

"CONFLICT DETECTION AND RESOLUTION IN THE NETHERLANDS ATC-SYSTEM SARP II"

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Abstract

The paper focuses on two conflict detection methods which are developed for overflying aircraft in the Netherlands airspace and are based on long-term trajectory predictions. The aim is that the conflict detection programs produce few "false alarms" and consume very little on-line processing time. This is met by the so-called "block method", which is described in this paper.

Also investigations are discussed with respect to a more complicated method, known as the "critical-distance method". The latter method will reduce the false alarm rate to its minimum value, set by the uncertainties in the trajectory predictions in the ATC-computer system and by the lateral deviations from track of the aircraft.

I. Introduction

This paper presents two conflict detection methods for overflying aircraft on crossing routes, called "block method" and "critical-distance method". Both methods can be used by air traffic controllers mainly in the planning stage and are based on long-term trajectory predictions up to a maximum of approximately 20 mins. ahead. The block method is envisaged for the SARP II (Signaal Automatic Radar Processing) air traffic control system of the Netherlands, that will become operational by 1978. It is a comparatively simple method requiring little computer time and computer storage. However due to a limited precision and the absolute safety level that is required, it results in a certain amount of false alarms. The critical-distance method is regarded as a possible later refinement. It can give an indication of the "seriousness" of a conflict and it reduces the false alarm rate to the theoretical minimum. This minimum is set by the uncertainties in the trajectory computations and by the lateral deviations of the aircraft, the latter originating from navigational inaccuracies or "vectoring". However, this method is more complex than the block method and uses more processing time.

Based on the lay-out of the Netherlands air route structure, chapter II explains the requirement for automatic conflict detection for overflying traffic in the Netherlands Flight Information Region.

Chapter III discusses some of the basic features of the SARP II computer system, in which the conflict detection programs will be implemented.

The basic principles and operational use of the block method and the critical-distance method are presented in chapter IV, while more detailed discussions on both methods are given in chapters V and VI respectively.

The study has been carried out under contract with the Department of Civil Aviation (RLD) of the Netherlands, which was also closely involved in the investigations.

II. The Netherlands airspace structure and the requirement for automatic conflict detection.

As fig. 1 shows, the Netherlands ATC-system incorporates five main route sectors surrounding the terminal control area (TMA) of Schiphol Airport. Within these sectors the transit routes are situated, most of which are "dual".

There is a team of en-route air traffic controllers, consisting of a planning and an executive sector controller, for each of the five route sectors. Over the terminal control area of Schiphol, control of the transit flights is transferred directly from the en-route team of the entry sector to that of the exit sector.

Each time an aircraft is handed over from one control team to another, co-ordination between the teams is necessary. Co-ordination in this context means, a consultation between the two controllers concerned, such that the receiving controller can accept the new aircraft in a way that he can separate it from his other traffic. Co-ordination can also be executed when there is a potential conflict on crossing routes.

In the present ATC-system, the search for potential conflicts between overflying aircraft over the TMA is performed by the so-called TMA-controller, who also serves as an intermediary between the executive sector controllers. The present SATCO-system gives a rough indication of the potential conflicts to the TMA-controller on the base of estimated times of arrival over the TMA. It makes use of simple height- and time-difference criteria.⁽¹⁾ The TMA-controller can suggest possible solutions to the executive sector controllers involved.

In the SARP II-system the conflict search will be performed by adequate computer software, based on more sophisticated criteria and algorithms. There will be no special TMA-controller in this concept.

The aim of the new conflict routines is:

- early warning of potential conflicts over the TMA to the sector controllers as soon as an aircraft enters the Netherlands Flight Information Region
- consecutive updates when the flight advances
- assistance in the solution of conflicts
- implicit improvement of the capacity of the airspace with respect to overflying aircraft.

"minitable" containing additional information. The PVD's can also serve as input device via the display of function characters which can be activated by lightpen.

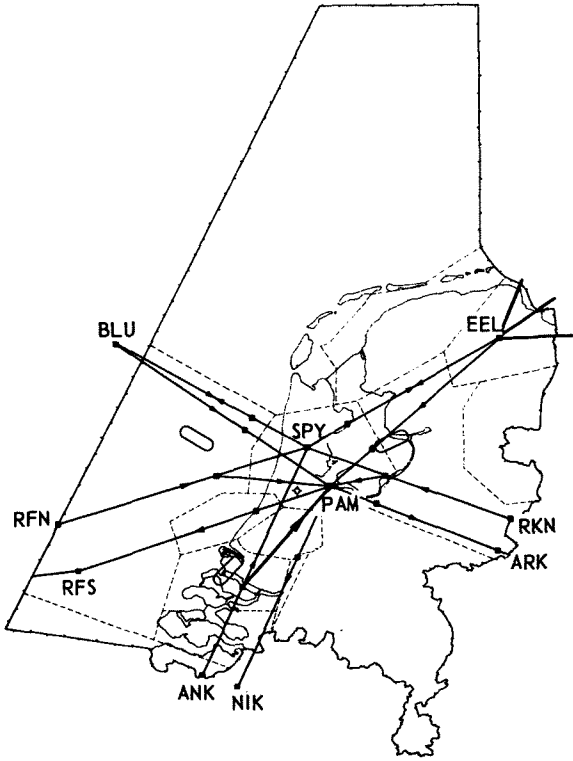


FIG. 1 TRANSIT ROUTE STRUCTURE IN THE NETHERLANDS
FLIGHT INFORMATION REGION (◊-SCHIPHOL AIRPORT)

