The trends in the fixed wing field can be used as an illustration The main emphasis appears to be on the realisation of true All-Weather flight and here, because of the increased difficulty of the pilot's task in bad weather, the approach seems to be one of increasing automaticity Examples of this are in the development and use of automatic approach and navigation facilities linked with the basic autopilot by means of suitable couplers

Whilst the helicopter system, described here, has been designed to be as simple as possible it is capable of development in the same way as its fixed wing counterpart

However, with development comes increasing complexity, which unfortunately usually brings with it decreasing reliability

Because of the special nature of the helicopter it appears that " black-boxes " will, for some time, be used to provide stability and great reliance will have to be placed on the " black-boxes " in all-weather operation

Here lies the difficulty, more complexity and more reliability are needed together, and this is where engineering development must play its part Until an equipment can be produced that will never break down it might be necessary, in the civil field particularly, to accept some essential duplication with its attendant weight penalty

In conclusion the author wishes to state that any opinions expressed are his own and are not necessarily those of the Ministry of Supply He would also like to express his thanks to his colleagues at R A E for their comments and advice on this paper and for their help in preparing the diagrams and simulator records

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Discussion

The Chairman said that the audience had heard a very interesting exposition of a very difficult subject and the authors were to be congratulated in having taken them through it in a very successful way It had been hoped that Mr B H Arkell, of the Sperry Gyroscope Co , would open the discussion, but he was temporarily indisposed and the Chairman had been asked to read his remarks, which raised the first questions in the discussion

Written contribution received from **Mr B H Arkell** (*Sperry Gyroscope Co*) (*Founder Member*) —

Mr Chairman, Ladies and Gentlemen I would like to begin by congratulating the two lecturers on having produced a paper of considerable interest to us all here tonight This subject has not been discussed in such great detail here before and I think that what we have heard tonight will give us considerable food for thought The development of this equipment is certainly a pioneering effort as far as this country is concerned and as such it is worthy of considerable merit

It is now generally conceded that, since helicopters are normally only neutrally stable, some form of artificial stabilisation is a desirable feature to introduce positive stability and so reduce pilot fatigue But I would like to utter one word of warning which is addressed more particularly to the helicopter designers I think it would be most undesirable if the introduction of automatic stabilisation had the effect of encouraging designers to place too much reliance on achieving stability by this means alone when some stability was attainable by aerodynamic means The best possible aerodynamic stability should still be a primary requirement Quite apart from the fact that the helicopter may at some time or another have to be flown without the aid of the automatic pilot, a very practical reason for making inherent stability a primary requirement is that the less work the " little black boxes " are called upon to perform, the lower will be their cost

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There are one or two other points I would like to make I have not yet had an opportunity of flying a machine with this equipment fitted, but I hope that may be remedied in the not too distant future However, I remember, back in 1944, being present when the first-ever automatic pilot installation was made in a Sikorsky R 4 helicopter at Floyd Bennett Field The installation proved to be reasonably effective in the cruising flight condition but when applied in hovering flight, the helicopter had a tendency to " creep around " although its attitude remained, to all intents and purposes, straight and level

At that time, the tendency was put down to the fact that the gyro references were related to fuselage attitude and the " creep " was due to the slight discrepancy between the fuselage attitude and that of the rotor tip-path plane From this, a long controversy developed as to whether the fuselage attitude was adequate as a reference or whether the designer of an automatic pilot for helicopters would need to use " rotor plane sensing " with all its attendant slip ring difficulties I understand that current thought in the U S A appears to conclude that rotor plane sensing is unnecessary but I would like to ask the two speakers tonight whether they have reached any conclusion on this question and whether the equipment described tonight would be subject to the tendency to " creep " in hovering flight if not controlled by ground datum plan-position signals

As far as I am aware there is no system in existence at the present time which provides ground reference plan-position signals of sufficient accuracy to be suitable for monitoring the " automatic hover " mode of operation Yet there is a definite requirement for an automatic hovering facility Indeed, if equipment providing such a facility were readily available, it would greatly increase the demand for helicopters

I would conclude by saying that I am particularly impressed by the possibility mentioned in the lecture, of arranging for suitable couplers to be introduced into the system to provide automatic navigation and approach facilities This seems to be a most promising line of development as far as city centre operations are concerned, and I would like to ask how long it may be before such a facility will be fully developed

