DISCUSSION

The **Chairman** said that Mr DE GUILLENCHMIDT need have had no qualms about his English, for his lecture had been very well understood There were many points arising from it on which members would be extremely interested to have answers

It would be fitting, he suggested, for a pilot to open the discussion and to give his reactions towards the simulators which they had heard described

Mr Ken Reed (*Member—Saunders-Roe Ltd*), said he felt sure that the fixed wing simulator as discussed by Mr NORMAN HILL was in a different category and he did not wish to make any comments The helicopter, however, was rather a different proposition

His own impression was that in the paper four assumptions appear to have been made, first, that the problem of helicopter training had begun to appear in full quite recently, second, that the helicopter was difficult to fly, third, that in a prototype there were advantages in handling characteristics being presented to a pilot through a simulator, and fourth, the question of relative costs

He was not certain what the problem of training was, because from the information that was generally obtainable—in Britain, at any rate—it appeared that there were ample pilots for the aircraft that were available for them to fly He deplored the numbers and types that were available to fly He thought that there were sufficient pilots trained to cope with the present and immediate future demand for helicopter flying

Speaking of training establishments, he said that some people had, for want of a better word, 'fiddled' a course through the various Service channels One Volunteer Reserve gentleman had undergone a helicopter course, although it was reasonable to assume that he would not be flying helicopters, particularly in the V R If there was a training requirement he wondered why there was no obvious specification for a training aircraft

Following on from these points, he thought that the reasons which had been given for the simulator were substantiating the reason why simulator development should be proceeded with He did not agree that the helicopter was difficult to fly It was no more difficult than any other machine It was a question of being shown how to do it and of practice, coupled with adaptability

Experience had shown that the pilot of a fixed wing machine took in the order of three to five hours 'dual' prior to carrying out his first solo flight in a helicopter, these figures depended entirely on the individual's past experience on fixed wing aircraft It must be borne in mind that both Service and civilian pilots have been trained on an operational aircraft and not, until very recently, some on a trainer

He did not think anybody could suggest that the length of time was excessive and he did not see that a simulator could possibly reduce it He knew of two *ab initio* pilots who had required between eight and twelve hours, this being comparable to the requirements on fixed wing aircraft, and he did not think that a simulator could improve upon this, it certainly in the light of experience could not make them more efficient at this stage

Turning to the question of prototypes, he said he was given to understand that helicopter theory from the designer's point of view, was still nowhere near the stage of that for a comparable fixed wing aircraft He would very much like to see fed into the simulator the reactions of an aircraft at altitude, particularly with zero air speed, he wondered how this formula could be incorporated

Could a simulator give to a test pilot, for instance, some indication of what he expects to have in control movements, control forces, breakout forces and such like If a designer knew what an aircraft would do, there was no point in putting it all through a simulator if it was known that safety was ensured

Furthermore, if some peculiarity necessitated a simulator, the designers would put all their design features into it, but if they were wrong, the pilot would form impressions which were completely incorrect This would be far more dangerous than letting the pilot have the prototype without that knowledge, but with the knowledge he had gained from discussions with technicians

He recalled the international agreement on licensing and the minimum number of hours on solo and dual flying before a licence could be obtained No matter how

many hours were carried out on a simulator or in what he called ' synthetic training,' this would not affect the issue , a pilot had to fly an aeroplane to get his licence Consequently, at this stage he could see no unfavourable balance of cost against the small helicopter trainer The cost of the simulator was over and above that of the helicopter anyway, and so it was an added capital expenditure of relatively low efficiency value

Nevertheless, in spite of all he had said, he felt that a simulator had its advantages when considering large operational helicopters which automatically required crew training as a team, also operation and practice with navigational aids and instrument flying , but this was a direction which necessitated a bigger type of machine

Dealing with the elementary side of flying, he said that men who had responded magnificently in a link trainer had sometimes been in trouble when put in an aircraft, while others had sweated in the link trainer knowing full well that the handling of an actual aeroplane would be different Although he would like to know the author's reaction on this aspect, he could not see that a simulator or synthetic trainer had any advantages over a small aircraft unless, perhaps, from a purely psychological point of view

The **Chairman** said that they were indebted to Mr REED for his frank statements The question of whether there was any need to go to great length to train new pilots was a very interesting one

In view of the probability that before many years had elapsed the Navy would be using helicopters on a very big scale, he invited Lt -Commander FRADD to comment on this aspect

Lieut Commander P H Fradd, R N (*Naval A/W Division, Admiralty*), said that his own field was a narrow one and he hesitated to challenge anyone with commercial knowledge In view of the expansion of training for the twin rotor helicopter, the Navy, which was always extremely interested in economics, combined with efficiency, hoped that it saw a means of both in the use of the simulator

