
The Implications of All-weather Landing in the U.K.

O. B. ST. JOHN

Superintendent, Blind Landing Experiment Unit, Royal Aircraft Establishment, Ministry of Aviation, U.K.

and R. C. MORGAN

Chief Project and Development Engineer, British European Airways, U.K.

I. INTRODUCTION

Much has been said in the past about the differences between the American and the British approaches to the question of landing in low visibility. I believe that most of the apparent differences have arisen because the original aims were different, so that a strict comparison was not indeed possible. In Britain, we opted to go straight to an automatic system with a capability of fully blind landing as the goal. In the United States, the initial goal was operation down to a cloud base of about 100 ft, and the solution was understandably different. But in the past two years, the differences have certainly diminished and will, I believe, continue to do so, especially as we are both finding that safe operation down to a decision height of 100 ft demands a performance almost as good as that required for blind landing. Having said this, I can do no more, in this paper, than give a general picture of the situation as it is now in Britain, and make specific suggestions to solve the problems that will arise.

The All-Weather Operations Panel of I.C.A.O. have proposed five categories of low visibility operation, defined in terms of decision height and runway visual range. They are as follows:

Operational Category I. Operation down to minima of 200 feet decision height and R.V.R. 800 metres with a high probability of approach success.

Operational Category II. Operation down to minima below 200 feet decision height and R.V.R. 800 metres and to as low as 100 feet decision height and R.V.R. 400 metres.

Operational Category IIIA. Operation to, and along, the surface of the runway, with external visual reference during the final phase of the landing down to R.V.R. minima of 20 metres.

Operational Category IIIB. Operation to, and along, the surface of the runway and taxiways with visibility sufficient only for visual taxiing comparable with R.V.R. value of the order of 50 metres.

Operational Category IIIC. Operation to, and along, the surface of the runway and taxiways without external visual reference.

Decision height is formally defined as the specified height at which a missed approach must be initiated if the required visual reference to continue the approach to land has not been established.

Category IIIB corresponds to a minimum runway visual range of 50 metres, which is approximately equivalent to a meteorological visibility of 25 metres. At visibilities less than this, ground transport systems relying on visual information are seriously affected, and many new techniques would need to be used which may not be economically justified for a long time, if ever, in most parts of the world. This limit therefore provides an intermediate target which is consistent with the current British operational requirement for automatic landing. The majority of this paper will be concerned with problems associated with reaching Category IIIB operations, although some indication will be given of the techniques which are being considered for even lower visibility operation.

2. WHY HAVE A BLIND LANDING SYSTEM?

In examining the reasons for advocating a blind landing system, I am talking mainly in relation to B.E.A. and the Trident, because it was the first aircraft to be certificated by the Air Registration Board (A.R.B.) for automatic control to touch-down in regular passenger service. The same arguments undoubtedly apply to the VC10, the Concorde and others yet to come, with some slight differences. With an aircraft such as the Concorde, the combination of factors, such as high approach speed, the inevitable pitching characteristics of an aircraft of this type and large eye-to-wheel height, may raise piloting problems which make the use of an automatic landing system not only desirable, but perhaps essential, even in clear weather conditions, to provide safety. For any aircraft, however, the prime reason for having a blind landing system is to be able to operate with greater regularity, safely, irrespective of weather conditions. The ultimate decision to fit such a system, however, will be dictated by financial considerations: for regularity, the effect on operating costs can be calculated, but justification of cost on safety grounds is less straightforward.

Almost ten years ago, B.L.E.U. had demonstrated that the combination of a good autopilot, I.L.S., radio altimeter and a magnetic leader cable could land an aircraft with remarkable consistency, entirely automatically. This was a simplex system, however, and as such was not adequately safe, in the context of passenger-carrying aircraft. In fairness to B.L.E.U., about 15,000 automatic landings have so far been made with this type of system, without incident, in all weather conditions, including dense fog, but to B.E.A. this is a small number, being roughly equivalent to the number of landings made in one month in summer.

It seemed practical, at that time, to achieve safety by adding redundancy and so produce an equipment that would survive any single failure. The complementary problem of ensuring that the performance was adequate under all conditions was felt to be of secondary importance, although this is not surprising in view of the precise nature of the guidance which was then obtainable from both the radio altimeter and the magnetic leader cable. At this point, in spite of optimistic estimates of both weight and cost, which have both turned out to be about half the reality, it was decided that the cost could not be justified purely in terms of improved regularity and hence, revenue.

