INTERDICT # 61
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ASSUMPTIONS REGARDING ATTRITION OF AIRCRAFT IN THE CENTRAL EUROPEAN SCENARIO

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The anti-air defense of the Russian Front described in the Central European Scenario can be schematically portrayed as in Figure 1.

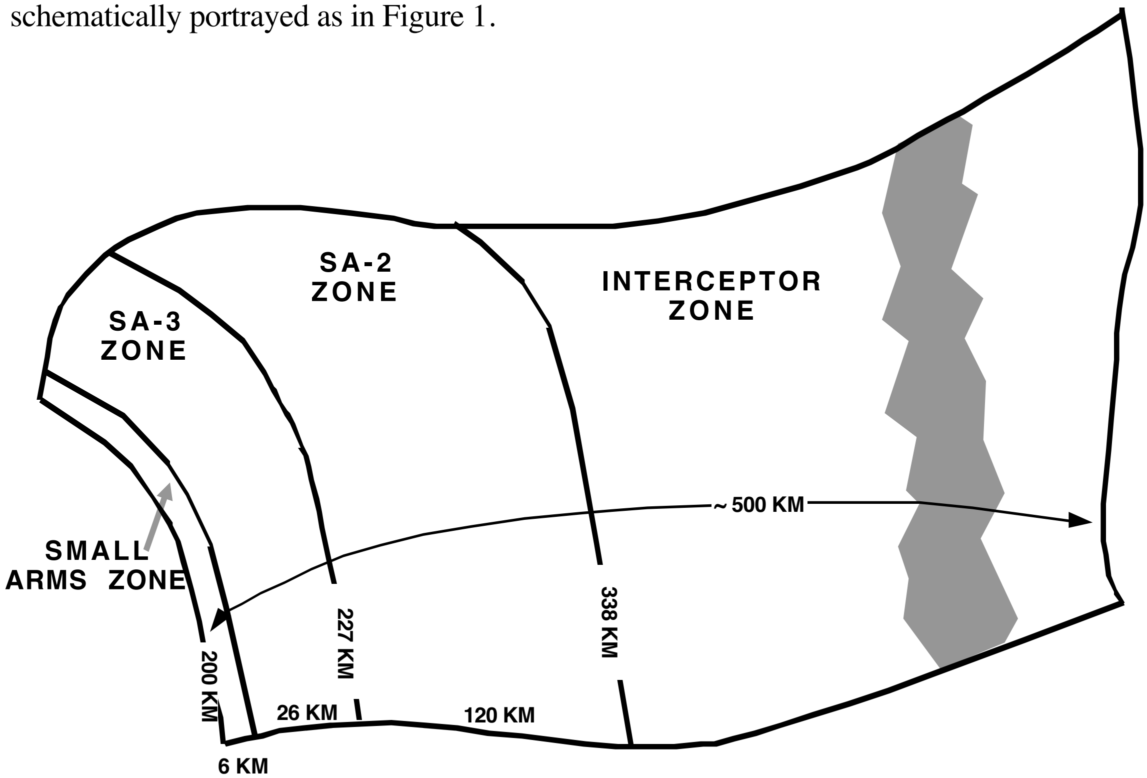


Figure 1

Total inventories of weapons and Average Densities in zones are tabulated in Table I.

This array of air defense weapons is certainly formidable; in fact, if the weapons are credited with quite reasonable single-shot kill probability (p_{KSS}), the defense is essentially impenetrable. Since air defense takes up about 30 % of the total USSR Front manpower, as opposed to approximately 10 % for the U.S. Corps it might be questioned that the Russians would actually unbalance their forces in this manner. However, we have accepted the scenario tabulation as above for study purposes.