Mr Curties said that with regard to the rotor plane attitude, stabilisation could be achieved without a knowledge of the rotor plane, as was apparent from the theory which had been put before the audience Clearly, to hover relative to a point on the ground—or to define one's position relative to the ground rather than air—one would need to know something about the lift vector and the movement of the surrounding air or have some suitable ground reference He thought that one would not choose the rotor plane method because of the attendant difficulties and limited usefulness

Mr Collomosse said with reference to " automatic hovering ' since a helicopter flew at low altitudes it was constantly subject to disturbances from the surrounding air Whilst a " stabiliser " system of the type described in the paper would correct changes in attitude, such a system would be largely ineffective in correcting linear displacements of the aircraft and a drift would result In order to hover automatically over a point on the ground, therefore, it was necessary to have signals available proportional to these linear displacements

Even with plan-position signals available there would still be a tendency to creep in gusty conditions due to servo and aerodynamic lags A recent article in the " Aeroplane " (12th Oct , 1956) entitled " Photo-electric Hovering " described an American system in which a beam of light was projected vertically from the point on the ground over which it was desired to hover, and photo-electric cells installed in the aircraft were used as error detecting elements According to the figures quoted in the article, the aircraft hovered at 1,000 ft for about 20 minutes within a 20 ft circle above the preselected ground point in winds of 20—30 m p h

Mr Curties then added that he had missed one point in his original answer A tendency to creep in hovering flight could also be due to changes in ground conditions The wind was rarely constant on the ground, and since a system without ground reference was essentially trying to define the attitude of the aircraft it was clear that if the wind was variable the helicopter would creep around

Mr W H Sear (*Chief Test Pilot, Westland Aircraft Ltd*) (*Member*) asked Mr Curties whether, before black boxes had first been put into the S 55, any consideration

had been given to increasing the basic stability of the aircraft In America many ways had been found of increasing the stability of a single-rotor helicopter before auto pilots had been installed

Mr Curties said that he was familiar with the Bell system, and with the somewhat similar Hiller system It was known that something could be done with tail planes in regard to the pitch axis in forward flight but that did not do any good in roll The R A E had taken the view that the black boxes provided the most powerful method, and they had gone for them

Mr Sear then asked about the presentation of auto pilots There had been an infiltration of American auto pilots into British helicopters, and our pilots now had two entirely different presentations to cope with—because in the British type the trimming devices consisted of a separate control box whereas in the American types it was put on to the cyclic stick MR SEAR hoped that consideration would be given to the desirability of introducing some standardisation between the two He wondered whether Mr Curties could say whether it would be possible to get the two types closer to each other

Mr Curties said that one of the snags was that the two systems were of diametrically opposite design There were different ways of tackling the problem, and he believed that our way was the best He could possibly go some of the way to help Mr Sear by making the switch units look alike For example, we used a rotary selector switch for switching on and the Americans used press buttons Some standardisation could possibly be achieved there

The trimming question was more difficult, because the trimmers were performing different functions in the two systems There was really no reason why the trimmers should not be built on to the cyclic stick, as a projection on the hand grip but with the British system complexity would be added to if a press button type of trimmer were required instead of a wheel

Mr Sear then asked about future development, in connection with the use of auto pilots doing G C A If some form of approach mode could be fed back from the rate-of-descent indicator so that the rate of descent could be pre-determined and put on the rate-of-descent selection, controlled by the auto pilot to maintain a fixed rate of descent, it would make the pilot's task vastly easier, because it was the rate of descent that was the whole problem

Mr Curties said that the R A E appreciated such considerations, but he could not describe future developments in any detail

Mr Sear asked if there were something coming along

Mr Curties said that Mr Sear was putting him in a difficult position, and all he could say was that they were studying that sort of problem

Mr P A Hearne (*Helicopter Project Engineer, B E A*) said that he would like to give a brief account of the very strong civil interest which existed in the type of equipment which had been described All-weather operations were of course an absolute necessity for helicopter airline operation, and for some time B E A had been carrying out experimental flying towards this end They started by carrying out a good deal of instrument flying in actual and simulated conditions, from which it became apparent that unless future helicopters had greatly improved flying characteristics it would be impossible to schedule operations involving instrument flying

