Analysis of Pilot Warning Indicator Performance in Terminal Area Traffic

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Three pilot warning indicator concepts for collision hazard avoidance are analyzed using computer fast-time simulation. A hazard measure is defined based on a $\frac{1}{2}$-g maximum horizontal acceleration, a maximum climb or dive angle of 10° for each aircraft, and a 20-sec warning time, through escape completion. The traffic model is based on flight tracks recorded in the Atlanta terminal area over a 11 hr period during August 1967. The basic PWI concept studied alarms on range to flashing beacons mounted on intruder aircraft as a function of relative azimuth and elevation. The alarm-hazard epoch ratio is about 17/1 to maintain the missed-alarm rate below 10%. Beacon vignetting or range-rate discrimination are shown to reduce the false-alarm rate by about 75%.

Nomenclature

Protected aircraft	= the aircraft being protected by a PWI.
Intruder aircraft	= aircraft in the airspace surrounding the protected aircraft; alternatively, "other" aircraft.
Threat aircraft	= aircraft that present a collision hazard to a protected aircraft. The term "acceleration-hazard aircraft" indicates the hazard is based on the acceleration-hazard criterion defined in Sec. 3.
Pilot-warning indicator	= device to indicate to the pilot by an alarm the presence of a threat aircraft.
Valid alarm	= an alarm due to a threat aircraft.
False alarm	= an alarm due to an intruder aircraft not defined to be a threat.
Missed alarm	= an epoch when a threat aircraft does not produce an alarm.

I. Introduction

THE mounting rate of aircraft midair collisions has spurred a national effort to develop a pilot warning indicator[1] (PWI) to assist in the detection of collision threat aircraft. Most midair collisions involve light aircraft flying in visual flight rule (VFR) conditions during daylight hours.[1]

Development of a PWI, Fig. 1, based upon optical infrared detection of flashing xenon beacons (in use by several airlines and a growing number of general aviation aircraft) was initiated by the NASA Electronics Research Center.[2] This PWI is not meant to compete with automatic collision avoidance systems (CAS), but to provide a simple, inexpensive, partial solution to the hazard avoidance capability of general aviation aircraft in VFR conditions in terminal areas.[1] Initial PWI development by NASA and others using optical-IR techniques has centered on systems that alarm when the detected signal reaches a preselected alarm threshold, providing a range guard. By appropriate design of the detector optics and sensor characteristics, the designer has a means for shaping the alarm volume for the range guard. Conceivably, it might be shaped to minimize alarms from aircraft at nonthreatening positions, while affording ample warning time for threat aircraft.

There are a number of problems to be addressed in the design of an optical system, such as the variable attenuation of IR radiation in the atmosphere, standardization of xenon beacons, variation in detector sensitivity with temperature, time, voltage, etc. The present study addresses the question of selecting an alarm-volume for an optically "perfect" system, one where the range to a threat aircraft can be measured exactly, essentially. The objective of this study is to establish range-detection requirements for the range-guard class of PWI in terminal area traffic, and to evaluate several concepts for reducing "unnecessary" alarms.

A hazard criterion is postulated as a performance measure for PWI alarming. A parametric analysis of the PWI is made using computer fast-time system simulation (FTSS), wherein each PWI design is "flown" on all aircraft for the complete (frozen) traffic sample. The alarming is evaluated against hazard encounters.

The study was carried out using an IBM 360/75 computer and an air traffic model obtained from traffic data re-

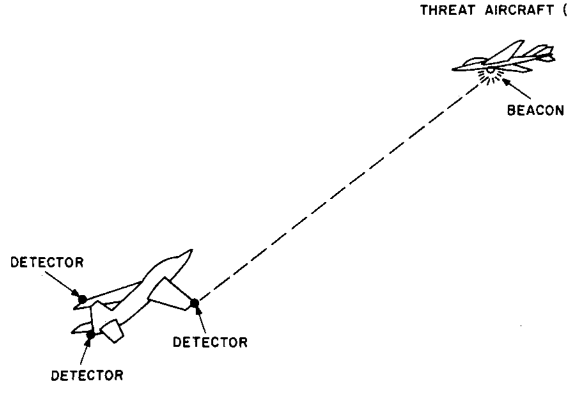

Fig. 1 Sketch illustrating optical/IR PWI in operation.

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Index categories: Air Navigation, Communication, and Traffic Control Systems; General Aviation Systems (Including Ground Support); Aircraft Flight Operations.