At that time, some of B.E.A.'s aircraft were still approaching at 85 knots, but other airlines' experience with swept-wing jet aircraft, with their poorer manoeuvrability, slower engine response and higher approach speed made it certain that considerable development would be necessary in approach aids even to maintain existing weather minima in safety, let alone reduce them. It seemed likely that with intensive development of flight directors and crew training programmes, followed by prolonged demonstrations to the A.R.B., it might be possible to maintain existing minima, or even reduce them towards what are now called Category II minima. It also seemed possible that, with more reliable autopilots to avoid any possibility of excessive flight path deviations resulting from a malfunction, coupled approaches could be made safely down to 100 ft, leaving the pilot to decide whether to land manually or overshoot. But both these solutions were of an interim nature and their adoption would merely have delayed attacking the real issues of bad weather operation, postponing them for a future generation of aircraft.

With these thoughts in mind, the knowledge of B.L.E.U.'s achievements and encouragement from the Minister of Aviation of the time, B.E.A. took what they now describe as a step in blind faith and decided that the Trident should be designed to be capable of fully automatic blind landing. At the time, there were no regulations to cover automatic landing, nor were radio guidance aids available with the necessary performance and integrity. It seemed unlikely that a magnetic leader cable, which required way-leave of the last 5000 ft before the threshold, would ever be an internationally acceptable system. It was believed that I.L.S. could be developed to provide

satisfactory azimuth guidance for touch-down but, as a precaution, the initial contract for the Trident called for automatic flare only; that is, control to touch-down in the pitch plane only, following an automatic approach. This was extended to cover full automatic landing as soon as the use of I.L.S. localiser for azimuth guidance to touch-down had been proved.

Using current techniques, *i.e.* an instrument approach followed by a manual landing, little is gained by reducing minima in current operations. B.E.A. estimate that the landing success, that is the likelihood of completing a landing, when operating with the decision height of 100 ft and an R.V.R. of 400 metres, would be about 25%. For B.E.A., a reduction of limits from Category I to Category II would result in 550 landings being lost instead of 700 in a year and this slight increase in regularity must be viewed in the light of the extra risk involved. An estimate of the relationship between risk of landing and R.V.R. was made by Calvert of R.A.E. and presented to the 15th I.A.T.A. Technical Conference in 1963. This has been reproduced with slight modifications in Fig. 1: the dotted extension has been added merely to show the inevitable trend, and an operational analysis of more recent records shows that this curve is, if anything, optimistic, when applied to future operations.

For Category I conditions the pilot has at least 12 seconds before starting the flare in which to make minor corrections, and it can be argued that the difficulties associated with assessing his position and completing the landing, are not critical. Ideally, the visual sector will be such that he can see the aiming point on the runway, or at least the threshold, from a height of 200 ft.

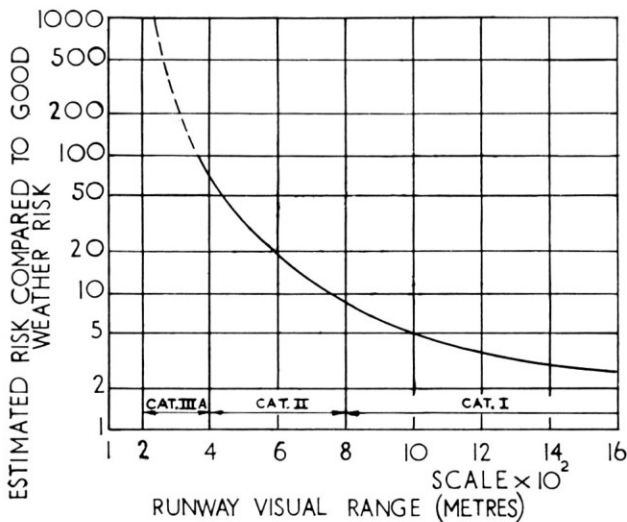


FIG. 1 — Relationship between estimated landing risk and R.V.R.

Nevertheless, even under these conditions, there can be significant piloting problems associated with the judgment of height and rate of descent, because the visual guidance in pitch is fundamentally poor and this is accentuated by changes in the visual segment due to variability of the fog structure.

At the lower end of Category II, the visual information is so poor that the average pilot is unlikely even to become really proficient, and therefore safe, in making the final landing manually. Because such conditions pertain so infrequently, it will be impractical to get the regular practice which is essential to achieve consistency. Simulators with visual attachments can help to some extent, but there is no substitute for the real thing.