The Navy as yet had no simulator of any sort for conventional aircraft, but one was on order Unfortunately it had the disadvantage, through the fault of the Navy and of no one else, of being ordered late, and consequently it would not achieve as great a saving as if it had arrived with the first of the aircraft

If the helicopter field developed fast enough and the Naval Staff finally decided that a helicopter simulator was required, he hoped that it would arrive in good time

He had been to Paris as recently as the past week and had seen the French simulator, which simulated only hovering While this was of considerable value, it was not sufficient, and what was needed was a fuller simulation of a helicopter

He sympathised in some respects with the views of the previous speaker, whose school of thought was equally applicable to the conventional trainer Some people considered that only air experience was of use He was himself old enough to sympathise with that school of thought, but he was sufficiently open-minded to believe that possibly he was wrong There was some hope, he thought, that simulation would reduce costs

The Navy was very conscious of the question of cost, and with a smaller air fleet it could not afford to use more aircraft than were needed He would like some method, both with the conventional aircraft and with the helicopter, of cutting the initial costs, and if it was possible to get a simulator which would give a fuller simulation of helicopter flight, the Navy would be extremely interested

The **Chairman** said that there seemed to be a tacit acceptance of the value to a large operator, Service or civil, of the Redifon type of simulator, which trained people in procedures That was to say, it got people, in effect, hand and foot reaction perfect to deal with all normal flight procedures and with emergencies, but it did not attempt to train them *ab initio*

The question on which there was obviously more scope for controversy was whether a simulator could effectively train people *ab initio* and, even more so, whether it could satisfactorily reproduce the expected flying qualities of a prototype aircraft before it had flown This was an important point, and it would be interesting if Mr DE GUILLENCHMIDT could indicate the consensus of opinion of pilots who had

had the opportunity of " flying " the simulator when it was set up to reproduce a particular helicopter, and of comparing it with the flying qualities of the aircraft itself

He invited comments on the prospects of reproducing on a simulator the expected handling qualities of a completely new aircraft, and he wondered whether Mr ZBROZEK would like to say something of control and stability problems involved

Mr J K Zbrozek (*R A E, Farnborough*), said that the problem of simulation was much more difficult than it appeared First, the aerodynamic derivatives have to be known with some accuracy, and then the " known " dynamics of the aeroplanes have to be simulated in a convincing manner to the pilot It is still unknown what minimum number of aircraft motion parameters (linear or angular displacements, or velocities, or accelerations) have to be simulated and how they should be simulated, to give to the pilot an impression as near as practicable to the actual aircraft handling But in spite of these difficulties it is felt, that the simulator can reveal the basic handling difficulties of a new design, even if some of the estimated derivatives are as much as 50% wrong

He did not agree that the helicopter was easy to fly It was, he thought, very difficult This was why he felt that the development of a simulator fully representative of the helicopter characteristics would be of great value in training

There were doubts about the value of the simulator in investigating the handling qualities of a fixed-wing aircraft While experience generally showed that simulators might not always display accurately the actual flying qualities of a machine, a simulator should prove very useful in investigating the general behaviour of a prototype and in enabling some of the characteristics of an aeroplane to be improved Pilots had found it very useful to have a handling of an aircraft before flying it for the first time As long as the derivatives were known and could be incorporated properly into the machine before the first flight, the simulator could be of practical help

Summing up the present state of knowledge on stability and control of helicopters, he thought it was possible to predict and simulate with some degree of accuracy stability and control at least in the conventional semi-steady conditions of flying, such as hovering, forward flying and auto-rotation It would be some time before anything like a vertical descent or engine cut could be reproduced, it is not possible to produce a full simulation of all movements and conditions of a helicopter in the air For initial training, however, a simulator would be extremely valuable

With the coming of bigger helicopters, there were other problems which could prove very expensive trying to solve on a full-scale aeroplane With the increasing size and complexity of the helicopter, and the necessity to study not only the plain aerodynamics but all the gadgets, a simulator would be very useful not only as a trainer but as an automatic computer with physical output in true time scale

He was sorry to disagree with the pilots, but although his original opinion based on very limited experience was that a helicopter was comparatively easy to fly, from a theoretical point of view his feeling was that this was not the case, and flying the helicopter requires more skill and concentration than experienced pilots would like to admit

