCRAFT PERFORMANCE
(for Sample Flight Plans)

| | B 36 | B 50 | B 47 | B 36T |
|---|---|---|---|---|
| Combat Radius (n.m.) | 3,220 | 2,300 | 1,640 | 3,680 |
| Bomb Load (lbs) | 10,000 | 10,000 | 10,000 | 10,000 |
| Speed (knots) Ave. | 198 | 246 | 412 | 201 |
| Combat | 360/25,000' | 350/25,000' | 474/35,000' | - |
| Ave. Fuel Consumption (gal/hr) | 825 | 570 | 1,664 | 675 |
| Flight Plan: | | | | |
| Cruise out at | 10,000' | 10,000' | 27,500'-35,300' | - |
| Climb 30 min. before target to | 25,000' | 25,000' | - | - |
| Cruise back at | 25,000' | 30,000' | 37,000'-42,500' | - |
| Normal Engine Power Used | 30 min. | 30 min. | 12 min. | - |
| Take-off Weight (lbs) | 357,500 | 169,750 | 185,000 | 326,000 |
| Combat Weight (lbs) | 244,000 | 119,000 | 122,000 | - |
| Empty Weight (lbs) | 151,500 | 78,384 | 78,640 | 137,165 |

c. The sample flight plans of Table I utilize altitudes less than those of which the aircraft are capable, and which are so low that the A/C may be excessively vulnerable if these altitudes are employed over enemy territory.

3. With the assistance of basic aircraft data derived from estimated power, lift, drag, and compressibility characteristics provided by the Design Research Branch of BuAer, and using graphical methods of computation outlined in reference (c), more suitable performance data have been calculated.

4. Such performance calculations result in Weight, Speed, Altitude diagrams of which Figures 1 and 2 are examples. From such diagrams, the following may be estimated:

a. The bomb or weapon load which can be delivered at any distance from base, for any flight and refuelling plan.

b. The distance from base to which a fixed weapon load, such as an atom bomb, can be delivered, for any flight and refuelling plan.

c. The speed of the bomber during any portion of a flight plan, for use in estimating vulnerability to enemy defenses.

5. For the purposes of this study, the capabilities of the bombers considered will be examined for each of the following flight plans.

a. B36

1. Plan Able: Similar to that of Table 1 and reference (a). Most of target approach at 10,000 ft. bombing and withdrawal at 25,000 ft. Economical cruising speed, except for 1/2 hour at normal power with reciprocating and jet engines in the target area.

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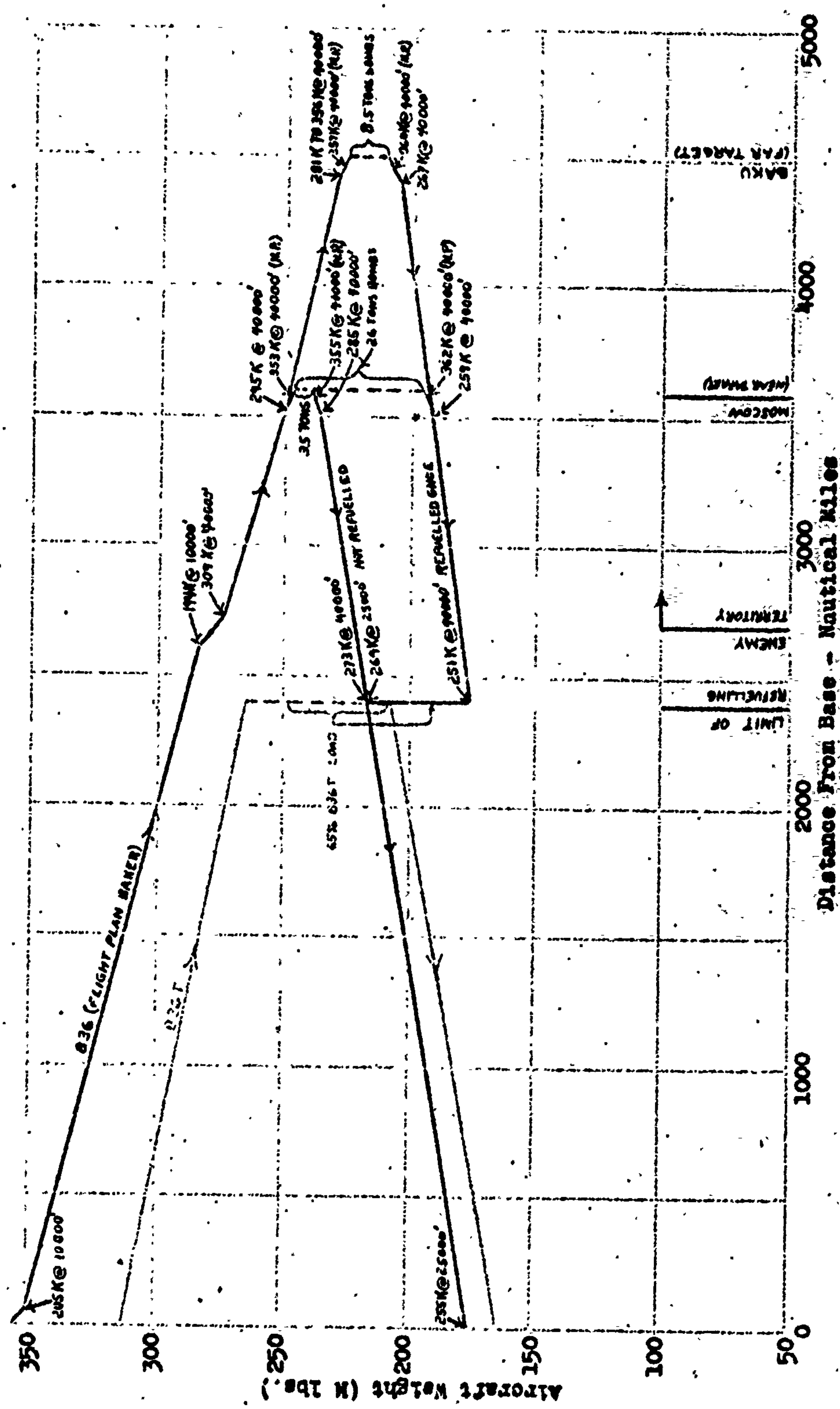


FIG. 1: EXAMPLE OF WEIGHT, SPEED, ALTITUDE DIAGRAM FOR B-36
40,000 FEET OVER ENEMY TERRITORY CRUISE POWER EXCEPT ½ HOUR OF NORMAL POWER

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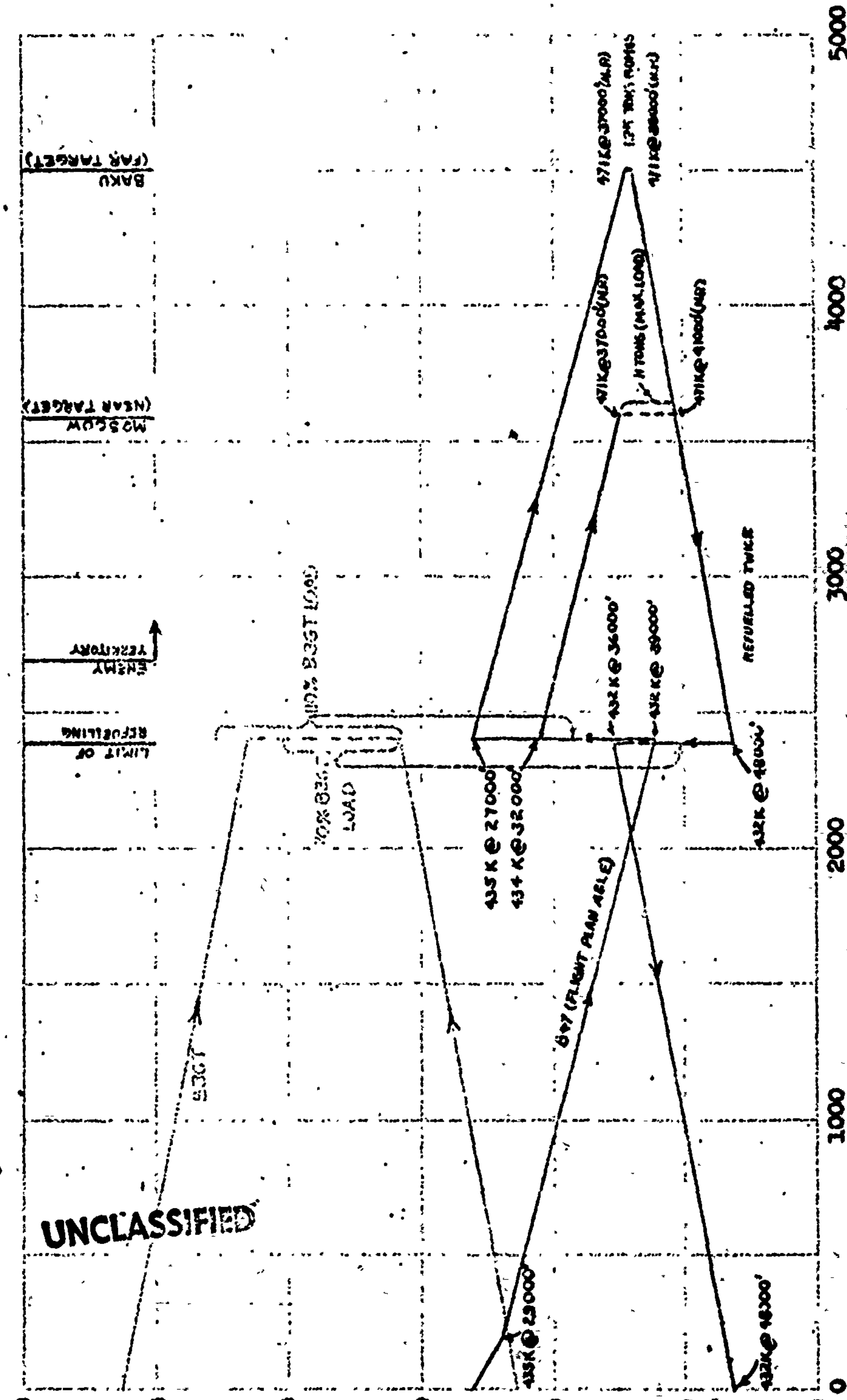


FIG. 2: EXAMPLE OF WEIGHT, SPEED, ALTITUDE DIAGRAM FOR B-47
CRUISE POWER EXCEPT FOR 12 MINUTES AT NORMAL POWER


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2. Plan Baker: Cruise out and climb so as to reach 40,000 ft. at European coast, remaining at 40,000 ft. over enemy territory. Economical cruising speed, except for 1/2 hour at normal power with all engines in the target area. Refuel on return at 25,000 ft. (B36 cannot refuel on outward leg under Plan Baker because non-refuelled weight on reaching Europe is maximum at which 40,000 ft. may be reached at normal power on all engines.)

3. Plan Charlie: Same as for Plan Baker, except that enemy activity forces use of maximum speed during 1/3 of the miles flown over enemy territory.

b. B50

1. Plan Able: Similar to that of Table I and reference (a). Most of target approach at 10,000 ft., bombing at 25,000 ft. with withdrawal at 30,000 ft. Economical cruising speed, except for 1/2 hour at normal power in the target area.

2. Plan Baker: Cruise out and refuel at 10,000 ft., climb so as to reach 30,000 ft. at the European coast, remaining at 30,000 ft. over enemy territory. Economical cruising speed, except for 1/2 hour at normal power in the target area.

c. B47

1. Plan Able: Similar to that of Table I and reference (a). Altitude increases continuously and is the maximum at which normal power would provide 300 ft/min climb. Economical cruising speed, except for 12 minutes of normal power in the target area.

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d. Refuelling

1. It is assumed that air refuelling on either or both outbound or inbound legs of a flight is feasible.

2. It is assumed that both bombers and tankers are based in the same area. (Otherwise bombers should probably operate from any forward base suitable for refuellers.)

3. It is assumed that bombers can be refuelled up to, but not beyond the gross takeoff weights of reference (a) and Table I.

4. It is assumed that refuelling must be accomplished before reaching Europe, and thus a refuelling limit 2400 n.m. from base is established.

6. Typical bomber speeds while over enemy territory have been estimated from the aerodynamic data available and are presented in Table II.

