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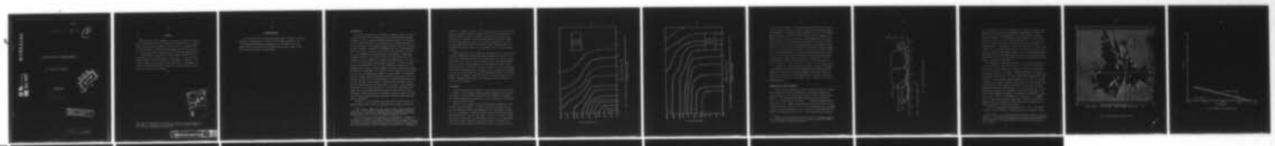

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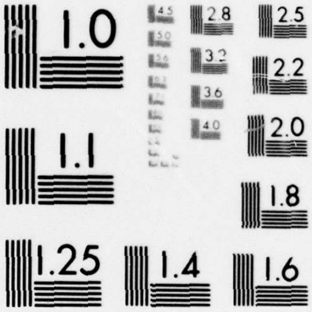
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⑥ LOW LEVEL ATTACK OF ARMORED TARGETS

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ABSTRACT

The proliferation, redundancy, and diversity of Soviet surface-to-air defenses, especially in defense of the battle area, severely limits the air space in which tactical aircraft can operate effectively and survive. Further complications arise when the scenario is Central Europe where weather and terrain play an important role.

Improvements in survivability may be gained through aircraft performance, ECM, penetration aids, and tactics. In the context of Central Europe, the latter method of improvement is explored. Low-altitude penetration and weapon delivery, with the requirements it places on defense penetration, navigation, target acquisition, munitions and training, is discussed.

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ACKNOWLEDGEMENTS

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INTRODUCTION

During the closing days of the war in Southeast Asia, U.S. tactical aircraft were able to penetrate the relatively heavily defended air space of North Vietnam at medium altitudes almost at will because of the limited diversity of the surface-to-air defense systems and the effectiveness of the fighter-carried ECM pods and other electronic warfare equipment. During the 1973 Middle East War, the Israeli Air Force was forced to change tactics due to the proliferation, diversity, and redundancy of Arab surface-to-air defenses. Indeed, the standard low level run-in with a pop-up for weapon delivery in the classical close air support role had to be abandoned due to the severity of the defenses and resulting high attrition. Attacks were then directed toward targets not in contact generally using toss or loft bombing, the accuracy of which degraded as avionics maintenance became infrequent or impossible. As a result of these factors, tactical aircraft killed an insignificant number of armor targets.[1] The highest percent of armor targets killed per sortie came toward the end of the war when Israeli aircraft could operate in a more permissive environment and use PGMs from a medium- to high-altitude delivery profile--one that would have been suicide earlier in the war. Interviews with Israeli pilots revealed that they felt the defenses could have been beaten and targets could have been killed if they could have used high-speed, low-altitude run-in *and* munition delivery tactics--staying low all the way--with munitions which were effective under those delivery conditions.[2]

Analysis of the 1973 Middle East War and the surface-to-air defenses present there, which are representative of those available to

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[1] This is not to imply tactical aircraft were totally ineffective in the war. Their value in keeping enemy air from attacking Israeli ground forces is difficult to measure; and, the IAF had a very favorable exchange ratio in air-to-air combat throughout the war.

[2] The effectiveness of ECM should not be discounted. However, it is difficult to predict its effectiveness, especially in an environment where there is a large number of diverse defense systems. Although the Israelis could not establish quantitatively how much it helped, they felt that what ECM they had did degrade the capability of the defenses.

Warsaw Pact countries, leads to the conclusion that it may be extremely costly for present generation fighter aircraft to again penetrate highly defended air space at medium altitudes with a family of ECM pods (not yet available) and defense suppression techniques. Based on these considerations, there is currently an emphasis on very low altitude penetration (200 ft or less) of heavily defended areas to avoid GCI and target acquisition and guidance radars of the defensive systems.

Continuous low-altitude flight for extended distances over heavily defended, unfamiliar territory introduces problems in the ability of the aircrew to navigate sufficiently accurately to the target, acquire and identify the target in time to deliver a munition with sufficient accuracy to have a high probability of destroying the target, minimizing the need for repetitive attacks or passes. Current and planned air-to-surface weapons require the target to be acquired before weapon release and that the weapon be released essentially before the aircraft passes over the target. Hopefully, very low altitude flight also introduces masking problems which could degrade the effectiveness of the penetrated defenses.

THE PROBLEM

The problem tactical air power is faced with is how to kill armor *and* survive. The 1973 Middle East experience suggests that low-altitude penetration and munition delivery tactics should be considered in a heavily defended environment such as we could expect to encounter in a war in Central Europe.

Weather is a driving factor in the selection of penetration and munition delivery profiles. In Central Europe, about 85 percent of the time during the winter, the weather is less than 5000 ft ceiling and 5 n mi visibility. During the summer, the same conditions exist about 50 percent of the time (see Figs. 1 and 2). In order to operate with visual systems that provide adequate resolution for target identification, weather generally forces the aircraft up from the low level penetration altitudes into the most lethal part of the surface-