	Small Arms Zone	SA-3 Zone	SA-2 Zone	Interceptor Zone
Area	1200 km^2	5500 km^2	34,000 km^2	110,000 km^2
• Airfields	0	0	0	23
Density				1/4800 km2 48 all weather and 132 day fighters
• SA-2 Site	0	0	15	12
Density			1/2260 km^2	N.A. Positioned as four terminal defenses of 3 sites each
• SA-3 Site	0	29	25	14
Density		1/180 km^2	1/1360 km^2	N.A. Reserve unit weapons not operating while in Interceptor area.
• 57mm Dual Optical	-	276	204	-
Density		1/72 km^2	1/167 km^2	
• 57mm Single Radar	6 per SA-2 Site -- Low Level Defense			
Density			1/230 km2 SA-2 Site Protection	SA-2 Site Protection
• 23mm Quad Optical Angle Radar-range		102	246	
Density		1/54 km^2	1/138 km^2	
• 14.5 AA MC Vehicle Mount	2484	1242	5562	-
Density	2/km^2	1/4.5 km^2	1/6 km^2	

Table 1 - Defense Disposition Density

If faced with such defenses as these, the first effort of the U.S. Air Force would undoubtedly be to obtain a measure of air superiority and minimize at least the (air) interception threat. Until this objective was achieved, no resources would be allocated to Interdiction and only a minimum to Close Air Support. Since our current objective is to study Interdiction we merely postulate, as described below, that apparent enemy capability is reduced, in manner unspecified, by some air superiority operations. How this is to be accomplished, if at all, is subject matter for a different study - Air Superiority Operations.

Attrition factors per sortie are developed for interdiction targets positioned at type locations 1 - 7 as sketched in Figure 2.