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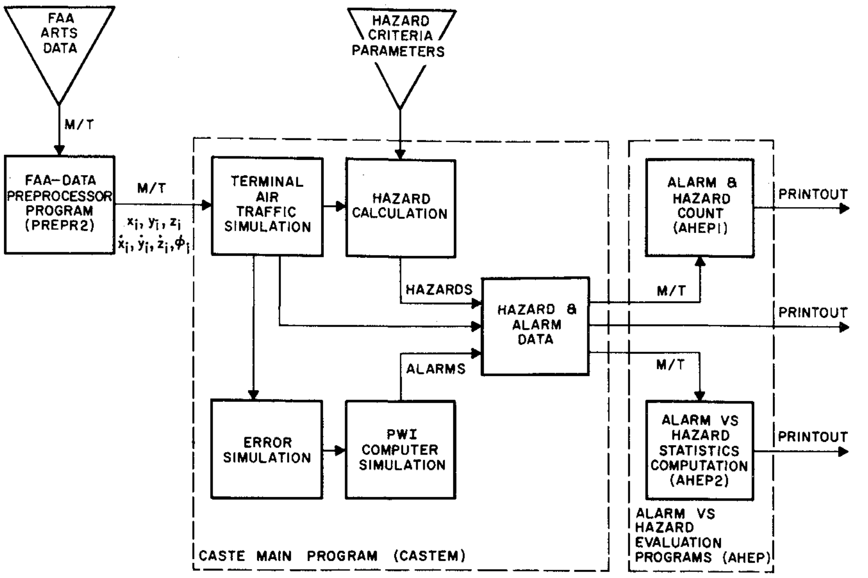

Fig. 2 NASA/ERC CASTE computer programs used in evaluation of PWI in terminal area traffic.

corded by the FAA in the Atlanta terminal area during a 5-day period in August 1967. The PWI parameters were varied in successive runs, and the alarms compared against the collision hazards.

2. PWI Computer FTSS Program

A schematic of the Collision Avoidance System Technical Evaluation (CASTE) program is shown in the flow diagram of Fig. 2. The over-all flow of the CASTE calculations is discussed here and further details are given in Refs. 3 and 4.

FAA ARTS smoothed data (Sec. 4) are processed through the Data Preprocessor Program (PREPR2) giving aircraft position and velocity components in airport x, y, z coordinates for each time epoch. These data enter the Caste Main Program (CASTEM) through the Terminal Air Traffic Simulation subroutine, which computes the relative orientation and relative velocity of all aircraft to all other aircraft. Every epoch, collision hazard criteria and the PWI alarm criteria are evaluated in Hazard Calculation and PWI Computer Simulation, respectively. The relevant data are stored in Hazard and Alarm Data.

Hazard and alarm calculations are made for each aircraft as a protected aircraft, treating every other aircraft as an intruder aircraft. The calculations are repeated every (3 sec-spaced) epoch.

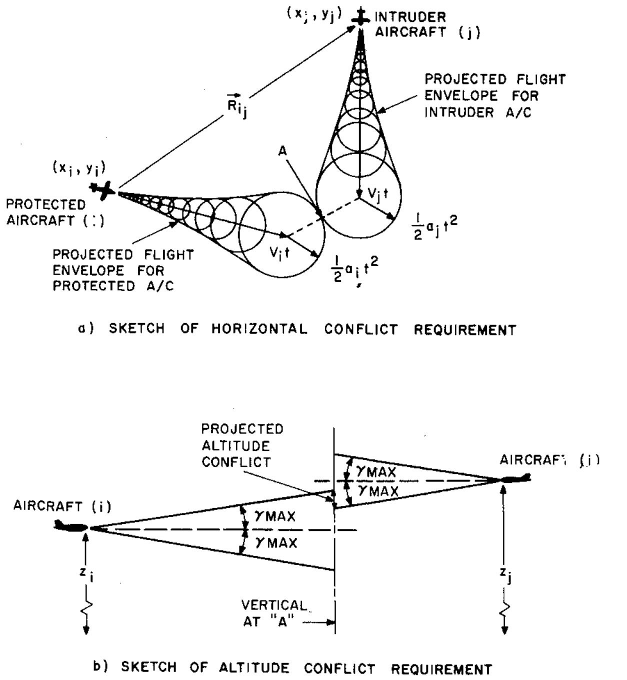

Fig. 3 Sketch illustrating acceleration-hazard criterion.

3. Hazard Criterion

To achieve satisfactory collision avoidance, four distinct sequential tasks are performed. They may be performed entirely by the pilot or by some pilot-PWI-CAS combination. They are: 1) to detect threat aircraft, 2) to evaluate collision hazard, 3) to select an appropriate escape maneuver, and 4) to perform an escape maneuver, monitoring the threat aircraft to avoid canceling maneuvers. A complete CAS performs all four tasks. The class of PWI under consideration here is intended to aid the pilot with tasks 1 and 2.

As a measure of PWI performance it is essential to define a collision hazard. Attention is drawn to the extensive study of this problem reported in Refs. 5–7. Unfortunately, a consensus on the definition of a hazard criterion has not been reached in the PWI-CAS engineering community. A criterion is proposed here in order to furnish a quantitative basis for evaluation, but it is recognized that considerable research and evaluation are needed to reach a generally accepted criterion.