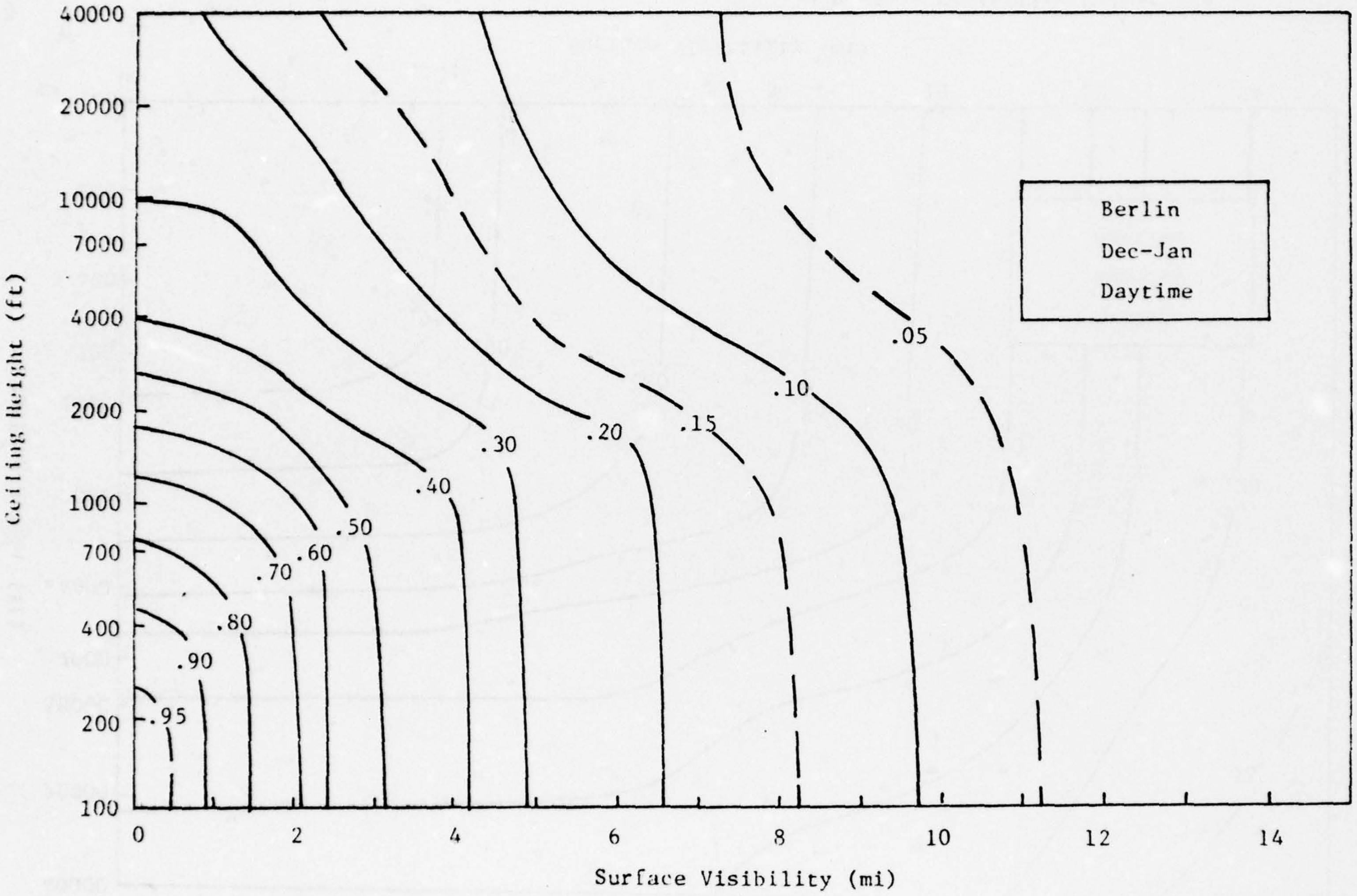

Fig. 1--Probability that Concurrent Ceiling and Surface Visibility Values are Equaled or Exceeded

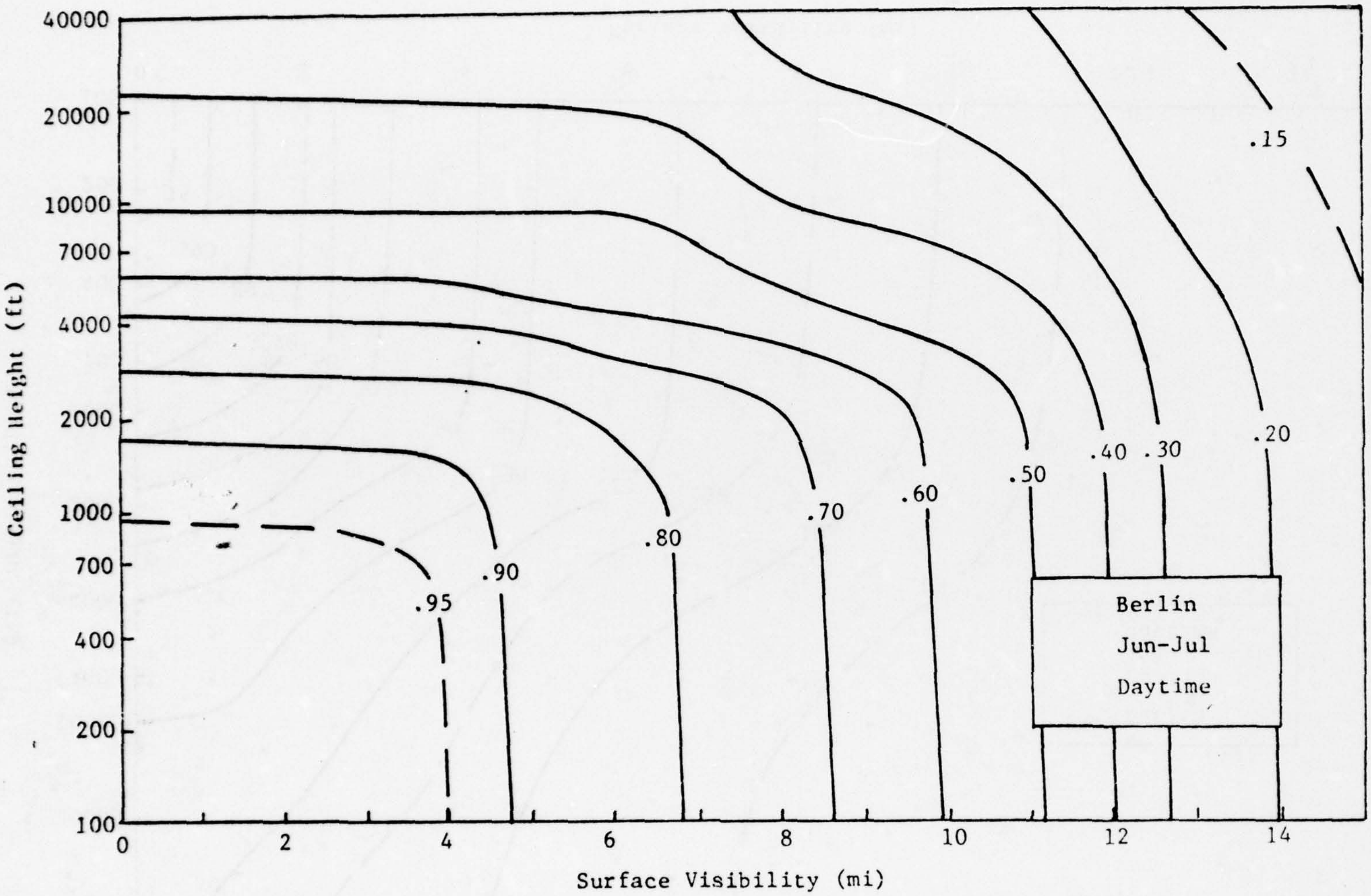

Fig. 2--Probability that Concurrent Ceiling and Surface Visibility Values are Equaled or Exceeded