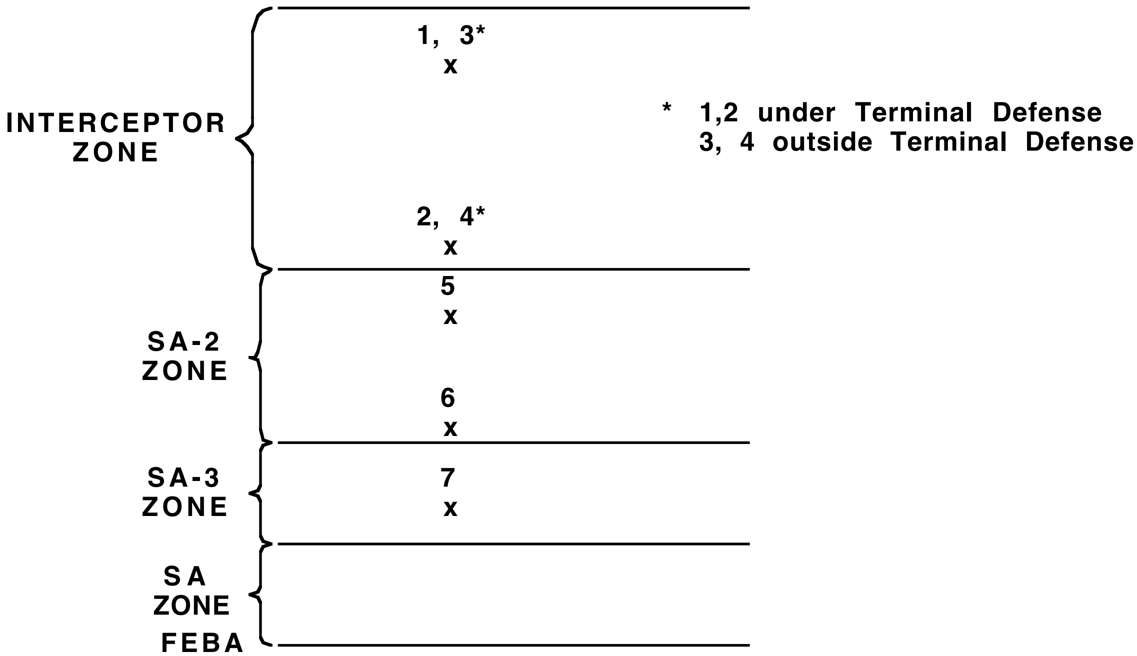


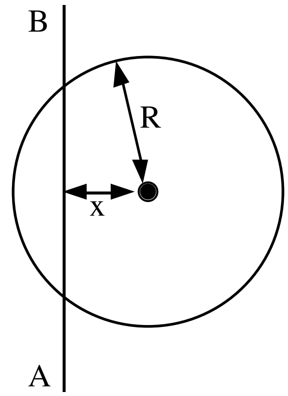
Figure 2

Any given aircraft attacking any one of the target locations must of course transit all intervening defense zones, with some risk of being shot down within each zone. The total probability of survival to target is taken as $\prod_i (1 - p_i)$ where p_i is the probability that the aircraft will be shot down in the i^{th} zone transited. Probability of return to base is taken as $\left[\prod_i (1 - p_i)\right]^2$, which assumes that conditions on return are identical to those on the outbound flight. Terminal defense $p_{s_{TD}}$ is another multiplier.

Now we assume that the very <u>worst</u> conditions under which interdiction operations will be attempted are those in which the per sortie probability of loss is 5% for the most difficult mission attempted. We will develop theoretical probabilities of loss for each zone and each differing mission on a comparative basis and then normalize our results to give $p_{s_{TD}}\left[\prod_i (1 - p_i)\right]^2 = 0.95$ for the worst mission.

The basic equation used for computation of survival probability against ground based weapons is:

$$p_s = \exp\left[-\oint_{A-B} \Phi \, dt\right]$$



where

$$\Phi = \frac{-\ln(1-p)}{\tau}$$

Integration is on time in the track $A-B$, length of exposure is determined by the speed of the aircraft and the offset distance x, p is the kill probability per round delivered, and τ is the characteristic interval between shots for the weapon in question. For guns τ is determined directly from the cyclic rate of fire; for missiles

$$\tau = \frac{R}{v_F} + t_R$$

where R = range

v_F = fly-out velocity of the missile

t_R = is a reaction time for shoot-look-shoot interval.

The Φ is applicable only within the coverage envelope of the system under consideration (further modification of envelope by firing doctrine is described below).

Inputs used for the various weapons available to the USSR Front are in Table II. These inputs result in very low survival probabilities for aircraft, especially when within range of missile installations. There probabilities will be arbitrarily increased (without changing value relative to each other) at a later point in the calculations, partly in order to get on with the problem and partly because there are several actual degradations of defense capability not currently quantifiable.

Table II - (to be developed)

The survival probabilities are quite dependent on the firing doctrine employed by the defense. The defense should be credited with rational expenditure of limited means in order to achieve their prime objective - defense of assigned targets. - with some resources devoted to a secondary objective - attrition of aircraft transiting.

The following doctrinal assumptions are made:

1) Defending missiles will not fire if attacking aircraft can evade interception by a 2 g turn initiated concurrently with missile launch.

2) Defense missiles can discriminate between aircraft attacking targets assigned to that site for protection (protected targets) and aircraft merely transiting the zone.

   a) Against aircraft on the inbound leg attacking a protected target, missile system will expend resources as necessary on a shoot-look-shoot basis

   b) Against aircraft on the outbound leg, or merely transiting the zone, missiles will be expended down to the level required for 90% probability of preventing a single aircraft from successfully attacking a protected target (including the site itself).

3) Defensive guns also can discriminate between aircraft attacking targets assigned to that site for protection (protected targets) and aircraft merely transiting the zone.

   a) Guns will exhaust ammunition if necessary, against aircraft on inbound leg attacking protected targets.

   b) Guns will expend down to 75% of available ammunition against aircraft on outbound leg or transiting zone.

4) Restraints:

   a) Missiles are assigned to single targets on a "best-qualified" basis; i.e., only one site engages any given aircraft at a time, and that is the site best-qualified as to range, degree of engagement , and ammunition supply status.

   b) Guns are always free, subject to ammunition ground rules, to engage the most lucrative single target within range. Guns concentrate fire as batteries.

   c) Interceptors are free only within the interception zone and outside terminal defenses.

There is an implicit assumption in the above that acquisition and guidance radars do not degrade defense capability within the effective engagement range. This assumption is defended by the following considerations:

1) The enemy is unlikely to deploy a system which is severely radar-limited under normal conditions.