The reasons were, first, the great amount of mental effort and concentration required from the pilot in controlling an unstable aircraft, which induced very severe pilot fatigue in flight periods of 1¾-2 hours and, secondly, the impossibility of exercising complete control of the helicopter in moderate or severe turbulence This was a very serious consideration, because, as one pilot had expressed it, in these conditions the indications of the instruments demanded so many simultaneous corrective control actions that the pilot's co-ordination between his mental interpretation of the instruments and his muscular movements of the controls tended to disappear completely, and he could no longer maintain complete control of the aircraft

A third reason was the great difficulty of instrument flying at below speeds of 35-40 knots In the case of the Bristol 171 this limitation arose particularly because of the deterioration of directional stability, which prevented the pilot from maintaining a desired heading, but all helicopters had this low speed limitation for one reason or another

In scheduled operations flights had to be made in all weather conditions, severe turbulence or not Likewise, if steep instrument approaches were to be made into sites in built-up areas forward speed had to be reduced to about 20 knots in order to avoid an excessively high rate of descent All this had to be done without making excessive demands upon the pilot's mental efforts—and no offence was intended by that remark ! The low speed limitation had been exemplified that afternoon, when doing some tests on an approach aid which was being developed with a view to coupling to the auto-pilot equipment under discussion Doing fairly steep approaches through low cloud it had not been possible to maintain a 17 degrees glide path and the angle had had to be reduced to 9 degrees

It was hoped to achieve scheduled airline operation by fitting an automatic stabiliser or automatic pilot , in fact, the Newmark equipment would be fitted to one of their helicopters for experimental and development flying towards this end during the next few weeks

In a developed equipment B E A would like to see among other features a completely fail safe system, so that the auto pilot would never put the helicopter in a dangerous attitude, couplers for navigation and particularly approach aids, and probably some form of constant ground speed and rate of descent—in other words, automatic throttle-control The latter two requirements arose from the difficulties, in flying on the approach, in the very unstable part of the power/speed curve well below the minimum power speed

In passing, MR HEARNE wanted to know the reason why the Americans seemed to favour the differential type of auto pilot, as opposed to ours

MR HEARNE then turned to the failure case and ways of insuring against it It was obvious that if we were going to schedule instrument flying operations we must guard against the possibility of the auto stabiliser failing in the middle of a turbulent cumulo-nimbus cloud a long way from home or on the approach into South Bank, with St Paul's Cathedral and other high buildings nearby While working in America this summer he had been impressed at the amount of work which they were doing on flight director systems In fact, the Sperry Company in America had an instrument which had gone through most of its development stages prior to production A crude analogy of a flight director system was that it presented to the pilot visually the information which the auto pilot presented to the servo control in the form of an electric current The instrument indicated the amount and direction in which the pilot had to move the controls Both the Sperry and the N A C A experiments had shown that by suitably frigging the terms—the rate of pitch, rate of roll or rate of yaw—fed into the instrument the pilot could maintain instrument flights in an unstable machine much more easily than before

Fitment of an instrument of this type would probably enable the pilot of a helicopter which had lost its stabilisation system to maintain control for the rest of its flight, though possibly over a limited speed range

The other most powerful method, which should be pursued, was to improve the flying qualities of the helicopter itself MR HEARNE said that he had been sufficiently encouraged by Mr Collomosse s simulator responses to bring along some of his own, which he had obtained while working at M I T Briefly, they showed that by fitting a tail plane of only about 2 per cent of the rotor area there was a very marked improvement in the helicopter α response By altering the m_μ derivative, which was partly controlled by the fuselage drag, to half its value, i e by reducing fuselage drag, it was possible to obtain a smaller improvement, as it was by altering the $\frac{m_\alpha}{\Omega}$ value to twice its value, by increasing blade weight or altering other rotor characteristics, when an improvement in response was obtained which was not too far away from the type obtained with an auto stabiliser

MR HEARNE'S last point concerned ratios He said that the ratios of the position/rate signal feed backs used in our system seemed to be rather different from those used in some American equipment He wondered whether Mr Collomosse could state what were the ratios in the existing equipment, and whether the response from the actual aircraft was similar to that shown on the computor Also what type of

response curve was favoured by pilots? If, following a disturbance, the attitude of the aircraft continued to increase before the stabiliser corrected it the pilot might be rather worried since he would be uncertain as to what attitude the aircraft would reach before corrective control was applied