Mr G Hellings (*Chief Engineer, Air Trainers Ltd*), said that, naturally, he endorsed most of what had been said in favour of simulators He was often asked whether he could with confidence build a complete simulator before a prototype aircraft flew, because this would be of great value The answer, he thought, must be that the simulator could do only what the design office of the aircraft firm forecast that the prototype would do If the prototype did not always do what the aircraft firm's brochure said it would do, the simulator also would fall short The difference, however, was that the simulator would be less costly to put right

He joined issue a little with Mr HILL'S suggestion that pilots did not fly by the seats of their pants and, therefore, there was no point in attempting to simulate G It was obvious that a good deal of G could not be simulated, but he would very much like the author either to confirm or deny the impression which he had conveyed that there was no point in trying to do it

Mr J S Shapiro (*Founder Member—Consulting Engineer*), said that, speaking mainly as a designer, he joined issue with Mr ZBROZEK and considered that the flying of a helicopter was relatively easy It was not a matter of opinion, it was a matter of statistics of training, and as such had been confirmed sufficiently to be much more

of a fact than an opinion

He did not understand how Mr Zbrozek could so lightly glance over the question of what should be fed into the simulator His own opinion was that it was this very question, and not the solution of the equations, which had baffled helicopter designers He had not yet come across equations which were so difficult to solve that they could not be solved by one of the more advanced methods of computation, beginning with calculating machines and ending with electronic computers of the analogue type

The question which had to be examined was whether the type of simulator as developed by Mr de Guillenchmidt's company added anything to the range of devices which could be used for the solution of equations As far as he could tell, it was not claimed to have done more than that

He wished to point out that there was greater ignorance about pilots than about helicopters If there was really a very good justification for the kind of simulator which they had heard described, it was to find out something about pilots He would like to see a programme of research initiated by somebody who would say what pilots really wanted as a matter of fact and not as a matter of opinion No step in helicopter development would contribute more to the improvement of helicopter characteristics than this

The question of simulators for training was one of cost, and it was obvious that as helicopters grew, simulators, even if they did nothing more than leave all the passengers and load behind and simulated simply a cockpit, were bound to represent a vast and most profitable saving

Dr O P Mediratta (*Louis Newmark, Croydon*), said that one point which so far had not been brought out very clearly, was that the use of the simulator, apart from helping the pilot to learn how to fly, also helped the designer to design an aircraft and the equipment which went into it

The simulator could, clearly, do no better than the accuracy of the aerodynamic data which was fed into it Nobody would make the claim that it was possible to predict everything It was, however, absolutely certain that only by making a rational analysis of what already existed, and putting it in such a form that the results could be repeated, under controlled conditions, as many times as was desired, could positive conclusions be reached

In test flying for handling qualities, there was one very important link in the whole system and that was the human pilot If the helicopter, or any machine, was designed and put in the hands of the pilot, he was the only person who could say what the machine did and whether he liked it or not

If the same machine was tried on the simulator, one could use the results for two purposes first, to judge what the machine really did and second, keeping always in mind that the aerodynamic data was at best only estimated, one could work backwards and if it did not do what the pilot said it did in actual flight, one could fiddle the knobs on the simulator until it did what it should This could serve one very important purpose of putting the aerodynamic data in order for use in future design The simulator could then be used, with the human pilot as a part of the servo mechanism, to design the machine to do what the pilot really wanted

There was, also, another very important field where the simulator was of very great value and that was in the design and development of Autostabilisers and Autopilots in which his firm specialised They had found from experience of the R A E Flight simulator that positive results could be obtained, which helped in the development of such equipment This was an important point because even if the aircraft could be made available early enough, which was very seldom the case, the cost of doing the same development work on actual aircraft would undoubtedly be enormous

Mr C J Carter (*Ministry of Supply*), said that the argument that there was no need for simulators because there were sufficient helicopters to go round, had no relevance in the military sphere Obviously, what an air force was doing in peacetime was preparing for a state of war, and it did not wait until war arrived before making its plans

He did not know how widely the helicopter would be used by the Air Force or Navy in a future war, but the Services would want to make as much use as possible of the aircraft that were available for operational and not for training purposes Therefore, the military viewpoint must be that in wartime there would not be enough helicopters to go round and hence, that consideration must be given during peacetime to the value of a simulator in saving some of them

Mr A B Murray (*Companion Member*), commenting on Mr REED'S statement that there was no basic helicopter trainer, suggested that this might be the basis of all the trouble A basic trainer would not be quite as expensive as the present aircraft, and it would obviate the need for a simulator It would also be possible to obtain practice on a cheap machine cheaply

Mr R Annenberg (*Air Trainers Ltd*), who spoke as a member of the simulator industry, said it seemed that the technical members engaged on helicopter work were almost crying out for simulators which would enable them to make assessment of a lot of the data which they wanted for design purposes This would put the simulator industry along different lines of thought