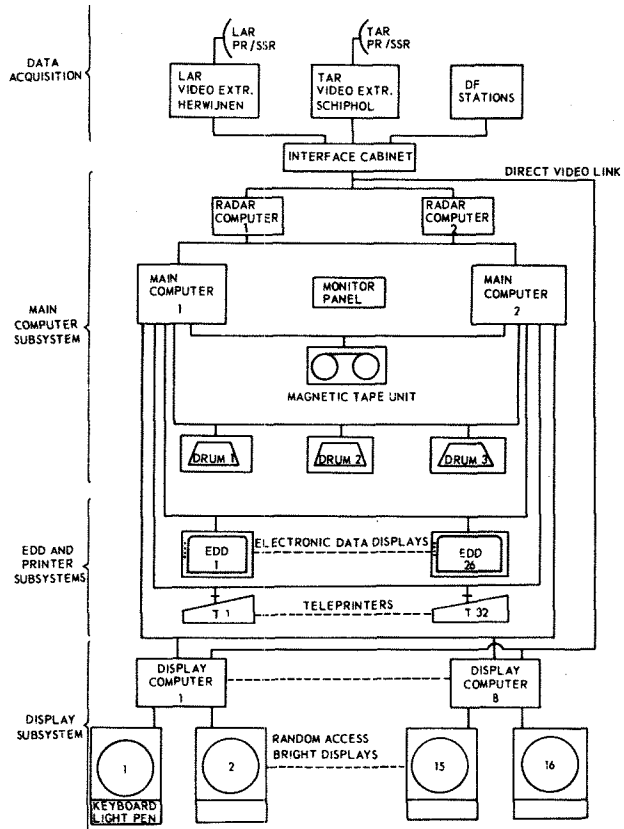


FIG. 2 LAYOUT OF THE OPERATIONAL SARP II SYSTEM

III. Concise description of the SARP II-system

The Netherlands was among the first countries in the world to introduce computer aided air traffic control. The SATCO-system installed in 1959, mainly served as a flight plan processing system with stripprinters and later-on with electro-mechanical flight progress boards. This system has been gradually improved and is still in use today.

For many reasons a new system was wanted that could also accept automatic input of digitized primary- as well as secondary radar data. This was to be the SARP-system. The first phase of this system, known as SARP I, is already in use for approach control in cooperation with SATCO, the latter for en-route control.

The next phase of the SARP-system, called SARP II, is expected to become operational by 1978. It will completely replace SATCO/SARP I and serve both approach and en-route control. (2)

In figure 2 the layout of the SARP II-system is presented. Digitized radar data, originating from a long distance-(LAR) and a terminal area radar (TAR), are fed to the radar computer. The tracked radar positions from the radar computer are transferred to the main computer. Electronic data displays (EDD's) provide flight plan information. A total of eight display computers serve two bright displays (PVD's) each. Only synthetic information is displayed such as tracked plots with labels and a

IV. The conflict detection methods

Introduction

The conflict detection has to be executed for overflying aircraft on predetermined transit routes. A total of 20 transit routes has to be considered (Fig. 1). Flights originating from one and the same sector are not tested against each other. So, only aircraft on crossing and joining routes are compared by the conflict detection logics.

Over the TMA, each aircraft occupies a certain height band, the vertical extensions of which depend upon the fact whether the flight is a level, climbing or descending flight. These levels are assigned by the controller of the entry sector. Besides the two preceding characteristics of each flight, viz. the route and the flight level(s) occupied, also the estimated time of arrival at one of the two TMA reporting points, i.e. PAM or SPY, has to be known. This estimated time of arrival (ETA) is generated by the so-called "trajectory computation", making use of the performance specifications and the flight plan data of each aircraft.

The conflict detection methods must guarantee a minimum horizontal separation of 5 NM or a vertical separation of 1000 ft (2000 ft above FL 290).

However, these separation minima must be "translated" into computer algorithms as will be shown later. The aircraft are allowed to have a maximum lateral deviation of 5 NM from their nominal track due to "vectoring" or navigational inaccuracies. Also errors in the computation of the estimated time of arrival at the TMA reporting point must be accounted for.

In fig. 3 a simplified schematic representation of the relation between the block- and the critical-distance method is given. The block method can be considered as a sub-optimal conflict search, while the critical-distance method is optimal under the given operational constraints. The latter method lowers the number of false alarms of the block method, but it requires much more computer time.