to-air defense envelope. To decrease exposure time, hence attrition, aircraft could be forced very high to avoid the short-range systems, but atmospheric conditions, target acquisition systems, and munitions make it difficult for the aircraft to detect and kill targets from high altitude.[3] Exposure to surface-to-air defenses could be significantly decreased by aircraft maintaining very low altitude and high speed under the weather and under defense radar coverage throughout the entire flight. Now the problems become defense avoidance, target detection, and appropriate munitions. The problem is further complicated by time compression. At low altitude and high speed, events occur closer together which places constraints on the weapon system not required in higher altitude attacks. In particular, the time between target acquisition and weapon release may be very short. In fact, too short to allow the pilot to convert to a first pass attack.

The major factors affecting the aircrews' success in attacking armor targets from low-altitude, high-speed weapon delivery passes appear to be penetration of enemy defenses, navigation, target acquisition, and munition effectiveness/design. Aircrew training for this tactic is also a critical factor. Each of these topics will be addressed below.

PENETRATION OF ENEMY DEFENSES

Over the past several years, the Soviets have produced an impressive arsenal of surface-to-air defenses. This can be taken as a direct response to the threat they perceive from U.S. ground attack aircraft. The defenses which defend the battle area include the SA-6, -7, -8, and -9, plus the ZSU-23 [illegible] ad-mounted, radar-directed anti-aircraft gun. Deeper penetrations by tactical aircraft can also bring into play the SA-2, -3, and -4. An illustration of the coverage of the battlefield is shown in Fig. 3. Notice must be taken that the battle area defenses are all *mobile*. Each system is self-contained

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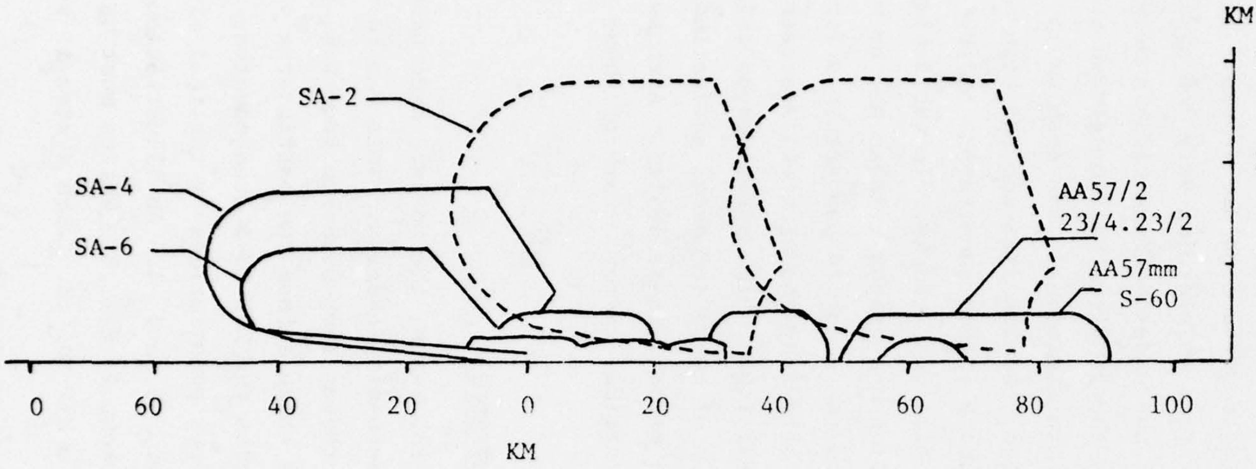
[3] These higher altitudes expose the aircraft to defending manned interceptors and other surface-to-air defensive systems that make up the overlapping coverage now deployable.



SOURCE: U.S. Army Field Manual 100-5.

Fig. 3--Battlefield Defense Coverage

on its own vehicle for ease of movement with the Soviet ground forces. Although this mobility offers significant improvement in defense of the air space over Soviet army assets, it also possesses inherent problems. Namely, if these defense systems operate in a mode where they move, stop, set up, fire, tear down, move, etc., there is little chance to exploit the terrain for the "best" place to establish a firing position. Consequently, natural obstacles such as trees, hills, villages, etc. may effectively block part of the field of view of the tracking radars of these mobile systems. This factor becomes increasingly important if early warning and acquisition radar information is denied the sites and they must provide their own acquisition function, as well as tracking and guidance.[4]

If information regarding the location of battlefield defenses is accurate and timely (and that is a big if), it would be possible to plan a route to the target area to exploit the natural obstructions or local masking about the sites. Favorable penetration routes and attack paths could cut the number of firing opportunities significantly. For example, shown in Fig. 4 is the visible area (unshaded) for a missile site. Two paths were taken through the site. They are labeled 41 and 43 on the figure. Figures 5 and 6 show, for this missile site, the difference in the number of intercepts as a function of target speed and altitude for the two paths. It is clear that there is real advantage in being able to judiciously choose the flight path. Indeed, in this example, the number of intercepts is reduced by as much as a factor of three by choosing path 41 over path 43. It appears that if terrain features can be exploited to reduce the aircraft's exposure time to 20 seconds or less, these mobile defenses would be severely degraded in their effectiveness.

There are systems under development which can aid in obtaining accurate, timely information regarding location of defenses. Among

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[4] This aspect of the attrition problem should be studied carefully. Analysis of the required positioning for early warning and acquisition radars that serve mobile defenses and the placement opportunities in the V Corps area, for example, might reveal important limitations of these systems.