He would also like to know whether pilots preferred a controller which imposed a signal proportional to the applied force by the pilot, or to the amount of movement of the pilot's control

Mr Curties said that he would first like to answer the point about the parallel or differential arrangement He thought he had explained in his lecture why the R A E preferred the parallel, but he may not have explained it adequately He believed that the series arrangement was used mainly to satisfy certain safety requirements but these safety requirements could be satisfied with a parallel arrangement One could, for example, provide safeguards in the parallel arrangement by putting in limit switches which were operative in the cruise mode only, since in the stabiliser mode the pilot was holding the stick and could cope instantly with any trouble that arose He thought that the series arrangment prejudiced the design of the system and often introduced additional complexity The parallel one was the most flexible, and it would certainly be better, in the case of a full auto-pilot, than a series arrangement

With regard to auto pilot parameter values, the optimum ones for our test aircraft were obtained in flight He thought that these were similar to some being used in America The simulator responses were typical rather than actual

The last point raised concerned the respective merits of force and movement control He had had no experience of a true force control, in which the stick was not moved The control with which he was dealing, although containing a sensing element which was a force element, moved the stick the moment force was applied, thereby giving the pilot the effect of a movement control He had not tried a system in which the stick did not move, and the pilot merely applied a force

Mr Collomosse said that roughly speaking the choice of K_θ determined the frequency of response of the controlled aircraft and the K_q the damping Whilst the actual values of these parameters would depend on the aerodynamic properties of a particular aircraft, generally speaking a ratio of $\frac{K_q}{K_\theta}$ of about 1 would give a satisfactory response and adequate damping

Lt -Cdr G N C Fuller (*D A W, Admiralty*) said that although he had two questions to ask he had been steered off by Mr Curties as being outside the scope of his lecture He would like to make one observation, on the same grounds as that of Mr Hearne, who spoke about the Sperry Flight Director system He said that Mr Hearne had said that they were going into production with that system, and he would not dispute that fact, but he would like to observe that the American Services had said that they were not accepting the system at present because it gave so much information on one instrument that, with the very limited ability of pilots (referred to by Mr Hearne) they had been unable to accept it Although Sperry's might be pressing on with this system for civilian use the Services would not use their present idea of a flight director

Mr C N Jaques (*Head of Instrument Department, R A E, Farnborough*) said that the Chairman's invitation to him to take part in the discussion had placed him in an invidious position, in that Mr Curties was a member of his Department

He wanted, however, to make two points First, tonight the audience had heard a paper presented jointly by a member of an equipment firm and a member of a Government Department, who had been co-operating together in the development of this equipment He thought that that was an extremely good thing, and he would like to see more such papers in the aeronautical field

Secondly, the purpose of giving the lecture on the development of this equipment, which had been evolved solely for military and naval purposes, was to discover the extent of the interest of civil users of helicopters in the work which had been done The extent of that interest had already been demonstrated by the remarks of earlier speakers, so much so, perhaps, that Mr Curties had been embarrassed and unable to give a real answer to the question, " Well, what else is coming along? "

As an alternative to that question he put forward the suggestion that he, personally, would welcome hearing from those interested in the civil use of helicopters, either that

night or later, the definite requirements for this kind of equipment in the civil field If the people at Farnborough had in front of them the requirements of the civil side they could see how those requirements fitted in with what they might already be doing for military purposes

The Chairman said that Mr Jaques might have said that he had been put in an invidious position, but at any rate he had given the audience a wonderful opportunity It was up to the civil operators to set down their requirements in full and post them off to the R A E —with a copy to the Ministry ! We would then expect to see development proceeding apace

The Chairman said he would now throw the meeting open for discussion

Mr J S Shapiro (*Consulting Engineer*) (*Founder Member*) said that he wanted to make two points before asking one or two questions He thought that a slight confusion was apparent in relation to the stability of the helicopter as such, and the use of the black boxes First, much had been done to improve the stability of helicopters, but even if a helicopter were stabilised aerodynamically in relation to the air, the air itself was not stable The point was that when a helicopter had to be used in bad conditions the air was not stable, so what was the use of making the helicopter aerodynamically stable ? He did not say that it was completely useless, but the law of diminishing returns came into force—indeed, there was no return at all in a certain very important range of missions