## TABLE II

TYPICAL BOMBER SPEEDS (TAS)
and ALTITUDES OVER ENEMY TERRITORY

| | Cruise Speed/Alt. | | |
|---|---|---|---|
| | Approach | Withdrawal | Maximum Speed Used |
| **B 36** | | | |
| Plan Able | 190k/10,000' | 210k/25,000' | 340k/25,000' |
| Plan Baker, Charlie | 290k/40,000' | 260k/40,000' | 360k/40,000' |
| **B 50** | | | |
| Plan Able | 230k/10,000' | 260k/30,000' | 330k/25,000' |
| Plan Baker | 270k/30,000' | 260k/30,000' | 340k/30,000' |
| **B 47** | | | |
| Plan Able | 430k/27-37,000' | 430k/38-48,000' | 470k/37,000' |

C. BOMB DELIVERY CAPABILITIES (WITHOUT CONSIDERING LOSSES OR ABORTS)

1. In comparing the feasibility of alternative methods of delivering conventional bombs, two general criteria appear to be appropriate, as follows:

a. Economic Cost: In general, each unit of military accomplishment should be achieved at the lowest cost in national effort, as measured in man hours, or dollars. The economic cost of building, basing, and operating aircraft (excluding the cost of losses to enemy action) may be taken to be roughly proportional to the number of aircraft empty weight ton miles required to be flown for each unit of military accomplishment. For the type of mission under consideration, the aircraft dry weight ton miles per ton of bombs delivered appears to be an appropriate measure of cost. For comparing various aircraft types, expression of all types in equivalent numbers of one of them in costs of procurement and operation may be useful.

b. Cost in Cheap but Critical Materials, such as Aviation Fuel: The availability of such required materials as aviation fuel may be as great a controlling factor in determining the feasibility of a type of military operation as the economic cost of that operation. T[illegible]s of fuel required per ton of bombs is, therefore, a significant measure.

2. Table III, derived from Weight, Speed, Altitude diagrams previously described, summarizes the bomb delivery capabilities of the various aircraft

TABLE III

ESTIMATED BOMB DELIVERY CAPABILITIES OF MEDIUM AND HEAVY BOMBERS
(Excluding Effects of Losses or Aborts)

| Plan | Bomb Tons Over Target | Flying Hours Per Sortie: Bomber | Flying Hours Per Sortie: Tanker[1] | A/C Dry Wt. Ton Miles Per Ton of Bombs[2] | Tons of Fuel Per Ton of Bombs | B 36 Months Per Bomber Sortie[3,4] | Tons Per B 36 Month |
|---|---|---|---|---|---|---|---|
| From Alaska or Maine Bases | | | | ($X10^{-3}$) | | | |
| B36 | | | | | | | |
| No Refuelling | | | | | | | |
| Plan Able | | | | | | | |
| Near Target | 8 | 36 | - | 68 | 10.3 | .48 | 16.6 |
| Far Target | - | - | - | - | - | - | - |
| Plan Baker | | | | | | | |
| Near Target | 3.5 | 32 | - | 156 | 25.0 | .48 | 7.4 |
| Far Target | - | - | - | - | - | - | - |
| Refuelled Once | | | | | | | |
| Plan Able | | | | | | | |
| Near Target | 39 | 36 | 27 | 23 | 3.6 | .91 | 42.8 |
| Far Target | 20 | 45 | 27 | 52 | 8.1 | .97 | 20.6 |
| Plan Baker | | | | | | | |
| Near Target | 26 | 33 | 16 | 29 | 4.6 | .74 | 35.2 |
| Far Target | 8.5 | 39 | 16 | 106 | 16.4 | .80 | 10.6 |
| Plan Charlie | | | | | | | |
| Near Target | 17 | 32 | 16 | 45 | 9.1 | .74 | 23.0 |
| Far Target | - | - | - | - | - | - | - |
| Refuelled Twice | | | | | | | |
| Plan Able | | | | | | | |
| Near Target | 43 | 36 | 29 | 22 | 3.3 | .95 | 45.3 |
| Far Target | 43 | 45 | 38 | 28 | 4.1 | 1.15 | 37.4 |
| B50 | | | | | | | |
| Refuelled Once | | | | | | | |
| Plan Able | | | | | | | |
| Near Target | 7 | 29 | 15 | 69 | 11.8 | .50 | 14.0 |
| Far Target | - | - | - | - | - | - | - |

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TABLE III

| Plan | Bomb Tons Over Target | Flying Hours Per Sortie | | A/C Dry Wt. Ton Miles Per Ton of Bombs[2] | Tons of Fuel Per Ton of Bombs | B 36 Months Per Bomber Sortie[3,4] | Tons Per B 36 Month |
|---|---|---|---|---|---|---|---|
| | | Bomber | Tanker[1] | | | | |
| **B50** | | | | | | | |
| Plan Baker | | | | | | | |
| Near Target | 5.9 | 29 | 10 | 72 | 11.6 | .42 | 14.3 |
| Far Target | - | - | - | - | - | - | - |
| Refuelled Twice | | | | | | | |
| Plan Able | | | | | | | |
| Near Target | 10 | 29 | 18 | 52 | 8.9 | .54 | 18.5 |
| Far Target | 10 | 37 | 25 | 70 | 11.5 | .71 | 14.1 |
| Plan Baker | | | | | | | |
| Near Target | 10 | 29 | 17 | 52 | 8.7 | .53 | 18.9 |
| Far Target | 10 | 37 | 25 | 70 | 11.4 | .70 | 14.3 |
| **B47** | | | | | | | |
| Refuelled Twice | | | | | | | |
| Plan Able | | | | | | | |
| Near Target | 11 | 17 | 45 | 44 | 14.0 | .80 | 13.8 |
| Far Target | 1.3 | 21 | 45 | 779 | 160 | .99 | 1.3 |
| **From United Kingdom or North Africa Bases** | | | | | | | |
| **B36** | | | | | | | |
| No Refuelling | | | | | | | |
| Plan Baker | | | | | | | |
| Near Targets | 18 | 11 | - | 15 | 2.2 | .14 | 130 |
| Far Targets | 9 | 14 | - | 40 | 5.6 | .16 | 57 |
| **B50** | | | | | | | |
| No Refuelling | | | | | | | |
| Plan Baker | | | | | | | |
| Near Targets | 10 | 12 | - | 12 | 1.6 | .08 | 112 |
| Far Targets | 10 | 16 | - | 15 | 1.9 | .09 | 97 |
| **B47** | | | | | | | |
| No Refuelling | | | | | | | |
| Near Targets | 11 | 7 | - | 11 | 3.4 | .10 | 110 |
| Far Targets | 1.5 | 9 | - | 96 | 31.6 | .11 | 13.5 |

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(cont. from page 20)

| | | |
|---|---|---|
| <u>World War II</u> | | |
| ETO - 1945 | 8 | 2.4 |
| XX Air Force - 1945 | 16 | 3.6 |

Notes: 1. Bomb loads are estimated for aircraft operation <u>with no fuel reserve</u>, and are, therefore, more optimistic than those of reference (a).

2. If tanker is not required to give up entire load of spare fuel to one bomber, only proportionate share of tanker hours is charged to sortie.

3. Dry weight of aircraft taken as follows:

| | |
|---|---|
| B36 | 76 tons |
| B36T | 69 tons |
| B50 | 39 tons |
| B47 | 39 tons |

4. Optimum sortie rates of aircraft taken from reference (b) with specified adjustments as follows:
   (a) From Alaska or Maine operating over Arctic areas - 50% of optimum.
   (b) From United Kingdom or North Africa - 90% of optimum.

5. In terms of procurement and cost of operation, the B50 is taken to be equivalent to 0.6xB36 or B36T and the B47 is taken to be 0.75 x B36.

6. Since coast of Europe is about 2700 n.m. from Fairbanks or Maine, 2400 n.m. from base is assumed to be greatest distance at which refuelling may be carried out.

7. It is assumed that refueling only up to takeoff weight is feasible and that an aircraft must be refuelled before dropping below landing weight.

8. Full utilization of all spare fuel in tankers is assumed, i.e., that tankers may refuel more than one bomber, and that one bomber can accept fuel from more than one tanker.

9. Tankers are assumed to take off from and return to same bases as the bombers they refuel.

considered, and measures of cost. It illustrates the effects of refuelling and the use of altitude and speed. For purposes of comparison, capabilities of the same aircraft from United Kingdom or Africa bases are estimated, as are measures of effort of bombing campaigns during World War II derived from reference (d).

3. From Table III, the following general conclusions may be noted, while bearing in mind the fact that considerations of aircraft losses or aborts have not been introduced.

From Alaska or Maine Bases

a. Use of the B36 as a bomber requires lowest cost and fuel per ton of bombs, on near and far targets.

b. Refuelling of the B36 one way can enable reaching of far targets--or near targets if maximum speed part of the time over enemy territory is required--and reduces greatly the cost and fuel per ton of bombs.

c. Refuelling the B36 twice can further reduce the cost and fuel per ton of bombs, but only if low altitudes over Europe are acceptable.

d. Use of 40,000 ft. altitude over Europe by the B36 reduces bomb loads to about half that deliverable at lower altitudes, and roughly doubles cost and fuel per ton of bombs.

e. A requirement that the B36 fly at 40,000 ft. and employ maximum speed for 1/3 of the miles over Europe would further reduce bomb loads and prevent reaching of far targets.

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f. Use of the B50 as a bomber generally doubles the cost and fuel per ton of bombs over use of the B36.

g. Refuelling the B50 also reduces cost and fuel per ton of bombs over non-refuelling, and refuelling twice should enable reaching far targets with maximum bomb loads.

h. Use of the B47 as a twice refuelled bomber should allow delivery of bombs to near targets at costs comparable to that for the B50. Although the B47 could reach far targets, loads would be small and costs per ton high.

From Overseas Bases

i. From United Kingdom or North Africa bases, bombs should be deliverable without refuelling at from 1/3 to 1/5 the aircraft cost and fuel per ton as with refuelling from North American bases.

j. During World War II, bombs were delivered at 1/3 to 1/5 the aircraft cost and fuel per ton as would now be required with refuelling from North American bases.

k. It should be noted that the bomb delivery capabilities of Table III are calculated on the basis of somewhat optimistic performance data, and with no allowance for fuel reserves.


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4. For delivery of atom bombs, measures of capability somewhat different from those of Table III may be applicable. Here, cost of delivery is less important because of the strategic scarcity of the bombs themselves. Capability of delivery, therefore, is measured by comparing the distance at which A-bombs can be delivered with the aircraft performance associated with such delivery. Figure 3 illustrates such distances and the effects on them of aircraft type and flight plan, with the A-bomb assumed to be the equivalent of a 10,000 pound bomb load.

5. From Figure 3, the following conclusions may be noted.

   a. For the B36, on low performance flight plan Able, a 10,000 pound load could be delivered to near targets only. Refuelling once should enable delivery to all targets with cruise at 40,000 ft. over Europe, and to half the target area on plan Charlie--allowing 1/3 of miles over Europe at high speed. Refuelling twice would provide 1500-2500 extra miles of combat radius beyond that needed to reach target area for evasive routing--but at the price of low performance.

   b. For the B50, refuelling once should enable reaching near targets with a 10,000 pound load, and refuelling twice far targets--in each case cruising at 30,000 ft. over Europe.

   c. For the B47, refuelling twice should enable reaching perhaps two-thirds of the target area with this load.