2) ECM, reduced cross-section, and radar attack are among the methods contemplated by the general degradation factor assigned later.

The combination of all the above factors produces p_s versus x curves (undegraded) for transit of, or attack within, a single site's coverage as presented in Figure 3.

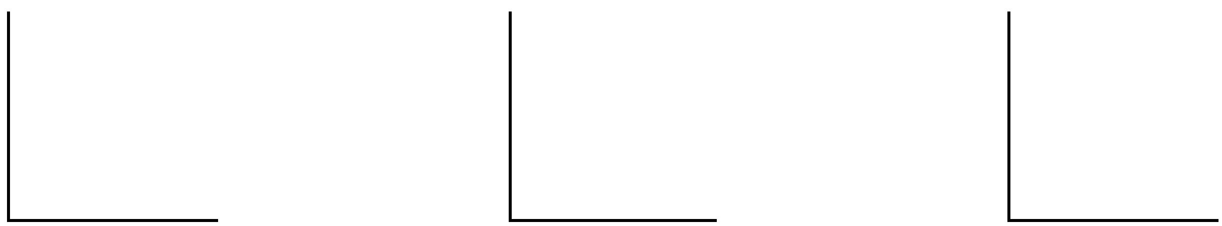


Figure 3 - (curves to be developed)

The next step is to estimate the exposure of the aircraft in transit of a gun or in attack of a protected target. For either case, we can consider separately the exposure to each class (e.g., SA-2) of defense weapons and multiply the resulting p_s's.

The distribution of weapons within a zone can be from optimum zone coverage, or it can be concentrated to a certain degree for coverage of specific targets. Study of a type situation within our European scenario reveals concentration patterns as presented in Figure 4.

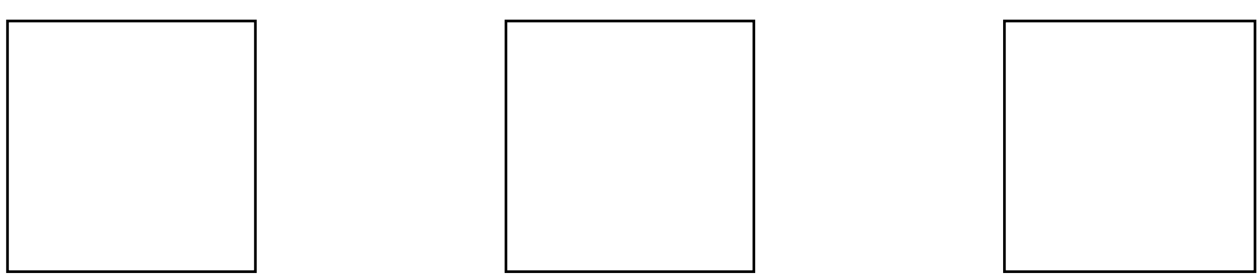
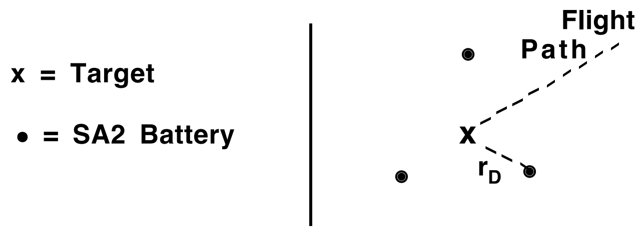
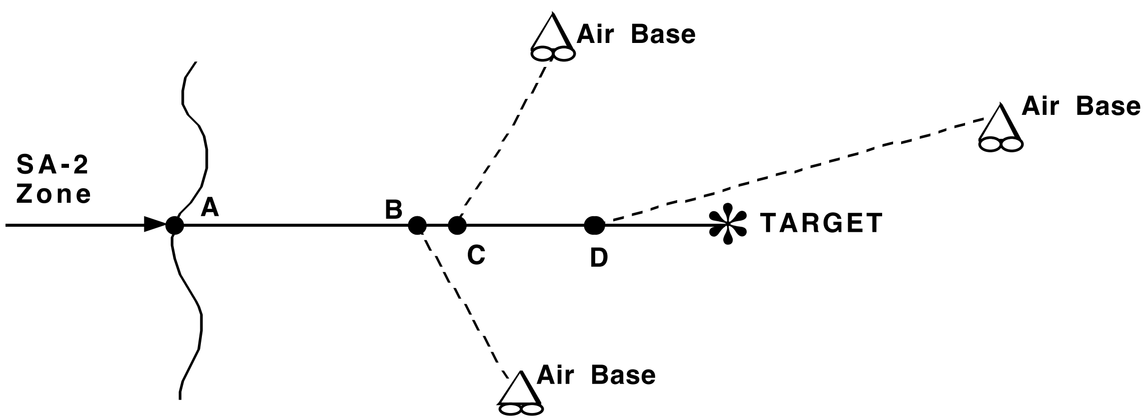