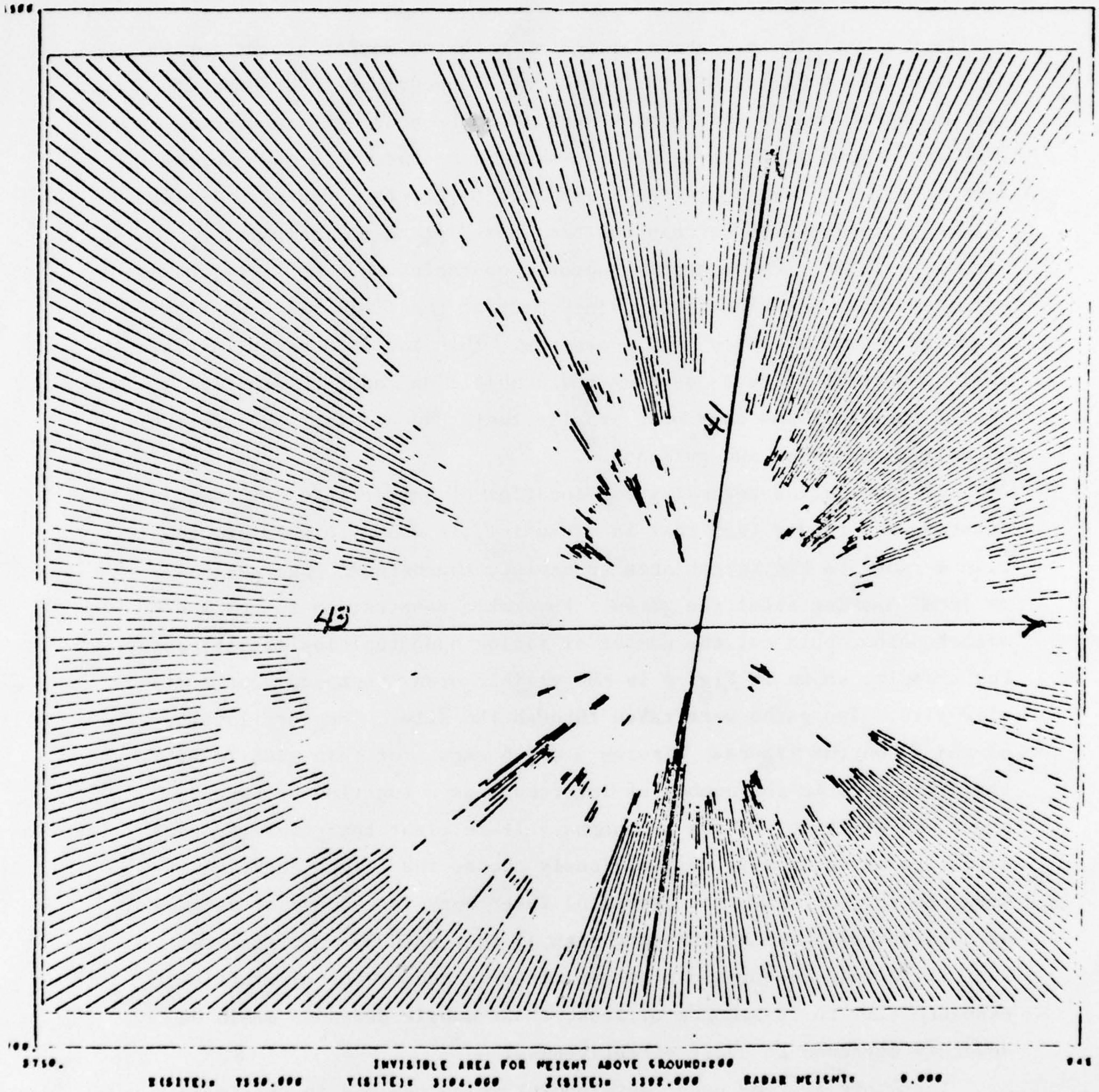

Fig. 4--Missile Site Radar Coverage

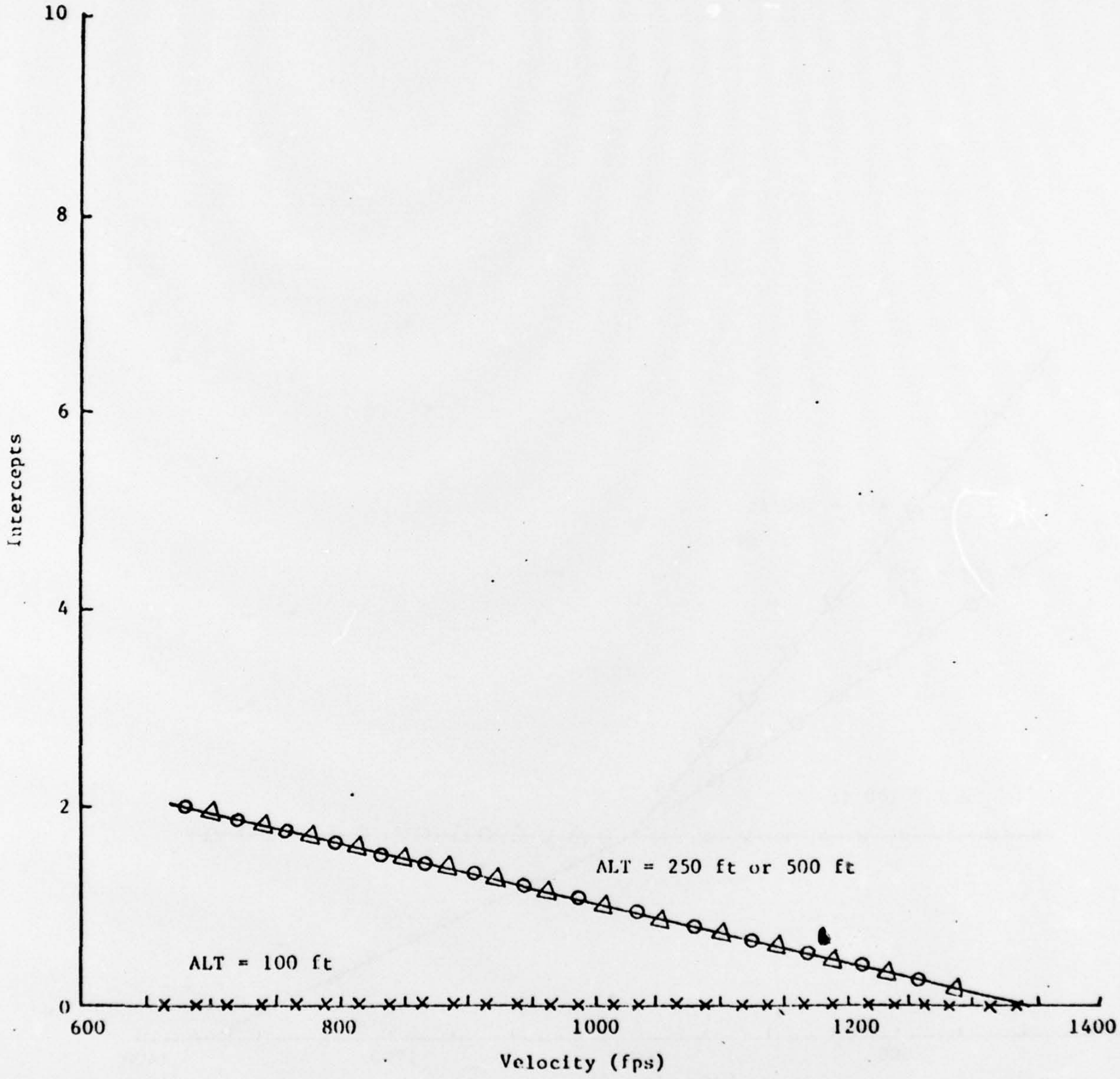

Fig. 5--Number of Intercepts, Path 41

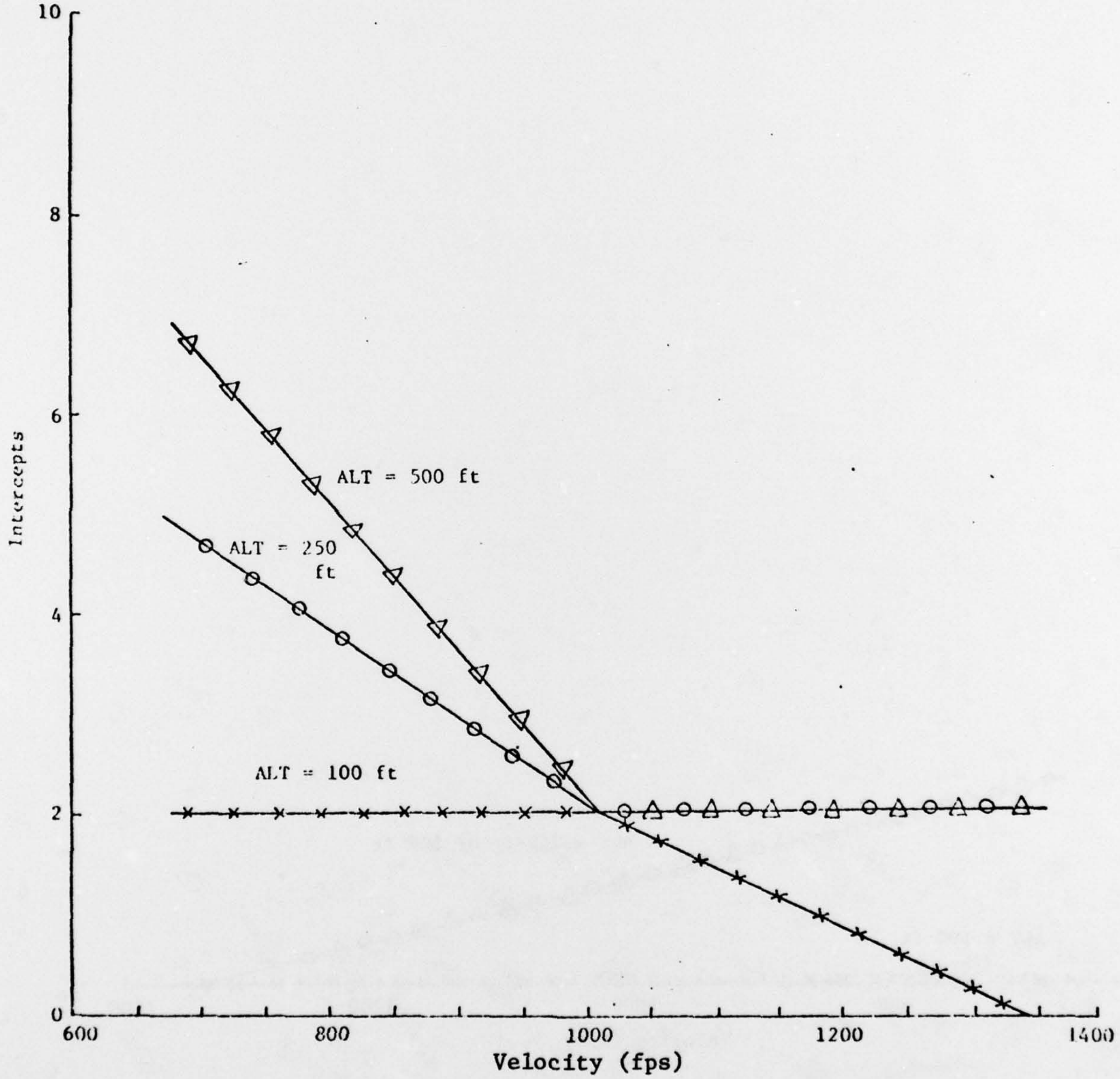

Fig. 6--Number of Intercepts, Path 43

them are Advanced Location Strike System (ALSS), Precision Emitter Location Strike System (PELSS), Compass Sail, Compass Bright, Quick Look 2, etc. Of course, the C^3 problem in coordinating all of this information and making it available to the aircrew in time to be exploited is another very real area of concern.

NAVIGATION

Precise aircraft navigation at low altitudes increases the probability of avoiding ground-based defense related systems and of arriving at a point from which the target might be acquired. Being at the right place at the right time becomes extremely important when depending upon ECM, Wild Weasel, or other mission support elements (TACM 3-1). Dead reckoning has been, and still is, the primary means of navigation. However, when flying at very low altitudes and high speeds, the probability of becoming lost or disoriented is increased, particularly over unfamiliar, rugged terrain and when ceilings and visibilities are reduced.