A collision hazard exists, simply, when aircraft are projected to collide within a certain time. The simplest projection is to assume that both aircraft will maintain their present velocities (combined speed and direction). A hazard might be defined in terms of the distance of closest approach. As discussed in Ref. 4, however, this criterion makes no allowance for course changes due to turns, climbs, heading corrections, speed changes, etc., which occur frequently in terminal-area flight.

To admit subsequent course changes, an alternate collision hazard criterion is proposed, termed the acceleration-hazard criterion. Horizontal and vertical conflicts are separately defined, reflecting the characteristic differences between horizontal and vertical maneuvers.

The proposed hazard criterion is discussed with reference to Fig. 3. The time scale t is defined with zero as the present time. The protected aircraft at (x_i,y_i,z_i) and the intruder aircraft at (x_j,y_j,z_j) have component velocities $(\dot{x}_i,\dot{y}_i,\dot{z}_i)$ and $(\dot{x}_j,\dot{y}_j,\dot{z}_j)$, respectively, at $t = 0$.

Horizontal Hazard Criterion

In the horizontal direction the hazard criterion of Holt et al.[7] is adopted as illustrated in Fig. 3a.

Let a_i and a_j represent the magnitudes of the maximum expected horizontal accelerations of the respective aircraft in typical flight. The envelopes of possible positions for both aircraft until some time t, allowing for acceleration in any horizontal direction, are sketched in the figure, where V_i and V_j are the respective horizontal velocities. If the envelopes of the two aircraft intersect during the escape time t_e, such as at point A, then the horizontal hazard criterion is met.

The equation for the horizontal hazard criterion is

$$\{[x_j - x_i + (\dot{x}_j - \dot{x}_i)t]^2 + [y_j - y_i + (\dot{y}_j - \dot{y}_i)t]^2\}^{1/2} \leq \tfrac{1}{2}a_{tot}t^2 \quad (1)$$

for $0 \leq t \leq t_e$ where $a_{tot} = a_i + a_j$.

Holt et al.[7] have studied aspects of this criterion and attention is drawn to that report. In particular, it should be noted that the horizontal hazard criterion employs only the relative horizontal position and velocity vectors of the intruder aircraft, a maximum horizontal acceleration for both aircraft, and an escape time.

In the present study, a value of a_{tot} equal 1g is used, corresponding to $\frac{1}{2}$ g for each aircraft, a 27° equilibrium bank angle. An aircraft could pull many more g's in an emergency maneuver, but it is beyond the scope of this study to protect against highly unusual events.

The escape time, t_e, represents the time required for a pilot to perform the four collision-avoidance tasks after an alarm. Establishment of an escape time for general aviation pilots as a group could properly be the subject of considerable study: 20 sec is taken in this study, based upon an allotment of 3 sec for pilot acquisition of the intruder, 7 sec for threat evaluation and escape maneuver selection, 2 sec for application of aircraft controls and aircraft response, and 8 sec for aircraft escape, for example to descend 260 ft in a $\frac{1}{4}$-g dive.

It is assumed the PWI provides the pilot with relative bearing of the threat aircraft. If not, t_e must be increased to allow greater time for acquisition of the threat aircraft.

It is important to note that the horizontal hazard criterion is intended to help a pilot perform tasks 1 and 2, detection and evaluation of collision threats. The probability that coaltitude aircraft meeting this criterion would collide if no evasive action were taken is relatively small. Yet, it is believed, a reasonable possibility exists, so the pilot should be alerted.

Altitude Hazard Criterion

Aircraft typically climb and dive at angles of 3° to 6°. Therefore, climb or dive maneuvers of either aircraft are admitted by assuming a maximum climb and dive angle, $\gamma_{\max}$. In this study, $\gamma_{\max}$ of 10° is used.

The altitude criterion is illustrated in Fig. 3. Point A in Fig. 3a is an intersection point of the two projected horizontal envelopes. Although each aircraft might follow some curved route in the horizontal plane to reach point A, a straight line is assumed. The vertical planes from each aircraft passing through A are shown in Fig. 3b. The projected altitudes each aircraft could reach are defined by the limits

$$z_{\max} = z + r_A \tan\gamma_{\max}$$
$$z_{\min} = z - r_A \tan\gamma_{\max} \quad (2)$$

where

$$r_A = [(x_A - x)^2 + (y_A - y)^2]^{1/2}$$

and x_A, y_A are the coordinates of point A. An altitude hazard is defined if the projected altitudes for the aircraft conflict, i.e.

$$(z_{\max})_j \geq (z_{\min})_i$$
and
$$(z_{\min})_j \leq (z_{\max})_i \quad (3)$$

Acceleration-Hazard Criterion

A collision hazard is defined if both the horizontal hazard criterion, Eq. 1, and the altitude hazard criterion, Eq. 3, are met. The combined criteria will be referred to as the acceleration-hazard criterion.