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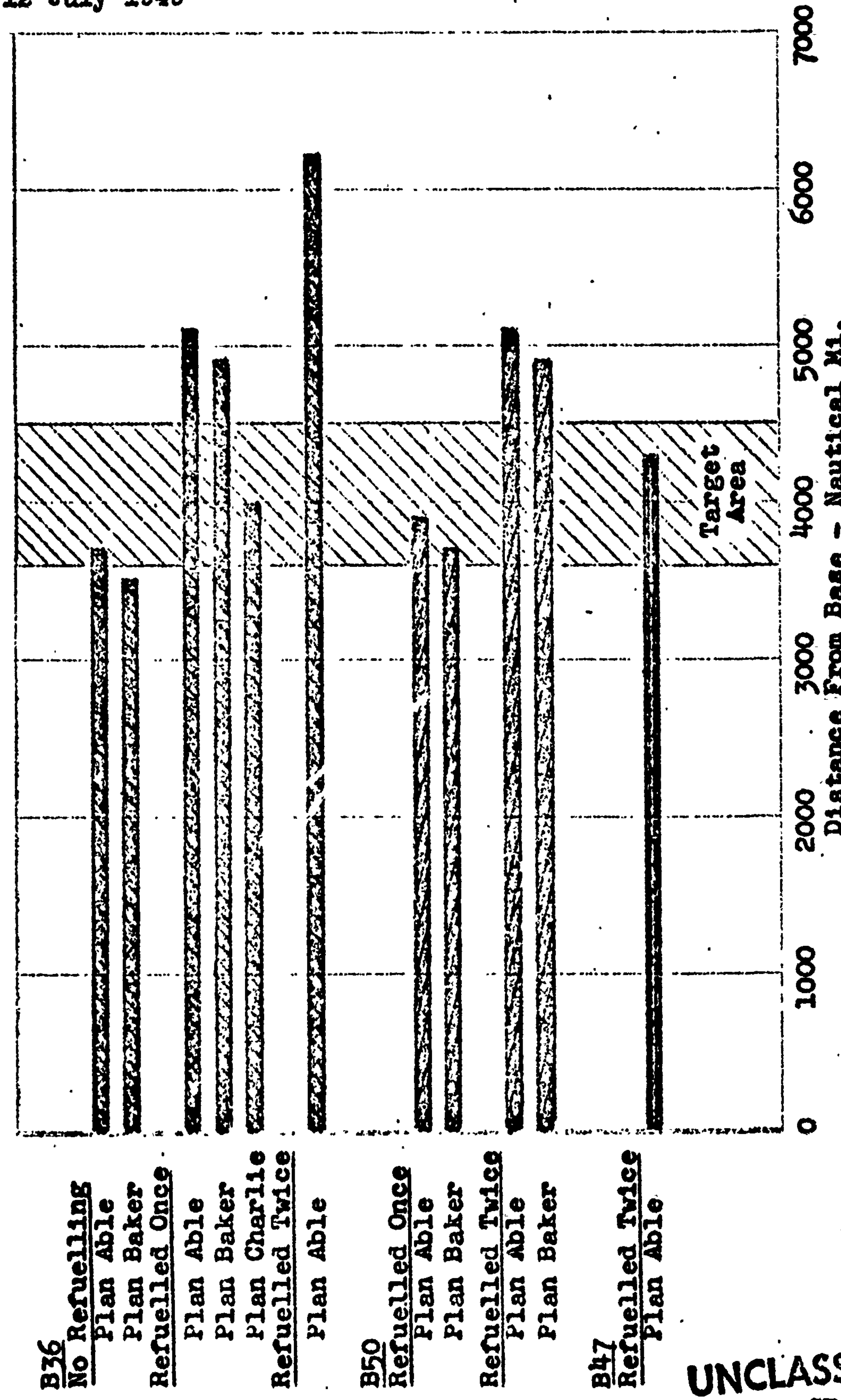


FIG. 3 DISTANCES TO WHICH 10,000 LB. LOAD MAY BE DELIVERED AS AFFECTED BY PLANE TYPE AND TACTICS

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D. TENTATIVE MEASURES OF LOSSES AND ABORTS

1. Decisions as to the feasibility of any plan for a bombing campaign, the force requirements and replacements required for a sustained campaign, and the relative suitability of alternative aircraft types and tactics will be affected by expected losses and aborts and their variation with aircraft type and tactics. It is necessary, therefore, to form some estimate of the losses and aborts expected to be associated with the proposed type of operation.

2. Reference (b) provides estimates of operational losses and aborts of unescorted bombers at night. Reference (e) discusses certain methods for deriving such planning factors. Pertinent estimates from these documents may be summarized as follows:

   a. For operations during 1948, an operational loss rate of 2.2% to bombers at night was suggested. Low capabilities were assigned to USSR defense forces for interception or infliction of anti-aircraft damage on bombers operating at 25,000-30,000 feet at night. Almost all of the 2.2% was assumed to be non-enemy inflicted loss.

   b. For 1950, however, an enemy capability of inflicting losses from interceptors at night is assigned, which is equal to day capabilities in 1948. To account for saturation effects, the expected loss rate of reference (b) is expressed in terms of the numbers of units involved. It is roughly equivalent, however, to an expected loss rate of .1 B50 type bomber for each interceptor (presumably of conventional type) contacting a raid.

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c. Reference (e) estimates that in the case of the Eighth AF during World War II, .17 bombers were lost per interceptor in contact with the bombers themselves. A formula is suggested in reference (e) by which this loss rate may be adjusted for speeds of participating aircraft, as follows:

Probability of Loss per Interceptor in

$$\text{Contact} = 1 - 0.96^{(V_I / V_B)^3}$$

where:

$V_I$ = Speed of Interceptor

$V_B$ = Speed of Bomber

d. For anti-aircraft fire, an overall loss rate of 2% is assumed for 1950 in reference (b).

e. Reference (b) estimates that 16% of enemy interceptors with operational units based within range of a bomber route will sortie against a day raid, and that 60% of those sortieing can be expected to encounter the bomber force. This estimate is based upon World War II experience in the ETO against the GAF in 1944.

f. Reference (b) estimates that 14% of bombardment aircraft dispatched will not accomplish their mission for reasons other than enemy action (will abort). This factor is applicable to all types of bombers and lengths of mission, and likewise appears to be derived from World War II experience without adjustment.

g. Reference (b) estimates that 1% of sorties will result in non-operational loss of aircraft (losses due to causes other than enemy action).

h. It must be emphasized that the above factors are intended as general guides to overall planning. For specific plans in specific areas, special studies are made. Where no firm basis upon which to estimate future experience exists, World War II factors are suggested until such a basis appears.

3. The selection of loss and abort factors for estimating the feasibility of the subject type of operations, and alternative tactics, therefore, requires further discussion. It seems most reasonable to use as a starting point the planning factors recommended for use by the Air Force in reference (b), altering them only as reason appears. In the following examination, the following factors will be considered separately:

a. Of the enemy interceptors with operational units based within range of a bomber route, the proportion which will sortie.

b. Of the enemy interceptors which sortie, the proportion which will reach an attack position on a bomber.

c. The expected number of bombers lost per interceptor attack.

d. Losses to anti-aircraft fire.

e. Aborts.

f. Non-operational losses to aircraft.

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4. Proportion of Enemy Interceptors Which Sortie

a. The estimate of reference (b) that 16% of operational interceptors within range of a bomber path will sortie against a strike appears reasonable. Although derived for day strikes in the ETO, its application to interceptors equipped for action at night seems sound. This factor, however, was derived from a period when continuous day and night raids were the rule, and shortage of pilots and perhaps fuel may have been limiting factors. The limitations of raids to a very small part of each night to provide maximum cover of darkness might considerably increase the percentage of sortieing fighters.

b. In the absence of better information, a range of values of this factor of .15 - .2 for the B50 at high altitude will be used.

c. For bomber aircraft at other altitudes or speeds, some variation in this factor would be expected. Higher altitudes normally provide longer early warning ranges, particularly against large aircraft. The areas from which interceptors can be gathered or staged in to reach a bomber track before passage of the bombers is roughly inversely proportional to bomber cruising speed. This effect might be true only at the periphery of the enemy's defense zone, while deep defenses would enjoy ample warning regardless of bomber speed. Separation of defense belts, or evasive changes of course would tend to prolong this effect, however, and it will be used for this estimate.

d. For the purposes of this study, after consideration of the foregoing, the percentage of operational interceptors sortieing will be estimated as follows:

| | |
|---|---|
| B36 | |
| Plan Able | 25-30% |
| Plan Baker, Charlie | 15-20% |
| B50 | |
| Plan Able | 20-25% |
| Plan Baker | 15-20% |
| B47 | 10-15% |

5. Proportion of Enemy Interceptors Sortieing Which Reach an Attack Position

a. The general magnitude of the estimate of reference (b) that 60% of sortieing interceptors will contact bombers is confirmed from several recent sources:

1. Reference (f) concludes that the probability of intercepting maneuvering bombers at 34,000-40,000 ft. altitude and 400 knots with jet fighters is approximately 70% by daylight. For a single bomber flying at 40,000 ft., this probability is about 60%. These percentages are expected to vary, of course, with conditions of altitude, visibility, radar warning, etc.

2. Reference (g) concludes that even when evasive action in the form of 20 degree bank is employed, the F80-A jet fighter when limited to 480 mph T.A.S. can make successful and repeated tracking attacks on bombers at 40,000 ft. and 430 mph.

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3. Reference (h) reports that during Exercise "Dagger", 60% of regular squadron fighter sorties intercepted day B29 raids at 25,000-30,000 ft., even though state of training, and control net performance was low. Half the known reasons for failure were due to lateness in taking action, and another fifth to limitations in ground control.

4. Reference (h) also reports that for Exercise "Dagger" night fighters, "attacking" bombers generally at 18-23000', 69% of control attempts resulted in an attack after visual identification. When RCM were used, this efficiency was reduced to 46%. On the average, each night fighter sortie completed about one combat.

5. Calculations have been made of the ability of fighters capable of 550k and 2g turns at 40,000 ft. to intercept 500k bombers. The results of such calculations indicate that with reasonable AI radar performance and errors in control, better than 80% of sortieing fighters should reach rear hemisphere attack positions.

b. Estimation of this measure for the subject type of operation, and of its variation with plane type and tactic is difficult because of its dependence on the following factors, among others:

1. Speeds, rates of climb, and maneuverability of interceptors, which may vary over wide limits, as illustrated in Fig. 4, taken from reference (i). (It should be noted that the example performances are without AI radar.)

2. Speed and altitude of bombers.

3. Efficiency and capacity of enemy close control or loose control systems.

4. The efficiency of the enemy in passing interceptor control from one center to another.

5. Performance of enemy AI radar.

6. Possible enemy employment of unconventional control systems, such as from large, radar equipped aircraft which might "fly formation" on bombers for long distances over enemy territory.

7. The efficiency of RCM against enemy control or AI radars.

c. In order to reflect the effects of bomber speed, altitude and interceptor speed and time to climb, the following partly arbitrary method of estimating the proportion of enemy interceptor sorties in contact, yielding values illustrated in Fig. 5, was developed:

1. The proportion of 60% from reference (b) was applied to current jet interceptors and B50 aircraft cruising at 30,000 ft. on flight plan Baker.

2. Under other conditions, interceptor effectiveness is taken to be proportional to the miles of travel at a velocity equal to the difference in speeds between bomber and interceptor, for the time during which a bomber travels 200 miles, less the time for an interceptor to climb to altitude and less 5 minutes dead time.