Detection, tracking, and firing opportunities for ground-based defenses are reduced as penetration velocity increases and flight altitude above the ground decreases. These two flight regimes place competing demands upon the airframe, propulsion system, and avionics of the aircraft. The slower the desired airspeed, the simpler the task for designing an airframe for "contour flying" at very low altitudes over rolling terrain and under adverse weather conditions. The higher the airspeed, the more difficult the task of maintaining a given altitude and track. High speed and "nap of the earth" flying require stronger airframes, increased power, and the avionics to maintain altitude and position. All of these tend to increase cost.

Self-contained aids to augment the dead reckoning capability of tactical aircrews at low altitude and high speeds have been preferred because they are less vulnerable to countermeasures. Inertial systems are completely self-contained and covert. However, not all aircraft are so equipped and even the most advanced systems may require updating to meet the demands imposed by newer target acquisition systems' fields of view. Updating may be achieved by on-board radars and other sensors. Presently installed radars depend upon clearly distinguishable check points for accurate readings and are also subject to countermeasures (admittedly, a tough countermeasure problem at low altitude). Radar beacons are useful for precise positioning when targets are relatively close to friendly positions. Navigational grids exist and others are in development to facilitate aircraft positioning. LORAN was used in Southeast Asia for low-altitude delivery of munitions and unattended ground sensors. This system is potentially vulnerable to direct attack against the transmitters and jamming. The Global Positioning System (GPS) is a satellite system under development which promises the desired accuracy (on the order of 10 m) and reduced physical vulnerability; however, it is still somewhat susceptible to jamming.

Directly associated with the high speed aspect of low-altitude navigation is the need to avoid flying into obstacles during reduced visibility conditions and to maintain constant altitude over the ground. This has been met by installing terrain avoidance radar and complicated auto-pilot systems in aircraft such as the F-111. This could be augmented by some form of night vision device such as Forward Looking Infrared (FLIR), as was demonstrated in SEA.

The above discussion leads to the conclusion that further investigation is warranted of the cost of achieving an acceptable capability to fly and navigate precisely at low altitude and high speeds versus other options for getting aircraft to the point from which they may acquire the target. For example, tradeoffs between speed and altitude may be possible. Higher speed and less attention to low altitude might lead to the same exposure with less investment in terrain following systems. This could complement the desire for high-speed aircraft to facilitate avoidance of enemy interceptors.

TARGET ACQUISITION

Now that we have navigated to the target area threading our way through enemy defenses, how well can we find the target? Not only is this task complicated by atmospheric conditions and countermeasures at the target, it depends on where the targets are to be found. If we are talking about a close air support operation where there are large numbers of targets, then the problem becomes one of IFF and target movement. If we are talking about attacking assembly areas, we may be talking about target concealment and attacking during the night. In any event, as in the case of defense location, accurate and timely information regarding target location must be obtained, coordinated, and provided to the strike aircraft.

Earlier, when we were discussing the use of local masking as a method of defense avoidance, no mention was made of target acquisition. This is a two-edged sword. If you are working against a defended target and the defense cannot see the aircraft, the aircrew likely cannot see the target at all, or for any substantial period of time. For example, if the target is a tank column on a road with ZSU-23-4 and SA-8 or -9 intermingled with the armored vehicles, and if the aircraft minimizes exposure time by attacking across the road, the time available for detecting the target and choosing an aimpoint is very short. On the other hand, if the aircraft flies down the road, there is more time to detect the target, convert to an attack, and make a munition delivery pass, but exposure time, hence attrition, increases. There is an obvious tradeoff. Furthermore, if the aircraft is required to make an absolutely level delivery pass--allowing no pop-up for target acquisition, additional importance is placed on precise navigation and target location information. The picture one has of the world shrinks considerably as altitude decreases. Figure 7 depicts the difference in area of the earth viewed from altitudes of 25,000 ft, 15,000 ft, 5,000 ft and 200 ft.

The signatures of most targets of interest are not substantially different from either man-made or natural background clutter. Terrain masking also limits the range at which a clear line of sight to the target is possible. Hence, reliable long-range cueing information, which would enable a pilot to correct his course to intercept the desired target, is essential but may not be available. The approach