Mr ZBROZEK pointed out that a computer was needed to solve the equations, and nobody had mentioned that the simulator would be used as a computer

Mr Annenberg replied that perhaps his question had been badly phrased From what had been said, he rather imagined that Mr Zbrozek's difficulties were mainly a matter of being able to get an estimate of the stability derivatives that he wanted to put into the computer

Mr Zbrozek agreed that that was one of the difficulties, but for that purpose one could use other computing machines and not necessarily a simulator On the simulator it is possible to simulate not only a helicopter itself, but to study its responses including pilot dynamics A simulator was an actual physical installation with which one could study the root of the trouble, for which the computer machine was no good While it would be useful to use a simulator as a computing machine, that was not its primary purpose

Mr J Wotton (*Member—Hunting Percival Aircraft Ltd*), said that he represented a firm whose main business was making basic trainers of the fixed wing type, and he was quite sure that his company would view with some concern any suggestion that training could in a large measure be replaced by simulators

Having listened to the papers and to the discussion, and from his own experience both with fixed wing aircraft and with helicopters, he could see a use for the simulator as depicted by Mr HILL in his excellent film and in the paper, for the training of crews in all their vital actions—a simulation, in fact, of drill in all its aspects , particularly in large aircraft

He could see the use of a simulator for training a pilot in any type of aircraft or helicopter when that aircraft's characteristics were known and hence a simulator was designed to incorporate those characteristics , but he could not see the possibility of a simulator being designed in advance of a prototype aircraft or helicopter in which the characteristics of the aircraft were, in fact, faithfully portrayed

The Jet Provost trainer, which had just been flown, was based on the standard Provost With all the control surfaces, the planform of the machine, the wetted area, and so on, faithfully followed from the previous machine, one would have expected that it would be possible to say that the machine would do this and that , but that was not the case The jet Provost was flying very well, but it had been necessary to go the whole gamut of control and stability adjustment to make the machine what it was today

From his own somewhat limited experience of helicopter flying, but on a number of different types, he said that whilst the characteristics might be fundamentally similar, they were in fact so diverse that he would hesitate to suppose that one could design a simulator embodying those characteristics before the aircraft flew

The **Chairman** remarked that that was a fairly healthy note on which to end as there was a marked division of opinion on the practicability of reproducing, in advance on a simulator, the flying qualities of a prototype aircraft

He wished to put a question to the first author Could Mr HILL indicate the rate of exchange of simulator hours as compared with actual flight hours ? He had got the impression from a remark of Mr Hill's that it was a " one for one " ratio, but he would be slightly surprised if it were so In the eyes of the licensing authorities, in fact, did one hour in the simulator count as one hour in the air ?

Mr Hill (in reply) said he believed that to introduce the effect of G into the simulator of a fixed wing aeroplane to be hardly worth while unless it could be done really well To try to introduce the effect of, say, $1\frac{1}{2}$, 2 or $2\frac{1}{2}$ G in a device weighing

perhaps two tons, and at the same time expect it to be effective in the training sense, as it must be, was perhaps hoping for too much Clearly, some kind of whirling arm might be necessary, and it might even attain the size of the Eiffel Tower to get the desired effect In the absence of a firm requirement this line of research had been left alone

He agreed that the helicopter simulator was somewhat different, and no doubt in the early stage trainees would expect some change in attitude in relating control movements to the horizon

On the question of the hour for hour ratio with the simulator as against flight, he could not really speak on behalf of any user, but it seemed the normal time in the simulator for conversion to a four engined type was about 35—40 hours The time in the air post-simulator course for the recurrent check was in the region of 1½ hours, and it used to approximate 4—5 hours The most that could be given in the air for conversion on a machine like the stratocruiser was somewhere between 15 and 20 hours

He disagreed entirely with Mr REED'S suggestion that there was no helicopter training problem There would immediately be a big training programme with any expansion in the helicopter world As far as the individual was concerned, the problem was one which touched the pocket, for apart from the operational cost of the aircraft, some £30 per hour represented the current figure of insurance premium for helicopter flying training To him it seemed that such figures represented a very real training problem

Cost of conversion in the Armed Forces was another matter, for the services were not perhaps affected by the need for such economies as those mentioned None the less, when considering pilot training on multi-engine, possibly multi-rotor, helicopters and the tactical devices needed for conducting any future war, he could visualise quite useful benefits from a synthetic trainer which could at least provide the helicopter crew with equipment for full familiarisation with the performance of the aircraft, its power plant and equipment