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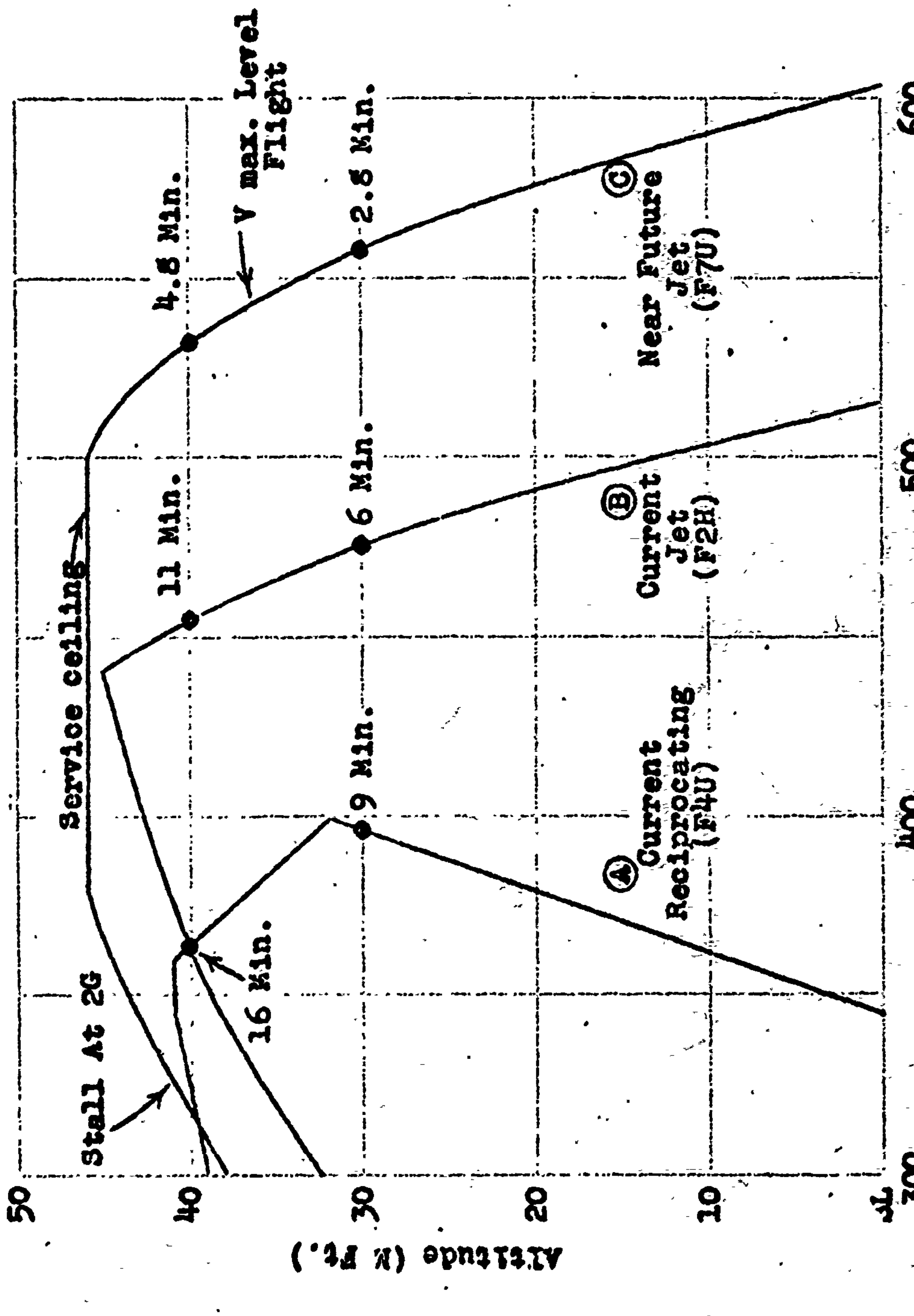


FIG. 4 TYPICAL INTERCEPTOR PERFORMANCE
(Times are Time to Climb to Altitude)

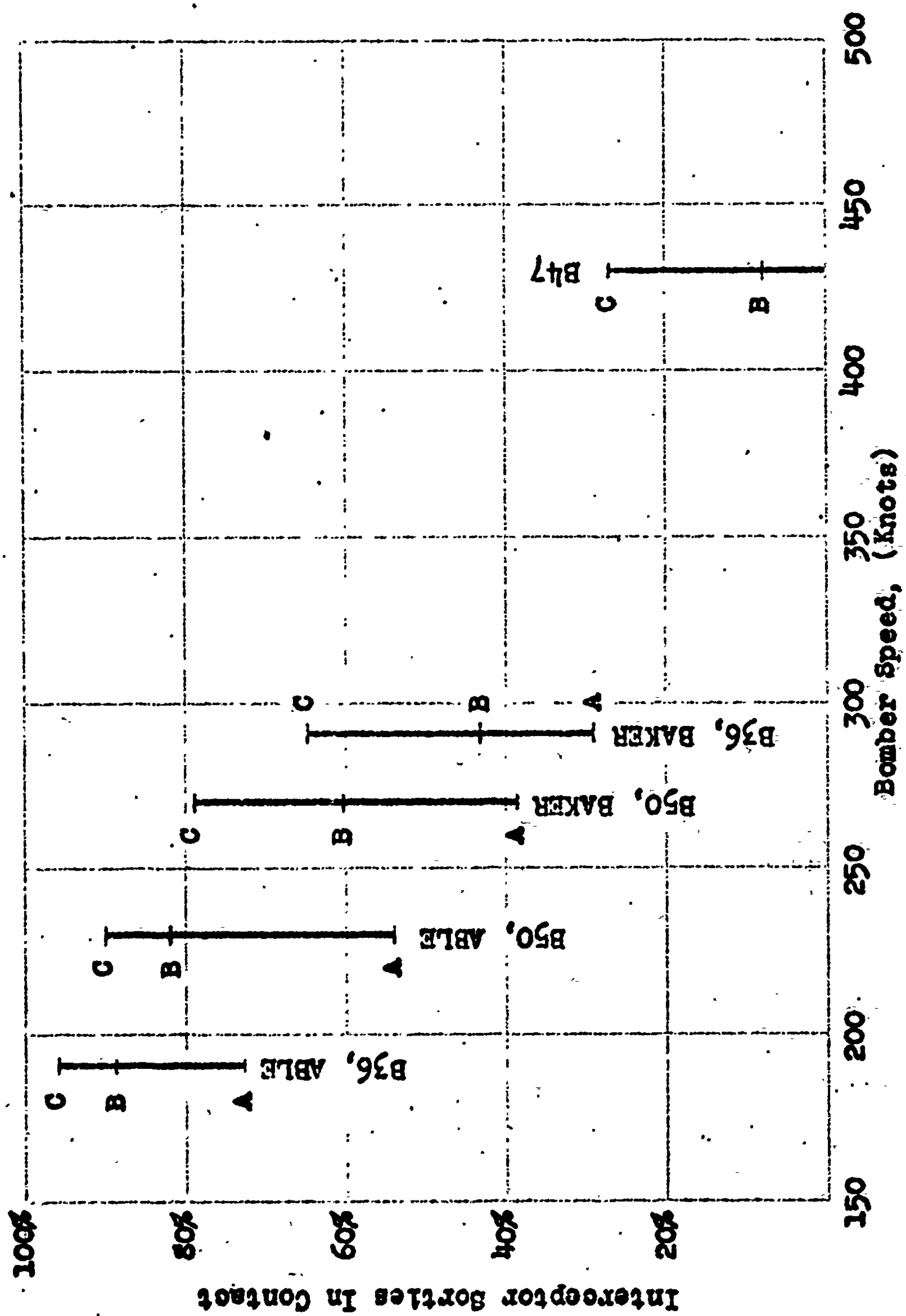


FIG. 5 RANGES OF ESTIMATED VALUES
PROPORTION OF INTERCEPTOR SORTIES IN CONTACT
Interceptor Types A,B,C

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3. The formula, used for values of Fig. 5, is, then:

$$P = 1 - e^{.014(V_I - V_B)(T_B - T_C - 5)}$$

where:

P = Proportion of sorties intercepting. (Probability that a sortie will intercept.)

.014 = normalizing factor

$V_I$ = Interceptor speed (knots)

$V_B$ = Bomber speed (knots)

$T_B$ = Time for bomber to travel 200 mi. (min.)

$T_C$ = Time for interceptor to climb to altitude (mins.).

4. It should be noted that this assumes that the entire interception must be completed during 200 miles of bomber travel, else difficulties of passing of control, etc. will defeat the interceptor. It also assumes that time to climb is wasted, although in fact it is utilized in forward travel and positioning. With less stringent limitations than those assumed, the advantages of bomber speed and altitude would be less than indicated.

d. For the purposes of this study, after consideration of the foregoing, the percentages of sortieing interceptors reaching an attack position will be estimated as follows:

B36

| | |
|---|---|
| Plan Able | 70-90% |
| Plan Baker, Charlie | 30-50% |

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| | |
|---|---|
| B50 | |
| Plan Able | 60-80% |
| Plan Baker | 40-60% |
| B47 | 10-20% |

6. Expected Number of Bombers Lost per Interceptor Attack.

a. This measure is also subject to very wide fluctuations depending as it does on such factors as:

1. Interceptor armament and fire control system errors.

2. Bomber armament and fire control system errors.

3. Vulnerability of bomber to fighter weapons.

4. Vulnerability of fighter to bomber weapons.

5. Fighter and bomber tactics regarding approach angles, speeds, ranges of open and cease fire, and amount of ammunition expended.

6. Altitude of engagement, which has marked effects on projectile slowdown.

7. Amount and distribution of fuel in the bomber at the time of attack.

b. Current knowledge and indications concerning this measure include the following:

1. Reference (e) estimates that .17 bombers were lost per interceptor in contact in the Eighth Air Force during World War II.

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2. Reference (b) suggests a factor of .1 for B50 bombers.

3. Reference (h) states that, for ETO night fighters, the overall ratio of enemy aircraft destroyed to the number of combats increased during World War II from .70 to .80. For second TAF night fighters in Europe the mean "lethality" rate was fairly constant at .88 over a period of six months.

4. Reference (h) reports that, on the basis of gun camera films made during day combats in Exercise "Dagger", of every 100 interceptor sorties in effective combat, 32 bombers would have been destroyed, and 50 probably destroyed. These conclusions were on the assumption that bombers were unarmed, and on the basis of no reliable bomber vulnerability data.

5. Reference (j) summarizes results of British wartime night fighter combats for various types of aircraft, AI radar, and control methods. In general, 30-70% of AI detections led to visual contact, of which 50-70% led to combat, of which 60-90% led to destruction or probable destruction of bombers.

6. The function suggested in reference (e) for adjusting this measure for differences in fighter and bomber speed would yield values illustrated in Fig. 6. This formula neglects, however, the effects of differences in armament and vulnerable areas among bomber and interceptor types. Also, the effect of relative speeds is not believed to be nearly as great as this formula would indicate, particularly beyond an interceptor speed advantage of 100-150 knots.

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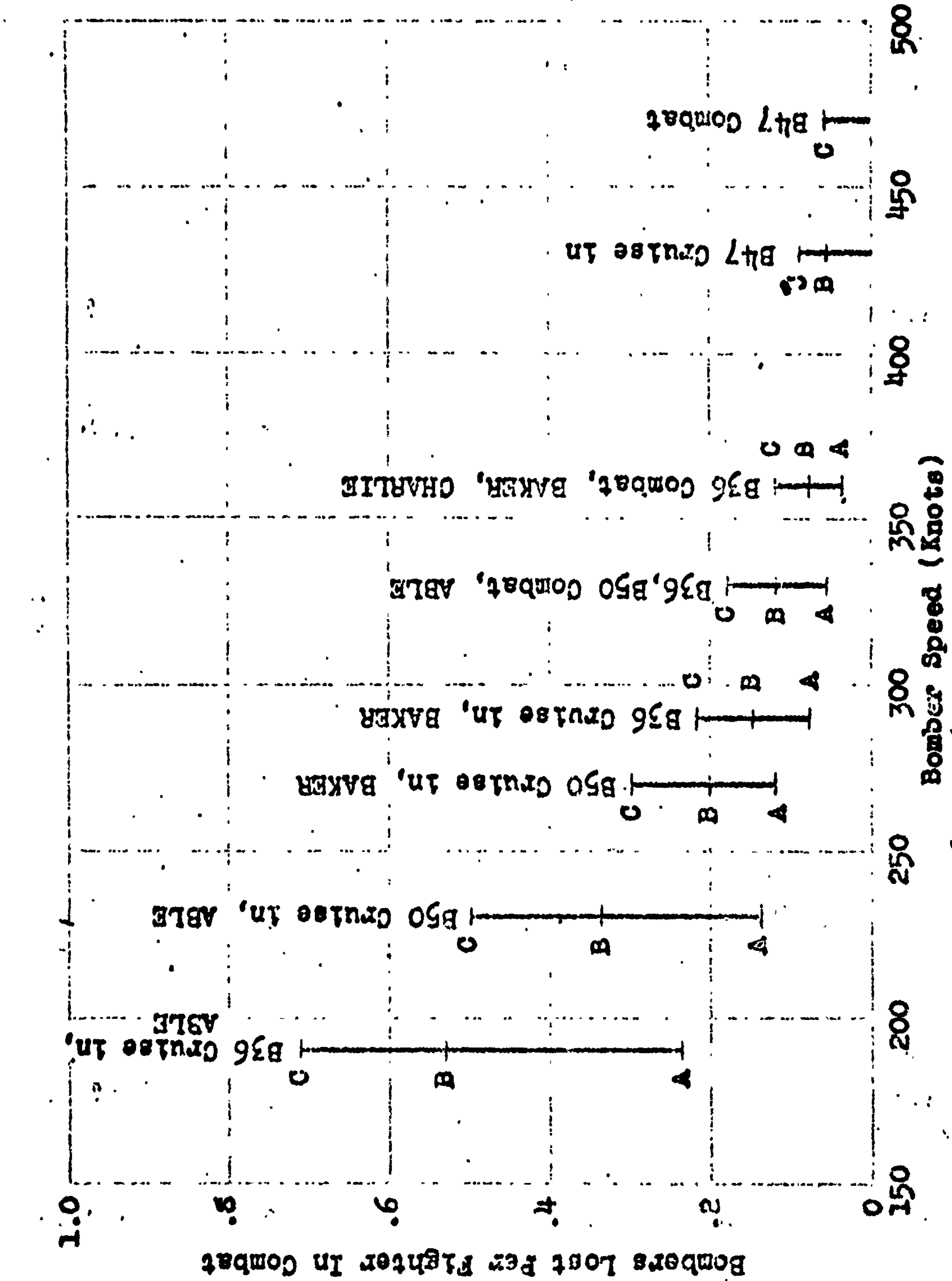


FIG. 6

$$\text{LOSS RATE} = 1 - .96^{\left(\frac{V_I}{V_E}\right)^3}$$

Interceptor Types A,B,C

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7. Current studies of the outcome of the fighter-bomber duel yield, of course, a wide range of results as conditions are changed. Reference (k) is an example of a study bearing on this question which will soon be supplemented by issuance of Ballistics Research Laboratory and OEG studies of measures of effectiveness of specific bomber and fighter armaments and the results of corresponding duels.