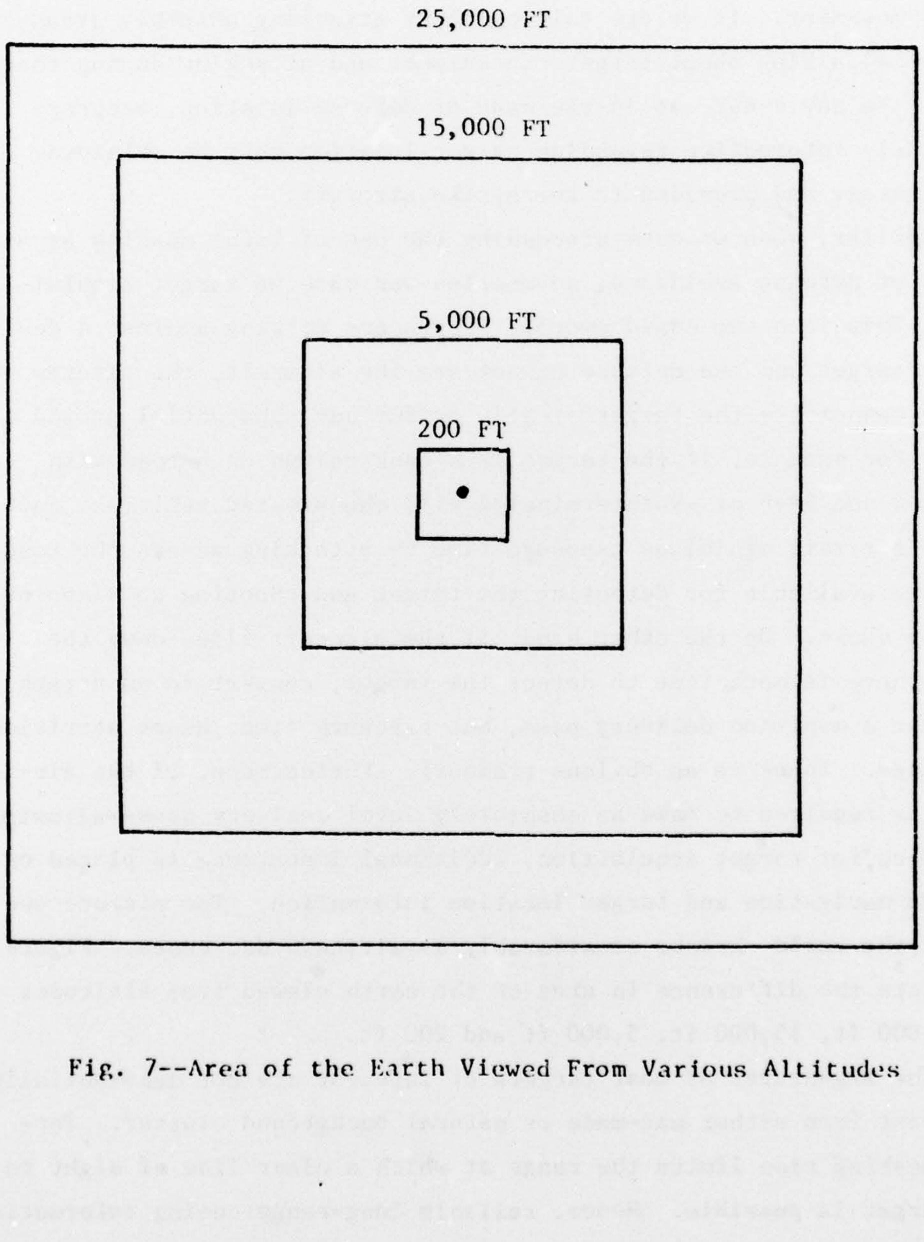

Fig. 7--Area of the Earth Viewed From Various Altitudes

will generally have to be made on the basis of the predicted position of the target and the accuracy of navigation to that predicted position.

Sensors which operate at either infrared or visible wavelengths must be used in order to achieve sufficient angular resolution for target recognition. However, even in relatively good weather, such sensors generally do not permit reliable recognition of vehicle size targets at ranges beyond approximately 3 km. Under severely degraded visibility conditions, the recognition range may not exceed 1 km. Thus, when a high-speed approach is made, little time to both recognize and react to the target is available. If, furthermore, the field of view of a high resolution sensor is 10 degrees, say, this means that the total cross-range error must not exceed approximately 0.5 km to insure that the target is within the sensor's field of view if recognition first becomes possible at a range of 3 km. The allowable cross-range error is correspondingly decreased as the recognition range decreases because of degraded visibility. Somewhat better or worse performance can be achieved, depending upon the nature of the clutter. In the absence of clutter, any blob of sufficient contrast can be assumed to be the target. In such cases, an appropriate course correction can be made at relatively long range and preparations made for the attack well before the target is recognized. In the more usual case, however, clutter competes with the target and there is a significant possibility that the target will not be seen even when it is within the sensor's field of view.

It should be apparent that with present sensors and present weapon delivery systems, there is relatively little margin for error or uncertainty of any kind. There is a need for longer range cueing sensors to alert the pilot to the presence of a potential target within his field of view. Increased resolution and discrimination capability at all ranges is also needed. Such information would provide the pilot with the information needed to decide whether a course change should be made, and it would also increase the time available to launch an attack. Although some improvements along these lines can undoubtedly be made, major breakthroughs in this area are unlikely. The more likely path to improved tactical strike operations may lie in the development of accurate guided weapons which can be launched at very short ranges or after the target has been overflown.

LOW-ALTITUDE MUNITIONS

Current air-to-surface munition designs require that the aircraft point toward the target and release ordnance before the aircraft passes over the target. This can impose severe limitations on the opportunities for first pass weapon delivery.

In the environment we are considering, low-altitude and high-speed weapon delivery, the time remaining after target acquisition for the aircraft to position itself in order to make a first pass attack can be extremely short. In fact, if a *continuous* low-altitude weapon delivery pass is required, the likelihood is that the target may not be detected before the aircraft passes it. There are two options with current munitions, either make a second pass or divert to another target. In any case, exposure time in the target area is increased. What are the alternatives?

Free fire zones can be established into which armored vehicles are funneled so that anything within these areas is a fair target and can be attacked indiscriminately. The locations of these zones would be fixed and well marked by a prominant IP for ease of location; however, it still requires information to be passed that the targets are there. This type of target area could relieve the restrictions imposed on the munition and IFF, in that an area weapon, if appropriately designed, could effectively kill or disable a large number of vehicles in the area. Without free fire zones, the aircrew may be left with a system or systems which, due to a combination of errors, place the aircraft off axis with respect to the target, or too close for the first pass use of PGMs with unitary warheads or forward firing guns.

An alternative which could compensate for inaccurate target location (within reason) is an area weapon. Proper design of the weapon would allow enough flexibility so that the munition could be delivered effectively by a variety of tactical aircraft, e.g., A-10, A-7, F-4, F-15, and F-16, against target areas of differing size.

Design considerations include release speed and altitude, target element characteristics, target area variations, density of targets, effective radius of the submunition, number of submunitions, and pattern size. The dispenser may be captive or free-fall. Submunition dispersal may be aerodynamic or forced.

USAF ground attack aircraft, which will be in the inventory through the 1990s, represent a range of performance characteristics. The two extremes are the relatively low performance A-10 and the high performance F-16. Attempting to design a single dispenser munition for a range this wide could prove to be extremely costly. Separation problems are very different at airspeeds of 300 knots and 600 knots. Operating altitudes for current and programmed ground attack aircraft also vary widely. Is it best to design a single compromise dispenser for all altitudes and airspeeds? Should there be a low speed and a high speed dispenser--each of which can operate at all altitudes? Should there be a low altitude and a high altitude dispenser that can operate at all air speeds? These are difficult questions to answer.