He said that for this evening he looked upon himself as a bit of an interloper, but he had been anxious to let everyone know to some extent what had been accomplished with simulators as training aids for aircrews of fixed wing aircraft He had been anxious to stimulate discussion, and if he succeeded in doing so he would be perfectly happy with the results of the meeting

Mr de Guillenchmidt (in reply), dealt first with the concern about the supply of helicopter pilots At present, he thought, there were probably enough helicopters but not sufficient pilots, whereas a few years ago the position was quite the reverse and there were many more pilots than helicopters For those with the responsibility, the question was rather one of the near future than of the present Helicopters could go anywhere, and the pilots would be needed soon

Apart altogether from any question of war, France had suddenly become concerned about the position this year Towards the end of the Indo-China war, when the helicopters flown by the Americans were handed over to the French, there were not the pilots available As a result, France had begun to train them at the rate of about 100 a month It was a difficult undertaking, but had it been foreseen preparations could have been made accordingly Any general expansion in the use of helicopters would quickly bring the problem into prominence

The actions of helicopter pilots, he thought, were not instinctive as in the case of pilots of fixed wing aircraft, and training on the ground would develop pilots' reactions more quickly and safely On the question of co-ordination, some people said jokingly that the helicopter pilot had something to do with both hands, both feet, and the teeth It was a problem of co-ordination of several controls which was not found in the fixed wing aircraft Pupils' reactions certainly should be educated

A test pilot was skilled, of course, and all seemed easy to him but not all future pilots might become skilful quickly Some pilots would take much longer than others to show their ability to handle the controls

He thought that there was no possible comparison with a conventional Link Trainer which was not intended for teaching to fly and which, it was known, gave a different response from actual aircraft, whilst the DX 50 simulator claimed to give, with a very high accuracy, the real response in hovering flight of the helicopter which was being simulated

In fact pilots who had " flown " this simulator said that they had had the impres-

sion of actually hovering the real aircraft, with identical control movements and a full psychological effect Furthermore, a fairly good physical effect was achieved due to the correct reproduction of the angular accelerations

Referring to the need for testing prototypes, he agreed that there was no difficulty in solving the equations of motion in hovering flight The difficulty was to see the influence of any one given parameter, because many parameters were involved with different degrees of influence It was difficult to foresee what would happen if a slight modification of one of the parameters was made one way or another Many pilots, in fact, were surprised at the change in handling characteristics when some of the parameters were changed, and it was a useful experience for them to understand better the philosophy of the helicopter It was necessary that the characteristics should be accurately portrayed

In one instance, a pilot did not find on " flying " the helicopter simulator the characteristics of a machine which he knew well Investigation showed that the fault was due to an error in one of the characteristics supplied by the constructor of the helicopter

Work had been done on a prototype helicopter After showing a pilot an aircraft with characteristics familiar to him, the characteristics were changed to those of a helicopter still on the drawing board Although the equations of the aircraft were known, some of the handling characteristics were not as anticipated Consequently, the values of certain parameters were changed in the aircraft still on the board To do this after flight tests would have been far more difficult and costly

He thought it was difficult to build a simulator for fixed wing aircraft which would portray exactly the response of the aircraft in all flight conditions, because to simulate such an aircraft one must know accurately all of its aerodynamic derivatives This was difficult to investigate, because calculations give rather poor information on the subject, flight testing is difficult to perform and information is more often obtained through tunnel tests which necessitate many corrections, and often the derivatives which are fed into the simulator are not exact

There was less difficulty with the helicopter because hovering flight was considered to be the critical part of the helicopter's flying condition Nearly all the effects were then mechanical effects, and these were much easier to calculate than the aerodynamic derivatives This, he thought, was why his company's simulator was so accurate as regards flight It would be a greater problem to do the same thing with a fixed wing aeroplane, especially with a faster machine or one with a wide range of flight conditions Although it was not too easy with the helicopter, it was not too difficult

His Company had worked on the question of the human transfer function Recordings and analytical studies of the transfer functions of trained and untrained pilots lead to most interesting results concerning the optimum conditions to be satisfied in helicopter design and give way to a new approach to training methods and to control-aid problems

Speaking of the investigation regarding auto-pilots, he said that the simulator was a good means of adjusting the parameters of such devices as well as of other auxiliary equipment such as stabilisers and blind flying instruments For flying at low levels above the sea, it was important that the devices should be accurate, but it was difficult to test the auto-pilot at such low height above the sea because if it did not work there was not much that could be saved

He did not think that a cheap helicopter trainer existed The complexity of the helicopter was such that it was not the cockpit or the instruments which were costly The mechanical parts and the rotor prevented too much cheapness In any case, if a machine was too rugged nasty vibrations could occur and the aircraft might fall to pieces He thought that the necessity for adjustable features would make a training machine more expensive than the ordinary helicopter