The A.R.B.'s new safety target for future automatic landing systems (*see* section 4), aims at achieving, in low visibility, the same overall safety standards that are being reached in current operations. There is no justification for accepting a lower safety standard and for the future it is hoped that safety will improve, but this will not be achieved by using present techniques in lower minima. Furthermore, although it is true that a well-trained pilot can make a manual landing, using a flight director even under very low visibility conditions, the task requires intense concentration, to the exclusion of other responsibilities: once no outside clues are available, his task is that of a 'human servomotor', and this is thoroughly wasteful.

In plain language, the safety of current operations in the lowest minima allowed is not good enough. The only practical remedy would seem to be an automatic system which will ultimately enable us to arrive at our destination every time, safely, without asking the pilot to perform feats of airmanship.

3. THE PRESENT SITUATION AND FUTURE PLANS

All B.E.A. Trident aircraft are fitted with equipment designed for automatic landings and several hundred experimental landings have already been made. To explain the programme for the introduction of automatic landing into regular airline service, however, I must explain briefly the terminology.

In connection with the Trident airborne equipment, there are three possible grades of system providing different levels of reliability, and consequently safety.

(i) A single channel, or simplex, system in which certain faults can cause disturbances to the flight path. This type has been used for most of the experimental work at B.L.E.U.

(ii) A 'fail-steady', or duplex, system in which any fault disconnects the autopilot, leaving the aircraft in trim without seriously affecting the flight path.

(iii) A 'failure survival', or triplex, system in which any single failure does not affect the performance of the system.

The triplex automatic flight control system for the Trident has been developed and manufactured by Smiths Industries. An alternative means of achieving failure survival, using a duplicated monitored system, has been developed by Elliotts for the VC10.

The Trident was certificated by the A.R.B. in June 1965 to make automatic flares, that is, control to touch-down in the pitch plane only, following an automatic approach. Duplex, or 'fail-steady' equipment, is now being used and several hundred auto-flares have been made in regular passenger-carrying service. During 1967, it is hoped to have a triplex, or 'failure survival', system certificated for full automatic landing, to be used in current operating conditions.

Experience in service will then allow evidence to be accumulated to satisfy the A.R.B. that the system is safe enough for use in lower weather minima, although certification for operating in actual low visibility conditions will of course be dependent on the provision of all the necessary facilities at the airport in question. These facts, coupled with the inherent difficulties of introducing any equipment into aircraft which are already in service, make it impossible to commit B.E.A. to a firm time-scale.

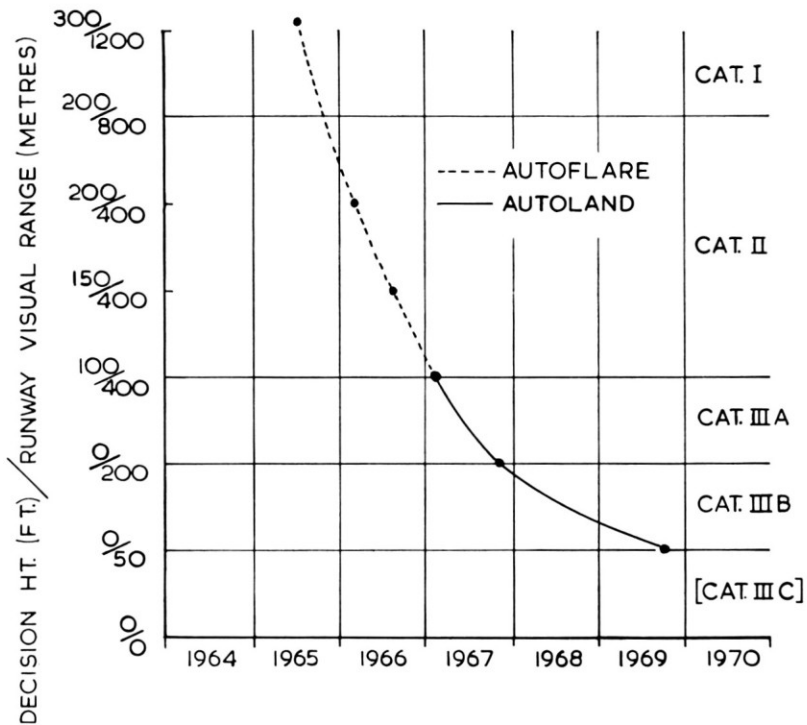


FIG. 2 — Target programme for certification of all-weather operations

A target development programme is, however, shown in Fig. 2 up to and including Category IIIB conditions. The programme relates to operation at London Airport for which a Category III I.L.S. is due to be available by the end of 1967. To attempt to forecast truly blind operation, at this point, would be futile because the factors which will predominate are unlikely to be technical.