One of the more important design requirements for very low altitude delivery is submunition dispersal. Current U.S. designs produce relatively poor patterns, hence coverage, at low altitude due to either too few submunitions or poor dispersal because extremely low altitude delivery was not a design consideration. There are two alternatives for obtaining pattern size, namely, aerodynamic dispersal from a free-fall system such as Rockeye, or forced ejection from a system such as the UK BL 755 or FRG Strebo. Two popular techniques for forced ejection are either propellant (explosive) or a form of gas ejection. Propellant ejection appears on the surface to be the most desirable of the two in that relatively little dispenser volume is lost to the propellant, hence numbers of submunitions can be kept as high as possible. The problem is, though, that the force exerted on the submunition during ejection is so great that a large number of structural failures occur in the submunitions, which results in an ineffective munition. Further R&D is required on this technique. Gas ejection can be accomplished in at least two ways; first, by inflating bladders which push the submunitions out, or by forcing gas directly into dispenser tubes thus ejecting the submunitions. The difficulty with these two techniques is that both require a substantial part of the volume of the dispenser for the ejection mechanism alone, hence displacing a significant number of submunitions, and a number of discrete functioning events must occur in sequence which raises reliability problems. A certain amount of pattern control can be exercised by the amount of gas used, however, this feature is currently not easily exploited.

Aerodynamic dispersal can be accomplished at low altitude by spinning up the dispenser at a high rate in a short period of time, with appropriate fuzing that causes the dispenser to open at the proper point in space. Current spin dispenser designs are obtaining very high spin rates in less than one second, which, if properly controlled, results in pattern sizes about 2.5 times larger than could be obtained in the free-fall mode from low altitude.

Of course, pattern size is not the only goal. There must be a compromise between pattern size, number of submunitions and submunition effectiveness. The latter two may be called the kill capability within the pattern. Current antiarmor submunitions all incorporate a shaped charge warhead. The quality of shaped charges is comparable throughout the free world, as this technology has been available for over 25 years. There is research on-going to improve the kill capability of shaped charge warheads by modifying them to obtain larger hole volume in the target, which is directly related to kill probability. The problem with shaped charge submunitions is that they must impact the target to kill it--a near miss is ineffective. What we need is a submunition that has an effective area larger than the plan area of a tank and a high kill probability, while maintaining a relatively small size so as not to cut the number carried per dispenser drastically. A submunition with an area of effectiveness four times that of the area of a tank could produce an increase in fractional kill of an area target by a factor of four or more for a single weapon. Of course, if the kill mechanism of the submunition must deal with other than the relatively soft top of the tank or new armor designs, the submunition must be properly designed to account for penetration of thicker or more complex armor. There is also a tradeoff between the number of submunitions and the effectiveness per submunition, which, depending on the target area, may be nearly a linear relationship. New submunition designs offer substantial improvements in effectiveness without compromising the number in a dispenser load.

The type of dispenser is also an important consideration--should it be captive or free-fall? The first Air Force dispensers were captive, e.g., CBU-1, -2, etc. In the late 1960s, it was decided that free-fall dispensers would replace the captive dispensers. This was partly due to a change in weapon delivery tactics from low level to higher level and dive deliveries, for which captive dispensers are not particularly well suited. Although pattern length from captive dispensers can generally be controlled by an intervelometer, pattern width is dependent on aircraft altitude and is generally optimized around a particular altitude. There are also safety considerations with regard to jettisoning captive dispensers, especially at high speed and low altitude.

Other possibilities exist for munitions compatible with low-altitude delivery. Area munitions have been developed which obtain very wide patterns intentionally. The philosophy being that the aircraft can affort to be ± X hundred meters off the proper path to the target and still have the ability to kill something. Furthermore, families of mines and antiarmor submunitions have been designed to obtain a mixed load in the same dispenser. The implications of the employment of this weapon concept have not been completely analyzed; however, the idea of slowing the progress of armor and attacking the armor directly with the same munition certainly has interesting implications.

Since it is desirable to make a single weapon delivery pass in the target area, and since, especially at low altitude, the chance of being at exactly the right point at the right time is not large, what about a weapon which does not require the aircraft to point at the target? For example, the pilot or WSO could have a helmet-mounted tracker with a slaved laser ranger. As the target is spotted, the pilot or WSO looks at the target, marks the location of the target (and/or designates it) relative to the aircraft's inertial reference point by means of a trigger or pickle button integral to the helmet-mounted system, the information is passed through the system to the weapon, the weapon is launched with either a completely automatic terminal seeker system, or into a basket and terminally guided from the aircraft via a data link until impact. Of course, the warhead could contain either guided or unguided submunitions, or it could be simply unitary. However, a cluster warhead with appropriate submunitions relaxes the accuracy requirements for the terminal seeker. Possibilities exist for invention, such as the application of microprocessors, miniature seekers, etc.

TRAINING

Even if all the problems surrounding penetration of defenses, navigation, target acquisition, and munitions were solved, the Air Force is still faced with the problem of training crews for continuous-low-altitude, high-speed tactics. Environmental and safety considerations currently restrict how low "low" is at tactical air bases in the U.S. and Europe. Range limitations may be as low as 100 ft some places, but this is generally not the case. The average aircrew gets very little training at altitudes below 500 ft. The RED FLAG program at Nellis AFB, Nevada, does a great deal to instill combat experience in aircrews, but even at Nellis, where altitude minimums are less of a problem, squadrons deploying to RED FLAG may be required to fly the minimum altitudes for which they have been trained at their home base.

Training for low-altitude navigation, "wings level" low-altitude turns, and weapon delivery must be practiced. The task may become more complex as we move into single-seat aircraft where one man is responsible for all functions. An analysis of the work load in a single-seat aircraft is essential. At any rate, we cannot afford on-the-job training. We cannot let adrenalin take the place of training. The will is there, but the facilities are not. Somehow more facilities must be made available to tactical air forces for realistic combat training in the future.

CONCLUSIONS

In conclusion, we will summarize the essential points made here. Tactical air power, when operating in a severe surface-to-air defense environment, has a few options for acceptable survival rates. One of them is continuous low-altitude flight. Penetration of defenses at low altitude may be accomplished by taking advantage of terrain and local masking to reduce exposure time. Requirements for accurate navigation systems are also imposed by this tactic. Timely and accurate information regarding target location is essential. Target acquisition systems and munitions compatible with low-altitude, high-speed tactics must be developed. Finally, even if all the appropriate systems were available, aircrews must be trained to apply this demanding tactic.