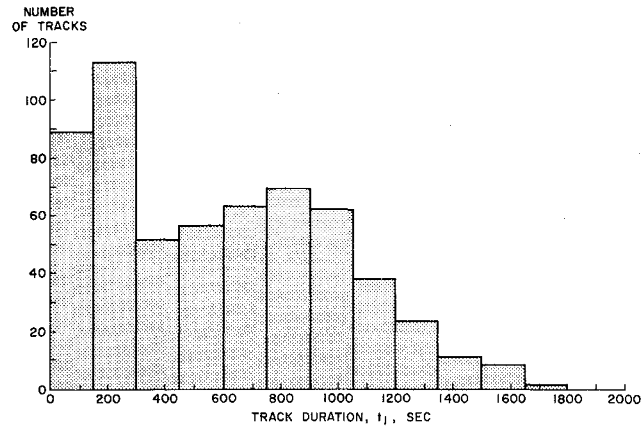

Fig. 4 Histogram of track durations.

4. Atlanta Flight-Track Data

Thirteen hours of aircraft track data were obtained by the FAA during morning, afternoon, and evening peak hours at Atlanta over a 5-day August period in 1967. The Atlanta Airport Radar Terminal System (ARTS) was employed, having a track-while-scan capability which gives range and azimuth of each aircraft and altitude for beacon-transponder-equipped aircraft. For aircraft without transponders, altitude was deduced from pilot-controller voice records.[8]

Details of the data collection technique and comments on its use in PWI studies are presented in Refs. 3, 8, and 9. Statistical data on the aircraft tracks and encounters are presented in Refs. 4 and 10. The track data have been employed in studies of the ATA time-frequency CAS[11] and the Langley doppler-radar PWI concept,[9,10] as well as the optical-IR PWI concept discussed here.[4]

Eleven hours of the Atlanta ARTS traffic data were provided by the FAA for the present study. The data include aircraft position and component velocity at 3-sec intervals called epochs.

The weather conditions during this period were generally overcast at from 400 to 10,000 ft. So, for the most part, the flights were operating under IFR.[9]

During the 11 hr, 584 tracks were recorded with a total track duration of 94.92 hr. The mean track duration is 9.8 min (585 sec). The number of tracks per hr varies from 41 to 69. The hourly average number of aircraft per radar scan varies from 5.0 to 12.7 with hourly maximums of 10 to 18.

A histogram of the track durations for the 11 hr is presented in Fig. 4. Essentially all of the track durations are less than 30 min (1800 sec). Two peaks in the duration show up, a sharp peak at about 4 min and a more distributed peak centered at about 14 min. The short duration tracks are generally departing aircraft having greater speeds, fewer turns, and early controller handoff. Arriving aircraft tend to have the longer track durations.

Because the PWI class under consideration is aimed at meeting the needs of general-aviation aircraft, only aircraft whose speed is 235 knots or less are simulated as protected

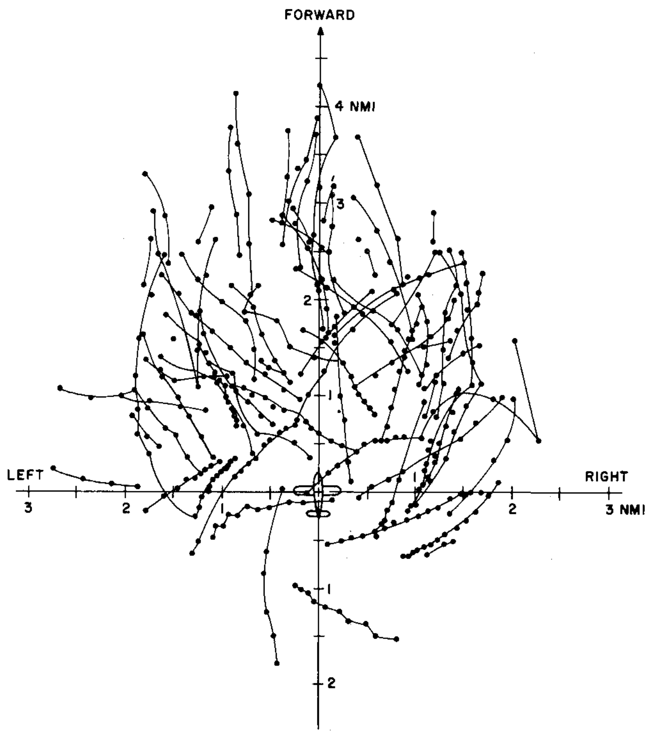

Fig. 5 Acceleration-hazard encounters relative to protected aircraft. $a_{tot} = 1g$, $t_e = 20$ sec, $\gamma_{\max} = 10°$.

aircraft. Higher speed aircraft are considered only as intruder aircraft.