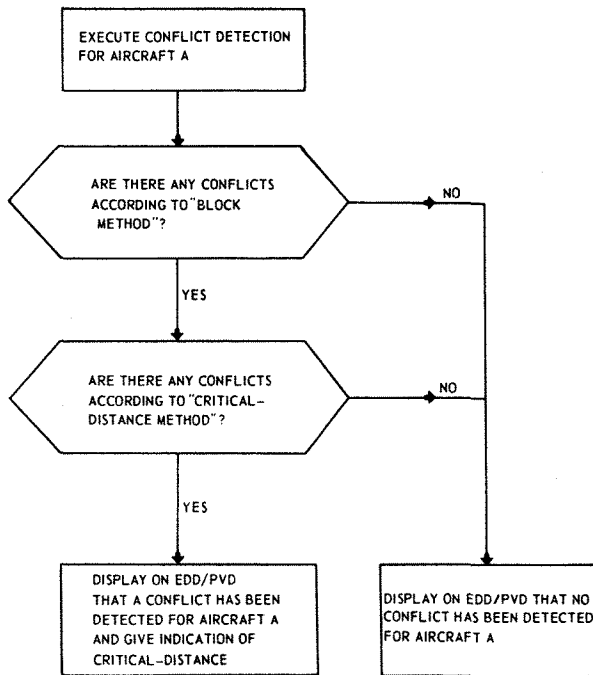


FIG. 3 RELATION BETWEEN BOTH CONFLICT DETECTION METHODS

Short description of the block method

In fig. 4 a crossing between two routes is sketched. Around the crossing point S two so-called conflict blocks are situated.⁽³⁾

A pair of aircraft, one aircraft on route 1 and one on route 2, is considered to be in conflict if both aircraft will be in their corresponding conflict blocks simultaneously, and if their vertical separation is less than 1000 ft.

The block lengths depend upon the minimum horizontal separation (= 5 NM), the route width (= 10 NM) and the angles between both routes. Time buffers are added to compensate for the possible inaccuracies in the trajectory computation.

Due to the fact that only one pair of discrete conflict blocks is assigned to every crossing of two routes stored in the computer, the method is not optimal.

It turns out however, that in practice a sub-optimum can be reached.

The method can easily be expanded to routes which do not cross but whose distance is too small to guarantee that no conflicts can occur, i.e. less than 15 NM distance for parallel routes.

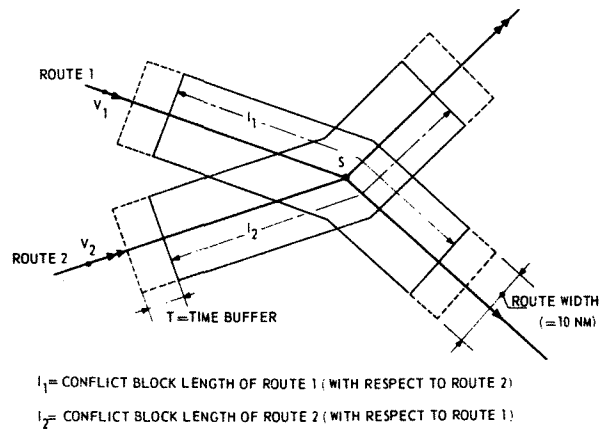


FIG. 4 CONFLICT BLOCK GEOMETRY

Principle of the critical-distance method

The principle of the critical distance method is shown in fig. 5. At some moment, two aircraft are at known positions P and Q with speeds v_1 and v_2 respectively. Around each nominal aircraft position a rectangular buffer is assumed, accounting for the lateral and longitudinal uncertainty in the aircraft position. Now, the buffers are supposed to move with the proper speeds v_1 and v_2 . At a particular moment, when the aircraft have reached points P_c and Q_c , the distance between the buffers becomes minimal. This is called the "critical-distance".

If the critical-distance is less than 5 NM, there is a conflict.

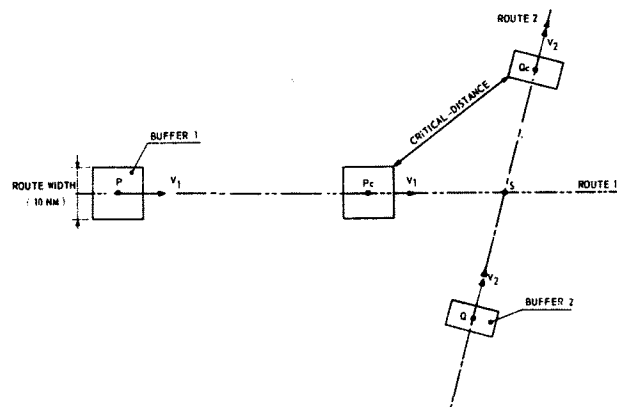


FIG. 5 PRINCIPLE OF THE CRITICAL-DISTANCE METHOD

Operational aspects

A conflict between aircraft is only displayed on that control position where the conflict-generating aircraft is under control or will be taken under control. If a conflict is detected, a flashing conflict symbol for the relevant flight appears on the EDD (Electronic Data Display) of the planning controller. A conflict can be solved by the planning controller with the assistance of the following additional information:

- on the EDD, the flight plan data of up to 6 flights having a conflict with the aircraft concerned, can be displayed
- the conflict-free levels in a height range extending from 3000 ft above to 3000 ft below the flight concerned, can be displayed upon request.

As soon as an aircraft, for which a conflict is predicted, is taken under control by the executive controller, a steady conflict symbol appears in front of the label on the PVD (Plan View Display). Conflicts can be solved by flight level change. A flight is deleted from the conflict search file, when clock time exceeds the time of arrival at the TMA-exit.