Figure 4 - (cures to be developed)

The pilot of an aircraft transiting a zone (including approach to a terminal defense within the zone) may have varying states of knowledge of defense doctrine within that zone, ranging from complete ignorance to complete information. We have assumed that he will know, by deduction from known locations of protected targets, the location of major defense concentrations; that he will be totally ignorant of the location of distributed zone defenses (primarily because they are highly mobile); and that he can select a flight path which will avoid major defense concentrations.



We will further assume that the typical protected target lies within the range of 3 SA-2 batteries optimally dispersed, but that knowledge of defenses allows 50% chance of picking optimum route.



Although the enemy has a numerical superiority in FI's (Fighter Interceptors), the offense has the advantage of initiative, and the enemy must adopt a doctrine which minimizes the chance that his fuel plus flying time will be exhausted by feints or over-expending on one raid with resulting likelihood of being caught on the ground refueling.

Figure 5

Therefore the enemy is credited with the following doctrine for FI's:

1) Against any given raid, the enemy commits the same proportion of his FI resources as we are committing of our offense resources.

2) Of these committed resources:

a) One three-plane element can meet the raid at Point A, emergence from the SA-2 zone.

b) One three-plane element per base remains air-borne near base to preclude raids on the base.

c) The remaining three-plane elements are vectored to meet the raid at earliest feasible intercept point (B,C,D, as function of relative velocity).

d) Aircraft which cannot engage on the in-bound leg will engage on the outbound leg to the limit of their resources.

The outcome of any given encounter between hostile elements is determined by the product of three probabilities - probability of detection p_D, probability of conversion p_C, and probability of kill p_k.

Values per pass assigned to U.S. and USSR planes are in Table III

<table>
<tr><th></th><th>P_D</th><th>P_C</th><th>P_K</th><th>No. Passes/Sortie</th><th>Available Sortie Time</th></tr>
<tr><td>U.S.</td><td></td><td></td><td></td><td></td><td rowspan="2"></td></tr>
<tr><td>U.S.S.R.</td><td></td><td></td><td></td><td></td></tr>
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Table III

The U.S. is credited with flying a multi-plane raid, with N_{ST} elements of two aircraft devoted to strike, N_{DS} devoted to defense suppression, and N_{CP} devoted to CAP.

The subscripts E and F are used to denote enemy and friendly aircraft, respectively .

Let N_{PI} = The number of interceptor aircraft element (3 or 2) passes on inbound leg

Let N_{PO} = Same number for outbound leg.

The probability of abort (driven off) due to defense for a strike element is:

$$\left[p_{DE} p_{CE} \left(1 - p_{DF} p_{CF}\right)^{\frac{N_{CP}}{N_{PI}}} \right]^{\frac{N_{ST}}{N_{ST}+N_{DS}}}$$

The probability of loss of any U.S. strike or defense suppression aircraft is:

$$\left\{ \left[p_{DE} p_{CE} \left(1 - p_{DF} p_{CF}\right)^{\frac{N_{CP}}{N_{PI}+N_{PO}}} \right] p_{kE} \right\}^{\frac{N_{ST}+N_{DS}}{N_{PI}+N_{PO}}}$$

Appendix B