There are 63 acceleration-hazard encounters (Sec. 3) during the 11-hr traffic sample. One encounter is defined as a continuous sequence of acceleration-hazard epochs for a protected aircraft—two encounters being counted for an aircraft pair where both are protected aircraft. The 94.92 hr and 63 encounters give a mean flight time interval between encounters of 90.4 min. Of the 584 tracks, 91% (529) experienced no acceleration-hazard encounters, 8% (47) one encounter, and 1.4% (8) two encounters.

In Fig. 5, the locations of the threat aircraft relative to the protected aircraft during acceleration-hazard epochs are plotted for the 11 hr. Straight ahead, relative to the flight direction, is upward on the plot. The epochs during an encounter are connected by a solid line. Generally the encounters originate at the furthest relative range and proceed toward the protected aircraft. Roughly, the envelope of the encounters is circular, centered 1 naut mile ahead of the protected aircraft with a 3-naut mile radius.

Characteristic differences are to be noted in the head-on, side-on and tail-on encounters, Fig. 5. Head-on encounters tend to have a high closing velocity, originating further away and having epochs spaced relatively far apart. Side-on and tail-on encounters frequently are aircraft on parallel tracks or converging at small angles, originating at closer range and extending for more epochs.

The 11-hr sample of Atlanta ARTS data provides a valuable data collection because it represents actual aircraft flight tracks, not subject to the questions concerning modeling which frequently surround traffic generator-produced data. Because the data are stored, all the PWI systems can be evaluated for the same traffic. The most serious criticism of the data concerns the validity of the dubbed-in altitude data. However, the statistical correlations of these data, Ref. 10, indicate that aircraft within an area tend to be distributed over a relatively small altitude range. As a consequence, the beginning of hazard encounters, which is most significant to a PWI system, is almost unaffected by altitude errors in the data.

Based on analysis performed in Ref. 4, the Atlanta ARTS traffic data sample is accepted for evaluating PWI for the Atlanta terminal area. It would be valuable to have available similar flight data from other terminal areas, enroute sectors, and, in particular, the vicinity of uncontrolled airports, where general-aviation aircraft have a strong requirement for PWI.

The track data are employed in this PWI study by taking the aircraft heading as tangential to the flight path and the roll angle as zero.

5. Range-Detecting PWI

In this section alarm volumes are analyzed for the basic range-detecting PWI concept.

In the early studies, a number of combinations of detector patterns and detector locations on the protected aircraft were simulated. It soon became apparent, however, many combinations have nearly the same alarm volume, so the analysis was directed instead to generalized alarm volumes.

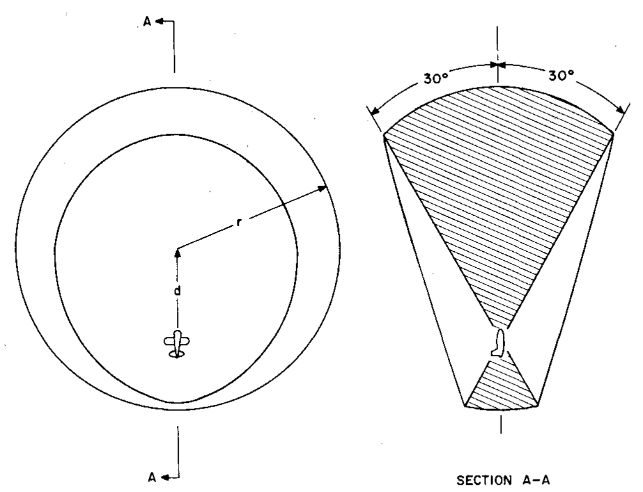

Fig. 6 Spherical alarm volume with ±30° elevation-angle coverage.

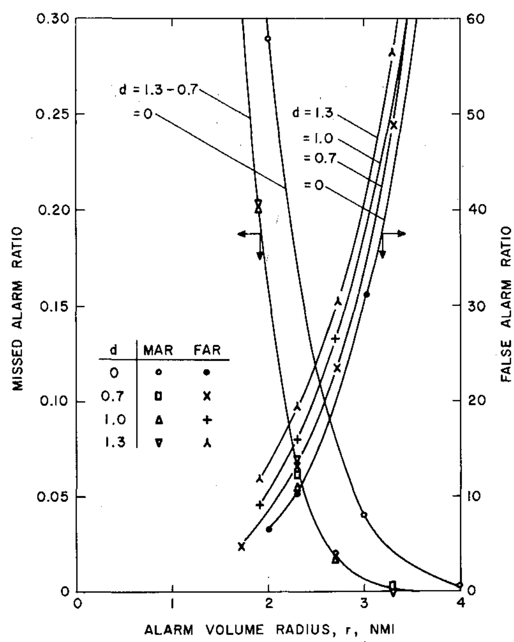

Fig. 7 Variation of missed-alarm and false-alarm ratios with alarm-volume radius.