Conflict detection logics

The conflict detection logics is illustrated by fig. 6. After entering the Netherlands FIR, transit A is compared with each preceding aircraft that can in some way get a conflict with transit A. Therefore, first a check for height separation and a rough comparison of the estimated time of arrival over the TMA (i.e. ETA_{SPY} or ETA_{PAM}) is executed for each flight, that can have a conflict with aircraft A. Next, the block lengths (see fig. 7) are derived from a matrix which is permanently stored in the computer.

Knowing the ETA's for the TMA-reporting points and the groundspeed over the TMA for each aircraft, the entry- and exit times of the conflict blocks are computed. After addition of time buffers, accounting for inaccuracies in the computation of the block-entry and block exit times, a check for overlap of the block occupancy times is carried out. Time overlap indicates a block conflict.

Next, the conflict state can be considered using the critical-distance method (see chapter VI). In case of a critical-distance less than 5 NM the conflict as well as its state can be displayed to the controller.

For any aircraft the conflict search is repeated 3 mins. prior to TMA-entry and after any relevant ATC input.

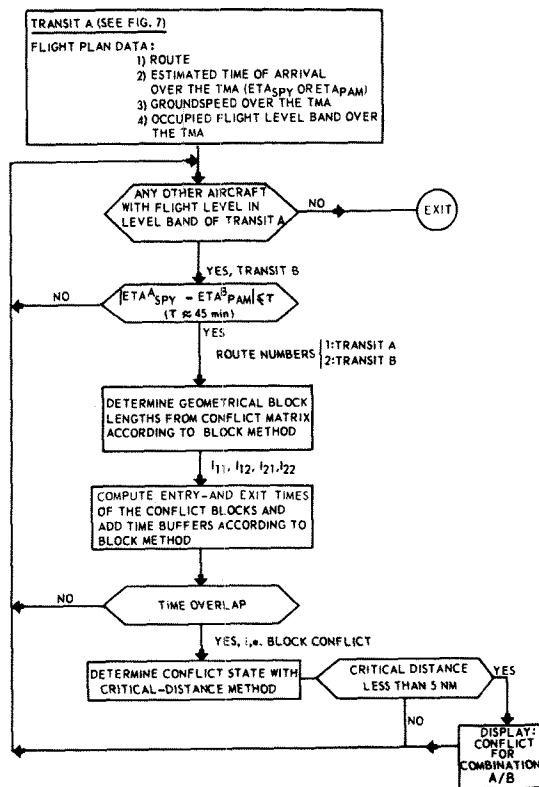


FIG. 6 FLOW GRAPH OF THE CONFLICT DETECTION PROGRAM

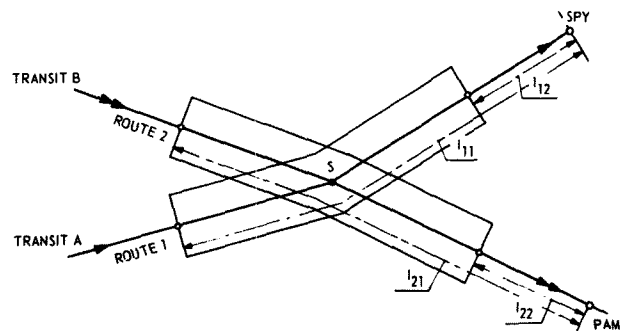


FIG. 7 DETERMINATION OF THE CONFLICT BLOCKS WITH RESPECT TO SPY OR PAM

V. Details of the block method

In this chapter, methods are presented for the determination of the block lengths. Firstly, the "conventional" conflict blocks are presented which only take into account the route geometry. Secondly, the concept of "optimal" conflict blocks is introduced, making use of additional information concerning flying direction and velocity ratio ($= m$). The velocity ratio being defined as the quotient of the maximum groundspeed and the minimum groundspeed of overflying aircraft.

Determination of the block length

In a first approach the block length L_G can be computed, taking only into account the route geometry, the minimum horizontal separation D_{\min} , and the route width W . As is shown in fig. 8, this block length, which is called "conventional" block length, becomes:

$$L_G = \frac{2D_{\min}}{\sin \varphi} + \frac{W}{\operatorname{tg} \frac{\varphi'}{2}} = 10 \left\{ \frac{1}{\sin \varphi} + \frac{1}{\operatorname{tg} \frac{\varphi'}{2}} \right\} \text{ NM}$$

$$\text{where: } \varphi' = (90^\circ - |\varphi - 90^\circ|); \quad 0 < \varphi < 180^\circ$$

$$D_{\min} = 5 \text{ NM}$$

$$W = 10 \text{ NM}$$

In this case a conflict between any two aircraft will be detected, whatever their ground speeds may be. However, pairs of aircraft (with realistic speeds) can be found which are in the two blocks simultaneously and as such would be declared to have a conflict, but whose minimum horizontal distance will never be equal or less than 5 NM. This will result in a false alarm to the ATC-controller.