He could best illustrate his other point by referring to an instance from an industrial job with which he was concerned It was the case of a pumping station, where there was one pump and a water-tower, to hold water as a reserve in case the pump failed Someone had worked out that the cost of the tower would cover the installation of twelve pumps working in parallel That was the situation that we were faced with in helicopter design If the stabilisation plus cruising control of a large helicopter cost about 200 lbs in weight, we could have three stabilisers for the weight it would cost in blade weight or other features to make the helicopter more stable aerodynamically A stable helicopter was a very good thing when the air was stable, but it was not so good if the air was not stable

He thought, therefore, that the development of black boxes was not a counsel of despair but a very sensible form of integration of the total effort of which aerodynamic thought and engineering design were capable In that sense the development which had been discussed deserved great credit and would make all those interested and concerned with helicopters feel much happier The helicopter was becoming a completely different vehicle, and should be looked at in a completely different light

He would like to know whether the force sensitive pick-off was in fact a force sensitive one, or was it simply a case of moving the little control a fraction to obtain the necessary result ? Was it, in fact, a question of displacement ?

Mr Curties said that it was really a displacement system It produced proportional control, the signal depending upon the small movement

Mr Shapiro asked whether the question of a mechanical datum had been considered In a sense, one would say that the development about which the audience had been told was an alternative to a mechanical datum Had the latter been considered and rejected, or was it just one of the alternatives which had not been taken into account ?

He had understood Mr Collomosse either to say or to imply that the arrangement whereby the rate gyro did all the stabilisation except under cruising conditions was better than that whereby horizon and rate signals were put in separately under stable conditions Was he correct in so understanding ?

Mr Collomosse said that the difficulties arose in manoeuvre cases If one wished to design a " stabiliser " system for straight line flight only, then a θ signal from a rate gyro and a θ signal from a horizon gyro could be used to provide a satisfactory system , in this flight condition the long term datum implied by this type of θ signal would not prove to be an embarrassment However, such a " stabiliser " system would only have a very limited application since the pilot would have to switch it out before carrying out a manoeuvre Further, stabilisation of the aircraft would be

lost during a manoeuvre when perhaps it was needed most The technique described in the paper of deriving a " short memory " θ signal from the rate gyro θ signal by means of a leaky-integrator network was one method of overcoming this difficulty, and enabled the " stabiliser " system to be used under all conditions of flight

Dr K H Doetsch (*R A E, Farnborough*) said that he wanted to make two points First, he thought that with regard to deflection *versus* pure force control the answer would be similar to what it was in the case of fixed wing aircraft In laboratory tests one usually found that the pure force sensitive system was the best for control In the air, however, with all the jerks and accelerations to which the hand was subject additional control was needed of the involuntary input of force upon the stick, otherwise unwanted signals would be fed into the system A limited amount of stick motion would provide just this means to separate the unwanted from the desired input

His other point referred to the question of tip path plane *versus* fuselage datum control He had discussed the matter with several people in the United States, who had gone to great lengths to measure the tip path But, as Professor Miller had said, what did the tip path plane mean? The lift vector was what really mattered, and this was—particularly in accelerated flight—not necessarily vertical to the tip path because the blades bent The case had therefore not yet been made out whether tip path provided really a better signal than that given by fuselage attitude

Mr Curties had made a valid point here We were really concerned, in automatic control—and particularly in hovering—with the position of the fuselage (or C G) relative to the ground If information fed from, or referring to, the ground was properly combined with fuselage references so as to retain a stable system everything required had been done

The Chairman said that he had one comment to make about the tip path plane and its possible use as a reference datum for instrument flight He wanted to quote from the Proceedings of the American Helicopter Society's 12th Annual Forum this year The author of a paper entitled " Helicopter Instrument Flight Operations " said " No improvement in instrument flight capability is afforded by the rotor attitude indicator as compared with the gyro horizon indicator using fuselage attitude as a reference " As the Americans were using fuselage attitude as a reference it would appear that they had abandoned the tip path plane conception

Flt Lt J L Price (*A & A E E*) (*Associate Member*), asked if any of the aerodynamicists present could inform him whether the fuselage attitude of an aircraft, which had not off set flapping hinges, would be sufficient, when compared with the Westland type of helicopter used in the test which had off set hinges and in which the fuselage more nearly followed the tip path plane