The alarm-volume geometry chosen is a sphere of radius r displaced a distance d ahead of the protected aircraft, as shown in Fig. 6. The sphere is cropped to a $\pm 30°$ field of view in elevation from the aircraft. Any intruder aircraft within this sphere, and also within $\pm 30°$ elevation relative to the protected aircraft, will cause an alarm. The elevation view and plan section through this alarm volume are shown in Fig. 6. The two variables of interest are the sphere radius, r, and displacement, d. The motivation for this alarm volume is its relation to the acceleration hazard criterion, discussed in Ref. 4.

The alarm criterion for the range-detecting PWI concept is:

range criterion

$$|\mathbf{R}_j - (\mathbf{R}_i + \mathbf{a}_i d)| \leq r \tag{4}$$

elevation-angle criterion

$$|\mathbf{n}_i \cdot (\mathbf{R}_j - \mathbf{R}_i)|/|\mathbf{R}_j - \mathbf{R}_i| \leq \sin 30° \tag{5}$$

where $\mathbf{a}_i$ and $\mathbf{n}_i$ are unit vectors directed forward and normal to the wing plane, respectively, of the protected aircraft. $\mathbf{R}_i$ and $\mathbf{R}_j$ are the position vectors of the protected aircraft and the intruder aircraft. An alarm is on if the alarm criterion is met.

Some 14 alarm volumes of varying radius and displacement were tested, and their missed alarm and false alarm performance are compared in Fig. 7. Here the number of missed-alarm epochs and false-alarm epochs are ratioed to the fixed number of hazard epochs and plotted as a function of the alarm-volume radius. The alarm-volume displacement is the parameter.

As the alarm-volume radius is reduced below about 2.3 naut miles, the missed-alarms increase markedly. On the other hand, above 2.3 naut miles the false alarms increase rapidly. The alarms are not significantly dependent upon the alarm-volume displacement, except near zero.

From the pilot's standpoint, 5–10% missed alarms is believed to be acceptable and to represent a large improvement over present inflight warnings. To also keep the false-alarm ratio under 20, the radius would have to be maintained fairly near 2.3 naut miles.

Figures 8 and 9 are crossplots of Fig. 7 for 2.3 and 2.7-naut mile radii showing the effect of alarm volume displacement. A displacement of 1.0 naut miles gives the minimum missed alarms, although for a 2.7-naut mile radius the curve is very flat.

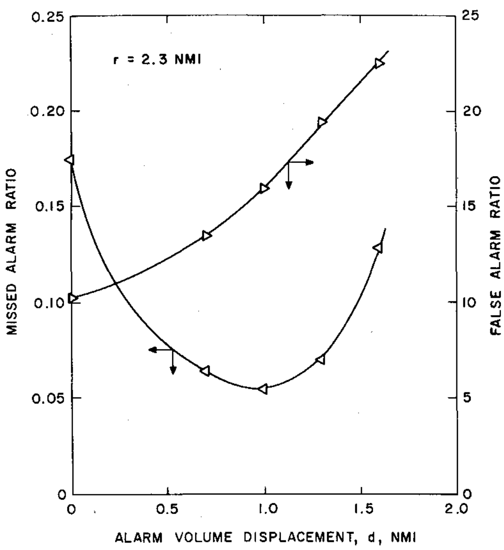

Fig. 8 Variation of missed-alarm and false-alarm ratios with alarm-volume displacement. r = 2.3 naut miles.

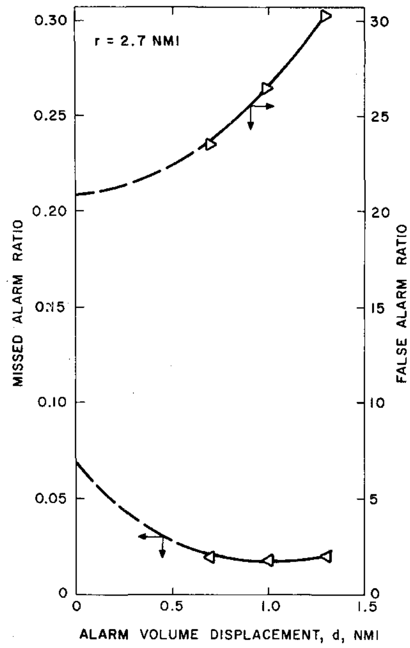

Fig. 9 Variation of missed-alarm and false-alarm ratios with alarm-volume displacement. r = 2.7 naut miles.