The saving of time in training was an open question Although the whole course of primary training was about 40 or 50 hours, generally fewer than 10 hours were needed to solo He would not say that with a trainer a pilot would go straight on to a helicopter, but certainly the solo period could be reduced by 50 per cent After passing solo a pupil was not immediately a pilot and would have many things still to learn and become accustomed to A saving of an average of about 10 hours would be quite a conservative figure

The **Chairman,** in concluding the discussion, said that they were all indebted to the two authors for introducing a very stimulating and controversial subject

Obviously, there were clearly marked lines of demarcation in people's views as to the values of a primary trainer and a prototype simulator Those engaged in designing would have some interesting thoughts ahead of them It would be very nice to feel that one could know the flying qualities of an aircraft ahead of the flying date, for this would ease many of the burdens

He moved a sincere vote of thanks to the two authors, and especially to Mr de Guillenchmidt who had come over from France specially to give his paper

The vote of thanks to Mr HILL and Mr DE GUILLENCHMIDT was carried unanimously with acclamation, and the proceedings then terminated

WRITTEN CONTRIBUTIONS TO THE DISCUSSION

From J K ZBROZEK (*Aero Flight Section, Royal Aircraft Establishment*)

From the discussion which followed the most interesting and stimulating Lecture, the writer received an impression that many of the controversial arguments arose from misunderstanding of the simulator role and limitations It is hoped that this brief note may help to put the whole problem of simulators in better perspective

No flight simulator can claim to be unlimited substitute for real flight, but modern flying is rather a complex matter, and it would be useful to split pilots' training into simpler and cheaper " subassemblies " of training Then, quite probably, some parts of pilot training could be achieved by the use of simulators

There is no doubt that " Link-Trainer " instructor could " fly " the Link much better than even a good pilot, but one has to remember that the object of Link training is not to produce efficient Link pilots, but to train pilots in automatic comprehension and interpretation of blind flying panel readings

The Redifon simulator does not teach the pilot to fly but to operate the new aircraft For an experienced pilot, to fly, *i e* , to manoeuvre any new but conventional type of aircraft is comparatively straightforward However, to know how to use flaps, undercarriage, dive brakes, engine controls, etc , how to interpret the readings of dozens of dials and how to use dozens of switches and knobs, requires a lot of thinking and remembering and is not very easy especially in an emergency To learn to operate the multitude of gadgets in the pilot's cabin can be quite successfully achieved on the ground It was a common practice to spend hours in the pilot's cockpit of a single-seater fighter, just gazing at all the knobs and switches, before one was allowed to make the first take-off It was realized that familiarisation with the cockpit was as important as feel of controls, and this could be done on the ground The Redifon simulator is a glorified enlargement of this approach, with the object of training pilots in operational use of new aircraft in the most realistic conditions No one, however, not even the makers, would claim that one can learn *ab initio* to fly the aircraft using the simulator

Another application of flight simulator is to use this instrument in the study of aircraft dynamics and control In some new designs, the aircraft dynamic characteristics, especially the artificial feel of controls, could be so widely different from known and approved characteristics, that it is very difficult to draw any conclusions about its handling on the basis of calculated responses to assumed inputs We have to bring the pilot into our equations of motion, and one way, and maybe the only one, is to let the pilot fly the " simulated " aircraft It is fully realized that no simulator can, faithfully, reproduce display of flying qualities, but if we concentrate, *e g* , on the aiming characteristics of aircraft, then a comparatively simple display should be satisfactory This approach has been used successfully and some improvement in the aircraft handling was made before the first flight, which, in turn, proved that the deductions from the simulator were correct It was said, that no reliable estimates of aerodynamic derivatives could be made in the design stage This is partly true, but if aircraft response is sensitive to a value of any of the derivatives it is only too easy to cover the range of values of this derivative on the simulator and find out where the safe region is and design for it After all, it must be a poor aerodynamic team which cannot predict aerodynamic derivatives with some known accuracy

The Dorand helicopter simulator does not follow any of the above described patterns, but nearest to it would be aiming simulator It was rather unfortunate that during the same session two simulators, of so widely different applications, were discussed This fact was partially responsible for some confusion in the discussion which followed