To lower the false alarm rate for the block method, the concept of "optimal" conflict blocks was developed.⁽⁴⁾ Now, a certain maximum ratio of the groundspeeds of the two aircraft on crossing routes is taken into account resulting in a reduction of the block length. It can be shown that the length of an "optimal" conflict block for a crossing of straight routes (intersection angle φ) and a velocity ratio m (by definition $m \geq 1$) is:

$$\text{"Optimal" } L_G = [L_A, L_B]_{\max}$$

where:

$$L_A = \frac{2D_{\min} \sqrt{1 - 2 \cos \varphi + m^2}}{(m+1) \sin \varphi} + W \frac{(m-1)}{(m+1)} \cdot \left(\frac{1 + \cos \varphi}{\sin \varphi} \right)$$

$$= 10 \left\{ \frac{\sqrt{1 - 2 m \cos \varphi + m^2}}{(m+1) \sin \varphi} + \frac{(m-1)}{(m+1)} \cdot \left(\frac{1 + \cos \varphi}{\sin \varphi} \right) \right\} \text{ NM}$$

and

$$L_B = \frac{2D_{\min} \sqrt{1 - 2 m \cos \varphi + m^2}}{(m+1) \sin \varphi} + W \left(\frac{1 - \cos \varphi}{\sin \varphi} \right)$$

$$= 10 \left\{ \frac{\sqrt{1 - 2 m \cos \varphi + m^2}}{(m+1) \sin \varphi} + \left(\frac{1 - \cos \varphi}{\sin \varphi} \right) \right\} \text{ NM}$$

$$0 < \varphi < 180^\circ$$

When $m = \infty$ is substituted in these formulae, the "optimal" block length equals the "conventional" block length.

In figure 9, the "optimal" block length is given as a function of the intersection angle φ for three velocity ratios. It turns out that it is attractive to use "optimal" conflict blocks, especially when the velocity ratio is low and the angle φ is less than 90° .

The determination of the "optimal" conflict blocks is of a rather uncomplicated nature for a crossing of straight routes. For the general case, a computer program has been developed to compute analytically the dimensions of the "optimal" conflict blocks. In figure 10 the situation for crossing point S is illustrated. Suppose in this hypothetical case, there are two aircraft with ground speeds v_1 and v_2 on routes 1 and 2, arriving at time T_P at reporting point P and at time T_Q at reporting point Q. These times T_P and T_Q can be chosen in such a way, that the minimum horizontal distance (D_{\min}) between the aircraft that can occur somewhere, is exactly 5 NM. These T's are called "critical" ETA's and the difference $T_P - T_Q$ is called a "critical"

Δ ETA. With these critical Δ ETA's the lengths of the "optimal" conflict blocks can be computed.

Four cases have to be distinguished, as indicated in the matrix below. The critical Δ ETA's for these cases are distinguished by indices I, II, III and IV as is also shown in the matrix.

	Aircraft 1 is the first to arrive at S (fig.10)	Aircraft 2 is the first to arrive at S
$V_1 = V$ * $V_2 = m \cdot V$	Δ ETA _I	Δ ETA _{II}
$V_1 = m \cdot V$ $V_2 = V$	Δ ETA _{III}	Δ ETA _{IV}

* Note: Remember that m is defined $\frac{V_1}{V_2}$ if $V_1 \geq V_2$
and $\frac{V_2}{V_1}$ if $V_1 < V_2$, so that always $m \geq 1$.

Consider the situation that the entrance of an aircraft in its conflict block exactly coincides with the departure of the other aircraft from the corresponding conflict block for the 4 Δ ETA's in the matrix.

- In this case no superfluous airspace will be occupied, forming the basis of the optimality principle.

This leads to the following equations for the "optimal" conflict blocks.

$$\Delta \text{ ETA}_I = \frac{1_{21}}{mV} - \frac{1_{12}}{V}$$

$$\Delta \text{ ETA}_{II} = \frac{1_{22}}{mV} - \frac{1_{11}}{V}$$

$$\Delta \text{ ETA}_{III} = \frac{1_{21}}{V} - \frac{1_{12}}{mV}$$

$$\Delta \text{ ETA}_{IV} = \frac{1_{22}}{V} - \frac{1_{11}}{mV}$$

These 4 equations have a unique solution for the "optimal" conflict blocks:

$$l_{11} = \frac{mV}{m^2 - 1} \left\{ \Delta\text{ETA}_{IV} - m \Delta\text{ETA}_{II} \right\}$$

$$l_{12} = \frac{mV}{m^2 - 1} \left\{ \Delta\text{ETA}_{III} - m \Delta\text{ETA}_I \right\}$$

and

$$l_{21} = \frac{mV}{m^2 - 1} \left\{ m \Delta\text{ETA}_{III} - \Delta\text{ETA}_I \right\}$$

$$l_{22} = \frac{mV}{m^2 - 1} \left\{ m \Delta\text{ETA}_{IV} - \Delta\text{ETA}_{II} \right\}$$

These lengths are for a given route geometry only dependent upon the velocity ratio (recall that ΔETA is inversely proportional to V). It is beyond the scope of this paper to describe the analytic computation of the ΔETA 's.