4. THE SAFETY CRITERION

The realisation of the above programme is entirely dependent on first satisfying the A.R.B. that the overall system is safe, although the operational clearance is given by the Safety branch of the Ministry of Aviation. The present world-wide landing accident rate is about one fatal accident per million landings; the A.R.B. have proposed an overall safety target of not more than one fatal accident in ten million landings, as a result of using the system. This target alone, however, is not enough: one must not allow a landing to be made in circumstances which imply a high risk, even though the conditions occur so infrequently that this first target is satisfied. A further figure is therefore necessary, to define the maximum risk which may knowingly be incurred on any specific occasion: the appropriate target here is a fatal landing accident risk of three in a million. This second figure is, in a sense arbitrary, but is approximately equivalent to the average risk incurred in making an additional flight, which is implied by a diversion.

How can such figures be applied in designing an automatic landing system? There can be no question of assembling a number of independent, even if well-proven, sub-systems in the hope that, together, they will form a system that can be shown later to meet the safety requirements. It is essential to consider first the system as a whole and allocate specific targets to the individual component parts. An intensive, generalised, study has been made at B.L.E.U. of the performance required in the different areas on the principle that the individual targets should be roughly equally difficult to achieve. One of the first results of this study was a proposal for a specification for the Category III I.L.S. ground equipment which would need to be compatible with all airborne systems. Discussions are proceeding with a view to getting an international version ratified by the International Civil Aviation Organisation.

A breakdown of the safety target into its two principal components, performance and reliability, is shown in Fig. 3. Good performance is a question of ensuring that, when everything is working as designed, gross errors cannot occur. Reliability is concerned, not only with ensuring that failures occur very infrequently, but that gross errors are avoided even if failures do occur. In Fig. 3, the different sources of error are independent so that the risks can

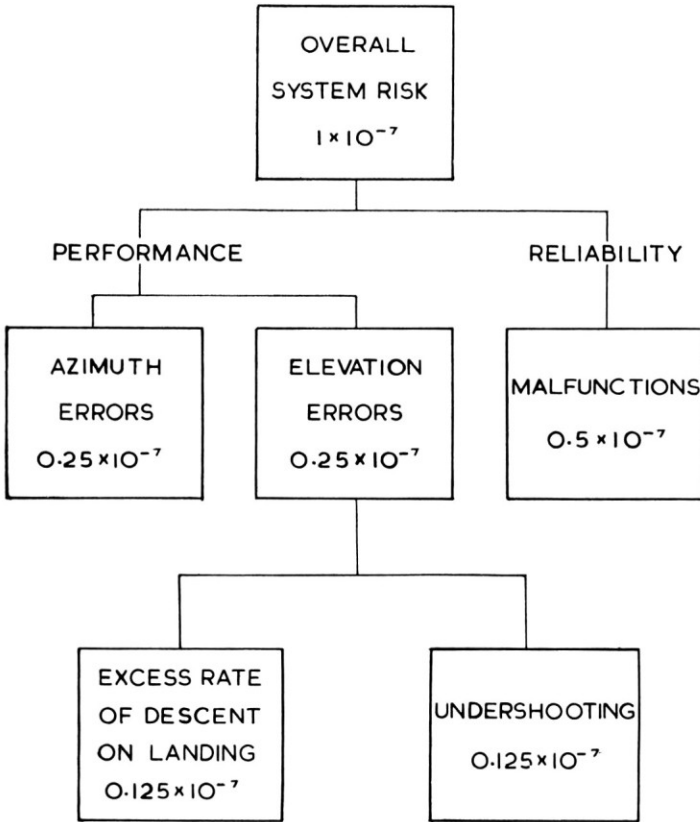


FIG. 3 — Subdivision of fatal landing accident rate

be divided simply and arithmetically. An equal share has been allowed for performance and reliability: performance has been equally sub-divided into errors occurring in azimuth and elevation and finally, the errors in elevation have been broken down by those caused by undershooting and those caused by too great a vertical velocity. These sub-divisions are, of course, arbitrary and each system designer may have a somewhat different breakdown.