8. Fig. 7 illustrates the range within which expected values may lie, for the particular case of a 500 knot jet bomber and a 550 knot jet fighter, and assuming that both fighter and bomber use <u>optimum</u> tactics. A typical value for the case of a 5" rocket armed fighter against a 20 mm tail turret armed jet bomber (or a 20 mm fighter as a .50 cal. bomber) is believed to be .3 bombers destroyed per fighter attack, with an exchange rate of between 1 and 2. Such results are derived for rear hemisphere attacks. When armament and sighting equipment suitable for front hemisphere attacks are available, the relative safety of the fighter should be greatly increased, with bombers destroyed per attack probably decreased somewhat. It should be noted, however, that no exchange rates sufficiently large to deter interceptors from pressing home attacks are to be expected.

9. For the particular bombers examined, no precise vulnerability data are available. In general, however, the following appears to be true:

   a. As the size of a bomber increases, its vulnerable area to contact weapons such as 20 mm increases, while its vulnerable area to fragmentation weapons decreases.

   b. Jet engines are much more vulnerable to all types of weapons than are reciprocating engines--by a factor of two to five.

c. For the purpose of this study, after consideration of the foregoing, the number of bombers lost per interceptor in contact will be estimated as follows:

| | |
|---|---|
| B36 | |
| Plan Able | .30 - .40 |
| Plan Baker | .20 - .30 |
| *Plan Charlie | .10 - .20 |
| B50 | |
| Plan Able | .30-- .40 |
| Plan Baker | .20 - .30 |
| B47 | .10 - .20 |

7. <u>Losses to Anti-Aircraft Fire</u>

   a. The estimate of reference (b) that 2% losses to anti-aircraft fire should be expected appears to be a reasonable basis for this study. It provides for the use of VT fuzes, but not of guided missiles of the Wasserfall type which may eventually increase this rate.

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*All combats are assumed to take place at cruise speed, except for Plan Charlie, where provision has been made for use of V max. during 1/3 of distance over Europe.

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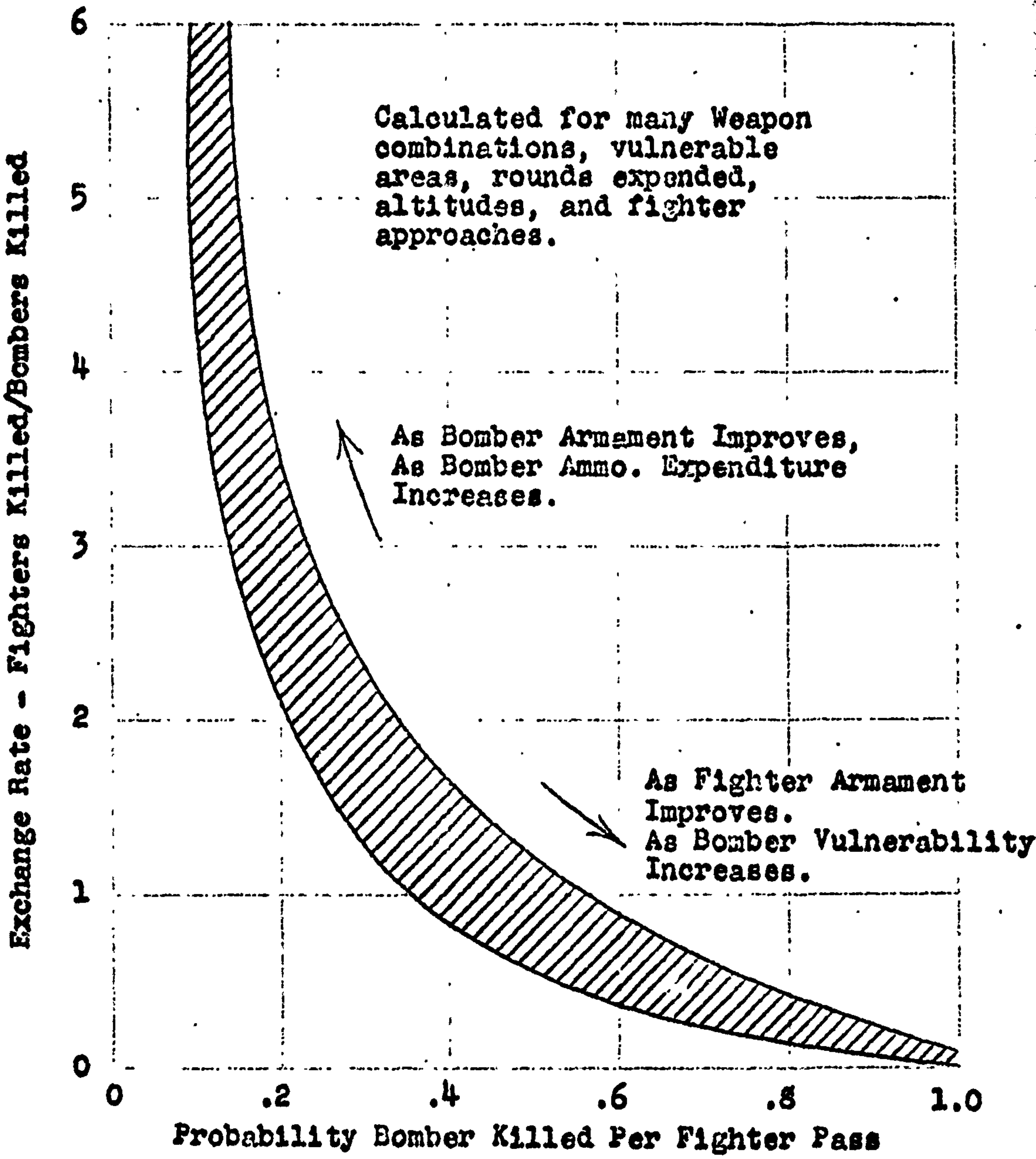


FIG. 7 RANGE OF POSSIBLE BOMBER-FIGHTER DUEL RESULTS
500 K Bomber VS 550 K Fighter

b. Considerations concerning application of this measure to subject operations are as follows:

1. Losses to AA should be inversely proportional to aircraft target speed, since this determines time in the firing area and the volume of fire received.

2. Small raids should sustain higher percentage losses than large raids, because of the greater AA concentration per aircraft of small raids.

3. As noted previously, the B47 would be expected to be more vulnerable to fragmenting AA than the B36 or B50 because of its jet engines, although this might be offset by relative fuel quantities and distribution.

4. Losses of bombers to aimed fire from conventional guns firing VT fuzed ammunition should decrease rapidly with aircraft altitude, particularly as such altitudes approach the maximum gun range. Reference (1) provides a function for single shot hit probability taking the following form:

$$\rho(r) = ae^{-br},$$

where

$\rho$ = single shot probability.

a,b = constants depending on gun and fire control system errors, target area, etc.

r = slant range.

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Expected hits from aimed fire on single aircraft (rather than formations) may be estimated from the function:

$$H = \int_R^h \rho(r)\, n\,(r)\, dr$$

where:

H = Expected hits.

n = Rounds fired per unit change in r.

R = Maximum open-fire range of guns.

h = Aircraft altitude (minimum range of guns).

5. Figure 8 illustrates an example of the relative differences with altitude of expected hits from AA.

c. For the purposes of this study, therefore, the estimate for losses to AA of reference (b) will be taken to apply for B50 aircraft at 30,000' altitude on flight plan Baker, other conditions adjusted for speed, altitude, vulnerability and size of raid as follows:

| | |
|---|---|
| B36 | |
| Plan Able | 4 or 2% |
| Plan Baker, Charlie | .6 or .3% |
| B50 | |
| Plan Able | 6 or 3% |
| Plan Baker | 4 or 2% |
| B47 | 1 or .5%, whichever is greater. |

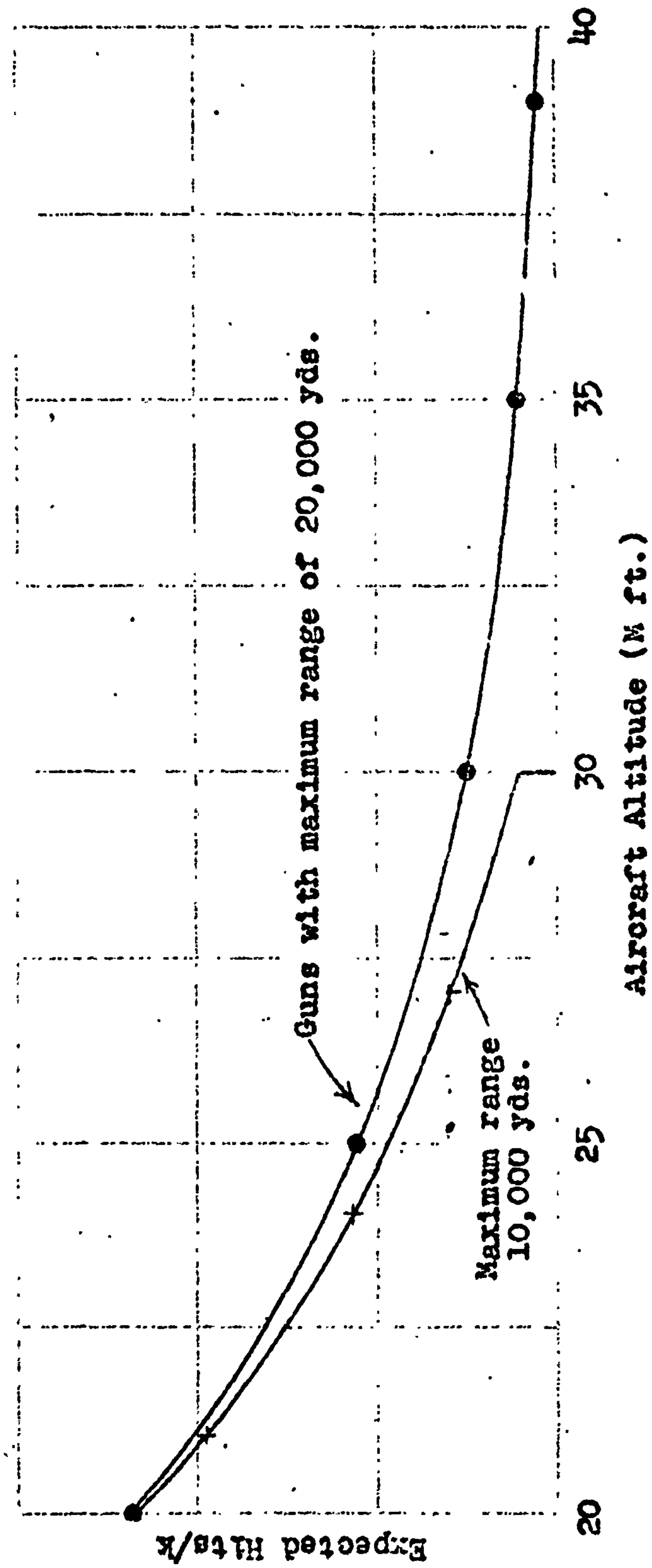


FIG. 5 RELATIVE EFFECTS OF A/C ALTITUDE ON EXPECTED AA HITS

k is a constant depending upon A/C speed, number of guns, rate of fire, etc.