The basic philosophy of helicopter simulators is based on the fact that helicopter responses are widely different from those of fixed wing aircraft The response of

fixed wing aircraft is described as " natural " which is probably correct, but helicopter responses are far from it Using loosely the technical " jargon," at some frequencies of helicopter oscillations the helicopter response may get out of phase with pilot effort, which may lead to divergent oscillations, actually induced by a pilot It can be argued that similar circumstances may arise in fixed wing aircraft, *e g* , in the case of lightly damped short period oscillations Fortunately for fixed wing aircraft, the frequency of this oscillation is usually so high that the pilot realizes the futility of his efforts and does not try to correct it However, there are known cases of some other modes of aircraft response, where the pilot may easily induce oscillations Many of the helicopter accidents were due to helicopter plus pilot dynamic oscillations, usually termed as a case of " over-control "

One of the objects of the Dorand simulator is to train helicopter pilots to master this dynamic difficulty peculiar to the helicopter From this point of view the simulator can replace *ab initio* trainer No doubt, the final training has to be done on the actual helicopter, but considerable saving in the expensive flying hours should be thus achieved After all, this is a similar approach to glider-pilot training, and has been used, with considerable success, by glider instructors In this case, the pupil was " flying " the glider in natural wind, the glider being suspended from pylon

For the helicopter simulator used as a primary trainer, the aerodynamic derivatives need not be known accurately, especially in hovering, where mass and inertia of helicopter, flapping angle of blades and control gearing are the main parameters It is not known if the presentation of helicopter responses as used on the Dorand simulator, is best within practical limitations, but this could only be proved or disproved by experiment

The use of Dorand simulator as the instrument for a study of dynamics of a new design is probably limited, due to difficulties in estimation of aerodynamic derivatives, especially at higher speeds Nevertheless a similar argument can be used as for fixed wing simulators, that the main shortcomings of a new design should show up on the simulator, especially if some novelties are introduced in the control system

It is worth mentioning, that prediction and hence simulation of stick forces of a new design of helicopter are almost impossible for manual controls, which is a very serious drawback in this application of the simulator With power controls, this limitation should not arise

From MR K M REED

Several speakers and M P de Guillenchmidt would appear to have misunderstood one or two of my comments

First, I did state that in *Britain* I could not see this very recent great demand for helicopter training, M de Guillenchmidt spoke broadly in his paper but replied that approximately 100 French pilots were required urgently to be trained for Indo China That, I in no way doubt, but I was speaking of, and pointed out the situation as far as I knew it in this country

Second, at least three speakers, including M de Guillenschmidt stated that helicopters were difficult to fly, and one speaker, Mr Shapiro, went so far as to say that facts proved this to be correct I am quite prepared to challenge these facts, furthermore, a pilot did not, at the meeting, disagree with me Once again I will say that helicopter flying is like any other accomplishment, one must be shown how, have the adaptability and practice, then it is relatively no more difficult than flying an aeroplane After all I have already stated that the majority of pilots have been trained from scratch on an operational helicopter Consider the situation if initial training was carried out on a fixed wing operational aircraft

Third, speakers who were mainly technicians agree with a simulator to feed in their theories and so prove to them whether they are right or wrong, but here we are discussing something which costs a considerable amount of money to augment elementary training when, in fact, we still do not have elementary training aircraft, this appears to me to be putting the cart before the horse at this stage

Fourth, remarks made suggested that a simulator would assist designers to know exactly what pilots wanted from control movement, forces, etc I see very little difference between helicopter aircraft or fixed wing aircraft for these requirements Up to the present, helicopter pilots have had to accept the best that designers can give The fixed wing aircraft from controls and movement, etc , is well developed

and should be the datum for designers when considering helicopters I should have thought the time had passed when individual pilots should have to tell designers what was required I think by now they should know, furthermore, individuals are not necessarily right

M DE GUILLENCHMIDT'S reply to the written contribution of Mr J K ZBROZEK

The writer fully agrees with the comments presented by Mr Zbrozek in his written contribution to the discussion which followed the Lecture on Flight Simulators

He feels in the same way that some confusion arose from a misinterpretation of the philosophy of the different types of simulators and their applications

The name of " flight simulator " is often indiscriminately used to indicate such basically different devices as the Link type trainers, the Operational simulators and flight simulators designed for the study of aircraft dynamics and control, in addition to any form of missile or flutter computers

The DX 50 helicopter simulator which, it may be mentioned, is the first device of its type to have been devised up to now, brings again something new to the field of simulation and cannot be really compared to any of the above mentioned developments

There is no doubt that an accurate simulation of the various flight conditions, especially at higher speeds, is subject to correct estimation of aerodynamic derivatives, but it is emphasized that for helicopters the critical flight condition, for training as well as for design purposes, is hovering flight

This is due to the particular dynamics of the aircraft itself and probably also to the fact that a high number of degrees of freedom is involved

In other flight conditions, stability characteristics being much improved, the control problem becomes much easier