In the SARP II-system the "optimal" conflict blocks for a fixed maximum velocity ratio $m=4$ will be used. But further refinements based on the use of different matrices for various velocity ratios are considered for implementation in the future. (5)

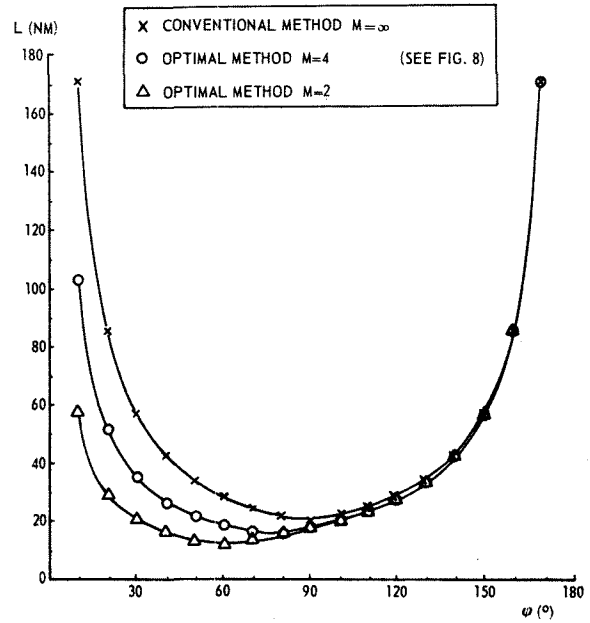


FIG. 9 "OPTIMAL" CONFLICT BLOCK LENGTH AS A FUNCTION OF INTERSECTION ANGLE ϕ

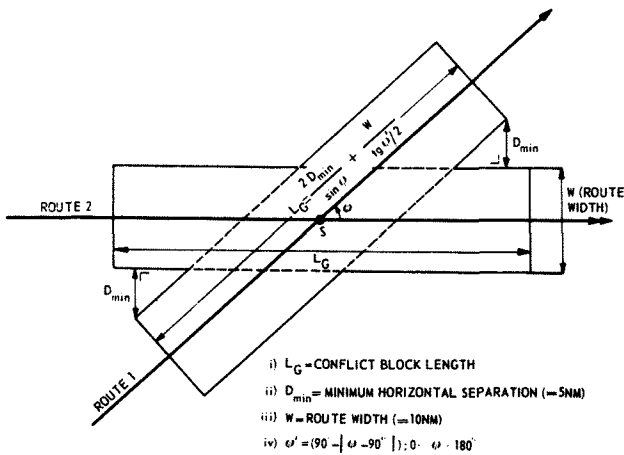


FIG. 8 BASIC CONFIGURATION OF THE CONFLICT BLOCKS FOR A CROSSING ("CONVENTIONAL" BLOCK LENGTH)

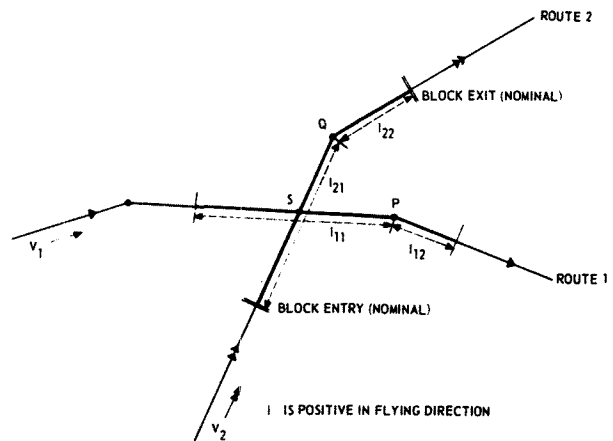


FIG. 10 DETERMINATION OF THE "OPTIMAL" BLOCK GEOMETRY FOR GIVEN "CRITICAL" ΔETA 'S

VI. Details of the critical-distance method

Introduction

In chapter IV the object of the critical-distance method was indicated. This method will now be explained in more detail with the aid of the flow graph of fig. 11.⁽⁶⁾