For a 2.3-naut mile radius the false-alarm ratio for a 1.0 naut miles displacement is 16. It could be reduced to about 12 by decreasing the displacement, but the missed alarms would become very sensitive to the displacement. It appears most practical to use a 1.0-naut mile displacement and a radius near 2.3 naut miles, giving an alarm range forward of 3 to 3.5 naut miles and rearward of 1 to 1.5 naut miles.

For a 2.3-naut mile radius and 1.0-naut mile displacement there are 6,240 false-alarm epochs for the 391 acceleration-hazard epochs, or alarming 6% of the flight time compared to a 0.3% hazard time.

Modifications to the range-detecting concept are sought for reducing false alarms without significantly increasing missed alarms. Two possible schemes are discussed in the next two sections.

6. Vignetted Beacon

One limitation of the range-detecting PWI concept leading to a high false-alarm rate is that the intruder relative heading does not figure in the alarm criterion. An intruder within the alarm volume generates an alarm even flying directly away from the protected aircraft. Providing some indication of the intruder relative heading would screen such obvious false alarms.

Many schemes can be imagined to provide intruder relative heading, but possibly the simplest is to use beacon vignetting. This concept arose during discussions with Robert W. Simpson, MIT, consultant. As such, it is hereafter referred to as the "Simpson Beacon."

Pulsed xenon beacons are now mounted with their axes about normal to the wing-fuselage plane so light radiates essentially axisymmetrically about the aircraft vertical axis. The concept of the Simpson Beacon is, through use of appropriate reflectors or filters, to vary the radiated intensity of the beacon with azimuth angle from the aircraft heading. A continuous variation is possible, but in the interest of simplicity and cost, vignetting giving two discrete intensity levels, Fig. 10, is evaluated: within the sector $-\beta$ to $+\beta$ from straight ahead, the beacon intensity is taken as unity, the value for an unmodified xenon beacon in the range-

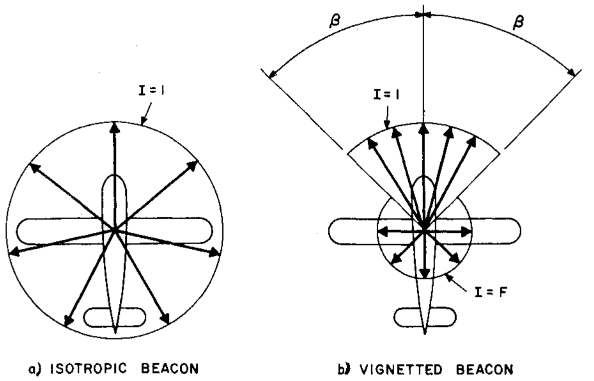

Fig. 10 Sketch of vignetted beacon patterns.

detecting PWI (Sec. 5), and for all other azimuth angles, is taken as F.

In equation form, the alarm range criterion for the Simpson beacon is:

$$|\mathbf{R}_j - (\mathbf{R}_i + \mathbf{a}_i d)| \leq r_{SB} \tag{6}$$

where $r_{SB} = r$ for $-\beta \leq \theta_{ji} \leq \beta$, $r_{SB} = F^{1/2}r$ for all other angles and θ_{ji} is the azimuth angle of the protected aircraft relative to the intruder aircraft heading. The elevation-angle criterion for the Simpson beacon is the same as for the range-detecting PWI, Eq. (5).

In this study, β is varied and F is taken as 0.25. The received signal varys inversely as range squared, so F equals 0.25 means that an alarm triggered at four miles in a head-on encounter triggers at two miles in an overtaking encounter. In effect, this shapes the signal pattern radiated from the intruder aircraft in much the same way as the alarm volume for the protected aircraft—greater range in the forward direction.

With an alarm-volume radius of 2.7 naut miles and displacement of 1.3 naut miles, Fig. 11, for β equal 180° (no vignetting), the missed-alarm ratio is 0.02 and false-alarm ratio is 30. As β is reduced, the false-alarm ratio decreases steadily; at 90° the false-alarm ratio is only 7.5, reduced 75% from the unvignetted value. Missed alarms do not increase appreciably until β is about 60°. For a 2.3-naut mile radius, the trends are similar, except the missed-alarm ratio is higher and the false-alarm ratio lower.[4]

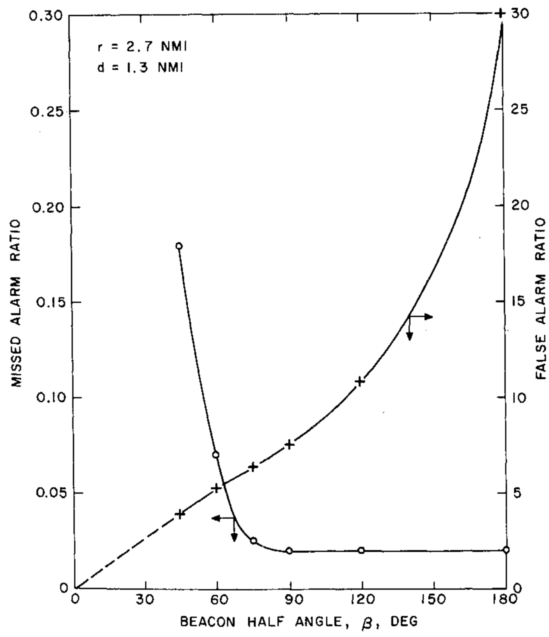

Fig. 11 Variation of missed-alarm and false-alarm ratios with vignetted beacon half angle.