Before the next stage can be reached, of allocating specific performance targets to components in the system, rather than to causes, it is necessary to define a fatal accident in quantitative terms. The expedient adopted has been to make use of estimated incident to accident ratios, where an incident can be defined in simple physical terms. The Air Registration Board, after studying available evidence of landing accidents, has undertaken to define these ratios. As an example, an incident is said to occur when an aircraft either runs, or lands, off the edge of the runway: for this case it is assumed that one fatal

accident will occur for each 30 such incidents. On this basis, taking the physical dimensions of the runway and aircraft undercarriage into account, it is possible to derive the target deviations shown in Fig. 4 from the safety

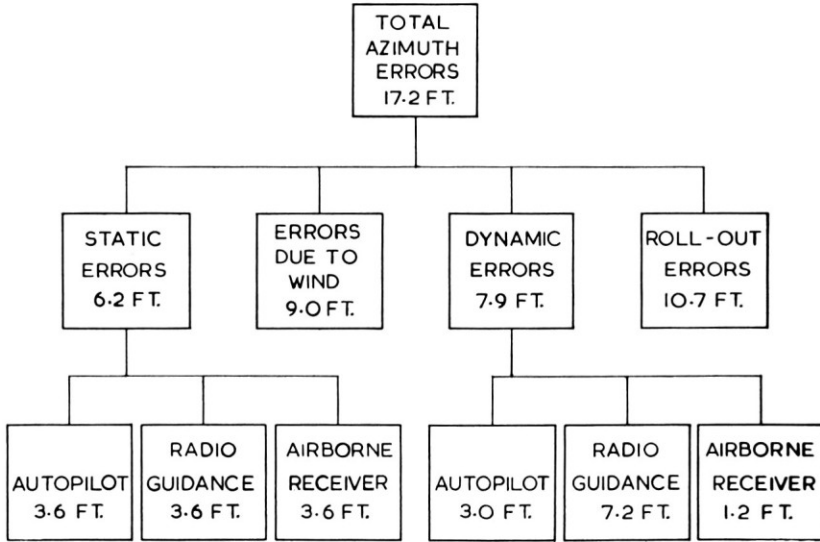


FIG. 4 — Allocation of permissible azimuth errors

targets of Fig. 3. The diagram shows the sub-division of azimuth errors due to four prime causes. The division between static and dynamic errors is set arbitrarily at a period of 100 seconds, on the basis that, for periods longer than this, changes will not be significant during the course of an approach. The allocation for ground-roll emphasises that major errors can accumulate subsequent to touch-down.

Having established the individual and overall target standard deviations, it is still necessary, in practice, to apply certain operational restrictions in order to conform with the second safety criterion that the fatal landing accident risk on a specific occasion should not exceed three in a million. As an example of this, knowing that the system is susceptible to wind turbulence, it will be necessary to impose operational limits in terms of maximum wind strength: these will, of course, vary from aircraft to aircraft and with the runway width available.

Designing to the above principles should give confidence, but there is little background of experience for this quantitative approach to safety, and there can be no question of proving in advance, to any degree of certainty, that the overall safety targets will be met because it would take too long. The evidence to be submitted to the certifying authority is likely to consist of a

combination of theoretical analysis, rig tests, flight trials and engineering judgment. In such a case, preliminary certification will only be possible for good visibility conditions, on the understanding that the pilot will be able to take whatever action is necessary to avoid an accident, in the event of a failure of any kind. As experience is gained and data accumulated in service, so will it be possible to achieve certification to lower weather limits but, because of the extremely stringent safety target, this will inevitably be a slow process.

5. AN ALL-WEATHER LANDING SYSTEM

Having stated the problem and listed some of the difficulties, the remainder of the paper will be devoted to describing in some detail the type of solution which we feel is most likely to provide the required safety and regularity. Safety must come first and be there from the start, but there must be some compromise as it is clearly always safer to stay on the ground. Regularity, which implies working safely to lower and lower limits, will follow with experience.

I must first distinguish between an automatic landing system and an all-weather landing system. The automatic landing system, as such, should require little explanation. The basic principles are well established and many automatic landings have already been made. The use of I.L.S. is assumed as the basic ground guidance aid with the addition of a radio altimeter in the aircraft to give accurate height for control during the flare. Also in the aircraft are the I.L.S. receivers and the automatic flight control system.

For use in fair weather, there is perhaps no need, on safety grounds alone, to have redundancy in either the control or the guidance elements, but as soon as blind landing is considered, a 'failure survival' system becomes essential to avoid leaving the pilot in an unsafe condition.

By definition then, an automatic landing system should be capable of landing the aircraft at the right place with the requisite safety and reliability. But this is not enough, and the operation is not complete until the passengers are safely within the terminal building.