Besides, a pilot being much less sensitive to a variation of say 10% of a variable than to variations around zero of the same variable, at least as far as training purposes are considered, the aerodynamic derivatives need not be known with such high accuracy

Speaking of aerodynamic derivatives, it may be noted that though in the actual DX 50 the coefficients of the variables of the equation system to be solved have been assumed constant, by setting the dials to a given value, the specially designed computer of this simulator can easily solve non-linear problems as well

Without any great complications the coefficients can identify functions, *e g* , of time or of one or more variables of the system so that it will be always possible to solve a system of differential equations of the following general type

$$u'' = f_1(u, v \quad z) + f_2(u', v, \quad z') + f_3(t)$$
$$v = g_1(u, v \quad z) + g_2(u', v' \quad z') + g_3(t)$$
$$z'' \text{ Æ } l_1(u, v \quad z) + l_2(u, v' \quad z) + l_3(t)$$

the terms f_1, f_2, f_3 l_1, l , l_3, each representing any function of the unknown variables u, v, z of the system or of time t

Moreover, by grouping several double-integrating units in series, the order of the differential equations may be elevated

It is also possible to introduce into the system terms of the form

$$f(u'', v'' \quad z'')$$

since the acceleration of the follower fly-wheel may be measured electrically by means of an accelerometer

Other terms of the type

$$f\left(\int udt, \int vdt \quad \int zdt\right)$$

may also be introduced

Furthermore, the follower fly-wheel may be also adapted to control devices for insuring a change of co-ordinates

In his contribution, Mr Zbrozek mentions finally the difficulty of prediction of stick forces

https://doi.org/10.1017/S2753447200002493 Published online by Cambridge University Press

This is certainly true but there has been no problem of that kind in the DX 50 simulator because there are no stick forces in the hovering flight of a helicopter, other than frictional or artificial spring-centring forces

In forward flight, the stick forces would however have to be introduced, unless power controls are present

But again for training purposes no high accuracy would be wanted

Mr Norman Hill's reply to Mr J K Zbrozek

With regard to the interesting written contribution from Mr J K Zbrozek, it also is my impression that many had no clear understanding of the role of the simulator and its limitations as a training machine and for this very purpose the discussion was arranged It is therefore hoped that many left the meeting with a clearer impression of the role and limitations of the flight simulator as a training device and as a tool or research instrument, and doubtless, Mr Zbrozek's letter will assist in their thoughts

Wide claims have been made by some of those engaged in the design and manufacture of synthetic training devices, but so far as I am aware, none has made any claim that the flight simulator forms an unlimited substitute for real flight and the modern pattern appears to involve the adoption of elementary synthetic training devices at the *ab initio* stage of the pilot training " pipe line," and at a later stage the use of a machine of an advanced type similar to that depicted in the cine film and having a high fidelity appearance and instrumental performance corresponding to the type aircraft to which the desired conversion or training is to be related, so resulting in more effective expenditure of training time in the air, for it follows that a trainee arrives at the aircraft at a much higher standard of proficiency than could otherwise be attained in the given time

" Link " is the trade name of a well known manufacturer and is used to cover a variety of training devices of numerous types, so that perhaps I may be forgiven if I suggest that here Mr Zbrozek is attempting to describe or refer to the basic type of machine produced by the said manufacturers for many years

It appeared that most of those who spoke on December 10th, including myself, clearly understood that the flight simulator, whether designed and built by Redifon or any other Company, does not teach men to fly, and reference to my words on the previous pages confirms this thought In other words, in this form of training the emphasis throughout is upon instrument flight conditions Flying training is usually accomplished at an earlier stage before the simulator training stage, in other words the simulator trainee possesses a high standard of skill from his earlier experience on basic training

All reference to the use and application of flight simulators for the study of aerodynamics and control was avoided in my notes because this form of research and usage is at a comparatively early stage in its development, but none the less, I am aware of the immense potential of such machines and much research is to continue in this direction but is scarcely a matter for discussion under the title of these notes I do, however, appreciate Mr Zbrozek's reference to this important development

It is appreciated that there is a wide difference between the two machines described and this difference clearly activated the discussion very satisfactorily and in that sense our objectives in arranging the discussion were achieved

The Dorand helicopter simulator in my opinion represents the first step in what will become the complete range of synthetic training devices for this type of aircraft, and it is easy to forecast a terrific future for such a machine within the next five to ten years, and doubtless these will develop up to the operational type of machine corresponding with the status of the advanced flight simulator as used today for fixed-wing aircraft, and as Mr de Guillenchmidt made clear, it is intended as an *ab initio* trainer