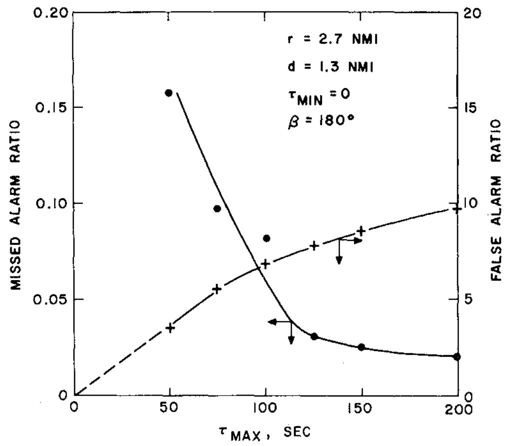

Fig. 12 Variation of missed-alarm and false-alarm ratios with τ_{max} for the range/range-rate PWI.

A β value of 90° might be practical for a commercial beacon because a ±15° tolerance for manufacturing reproducibility would have small effect on missed alarms. Also, for 90°, the false-alarm and missed-alarm ratios are relatively insensitive to alarm-volume displacement.[4] With a 2.7-naut mile radius and a 1.3-naut mile displacement, there are 3003 false-alarm epochs, for an alarm ontime of only 3% of the flight time.

7. Range/Range-Rate PWI

Another method of screening out alarms from aircraft flying away or closing only slowly uses the time derivative of the received beacon signal, called "range-rate discrimination."

Define p as the beacon signal intensity at the protected aircraft; p varies inversely with relative range R_{ij} squared on a clear day

$$p = c/R_{ij}^2 \tag{7}$$

It also depends upon the beacon radiation pattern and atmospheric attenuation, but the inverse-range-squared effect would generally be the predominant characteristic in any one atmosphere.

The ratio of p to its time derivative $\dot{p}$ is

$$p/\dot{p} = -R_{ij}/2\dot{R}_{ij} \tag{8}$$

which is proportional to the well-known τ used in CAS studies where

$$\tau = -R_{ij}/\dot{R}_{ij} \tag{9}$$

which is the time to close for aircraft on a linear collision course. Therefore

$$\tau = 2p/\dot{p} \tag{10}$$

The ERC PWI task force independently mentioned[2] a range/range-rate measurement as a means of determining the degree of collision threat.

Signal intensity at the protected aircraft varies due to atmospheric scintillation, smoke and haze. It is expected that these fluctuations could be smoothed by employing electronic smoothing techniques. This has not been explored, so we will assume that range-rate information provides only a crude measure of τ — identifying aircraft flying away ($\tau < 0$) or closing slowly ($\tau \approx 100$ sec).

The range/range-rate PWI concept has three criteria: Eqs. (4), (5), and

$$0 < \tau < \tau_{\max} \tag{11}$$

where τ is determined from Eq. (10).

The alarm results for this PWI concept are shown in Fig. 12 for an alarm volume of 2.7-naut mile radius and 1.3-naut mile displacement. For $\tau_{\max}$ of 125 sec, the missed-alarm ratio is 0.03 and false-alarm ratio 8, compared to 0.02 and 30, respectively, for the simple range-detecting system, Fig. 9. In other words, the missed-alarm ratio is nearly unchanged by adding range-rate discrimination, but the false-alarm ratio is reduced about 75%.

A $\tau_{\max}$ of 125 sec might provide a practical value for a working system since τ could vary ± 50 sec without degrading the alarm performance significantly. The alarm performance is nearly the same as for the Simpson beacon with β equal to 90°.

8. Discussion

The range-detecting PWI concept provides a means for warning the pilot of aircraft that are potential collision hazards, based on the acceleration hazard criterion, with less than 10% missed alarms. The false-alarm ratio would be between about 10 and 40.

Using either beacon vignetting or range-rate discrimination, the false alarm rate is reduced by about 75% for a missed-alarm rate of 2%. (In combination, only a small additional improvement is obtained.[4])

Vignetting beacons, by half-silvering the rear surface of the lens cover, for example, should aid visual detection of oncoming aircraft in the same way the PWI is aided.

The range-range rate concept has the advantage for the user that it can be employed without waiting for alteration of existing beacons.

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