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8. Aborts

a. It does not seem reasonable to assume that the percentage of aborts should be independent of the length of the sortie. The 14% estimate of reference (b) appears to apply both to ETO and XX Bomber Command operations, but the following should be noted:

1. From reference (d) it appears that about half of ETO aborts were due to weather, a quarter to mechanical causes, the remainder to other reasons.

2. On the other hand, the XX Bomber Command, flying from bases where good weather prevailed, on longer missions, using night tactics where formation flying was not required, experienced very few aborts due to weather. Three quarters of aborts were due to mechanical causes.

3. For the subject operations, mechanical aborts of a type varying with sortie length may be predominant. Improvement in power plants may be offset by the effects of demands for high power settings for long periods over enemy territory. Heavy reliance on radar, a fruitful source of mechanical trouble, will tend to increase aborts with length of mission, as may the necessity for pressurization of aircraft.

b. For the purposes of this study, therefore, aborts will be estimated at 5% plus 5% per thousand miles of combat radius.

9. Non-operational Losses

a. The estimate of reference (b) that 1% of sorties will result in non-operational loss of aircraft may be somewhat optimistic during the early phases of a war for

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operations with relatively inexperienced crews from and over Arctic territory. It checks well, however, with late World War II experience.

b. For the purposes of this study therefore, non-operational losses will be estimated at 1% of sorties, bomber or tanker.

10. Summary and Discussion of Loss Factors.

a. A summary of tentative measures of losses and aborts appears in Table IV. From this table it will be noted:

1. Subject to the severe limitations of present knowledge, and the validity of the methods of this study for developing relative loss measures, it appears that

a. Changes in flight plan of a given bomber--that is altitude and speed over enemy territory--can reduce losses to enemy action by 1/2 to 1/10.

b. Expected losses to interceptors as between B36 and B50 are comparable for comparable flight plans, but the B47 should sustain roughly 1/4 or less the overall losses of either conventional type. If the B50 were capable of sustained operation over enemy territory at 40,000 ft. altitude, its loss rate should be considerably less than for the flight plans considered.

2. For a given enemy force of interceptors, the absolute number of bombers lost to enemy action should be about constant, for any given bomber type, bomber tactic, and enemy efficiency. In other words, expected losses to enemy interceptors per raid should be considered to be a constant number of aircraft, not a percentage.

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## TABLE IV

### TENTATIVE MEASURES OF LOSSES AND ABORTS

| | Bomber Type and Flight Plan | | | | | |
|---|---|---|---|---|---|---|
| | B36 Able | B36 Baker | B36 Charlie | B50 Able | B50 Baker | B47 Able |
| 1. Interceptors Within Range of Bomber Track Which Sortie | 25-30% | 15-20% | 15-20% | 20-25% | 15-20% | 10-15% |
| 2. Sortieing Interceptors Which Reach Attack Position on Bomber | 70-90% | 30-50% | 30-50% | 60-80% | 40-60% | 10-20% |
| 3. Bombers Destroyed per Interceptor in Contact | .3-.4 | .2-.3 | .1-.2 | .3-.4 | .2-.3 | .1-.2 |
| 4. Bombers Lost per 1000 Interceptors Within Range of Bomber Track | 53-108 | 9-30 | 4-20 | 48-80 | 12-36 | 1-6 |
| 5. Bombers Destroyed by AA | 4 or 2% | .6 or .3% | .6 or .3% | 6 or 3% | 4 or 2% | 1 or .5% |
| 6. Aborts | 5% plus 5% per 1000 miles of combat radius. | | | | | |
| 7. Non-operational Losses | 1% of Sorties | | | | | |

3. The effect of changes in the general level of the measures of Table IV relating to enemy action would be the same as the effect of changes in the number of enemy units. In other words, the enemy may offset individual unit inefficiencies by increasing the number of units.

b. It is believed that the general level of these estimates of losses are favorable to the bombers, since theoretical calculations, allied experience against enemy aircraft in World War II, and current trials indicate that considerably greater loss rates are possible. The differences in measures among aircraft and flight plans may, however, be too large, since every possible advantage has been accorded to speed and altitude.

E. NAVIGATION ERRORS AND BOMBING ACCURACY

1. The feasibility of the subject type of operations may be adversely affected by:

a. Difficulties in locating and identifying unfamiliar targets after very long flights at night and high altitude, over poorly charted enemy territory, with considerable dependence on radar navigation, which in turn depends for its reliability on accurate radar mapping and the absence of successful enemy decoys or countermeasures.

b. Difficulties in dropping bombs with acceptable accuracy, using radar aiming, from altitudes and at speeds considerably greater than those used during World War II.

2. Reference (m) states that, at current aircraft speeds, dead reckoning plus manual celestial plus radar navigation will achieve sufficient accuracy so that "a 5000 mile mission can be accomplished." According to this reference, current

navigational methods will become of marginal acceptability as aircraft speeds approach 600 mph, and new methods, now under development, will be required at higher speeds.

3. Reference (b) provides estimates of bombing accuracy as follows:

| | Circular Probable Error |
|---|---|
| Visual Bombing from 20,000 ft. (Typical for World War II in ETO) | 1,170 ft. |
| Radar Bombing | |
| From 25,000 ft. | |
| Good Definition | 4,000 ft. |
| Poor Definition | 6,000 ft. |
| From 35,000 ft. | |
| Good Definition | 5,000 ft. |
| Poor Definition | 7,000 ft. |

These estimates for accuracy of radar bombing are stated as based on very meager data. If they were considered to be representative of expected operational accuracies, however, we would be forced to conclude that:

a. Even with individually aimed, rather than pattern, bomb drops, some 10 - 20 times World War II conventional bomb tonnages would be required per target or target system comprised of units 500 - 1000 feet in radius.

b. Such accuracies would probably be unacceptable for delivery of atom bombs on any but very large targets.

4. Other indications regarding expected bombing accuracy are, however, as follows:

a. Reference (n) suggests that $H_2S$ (British radar) bombing errors without bomb guidance on the order of 1700 to 2600 ft. are to be expected.

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b. Preliminary reports concerning current test of the Air Forces K - 1 bombing system are to the effect that circular probable errors in full radar control on clearly defined targets from 20,000 ft. are of the order of 450 ft.

c. The Navy's Bomb Director Mk 5, scheduled for test this year and, like the K - 1, equipped for full radar control and offset operation, is reported to have achieved 15 mil accuracy in mockup trials.

d. A factor for conversion of test or training results to expected operational accuracies is indicated by reference (o) wherein errors of the order of 350 ft. are reported for visual bombing from 20,000 ft. in training during 1944, and related to errors during ETO operations of 980 - 1260 ft. The principal factors affecting this large difference between training and operational errors are stated to be weather, target recognition, and ground smoke. The factors governing differences between training and operational radar bombing will be somewhat different, and may or may not have as large an effect.

5. For the purposes of this study, after consideration of the foregoing, the following assumptions will be made, with the realization that they may be unduly optimistic from the point of view of the bomber:

a. That navigation of bombers will be sufficiently accurate so that failures to complete missions due to errors in navigation can be considered as included in the measure for aborts previously discussed.

b. That careful selection of targets and training of crews should avoid unacceptable waste of atom bombs through inaccuracy of drop.


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c. That accuracy of conventional bombing will be such that, coupled with improvements of weapons and knowledge of their selection, bomb tonnages required for target system attack will be comparable to those of World War II.

F. <u>EFFECTS OF HOURS OF DARKNESS</u>

1. The subject operations are normally considered to utilize the cover of darkness over enemy territory. Flights on the order of 30 to 40 hours duration over polar regions, however, require considerable modification of familiar concepts of "day" and "night" operations. Under some conditions of latitude and course aircraft fly "faster than the sun."

2. Figures 9 and 10 provide means for visualizing the effects of season of the year, base location, and aircraft speed on conditions of daylight or darkness encountered at refuelling points or over Europe. These illustrations are calculated under the following conditions:

a. "Darkness" is assumed to occur when the center of the sun is at least six degrees below the horizon as seen from 40,000 ft. altitude. This may or may not be strictly valid since the degree of darkness sufficient to provide protection to bombers from visually controlled interceptors or AA fire depends upon several additional factors such as color contrasts, bomber size, specular reflections, direction of enemy line of sight, etc.

b. Examples chosen are for the B36 at speeds for flight plan maker, and the B47.

c. Great circle routes from base to the target are assumed.

d. It is assumed that time over target is always scheduled for midnight. It should be noted that at some seasons and when only one refuelling is required, it may be possible to refuel in daylight and still have all hours over Europe in darkness by reaching the target at a time other than midnight. Such possibilities are taken into account in Table V.



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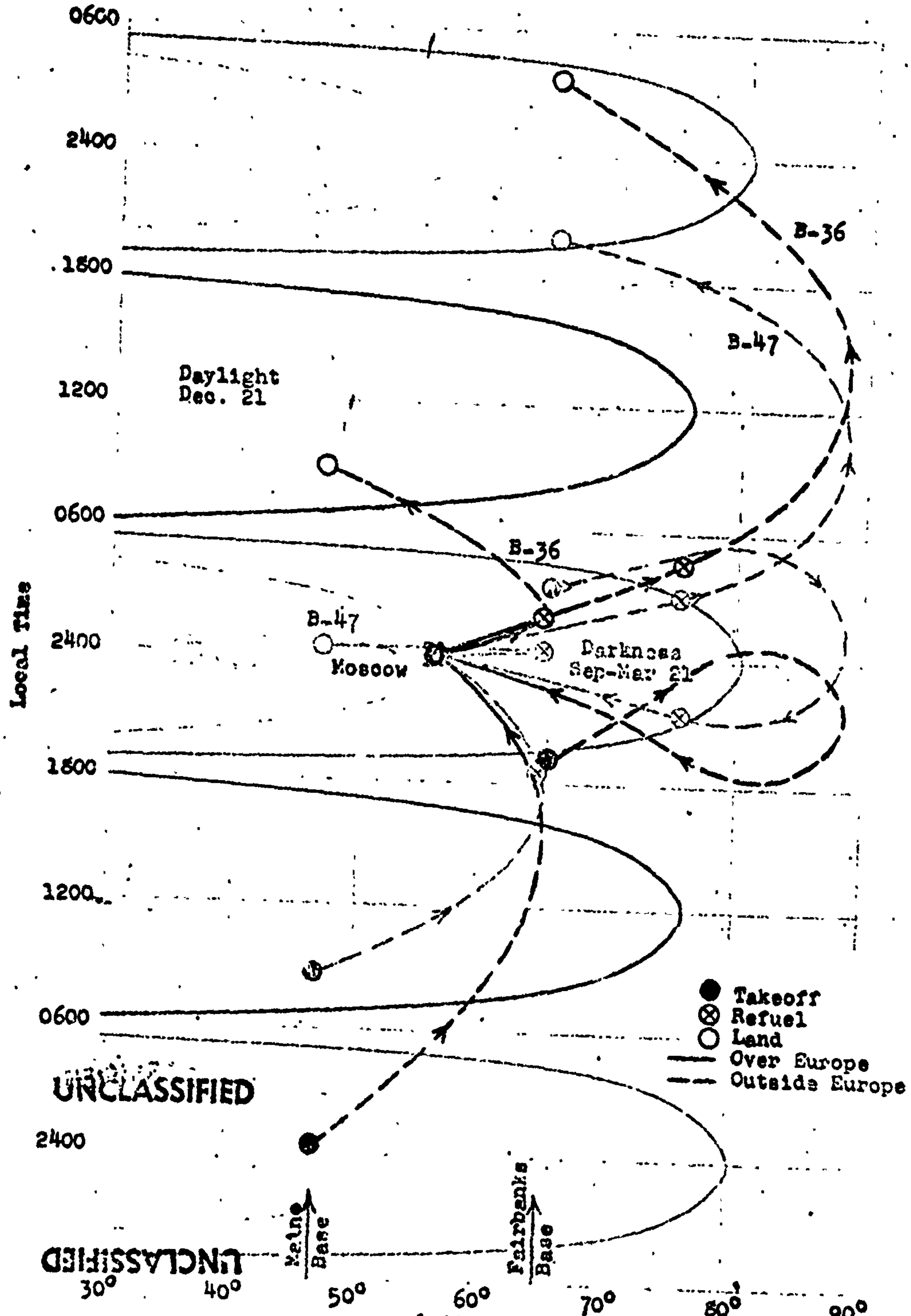