Before an aircraft can safely make a landing in low visibility, it is necessary to ensure that the overall environment into which the aircraft is operating is adequate for the weather conditions prevailing. First, this covers a check that all the ground aids, both guidance and air traffic control, are serviceable and that the weather conditions are within the limits specified for the aircraft type involved. Second, provision must exist for the guidance and monitoring of both aircraft and essential ground vehicles on the airfield. Lastly, it will be necessary not only to assure the pilot that all facilities are available, but also to pass him quantitative data as to visibility, wind conditions and runway surface, in order to minimise the risk by forewarning him.

An all-weather landing system can therefore be defined as the combination of an automatic landing system, together with the whole environment into which it has to operate.

6. THE ROLE OF THE PILOT IN ALL-WEATHER OPERATION

In the earliest days of flying, the pilot had to be, in every sense, in direct control, but with the progressive introduction of radio communication, navigation aids, power controls, automatic control equipment and so on, his role has changed. His control has become less direct, but he still does, and must continue to, retain his prime task of 'Captain of the Ship'. Above all, his is the responsibility to make the decisions that ensure the safety of the aircraft, having regard to all the aids available.

In current operations, the captain is directly responsible for the safety of the aircraft and, to a great extent, the operation as a whole. By a complex sequence of checks, both before and during the flight, he establishes that no unacceptable risks are being run. He is not, of course, asked to assess the actual risk, or even, in general, to weigh up adverse against favourable circumstances.

As an example, consider a pilot who approaches an airport in clear conditions. Before he decides to land there are a large number of factors to be checked. Information on many of these factors is derived from within the aircraft; for example, the proper control of the engines and undercarriage, as well as the visual check that the aircraft is in the correct position in relation to the airfield. For other factors, he is dependent on Airfield Control, who will pass to him a number of discrete pieces of information and on these he may be required to make a simple decision: for instance, is the surface wind within the specified limits for the particular type of aircraft involved?

In attempting a blind, or low visibility, landing, the principles are the same, but because the pilot cannot make a visual check, he is more dependent on instrument aids as well as information passed from Airfield Control. This not only involves passing more information to the pilot, but also necessitates a comprehensive check system on the ground, for example, to ensure the absolute integrity of the guidance system being used.

The Air Registration Board, in specifying the safety standards for a blind landing system, has suggested a maximum acceptable fatal accident risk (*see* Section 4) to be established before take-off, at some point before starting the approach and, where applicable and possible, during the approach and landing.

The existence of a defined maximum risk should not be allowed to impose further burdens of responsibility on the captain but, as far as possible, should

merely be used to lay down, in most cases quantitatively, the basis on which he can make his decision to land or take some alternative course of action.

Before taking off on a flight which may involve a blind landing, the captain will need to know, in general terms, that full facilities are available at his destination and that a diversion is available. In addition he will, of course, check that that part of the blind landing system, which is contained in the aircraft, is fully serviceable. A really comprehensive test set for this purpose could present serious problems because of its own unreliability: a possible alternative would make use of the redundancy built into the equipment to give a 'self-test' facility.

Immediately before starting the final approach, he will want confirmation that the guidance aids and weather conditions are within the limits laid down, and that the runway is clear. This basic information, if possible, should be in the form of a clear-cut statement that a full Category III or Category II facility is available but, in addition, more detailed information should also be made available to warn of any particular conditions to be expected. The provision of this detailed information is not concerned with assessing the risk, but with improving the safety of the operation by forewarning the pilot. Specific examples are the wind conditions, the expected visibility sequence and the runway surface condition.

On starting the final approach, before a low visibility landing, the assumption is made that the flight path defined by zero I.L.S. indication is correct, so that the I.L.S. signals provide the only indication of overall performance that is available to the pilot, and these can be used to guard against gross errors.

B.E.A.'s current crew procedure for use in low visibility operation is the monitored approach procedure, in which the second pilot flies the aircraft during the approach, either manually or indirectly through the autopilot. The captain monitors the approach visually and, if the visual sector is adequate, lands the aircraft manually. This sharing of duties could be used for all-weather operation, with the difference that the autopilot would be engaged throughout the approach and landing and there would be more dependence instrumental monitoring. The weakness in this procedure lies in the separation of the instrumental and visual information during the final approach and landing. Ideally, the captain should have all the vital information in one place: this could be achieved in the future by the use of a head-up display, providing instrument information and failure warning against the visual background.

In the event of the captain not being satisfied with the progress of the approach and landing, missed approach action will be necessary. Up to the present time, in current minima, it has been assumed that an overshoot is entirely safe: studies are now in progress to establish whether this assumption is valid, in terms of the A.R.B. safety criteria, and to suggest the form that the missed approach action should take. The main factor to be resolved here

is the performance that must be achieved during the overshoot and this, in turn, will involve reconsideration of the obstacle clearance limits. To achieve the high standard of performance needed, the use of automatic overshoot or an overshoot director is being considered.