Mr P Brotherhood (*R A E, Bedford*) said that Farnborough had thought of trying to develop a tip path plane indicator, but he was inclined to agree with Mr Curties that fuselage attitude and the rate of change attitude were sufficient to stabilise the helicopter It was very difficult to get the angle of the tip path plane with respect to the horizon Slip rings, and so forth, were needed and it did not seem to be worth it at the moment

The Chairman said that one got the impression that the tip path plane as a datum was thought of as a good idea some years back, but that it had not seemed to work out in practice, and people had gone away from it

Capt J A Cameron (*British European Airways Corp*) (*Member*) said he would like to congratulate both speakers on two most interesting papers We have with us tonight representatives of the Air Registration Board and the Ministry of Transport and Civil Aviation He would like to have their views on the subject of " black boxes " from an airworthiness point of view

Mr H C Black (*Air Registration Board*) said that for those in the A R B, the problem posed by black boxes was always a difficult one and that in the past their outlook had been that either the black box should not be allowed to go wrong or, if it did, it should be shown that no harm would result The problem became more acute if a black box was used to enable an aircraft to fly in conditions where total reliance was

placed on the black box continuing to do its job and it appeared that this applied to the one described In this case not only should the black box be designed so as not to cause a hazard if it went wrong but also it should be capable of continuing to fly the helicopter even if a fault occurred

MR BLACK had been impressed by Mr Shapiro's illustration of the pumping station and the water tower and thought that something like this was occurring in aircraft at the present day In a number of present day devices, for example the fixed wing auto-pilot and the powered control, duplication was employed to a certain degree and a number of complicated safety devices were designed in addition , and even then a fault analysis sometimes showed that failures could occur and the aeroplane had to be able to withstand a fault condition anyway

A recent development was the introduction of " comparator " circuits which were supposed to throw out a spurious signal and perhaps this provided a solution

If one had to have black boxes which never went wrong a possible way of achieving it would be to have three comparatively simple boxes and to employ comparator circuits to throw out any signal from one box which did not agree with the other two This might be considered as a possible different line of approach to mere duplication

In relation to blind flying of helicopters, MR BLACK agreed that the prospects of being able to fly blind in extreme turbulence relying solely on aerodynamic control did not at the moment seem to be good and, in the absence of some big improvement, the use of the black box either as an auto-pilot or as a stabilising device might well be more promising

Mr G G Roberts (*Research Director of Smiths Aircraft Instruments*) said that as a designer of black boxes he had to put in a word in their defence Firstly, we had heard of the reasons for duplication of the various black boxes, but safety could depend upon one thing, namely, the engine that drove the fan round, in the case of a single-engined machine There was no suggestion of that being duplicated or triplicated necessarily

The Chairman said that there was !

Mr Roberts said that he deprecated the fact that aircraft designers always regarded the black box as being suspect In the instrument and electronics industry great steps were being taken to make these boxes reliable It was a challenge to the industry to make them as reliable as an aircraft's undercarriage or engine, or any part of the rest of the aircraft, and he honestly believed that the industry would succeed in that endeavour The aim should be for an overall integrated system where the role of electronics and instruments were envisaged from the start of an aircraft design

The Chairman said that he only wanted to say that if the A R B insisted on triplication, the " 65 lb weight installed " would look a bit sick by the time they had finished !

Mr Black said that some years ago it had been suggested that if a particular piece of essential apparatus, designed with a very large number of safety circuits, had been started from the beginning as a design of three very simple circuits, without any safety device but with comparators, it could have been made lighter than it eventually turned out to be in the long run

Mr P F Cook (*Air Registration Board*) said that it was possible to make black boxes having far greater reliability than had been realised hitherto This was because at present, performance criteria and lightness were always given priority by aircraft designers If the designers of flying machines would co-operate much more with the designers of black boxes in the initial development stages so that the two were working together and their philosophy unified, a vastly greater degree of reliability could be provided than was now achieved

To pursue reliability one had to be ruthless For example, one of the most unreliable items in black boxes were the connecting systems—the plugs and sockets Attractive as these were to those maintaining the aircraft, they reduced reliability , therefore they should not be used There were other items—considered by many essential—which should be treated similarly but on which the electronics designer was at present overruled Mr Cook appealed very much for co-operation at the initial design conception between those responsible for the black boxes and those for the overall design of the machine