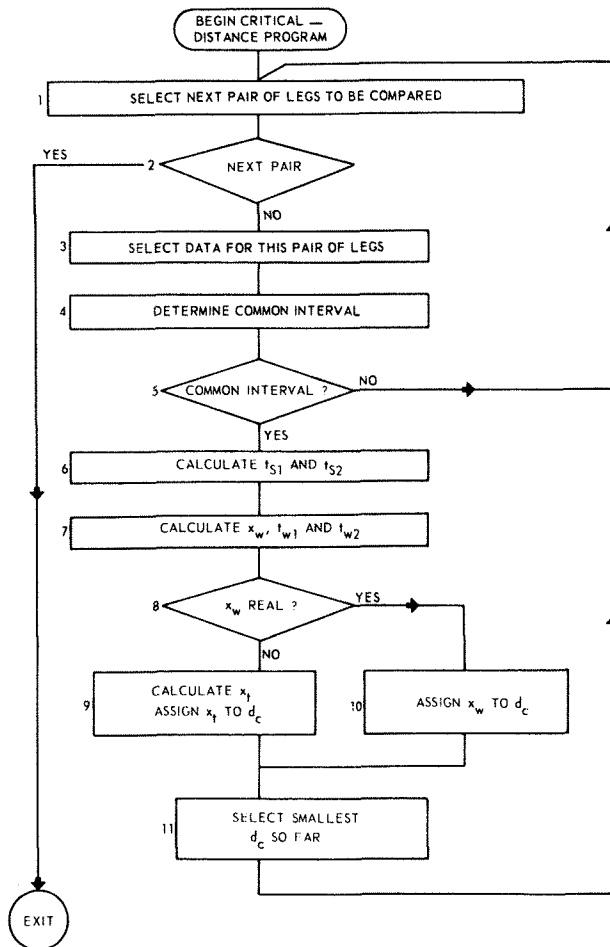


FIG. 11 FLOW GRAPH OF THE CRITICAL-DISTANCE METHOD

Assumptions for the calculation

An example of two flights is shown in fig. 12, to explain the principle of the method. In general, every route consists of an arbitrary number of consecutive straight sections, called "legs". In the example, flight 1 follows one leg, from A to B. Flight 2 follows the two-leg route CDE. The ETA's at points A, B, C, D and E are known from the trajectory prediction program of the SARP-system, as are also the groundspeeds V_1 and V_2 . To account

for the uncertainties in the ETA's, the critical-distance calculation is based on a "longitudinal tolerance", being the maximum assumed deviation of the ETA's. This tolerance in time is converted to a distance-tolerance by multiplication by the speeds V_1 or V_2 .

In fig. 12, ϵ_1 is the longitudinal tolerance for leg AB, in terms of distance. The longitudinal tolerance is not the same for all legs. It depends on errors in the ETA-prediction which are both caused by speed deviations and by the unknown way a bend is flown.

For the latter reason an increment to the tolerance is applied, depending on the angle of turn in some way, not to be discussed here.

Another uncertainty concerns lateral deviation from the centreline. It is taken into account by a lateral tolerance $\frac{W}{2}$, assumed to be 5 NM.

In fig. 12 the nominal (i.e. predicted) positions of the two aircraft at one minute-intervals are given as dots, the time in minutes being indicated above them. Around each dot a shaded rectangle, called "buffer", gives the lateral and longitudinal tolerances. I.e. at any given time the aircraft may be anywhere in the corresponding buffer. The critical-distance to be calculated is the smallest distance that will ever exist between the buffers of the two aircraft.

The longitudinal size of the buffer of flight 2 in fig. 12 is $2\epsilon_2$ before the turning point D, and $2\epsilon_3$ after it. For the reasons given, $\epsilon_3 > \epsilon_2$. At the turning point D there are two buffers. One is the last buffer of leg CD, the other one the first buffer of leg DE. The first of these two buffers has a length $2\epsilon_2$, as usual. However, the trailing part of the second buffer is given a length $\frac{W}{2}$ rather than ϵ_3 , for the following reason. ETA tolerances may amount to some 2 mins. flying time. For fast aircraft ϵ could then become as large as 20 NM. In order to avoid the buffer to extend far into a region where the aircraft will never be, is replaced by $\frac{W}{2}$ always when $\epsilon > \frac{W}{2}$.

Comparison of legs

Basically, each leg of one flight is compared with every leg of the other flight and for each such pair the critical-distance is computed. The smallest of the critical-distances is taken as the critical-distance between the two flights concerned. In our example two critical distances will be found, one for legs AB and CD, the other one for legs AB and DE. The principle of the method will be explained by closely following the flow graph.

Main steps of the calculation

Box 3 (fig. 11) selects the data of the pair of legs to be compared next; at first legs AB and CD. Only those sections of these legs should be considered that are flown by the respective aircraft simultaneously. Only in the time interval between 2 mins. and 3 mins. the aircraft are on legs AB and CD simultaneously. This interval, indicated (2, 3), is called "common interval" and is found in box 4 of the flow graph. If, however, it is found in box 5 that no common interval exists, no further calculations are needed and a next pair of legs can be handled.

In the case of the example the calculation proper for legs AB and CD starts in box 6. The coordinates of the imaginary intersection point S (fig. 12) are calculated, as well as the ETA's of aircraft 1 at S (t_{S1}) and of aircraft 2 at S (t_{S2}). These ETA's are calculated notwithstanding the aircraft on route 2 will never arrive at S; they are just parameters for the following calculations.

Under the assumption that both aircraft continue to fly straight legs, the critical distance x_w (w for "worst case") is calculated in box 7, as well as the time interval (t_{w1} , t_{w2}) in which this x_w will be reached ("critical interval").

It should be noted here that only if $x_w = 0$, i.e. if the buffers will overlap during some time, t_{w1} and t_{w2} are different. If $x_w > 0$, then $t_{w1} = t_{w2}$, so the critical interval has zero length.

In the example, for the extended legs AB and CD, x_w appears to be 0 between $t_{w1} = 5.50$ mins. and $t_{w2} = 6.16$ mins. The buffers of flight 1 at these two times are heavily shaded in fig. 12. Those of flight 2 are indicated by diagonals in them. Indeed, at $t_{w1} = 5.50$ mins. the buffers of both flights touch for the first time, at point P. At $t_{w2} = 6.16$ mins. they get loose again at point Q. Thus, only between 5.50 mins. and 6.16 mins., the two buffers overlap (partly, in this example) and x_w will become 0.