7. THE ALL-WEATHER AIRFIELD

I have already emphasised that an all-weather landing system can be thought of as an automatic landing system together with the environment into which it has to work. The techniques for automatic landing are well known and are already beginning to be used in airline service, but there is a great deal of research and development still to be done in connection with the operation of an airfield in blind conditions. I propose, therefore, in this section, to indicate some of the different areas in which work is being done and suggest how the whole operation might be co-ordinated.

7.1. *Facilities for landing ground roll*

To allow safe Category IIIB operation, a landing ground roll system has to be developed. An experimental system has already been investigated at B.L.E.U., using manual steering with I.L.S. localiser as the guidance aid, but the pilot also needs groundspeed and distance-to-go, which will require further development. A possible interim solution, which would be applicable to London Airport, has been suggested using a combination of I.L.S. localiser for steering, a wheel pick-off for speed and, in conjunction with A.S.M.I. (Airfield Surface Movement Indicator) operated by Air Traffic Control, distance-to-go.

7.2. *Airport ground movement control in poor visibility*

With the aircraft brought to rest on the runway, the more general problem of airfield movement in low visibility arises, for all vehicles, including aircraft. There are two basic solutions to the problem of airfield movement in low visibility, the visual and the non-visual. It is important to establish as soon as possible the limitations of a fully-developed visual system, so that the requirement for a non-visual solution can be examined. An initial visual solution which has been suggested for London Airport (Heathrow) involves centre-line lighting and markings for guidance, in conjunction with A.S.M.I. for control purposes. Further development of lighting patterns and a higher intensity taxiway light would be required, but such a system might well be suitable for operation down to Category IIIB visibility conditions. For this interim stage it is assumed that vehicular traffic, which moves only in paved

areas, will also be able to operate using the same technique as the aircraft. For crash vehicles, which must essentially have complete freedom of movement and cannot therefore rely on visual aids, it will probably be necessary to adopt non-visual techniques in rather better visibility conditions.

For operating in conditions where visual clues are either insufficient or totally absent, aircraft can be considered along with those vehicles whose movement is also confined to paved areas. In both cases, the pilot or driver needs steering, speed and position information. In addition, monitoring and control by the Airfield Control staff is necessary. For aircraft and vehicle guidance, B.L.E.U. have recently completed an appraisal of non-visual systems and preliminary field trials are in progress, using a single magnetic leader cable system. Modern airfield surveillance radar can track the smallest vehicle without difficulty on paved areas, and independent monitoring may be obtained from detectors spaced along the runways and taxiways. With the latter type of system, the presence of an aircraft or vehicle in a section of track can be indicated remotely by a lamp on a display board. The combination of these techniques should suffice to avoid collision.

There are still many problems to solve in this area, where a new approach may be necessary. As one example, the aircraft captain is traditionally responsible for avoiding accidents while taxiing, but this might no longer be tenable, under near-blind conditions, if the movement were being directly controlled by the Airfield Control Staff. In this connection careful consideration should be given in future airport design to the elimination of as many vehicles as possible, particularly those involved in refuelling, servicing and preparing the aircraft between flights, by the use of static supply systems.

Fire and Rescue vehicles cannot be confined to taxiways and, in certain circumstances, they may need to go outside the airport boundaries. Inertial systems, using vehicle heading and speed inputs, have been tried successfully as sources of guidance information, but the errors in position accumulate rapidly with time and occasional re-referencing is necessary. In addition, some form of anti-collision warning is essential, and for this purpose the use of F.M. radar and sonar systems is being investigated.

7.3. The collection of data at the airport

For both Category II and III operations, it is necessary to collect data continuously which can be classed under three headings: I.L.S., Meteorology and Operational Recording. For the first two, processed information must be passed to the pilot: the latter is mainly concerned with long term statistical monitoring of the landing system as a whole.

7.3.1. *I.L.S.* Although it is probably unnecessary to inform the pilot of any specific details, he must clearly understand that the I.L.S. has the necessary

integrity and performance to give adequate safety. One of the most difficult problems is to detect interference with the I.L.S. signals, and the Radio Department of the R.A.E. has recently made proposals for monitoring the radio environment. First, it is proposed to make a measurement of radio noise, in the frequency bands of both localiser and glide-path, using an omnidirectional aerial, receiver and a bank of filters in an attempt to isolate and identify different classes of noise. Second, the use of a directional aerial, near the runway threshold, is to be investigated in an attempt to measure the I.L.S. signal being received at the aircraft, by measuring the I.L.S. signal reflected from the aircraft. The majority of types of radio noise can then be detected since interfering signals are likely to be asymmetric with respect to the I.L.S. carrier frequency.