Mr J G M Pardoe (*Air Registration Board*) thought that they might get some pilots on their feet There were two ways of achieving safety control One was by means of duplicating and triplicating the black boxes and relying upon them absolutely and the other was some such means as the flight director system, so that if the black box went wrong the pilot could say " goodbye " to it and cope with the flight director

He had only a very limited experience of the behaviour of pilots It seemed to him that if pilots were given a black box and a standby, separate system, they regarded the black box with the utmost suspicion to start with, and monitored it most carefully, so that on the first hundred or even thousand flights it would not matter if the black box were not there But as they got familiar with it one might find that after 10,000 flights the pilots would metaphorically, if not actually, have their feet up and hands off and not be looking at what was going on

He would like to know the pilots' reaction and have an expression of opinion from them whether they thought that once these black boxes were put in, the pilots would come to rely upon them come what may, or whether they would continue to rely upon themselves and monitor the automatic control

Mr Curties said that there was a philosophy which held that one should not make a device too automatic Very often 90 per cent of the result could be achieved with 60 per cent of the equipment, but in order to get the other 10 per cent one had to go to an awful lot of trouble By not making these devices too automatic one left the pilot something to do, and in that way he was more likely to have his mind upon things and would not end up by sitting in his helicopter with his feet up, smoking a cigar

Lt -Cdr Fuller said that he had one thing to say upon the subject of pilots viewing these black boxes with the greatest of suspicion It had nothing to do with flying but it was an illustration of the pilot's feelings In the Mess they used to play a game which consisted of one person balancing a glass of beer on his forehead, sitting down and eventually lying flat on the floor and then getting up again trying not to spill any of the beer One could encourage many people to try this as long as they could look at the glass of beer, but when they were asked to do it with their eyes shut, the deterrent of the possible spilling of the beer down the neck was enough to put nearly everybody off The same thing applied in blind flying, except the pilot was always apt to think that there was a very grave chance of his not being alive to sample the cold beer

Mr C J Carter (*Ministry of Supply Headquarters*) wanted to say a few words upon the subject of black boxes, and since he enjoyed or suffered the rather ponderous title of Director of Air Navigation and Reconnaissance Research and Development, and his task was to see that enough black boxes were produced, the audience would not expect him to decry them He thought that R A E would agree that they did not impose them on the industry for their own sake , their only intention was to supply enough to meet the need

Everyone knew that they were not perfectly reliable, but they were definitely with us, both for fixed-wing and rotating-wing aircraft, and they *had* to be made reliable The point he wanted to make was that to overstress their unreliability, thereby creating a psychological anti-black box attitude, was to do a disservice to the industry

Mr D W Griffiths (*Airwork Ltd*) (*Companion Member*) said that auto pilots as such were right outside his ken, but his whole life had been tied up with black boxes and he agreed with Mr Cook and Mr Pardoe on the subject of their unreliability, particularly where plug and socket connections were concerned In the last month, on three airlines, there had been cases where aircraft had been held up purely by faulty plug and socket connections A tremendous advance would be made either when a black box was introduced with permanent plugs and sockets, or when they could be dispensed with, although he thought that if they were dispensed with the maintenance costs at first would be terrific

He said that Mr Collomosse had mentioned a radar beacon in connection with helicopter control correction, and he would like to know whether any project of that sort was under development

Mr Collomosse said that he had already referred to an article in the " Aeroplane " which described how a beam of light had been used for this purpose in the United States He said he was not allowed to comment on current developments

Mr Norman Hill (*Vice-President*) said that he always tried to put himself in the position of a potential operator and would therefore ask the price which had to be paid

Firstly, what was the weight penalty , secondly, what was the space penalty, and thirdly, what was the device likely to cost the operator ?

