This seems to be a very appropriate time to adopt a complete change in outlook, which will lead to simplicity, and avoid ambiguous situations; the reputation of the cloth is at stake at present with so many adverse criticisms in the national press about 'radar-assisted collisions', and letters to the editor of one national newspaper about the intelligent use of radar at sea.

If completely new rules should ever be drawn up do please let it be clear which code applies in good visibility and which in restricted visibility. Also it would doubtless be necessary for a vessel equipped with radar to be allowed a higher degree of manœuvrability than her sister without this aid.

'The Effective Use of Airspace'

from Wing Commander A. W. Southall

1. INTRODUCTION. It is almost two years since Wing Commander Dickie's survey (11, 259) emphasized the importance of improving methods of control so as to allow more movements in a given volume of airspace. Since then, much effort in many countries has been devoted to the problem. The magnitude of these difficulties is not surprising when it is recalled that, in addition to the professional difficulties of flying, navigation and control, various sections of industry are involved, and international agreement must be obtained. At every turn there are political and commercial problems which cannot be ignored by those responsible for initiating action to solve a very difficult practical problem. This note is written in an attempt to examine once again the various possibilities for improving airspace utilization, with the object of discovering some pattern which will lead to progress.

2. NAVIGATION. It has been stated that at all times both the controller and the pilot must know the absolute ground position of the aircraft, but it is by no means clear that this really is a requirement. It could well be sufficient to maintain the position of the aircraft relative to the traffic pattern, for this would satisfy the pilot's aim which is to travel in accordance with his flight plan, and also the controller's aim which is to ensure safety while making best use of the available airspace. If it is indeed sufficient to maintain position in relation to the traffic pattern, then we have the opportunity to view the navigation problem from a standpoint consistent with the control problem.

3. TRACKING. Given accurate tracking in the air, airspace limitations will become a much smaller problem without extra effort in the control centre. Let us consider the tracking device from the point of view of keeping the aircraft in position in the traffic pattern. First and foremost the device must keep going. Black boxes which are prone to failure are worse than useless, especially if bad weather makes their failure more likely. It has always been good navigation policy to cross-check the navigation, and for many years yet, some reserve navigation method will be required. If the main navigation device is not weather sensitive, then it may be possible for the ground radar to provide the reserve against occasional failure, and this would seem to be the most economic proposition. These general considerations lead to the question of presentation of tracking information on the overcrowded flight deck. It may well be found sufficient for the required track to be preset, and for off-track indications, and possibly

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warnings and automatic following, to be combined with the zero reader and automatic pilot. A simple programming arrangement to store changes of track would complete the picture and release the crew from a wearisome routine of continually monitoring the tape.

4. SEQUENCING. Quite rightly Dickie says that so-called automation techniques are not yet required: the fancy waistcoat must be resisted until its shape is defined and the need for it is proved. Responsibility for ensuring separation along the track, Dickie allots to the controller, and this is surely appropriate. However, for experienced airline pilots an error of 5 knots at 200 kts., or 0·02 M. at 0·7 M. is quite large, but causes a timing error of less than two miles an hour. So it seems that, if the pilot cooperates and account is taken of forward speed, then there is on the ground a picture which is at least as accurate fore and aft as it is laterally and vertically. And thus there is no need to treat progress in the fore and aft plane in an *ad hoc* manner. If we are freed from the need to know absolute ground position as a first priority, then it might be advantageous if the sequencing monitor is maintained by a comparison of airspeeds under the control of whatever current position information is available. Similarly, alterations of speed, for example in preparation for landing, might be initiated by reference to the surrounding traffic pattern rather than at fixed geographical points. All this is away from current practice, but this is an attempt to look at the future rather than to survey the past.

5. TIME ADJUSTING. Granted that for economic reasons civil aircraft will wish to fly as fast as possible, then whenever adjustments are necessary for sequencing purposes, a delay will be required unless a new track can be provided. Although it must be hoped that delays will disappear, there will be occasions, for example when an airfield is suddenly closed for some unforecastable reason, when expensive delays appear inevitable. There is, however, the possibility that engine handling practice might be modified so as to allow a short period at higher power for use when time adjustment could be effected by speeding up one aircraft rather than by interfering with the flight plan of several. In theory this might reduce the time between engine overhauls, but in practice the effect on individual engines would probably be slight. The added flexibility which the traffic control system might inherit, could be extremely valuable. But the cooperation of the engineers would be required, and it would not be easy to reconcile uneven and perhaps intangible, commercial benefits.