These two proposed monitors, which are to be used in the R. & D. phase, are complementary. By definition, the reflection technique can only function while an aircraft is approaching. The omnidirectional aerial, by contrast, will function all the time and its time-scale is also essentially longer: it will detect changes in the general noise level on a statistical basis. Both have to be interpreted by human agency and a decision made either to lower the category of the airfield until an improvement occurs or even, in a serious case, to divert an approaching aircraft.

In addition to these data requiring human interpretation, it is necessary to safeguard the integrity of the transmitted signal by the use of internal and near field monitors to measure such parameters as the course-line of the localiser and the glide slope, the sensitivity and the modulating tone frequencies. If any of these fall outside prescribed limits, immediate action must be taken to switch over to the second transmitter and so preserve continuity of service.

Finally, it will be necessary to be able to calibrate the I.L.S. at any time. Current techniques require good visibility and there is, therefore, a need to examine new methods which can be used under all weather conditions.

7.3.2. Meteorology. There are four main quantities which need measuring and reporting to the pilot — runway visual range, slant visual range, wind shear and turbulence: in the two former, an element of prediction is desirable. Runway visual range and turbulence are estimated at present, but there is an urgent need to improve techniques for operations in the lower visibilities of Category II and Category III.

Runway Visual Range. In most fog conditions the visibility along the runway is variable and for past operations, which have mainly been in R.V.Rs greater than 600 yd, this has not been critical: the measurement of R.V.R. at a single station by a human observer has been found to be adequate. For safe operation in lower R.V.Rs there is a need to establish that nowhere along the runway has the visual range fallen to an unacceptable level, and this

necessitates measurements being taken at multiple stations. Some form of automatic measurement will be necessary and the use of transmissiometers is being investigated.

Slant Visual Range. There has been a requirement to measure slant visual range and a technique which shows great promise is under development by the R.A.E. It has reached the stage where an operational trial is now taking place at London Airport by the Ministry of Aviation in co-operation with the Meteorological Office and B.E.A.

Wind Shear and Turbulence. Wind shear and turbulence can have a significant effect on instrument approach and landing performance, and although every effort is being made to design the control systems to be more tolerant of these effects, it will be necessary to establish the wind limits for operation. Investigations are now being made at Bedford into the effects of wind shear and turbulence on automatic landing performance. Results show that, at Bedford airfield, which is fairly flat and unobstructed, the value of the mean wind speed, which can easily be measured, is directly related to the r.m.s. value of the turbulence and hence could be used as a criterion to predict automatic landing performance. For sites which are neither flat nor free from obstacles, further investigations will be necessary, making use of full-scale and wind-tunnel experiments, with the object of developing a suitable measuring technique and classifying sites.

7.3.3. Operational recording. The certification of automatic landing systems to lower visibility limits can only be achieved by stages as a result of measuring landing performance under operational conditions. These data, combined with recordings of environmental factors such as the meteorological conditions and the performance of the guidance aids, can also be used to define operational limits for each stage of certification. A proposal has been made for a simple, automatic, all-weather ground system capable of recording landings to be installed at London Airport. This could cover all landings, both manual and automatic and would therefore allow continuous Operational Analysis, or form of Quality Control.

Finally, it is necessary to explain fully the circumstances surrounding any failure to complete a landing. The extent to which this requirement can be satisfied by both ground and airborne recording has yet to be established.

7.4. The processing of the ground-derived data

In so far as an efficient means of communication and control already exists between Air Traffic Control and the captain of the aircraft, it would seem desirable to use this system if possible. However, it is equally most undesirable to increase, by any significant amount, the communication between Air Traffic and the aircraft. Hence, if an additional communication channel is to

be avoided, the data collected must be processed in such a way as to avoid all unnecessary detail. Ideally, the pilot would simply be informed that a full Category II or Category III facility was available.

Currently, data are passed relating to runway heading, wind strength, visibility, etc. and it would appear that little extra would be necessary, apart from some details relevant to low visibility, such as R.V.R., S.V.R., visual sequence or fog structure.

The main addition that is required consists of the means of collecting and interpreting the many items of data that have been listed. This could comprise a small operations room where the state of each facility would be clearly displayed. This information would be combined to give Air Traffic Control the up-to-date status of the airfield facility as a whole.

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