FIG. 9 HOURS OF DARKNESS OVER EUROPE AT 40,000 FT.
Attacks On Near Targets

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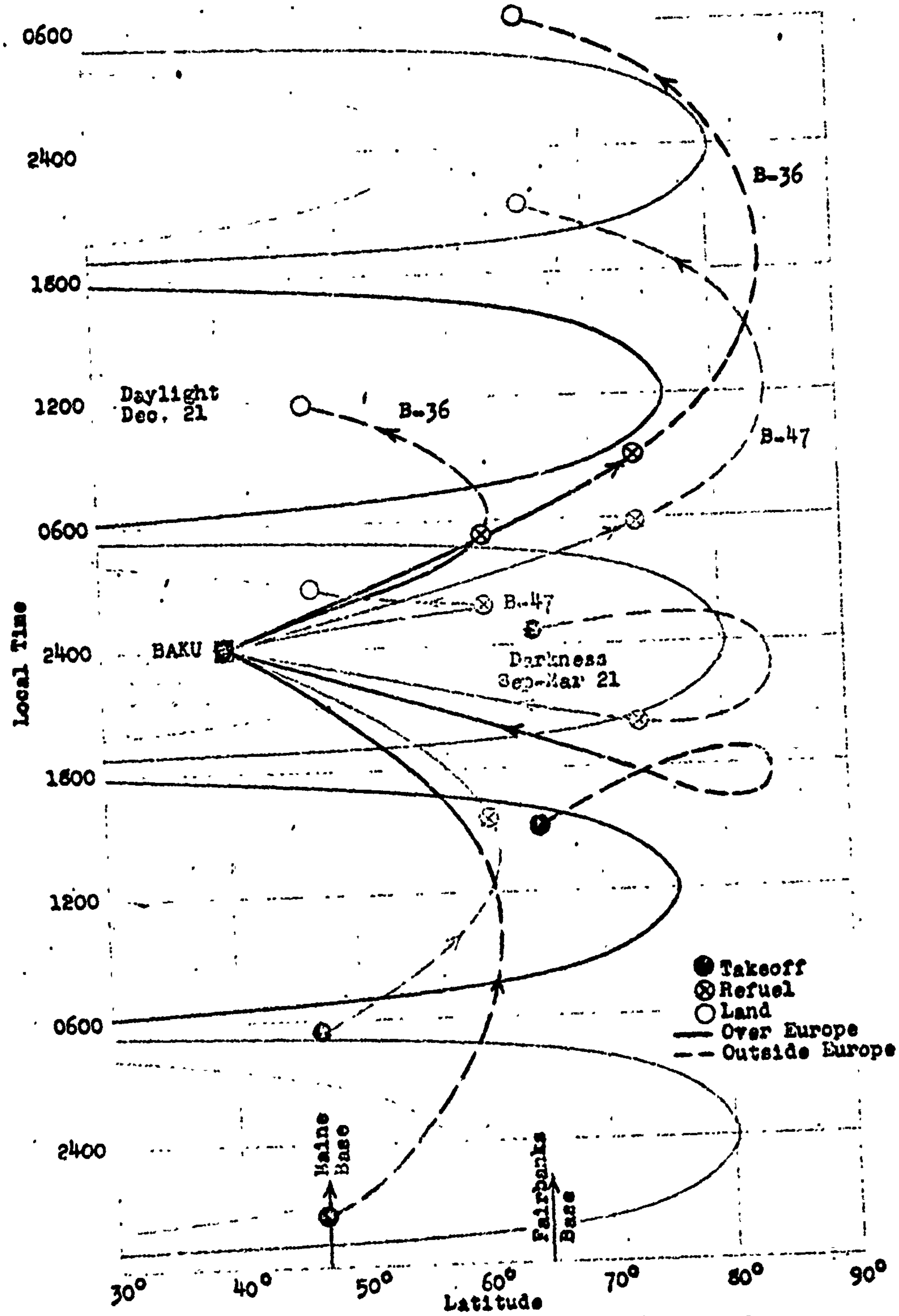


FIG. 10 HOURS OF DAYLIGHT OVER EUROPE AT 40,000 FT.
Attacks On Far Targets

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3. Table V summarizes information from Figures 9 and 10, adjusted to allow maximum hours of darkness over Europe, and refuelling by day, where possible. From this table it will be noted that:

   a. Although in midwinter all bomber hours over Europe can be in darkness, refuelling may likewise be necessarily in darkness. Such refuelling may not be technically or operationally feasible.

   b. During a substantial portion of the year, bombers of current speeds, will be unable to operate over polar regions against many USSR targets without considerable exposure over Europe during daylight.

   c. Use of the B47, by reason of its greater speed, may avoid or reduce substantially any daylight hours over Europe which might be required for the B36.

G. EFFECTS OF THE USE OF DIVERSIONARY RAIDS

1. It was noted in the introduction to this study that the use of diversionary raids is contemplated to reduce the degree of risk to atom-bomb carrying planes.

2. The use of diversionary raids should not be confused with the use of evasive routing. The latter reduces losses by reason of avoiding, or forcing the dilution of, enemy defensive strength. It would appear to be desirable if reduction of losses is worth attendant reduction in aircraft performance, bomb load and utilization rates, and increases in aborts, hours over enemy territory, and any necessary exposure during daylight. Such compensating effects can be evaluated, but because of their dependence on a particular enemy order of battle, will not be discussed here.

3. Diversionary raids depend for their effectiveness on the engaging of the same enemy forces which threaten the main attack. Any diversion so far distant from the main effort--in terms of either space or time--that new enemy forces can be brought to bear, or that interceptors can sortie, land and sortie again will increase, rather than reduce, overall losses.



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TABLE V

EFFECTS OF DAYLIGHT AND DARKNESS

(Assuming maximum available darkness employed inbound to target)

| | December 21 | | March 21, September 21 | | June 21 | |
|---|---|---|---|---|---|---|
| | Daylight Hrs. Over Europe | Refuel In | Daylight Hrs. Over Europe | Refuel In | Daylight Hrs. Over Europe | Refuel In |
| Near Targets | | | | | | |
| B 36 (Plan Baker) | | | | | | |
| From Fairbanks | 0 | Dark | 0 | Day | 4 | Day |
| From Maine | 0 | Day | 0 | Day | 6 | Day |
| B 47 | | | | | | |
| From Fairbanks | 0 | 2 Dark | 0 | 1 Dark<br>1 Day | 3 | 2 Day |
| From Maine | 0 | 1 Dark<br>1 Day | 0 | 1 Dark<br>1 Day | 4 | 2 Day |
| Far Targets | | | | | | |
| B 36 (Plan Baker) | | | | | | |
| From Fairbanks | 0 | Twilight | 4 | Day | 9 | 2 Day |
| From Maine | 0 | Day | 7 | Day | 11 | 2 Day |
| B 47 | | | | | | |
| From Fairbanks | 0 | 2 Dark | 0 | 2 Day<br>1 Dark | 5 | Day |
| From Maine | 0 | 1 Dark<br>1 Day | 0 | 1 Day | 6 | Day |

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4. Well planned diversionary raids can, therefore, be considered to be a part of the main raid so far as the overall effect of own and enemy numbers is concerned. The aircraft of the main and diversionary raids will suffer the same or higher overall losses as would a single combined raid, unless, by reason of consisting of lightly loaded, higher performance aircraft or by well-timed withdrawal, the diversionary raid can avoid normal losses.

5. For the purposes of this study, therefore, the effect of the use of diversionary raids on losses or force requirements will be assumed to be negligible.

## II. MEASURES OF COMPARATIVE SUITABILITY OF AIRCRAFT AND FLIGHT PLANS

1. Neither the bomb delivery capabilities of Table III nor the expected losses of Table IV can serve by themselves as measures of the feasibility of the proposed type of operations or of the relative suitability of different aircraft types and flight tactics. It is suggested that they should be combined to reveal more significant overall measures such as:

   a. Tons of bombs deliverable per aircraft lost, which it should be desirable to maximize.

   b. Size of raid necessary so that losses will be at acceptable rates.

2. Figure 11 illustrates the estimated effects of aircraft type, flight plan, and raid size on a payoff measure--tons of bombs per aircraft lost. This figure is calculated under the following assumptions:

   a. Conventional bombs are delivered from North American bases to near targets, at the capabilities of Table III, with the refuelling plan providing greatest bomb tonnage.

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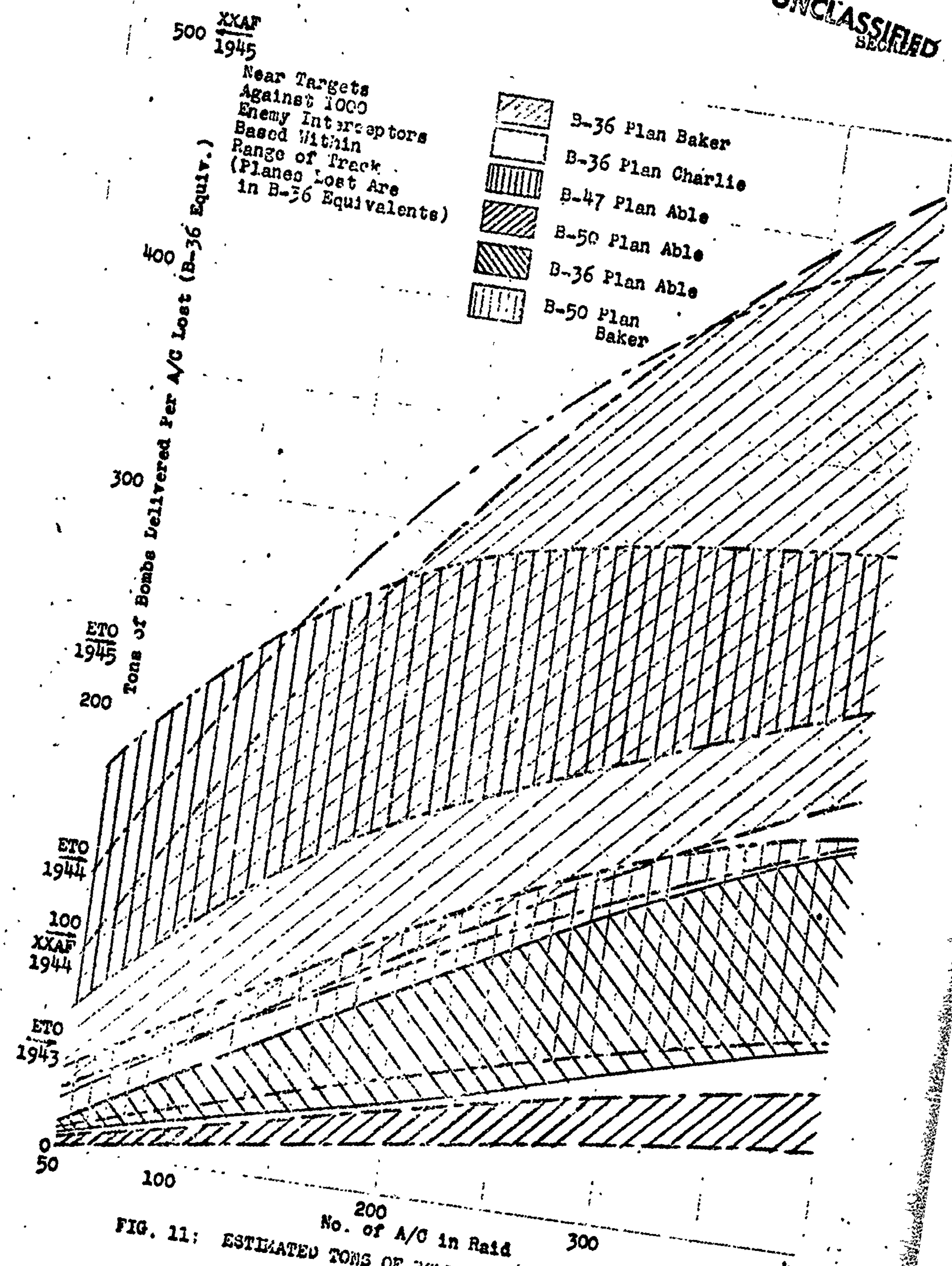


FIG. 11: ESTIMATED TONS OF BOMBS DELIVERED PER A/C LOST

b. The range of estimated losses is as shown in Table IV. (The upper edge of each band in Fig. 11 is for the lower limit of expected losses, and vice versa.)

c. Bombers are faced with a force of 1000 operational enemy interceptors based within range of the bomber track. (This, and following assumed numbers of enemy interceptors, is not to be taken as a considered estimate of the forces which may actually be faced. They are examples only.)

d. In order to place losses of different aircraft types on a comparable basis, losses are expressed in terms of B36 equivalent aircraft. The B50 is taken to be equivalent to .6 B36 or B36T, and the B47 to .75 B36, as in Table III.

e. Aborting bombers deliver no bombs, and suffer no losses except non-operational losses.

f. Tankers do not abort, and suffer only non-operational losses. (Such losses to tankers are included in aircraft losses.)

g. 40% of losses to interceptors or AA are sustained prior to bomb drop, as suggested by reference (b).

h. World War II tons of bombs per aircraft lost are noted, taken from reference (d), deliveries by and losses to heavy and very heavy bombers only being included.