6. SCHEDULING. It has already been suggested in the *Journal* that individual take-off times might be allotted as a clearance. One can find plenty of difficulties in this as in most other suggestions, but, realistically tackled, the difficulties could be met. Peak period airspace would then be more effectively used and the resultant savings might provide the commercial impetus which would enable the airlines to discourage those administrative errors which prevent the take-off being made on schedule.

7. FIXED HEIGHTS. If by a reappraisal of sequencing methods it is possible to obtain a closer control of fore and aft spacing, and this is found to stay close to the plan, then it might follow that the present concept of rigidly tied heights could be relaxed, to the delight of operators and pilots of modern aircraft. If the emphasis was shifted in this way, the natural scatter in height which occurs when aircraft of the same type are cruise climbing, would provide much of the separation which was needed. Across-track spacing which it is possible to obtain with an accurate navigation device, or which would occur in any case if tracking

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was inaccurate, would be available under radar surveillance as a further insurance against having to resort to fixed heights again.

8. POSITION FINDING DATUM. The above suggestion that it is perhaps not vital to know the aircraft's position in relation to the ground, but primarily in relation to the traffic pattern, might be taken to confirm the emphasis which Dickie placed on the possible value of collision warning equipment in the North Atlantic. In the light of Calvert's later paper, however (11, 327), the wisdom of adopting this equipment would appear questionable even before the complications of an electronic system are introduced. The problem of defining position in relation to the Earth's surface is one which cannot be avoided, and it forms the basis of the concept of position monitoring in relation to the flight plan. If, as seems probable, collision warning equipment is not found commercially attractive, then the difficulty in the North Atlantic must be solved by other means. There would seem to be room for improved control techniques, possibly by making use of planned forward speed and agreed wind forecasts, assisted by the increasing use of improved navigation devices in the air.

9. MONITORING. Reports of recent accidents suggest that radar is not always used to monitor the progress of aircraft navigating by other means. It seems that monitoring should be a prime function of radar and one which is being overlooked in the rush to offer navigation assistance. While this was no doubt correct a year or so ago, with increasing traffic, and better airborne aids, it may no longer be sound economics to use radio capacity for routine navigation traffic. If ground radar is promoted to the monitoring role, its capacity will increase considerably in numbers of aircraft handled, and the possibility of accidents or sequencing difficulties due to inaccurate flying in difficult circumstances will be eliminated because the radar will have the capacity to watch every aircraft, and to assist the occasional one seen to be out of place.

10. AUTOMATION. Automation is a popular word, but it is a method of carrying out a technique, and not a technique in itself. Too many black boxes could lead to problems of maintenance, and an unreliable black box is not commercially attractive. So, while the benefits of modern inventions must be grasped, care must be taken to avoid being dazzled by the array which is offered. With a little care and training on the part of the user, a simple reliable equipment may be far more effective than something more complex. On balance it is liable to be more efficient to find the technique and then apply automation in moderation, rather than to work out the technique for using a complicated electronic device which is apparently available.

11. SAFETY VERSUS ECONOMY. In any discussion of methods of obtaining greater efficiency, the need for safety must be remembered in the knowledge that when things become difficult, it is easy to invoke a safety clause and decide that nothing can be done. However, those who deal in statistics will point out that accidents do happen, and it may well be that they always will. So, although accident prevention must clearly be actively studied, the danger must be recognized that conscientiousness about safety might develop into a progress-stifling phobia.

12. PREFERENTIAL TREATMENT. Present arrangements where aircraft take their turn and no preference is given are satisfactory from many points of view. However, there are two very good reasons to consider changing this conveniently administered rule. First, it might not be out of place if visitors of top status were accorded their due order of precedence. More important, however, is the

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probability that control problems would begin to fade away as soon as arrangements were completed to give preferential treatment such as faster procedures and closer spacing to those who demonstrated that by better airmanship, or by fitting better aids, they could maintain better accuracy. The savings thereby effected might well pay for the better equipment or training in a very short time, and thus start a snowball of improvements propelled by a commercial impetus which could never be obtained while all are hobbled to the speed of the slowest member.