Only, if x_w occurs when both aircraft are on the legs considered, x_w is called "real". The $x_w = 0$ just found, however, is a "virtual" one, for it occurs outside leg CD, and it should therefore be neglected. The distinction between real and virtual x_w is made in box 8 of the flow graph, by means of the critical interval (t_{w1}, t_{w2}). If the latter overlaps with the common interval, the corresponding x_w is real, otherwise it is virtual. In the case under consideration the real critical distance is the minimum distance between the buffers at that boundary-time of the common interval that is nearest to the critical interval. In the example this

boundary time turns out to be 3 mins. Therefore, in box 9 of the flow graph, the critical distance x_t , between the buffers is calculated for given t ; here for $t = 3$ mins., $x_t = 31.2$ NM is found, which value is assigned to the critical distance, d_c .

So far the calculating steps for comparing legs AB and CD were discussed. Next, after returning to block 1, legs AB and DE are treated the same way, the only difference being that for these legs x_w appears to be real. Indeed, an $x_w = 5.7$ NM is found at $t_w = 6$ mins., i.e. $t_{w1} = t_{w2} = 6$ mins. The common interval is (3,9) now and hence it is within the critical interval (6,6). Consequently (fig. 11) $x_w = 5.7$ NM is assigned to the critical-distance, d_c .

In block 11 it is decided that the new $d_c = 5.7$ NM is the final critical-distance between flights 1 and 2, this value being smaller than the older d_c of 31.2 NM.

Evaluation

Boxes 6 and 7 are of a rather complicated nature and will not be discussed further therefore in this paper.

The critical-distance can be displayed to air traffic controllers in any relevant case, and can also be used to produce an alarm if it is below a preset value (e.g. 5 NM). In case of such an alarm the actual minimum distance between the flights concerned will usually turn out to be larger than 5 NM. Still the alarm was necessary, for the most

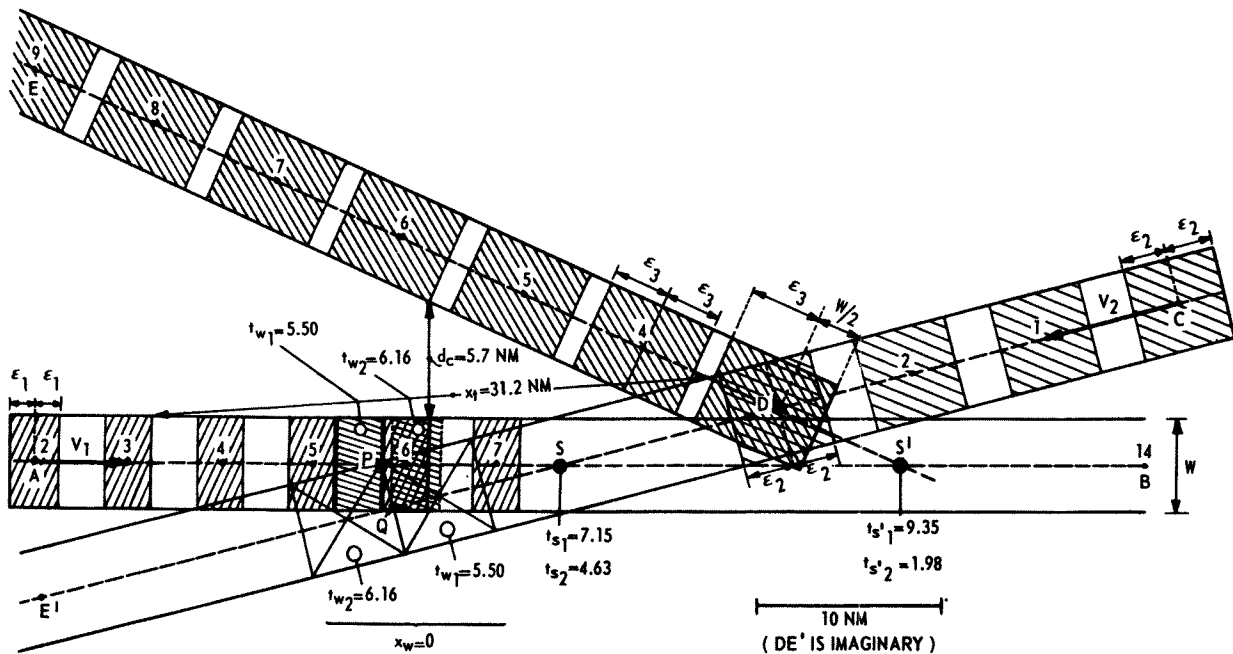


FIG. 12 EXAMPLE OF A ROUTE STRUCTURE FOR TWO FLIGHTS
($W=5$ NM IN THIS FIGURE)

critical lateral and longitudinal deviations within the given tolerances had to be taken into account. In this sense false alarms are reduced to the "theoretical" minimum.

The improvement in the theoretical false alarm rate, compared to the block method amounts to approximately 12 %. This value only holds for the block method in which the $m=4$ matrix is used, this matrix being foreseen in SARP II. If more than one matrix is used - i.e. matrices for different velocity ratios - this figure can be significantly reduced.

However, the critical-distance method offers much more flexibility than the block method, for the latter method can only be used for a fixed route structure with crossing flights. Besides this, the critical-distance method can be used as an indication of the "seriousness" of a conflict.

Acknowledgement

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