3. From Figure 11, it will be noted that:

a. As would be expected, bombs delivered per A/C lost increases continuously with size of raid.

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b. It would not seem advisable to use the low performance flight plan Able for either B36 or B50 bombers, since increased bomb load should be more than offset by increased losses.

c. As between flight plans Baker and Charlie for the B36, there would seem to be little choice, since the effects on bomb load and losses are offsetting.

d. As among aircraft, the B36 would seem to have greater capabilities than the B50 under all cases considered. The B47 should be superior to the B50 in bomb deliveries per loss, and also superior to the B36 in small raids, or if the enemy capabilities to inflict losses approaches the upper limits of Table IV.

4. For a calculation similar to that for Figure 11, but against far targets and the opposition of 2000 enemy interceptors based within range of the bomber track, the following changes in the conclusions of Fig. 11 would be noted:

a. The B47, because of its small bomb load at such ranges, should deliver tons per loss comparable to the other aircraft only for small raids, if then.

b. The B50, capable of maximum loads at far, as well as near, targets, should do about as well as the B36 so far as this measure of effectiveness is concerned.

c. Tons of bombs per aircraft lost should be of the order of 10-100 tons, rather than the 150-450 tons of Fig. 11.

5. Even though a particular aircraft and flight plan may be expected to yield a favorable measure of performance in terms of bombs delivered per aircraft lost, such operation may not be feasible because of very large raid sizes necessary to hold losses to rates acceptable from the standpoint of crew and national morale. Table VI presents estimated minimum size of raids required for given bomber loss rates. This table is calculated under the following assumptions:

a. The range of estimated losses is as shown in Table IV (the lower value for each entry of Table IV relates to the lower limit of expected losses, and vice versa).

b. Raids are opposed by the numbers of enemy interceptors based within range of the bomber track as shown.

c. Size of raid is the number of planes dispatched, not those delivering bombs.

d. Aborting bombers suffer no losses except non-operational losses.

6. From Table VI, when considered in conjunction with Figure 11, it will be noted that:

a. The highest possible performance flight plan will probably be required of any aircraft, regardless of penalty in bombload, unless very large raids can be dispatched.

b. The B47 now seems quite attractive, relative to other types, because of the small raids possible with this aircraft at low rates of loss.

c. Even when loss rates as high as 25% are acceptable, as may be true for delivery of atom bombs, raids considerably larger than the 8-10 proposed should be required--except possibly for the B47 operating against near targets.

d. The refuelling requirements for these flight plans, and the technical difficulties associated with successful refuelling of large flights of aircraft, may prevent raids of the sizes estimated in Table VI.

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TABLE VI

ESTIMATED MINIMUM SIZES OF RAIDS REQUIRED
FOR GIVEN BOMBER LOSS RATES

| Aircraft and Flight Plan | Near Targets 1000 Interceptors Bomber Loss Rate | | | Far Targets 2000 Interceptors Bomber Loss Rate | | |
|---|---|---|---|---|---|---|
| | 5% | 10% | 25% | 5% | 10% | 25% |
| B36 | | | | | | |
| Plan Able | 2100-4400 | 700-1400 | 240-480 | 4200-6500 | 1400-2900 | 470-950 |
| Plan Baker | 240-800 | 110-310 | 40-130 | 480-1600 | 200-680 | 80-250 |
| Plan Charlie | 120-530 | 50-230 | 20-90 | - | - | - |
| B50 | | | | | | |
| Plan Able | 2800-4700 | 710-1200 | 230-370 | 5300-8800 | 1400-2300 | 440-730 |
| Plan Baker | 480-1500 | 180-480 | 70-170 | 930-2800 | 320-950 | 120-320 |
| B47 | | | | | | |
| Plan Able | 50-180 | 20-80 | 10-30 | - | - | - |


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I. ESTIMATED FORCE REQUIREMENTS - CONVENTIONAL BOMBING CAMPAIGN

1. Some 50,000 tons of bombs per month were dropped in connection with the highly successful campaign against land transportation in the ETO during 1944 and 1945. This level of effort is taken to be typical of that required for intensive attack of a target system.

2. Table VII provides estimates of the aircraft required to deliver such a campaign from North American bases. This table is prepared under the following conditions:

   a. The bomb delivery capabilities of Table III and the loss rates of Table IV are assumed.

   b. Bombers employ a refuelling and flight plan to yield the most favorable bomb tonnage delivered per aircraft lost.

   c. Bombers are faced with a force of 1000 operational enemy interceptors based within range of the bomber track for near targets, 2000 for far targets.

   d. Aircraft requirements are expressed in terms of estimated B36 equivalent numbers.

3. From Table VII it will be noted that:

   a. Aircraft required to be on hand is of the following general form, (although numerous adjustments must be made for tanker sorties and requirements, non-operational losses, etc.).

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TABLE VII

ESTIMATED FORCE REQUIREMENTS
CONVENTIONAL BOMBING CAMPAIGN OF 50,000 TONS PER MONTH

| | Bomber Loss Rate | Raid Size | Raids Per Month | A/C Required (B36 Equivalent) On Hand | A/C Required (B36 Equivalent) Monthly Replacement |
|---|---|---|---|---|---|
| Near Targets (1000 Interceptors) | | | | | |
| B36 (Plan Charlie) | 5% | 120-530 | 7-34 | 2900 | 220 |
| | 10% | 50-230 | 18-77 | 3000 | 430 |
| | 25% | 20-90 | 50-230 | 3200 | 1100 |
| B50 (Plan Baker) | 5% | 480-1500 | 5-14 | 3500 | 250 |
| | 10% | 180-480 | 14-38 | 3600 | 460 |
| | 25% | 70-170 | 44-110 | 3900 | 1100 |
| B47 (Plan Able) | 5% | 50-180 | 34-120 | 4700 | 310 |
| | 10% | 20-80 | 77-270 | 4800 | 550 |
| | 25% | 10-30 | 230-760 | 5400 | 1400 |
| Far Targets (2000 Interceptors) | | | | | |
| B36 (Plan Baker) | 5% | 480-1600 | 5-17 | 6600 | 470 |
| | 10% | 200-680 | 13-41 | 6800 | 910 |
| | 25% | 80-250 | 37-120 | 7500 | 2500 |
| B50 (Plan Baker) | 5% | 930-2800 | 3-8 | 4900 | 290 |
| | 10% | 320-450 | 8-23 | 5100 | 510 |
| | 25% | 120-320 | 25-68 | 5600 | 1300 |



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$$N = \frac{B}{b \cdot s\,(1 - a - .4\ell)}, \text{ where}$$

B = Tons of bombs required per month.

b = Bomb load per bomber sortie.

s = Sorties per month per bomber.

a = Abort rate.

$\ell$ = Loss rate.

It will be seen,,therefore, that the number of bombers required to be on hand for a campaign is proportional to tons of bombs required per month for the campaign, and that loss rates of the order of those shown have only small effects. Actually, dispatching small raids has the effect of increasing on hand rqquirements somewhat to provide aircraft to carry the bombs which will not reach the target because of the higher loss rate.

b. The aircraft on hand force requirements of this table do not depend greatly, therefore, on the assumptions of this study as to loss rates or the number of interceptors to be encountered.

c. Required replacements of aircraft on the other hand, are nearly proportional to bomber loss rates, and, therefore, the use of small raids increases monthly replacements.

d. Since force requirements measured in aircraft on hand, aircraft replacements, and bases for a campaign are increased by the use of small raids, such raids would appear to be limited to objectives or operations unsuitable for large groups of aircraft and which justify high loss rates.

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e. A campaign to deliver 50,000 tons of conventional bombs per month from North American bases would appear to require a force of 3000-6000 B36 aircraft, or their equivalent, and corresponding bases.

f. As among aircraft types, the B36 appears to have somewhat smaller on hand and replacement requirements than the B50 or B47 for a campaign against near targets. Against far targets, on the other hand, the B50 may be somewhat preferable to the B36, since it should still deliver its maximum load. None of the differences in requirements among aircraft are significantly large, however, in view of the uncertainties in performance characteristics on which they are based.

J. ESTIMATED FORCE REQUIREMENTS - ATOM BOMBING CAMPAIGN

1. It has been estimated that the lethal area of the World War II atom bomb is roughly equivalent to that of 2000 tons of conventional bombs. A campaign to deliver 25 atom bombs per month will be chosen for an example of force requirements, therefore, so that it may be related to the 50,000 tons/month conventional campaign discussed above.

2. Table VIII provides estimates of the aircraft required to carry out such a campaign from North American bases. This table is prepared under the following conditions:

a. The only requirements governing raid size are:

1. That it deliver, on the average, one atom bomb per raid. (It works out that raids should carry an average of 1.6 A-bombs to near targets, 1.7 bombs to far targets.)

2. That no more than 25% of atom bombs dispatched will be lost to enemy action prior to drop.

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TABLE VIII

ESTIMATED FORCE REQUIREMENTS
ATOM BOMBING CAMPAIGN OF 25 BOMBS PER MONTH

| | Bomber Loss Rate | Raid Size | Raids Per Month | A/C Required (B36 Equivalent) | |
|---|---|---|---|---|---|
| | | | | On Hand | Monthly Replacement |
| Near Targets (1000 Interceptors) | | | | | |
| B36 (Plan Charlie) | 35-40% | 12-54 | 25 | 170-770 | 120-520 |
| B50 (Plan Baker) | 35-40% | 42-100 | 25 | 430-1020 | 240-610 |
| B47 (Plan Able) | 35-40% | 6-18 | 25 | 100-320 | 40-140 |
| Far Targets (2000 Interceptors) | | | | | |
| B36 (Plan Baker) | 35-40% | 52-170 | 25 | 980-3200 | 470-1500 |
| B50 [illegible] an Baker) | 35-40% | 77-210 | 25 | 1300-3400 | 440-1200 |

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b. It is assumed that losses and aborts will occur among atom-bomb carrying planes in the same proportion as to other planes of the raid, but that aborts will bring bombs safely back to base. (This assumption may not be reasonable if the use of diversions or selective placing of planes in a raid can reduce losses to A-bombers.)

c. Bombers employ a refuelling and flight plan to provide highest performance with a 10,000 pound load (Figure 3).

d. Loss rates of Table IV are assumed.

e. Bombers are faced with 1000 enemy interceptors based near track for near targets, 2000 for far targets.

f. Aircraft requirements are expressed in terms of estimated B36 equivalent numbers.

3. From Table VIII it will be noted that:

a. Since the condition is set that no more than 25% of A-bombs (and, therefore, aircraft) will be lost before drop, overall aircraft loss rate is constant at 35-40%.

b. Because of the higher overall loss rate, raid sizes are smaller than those of Table VII. If such a loss rate is unacceptable, raid sizes would be those of Table VII. As raid sizes increase to reduce losses, the need for the A-bomb may tend to disappear, since the larger raid may be capable of carrying the equivalent of one or more A-bombs in conventional explosives.

c. Since raids per month, rather than overall tonnage of loads of all aircraft, is now fixed, force requirements will vary with raid size, and depend on enemy capabilities to inflict losses.

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d. It should be possible to carry out the A-bomb campaign of Fig. VIII with a far smaller inventory in aircraft and bases on hand than the presumably equivalent (for some targets) conventional campaign of Fig. VII. Monthly replacements of aircraft, however, may be comparable to--or even exceed--those required for the conventional campaign.

e. As among aircraft, the B47 appears to enjoy an advantage in smaller force requirements for attack on targets within its radius. The B36 may still be superior to the B50 in force requirements for this role.

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