13. SUMMARY. To summarize, the following suggestions in order of importance are made as possible avenues to the more effective use of airspace:

(*a*) Recognize the probability that preferential treatment for those who qualify may generate a commercial impetus which will demand progress.
(*b*) Concentrate the ground radar on its invaluable monitoring function.
(*c*) Enlist the cooperation of operators in agreeing standard procedures.
(*d*) Make use of the fact that forward speed is accurately maintained.
(*e*) Relax height restrictions at every opportunity.
(*f*) Assist sequencing by introducing clearances for set take-off times, to the advantage of those who can cooperate.
(*g*) Alter engine limitation practice to assist in sequencing by allowing short periods of higher speed when required.
(*h*) Present and report tracking information in relation to planned track.
(*i*) Resist automation until the commercial advantages can be seen.
(*j*) Ensure that safety requirements do not stifle progress.

Wing Commander Dickie comments:

Although we hold substantially the same views there are one or two comments which I would like to make.

2. Dealing next with the question of airspeed I do not dispute the fact that forward speed can be maintained with a high degree of accuracy. However, in traffic control as we know it today, ground speed is the thing that really matters and this cannot be maintained unless the pilot can vary his airspeed over a wide range in order to cancel out the effects of wind velocity. Moreover in all other forms of traffic control the speed of the vehicle has to conform with the requirements of the controller and it is only by this means, with ground speed controllable over the full range from maximum to zero, that safe high density operation is achieved. No railway system for example could maintain its present movement rates if trains had to maintain a forward speed of 60 kts. ± five until they were within a few miles of their next scheduled stop. Neither could shipping cope if surface vessels were unable to decrease speed when navigating coastal waters.

3. What all this means of course is simply that A.T.C. could handle much more traffic without imposing delays if aircraft could change speed when required for traffic control purposes. This leads into economic and other problems associated with the operation of aircraft engines and with aerodynamics. The idea put forward by W/Cdr. Southall of altering current engine operating practice is intriguing and I look forward with interest to hearing what the experts in this field may have to say about it. I am quite sure that the ability of a pilot to maintain a single notified airspeed with accuracy will not prevent longitudinal separation from varying appreciably from the plan. The wind velocity is still going to cause trouble especially at junction and crossover points.

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4. On the subject of anti-collision devices I remain unconvinced that something of this kind will not ultimately prove the logical answer in many parts of the world. It seems such a pity to restrict all aircraft movements all the time in order to remove the one case in a million or so. The fear of collision is very real. The risk of collision, however, is in my opinion very slight and I base this opinion on wartime experience of traffic densities very much greater than any achieved before or since. Thus what I suggest we need is a 'separation monitor', rather than an anti-collision device, to eliminate the fear by removing the ignorance factor and telling the pilot (*a*) when the one in a million cases is arising, in good time for him to do something about it and (*b*) confirming positively in all other cases that all is well.

5. I sometimes wonder whether, when traffic is light, there is any fundamental difference between VFR flight at 120 knots or so in clear air, under which condition 'see and be seen' worked out fairly well, and IFR flight at much higher speeds but with the equivalent of visual sighting over much greater distances, with range measured accurately and possibly with relative height and 'other aircraft heading' conveyed with a degree of precision far greater than that ever achieved by the human eye. It is even conceivable that in much of the airspace of the world a device which enabled the pilot to do no more than maintain a safe height difference between his own and other aircraft within say thirty miles range, would be perfectly adequate without azimuth or any other information at all.

6. So I return to my main theme. Let us find a means of detecting and dealing with the rare event and move away from a situation in which safety can only be insured by assuming, in our ignorance of the true situation, that the rarity is the commonplace and consequently imposing traffic restrictions and delays which are in fact quite unnecessary on all but a very small proportion indeed of occasions.

7. I must add, of course, that as in the case of my original paper, the views I have expressed are my own and do not necessarily reflect those of the Department to which I belong.

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