It had never before been his good fortune to hear two speakers who were so well integrated in their thinking and their work

Mr Curties said that this simple experimental system had a dry weight of about 65 lbs , but he thought that the auto pilot people always cheated a little bit They gave the weight of the black boxes and glossed over the fact that to put them into the aircraft one needed cable harness and brackets The 65 lbs for this simple system therefore might become about 100 lbs when the device had been installed If an " all-singing, all-talking, all-dancing " version was required the weight would rise Space did not appear to be a problem With regard to size anyone familiar with electronic equipment would know that a 100 lbs of black boxes would be of similar size whether it was for an auto pilot or for a television set There always seemed to be plenty of space in a helicopter for such a device He did not think that he was qualified to speak about price Perhaps one of the representatives of the manufacturers would say more about that

Flt -Lt Price said that he would like to know if it was possible to get an aircraft into service appreciably quicker by using black boxes than by modifications to the outside of the aircraft to increase its aerodynamic stability In his opinion, if a black box would enable the job to be done tomorrow, then it would be preferable to continue with the black boxes rather than with an aerodynamic development which would work in two years time He asked the lecturers' estimate of the worth of black boxes as against aerodynamic development in this connection

Mr Curties said that he was a believer in the black boxes However one did not merely take a black box off the shelf and put it into any helicopter , it had to be tailored to suit Black boxes were with us now, and the aerodynamic devices which we had seemed to be inferior at the moment

Mr Collomosse said that " stabilisation of a helicopter " implied two things *viz* ,

(i) transforming the unstable motion into a stable one ,
(ii) making the frequency and damping of this stable motion satisfactory to the pilot ,

and he did not know of any aerodynamic developments which claimed to be able to achieve this in all axes under all conditions of flight Until both these requirements were met he considered that there would always be a case for using black boxes to do the job

In this respect it was interesting to examine the experience gained from fixed wing aircraft Generally speaking whilst (i) was satisfied it was often found necessary to improve the stability of the aircraft by the use of an autostabiliser, i e use black boxes to meet requirement (ii)

Major D D Evans (*Louis Newmark Ltd*) felt there was a certain tendency amongst the Airframe and Helicopter manufacturers at this stage, of assessing black boxes in the order of weight, size and reliability He thought that the position had now been reached when black boxes had to be considered as necessary ingredients and as such, used by the Design Staffs Matters of weight and size had, therefore, to be conceded in the first instance, until reliability had been achieved

Equally, the instrument side of Industry had to face this reliability problem and make it their first objective One of the hold-ups in this country was our insistence on type-approved components, the majority of which were obsolescent or obsolete If a little more money and effort could be devoted to the basic design of components, it would materially help to bring us into line with foreign competition

He was sure that the black box technique, available over here, was as good as anywhere, and given the basic raw materials and components, the black boxes would be equally as reliable as those available in other countries, besides which, they would be as reliable as other vital parts of the aircraft, notably the engines

Mr R A Palmer (*Chief Pilot, Smiths Aircraft Instruments*) said that he would like to respond to Mr Pardoe's point about black boxes In common with a number of other people he had been at the mercy of something worse than black boxes He referred to experimental black boxes ! He had learned some years ago that the air of suspicion which surrounds a black box in the pilot's mind was often dispelled by experience, because it was through experience that he learned whether or not the contents of the box had been correctly conceived and designed If the device had been correctly built and its conception was good the pilot's faith in it built up very rapidly

He shared Mr Black's faith in duplication (and even triplication, if the weight could be laid down), plus comparator networks and safety interlocks on all these systems

The Chairman said that it had been a most enjoyable evening of discussion following two excellent papers He would not attempt a summing-up, but the impression he would take away was that the possibilities of making helicopters satisfactory over a very wide speed range by making use of electronic devices, auto pilots and the like, were much better and clearer, and were viewed with a little less suspicion than they had been a few years ago, when the idea began to form

What was most necessary was reliability in the details It was the unreliability of details which could " kill " aeroplanes Little things counted a great deal A fuel gauge might not work, or the gyro horizon might not work, just before take-off, and the resultant delays and effort to rectify made the operators suspicious of all such components Manufacturers had to concentrate their efforts more than hitherto on the details—such as connectors, and the like

The other point, which was a most attractive feature of the evening and which had been mentioned by Mr Jaques, was the close co-operation between a Ministry of Supply Establishment and a private firm, taking the shape of a joint lecture This was illustrative of the good which could be achieved if a job were tackled wholeheartedly as a joint effort They had been most grateful to have heard details of this work given tonight

On behalf of the Association the Chairman thanked the two speakers and those who had taken part in the ensuing discussion for a most enjoyable evening

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